



Woodworking

Nancy Macdonald





2ND EDITION

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Woodworking

Nancy Macdonald

SECOND EDITION

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Preface

INTRODUCTION

Woodworking is designed for an introductory woodworking course in high schools, colleges, and continuing education, but is also a must-have for adult hobbyists.

The focus of this book is on a step-by-step approach; it builds the knowledge of the learner by introducing the basics of woodworking — tools, materials, and safety — and then goes on to present the various techniques required for completing wood projects. It also offers a unique blend of basic and more advanced projects so that the book remains suitable for learners as they develop their skills and become more experienced in woodworking techniques. In addition, this book provides insight from practicing professionals in the industry by providing practical advice to those who wish to start a career or run their own business.

Comprehensive and complete with full-color photos and graphics, this book offers a project-oriented and colorful introduction into the world of woodworking.

HOW TO USE THIS BOOK

This book is logically organized into eight sections providing insight into the woodworking industry and a logical sequence to understanding the woodworking techniques and processes involved in building projects.

Section 1: Introduction to the World of Woodworking

This section includes everything you need to know to get started in woodworking. Chapter 1 provides an introduction to the industry, including key information on finding and obtaining a job and getting ahead in this occupation. Chapter 2 offers important safety information on how to avoid hazards and develop safe practices in the shop.

Section 2: Tools of the Trade

Chapters 3 through 5 cover the necessary tools for completing various wood projects. Explanations on the use of hand, portable, and stationary tools are presented in these chapters, along with general safety rules for their use.

Section 3: Clamps, Fasteners and Adhesives

This next section includes Chapters 6 through 8, covering the materials required for assembling wood projects. Understanding how clamps, fasteners, and adhesives work, as well as their different types, is a critical component in woodworking construction.

Section 4: Woodworking Materials

Wood, panel products, veneer, and synthetic materials are discussed in Chapters 9 through 12. Coverage includes an explanation of the advantages and disadvantages of each of the materials, so that a woodworker can make an informed decision on how to choose the best material for the project.

Section 5: Joinery and Assembly

This section begins setting the foundation for all the chapters that are to follow, providing the basics of construction techniques. It includes Chapters 13 through 19, covering construction methods, stock preparation, case joints, frame joints, rail joints, housed joints, and making wide panels and thick blanks.

Section 6: Cabinet and Furniture Anatomy

Moving on to construction of actual wood products, Chapters 20 through 28 provide step-by-step instructions on how to build base and wall cabinets, doors and drawers, tables and desks, chests, beds, chairs, and the installation of hardware.

Section 7: Finishing

A project is not complete until the finishing touches are added, and this section explains how to accomplish this task. Chapters 27 and 28 provide direction on how to prepare the surface of your project to the final application of various finishes.

Section 8: Special Topics

This section provides a wide array of topics for the more experienced woodworker. Spanning Chapters 29 through 34, it offers instructions on bending wood, veneering, decorative techniques, designing a project, fabricating countertops, and, finally, running your own business.

With the comprehensive coverage of all these topics, this book provides all the need-to-know information for achieving success in the woodworking industry.

NEW TO THIS EDITION

- Substantially more in-depth coverage of stationary power tools to familiarize and help properly train new woodworkers in the effective use of various shop tools that they will encounter in the shop
- New and expanded information on casework, millwork, trim, and installation procedures for kitchen cabinets
- Increased emphasis on safety to highlight the importance of safe practices in the workshop to avoid injury
- New information on "green" practices, focusing on the importance of remaining environmentally conscious when working in the woodshop
- New visuals of various woods and descriptions of their characteristics, illustrating how these commonly used North American woods react with different tools and materials, and guiding woodworkers to make wise choices about their pieces in order to reach the desired results
- Project index offering a quick reference to the "Build It" and "Project Challenge" projects in the book so both new and experienced woodworkers can quickly and easily locate specific projects based on their interests

FEATURES OF THIS BOOK

This edition is full of robust features that will both enhance and facilitate the learning experience. Along with comprehensive coverage, each chapter provides a wide array of helpful tips, safety information, and step-by-step instructions to help learners complete projects.

A Learning Guide:

- **Full-color** photos from a professional woodworking shop illustrate tools and materials, various techniques, and accompany step-by-step instructions for the building process.
- **You'll Learn** and **Check Your Knowledge** are presented with each chapter. You'll Learn provides the learning objectives for each chapter, while Check Your Knowledge follows up the chapter with a complete set of review questions to evaluate comprehension of concepts.
- **Applied Science** and **Applied Math** boxes are integrated throughout the book. Chock full of interesting facts, these boxes make the connection between woodworking and the importance of understanding the characteristics of wood and various materials, as well as accurate measurement and calculations, for success in building projects.
- **History Fact** boxes provide interesting background on the history of woodworking so that learners may have a more well-rounded understanding of the industry.
- **Green Reminders** boxes present various ideas for more environmentally conscious woodworking.
- **Woodworking Tip** boxes are also integrated throughout the book, highlighting practical advice from the author on how to best achieve results through smart and safe shop practices.

- **What's Wrong with This Picture** challenges students to find the errors and safety violations in the given picture.
- **Activities** at the end of chapters combine the knowledge presented in the chapter with further research and study. Helpful as homework, or as an opportunity to expand knowledge of specific topics, these activities encourage independent learning and development of critical thinking skills.

A Safety Guide:

- **Chapter 2** recognizes safety as an essential element in success in the woodworking business. This chapter provides valuable information on general safety practices — including woodworking hazards, basic safety rules, shop dress, shopkeeping, and necessary shop practice. Exclusively focused on safety, this chapter should be carefully read prior to beginning building projects.
- **Caution** boxes are integrated throughout the chapters to help further emphasize this important lesson. Each box provides a caution or a warning about the use of various shop tools and particular techniques. These should be carefully adhered to whenever presented in the book.

A Guide to Building Projects:

- Step-by-step **Procedures** are integrated into the chapters; they provide instructions on various tasks that are essential to the completion of the projects at the end of the chapter. Each Procedure provides explanations along with photo sequences to help in understanding these basic concepts.
- Step-by-step **Build It!** projects at the end of the chapters provide a simple project based on the concepts learned in the chapter. It is here that learners can take their knowledge and apply it to the creation of an actual hands-on wood product.
- Step-by-step **Project Challenge** projects at the end of the chapters provide a more advanced project based on concepts learned in the chapter. A learner may tackle the more advanced project once they have mastered the Build It! project presented in the chapter.

A Guide to The Industry:

- A **Success Story** opens each section and provides insight and advice to the aspiring woodworker. Stories are drawn from practicing professionals from across the United States, describing different aspects of the occupation — the advantages and drawbacks, the dedication and commitment required, and the sense of accomplishment from a job well done. Each offers practical advice on how best to succeed in the industry.
- **Chapter 1** provides valuable background on the industry — its history, available careers, and practical advice on finding and obtaining work, and getting ahead in the occupation.
- **Chapter 34** provides the final wrap-up for the book, offering advice on how to start and run your own business successfully.

ALSO AVAILABLE TO ACCOMPANY THIS BOOK

Along with the *Woodworking* book, we are proud to offer supplemental products that will help support classroom instruction and involvement in learning about the world of woodworking.

Woodworking Instructor Resources This CD-ROM is full of helpful tools for the instructor teaching a woodworking course. Each component follows the chapters in *Woodworking* and is intended to help instructors prepare classroom presentations and student evaluations:

- ***Instructor's Resource Guide*** is available in electronic format and includes lesson plans with correlation to the accompanying PowerPoint presentations, as well as Answers to the Questions in the book and the workbook.
- ***PowerPoint Presentations*** designed to follow the lesson plans in the *Instructor's Resource Guide,* including an outline of each chapter along with photos and graphics from the chapter to help illustrate important points and enhance classroom instruction. These presentations are editable, allowing instructors to include additional notes and photos/graphics from the Image Gallery included on this CD.

- ***Computerized Testbanks*** are available in ExamView format. Containing over 1000 questions and organized by chapter, questions may be edited, added, or deleted to suit individual class needs. Questions can be used in their current format, or instructors may easily create their own exams based on these questions.
- ***Image Gallery,*** containing graphics and photos from all the chapters in the book, provides an additional option for classroom presentations. Instructors may choose to add to the existing PowerPoint presentations on this CD, or may wish to create their own presentations based on the book.

Woodworking Workbook

Containing various types of questions based on the chapters in the book, in addition to skill sheets based on the Procedures in the book, this *Workbook* provides learners with a tool for evaluating their knowledge of the content. Its flexible format makes this a useful resource for homework assignments. Answers to the *Workbook* questions are provided in the accompanying *Instructor's Resource Guide,* available in print or electronic format.

ABOUT THE AUTHOR

Nancy Macdonald is a professor at the State University of New York College at Delhi, in the Technology Division/Woodworking Program. Her educational credentials include a B.A. from Hartwick College, an M.A. from Yale University, and an M.S. in Vocational/Technical Education from the State University of New York at Oswego. Ms. Macdonald is also the recipient of the NYS Chancellor's Award for Excellence in Teaching.

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Woodworking

Nancy Macdonald

SECOND EDITION

SECTION I


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Introduction to the World of Woodworking


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SUCCESS STORIES

Mario Rodriguez

Title

Furniture maker and restorer; partner and instructor, Philadelphia Furniture Workshop in Philadelphia, Penn.; author Traditional Woodwork: Adding Authentic Period Details to Any Home *and* Building Fireplace Mantels: Distinctive Projects for Any Style Home

Education

After getting a bachelors degree in Art and Applied Design from H. H. Lehman College, he began a four-year apprenticeship with the Carpenters and Cabinetmakers Union in New York City.

History

Mario's interest began with a sofa he bought: It arrived damaged, so he bought a few simple tools and a book and actually built himself a new one. "It was very satisfying," he says. "But I also recognized that I needed some proper instruction." So he went to the Carpenters' Union in New York City, took an exam, and was placed into an apprenticeship program. By day he did construction, and by night he went to class. After that, he got into cabinetmaking and stair building. In 1979, he opened his own business, which did architectural millwork, restoration, refinishing, and furniture reproduction. During that

time, he was an instructor at the Fashion Institute of Technology. He closed shop in 2001 to teach full time, and he helped found the Philadelphia Furniture Workshop in 2006. The school offers classes for serious amateurs evenings and almost every weekend. When he's not at school, he's at his own studio. Today, he makes six to 12 of his own pieces per year, sometimes commissions and sometimes his own designs on spec. He's also a frequent contributor to *Fine Woodworking* magazine.

On the Job

Since classes are held evenings and weekends, Mario's hours are unpredictable. He figures he works a 40-hour workweek, just not in the traditional 9-to-5 schedule. When he's not teaching or preparing to teach, he's in his studio at the drawing board or the saw. "I like the variety," he says. "If I were just spending time working in the shop I would not be as a happy. Now I can design a project, base a class on it, *and* turn it into an article!"

Best Aspects

"The time I spend at the bench is still the most satisfying part," he says.

Challenges

Designing something is a process, he says — one that's not always easy. "It's rare I'll build something and it turns out beautiful the first time." Thus, it can be a challenge to teach this stage to students. It's also a balancing act, he says, to show them how to build efficiently while maintaining high standards.

Importance of Education

If you're interested in a woodworking career, "enroll in a serious structured program," Mario says. "The students that make the best progress are those who have done so, and have pursued very specific interests."

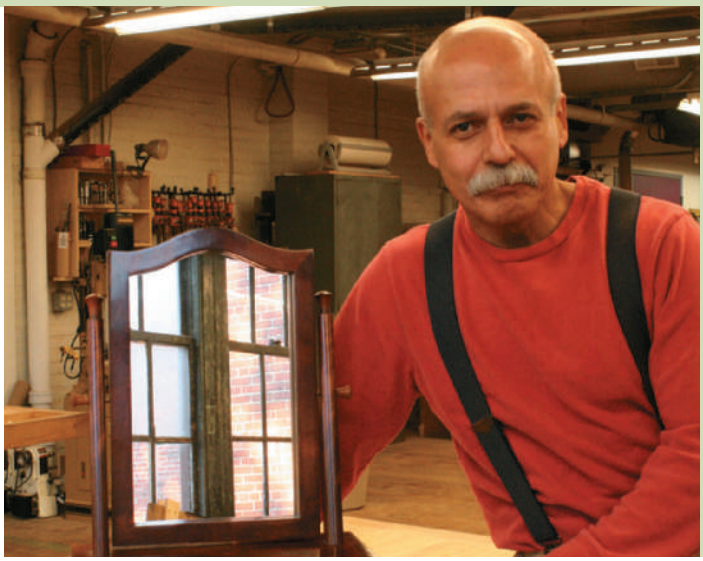


Image courtesy of Mario Rodriguez.

Future Opportunities

"I want to see us grow," says Mario. "I recognize a need to teach this for young kids. But I also want to reach out to other populations."

Words of Advice

Affiliate yourself with a local woodworking organization, Mario advises. These groups can be great resources for ideas, support, and even just socializing.

Story originally written by Margaret Magnarelli, 2008. Interview and photo provided by Mario Rodriguez.



1

The Woodworking Industry

You'll Learn

After studying the chapter, the student should be able to:

- Give a brief history of woodworking
- List occupations associated with the woodworking industry
- Be aware of the educational requirements for various jobs
- Utilize the Internet in researching career options
- Develop a résumé
- Present a professional appearance at an interview
- List work habits that will ensure a successful career

INTRODUCTION

People have been working with wood for centuries to create a variety of things, from shelters to the sailing ships they used to explore the world. Methods have changed considerably over the years, but we remain a society that appreciates wood for both its utilitarian qualities and its beauty. In this chapter, we will explore the history of wood usage, woodworking careers of the past and present, and ways to prepare for a career in the woodworking industry.

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HISTORY

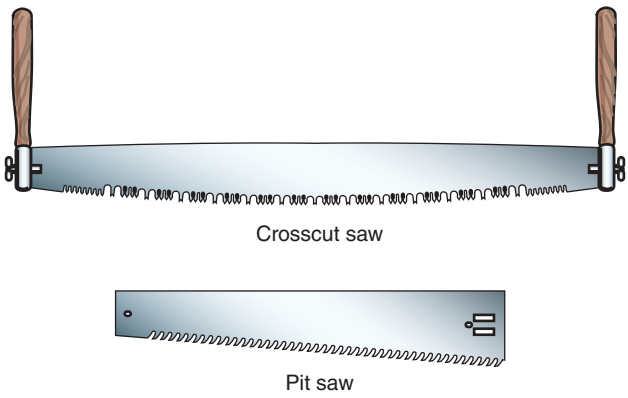
Early humans used wood for fire, which gave them both heat and a way to cook food. Wooden clubs were used as weapons. The first tools were made of stone and bone, often fastened to wooden handles. The discovery of bronze and iron enabled the development of more sophisticated tools. Some tools have not changed much since our ancestors first designed them. The planes, saws, and hammers used in ancient Rome look very much like the tools we use today. Although the introduction of metal made tools more efficient, it was still a long and laborious process to turn raw materials into finished products, since everything had to be done by hand (see **Figure 1-1** and **Figure 1-2**).

By the 1600s, the forests of Europe had been heavily logged. During the age of exploration, North America abounded in forests. The New World was a resource of incalculable value, and the forests were a great part of this value. There were literally millions of acres that had never been cut. The early colonists began to clear land for farming and harvesting the lumber. The white pine of the Northeast was highly prized by shipbuilders for masts. Wood was needed to build houses and public buildings.

During the 1600s and 1700s, much of New England's forest was stripped to make charcoal for the smelting of iron. The first source for soap and baking soda was potash produced by burning trees. The virgin long-leaf pine forests of the southeastern United States were decimated to produce pitch and later turpentine. Pitch was used in shipbuilding, and England in particular needed a supply. During the nineteenth century, turpentine was as important a commodity as petroleum is today, and like petroleum, it was used in a multitude of ways.

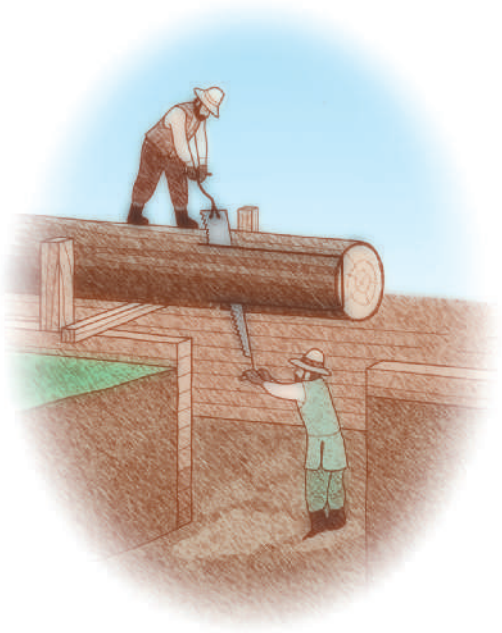
Early settlers needed wood for building homes, barns, business establishments, and the ships that transported goods. They built mills powered by **waterwheels** to grind grain for flour and to turn logs into lumber. The power to run machinery was generated by a large wooden wheel, which was turned by running water provided by a stream or by a mill pond from which water could be released. As the waterwheel turned, power was transferred to the tools through a system of belts and pulleys (see **Figure 1-3** and **Figure 1-4**). Mills also provided the power to run the looms in the manufacturing of textiles, which was a huge industry in the Northeast during the 1800s.

The number of water-powered mills in the United States grew rapidly, and they became more powerful over time. In 1790, there were around 7500 small mills in operation, mainly for milling lumber and grinding grain. By 1825, there were about 16,000 mills in Maine, New Hampshire, Vermont, and New York. Twenty-five years later, in 1850, that number had mushroomed to 60,000. The largest waterwheels were 70 feet in diameter and were capable of producing as much as 250 horsepower. The industrial revolution was well underway at this point, and the mills



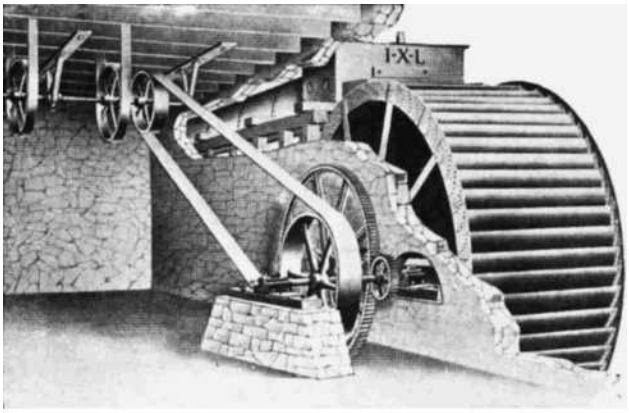
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FIGURE 1-1 Crosscut and pit saws were saws that required two sawyers and were typically from 40" to 80" long. Crosscut saws were used to fell trees and cut them into movable sections.



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FIGURE 1-2 Pit saws were used to cut planks from the log. One operator usually stood in a pit (hence the name), while the other worked the saw from above.



SPUR MASTER WHEEL ON END OF WATER WHEEL SHAFT

Image courtesy of The Society of Preservation of Old Mills, Glen Mills, Pennsylvania.

FIGURE 1-3 Power is transferred from the turning waterwheel to the belts that drive the machines.

provided much of the impetus for that period of enormous growth and expansion.

The advent of steam power and later electricity made it easier to process lumber, and allowed lumber to be processed much faster. The waterwheels could only operate when sufficient water was available, and they needed to be close to a water source. Electricity changed things tremendously: Tools once manipulated only by hand could now be powered by electricity. Working with wood was less laborious and could be accomplished far more quickly.

We rely on electricity so heavily today that it is hard to imagine living and working without it. Most shops today are full of both large and small electrical power tools, as well as air-activated tools. Technology has dramatically changed the way wood is processed. We have tools at our disposal that our ancestors could not begin to imagine. Computers are an integral part of the industry, used for estimating, creating drawings, and actually building products.



HISTORY FACT

The invention of the circular saw, which no carpenter today can imagine working without, is credited to the **Shakers**. The Shakers were a utopian community that flourished between the late 1700s and early 1900s. They were incredibly industrious and inventive, and they built furniture that is still widely admired and imitated today. The story is that a Shaker woman was sitting at a window, working at a spinning wheel. As she worked, she watched Shaker craftsmen sawing wood to length and width using handsaws. She had the inspiration that a saw blade that could turn like her spinning wheel would be more efficient. The Shakers, innovators who always looked for ways to be more productive, tried the idea. It worked incredibly well, cutting down the time and labor needed to saw wood; so the forerunner of the modern circular saw was born. ■

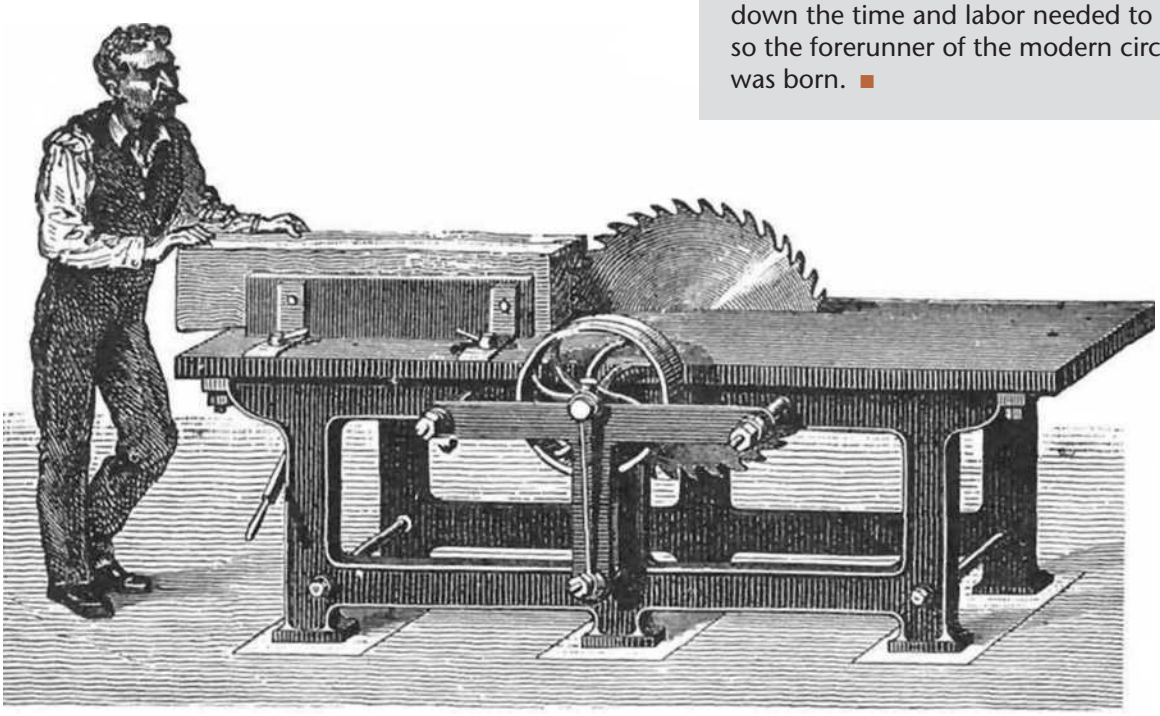


Image courtesy of The Society of Preservation of Old Mills, Glen Mills, Pennsylvania.

FIGURE 1-4 This early table saw is tied into the belt system seen in Figure 1-3, which spins the saw blade.

It is possible today for an operator using **computerized numerical controls (CNC)** to program a machine to perform a sequence of operations automatically, resulting in great precision and a high degree of reliability. The integration of computers with equipment has improved production speeds and capabilities, simplified setup and maintenance requirements, and increased the demand for workers with computer skills (see **Figure 1-5**).

CAREERS IN WOODWORKING: PAST AND PRESENT

During the Middle Ages in Europe, men working in the trades usually joined associations called *craft guilds*. The guilds were the forerunners of today's unions. A young man would be sent out to train with a **master** at the age of 7 or 8 and typically worked for him for a period of seven years. He was called an **apprentice**. The employer provided a place in his home for the apprentice and fed him in exchange for his labor; the apprentice was legally bound over to the master by his father. At the end of his apprenticeship, and upon demonstrating his skills, the apprentice gained **journeyman** status. They were called *journeymen* because they often left their towns to seek employment. Journeymen worked for masters, who trained apprentices and employed journeymen, who were paid by the masters; so the power and wealth of the guilds was concentrated in the hands of the masters. To gain master status, a journeyman had to demonstrate his skills to the masters in his guild, and they decided whether he would be moved up or not. This was an extremely competitive process.



HISTORY FACT

The medieval craft guilds system became widespread in the eleventh century in Europe, as towns and cities started to develop after the Dark Ages. The word *craft* comes from the old English *craft,* which means *skill.* ■

Today, a good share of the workforce is involved in one way or another with the processing and manufacturing of products that originate from trees. More than two million people are employed in one capacity or another in working with wood. There are several broad categories of employment. These categories are forestry, lumber processing, papermaking, wood construction, furniture manufacturing, millwork, and the distribution of wood products. Of course, within each of these larger categories are smaller ones. For example, under construction there are three subcategories: *craft, technical,* and *professional.*

Craftspeople are carpenters, precision woodworkers or cabinetmakers, and millwrights (see **Figure 1-6** through **Figure 1-10**). The formal training and education required for craftspeople is less than that for technicians and professionals. A person entering one of the craft trades may attend a vocational school and work as an apprentice to a more highly skilled craftsperson, or he may learn through on-the-job experience.



Image courtesy of C.R. Onsrud Inc, www.cronsrud.com

FIGURE 1-5 A CNC router.



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FIGURE 1-6 Joists set for a deck by carpenters.


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FIGURE 1-7 Deck completed by carpenters.


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FIGURE 1-8 Porch roof framed by carpenters.


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FIGURE 1-9 Carpenters install hardwood floors.


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FIGURE 1-10 The chairs seen here, and the casework in the background, were built by woodworkers.

Technicians include drafters, forestry technicians, and engineering technicians (see **Figure 1-11**). People working in these fields need a minimum of a two-year college degree in their specialty.

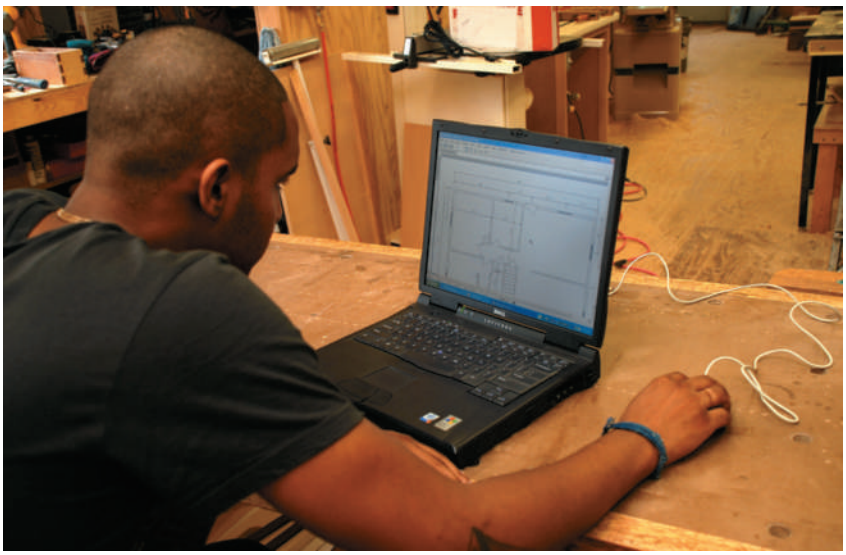
Professionals are foresters, furniture designers, teachers, and architects. Professionals need higher academic degrees, such as a bachelor's degree or higher.

Investigating Careers

There are two good resources you can utilize on your computer to learn more about careers in the various categories. One is the U.S. Department of Labor's **Bureau of Labor Statistics**, found at *www.bls.gov*. Here you will find information on wages by area and occupation, employee benefits, state and local wages, plus a lot more. A second good resource is the **Occupational Outlook Handbook**. It can be reached from the *www.bls.gov* Web site and provides information on the nature of the work, working conditions, employment, training and advancement, job outlook, earnings, related occupations, and sources of additional information.

Finding a Job

Use all the resources available to you as you search for a job. Talk to a career counselor at your school if you can. Read the help-wanted section in your local newspaper. Put the word out that you are looking for a job, and talk to people in your field of interest to find out how they got started. Most people do not mind being asked for advice, so go ahead and ask. Check the paper for job fairs and attend them, and find out what



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FIGURE 1-11 Plans being drawn using drafting software. Most drafting is done this way, and there is a high demand for technicians with these skills.

opportunities exist in your area in terms of employment. Your local chamber of commerce can help with this.

You may have the opportunity to do an **internship** as part of your academic studies. An internship is supervised practical training undertaken by a student or recent graduate. It is a great opportunity to explore an area of work you are interested in, and you may develop some excellent contacts that will be useful when you are job hunting. You may even be offered a job by the company that sponsored the internship; and if you do an internship, or have related job experience, be sure to mention it in the "Experience" section of your résumé.

Many construction trades have **labor unions**, and you might investigate this path. A labor union is an organization of wage earners formed for the purpose of serving the members' interest with respect to wages and working conditions. You start in a union as an apprentice. Today's union apprentices are paid, although at a much lower rate than journeymen. The apprentice must successfully complete a series of classes and put in the required time, and then he is promoted to journeyman status and wages. If you are interested in learning more about becoming a union member, look up the local union office and set up an appointment to talk to someone.

There are numerous woodworking associations that may be helpful in your job search. An Internet search will yield a great deal of information. There may be a local group you might want to get to know, and these contacts could lead to a job.

Another source of good information is trade magazines, available at bookstores and newsstands. There is usually a classified section in which you may find jobs or apprenticeships advertised. You will also find numerous trade-specific advertisements, and perhaps you would like to work for one of these companies. Reading trade magazines will also increase your knowledge of the field.

WOODWORKING TIP:

Does your school have a local Skills USA chapter? Skills USA is a national organization serving high school and college students who are enrolled in technical, skilled, and service programs. Skills contests are held at the regional, state, and national levels. The organization promotes leadership, teamwork, and citizenship development, as well as skill development.

Preparing a Résumé

Your first step in any job search is to develop a **résumé** — a brief account of your professional or work experience and qualifications, designed to give potential employers a snapshot of who you are and what you can offer a company. The first résumé item is your full name, followed by your address and phone number. There are a wide variety of résumé formats, and you should look at several. They traditionally include the following information, generally arranged in sections:

- Position sought
- Education
- Experience

- Activities
- References

You may also wish to include a section for things that make you special, such as awards you may have earned, or ways in which you have been recognized that are noteworthy and say something positive about you. You might title this section "Awards" or "Honors." You will also want to develop a list of references at this time. If you have work experience, ask your supervisor if he is willing to give you a good reference. It is important to ask people for their permission before using them as references. Three to five references are plenty, and you should pick people as references who know something about you and your work habits. Avoid using relatives and friends as references.

Next, have a draft of your résumé evaluated by others and get their feedback. They may very well think of items that they believe are important about you that you have not thought to include. Incorporate any changes you choose to make, and then get someone — preferably several people — to proofread your final draft. Your résumé says something about you. It should not contain spelling errors or other obvious mistakes. This says to your potential employer that you are careless, and this is not an impression you want to convey. By the same token, your résumé should be neatly formatted and cleanly printed on good quality paper. It should be easy to read, and should not be more than two pages long. You can probably fit all your information on one sheet, which is preferable. Look at sample résumés you can find at school or on the Internet. Presentation is important, so take the time to do a good job. **Figure 1-12** shows a sample résumé.

Once you have a résumé, and have located some places to apply for a job, do a little bit of research. Find out a few things about the places where you think you might like to work. The chamber of commerce can help here, too. See if the company has a Web site, and check it out. Now, write a cover letter for your résumé, expressing your interest in a position with them, and politely request an **interview**. An interview is a formal meeting, usually in person, arranged for the assessment of the qualifications of an applicant. Assuming you have obtained information about the company, say something that indicates your knowledge.

Interviewing

First impressions are lasting: you have heard this before. It may not be fair, but it is true. The first thing a person notices about you is the way you look. You should be well dressed and well groomed — leave the cap at home. Dress in a way that would impress an adult in a position of authority. What you wear depends on the type of job for which you are interviewing. Work clothes are appropriate for a job that is manual in nature, but they should be clean and neat. If the job is a technical or professional job, you should be wearing your best dress clothes. You should bring a copy of your résumé with you.

Being able to converse intelligently about the company you are interviewing with is impressive to a potential employer. It demonstrates the level of your interest and the enthusiasm you are likely to bring to the job, so do your homework on that score. Be respectful; treat the interviewer as a potential employer, not a buddy. Be prepared with a list of questions about the job and the company. At some point, the interviewer is sure to ask you if you have any. You want to walk away with as much information as you can. If you have samples of your work, or a portfolio, be sure to take that, and be ready to show it. Make sure it looks as professional as your résumé and your appearance.

Interviewing is not easy. Like most things, it is a skill developed over time. Participating in mock interviews is a great way to practice and hone your interviewing skills.

You may or may not be offered a job at the time of the interview. Often a number of applicants are being interviewed, and the selection is made once all the interviews are complete. When you get home from the interview, sit down and write a thank-you note for the interview, and once again express your interest in the job.

Keeping Your Job

Great, you've landed the job! Now you have to hang on to it. There are a few very simple, common-sense habits you can develop that will serve you well in any employment situation. Even if you decide this is not the job for you, you want to do your best while there, so you can leave with a good recommendation.

A few things will make you a good and valued employee:

- Be on time. Better yet, be a little early. Allow ample time for your commute, so unexpected delays do not cause you to be late. People are depending on you to be there.
- Be prepared. Any tools you need to do your job should be in good condition, and you should have them with you.

YOUR FULL NAME
Your Street Address
City, State 00000
111-555-1234
you@hotmail.com

OBJECTIVE: Entry level carpenter

EDUCATION:

- High School Diploma, 2009
- Associate of Occupational Studies majoring in Building Trades, State University of New York at Delhi, 2011

WORK EXPERIENCE:

- May 2011 - present: Carpenter, TR Smith Residential Construction Company
- January 2011: Internship with TR Smith Residential Construction Company
- Summer 2010: Roofer, Jay Edwards Roofing Contracting
- Summer 2009: Framing carpenter, Three Brothers Carpentry
- 2007–2009: Stock Clerk, Price Chopper

ACTIVITIES/HONORS:

- Vice president of high school vocational club
- Habitat for Humanity volunteer
- Enjoy hiking, fishing, hunting

REFERENCES AVAILABLE UPON REQUEST

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FIGURE 1-12 Sample resumé.

- Be willing to learn, and listen more than you talk.
- Be professional. Treat everyone with respect and tolerance. Your personal beliefs have no place at work.
- Be willing to do all that is asked of you and more. When you finish a task, do not sit around; find out what needs to be done next. Show energy and initiative.
- Do your best. Take pride in your work, whatever it is.
- Remember that work is work. It is not meant to be your social life. Avoid getting involved in long, chatty conversations that are not work related when you are on the clock. This is a real turn-off to any employer.
- Be honest. You know you should not steal, but if you are not working diligently while on the job you are engaged in a type of theft that costs your employer money.
- Be dependable. Do not take time off unless you genuinely need to. You are part of a team, and if you are missing, the team cannot do its job as effectively. If you are unable to attend work for any reason, make sure you call in and let your supervisor know prior to the beginning of the workday.
- Be sensitive to cultural differences and do not assume your personal views are shared by your co-workers. Treat others with the same respect and sensitivity that you want them to show to you.
- Have a positive, can-do attitude. Being negative about your job or your co-workers is a real advancement killer. On every job, there are people who constantly gripe about the way things are, and it is easy to get pulled into this. Don't.

Leaving Your Job

At some point, you will probably change jobs. The way you leave a job is important, because it affects your reputation and the quality of the reference you will be given. Be aware that even if you do not list your former employer as a reference, a smart prospective employer will call your last employer anyway. So when it is time to leave, give sufficient notice. Never quit in anger, no matter how justly aggrieved you may feel. It does not matter. In the same way that you wanted to make a good impression at your interview, you want to leave in such a way that your employer still feels good about you. You have probably heard the expression about not burning your bridges; always keep the possibility of returning to that company open. Once you have given your notice, continue to work just as hard and be just as dependable as you would if you planned to be there forever.

Getting Ahead

If you follow the practical advice given above, you will get ahead. It is that simple. Keep open to learning new skills, too. The more you learn and can do, the more tools you have to succeed. Take advantage of any on-the-job training you can get. When you change jobs, look for one that will better you financially, but also one that will give you the opportunity to better your skills or learn new ones. The more you know, the more valuable — and therefore the more marketable — you will be.

Maintain good relationships with everyone you work with. Three years from now, you do not want to walk into an interview for a new job only to find someone you have not been nice to sitting on the other side of the desk, making decisions about your future.



Summary

People have been working in wood-related jobs for thousands of years. Methods of work have changed, certainly. Today, there is a greater variety of career paths to choose from, which can be a bit overwhelming. Using the many resources available to you, you can begin to narrow the field to dovetail with your skills and interests. Regardless of your career aspirations, it is important to develop a good résumé and the interviewing skills needed to gain a job. Keeping that job and advancing in it is largely within your control. Develop good work habits, and keep learning!



Key Terms

apprentice
Bureau of Labor Statistics
computerized numerical controls (CNC)
internship
interview
journeyman
labor unions
master
Occupational Outlook Handbook
résumé
Shakers
waterwheels



Check Your Knowledge

1. Why was harnessing the power of water important?
2. Describe the ancient guild system.
3. Where would you look to learn more about different careers, including earnings and job outlook?
4. List several resources a job seeker might consult.
5. Why is it a good practice to investigate a company you would like to work for?
6. List five habits that will make you a valuable employee.
7. Why is it important to leave a job on good terms?



Activities

1. Develop a résumé and have it critiqued by someone whose opinion you value.
2. Practice your interviewing skills with a partner.
3. Research several related jobs and compare them in terms of the nature of the work, working conditions, job outlook, and earnings.
4. Make an appointment to talk with someone who is successful in a job you think might be interesting and rewarding. See what you can learn from him or her about their job and what he or she did to become successful.
5. Make a list of all the ways you use electricity during the day. List the ways your life would be different without it.
6. Take an actual or online tour of an old waterwheel-driven mill.
7. Visit a modern manufacturing facility.



2

General Safety Practices

You'll Learn

After studying the chapter, the student should be able to:

- Correctly identify and define the most important safety attribute in the shop
- Understand and explain the importance of personal safety equipment
- List hazards faced in the cabinet shop and describe how to protect against them
- Detail reasons for keeping the shop in pristine condition
- Understand the importance of keeping tools in top condition
- Explain how to be prepared for an injury
- Explain what to do should an injury occur

INTRODUCTION

Safety is a special concern for any individual spending time in a woodshop. The tools we work with have the potential to do us serious harm. However, by being aware of special safety concerns connected with woodworking, and by exercising good common sense, we can all come to the end of our careers still able to count to ten on our fingers. And of course, the first hazard most of us think of is a gruesome accident resulting in the loss of a finger, or worse. But other, less visible hazards face us in the shop as well.

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We must guard ourselves not only against being cut, but also against such dangers as wood dust, noise, hazardous fumes, lifting injuries, and fire.

These dangers may sound intimidating, but good habits and a good safety attitude will serve you well. What do you think your most important piece of safety equipment is? Asked that question, you might say safety glasses, dust masks, perhaps hearing protection, or good guards on the equipment you use. These are all essential items, but the most important tools you can bring to woodworking are located right between your ears: They are the awareness, the attitude, and the knowledge that you bring to every aspect of your time in the shop. Safety is a habit that you develop, and like all habits, it will become instinctive over time.

OSHA

OSHA is the acronym for the Occupational Safety and Health Administration, a federal agency that was created by Congress and signed into law by President Nixon in 1970 to ensure safe and healthy working conditions for all workers. It is part of the Department of Labor. OSHA's mandate is to set and enforce standards that ensure safe working environments and prevent injuries. OSHA inspectors are highly trained compliance officers who can and do make unannounced site visits to make sure employers are following OSHA's safety regulations. Noncompliance with OSHA regulations can result in heavy fines. Since OSHA inspectors cannot be everywhere, it is up to employers and employees to keep themselves safe by following some of the basic rules we will cover in this chapter.

THE NUMBER ONE SAFETY RULE

The number one safety rule is to stay alert! You must keep your attention on what you are doing. If you are unable to do that, you have no business operating dangerous tools. It is an interesting fact that many woodworkers who are badly injured in the shop have been working in the trade for some time. They allowed their attention to wander, or took a shortcut that they should not have taken, and the result was a careless mistake that caused an unnecessary injury.

WOODWORKING HAZARDS

So what are the greatest dangers we face? Again, you may think of physical things — cuts, wood dust, and so forth. But again, the importance of awareness, knowledge, and attitude must be emphasized. With that in mind, these are the greatest hazards in a woodshop:

1. Ignorance of how tools function or correct procedures for using the tools
2. Overconfidence that leads to carelessness
3. Rushing or hurrying
4. Disregarding the basic rules of safety

Basic Safety Rules

There are several basic safety rules that apply no matter what tool is being used. These principles form the foundation for creating a safe working environment for yourself and others.

First, be sure you are familiar with the tools you use, and use them to do what they were designed to do. For example, do not use a chisel as a screwdriver or a pry bar; take the time to go get the screwdriver. That is a simple example, but it should bring to your awareness that it is not only those tools that make noise that can hurt you. We often do not give our hand tools the respect they deserve, and we must, because an improperly used or improperly tuned hand tool can do serious damage.

Second, use **tool guards** whenever possible. Tool guards are safety devices designed for use with specific tools; they keep the operator's hands from getting dangerously close to spinning blades, bits, and cutters. **Figure 2-1** shows an example of a table saw guard. Many of the guards that come with machines are poorly designed, and there is a tendency in the woodworking community to operate tools without their guards. This is not a good idea. There are good aftermarket guards available, or you can fashion your own, but do use them whenever possible. Tool guards must be removed to perform certain operations. For example, machining dados on the table saw cannot



Image courtesy of Delta Power Equipment Corporation.

FIGURE 2-1 Table saw equipped with a blade guard.

be done with the guard in place. When we do have to operate machinery without guards, we should be especially vigilant.

Third, use auxiliary **jigs** and safety devices when needed. A jig is a purchased or shop-made device that makes a job safer and easier. If you are using the drill press, for example, to bore a hole in a small piece, find a way to hold it so that your fingers stay out of the danger zone, such as holding it in a clamp (see **Figure 2-2**). Use **push sticks** to rip narrow pieces on the table saw. A push stick is a shaped wood or plastic device that allows the operator to move material past the blade without putting his fingers into the danger zone (see **Figure 2-3**). Take the time to perform operations safely; you will lose a lot more time if you get hurt.

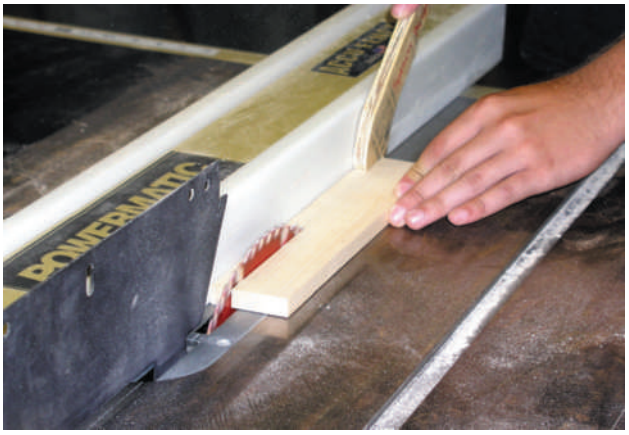
Fourth, maintain your equipment. As we cover the various tools in the next few chapters, we will talk about how to maintain them. Taking the time to take care of your equipment is important, both for safety reasons and for reliable results in your woodworking endeavors. Developing a routine to take care of your tools pays great dividends.

Most important of all: Pay attention and be alert. Your tools cannot think or reason. They cannot differentiate between your flesh and a piece of wood. Most tools have sharp cutting edges, and are moving at very high speeds. Maintain a healthy respect for your tools. A little bit of fear, or at least an awareness of possible problems, is a good thing. Be careful. Your safety is your responsibility.



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FIGURE 2-2 A simple auxiliary jig for holding a small piece while boring on the drill press is a hand-screw clamp.



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FIGURE 2-3 A push stick ensures that your fingers stay well away from the blade when ripping narrow pieces on the table saw.

Eyes, Ears, and Lungs

When you open to a chapter on safety, protecting your eyes, ears, and lungs is probably what comes to your mind first; and indeed, we must protect ourselves in these respects. Personal safety equipment should be a basic part of your tool kit, and you must develop the habit of using it. Simply having it in your toolbox will not protect you; you must use it. You will quickly get used to the gear, and once you do, you will not feel right if you do not use it.

Your eyes should be protected against flying debris and dust. This means wearing OSHA-approved safety glasses, goggles, or a face mask (see **Figure 2-4a** through **Figure 2-4c**). Whichever you choose, it should fit well and not be so scratched that it interferes with your vision. If you need corrective glasses to see, you can use these in the shop, provided that they are shatter resistant, or you can have a pair of safety glasses made with your prescription. If you wear your regular street glasses in the shop, purchase side shields that slide onto the bows of your glasses.

Most of you probably already were aware that your eyes have to be protected, but we also should protect our hearing. Many of the tools we use are loud, and over time, exposure to this noise will cause

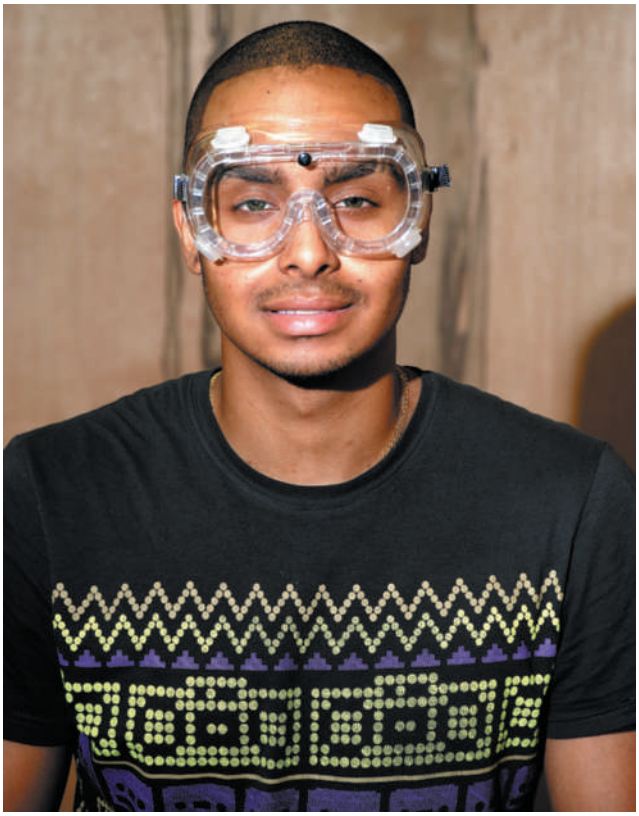
WOODWORKING TIP:

Donate one of your orphaned socks to keep your safety glasses from getting scratched banging around loose in your toolbox.



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FIGURE 2-4a Safety glasses.



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FIGURE 2-4b Safety goggles.



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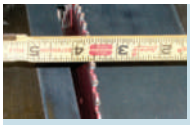
FIGURE 2-4c Face shield.



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FIGURE 2-5a Disposable plugs — good.

hearing loss. Several types of hearing protection are available (see **Figure 2-5a** through **Figure 2-5c**). Good hearing protectors will screen out high frequencies,



SCIENCE CONNECTION

Sound is measured in decibels. A person who is regularly exposed to 110 decibels for a period of more than one minute risks permanent hearing loss. At 100 decibels, no more than 15 minutes of unprotected exposure is recommended, and prolonged exposure to any noise above 90 decibels can cause gradual hearing loss. So how loud is loud? Here are some examples of common sounds and their decibel levels:

140 decibels — rock concerts, firecrackers
120 decibels — snowmobiles
110 decibels — chainsaw
100 decibels — woodshop
90 decibels — lawn mower, motorcycle
80 decibels — city traffic noise
60 decibels — normal conversation
40 decibels — refrigerator humming
20 decibels — whispered voice ■



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FIGURE 2-5b Ear buds — better.


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FIGURE 2-5c Ear muffs — best.


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FIGURE 2-6a Paper dust mask.

which cause the most damage, but will still allow you to hear normal conversation. The use of combination hearing protector/radios in a shop with more than one worker is discouraged, because it tends to distract a person from what others are doing nearby; and being safe in a multiple-person shop is a little like defensive driving — you not only have to follow all the rules of the shop yourself, you also have to watch out for the other guy, who may not be as careful as you are.

When you are creating airborne dust — while sanding, for example — you should wear a dust mask or a respirator with dust filters (see **Figure 2-6a** and **Figure 2-6b**). The better it fits, the more effective it will be. Wood dust can cause respiratory disease and has been linked to certain types of cancer, such as lymphoma. Wood dust from some species can also cause skin irritation and allergic reactions. If you notice you are having a reaction to certain kinds of wood dust, you must be extra careful. If you are sensitive to a particular kind of wood, you may become more allergic to it over time.

There are times when you may need to use a respirator because the fumes of some finishes are toxic


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FIGURE 2-6b Respirator. Most respirators have replaceable filters for both dust and chemical protection.



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FIGURE 2-7 The well-dressed and safety-conscious woodworker wears an apron, safety glasses, and hearing protection.

and should not be breathed in. The same is true for some adhesives. Your respirator should fit well and have the proper chemical filters, which are not the same as dust filters. Most respirators can be fitted with different kinds of filters for various operations.

Shop Dress and Shopkeeping

Most of what we will cover in this section boils down to common sense. Avoid loose clothing or dangling jewelry that can get caught in a piece of machinery. If you have long hair, tie it back for the same reason. You must have and use eye, ear, and lung protection. Wear protective shoes, such as work boots. Wearing a shop apron of some sort is a good idea; not only will it cut down on the amount of clothing that ends up in the rag bag due to glue and finishing stains, it also provides a place to easily carry the tools that you use repeatedly and need closest at hand as you work around your shop (see **Figure 2-7**). Shorts are discouraged, because they offer less protection than long pants.

As far as housekeeping goes, keep your shop clean. Do not allow scraps to accumulate by or on your saws or anywhere else on the floor. Watch out for tripping hazards, and do away with them. Keep surfaces clean and picked up: You will have more room to work, and it will be far easier to find things. If you clean as you go, you have less mess in the end and your work area will be much safer. Wood scraps and dust can also present a fire hazard, so your shop should be equipped with an approved fire extinguisher in the event of fire; but it is your job to make sure you never need to use it. Combustible rags should be properly disposed of, either in a fire-rated container, in a bucket of water, or spread out so that the solvents in the finish can evaporate (see **Figure 2-8**). If you work with green wood, you must be particularly careful to clean up when you finish working for the day, because the combination of wood dust, moisture, and sufficient oxygen can lead to spontaneous combustion.

Sweeping the shop is not enough. Periodically you must vacuum the accumulated dust from on top of the lights, in corners, and in all the other nooks and crannies. The more small items you can stow in closed cabinets, the less cleaning you will have to do. A good dust-collection system will cut down tremendously on the amount of dust and wood chips in the shop. Air filters can be mounted that will filter the small particles that escape the dust collector, and this

CAUTION

Baggy clothing is not acceptable attire in the shop and should be avoided since it can get caught in power equipment.



Image courtesy of Eagle Manufacturing Co.

FIGURE 2-8 OSHA approved fire can for disposing of flammable materials.



SCIENCE CONNECTION

Spontaneous combustion is a type of combustion which occurs without an external ignition source. Substances such oil finishes absorb oxygen and release heat as they cure. This is not a problem on a workpiece, where the heat dissipates into the air, but in a wadded-up rag, sufficient heat can build up to cause the rag to burst into flames. ■



Image courtesy of POWERMATIC® and JET®.

FIGURE 2-9 The portable, small shop dust collector seen here does an excellent job.



Image courtesy of POWERMATIC® and JET®.

FIGURE 2-10 The air filter pictured will pick up the dust that is fine enough to escape any dust collection system.

helps keep the air clean. These are essential investments for anyone spending much time in a shop (see **Figure 2-9** and **Figure 2-10** for examples of each).

Your shop should have good lighting. Ideally, it should have some natural light, good overhead lighting, and specific task lighting. This is especially important for finishing work. And as mentioned before, your tools should be kept in top condition.

Shop Practice

Although there are specific safety concerns and rules for individual machines that we will address when we discuss these tools, there are several general points that can be made. We have talked about the importance of giving your undivided attention to a given task and also about personal safety equipment and keeping your shop clean. The following points reiterate some of this information, and these will give you some general guidelines for working safely in the shop.

1. Do not overreach: You need to be securely balanced at all times. Putting yourself in danger of losing your balance in the vicinity of any sharp spinning blade, knife, or cutter is a bad idea.
2. Do not struggle with work that is too large for you to easily handle. Get help, or figure out a safer way to work with the piece. Maybe you are working alone and you cannot safely cut a big piece of plywood on the table saw. In that case, you could cut it with your circular saw and a guide. Bring your creativity and ingenuity to bear not only on the projects you build, but also to the process of building them safely and efficiently.
3. Do not work with dull or dirty tools. It may surprise you, but you are far more likely to get hurt with a dull tool than with a sharp one. In addition, you are not going to like the results you get with a dull tool. Sharpening is not as mysterious as you may have been led to believe. Learn how to do it and keep up with it.
4. Disconnect tools from their power source when making adjustments.
5. Do not force cuts. Trouble with a cut means something is wrong, and you need to back off and figure out what the problem is before you injure yourself, harm your equipment, or ruin that precious piece of curly maple you have been hoarding.
6. Allow power tools to reach full speed before cutters come into contact with the stock.
7. Keep your mind on what you are doing. It has been said it before, but it bears repeating.

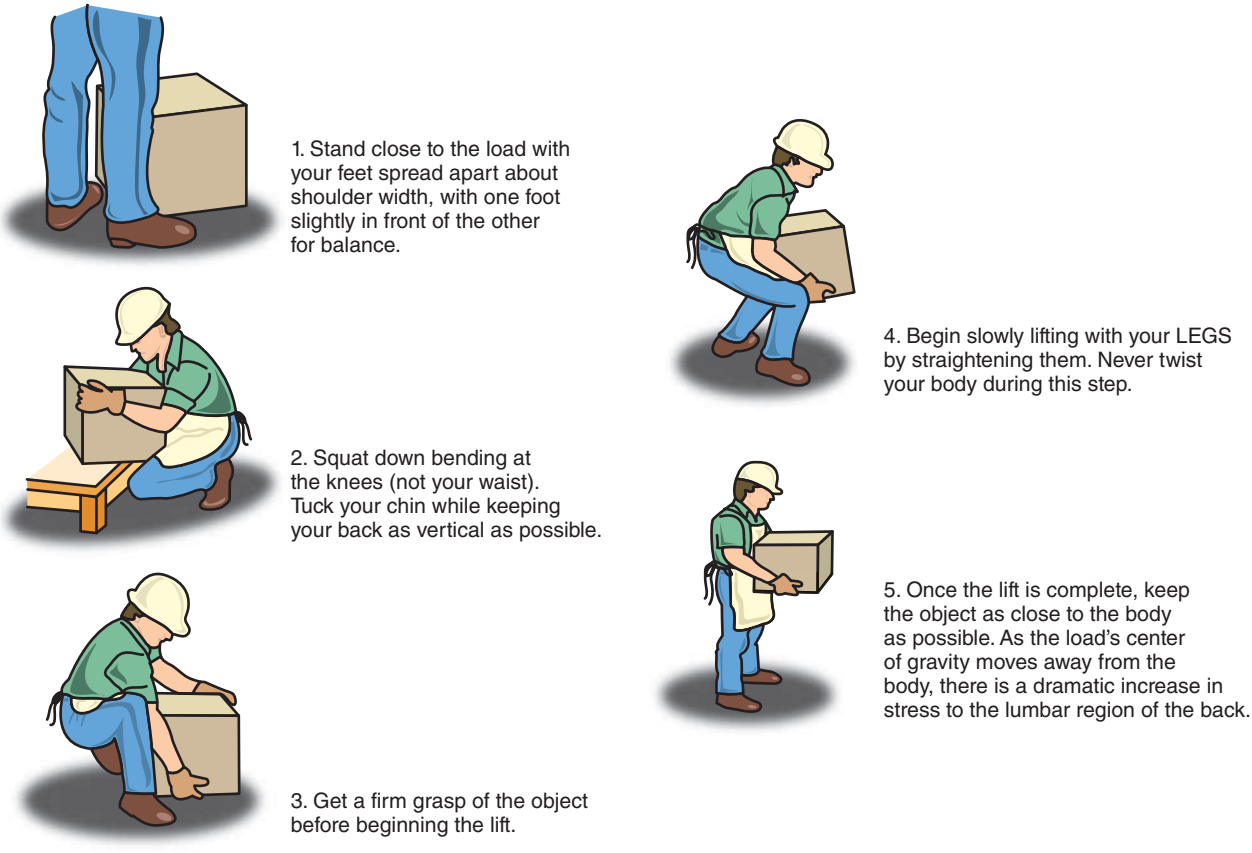
8. Do not work when tired, upset, or under the influence of alcohol or drugs, prescription or otherwise. All of these things conspire to take your attention away from what you are doing, and anything that will distract you from bringing your full concentration to the task at hand creates a risk you should not take.
9. Learn how to lift properly to avoid back injury (see **Figure 2-11**).

Be Prepared

Accidents do happen. The chance, frequency, and seriousness of injury are substantially reduced by following the basic, common-sense rules that have been laid out. Some things are going to happen, without a doubt. You will get splinters: Count on it. Your shop should have a well-supplied first aid kit, and everyone should know where it is. It should contain, at a minimum:

- Splinter tweezers
- Needles for splinter removal
- Providone-iodine solution for killing germs
- Latex gloves
- Instant ice packs to reduce swelling and for transporting amputated parts to the hospital
- Clean plastic bags for amputated parts
- An asthma inhaler (to counteract allergic reactions)
- An eye cup and eye wash
- Small mirror for eye inspections
- Band-Aids of various sizes
- 4" × 4" gauze pads, sterile rolled gauze, and adhesive tape for bandaging
- Butterfly bandages for drawing together large lacerations
- Sharp scissors for cutting bandages

Make sure your first aid kit is fully stocked, and replace items that are used so that next time they are needed they will be there.



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FIGURE 2-11 Lift intelligently: Use your legs.

A shop should have a phone, and an emergency number should be posted nearby. In addition, an understood procedure should be in place should a serious accident occur. Pressure should be applied to a badly bleeding wound, and medical attention should be sought immediately. In case of an amputation, pressure should be applied to the wound, and the digit should be found, wrapped in a damp paper towel, placed in a ziplock bag, and then that bag put in another ziplock bag containing ice. The victim and the digit must immediately be transferred to the hospital. Know where your nearest hospital is and how to get there: Time is of the essence if the digit is to be saved. Remain calm. Keep protective gloves in your kit to avoid blood-borne diseases.

To cut down on the time you spend picking splinters out of your hands, keep a pair of gloves in your tool kit, and do not hesitate to put them on when moving material in bulk, as when you visit the lumberyard and sort through the racks for the very best stuff.



Summary

Safety is your responsibility. Take it seriously. Dress properly for working in the shop and wear the correct gear. Learn your machines, including their limitations, and take care of your equipment, including hand tools. Keep your shop clean and neat, and watch out for the other guy, who may not be as safety conscious as you are. Develop good habits and adhere to them. Keep your first aid kit stocked, and know how to react in case of a serious accident.



Key Terms

jig **push stick** **tool guard**



Check Your Knowledge

1. Of all the things we can use to keep us from harm in the shop, what is the most important and why?
2. What items make up your personal safety gear, and what do they protect you from?
3. What advantages are gained from having a clean, well-ordered shop?
4. Why is proper care and maintenance of your tools and equipment important?
5. How should you be prepared in the event a serious accident?



Activities

1. Given what you have learned in this chapter, grade your shop and its users for safety. Can safety in your shop be improved?
2. Share tool injury horror stories, and analyze how these accidents might have been prevented.
3. Visit some commercial shops and rate them on safety. Are they places you would feel safe working in, day in and day out? Why or why not?



What's Wrong with This Picture?



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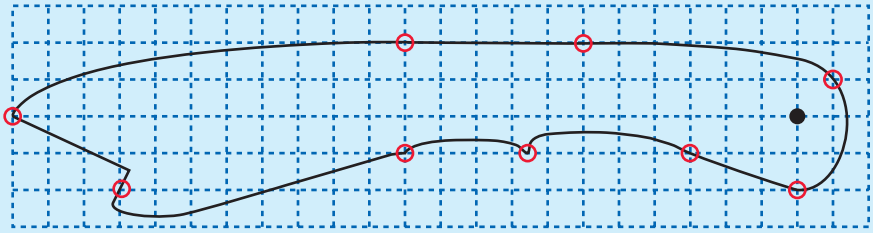
BUILD IT!

Push Stick



A

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B

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Push sticks are used to move material past a spinning blade, bit, or cutter, when doing so without one would bring your fingers too close to the blade. Think of your push stick as a sacrificial finger: It feels no pain, and it is easily replaced. **Figure A** shows a completed push stick.

TOOLS REQUIRED

- Measuring tape or ruler
- Straightedge
- Combination or try square
- Pencil
- Coping saw, jigsaw, band saw, or scroll saw

MATERIAL REQUIRED

- 1/2" plywood, MDF, or solid stock measuring approximately 3" × 12"

STEPS

1. Lay out a grid of squares on your material, each measuring 1/2" × 1/2".
2. Working from the diagram, transfer the pattern to your material, as shown in **Figure B**. First lay out the points indicated by the small red circles — this makes transferring the pattern easier. The most critical part of your push stick is its square mouth.
3. Carefully cut out the push stick using a coping saw, jigsaw, scroll saw, or band saw.
4. Drill a 1/4" hole in the handle if you want to be able to hang it.
5. Sand the edges smooth.

PROJECT CHALLENGE

Long-Base Push Stick

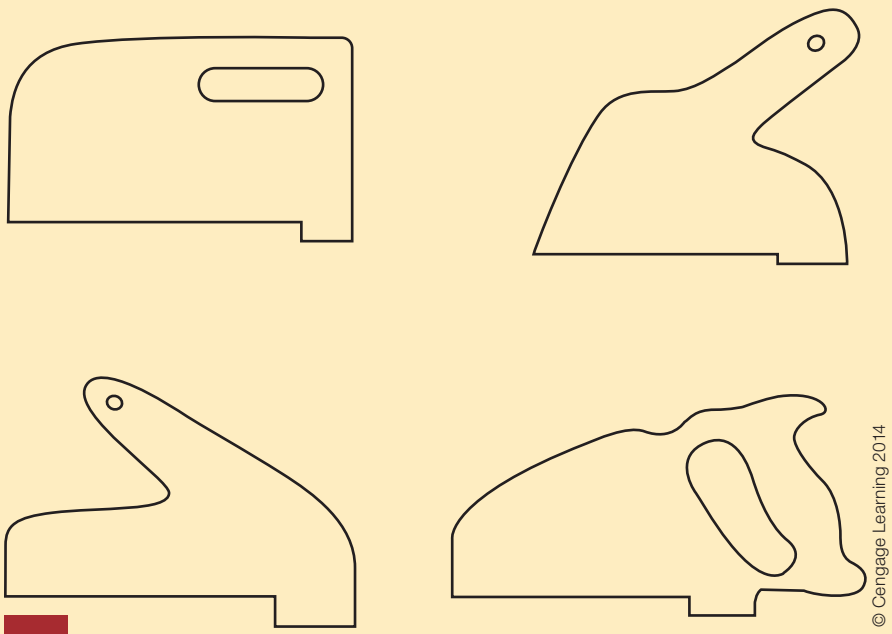
STEPS

1. A long-base push stick is shown in **Figure A**. Review the long-base push stick designs shown in **Figure B** and select one.
2. Lay out the design you have chosen on 3/4″ or 1/2″ plywood, MDF, or solid stock that is approximately 6″ wide and 12″ long. The notch in the base should be large enough to hold the stock but shallow enough not to contact the table.



A

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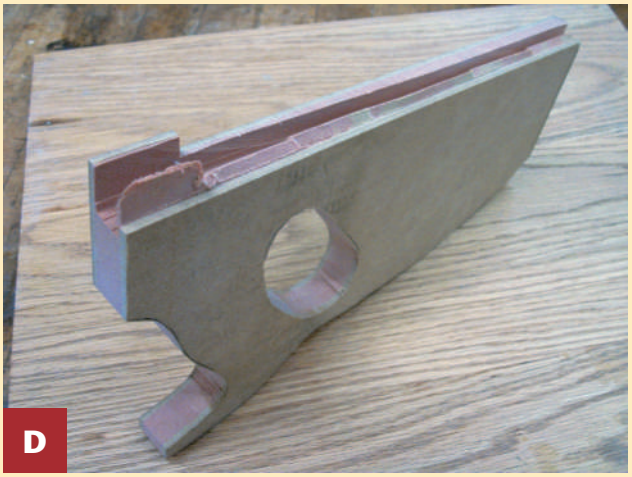


B

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3. Cut out the push stick with a coping saw or jigsaw. If yours has an interior handle, drill a hole that your coping saw or jigsaw blade will fit through. Release the blade on the coping saw and feed it through the hole. Reattach the blade and make the cut (see **Figure C**). The jigsaw blade is simply inserted into the hole.
4. Sand the sawn edges smooth and round over the handle for a comfortable fit.
5. If your push stick does not have an interior handle, you may wish to drill a hole through it so you can hang it.

   NOTE: Push sticks are consumable items. As they are used they get chewed up and are no longer effective or safe. Periodically check your push sticks, and when they show wear, make new ones. **Figure D** shows a push stick that needs to be replaced.

SECTION II


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Tools of the Trade


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SUCCESS STORIES

Thomas Lie-Nielsen

Title

Founder, owner, and designer, Lie-Nielsen Toolworks, Inc., Warren, Maine.

Education

Thomas graduated from Hamilton College, but in terms of woodworking, his education was hands-on: His father owned a boat-building shop, and Thomas helped out during his teens and twenties.

History

Without a career goal in mind after graduating college, Thomas found himself following his wife to New York City, where she'd gotten into graduate school. There, leveraging his experience at his father's boat shop, he found a job working for Garrett Wade, a mail-order woodworking tool retailer. After his wife finished school, the couple returned to Maine. His father had sold the boat shop, but there were some tools that customers of Garrett Wade's were asking for that were no longer available. "I figured I could make them," says Thomas. He already had one piece in mind: a bronze-edge plane. "Because I was young and didn't have kids or a big mortgage, I was able to spend

the next few years learning what I needed." He got his first tool made — learning machining, polishing, and casting in the process — and sold it through his former employer. By the mid-eighties, he'd designed three tools and started selling direct, advertising via small classifieds in woodworking magazines. He's been in business for himself ever since.

On the Job

Thomas works 12-hour days, managing a staff of 80 people, overseeing the production, hiring, and financial aspects of the business. But his most satisfying responsibility is new tool development. The company introduces some six new tools per year, and Thomas is involved in everything from prototyping them to testing them, which is the only hands-on woodworking he does these days.

Best Aspects

"I love when customers write to us to say the tools raise their skill level, help them do better work, and improve their woodworking life," says Thomas.

Challenges

Thomas's biggest challenge is employees — from finding good ones to training new ones to managing those he already has. "Starting as a one-person business and growing to 80 people was an adjustment," he says. "This is not something I set out for myself as a career goal, but it comes with territory." Over the years, he's developed his management philosophy: "My aim is to make this the kind of business that I would want to work for as an employee."

Importance of Education

"Learn as much as you can about woodworking, and always ask questions," says Thomas. As an employer, he finds that formal training is a plus.



Image courtesy of Thomas Lie-Nielsen.

Future Opportunities

Thomas wants to maintain the company's profitability, as well as its place as the leading hand tool manufacturer.

Words of Advice

"Don't listen when people say you can't do something," says Thomas. "I was told that, and if I'd listened, I wouldn't be where I am today."

Story originally written by Margaret Magnarelli, 2008. Interview and photo provided by Thomas Lie-Nielsen.



3

Hand Tools

You'll Learn

After studying the chapter, the student should be able to:

- Correctly identify the hand tools used in woodworking
- Explain the uses of each tool
- Understand how to use hand tools safely
- Know how to select and properly care for hand tools

INTRODUCTION

Tools that are powered only by the operator are called **hand tools**. There are people who are not too excited about hand tools. Sure, the measuring and layout tools are necessary, but don't we have machines now for cutting, shaping, and drilling? Happily, we do, but in the rush to do everything by machine, we sometimes overlook hand tools that could do the job as easily and quickly without all the noise and dust, not to mention the expense of multiple machines. Very few of us would give up our power tools, nor is that being suggested. Power tools have enabled us to produce more work with less effort than the cabinetmakers working in the seventeenth century. The point is that we should not overlook hand tools. Most people who have tried hand tools have gotten discouraged with poor results and have largely given up. Much of this has to do with the fact that the tool

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is improperly tuned or simply not tuned at all. There are also some very low-quality tools on the market. Buy the best hand tools you can afford, and maintain them.

There is another good reason to become proficient with your hand tools, especially as a beginner. By cutting, planing, and shaping material by hand, you learn a lot about it. Different types of wood have different cutting, planing, and shaping characteristics. This is important information to have as you go on to work more extensively with machines, because you will have learned to "read" the wood, and you will understand the importance of grain direction. You will know which woods are prone to chipping or tearing out. Armed with this information, you will have a much better understanding of how a given piece of material will react when machined.

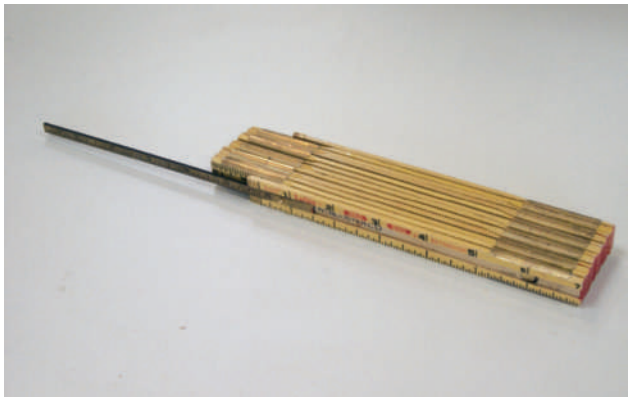
Hand tools are divided into six general categories by use or type: measuring, layout, and marking tools; saws; chisels and planes; drilling tools; shaping and smoothing tools; and striking and fastening tools.

MEASURING, LAYOUT, AND MARKING TOOLS

We begin with the tools you will need to use first, and there are many options. As the saying goes, using the right tool for the job ensures success.

Measuring Tools

Steel tapes and **wooden rules** are the woodworker's primary measuring tools (see **Figure 3-1**). Rulers are also used. These tools are used for measuring width, length, and thickness, and for layout in conjunction with the other layout and marking tools. Good steel tape measures are available in lengths ranging from 12 feet to 30 feet. They retract into a case when not in use and have a hook on the end, so they can be hooked over the end or edge of a piece of stock for measuring. Longer tapes have wider and therefore stiffer blades, which is an advantage when manipulating the tape over a long distance or when measuring overhead. Wooden rules fold up and are typically available in 6-foot and 8-foot lengths. A nice feature is an insert, which allows you to accurately take inside measurements (see **Figure 3-2**). Under the insert is a good place to put your name, to distinguish your rule from everyone else's.



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FIGURE 3-2 A wooden rule with an insert allows you to take accurate inside measurements.



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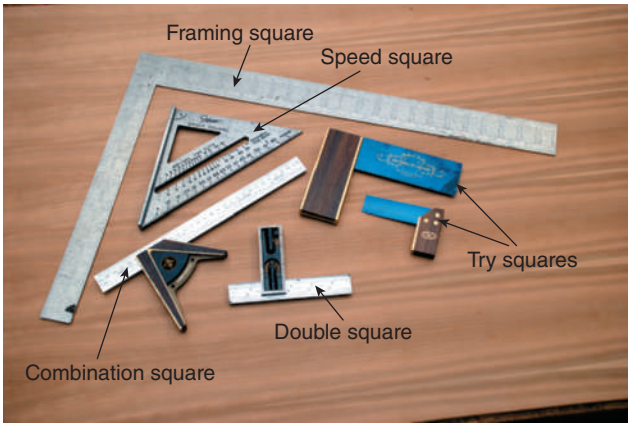
FIGURE 3-1 Tapes and rules.

Layout Tools

A key layout tool is a true **square**. A square is a T-shaped or L-shaped tool used for drawing and testing right angles. When you build things, you need to be concerned with your constructions being structurally sound. Part of this comes from the material selected, but the rest lies in how the individual components of the piece are aligned and attached to one another to make the whole. The squareness of individual parts to one another and to the whole is something that is checked regularly in a cabinetmaking shop, because it is very important. For example, if a chest of drawers is not square, it will not sit flat. If the chest is square, but the drawers are not, it will be difficult and time-consuming to fit your drawers, and they will not work the way they should. So to save yourself untold aggravation and time — and to produce a functional and attractive cabinet or piece of furniture — you need to be able to accurately lay out and cut straight lines. To check whether pieces are square to one another, a number of different squares are utilized (see **Figure 3-3**).

The most important thing about your square, no matter which one you use, is whether or not it is truly square. If it is not, your layout will not be accurate. There is a simple way to check your square for accuracy (see **Figure 3-4**).

Combination squares are composed of two primary parts: a metal *rule* and a metal *head*. The rule slides along in the head and can be fixed as desired. The combination square (shown in Figure 3-3) is used to reliably mark and check both 90° and 45° angles. Like all the squares, the combination square is indispensable for checking the accuracy of machined pieces, as well as tool setups.



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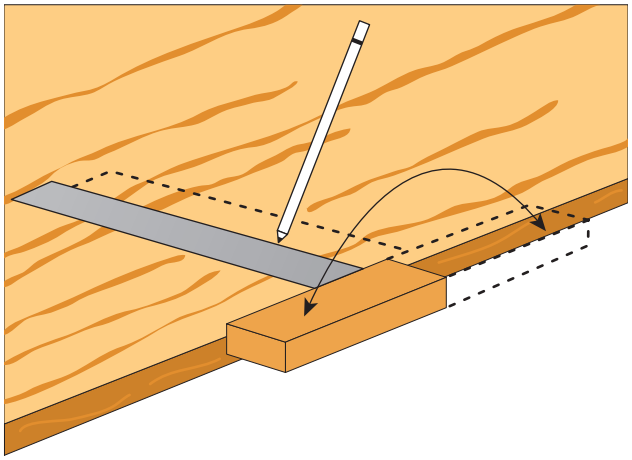
FIGURE 3-3 Framing square, try squares, double square, combination square, Speed Square.

Try squares come in a range of sizes. A try square consists of a metal straightedge, often ruled, set at a right angle to a straight piece, and it is used for measuring and marking square work. The head is usually fixed, but not always. A variant of the try square is the double square, which has a sliding head. Higher-quality tools have the markings stamped or etched on the rule. Inscribed marks have a far longer usable life than those that are merely painted on.

The **Speed Square** is more of a carpenter's than a woodworker's tool, but if accurate, it can be very useful for marking and checking 90° and 45° angles. Speed Square is a trademark name for a three-sided, triangular-shaped measuring tool manufactured by the Swanson Tool Company. It can also be used to lay out angles for roofs and stairs.

A square that is rather different from the others is the **bevel square**, also called a **sliding T-bevel**. It consists of a *blade* and a *head*. The blade of the bevel square pivots and can be locked in place at any angle to the head. This is useful for transferring angle measurements and can be used in conjunction with a protractor to mark out or check angles other than 90° and 45°. A protractor is an important tool for accurately laying out angles. It does not have to be fancy. **Figure 3-5** shows two sizes of bevel squares and a basic protractor.

Another commonly used layout tool is a **compass**, which can be used for laying out circles and arcs and for stepping off measurements. Compasses made specifically for woodworking are called **dividers**. They have two metal legs, one of which can be removed and replaced with a pencil. Most compasses and dividers



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FIGURE 3-4 Check square by drawing a line and then flip the square over. IF it is true, then the blade will be on the drawn line.



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FIGURE 3-5 Bevel squares and protractor.

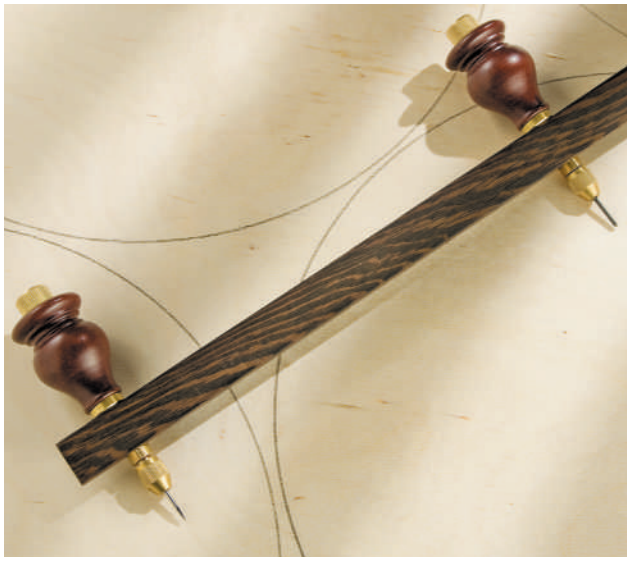


Image courtesy of rockler.com

FIGURE 3-6a Trammel Points.



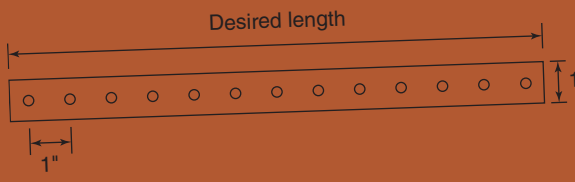
Image courtesy of rockler.com

FIGURE 3-6b Trammel Points in use.

are pretty limited in what they can do because of their size; if we need to mark out a circular tabletop, we need something bigger. The answer is **trammel points**, which are two sliding sockets that carry steel points or pencil points; they are attached to a straight piece of metal or wood stock. Depending on the length of the rod used and where the trammel points are fixed, arcs and circles of any size can be marked out (see **Figures 3-6a** and **Figure 3-6b**).

WOODWORKING TIP:

Trammel points are nice to have, but should you find yourself needing to mark out a circle that is beyond the size possible with your compass, and you do not have trammel points, you can easily make a **beam compass** *that will work nicely. A beam compass consists of a flat piece of stock with two or more holes drilled in it, one of which holds a finish nail to anchor the compass and another that holds a pencil tip to mark the arc or circle desired. You can tailor a beam compass to a specific task or make it more versatile by drilling a series of evenly spaced holes the diameter of a small finish nail (see* **Figure 3-7**).



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FIGURE 3-7 Beam compass.

Marking Tools

Marking tools include anything used to inscribe layout or cut lines. If you have a carpenter's pencil, save it for your carpentry work: woodworkers work within very fine tolerances, and a fine line is required for accuracy. Number two pencils will work, but they should be very sharp. Some woodworkers use a **marking knife**. A marking knife gives you a very accurate, fine line that will not be smudged, as a pencil line can be. Another advantage to using a knife is that you are not only drawing a line, you are **scoring** it, which severs the top fibers of the wood and makes splintering and tear-out cutting less likely (see **Figure 3-8**). A scored line also creates a registration point for starting a cut with a handsaw. The one downside to marking knives


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FIGURE 3-8 Using a marking knife scores the line.

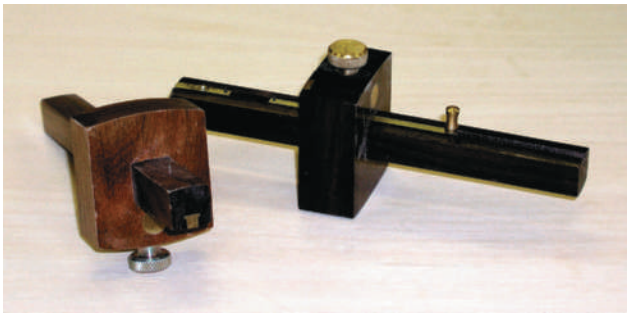

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FIGURE 3-9 Marking and mortising gauges.

is that the line can be hard to see, but lightly running your sharp pencil along a scored line will make it much more visible.

Another marking tool is called a **marking gauge**, which consists of a *beam*, a *headstock*, and a *marking implement*, usually a pin, a knife, or a wheel (see **Figure 3-9**).

WOODWORKING TIP:

If you use pencils for your layout work, it is useful to acquire a white one to use when working with dark-colored wood such as walnut, where a dark pencil line can be difficult to see. White pencils can be found at art stores.

Its purpose is to scribe a line parallel to a reference edge or surface. The headstock slides along the beam and is locked in place by a locking screw. The marking implement is fixed to one end of the beam. The headstock is set so that the distance between it and the marking implement equals the distance from the reference edge to the line to be scribed. The user holds the headstock tightly against the reference edge and draws the gauge along so that the headstock follows the reference edge (see **Figure 3-10**). The marking implement, in contact with the surface, scribes a line. The marking implement chosen depends on the operation to be performed. A steel pin does the best job when scribing with the grain, while a knife is better for scribing across the grain.

A **mortise gauge** is a type of marking gauge that has two pins that can be adjusted relative to one another at the end of the beam. This gauge is used to scribe two parallel lines simultaneously and is commonly used to lay out mortise and tenon joinery.

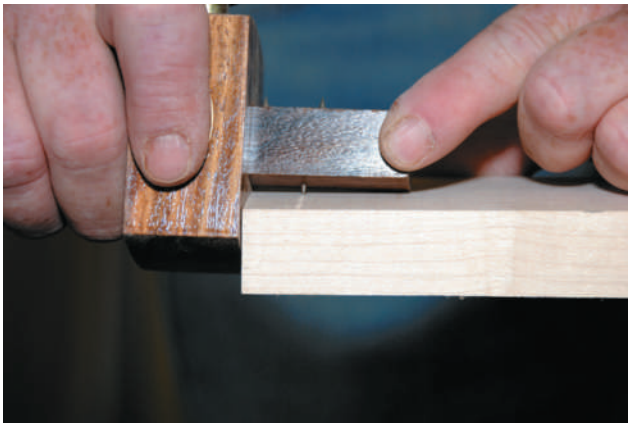

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FIGURE 3-10 Using a marking gauge.

WOODWORKING TIP:

When you need to lay out a curve, often it is not circular. A simple way to lay out a **fair curve**, *one without flat spots, is to use a thin, flexible piece of wood. It should be flat on one side (see* **Figure 3-11**).

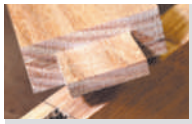

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FIGURE 3-11 Laying out a curve.

SAWS

Cutting material to a specific size and shape is accomplished with a variety of different saws (see **Figure 3-12**). Different saws are designed to cut wood in different ways. Years ago, before the proliferation of good, affordable power tools, a cabinetmaker had a great many saws as part of his kit. Today we do most of our cutting operations with machines, and as a result, we tend to have fewer handsaws. Prior to the wide use of power saws, a cabinetmaker would have both a **rip saw** and a **crosscut saw** in his kit.

A modern woodworker is more likely to have a **combination saw**. The rip saw is designed for making cuts with the grain. The cutting edges of the teeth on a rip saw have a flat front edge and are not angled, allowing each tooth to act like a chisel, which prevents the saw from wandering off the line of the cut. The crosscut saw is designed to cut efficiently across the grain. The cutting edge of each tooth on a crosscut saw is angled back and has a beveled edge, which allows the tooth to act like a knife and slice through the wood (see **Figure 3-13**). The combination saw is designed to perform both tasks.



HISTORY FACT

"It is far better to work with one plane, one saw, one chisel and a few accessories, all of them good, honest steel, properly sharpened, than it is to have a cellar full of inadequate devices."

How to Work with Tools and Wood (1942) from Stanley Tools. ■

The combination saw is the workhorse of the saws. Other, finer saws are used for more precise work. Three basic attributes govern how a saw cuts: the *shape* of the teeth, the *spacing* of the teeth, and the *set* of the teeth. The shape of the teeth may be like those of a rip saw or crosscut saw. Tooth spacing is referred to as **TPI**, or teeth per inch. The higher the TPI, the finer the cut the saw will make. A saw with fewer TPI will cut more quickly, but it will not make as fine a cut. The **set** of the teeth refers to how much the teeth are angled from the body of the blade. The more set, or angle, a saw has, the more aggressively it will cut; but it will also create a wider kerf. The **kerf** is the gap created as the saw is used (see **Figure 3-14**).

Many of the finer saws commonly used by woodworkers today are members of the **backsaw** family, saws which have a stiffening rib on the edge opposite the cutting edge. This rib allows for better control and more precise cutting than with other types of saws. Since the stiffening rib is thicker than the blade, backsaws are limited in the depth they can cut. Backsaws usually have relatively closely spaced teeth, often with little or no set. They may have either rip or crosscut teeth.

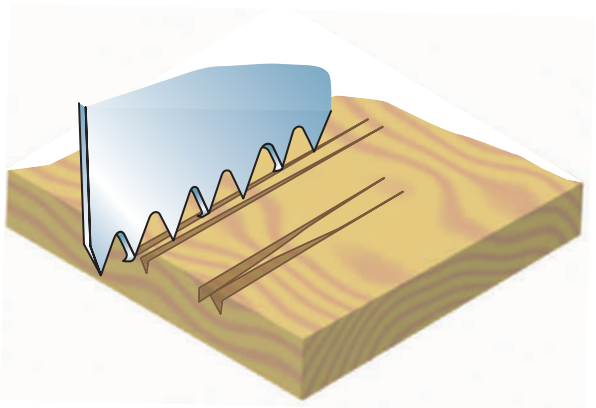
Included in the backsaw family are *miter saws, tenon saws, dovetail saws, gent's saws,* and *dozuki saws.* They can be found with different handle configurations and in different sizes. As you might expect, some are named for the purpose they were designed for, but they are not limited to those purposes.

The **miter saw** is the largest of the backsaws, at 20 to 30 inches long, and is used in a wooden miter box or in a metal frame used for making crosscuts at an angle (see **Figure 3-15**). They have largely been replaced today by the power miter saw.

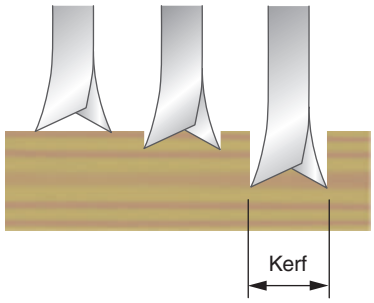


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FIGURE 3-12 From back to front: Tenon saw, gent's saw, dovetail saw, dozuki saw, coping saw.

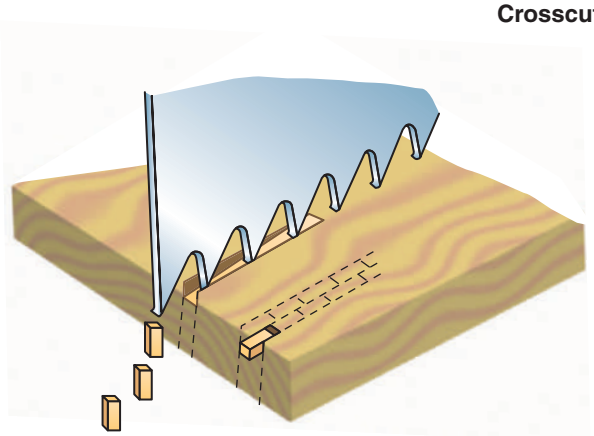


How a crosscut saw cuts

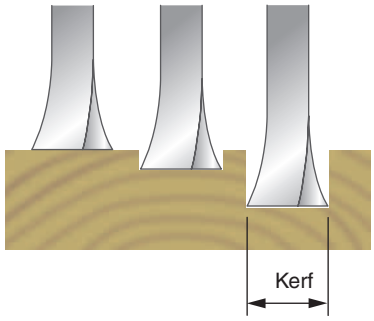


Cross section of crosscut teeth

Crosscut saw cuts



How a ripsaw cuts
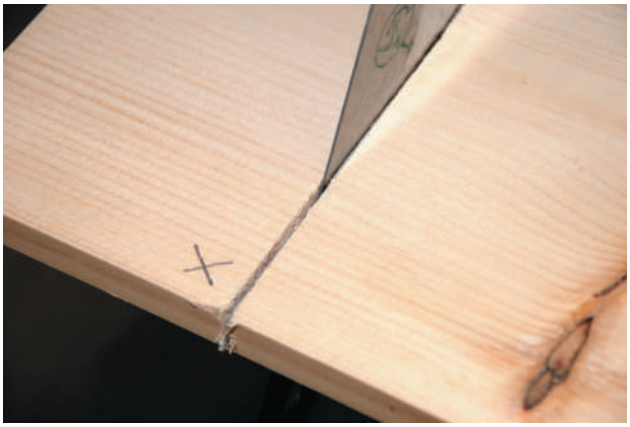


Cross section of rip teeth

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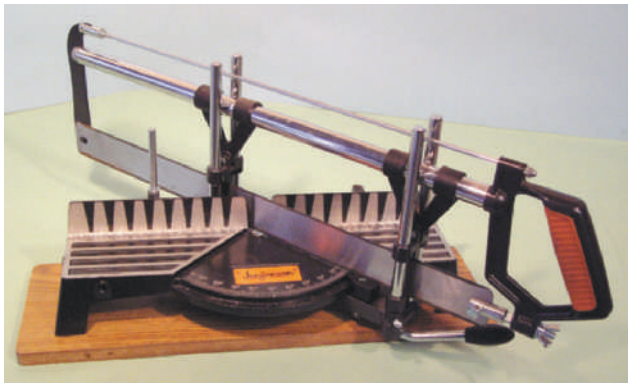
Ripsaw cuts

FIGURE 3-13 Cutting action of ripsaws and crosscut saws.



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FIGURE 3-14 Kerf.



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FIGURE 3-15 A handsaw miter box.

The **tenon saw** is a midsized backsaw used to cut tenons for mortise and tenon joinery. Tenon saws are available with rip-filed teeth for cutting with the grain and crosscut teeth for cutting across the grain. The teeth are relatively fine; 13 TPI is a common size.

PROCEDURE 3-1

Using a Handsaw


A

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B

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C

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STEPS

1. Using a square, mark a line on the finish side of your material and mark the waste side (see **Figure A**). Handsaw cuts are made on the good face of the material, as the back side has a tendency to splinter.
2. The saw cut is made on the waste side of the layout line. Part of the line is cut away, and the rest is left. Start the cut by holding the saw handle with your index finger pointing down to help guide the saw (see **Figure B**). Press against the blade to hold it in place with the thumb of your other hand (see **Figure C**). Make sure your thumb is above the teeth of the saw.
3. Start the cut with a downward motion of the saw. A crosscut saw should be held at about a 45° angle to the work, and a rip saw should be positioned at roughly a 60° angle. Once the cut is established, move your thumb off the saw and cut with long, steady strokes through the board.

Dovetail saws are small backsaws used to cut dovetails. They typically have 15 TPI and are usually manufactured with crosscut teeth, although rip teeth are more efficient, since they are usually used for cuts with the grain.

A **gent's saw** is a small dovetail saw with a straight, turned handle that is parallel to the blade, rather than the pistol-grip style handle found on most saws. This is the smallest of the backsaws and is used for small work.

The **dozuki saw** is a Japanese backsaw that has been used for centuries by cabinetmakers in Japan. It has been growing in popularity in the West. It has a straight, rattan-wrapped handle into which the blade is locked. Japanese saws differ from Western saws in that they cut on the pull stroke, rather than the push stroke. The blades are fine, with very little set to the teeth, yielding a smooth cut. There are a high number of teeth per inch, usually about 26. These blades are often replaced rather than sharpened. If you try a dozuki saw and find you like it, you may want to try another Japanese saw called a **ryoba saw**. Ryoba means "double" in Japanese, referring to the fact that there are teeth on both sides of the blade. One side has crosscut teeth for cutting across the grain, and the other has rip teeth for cuts made with the grain (see **Figure 3-16**). Ryoba saws come in different sizes for different uses. The longest saw, at 13″ or more, is designed for timber framing; the medium sized saw, at 11″–12″, is meant for carpentry work, and the smallest ryoba is 7″–9 1/2″ and is for joinery.



Image courtesy of rockler.com

FIGURE 3-16 Ryoba saws have crosscut teeth on one side of the blade and rip teeth on the other.

Another saw that may be used by a cabinetmaker is the **flush cut saw**. A flush cut saw has a thin, flexible blade, which is used to trim plugs, dowels, and other projections flush with a surface without damaging the surrounding area. This is possible because the teeth of the saw are set one way only. **Figure 3-17** shows two examples of flush cut saws.

The **coping saw** is the handsaw of choice for cutting curved lines, intricate shapes, and interior cutouts. It consists of a very fine blade held in a U-shaped frame, to which the handle is attached. The blade can be removed easily from the frame, allowing the user to pass it through a drilled hole in the wood; it is then re-attached to the frame so that cutting can be done from the middle of the piece (see **Figure 3-18**). It may be fitted with a variety of different blades depending on the cut desired. Due to the thinness of the blade, it is easy to change the direction of the cut, making intricate, curved cuts possible. The blade can also be rotated with respect to the frame, allowing for changes in direction that would not be possible if the entire frame had to be turned. Like the dozuki saw, and unlike most other saws, the coping saw cuts when you pull the saw rather than when you push it.

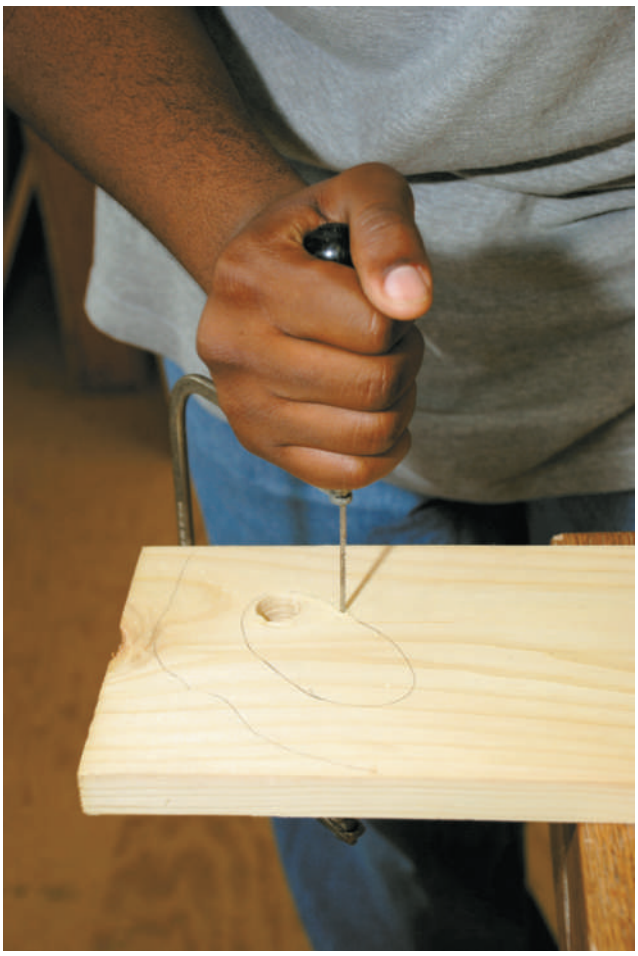
CHISELS AND PLANES

Today's cabinetmaker typically carries far fewer chisels and planes in his toolbox than did his historical predecessors. Again, this is due to the numerous



Image courtesy of Lee Valley Tools, Ltd.

FIGURE 3-17 Flush cut saws.



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FIGURE 3-18 Inside cut with a coping saw.

power tools we have access to today, including jointers, planers, shapers, and routers. While we may have fewer planes at our disposal than our ancestors did, there is still very much a place for these tools in the modern woodworker's box. Many aspiring woodworkers, and even some with quite a bit of experience, are unreasonably prejudiced against hand tools; this prejudice often can be correlated with unhappy experiences with chisels and planes in particular. The root cause is invariably a poorly tuned tool. Sharp chisels and planes are a pure pleasure to use; dull ones are not.

CAUTION

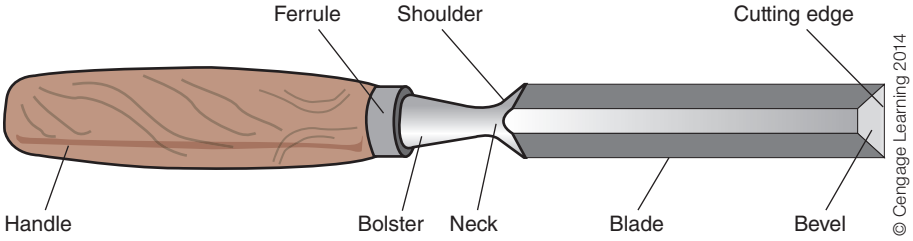
When using your chisels, always work away from your body, never toward it. One slip with the tool moving in the direction of your body can cause a serious injury.

The most commonly used **chisels** are called bench chisels, and have a blade like the one shown in **Figure 3-19**. A chisel may be defined as a metal tool with a sharp beveled edge that is used to cut and shape wood. Chisels are forced into the wood to cut. The driving force may be applied by hand or by using a mallet or hammer. Chisels come in various widths. A typical bench chisel set is shown in **Figure 3-20**.



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FIGURE 3-20 Chisels and tip protectors.



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FIGURE 3-19 Diagram of a chisel blade.

PROCEDURE 3-2

Using a Chisel to Cut a Hinge Recess

STEPS

1. Secure the material that you will be working on with clamps or in a vise so that it cannot move.
2. Mark out the area to be chiseled using the hinge as a guide and scoring your layout lines with a knife as shown in **Figure A**. Mark the depth of the recess.
3. Position a chisel that is about the same width as the recess on the scored line with the bevel facing in to the recess; strike it with a mallet, cutting to the full depth of the recess, as shown in **Figure B**.
4. Use a wider chisel to do the same thing along the back of the recess.
5. Take the same chisel used in Step 3 and make a series of cuts about a quarter inch apart from one end of the outline to the other, as shown in **Figure C**.
6. Cut away the waste as shown in **Figure D**, keeping the flat side of the chisel flat against the bottom of the recess.
7. Fit hinge in recess as shown in **Figure E**.


A

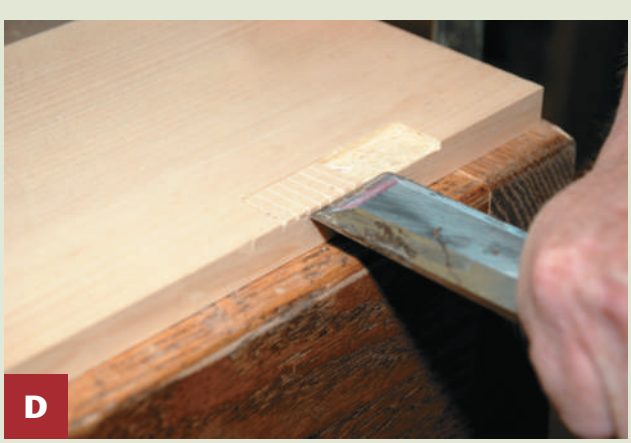
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B

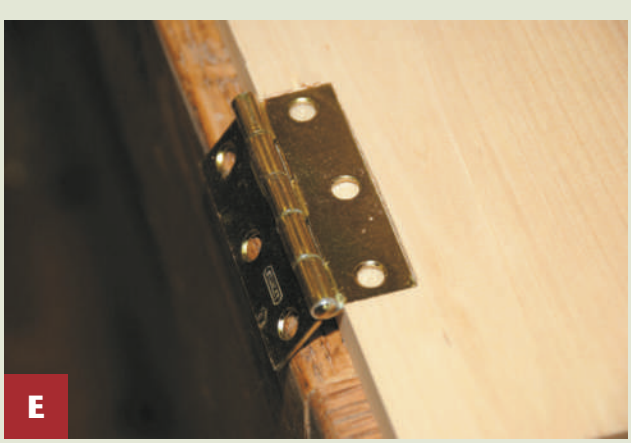
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C

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D

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E

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A **plane** is a tool used to flatten, smooth, and reduce the thickness of wood. A plane cuts like a chisel does, but the cut is much more controlled, because the cutter is held securely in the plane. A plane consists of an adjustable cutter attached to a firm body. The cutter extends beneath the bottom surface of the plane, which is called the **sole**. The flat sole of the plane holds the cutter at a constant angle as it rides on the wood and guides the cutter to remove only the highest parts of an imperfect surface. As the plane is moved across the surface of the wood, the cutter slices off shavings of wood. After several passes, the result is a smooth, flat surface.

Planes come in a wide range of shapes and sizes. Most planes today have a metal body, but some are wood. There are specialty planes designed for cutting joints and creating decorative moldings. **Figure 3-21** shows an assortment of planes.

Planes are categorized as *bench planes* or *block planes*. Bench and block planes are the planes most often found at work in today's woodshop. **Bench planes** are characterized by a cutting iron embedded in the plane with the bevel facing down, with the cutting iron attached to a chipbreaker. **Figure 3-22** shows the anatomy of a bench plane. Bench planes come



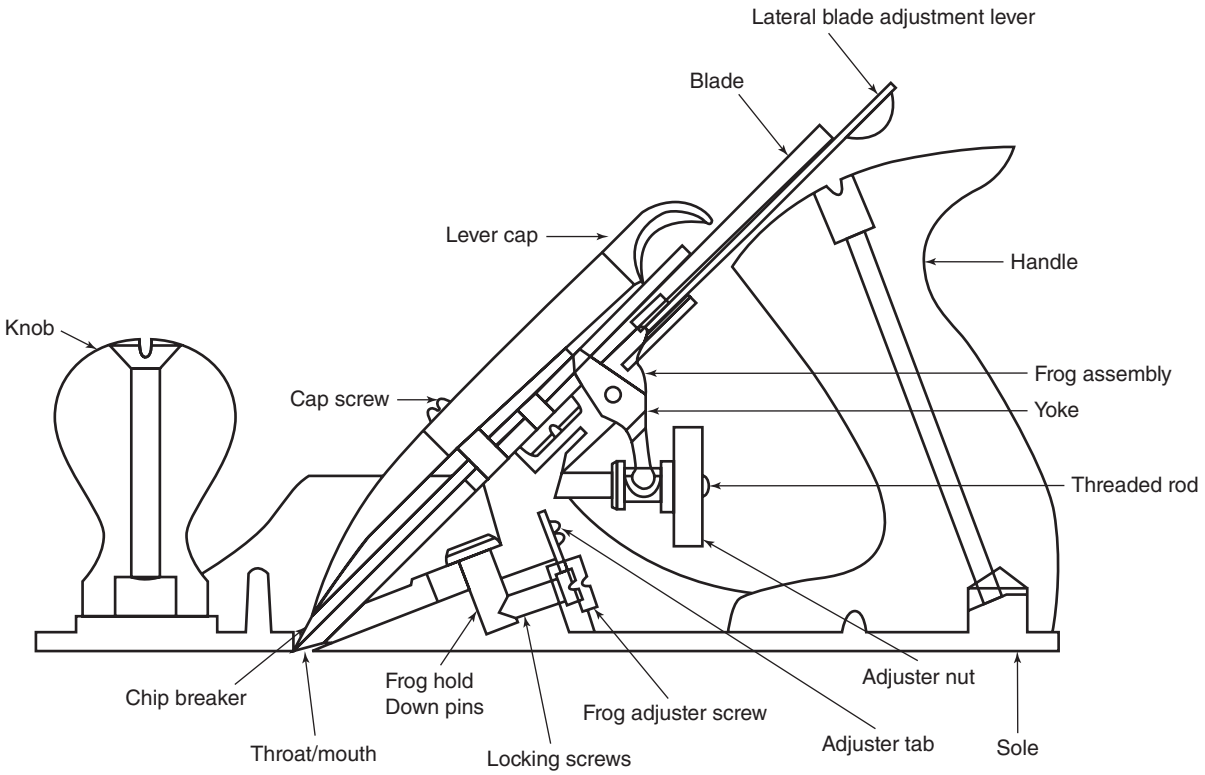
HISTORY FACT

Hand planes are ancient tools. Early planes were made from wood with the cutting iron protruding through a rectangular slot cut across the body and held in place with a wooden wedge, which was tapped into place with a small mallet or the heel of the user's hand. As time passed, plane bodies began to be made out of cast iron or bronze rather than wood. Roman planes discovered at Pompeii are similar to planes in use today. Most planes are pushed across the wood, but Japanese planes are pulled toward the user. ■



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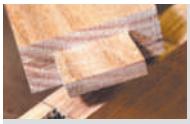
FIGURE 3-21 Different sized bench planes with a block plane in the front.



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FIGURE 3-22 Diagram of a bench plane.

in different sizes, denoted by a number. A number 6 bench plane is larger than a number 3, for example. The number 5 bench plane, often called a *jack plane,* is the most popular of the bench planes (see **Figure 3-23**).



HISTORY FACT

Bench planes are sometimes named according to their length.

- A smoothing plane is up to 10″ long.
- A jack plane is around 14″ long.
- A fore plane is around 18″ long.
- A jointer plane is around 22″ long.

Block planes differ from bench planes in that the cutting iron is embedded with the bevel up, and they do not have a chipbreaker. **Figure 3-24** shows a block plane, and **Figure 3-25** illustrates its anatomy. The angle that the iron is held at is also lower than that of a bench plane. Block planes are usually the first plane a beginning woodworker acquires. They are smaller than bench planes and can be used with one hand. These planes excel at cutting end grain. Block planes are good for small planing jobs. **Figure 3-26** shows some of the essential differences between block and bench planes.

It may surprise you to learn that chisels and planes do not come ready to use right out of the box. To get the maximum benefit from these tools, you have to do a little work. Look at your new chisels under good light, and you can probably still see the machining marks. The tool can be used in this condition, and often beginners do, assuming it comes ready to go. Doing that, however, is a mistake. Working with dull tools is frustrating, because you cannot make them do what you want them to, and they are far more dangerous than sharp tools, because they are more likely to slip. Getting poor results with dull tools can be very discouraging, and this is the reason so many dislike hand tools.



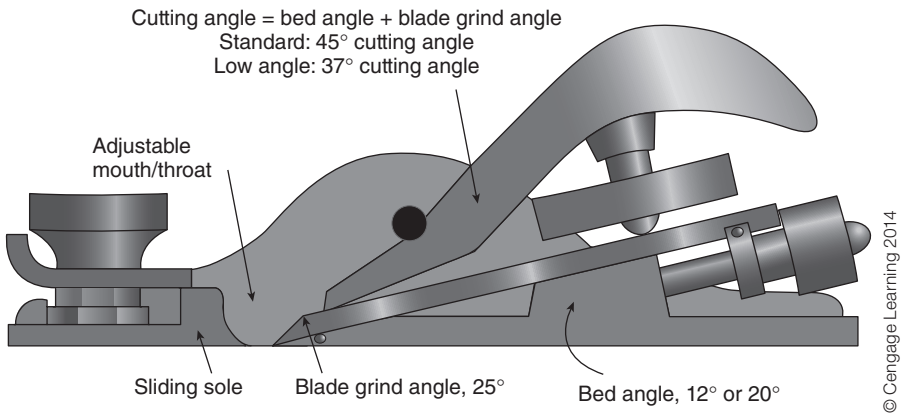
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FIGURE 3-23 The jack plane is the most commonly used bench plane.



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FIGURE 3-24 Block plane.



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FIGURE 3-25 Diagram of a block plane.

PROCEDURE 3-3

Setting Up and Using a Bench Plane


A

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B

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C

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STEPS

1. Release the cap lock and remove the lever cap from the plane. Take out the cap iron and the blade; they are held together with the cap iron screw.
2. The blade should extend about 1/16″ beyond the end of the cap iron, as shown in **Figure A**. If this needs to be adjusted, remove the cap iron screw, reposition the cap iron, and replace the cap iron screw.
3. Replace the blade assembly in the plane and secure it in place with the lever cap. Check the gap between the front of the plane iron and the front of the mouth. It should be between 1/32″ and 1/16″. If the gap is too wide or too narrow, remove the blade assembly. Loosen the two locking screws as shown in **Figure B**, and then adjust the frog adjuster screw to set the proper gap. Tighten the locking screws, reposition the blade assembly on the frog, and lock it in place with the cap lever.
4. Hold the plane upside down and check to see that the edge of the plane iron is level and centered in the mouth. If it is not, adjust it with the lateral adjustment lever.
5. Adjust your plane for depth of cut by releasing the cap lock and advancing the blade with the depth of adjustment knob so that it protrudes from the mouth about 1/32″. Reset the cap lock as shown in **Figure C**.

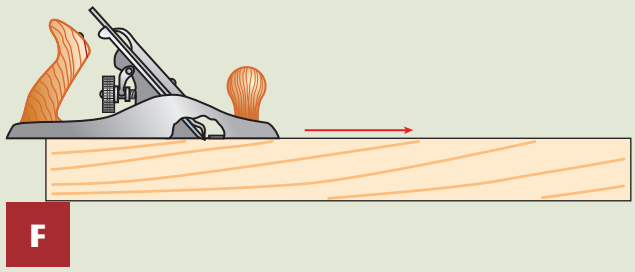
6. Secure a scrap piece and make a test cut. Shavings should be paper thin, as **Figure D** illustrates.
7. When planing, it is important to keep the sole of the plane flat against the work. Plane with firm, constant pressure. Hold the plane with two hands; start the cut with pressure on the front of the plane, and end it with pressure on the back of the plane, as shown in **Figure E**.
8. Plane with the grain of the wood as shown in **Figure F**.


D

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E

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F

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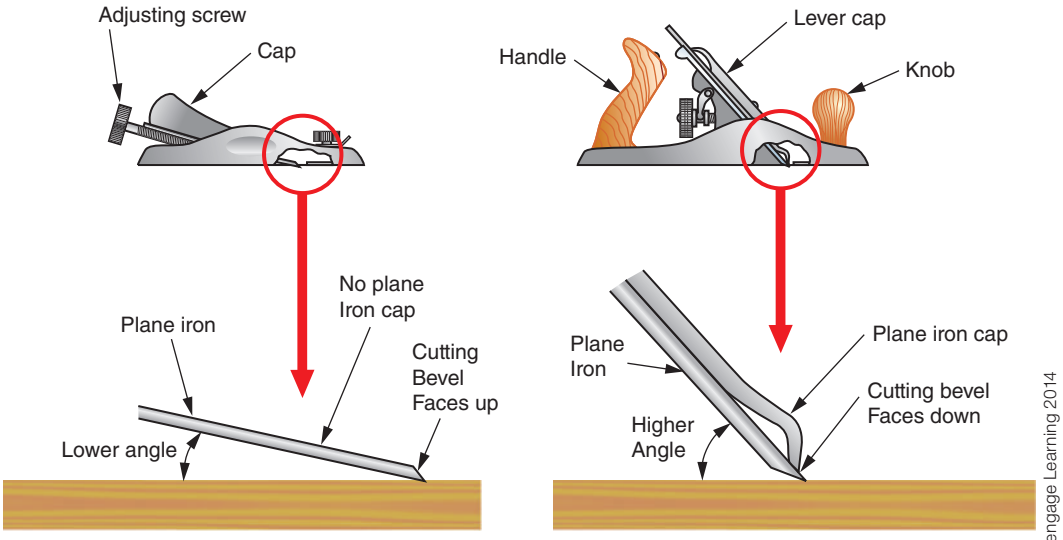


FIGURE 3-26 Differences between bench and block planes.



HISTORY FACT

Specialty planes were much more widely used a century ago than they are today, but they are still useful in different situations. **Figure 3-27** shows some specialty planes. Specialty planes include the following:

- Shoulder plane: trims tenons and other joints
- Rabbet plane: cuts and smooths rabbets
- Router plane: cuts grooves and shallow mortises
- Scrub plane: removes large amounts of material quickly
- Bullnose plane: has no front on its body, so it can be used in tight spaces
- Molding plane: cuts moldings along the edge of a board ■

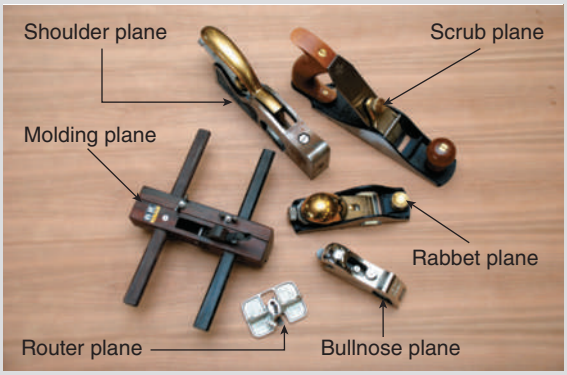


FIGURE 3-27 Specialty planes.

Sharpening tools is a mystery to many people, and no wonder, with so many different systems being demonstrated. You have several choices of systems for sharpening. Any of them will work, provided that the sharpening is done correctly. Different sharpening systems include *oil stones, water stones, ceramic stones, diamond stones,* and *sandpaper.* Oil stones use oil as a lubricant, water stones use water, and the other systems mentioned do not require a lubricant. Whatever system is used, the surface of it must be absolutely flat. Stones should be checked periodically for flatness with a square (see **Figure 3-28**). Water stones in particular tend to wear rather quickly. They can be flattened on a diamond stone, or on a stone made



FIGURE 3-28 Check a sharpening stone for flatness with a square.

PROCEDURE 3-4

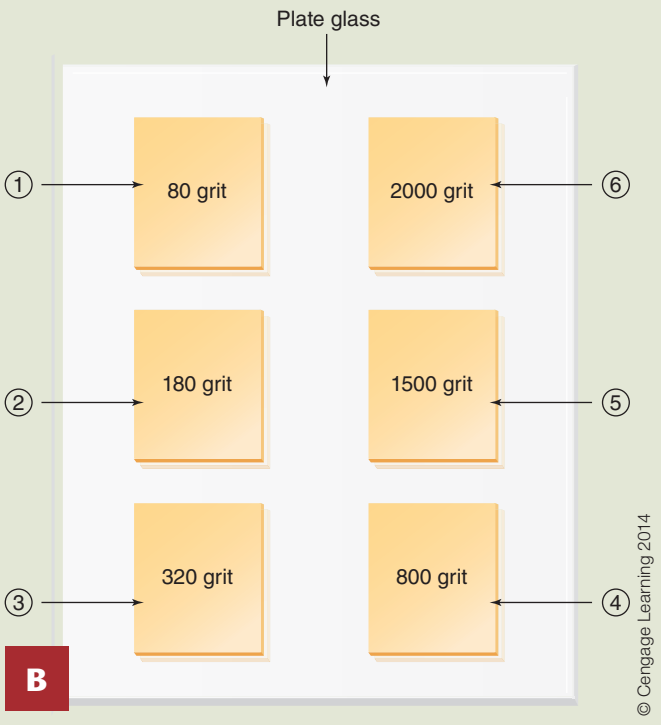
Sharpening Chisels and Plane Irons Using a Sandpaper System

STEPS

1. The substrate beneath the sandpaper must be absolutely flat. Plate glass 1/4″ thick is a good substrate; this is shown in **Figure A**. Medium-density fiberboard 3/4″ thick will also work. Self-adhesive sandpaper can be used, or regular sandpaper can be attached to the substrate with a spray-mount adhesive.
2. Start with the backs of your blades; the back of your chisel or plane iron is just as important as the bevel. The cutting action of the tool occurs where the back of the blade and the bevel intersect. The back of the blade should be flattened and polished, but you only need to do the first inch or so. Work though the series of grits, starting with the coarsest. Keeping the back flat on the abrasive surface, move it back and forth until it is uniformly scratched, and then move to the next grit; this is shown in **Figure B**. Ideally, the blade should have a mirror finish on the first inch or so by the time you are done, as shown in **Figure C**.



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3. Begin to work on the bevel. Jigs are available to hold the blade at the desired angle, as shown in **Figure D**. Work your way through the same progression of abrasives that you used on the back, and work each grit until you feel an even wire along the edge. Smooth that off by taking a couple of strokes with the back of the tool on the sharpening medium, and move to the next higher grit. When you are done, you should have a mirror finish on both the front and back of your blade.

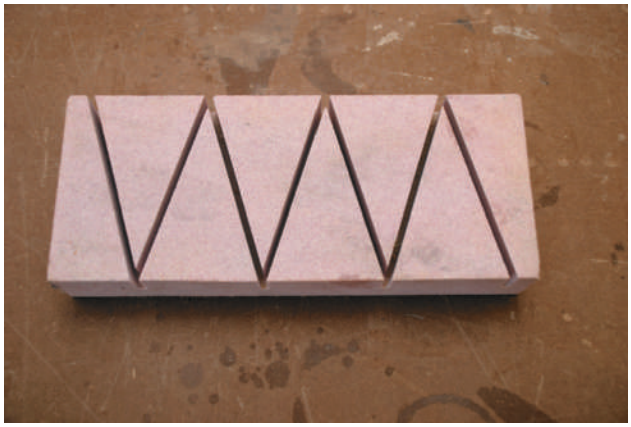

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FIGURE 3-29 A water stone can be flattened on a stone specifically for this purpose.

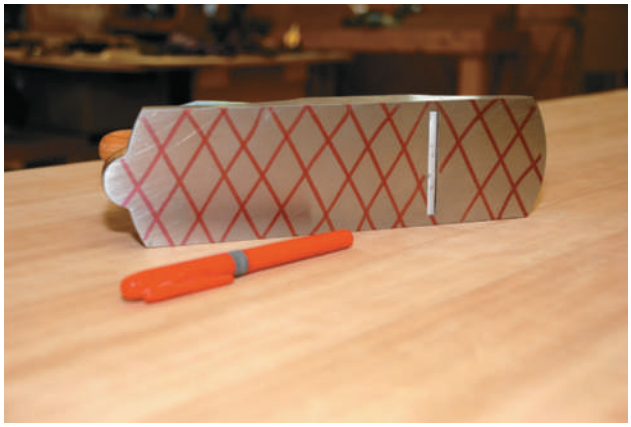

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FIGURE 3-30 Marking the sole of a plane with a permanent marker prior to flattening allows you to gauge your progress.

specifically for this task (see **Figure 3-29**). The procedure for sharpening is the same no matter what system is used. One starts with a coarse abrasive and gradually moves though progressively finer abrasives, until the desired state of sharpness is reached.

The soles of your planes should be dead flat. Check flatness with a true straightedge, front to back, side to side, and diagonally. If the sole is not flat — and this is something to check on new planes as well as used ones — you need to flatten it; if you mark the bottom with a marker, it will be easy to check on your progress (see **Figure 3-30**). Do not take the iron out of the plane to check it for flatness or to flatten it; after all, you will be using it with the iron in. Retract the iron so the cutting edge is protected, and then flatten the sole. Go about it the same way you did for your chisels.

DRILLING TOOLS

There are several hand tools designed for drilling, boring, and countersinking operations. The **brace**, sometimes called a *brace and bit,* is capable of doing the most rugged work. A brace has a chuck that holds the bit, a top spindle, and a U-shaped crank with another spindle. Pressure is applied to the top spindle, and the tool is rotated by the crank to drill a hole. The top spindle and the spindle on the crank turn freely.

The cutting bits used with the brace have screw tips (see **Figure 3-31**).

The **hand drill** is a small, portable drill that is operated by turning the handle. It is sometimes called an *egg-beater drill*, and it is easy to see why. The **Yankee push drill** has the advantage over the others, because it can be operated with one hand. It also has a magazine in the handle for holding bits, and the steel frame is spring loaded. Pushing on the top turns the bit and cuts a hole, which is useful for drilling pilot holes (see **Figure 3-32**).

GREEN REMINDERS

Using hand tools is a great green practice, since the only energy being expended is your own!



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FIGURE 3-31 Screw-tip brace bits.



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FIGURE 3-32 Yankee push drill, hand drill, brace.

SHAPING, SMOOTHING, AND SCRAPING TOOLS

Shaping and smoothing tools include *rasps, files, rifflers, spokeshaves, drawknives,* and *scrapers* (see **Figure 3-33**). Rasps, files, and rifflers are related tools. Both rasps and files consist of a long narrow bar of steel, which is usually fitted into a handle.

Rasps differ from files in that they have individually raised, triangular-shaped teeth. This gives them a more aggressive cutting action than files, so they cut more quickly than files but leave a coarser finish. They are useful for removing large amounts of material quickly, and they may be rounded or flat.

Files are flat, not rounded. Their steel shaft has sharp, parallel ridges cut into it before the steel is hardened. While they do not cut as quickly as rasps, they give a finer finish. Rasps are used more for shaping wood, whereas files are used for smoothing the surface.

Rifflers are curved tools that are double-ended and may be either rasp- or file-cut. The curved nature of the riffler allows it to be used in places where a file or rasp would not fit.

Rasps and files are graded for coarseness of cut. The coarsest rasp is the wood rasp. Cabinet rasps are the middle category, which is subdivided into *bastard, second,* and *smooth* cuts, each being finer than its predecessor. The finest rasps are categorized as *pattern-maker's rasps.* The roughest cutting file is called *coarse,* and is followed by bastard, second, and smooth cuts.



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FIGURE 3-33 (From left to right) Three rifflers, flat file, combination rasp/file, round file, cabinet scraper, and file cleaner.

Files in particular tend to get clogged, and as they do, they do not cut as well. It is important to regularly clean the debris from your files and rasps.

Files, rasps, and rifflers cut in one direction only. Therefore, they should not be scrubbed back and forth when in use. Rather, make your cut, lift the tool off the wood, and start again.

Another shaping and smoothing tool is the **spokeshave** (see **Figure 3-34**). The spokeshave is a tool that was developed for straightening and smoothing wooden rods or shafts, which might be used for wheel spokes, chair legs, or arrows. Today it is most often used for rounding surfaces. It consists of a metal blade held in a wooden or, more often, a metal frame. Spokeshaves are available with a flat sole, for smoothing flat and convex shapes, and a round sole, for working concave surfaces.

A **drawknife**, also called a *drawshave,* is a knife fitted with a handle at each end of the blade. It is used with a drawing motion to shave material from a surface (see **Figure 3-35**).



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FIGURE 3-34 Flat-bottomed spokeshave.



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FIGURE 3-35 Drawknife.

Scrapers are very useful for smoothing wood with highly figured or interlocked grain, as well as for cleaning off dried glue. Scrapers can do the work of a sander without the noise and dust, and they are most suitable for work with hardwoods. There are two related types of scrapers: *card scrapers* and *cabinet scrapers.*

Card scrapers are available in a range of shapes and sizes (see **Figure 3-36**). The most common is a rectangular shape about the size of a postcard. Scrapers are normally made from carbon steel, and they can be used alone or with a holder. Scrapers heat up quickly during use, and your thumbs can get tired keeping the scraper flexed, so a holder can be useful for jobs that will take more than a few passes. There are a number of holders available commercially, or you can make one to fit your hands, which is likely to be more comfortable than those mass-produced for a generic hand size.

Curved scrapers are readily available and allow scraping of surfaces that are not flat. A popular shape is the gooseneck scraper, which has a shape resembling a French curve. You can also make custom scrapers to exactly fit the profile you wish to smooth from a rectangular scraper or scrap steel.

A **cabinet scraper** consists of a hand plane body into which a card scraper is mounted. The scraper is held at a fixed angle (see **Figure 3-37**).

Scrapers cut by means of a **burr**, which is a sharp hook of metal that is turned on the edge of the scraper by burnishing it with a steel rod called a **burnisher** (see **Figure 3-38**).



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FIGURE 3-36 Card scrapers and holders.


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FIGURE 3-37 Cabinet scraper.


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FIGURE 3-38 Burnisher.

Scrapers produce fine shavings of wood, not unlike those produced by a plane. In use, the card scraper is grasped by the fingers, one hand on either side, and tilted in the direction of travel. It is flexed slightly with the thumbs, and it may be either pushed or pulled (see **Figure 3-39**). When you begin to get sawdust rather than shavings, it is time to sharpen the scraper again.

WOODWORKING TIP:

Custom scrapers can be made from old handsaw blades. Mark out the shape you want with a permanent marker, and then cut it out with a hacksaw. Use the grinder to bring it to final shape, and then smooth it with a file and turn a burr with a burnisher.


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FIGURE 3-39 Using a scraper.

STRIKING AND FASTENING TOOLS

Striking and fastening tools include *hammers, mallets,* and *screwdrivers.* **Figure 3-40** shows a selection of the wide variety of hammers and mallets that can be bought or made.

Hammers are tools meant to deliver blows to a target, causing it to move or deform. Their most common uses are for driving nails, fitting parts, and breaking up objects. The hammer itself is a hand tool that has a handle with a perpendicularly attached head. Most of the hammer's weight is in the head, which is metal. The head has a flat striking surface on one side; the opposite side may have a second striking surface or a claw for pulling nails. There are many different types and sizes of hammers. Lighter hammers are easier to use with smaller nails, and they allow greater precision.

Nail sets are used to drive a finish nail or brad beneath the surface. A nail set is a tapered piece of metal whose tip fits into the nail head. It is then struck with a hammer to send the nail beneath the surface of the wood (see **Figure 3-41**). Nail sets come in different sizes for setting different sized nails (see **Figure 3-42**).

CAUTION

Do not use any tool that has a loose, cracked, or splintered handle.

A **mallet** is a type of hammer with a softer head than the metal head found on hammers. The softer head prevents damage to a tool or surface. Mallets



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FIGURE 3-40 Hammer, mallets, and nail sets.



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FIGURE 3-41 Using a nail set.



Image courtesy of Stanley Black & Decker/Stanley Tools www.stanleytools.com.

FIGURE 3-42 Nail sets.



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FIGURE 3-43 Selection of slotted, Phillips, and multiuse screwdrivers.



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FIGURE 3-44 Racheting screwdriver.

are used for striking chisels, driving wedges, and for assembling joints that need a bit of persuasion. The heads of mallets used in cabinetmaking are usually wooden or rubber and are larger than the heads found on hammers.

A **screwdriver** is a hand tool that consists of a *handle*, a *shaft*, and a *tip*. Screwdrivers come in a wide variety of sizes with various types and sizes of tips for fitting different screws (see **Figure 3-43**). Screwdrivers allow the joining of components to one another with screws and also allow the attachment of hardware. Some screwdrivers have a ratchet action and can be fitted with various tips. The screwdriver shaft is locked to the handle for clockwise rotation to tighten screws; it is uncoupled for counterclockwise rotation to loosen screws (see **Figure 3-44**).

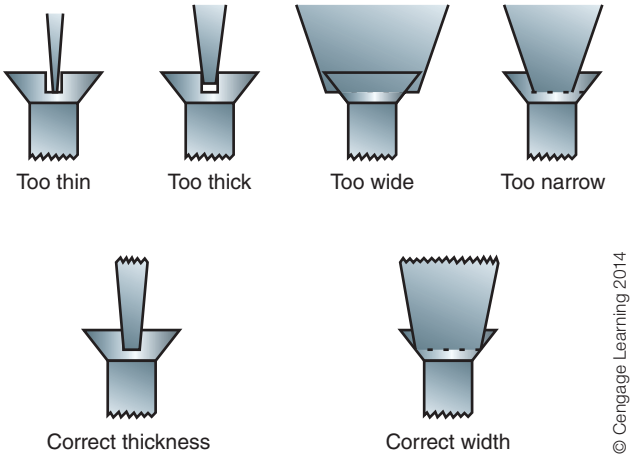


FIGURE 3-45 The screwdriver tip should fit this slot snugly.

A screwdriver's tip should snugly fit in the head of the screw (see **Figure 3-45**). Using a screwdriver that is too big or too small will ruin the screw recess or the screwdriver tip, and may slip and mar your work; if you are having a bad day, it may do all three. The point is that you need an assortment of screwdrivers, and there are many different types of screw heads. The oldest and most familiar are *slotted* and *Phillips*. A relative newcomer is the *square head*. Some screwdrivers will take different tips, which is an economical and convenient way to acquire a selection of various sizes.

CAUTION

Never hold your work in the palm of your hand when using a cutting tool or a screwdriver.

HAND TOOL SAFETY

In addition to the general woodworking safety rules discussed in the previous chapter, there are a few things to be cautious about when using hand tools. For one thing, it is very important to keep your tools sharp: A dull tool is more likely to slip and cause injury. Second, never work a tool toward your body, in case it does slip. Third, secure your work in a vise or with a clamp (see **Figure 3-46** and **Figure 3-47**). Above all, use common sense; remember that your best guard against injury is your brain.



FIGURE 3-46 The material being planed is held securely in the bench vise.



FIGURE 3-47 A handscrew clamp holds the work as dovetails are chopped out.

Other safety rules about hand tools include the following:

1. Select the right tool for the job, and use it correctly.
2. Use the correct size tool for the job.
3. Keep tools in good condition, and repair or replace when damaged.
4. Inspect tools before using, and do not use damaged tools. These include tools with broken handles, loose heads, and mushroomed ends.
5. Store tools safely, with cutting edge protected.
6. Grip tools firmly while using them.
7. Be sure your hands are free from dirt, oil, and grease when using tools.
8. Keep your tools and work area clean.
9. Watch your fingers, particularly when hammering.
10. Do not carry sharp tools in your pockets, and when carrying tools, keep the cutting edge or sharp point directed at the floor.
11. Pass tools to another person handle first.
12. Never strike a hardened steel surface with a hammer lest a small piece of steel break off and cause injury.
13. When using a screwdriver, place the object on a bench rather than holding it in one hand and pressing the screwdriver into it.
14. Wear eye protection when chipping or cutting with any tool.
15. Used knife blades should be disposed of in a puncture-resistant container.

Selecting and Caring for Hand Tools

Good-quality, well-cared-for hand tools are precision instruments that will last a lifetime. You will be well served if you buy the best hand tools you can afford. You may also be able to restore old tools that are no longer being manufactured. Once acquired, your hand tools must be properly maintained. They cannot be thrown carelessly into a toolbox or drawer; they need to be stored in locations that will protect them. To practice working with your hand tools, you can build a toolbox or wall cabinet for them, but it is important to keep them separated; it also makes them easier to find. The tips of chisels should be protected, both for your safety and theirs: Remember how long you spent getting them sharp?

You can keep your tools from rusting by wiping on a coat of light oil periodically. Surface rust can be removed with abrasives, such as a wet/dry sandpaper or an abrasive block. Periodically waxing the soles of your planes will ensure that they slide easily.

Many older tools are of higher quality than comparable tools today; they just need some attention to be brought back to use. They should not be considered "no good" just because they are old, and restoring old tools can save some money. Good hand tools are not inexpensive, but if you buy the best ones you can afford and take good care of them, they will last forever. After all, it is not as if their motors are going to burn out.



Summary

Your hand tools will be a valuable part of your tool kit if you take some time to tune them and keep them maintained. Few of today's woodworkers use hand tools exclusively, nor would most of us choose to do so. Power tools save energy and time, but developing skill with your hand tools will give you a tremendous edge. You will understand wood better, for one thing. When you use power tools, you are a step removed from the process of working it. In addition, since the processing is slower with hand tools, you have a chance to make corrections as you go that you do not get with power tools. Third, you

are not as dependent on your power tools. Rather than go through a time-consuming setup to do something with machines, you can do it by hand. Yes, you can process material quickly with power tools, but many times it takes longer to set up and test a power tool for a specific operation than it does to do the actual machining.

In conclusion, develop a good working relationship with your hand tools. Keep them sharp and safe from damage. Until less than a century ago, woodworking was primarily done with hand tools alone. While today's woodworkers do not need the extensive collection of hand tools that was necessary in the past, that does not mean that hand tools are obsolete. Get them out, get them into shape, and work with them; the rewards are worth it.



Key Terms

backsaw
beam compass
bench plane
bevel square
block plane
brace
burnisher
burr
cabinet scraper
card scraper
chisels
combination saw
combination square
compass
coping saw
crosscut saw
dividers
dovetail saw
dozuki saw
drawknife
fair curve
files
flush cut saw
gent's saw
hammers
hand drill
hand tool
kerf
mallet
marking gauge
marking knife
miter saw
mortise gauge
nail sets
plane
rasps
rifflers
rip saw
ryoba saw
scoring
screwdriver
set
sliding T-bevel
sole
Speed Square
spokeshave
square
steel tape
tenon saw
TPI
trammel points
try squares
wooden rule
Yankee push drill



Check Your Knowledge

1. What advantages do hand tools have over power tools?
2. List several layout tools commonly used in the wood shop.
3. Which will cut more quickly: a saw with fewer and larger teeth or one with more and finer teeth? Which one will give you a cleaner cut?
4. What is the difference between a *block plane* and a *bench plane*?
5. What specific safety rules should you observe when working with hand tools?
6. Describe how to keep your hand tools in top condition.



Activities

1. Check to see if your squares are truly square.
2. Take a piece of pine and make a few passes along the edge with your plane. Try planing from both ends of the board; notice the difference in the quality of the cut. Experiment with raising and lowering the blade: Raise the blade above the sole, check it for flatness, and true the blade if necessary. Then take out the blade, sharpen it, reassemble it, and try another few passes. See how fine and continuous a shaving you can make.
3. Experiment with planing different types of wood; observe how differently they work.



What's Wrong with This Picture?



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BUILD IT!

Candle Box

TOOLS REQUIRED

- Measuring tool
- Squaring tool
- Compass
- Handsaw
- Coping saw
- Hammer
- Nail set

MATERIALS REQUIRED

- 1/2″ pine; see Figure C to determine amount
- 4d finish nails

STEPS

1. You will be building the candle box shown in **Figure A**. Consulting the Candle Box Materials List given in **Figure B**, cut the required pieces to size.
2. Referring to the front view diagram given in **Figure C**, draw a grid of 1/2″ squares, and lay out the pattern for the back. A compass will be helpful in laying out a smooth



A

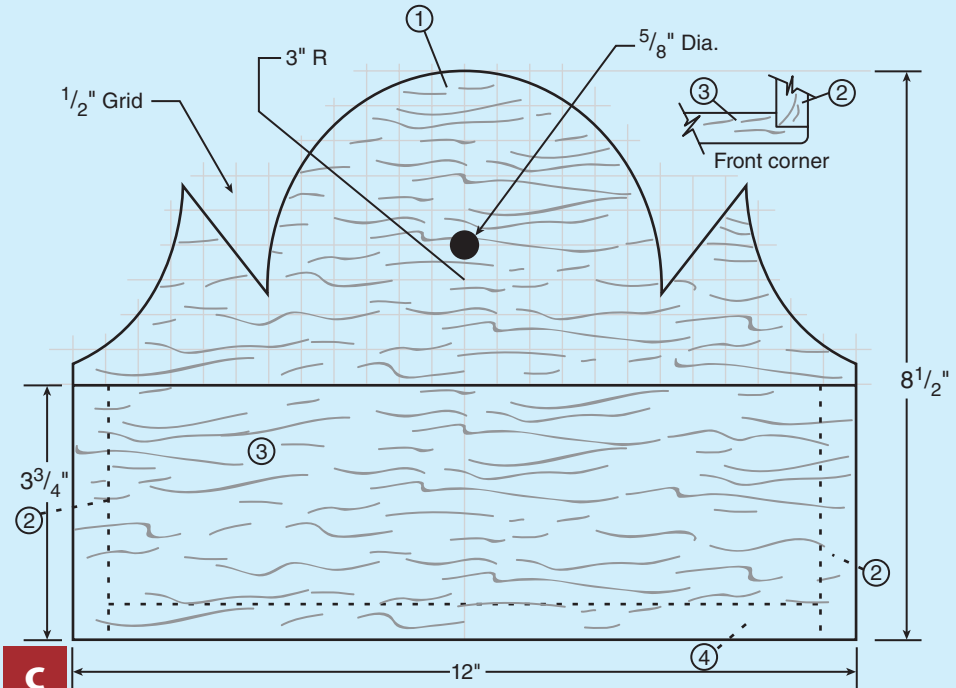
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Candle Box Materials List

Part	Dimensions (thickness × width × length)	Quantity
1. Back	$^1/_2$" × $8^1/_2$" × 12"	1
2. Sides	$^1/_2$" × $3^3/_4$" × $4^3/_4$"	2
3. Front	$^1/_2$" × $3^3/_4$" × 12"	1
4. Bottom	$^1/_2$" × 4" × 11"	1
5. 4d finish nails		as needed

B

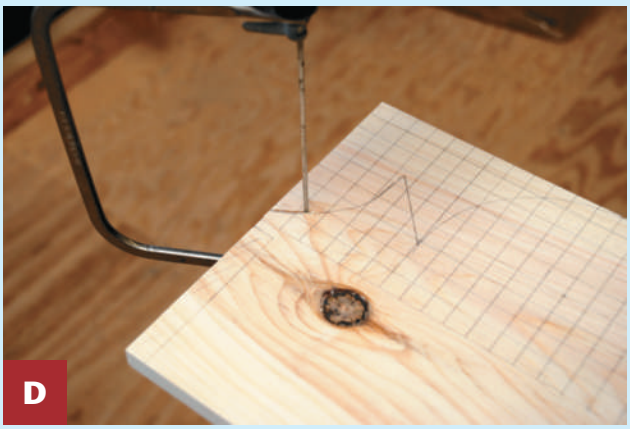
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C

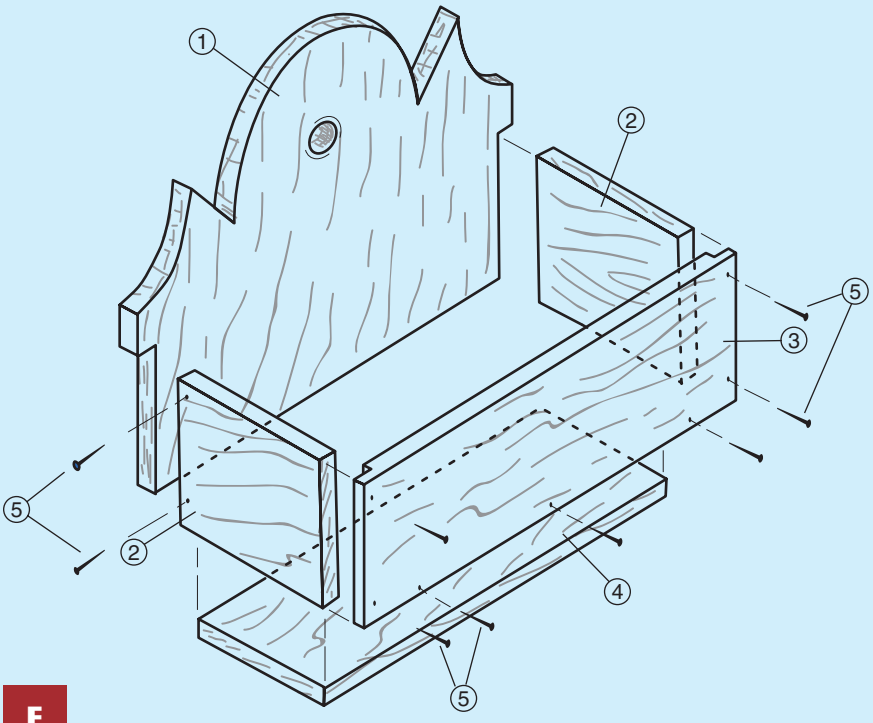
Front view

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D

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E

Exploded view

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curve. Cut out the pattern with a coping saw, as shown in **Figure D**.

3. Drill a 5/8″ diameter hole as indicated.
4. Notch the back to receive the sides. Refer to the exploded view shown in **Figure E**.
5. Cut a rabbet on either end of the front piece using a saw. Refer to the photos shown in **Figure F**. Smooth the cut with a chisel.
6. Assemble the box; glue and tack it together with 4d finish nails. Set the nails.
7. Sand and finish as desired.



F

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BUILD IT!

PROJECT CHALLENGE

Step Stool

STEPS

1. To build the step stool shown in **Figure A**, refer to the Materials List for Step Stool shown in **Figure B**; lay out and crosscut the top and legs to length from a piece of 1″ × 10″ wood using a handsaw.
2. Plane the pieces you just cut to a finished width of 9″.
3. Using a protractor, set your sliding T-bevel to 8°. On the top and bottom of each leg, lay out this angle on the edge of the board. See **Figure C**. The two lines should be parallel. Do this on both



A

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Assembly list for step stool

Part	Dimensions (thickness × width × length)	Quantity
1. Top	$^3/_4$" × 9" × 16"	1
2. Legs	$^3/_4$" × 9" × 9"	2
3. Stretchers	$^3/_4$" × 2" × 14$^1/_2$"	2
4. Screws or finish nails	#8 × 1$^5/_8$" 8d	12 as needed
5. Plugs or buttons	$^3/_8$"	8

B

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C

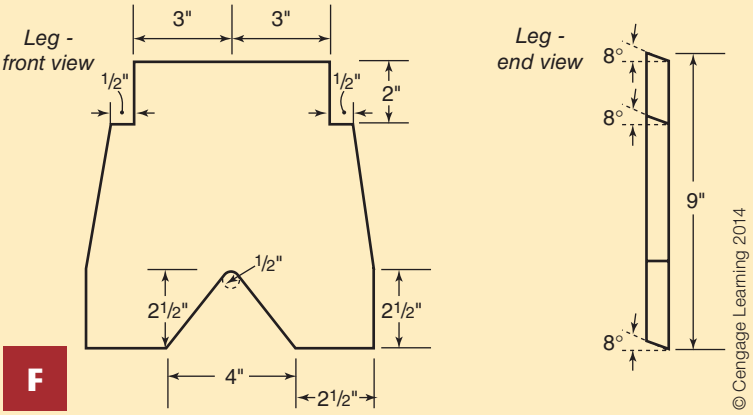
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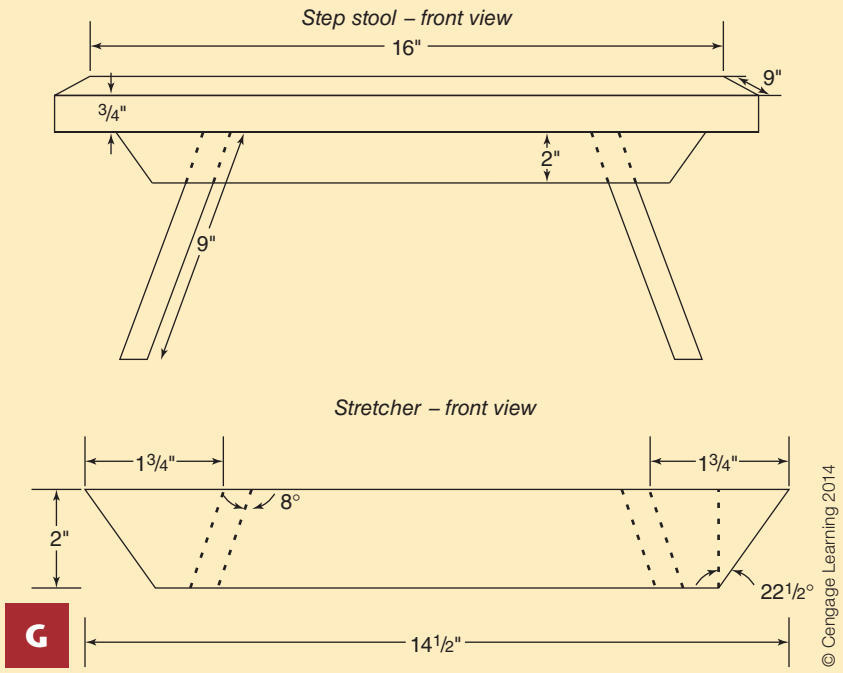


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sides, then use a straightedge to connect the two lines as shown **Figure D**.

4. Using a block plane, plane the legs to create the 8° at the top and bottom of each leg, as shown in **Figure E**.
5. Lay out the legs as diagrammed in **Figure F**. Find and mark the center of each leg. Measure out 3" in each direction, and lay out notches for the legs at an 8° angle, as shown in the side view of the leg. Cut out the notches with a saw.
6. Drill a 1/2" hole in the center of each leg, 2 1/2" up from the bottom.
7. Use a handsaw to make the remaining cuts on the legs.

8. Study the diagrams of the stool and stretcher shown in **Figure G**. Cut the stretchers to size and plane smooth. (Note the 22.5° angle on the ends of the stretchers.)
9. Lay out the dados on the stretchers, and use a backsaw to cut along the lines; then make a series of cuts in between to a depth of 1/4". Remove the waste with a chisel. Refer to **Figures H** and **I**.
10. Assemble the legs and stretchers. They may be glued and nailed with 8d finish nails or, for a sturdier stool, use 1 5/8" screws. If screws are used, counter-bore 3/8" holes 1/4" deep and drill 1/8" pilot holes. Plugs or buttons can be glued in the recesses to cover the screw heads.
11. Center the top over the legs and stretcher assemblies and nail in place. If you choose to use screws, counterbore the holes and screw upward through the stretcher; take care not to screw through the top of the stool.



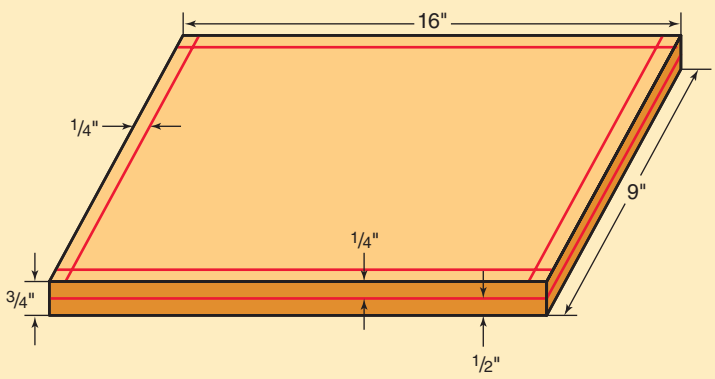
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J

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12. Lay out for a chamfer on the top by drawing a line 1/4″ in from the outside of the top and 1/4″ down on to the edge as shown in **Figure J**.
13. Plane to the lines.
14. Sand and finish as desired.



4

Portable Power Tools

You'll Learn

After studying the chapter, the student should be able to:

- Correctly identify commonly used portable power tools
- Describe the uses of each tool
- Demonstrate knowledge of the safe use of portable power tools
- Explain how to select and take care of portable power tools

INTRODUCTION

The advent of power tools changed woodworking tremendously. The first powered machines were large-scale machines used in shops. In the beginning, these were powered by means of waterwheels, which transferred the power of moving water to the belts that drove the machines. Electricity took the place of the waterwheels, and more sophisticated tools were developed. These large shop machines made much of the heavy labor of woodworking — such as ripping boards to width and planing them flat and square — less laborious, which allowed for higher rates of production. It was only a matter of time before portable power tools came along.

The second half of the twentieth century saw the rapid growth of portable power tools that ran on electricity. These portable, corded electrical tools were later joined by tools powered by air, known as *pneumatic*

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tools. These were followed by the development of tools powered by rechargeable batteries. Battery technology advanced rapidly; today, battery-powered cordless tools are very popular, although they are unlikely to replace all our corded and pneumatic tools.

Portable power tools may be divided into categories according to their primary function. These operations are *sawing, planing, drilling, shaping, sanding,* and *fastening*. Each of these operations, and the tools used for them, will be covered, and safety concerns specific to those tools will be addressed. There are, however, a few rules that apply to them all, which will be covered first.

SAFETY

The number one safety rule is, as always, be alert. The general safety rules covered in Chapter 2 will always apply; concerning portable power tools in general, the following are safety habits that should be developed:

1. Always wear eye protection, hearing protection, and dust masks or respirators with dust filters when necessary.
2. Avoid wearing loose clothing or dangling jewelry that can get caught in moving parts.
3. Disconnect tools from power sources before changing blades or bits, making adjustments, or when they are not being used.
4. Keep tools in good condition with regular maintenance.
5. Use the right tool for the job.
6. Examine each tool for damage before use and do not use damaged tools.
7. Check tool cords for wear and tear and replace them when worn or damaged. Damaged cords or plugs should not be used.
8. Keep track of the condition of extension cords, and use cords of a sufficient gauge.
9. Never carry a tool by its cord or hose.
10. Never yank the cord to disconnect it from the receptacle.
11. Do not use dirty, chipped, or dull blades, knives, or bits.
12. Make sure your work is adequately supported and held steady, ideally by clamps or in a vise, so you can use both hands on the tool.
13. Be sure to keep good footing and maintain good balance when operating power tools.
14. Be careful when setting down a tool after finishing an operation. Ideally you should wait until the bit or blade has stopped spinning.
15. Avoid accidental starting; do not hold fingers on the switch button while carrying a plugged-in tool.

CAUTION

When unplugging a tool, pull the plug, not the cord. Pulling the cord causes wear and may adversely affect the wiring to the plug. Regularly inspect all cords and replace cords that become worn or damaged.

SAWING TOOLS

Three tools will be covered in this section: The first two tools that will be discussed, the *circular saw* and the *jigsaw*, are truly portable power hand tools. The third is the *miter saw*, and although it is a portable tool, it is not a portable hand tool. The essential difference is that the circular saw and the jigsaw are brought to the work, whereas in the case of the miter saw, the material to be cut is brought to the saw.

Circular Saw

The **circular saw** is probably the most widely recognized and used of the portable sawing tools (see **Figure 4-1**). A circular saw gets its name from its blade,



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FIGURE 4-1 Circular saws.

which is shaped like a circle, with its cutting teeth arranged around the perimeter. The blade is driven by a motor. Circular saws are available in different sizes and take different sized blades. The size of the saw is determined by the size of the blade it takes, with 7 1/4″ being the most common size. Various blades are available for different operations.

CAUTION

Check the retracting blade guard frequently to make certain it works freely. Before setting down a saw that you have been using, check that the guard has returned to its starting position.

Circular saws may be electrical or battery powered. Some are ruggedly built; others are constructed for occasional use. There are both left- and right-hand saws, depending on which side of the saw the motor sits. The saw may be designed so that the blade mounts directly to the motor's driveshaft. These saws are sometimes called *sidewinders*. Alternately, the blade may be driven indirectly by a motor that is mounted perpendicularly via worm gears. These saws are called *worm-drive saws,* and they can generate much more torque. These saws are popular with framing carpenters. There are several models available, but their basic structure and underlying principles are the same (see **Figure 4-2**).

The circular saw is used to make straight-line cuts. The operator directs the saw by hand along a marked line. The saw should be held firmly in two hands and guided along the line in as straight a manner as possible.

CAUTION

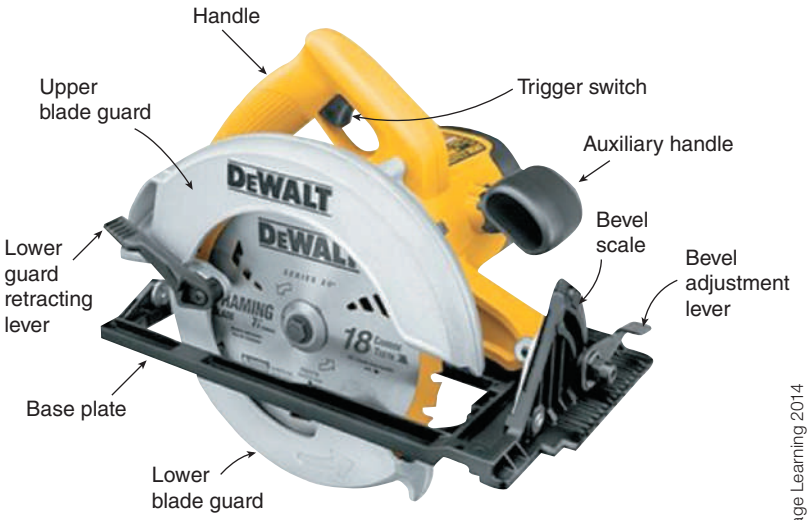
Never make a cut when the material being cut spans two supports. The saw will bind and may kick back toward the operator.

A circular saw is not designed to change direction as you go; doing so will result in the saw blade binding in the material and possibly being kicked back toward you. An edge guide or a straightedge clamped to the work creates a *fence;* properly used, it ensures much more accurate cuts than can be achieved using the saw freehand, without a guide (see **Figure 4-3**). The base can also be tilted to make bevel cuts.

CAUTION

When using a circular saw, always move the saw away from your body, never toward it.

Circular saw blades spin back toward the operator, meaning the teeth enter the wood on the underside of the material and exit on the top, so the underside of the material will show a cleaner cut. When the blade exits the material, it has a tendency to splinter, which is particularly distressing if you are cutting an expensive piece of veneered plywood, for example. So the good side that will show in the finished product should be face down when you use a circular saw.



Not shown: Depth adjustment lever — on other side

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FIGURE 4-2 Diagram of a circular saw.



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FIGURE 4-3 Making a circular saw cut using a straightedge clamped to work.

CAUTION

One of the most important safety habits you can have is remembering to maintain a healthy respect for your tools. In fact, being a little afraid of the tool is a good thing. Remember, a tool cannot think for you, nor can it distinguish between wood and flesh.

Jigsaw

A second portable power saw is the **jigsaw**. It takes a straight blade and is used primarily for cutting curves. Like the circular saw, a wide range of jigsaws is available. Two basic choices of grips are the *barrel grip* and the *overhand grip* (see **Figure 4-6**). Some jigsaws cut at a fixed speed; others have a trigger that allows the operator to control the speed. Both electrical and battery-powered jigsaws are available.

The jigsaw cuts with a straight blade that *reciprocates;* that is, it moves up and down. The teeth of the blade point downward, so the cut is started from the top side of the material, and cuts are made with the good side of the stock face up. **Figure 4-7** shows the basic anatomy common to jigsaws.

CAUTION

Secure and support your material as close to the cutting line as possible to avoid vibration. Keep the base of the saw in firm contact with the material being cut.

Like the circular saw, the jigsaw can make straight cuts, but it excels at making curved cuts. While a circular saw does the work of rip saws and crosscut hand saws, the jigsaw is more like a motorized coping saw (see **Figure 4-8**). The jigsaw can also be adjusted to make bevel cuts by tilting the base.

Jigsaws can be used to make cuts in the center of a piece of stock (see **Figure 4-9**). Drill a starter hole slightly larger than the saw blade. With the saw switched off, insert the blade in the hole until the *shoe* (another name for the base plate) rests firmly on the stock. Do not let the blade touch the stock until the saw has been switched on, then make your cut.

CAUTION

Never touch or otherwise surprise anyone who is using a power tool. Startling someone in this way could cause an accident or injury.

Miter Saw

Miter saws are very versatile tools. Also called a *chop saw* or a *drop saw,* this tool is used to make quick, accurate crosscuts (see **Figure 4-10**). A spinning, circular blade is pulled down into the material, which is held against a fence. The miter saw has an *index,* which allows the angle of the blade to be changed relative to the fence. This makes it possible to make cuts at almost any angle. These angled cuts across the face of the board are called **miters** (see **Figure 4-11**).

Miter saws are commonly sized by the diameter of the blade they take. Common blade sizes are 8, 10, and 12 inches. Miter saws are equipped with self-retracting blade guards. They retract when the blade is lowered into the work and come back down to cover the blade when it is raised. Some saws come with dust

WOODWORKING TIP:

A simple crosscutting jig can be constructed to ensure that your crosscuts are square to the edges of the stock. It consists of an edge guide that is screwed square to a fence. The edge guide should be at least as long as the width of the piece you are working with and wide enough to clamp to the board without getting in the way of the saw as you cut (see **Figure 4-4** *and* **Figure 4-5***).*

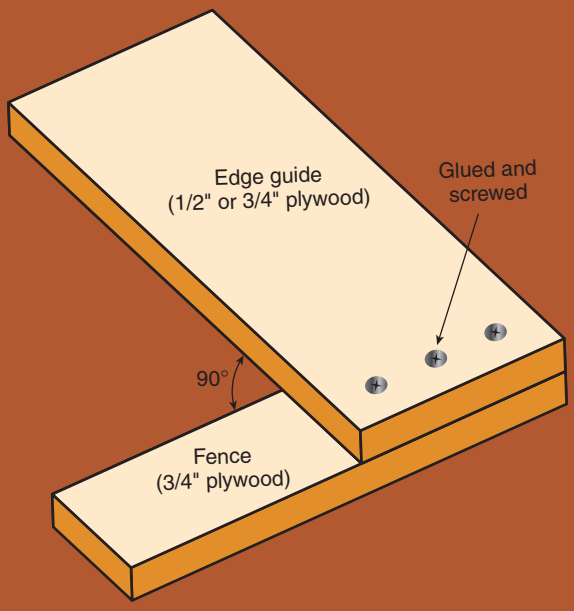


FIGURE 4-4 Crosscutting jig.

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FIGURE 4-5 Crosscutting jig in use.

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bags connected directly to the saw; these help draw the sawdust away when cutting. If a dust collection system is present, the bag can be removed and the saw connected directly to the dust-collection system. Some saws are equipped with a laser guide, which shows the user exactly where the cut will be made prior to cutting. Another feature found on some miter saws is a safety clamp, which helps to lock material into position prior to making a cut (see **Figure 4-12**).

There are three basic categories of miter saws: *simple miter saws, sliding miter saws,* and *compound miter saws*. A fourth, very popular type of saw combines the features of both the sliding miter saw and the compound miter saw.

PROCEDURE 4-1

Setting Cutting Depth on a Circular Saw



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STEPS

1. With the saw unplugged, retract the lower blade guard and set the base plate on the work piece, butting the blade against the edge of the stock as shown in **Figure A**.
2. Your saw will adjust by one of two mechanisms: It is either a pivot-foot saw or a drop-foot model. If it is a pivot-foot saw, release the depth adjustment lever. Then, keeping the base flat on the material, hold the handle and pivot the saw up and down until the blade clears the stock by about 1/4". One tooth, and at least part of the adjoining gullets, should project below the material. When the blade is at the correct depth, tighten the lever, as shown in **Figure B**. If your saw is a drop-foot model, loosen the depth adjustment knob, then hold the base plate steady as you pull up or press down on the handle. Then tighten the knob, as shown in **Figure C**.

PROCEDURE 4-2

Making Curved Cuts with a Jigsaw

STEPS

1. Clamp the material to be cut to a support; let the area to be cut overhang the support, as shown in **Figure A**, so that you do not cut into it with your saw.
2. Make cuts from the edge of the material into the tightest turns, as shown in **Figure B**. These are called *release cuts,* and they will keep the saw from binding.
3. Starting at the end of the board, feed the saw into the material, guiding the saw to keep it on the line. Saw to the first release cut; the waste will fall away. Turn off the saw. Make successive cuts to each of the release cuts, as shown in **Figure C**.
4. Complete the job by sawing back from the opposite end of each line into each release cut, as shown in **Figure D**.
5. Finish cutting the curves that remain uncut.



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FIGURE 4-6 Barrel and overhand grip jigsaws.


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FIGURE 4-8 The jigsaw excels at cutting curved lines.

FIGURE 4-7 Jigsaw.



Image courtesy of Stanley Black & Decker/Porter-Cable.

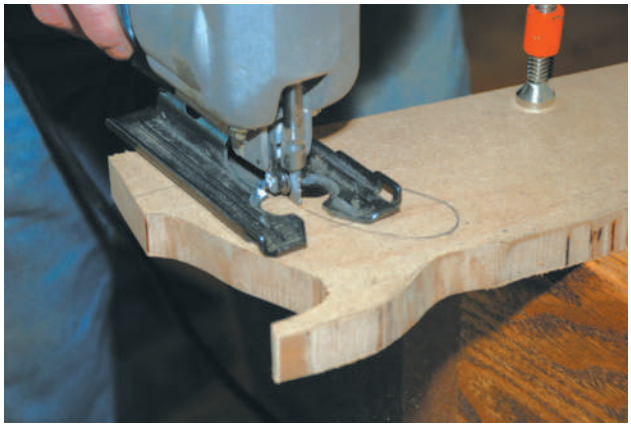
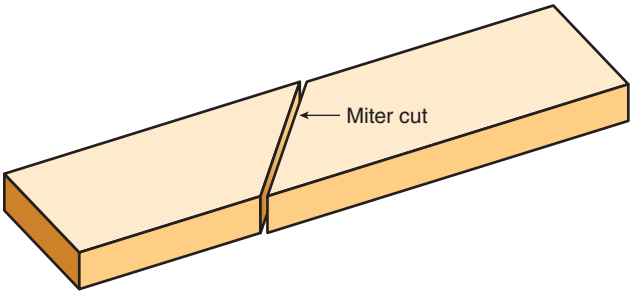

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FIGURE 4-9 Making an inside cut with a jigsaw.



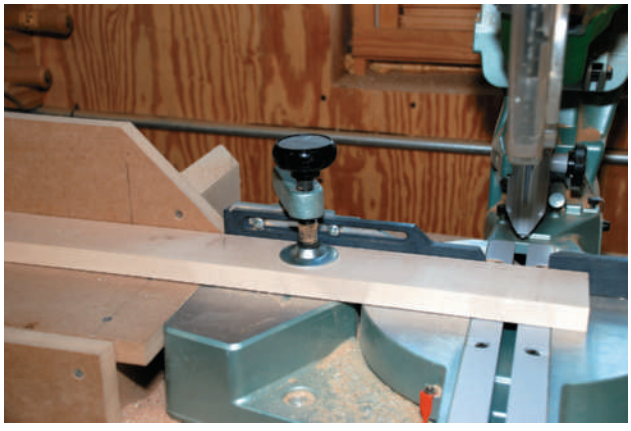
Image courtesy of Delta Power Equipment Corporation.

FIGURE 4-10 Miter saw.



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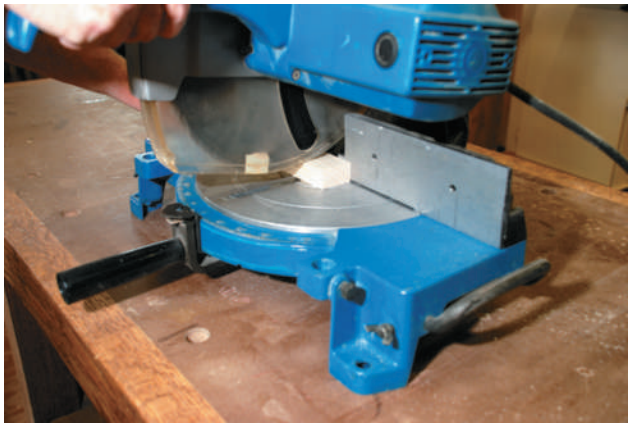
FIGURE 4-11 Miter cut.



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FIGURE 4-12 Safety clamp on the miter saw.

The **simple miter saw** is the oldest of the three types, and as its name suggests, the simplest in design. A spinning blade housed in a pivoting arm is brought down into the work, which is held securely against a fence that is an integral part of the base of the saw (see



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FIGURE 4-13 Making a cut on a simple miter saw.

Figure 4-13). The saw is called a *miter saw* because the blade can be moved from the 90° position in relation to the fence, allowing miter cuts of 45° or more, both to the right and left of a square crosscut. Most miter saws have automatic stops, called *detents,* at commonly used angles, such as 15°, 22½°, 30°, and 45°.

CAUTION

When using a miter saw, keep one hand on the trigger switch, and use the other hand to hold the material firmly against the fence. No free-hand cuts should ever be made.

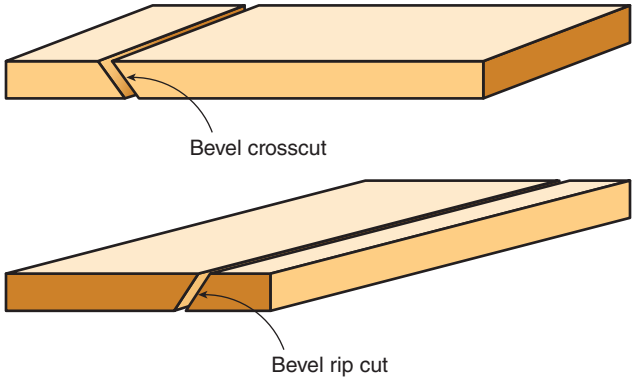
The **sliding miter saw** evolved from the simple miter saw and has the same basic features, but it has a greater crosscutting capacity and can cut pieces that are wider than the diameter of the blade. Rather than being fixed in place, the cutting mechanism of the saw is pulled out toward the operator, pivoted down into the material, and then pushed forward through the material (see **Figure 4-14**). As with the simple miter saw, angled cuts (miters) can be made across the face of the board.

The **compound miter saw**, sometimes referred to as a *CMS,* has the features of a simple miter saw. In addition, it is possible to change the angle of the blade relative to the horizontal plane, which makes it possible to make bevel crosscuts. A **bevel** is an angled cut made along the edge or end of a board (see **Figure 4-15**). Most compound miter saws can be tilted from 0° to 45° in one direction, but some saws can be tilted up to 45° in either direction. Using this feature with a miter cut creates a **compound miter cut**, which is angled across the face of the board and beveled as well (see **Figure 4-16**).



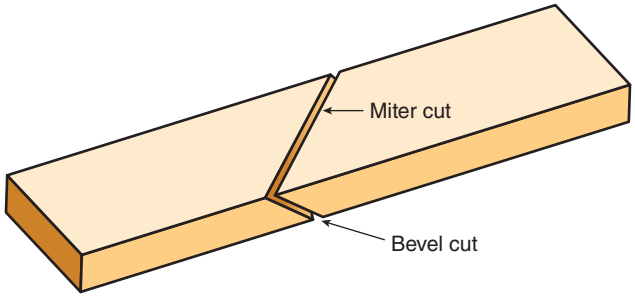
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FIGURE 4-14 Sliding miter saw in operation.



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FIGURE 4-15 Bevel cuts.



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FIGURE 4-16 Compound miter cut.

The **sliding compound angle miter saw** is the most advanced of the miter saws. It has all the attributes of the simple miter saw, the sliding miter saw, and the compound miter saw (see **Figure 4-17**). This is the most versatile of the miter saws, and its popularity among both carpenters and woodworkers has caused it to largely replace the radial arm saw.

Saw Blades

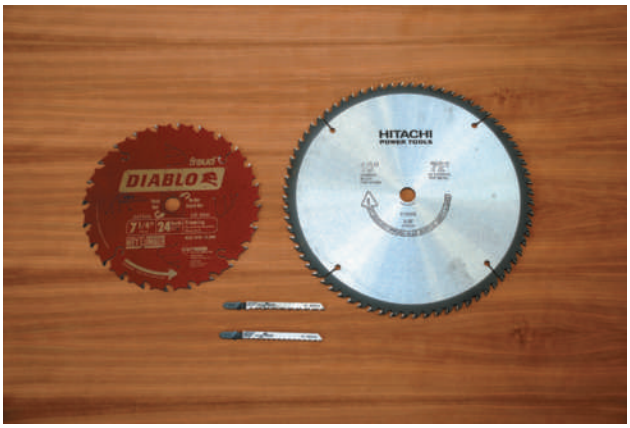
All of the cutting tools discussed can be fitted with different types of blades. Although the blades used on the circular saw and the power miter saw are both circular, and jigsaw blades are straight blades, a few observations common to all saw blades can be made.

Blades with fewer, larger teeth make faster cuts than blades with a greater number of small teeth, but blades with more teeth make finer, smoother cuts. **Figure 4-18** shows a circular saw blade, a pair of jigsaw blades, and a typical miter saw blade. Jigsaw blades may be for metal or woodcutting and are generally steel, although carbide-tipped blades may be purchased for specialty use. Blades with a higher TPI (teeth per inch) count yield better cuts. Blades for circular saws may be all steel or have carbide-tipped teeth and come in different configurations for ripping, crosscutting, and general purpose tasks. A 7 1/4" blade used for framing tasks, for example, will have 24 teeth, while a finishing blade has 40. Good miter saw blades have carbide teeth and a negative hook angle, which pushes the stock downward and against the fence, making the saw safer to use. Hook angle is



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FIGURE 4-17 Making a compound miter cut.



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FIGURE 4-18 Circular saw blade, jigsaw blades, miter saw blade (right).

the angle between the face of the tooth and an imaginary line drawn from the center of the saw blade.

Power Saw Safety Concerns

Whether you are using a circular saw, a jigsaw, or a power miter saw, it is important to keep track of where the blade is and to keep your fingers out of the danger zone. Your work should be well supported, and you should have a balanced stance. Larger pieces of wood may require a helper or clamps to hold it in place while you are cutting. The saw should be at full power before it enters the work. When using a circular saw, the depth of the cut should be set so that the teeth do not protrude below the work more than about 1/4 of an inch. You should never cut between supports, such as two sawhorses, because the saw will bind and may kick back. Check to make sure the blade is securely tightened before you cut.

CAUTION

When making adjustments to any power tool, be sure that the cord is disconnected from the power supply.

POWER PLANING TOOLS

Figure 4-19 shows a handheld, portable planing tool, and **Figure 4-20** shows the tool in operation. This tool is designed to quickly do the work of hand planes but with less effort. A cutter head typically holds two *knives,* and the depth of the cut is adjustable. The quality of the job done by the tool depends heavily on the condition of the knives and *sole,* or base, of the tool: a situation similar to using a hand plane.



HISTORY FACT

The first portable power tool was a drill invented in Stuttgart, Germany, in 1895 by Wilhelm Fein. The drill that more closely resembles the drills we use today, featuring a pistol grip and a trigger switch, was invented in Baltimore, Maryland, in 1917, by Duncan Black and Alonzo G. Decker. These two friends founded the Black and Decker Manufacturing Company in 1910. In 2010 Black and Decker merged with Stanley Works to become Stanley Black & Decker. ■



Image courtesy of Stanley Black & Decker/DEWALT

FIGURE 4-19 Portable power planer.



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FIGURE 4-20 Portable power planer in use.

DRILLING TOOLS

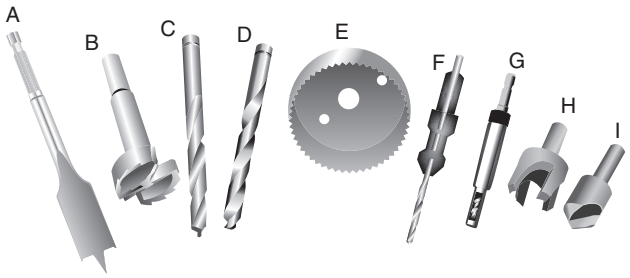
An electric or battery-powered cordless **drill** is the tool the average person is most likely to recognize, own, and use. As with the other tools discussed, there are a lot of drills to choose from (see **Figure 4-21**). Drills typically look something like a pistol, because they



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FIGURE 4-21 Assortment of drills.

have a trigger-like switch. They hold a **drill bit**, which is gripped by a **chuck** located at one end of the drill. Drill bits come in a range of sizes and configurations and are designed to bore holes. They consist of a *shank,* which is inserted into the chuck, and a *tip,* which does the work. In use, the drill bit is pressed against the material and is rotated by pulling the trigger on the drill, which causes thin shavings to be pared out of the target material.



A : Spade bit
B : Forstner bit
C : Brad point bit
D : Twist bit
E : Hole saw
F : Tapered drill with countersink
G : Self-centering bit
H : Plug cutter
I : Countersink bit

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FIGURE 4-22 Assortment of drill bits.

GREEN REMINDERS

It is important to recycle the portable rechargeable batteries in cordless power tools to conserve natural resources, to prevent rechargeable batteries from entering the solid waste stream, and ultimately, to preserve our environment. To find a collection site near you, visit the Portable Rechargeable Battery Association at *www.rbcc.org* or call the consumer help line, 1-800-8-BATTERY.

A corded drill may have a 3/8" or a 1/2" chuck. Better drills have variable speeds. The chucks of some drills are tightened with a chuck key, but new drills tend to have a keyless chuck. The first of the cordless tools were drills, and they remain the best selling of all cordless tools. As battery technology has developed, more and more powerful battery-driven drills have come on the market. Cordless drills are commonly available in 7.2-volt, 9-volt, 12-volt, 14-volt, 18-volt, and 20-volt sizes. A good drill will come with two batteries and a battery charger.

CAUTION

Before operating a drill, make sure the bit is securely held in the chuck by rotating the bit by hand: It should not exhibit any wobble. If it does, either the drill bit is bent and should be discarded, or the chuck has not been properly tightened around the bit.

Drills are used for drilling and boring holes, as well as for countersinking operations. A wide array of bits can be used (see **Figure 4-22**). Drills can also be fitted with screwdriver tips and sockets for inserting and removing screws and bolts.

WOODWORKING TIP:

Make a starter hole for a twist bit with a scratch awl.

SHAPING TOOLS

The **router** is the primary portable power tool used for shaping wood, though not the only one. Routers can cut grooves, create different types of edge molding, and may be used for joinery operations as well. As with the other tools that have been discussed, a bewildering array of choices face the buyer (see **Figure 4-23**).

Routers

Modern routers have been in common use since about 1960, and are more accurately called *spindle routers.*

A router consists of a base that holds a vertically mounted motor with a **collet** on the end of its shaft. The collet secures a router bit, which creates the cut. The height of the bit is adjusted to protrude through a *sole plate,* or *base plate,* which is generally circular in

PROCEDURE 4-3

Drilling Straight and Angled Holes Accurately

STEPS

1. To drill a straight hole, you must keep the bit perpendicular to the material being drilled. A try square or guide block can be very helpful. Make a guide block by cutting a 90° wedge out of one corner of a thick board. Center the bit in the drill over the mark to be drilled, butt the notched corner of the guide block to the bit, and clamp the block in place. Keep the bit flush against the corner of the block and bore the hole (see **Figure A**). When using a try square, keep the bit parallel to the square as you drill, as shown in **Figure B**.
2. To drill an angled hole, use a sliding T-bevel to guide the drill bit. Set the sliding T-bevel to the desired angle, and then line up its handle beside the point where you need to drill the hole. Center the bit over the mark and bore the hole, keeping the bit parallel to the blade of the sliding T-bevel while you drill, as shown in **Figure C**.


A

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B

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C

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FIGURE 4-23 D-handle router, plunge router, standard router.

shape. The tool is held by handles or knobs located on either side of the router.

Routers may be divided into two main categories: *fixed-base routers,* also called **standard routers**, and *plunge routers.* When using the **fixed-base router**, the depth of cut is set before the tool is turned on. The sole plate rests on the work in such a way that the bit is not contacting the material. Then the tool is turned on, and the bit is guided into the material mechanically. A **plunge router** is placed on the work with the bit raised above it, the motor is turned on, and then the bit is lowered into the material. More and more manufacturers are marketing router kits, which allow the router to be used as either a plunge or a fixed-based router simply by changing bases (see **Figure 4-24**).

Variations among routers include power, speed, method of adjustment, grip, and durability. The use for which the router is intended is probably the most important thing to consider when selecting the appropriate tool. A router is much more than an edge decorating tool. It can also be used as a joinery tool, a duplicating tool, and so on. It can be used with a wide variety of jigs to make dovetails, dados, rabbets, mortises, and perfect circles, to name but a few. A router is useful for creating recesses for hinges, locks, and inlays. It may be used freehand and controlled entirely by the operator, with a fence or piloted bit, or with an edge guide, or it may be mounted in a table. Examples are shown in **Figures 4-25** through **4-29**.



Image courtesy of rockler.com.

FIGURE 4-24 Router with fixed and plunge bases - edge guide shown at left.

CAUTION

Make sure a router bit is securely tightened in its collet prior to doing any work.

A **router table** holds the router in an inverted position below a table, and the bit is adjusted to protrude through an opening in the tabletop. Rather than the tool being brought to the work, the work is brought



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FIGURE 4-25 Routing freehand.



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FIGURE 4-26 Routing with a fence.



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FIGURE 4-27 Routing with a piloted bit.



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FIGURE 4-28 Routing with an edge guide.



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FIGURE 4-29 Using a table-mounted router.

to the stationary, table-mounted router. A router table is usually equipped with a fence, along which the work is passed.

The router works by cutting away material with a spinning bit. The bit is held in the collet, which in turn is held in a hollow shaft that is threaded to accept the collet nut (see **Figure 4-30**). The motor is housed at the top of the tool, and the bit may be raised or lowered to adjust the depth of the cut made.

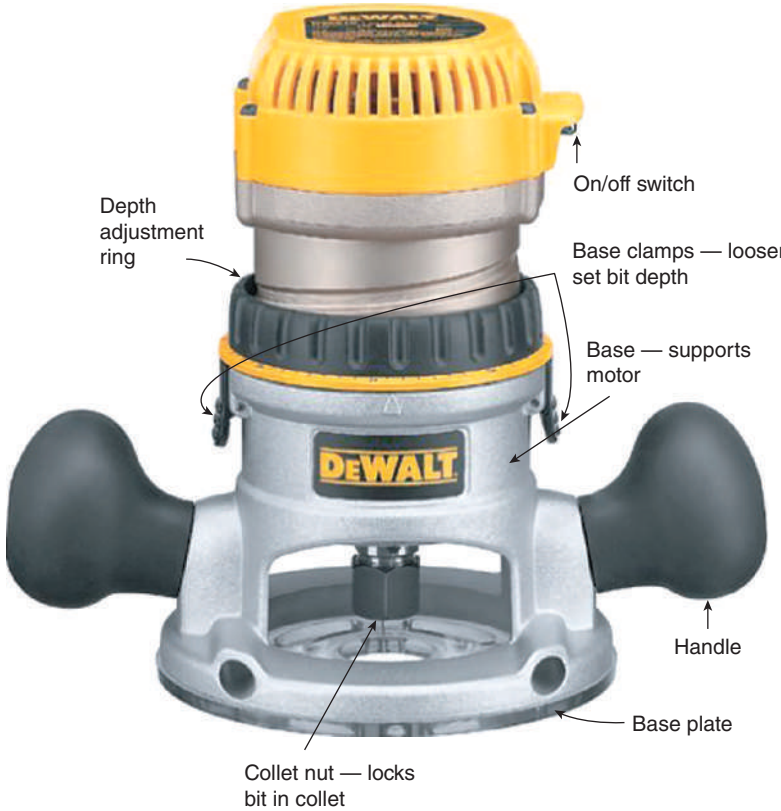


Image courtesy of Stanley Black & Decker/DEWALT.

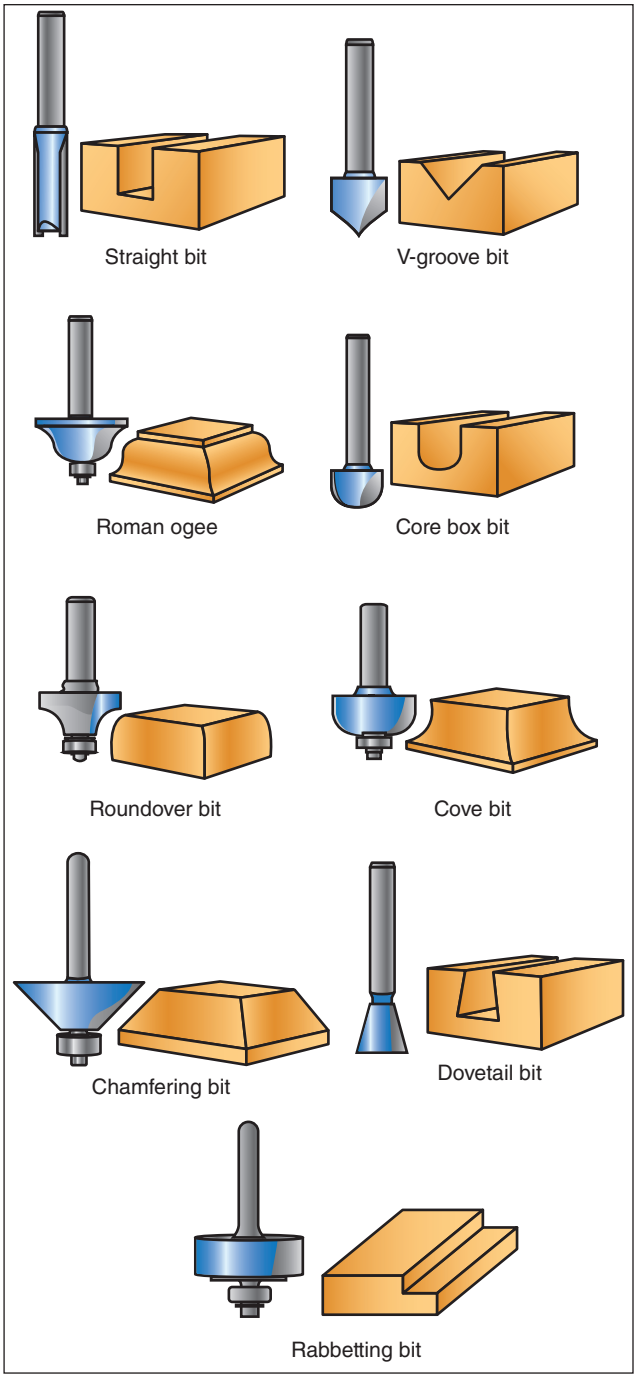
FIGURE 4-30 Standard router.

CAUTION

Check to be certain that a router is switched off before plugging it in.

The size and shape of the router bit dictates how much material will be removed and what the resulting cut will look like. Look at **Figure 4-31** to see a small selection of the wide array of router bits available.

Router bits spin at extremely high speeds and have sharp cutting edges. Some bits, such as panel-raising bits and lock miter bits, should not be used unless the router is securely mounted in a router table. As a rule, the bigger the bit, the more power required to make it cut.

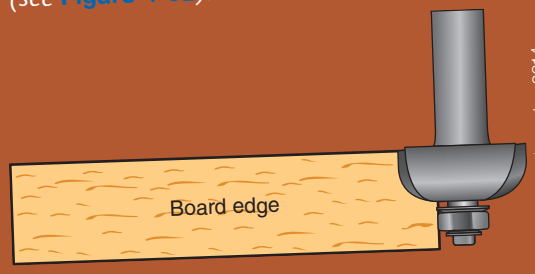


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FIGURE 4-31 Selection of router bits.

WOODWORKING TIP:

To easily see the shape a given router bit will make, hold the bit against a scrap. The material covered by the bit is what the bit will remove (see Figure 4-32).



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FIGURE 4-32 By holding up a router to a scrap of wood, ou can see the cut it will make.

Choosing a Router

Plunge routers excel at making cuts that need to be started in the middle of a piece of material. The router is positioned as desired, and then the bit is lowered, or plunged, into the work. At the end of a cut, the bit is easily raised, while the router stays in place. It is not as easy to make these kinds of cuts with a standard router, since the bit is locked at the depth of the cut it was set for.

Plunge routers tend to be bigger, heavier, and more powerful than standard routers — with a bigger price tag to match. Standard routers are, in general, lighter and deliver less power. They have the advantages of being easier to maneuver and less expensive. Either type can be used in a router table, but many router users prefer the standard router for this application. In practice, very few shops have just one router. The best situation would be to have both a fixed-base and a plunge router or to get a kit that allows you to switch back and forth between bases, as described earlier.

In addition to standard routers and plunge routers, there is another tool to be described in this section. It is usually called a **laminate trimmer**, because that is its primary use. Essentially, it is a small router (see **Figure 4-33**). It can be used for light router work, and it has the advantage of being smaller and lighter than regular routers, and therefore easier to manipulate. It is sometimes called a trim router.



Image courtesy of Stanley Black & Decker/Porter-Cable.

FIGURE 4-33 Laminate trimmer.

Using Routers

Routers are tremendously versatile tools and have probably inspired more how-to books than any other woodworking tool. They can be used freehand, with various guides, or set in a table to act as a stationary tool. A good collet is essential, since the collet holds the bit. Many routers come with both 1/4- and 1/2-inch collets (see **Figure 4-34**). This allows for the use of router bits with either 1/4- and 1/2-inch shanks. Bits with 1/2-inch shanks are sturdier and less likely to deflect under a load; so for a larger diameter bit, they are a good choice.

CAUTION

Inspect stock for nails or other foreign materials before cutting, routing, or carrying out similar activities.



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FIGURE 4-34 Collets and nuts.

Safety Considerations with Routers

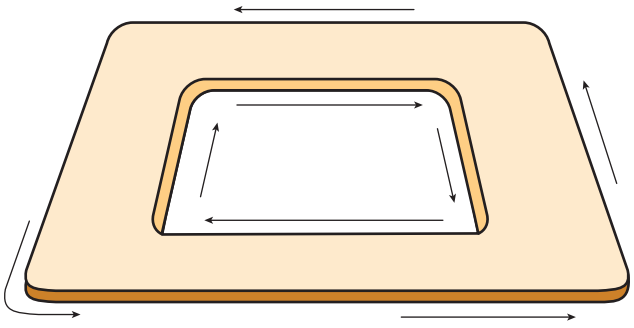
Hearing protection is a must when routers are being used. They spin at very high speeds — over 10,000 RPM — and they emit a high-pitched whine that will damage hearing, especially over time. Of course, safety glasses are a must. Like a power saw, the router should be at full speed before it is brought into contact with the work. Depending on the depth of the cut you are making, the best strategy may be to make several passes, increasing the depth of the cut each time. This causes less strain on the router, and you will get a much better cut. Try to move the router — or the material, if you are using a router table — at a steady feed rate. This will yield a cleaner cut with less burning, which can occur if you hesitate in one spot. Certain woods, such as maple and cherry, are prone to burning anyway. On the other hand, moving the router too quickly will result in a rippled effect.

The direction in which you move the router is very important. You should feed the router into the work against the rotation of the bit. This pulls the router into the work piece. When using a handheld router, this means you will rout from left to right (counterclockwise) if you are routing around the outside edge. But if you are routing inside a piece, you will move the router from right to left, in a clockwise direction. (see **Figure 4-35**). When a router is mounted in a table you will feed the material into the bit from right to left.



SCIENCE CONNECTION

The speed at which a router bit turns is measured in revolutions per minute, abbreviated RPM. The RPMs of a turning bit regularly exceed 10,000. ■



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FIGURE 4-35 Work against the rotation of the bit.

PROCEDURE 4-4

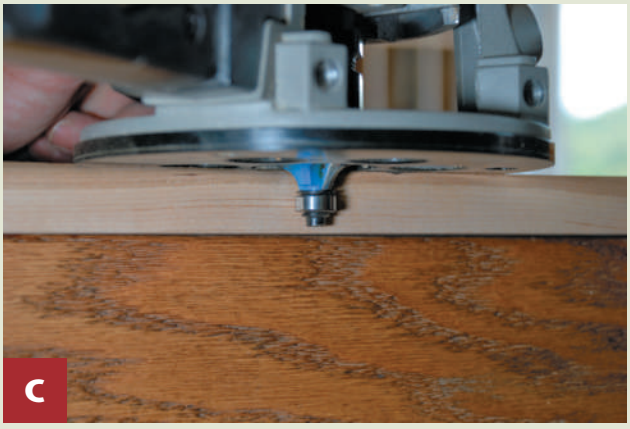
Shaping an Edge with a Piloted Router Bit


A

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B

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C

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STEPS

1. Select the proper piloted bit for the edge design desired. **Figure A** shows some choices.
2. Secure the bit in the router's collet, and tighten the collet nut with the wrenches provided with the router. The shank of the bit is placed all the way into the collet and then pulled out 1/16" before tightening the collet nut. Two wrenches are used to tighten the collet: One holds the shaft steady, while the other tightens the nut, as shown in **Figure B**.
3. Adjust the depth of the cut. For deep cuts, several passes at increasing depths should be made.
4. With the material secured to a bench with clamps, start the router without the bit touching the work, and then bring it into the work, gripping the router tightly by its handles.
5. Working from left to right in a counterclockwise direction, move the router along the material, keeping the pilot of the bit in contact with the edge of the material at all times, as shown in **Figure C**.
6. If the cut is not deep enough, adjust the cutting depth and repeat until the desired depth is reached.

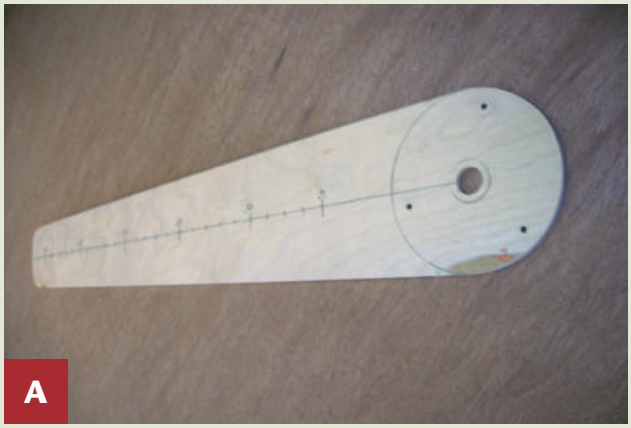
PROCEDURE 4-5

Making and Using a Circle Cutting-Jig with the Router

STEPS

1. Remove the base from the router and make a new base out of 1/4" plywood or high-density fiberboard like the one shown in **Figure A**.
2. Use the factory base to determine where the screw holes for attaching the base should go. Drill and countersink for the attachment screws, and attach the new base to the router.
3. Fasten the base to the material you wish to cut so that the distance from the attachment point to the router bit is the radius of the desired circle.
4. Using your router like a large compass, cut the circle. This should be done in a series of passes, lowering the bit a little each time. See **Figures B** and **C**.

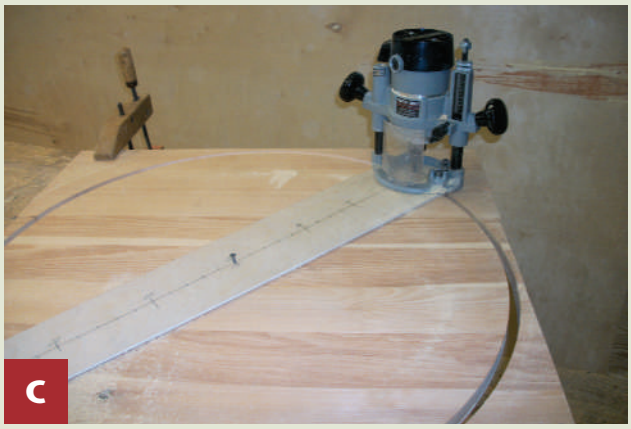
This jig can also be used to true up circles that have been cut close to a layout line with a jigsaw. In this case, the cut may be made in a single pass. The same jig may be used to cut curves, rather than complete circles.


A

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B

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C

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SANDING TOOLS

Portable power sanding tools are used to level and smooth surfaces. The surface is sanded with progressively finer grits of sandpaper until the desired smoothness is achieved. The three main portable sanding tools are *belt sanders, pad sanders,* and *disc sanders* (see **Figure 4-36**).

The **belt sander** is the most powerful of these sanders, and it works quickly. It is normally used only for the beginning stages of the sanding process or to rapidly remove material. The belt sander consists of a motor that turns a pair of drums on which a loop, or belt, of sandpaper is mounted. When the tool is powered, the drums turn and so does the belt.



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FIGURE 4-36 (Left to right): Disc sander, belt sander, pad sander.

As you might expect, belt sanders are available in different sizes, and each size takes different size belts. Typical sizes are 3 or 4 inches wide and 18 to 24 inches long. Regardless of size or brand, all belt sanders have the features identified in **Figure 4-37**.

To install a belt, first release the tension mechanism. This will allow you to remove the old belt and install a new one. There is an arrow on the inside of the belt, and the belt should be installed with the arrow pointing in the direction the belt will travel. After installing the new belt, put the tension back on. Now the belt needs to be checked to ensure that it is tracking consistently over the platen. This is achieved by slowly turning the belt adjustment knob, while running the sander and watching the belt (see **Figure 4-38**).

The belt sander is a great tool, but it takes a little more practice to operate than do either the pad or disc sanders. It is worth taking the time to master, however, because it is much more efficient, especially with large surfaces. Material to be sanded should be secured, or it will not be likely to stay in place; as it turns, the belt abrades the surface, which also pushes the material in the direction that the belt is moving. The belt sander should be held firmly in both hands and guided at a consistent rate over the surface being sanded. Let the sander do the work; do



Image courtesy of Stanley Black & Decker/Porter-Cable.

FIGURE 4-37 Belt sander.



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FIGURE 4-38 Tracking the belt on a belt sander.

not press down on it. Check the condition of the belt frequently, and clean it or change it as necessary. Once the grit is worn, little is accomplished except building muscle. Rough work, such as leveling, can be best accomplished by sanding without regard to grain direction, but final passes should always be made with the grain. To avoid rounding over edges that were not meant to be rounded, which is a common problem with belt sanding, sand the material before it is cut to size. The cardinal rule of using a belt sander is to keep it moving. Pausing, especially with a soft wood, will very quickly dig a trough that will extend your sanding time significantly.

WOODWORKING TIP:

Carpet remnants are handy to have when doing sanding jobs. To protect the piece you are sanding, place it on the carpet while sanding.

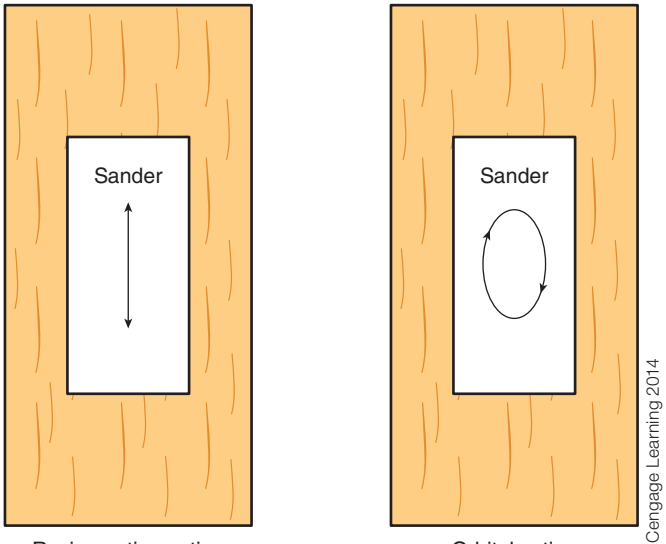
Pad sanders are sometimes called *finishing sanders,* and they come in different sizes and configurations (see **Figure 4-39**). A felt or foam rubber pad is attached to the base of the sander. Sandpaper is fitted over this pad with a lock and release mechanism that varies from sander to sander. Bigger, heavier sanders do the job more quickly, but smaller sanders are easier to manipulate. The anatomy of the various pad sanders is similar. Pad sanders use regular sandpaper and are sometimes named according to the size of pad they require; for example, there are 1/4- and 1/2-sheet sanders. Sanders that take a 1/4 sheet of sandpaper are sometimes referred to as **palm sanders**.

The cutting action of a pad sander may be one of two types. One is a *reciprocating action,* which means that the pad of the sander, and the abrasive mounted to it, is moved back and forth in a straight line. This is sometimes referred to as *in-line* or *straight-line* sanding. The other type of action is *orbital,* in which the pad is rotated in a series of small orbits or circles about a half inch in size. **Figure 4-40** illustrates reciprocating and orbital action.



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FIGURE 4-39 Pad sanders.

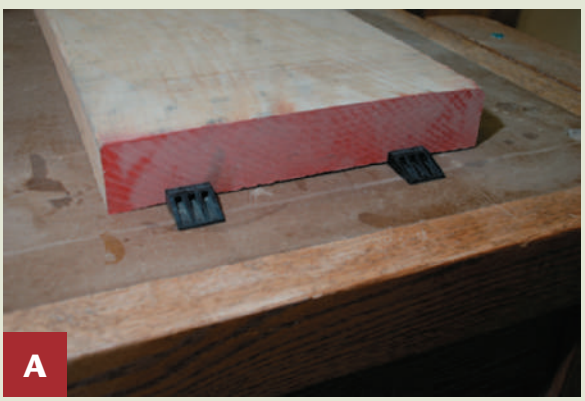


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FIGURE 4-40 Reciprocating and orbital action.

PROCEDURE 4-6

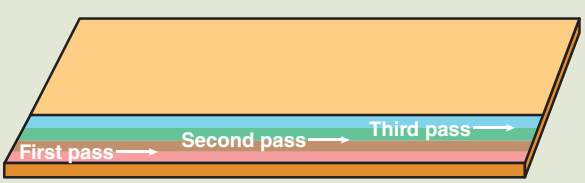
Sanding and Smoothing a Board Face with a Belt Sander


A

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B

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C

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D

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STEPS

1. Secure the material to your bench with stop blocks to keep it from moving while sanding, as shown in **Figure A**.
2. Start the sander before it is brought into contact with the wood, and then gently lay the belt on the stock. This will prevent gouging.
3. To remove material quickly, set the sander flat on the surface at a 45° angle to the grain of the wood, and move the sander forward immediately, as shown in **Figure B**.
4. Once the tool reaches the edge of the wood, pull it back until it overlaps your previous stroke by one-half the width of the belt, as shown in **Figure C**. To prevent rounding over the edges, never allow more than half the length of the sander to run off the end or edge of the material.
5. To smooth the surface of the material, use the same method described in Step 3, but work with the sander parallel to the grain of the wood, as shown in **Figure D**.

Disc sanders are sanding tools that hold a disc or circle of sandpaper. They are usually sized by the diameter of the abrasive disc they use, and 5- and 6-inch disc sanders are the most common, though larger ones are readily available. They come in different configurations; palm grip, pistol grip, and right-angle sanders, as illustrated in **Figures 4-41** and **4-42**. The palm grips are light one-handed tools that work well for finish sanding, while the pistol grips have a bit more power. The right-angle sanders are the most powerful and can do the most aggressive sanding of the three. They are based on the right-angle grinder used in the automotive trade. The sanding action of most disc sanders is *random orbital*, meaning the disc does not move in a perfect circle. There is a free-spinning counterweight located above the disc that pulls it this way or that way in a random pattern, resulting in a scratch pattern that is less easily discerned by the human eye than the scratch pattern left by an orbital sander.

Sanding discs may attach to the sander in two different ways. One system uses discs with adhesive on the back, which adheres the disc to the sander. The other design utilizes a hook and loop system, which works much like Velcro; this is a more reliable system and therefore more popular. A sander that uses pressure-sensitive adhesive (PSA) discs can be retrofitted to take hook and loop discs.



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FIGURE 4-41 Palm grip and pistol grip disc sanders.



Image courtesy of rockler.com

FIGURE 4-42 Right angle sander.

Using Sanders

Several things will improve your sanding results greatly: One is to progress through a series of grits, each finer than the one before it, and replacing sandpaper or belts when they are no longer abrading. It is important not to skip grits in sanding, because the surface being worked on is abraded away, leaving scratches. Finer grits take out the scratches made by the previous grit and leave finer, less noticeable scratches. Skipping grits — for example, following an 80-grit sanding with a 120-grit sanding, skipping 100 grit — creates more work to get the 80-grit scratches out.

It is imperative to clean the surface being sanded between grit changes, because any grit left on the surface will be pushed around by the next sanding and cause scratching. Sandpaper should fit the sander tightly. The pads under the sandpaper should be clean and smooth. As mentioned earlier, the operator's job is to guide the sander without downward pressure. Leaning on the sander, or exerting significant downward pressure, will shorten the life of the sander and leave an uneven surface.



FACTS ABOUT WOOD

Wood varies greatly between species with regard to how hard it is. Basswood and pine are quite soft, while maple is hard. Softer woods will abrade much more quickly than harder woods, which means the sanding process will go much more quickly with a softer wood. It also means, however, that a softer wood is much more susceptible to dents and scratches than a harder wood. ■

Sander Safety Concerns

Aside from the safety rules that apply to all tools, the greatest safety concern when sanding is the dust that is created. A few sanders are now being manufactured that allow the sander to be connected to a dust-collection unit (see **Figure 4-43**). Belt sanders usually have a bag, as do some pad sanders. Still other disc and pad sanders have a dust filter attached

(see **Figure 4-44**). These need to be thoroughly cleaned on a regular basis to do the best job possible. Discs with holes in them are meant to be lined up with the holes on the sander for best dust control. Pad sanders are also manufactured with holes in the base; for them to extract dust, it is necessary to perforate the sandpaper when attaching a fresh piece, using the perforation plate that comes with the sander (see **Figure 4-45**).

Dust can also be controlled by sanding on a down-draft table, which can be purchased or built. A downdraft table is basically a box with a perforated top. Pegboard makes a good top. A dust collecting unit is connected to the box. This has the dual advantage of holding the piece being sanded in place and pulling much of the dust that is generated down through the table into the dust collector.

Some systems work better than others, but regardless of the method used, or if no dust-collection system is available, it is important to wear a dust mask that fits well or a respirator with dust filters.



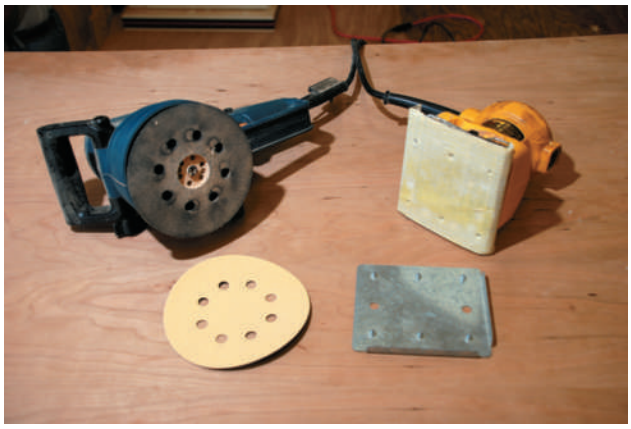
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FIGURE 4-43 Some sanders can be hooked directly to a dust collector.



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FIGURE 4-44 Dust bags or filters should always be used.



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FIGURE 4-45 Discs with holes for disc sanders; pad sander and perforation plate.

CAUTION

Before setting aside a tool you have been using, wait until the blade, bit, sanding belt, vibrating disc, or pad has stopped moving. This is not only for your safety: It also protects your work from accidental damage.

FASTENING TOOLS

Power-driven fastening tools include *finish nailers, brad nailers, pin nailers,* and *staplers.* The great majority of these tools are **pneumatic tools** that run on compressed air, usually supplied by a gasoline-powered or electric air compressor. There are also some light-duty electrical nailers and staplers, and battery-driven units have recently made their debut. Power fasteners are available in a range of model choices. Some are equipped with an antimar tip, which is a nice feature. Several manufacturers offer combination nailer/staplers. **Figure 4-46** shows a selection of power fasteners used in the shop.

Brad nailers, as their name implies, shoot brads. Brads are smaller than nails, but the principle is the same. Pin nailers shoot even smaller nails, called pins. These nails do not have heads, and leave a smaller hole than brads. They are ideal for attaching small, delicate pieces of trim. Finish nailers are bigger versions of brad nailers, and they can drive longer and heavier fasteners. These nailers are designed to shoot nails of a certain gauge. For example, an 18 gauge brad nailer shoots 18 gauge nails, while a 16 gauge finish nailer shoots 16 gauge nails. Pin nailers shoot 23 gauge pins. It is important to match the gauge of the nail and the gauge of the nailer, or else the nailer will jam. Contrary to what you might expect, the higher the gauge number, the thinner the nail. These nails, pins, and brads come in a clip and are available in different lengths (see **Figure 4-47**).

CAUTION

Check air hoses regularly for cuts, bulges, and abrasions. When they are worn, replace them.

Power staplers are very similar to power nailers; they differ only in the fasteners they drive. Staples are much better than brads in certain situations, such as attaching 1/4-inch plywood to the back of a cabinet; because of their shape, staples have greater holding power. They cannot, however, be used on parts of furniture that will be readily seen, because they cannot easily be hidden, as pins, brads, and finish nails can be. Staplers are available in different sizes, and depending on their size, they can drive staples ranging from 1/4 to 2 inches in length.

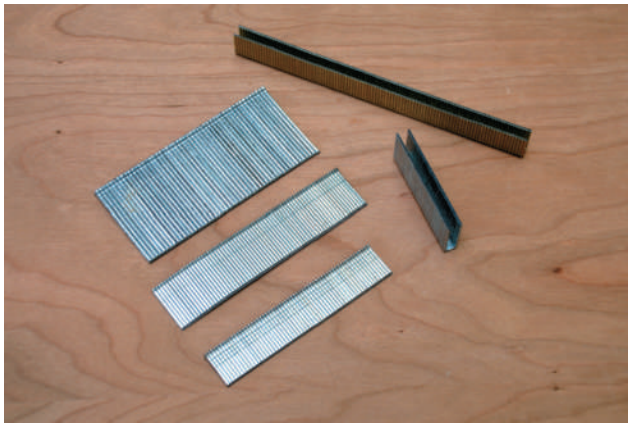
CAUTION

Pneumatic nailers are often referred to as "air guns," and for a good reason: The distance, speed, and force at which air-driven fasteners can travel make these tools extremely dangerous. An air gun should never be held with your finger on the trigger, because it can be accidentally discharged by a slight bump. Show the same respect for a pneumatic fastener that you would for a loaded gun.



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FIGURE 4-46 Pneumatic nailers and stapler.



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FIGURE 4-47 Clips of brads, finish nails, and staples.

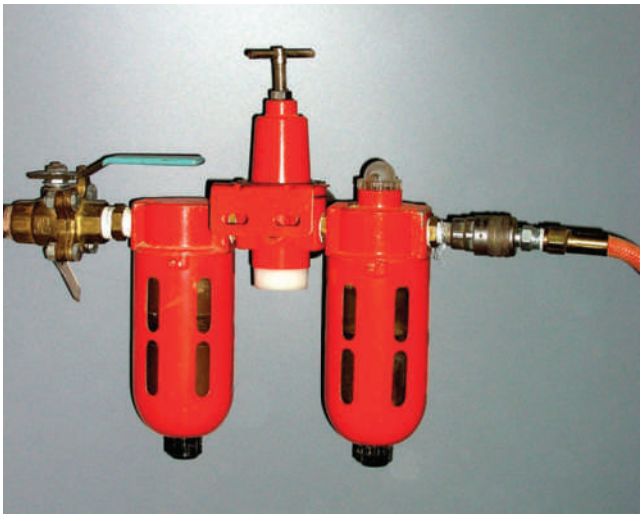
Using Pneumatic Fasteners

Pneumatic fasteners work on compressed air, meaning that a compressor is required. An air line runs from the compressor to the tool. The compressed air must be clean and moisture free, and it must be possible to regulate the air pressure. A filter for water and dirt can be installed at the compressor or in the line before it reaches the tool (see **Figure 4-48**). Pneumatic tools need to be lubricated. A few drops of light oil can be put in the end of the gun prior to each use, or an in-line automatic oiler may be installed on your compressed-air system.

The amount of pressure required to drive brads, nails, or staples varies depending on the length of the fastener and the material being fastened. Brads and nails should be set just below the surface for easy filling. Wire brads and nails are light gauge compared to finish nails. Because of this, they have a tendency to deflect if they encounter a grain change in solid lumber, particularly in harder woods. The result can be unacceptable. In addition, these fasteners are not easy to extract, due to the fact that they have virtually no head and break rather easily.

There are some specific safety concerns with pneumatic fasteners that the user should be aware of. Most importantly, always wear safety glasses. Additionally, observe these rules:

- Examine the tool and compressor before use to ensure that they are in good condition, and that the pressure setting is correct.
- Do not put your finger on the trigger until you are ready to shoot.
- Never point the tool at yourself or anyone else.
- Do not modify the safety settings by disabling them.
- Check lumber surfaces before fastening for knots or other impediments that may cause a ricochet.
- Keep your hands a minimum of 6″ away from the fastening point.
- Place the muzzle of the tool firmly against the work piece when firing.
- Use the fasteners that were designed for that tool; using an improper type can lead to misfires and jams.
- Take care of the air hose; inspect it for wear and tear and replace when damaged.
- Do not carry tools by the hose.
- When disconnecting the hose, make sure you have a firm grasp on both the tool and the hose connector.



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FIGURE 4-48 Compressor filter.

CAUTION

You should not use compressed air for cleaning; it is dangerous. If you must clean with compressed air, use a pressure no greater than 30 pounds per square inch (PSI).

Plate Joiners

Another portable power tool that is best categorized as a fastening tool is a **biscuit joiner**, or **plate joiner**. Invented in 1956 in Switzerland, the plate joiner became widely available commercially in the 1980s. A plate joiner is a tool used to join two pieces of material together, and the biscuit joiner has become a popular tool among finish carpenters and cabinetmakers for good reason: It is a great tool for connecting components quickly, and is especially useful with manufactured panels of all types. **Figure 4-49** shows the configuration of a biscuit joiner. It has an adjustable fence that can be set to various angles; the cutting height can also be adjusted. The slot-cutting mechanism is actually a 4-inch circular saw blade, which is pushed into the material, and the depth of the cut is governed by how the blade is set. **Plates**, or **biscuits**, are made of compressed beech and come in three standard sizes: 0, 10, and 20, with 0 being the smallest of the three. The biscuits are football shaped

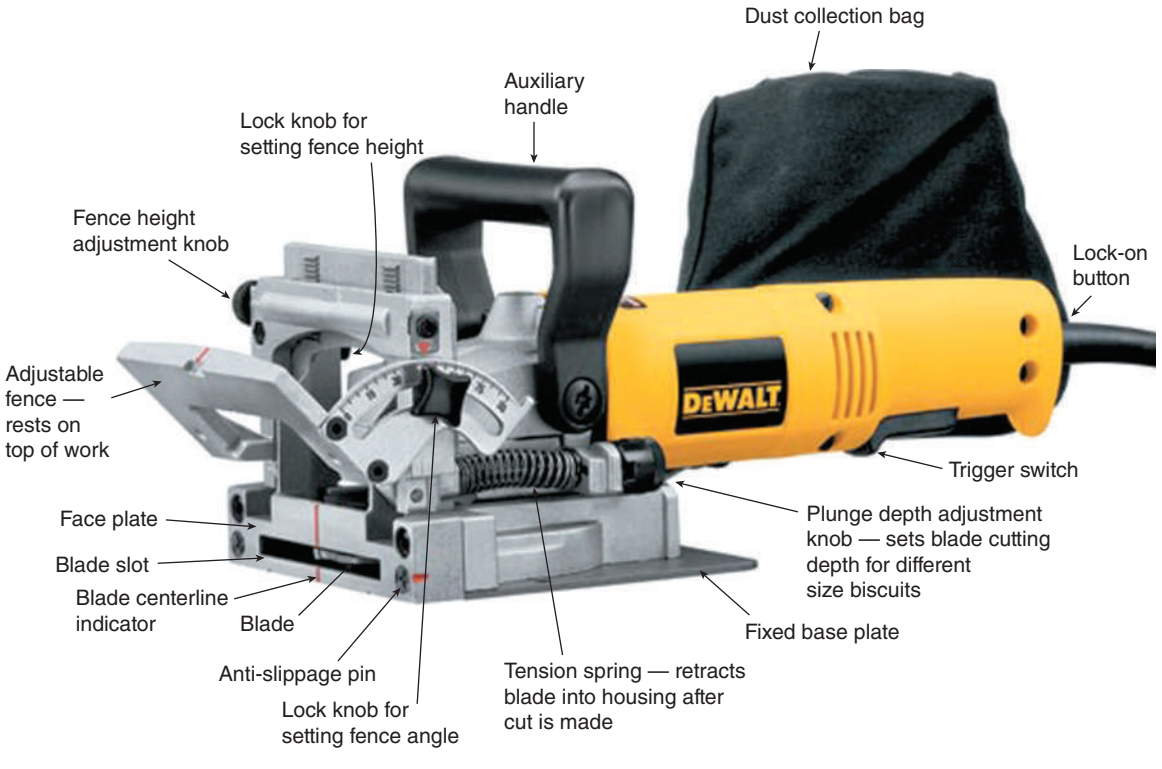


FIGURE 4-49 Biscuit joiner.

(see **Figure 4-50**). Glue is applied either to the biscuit or in the slot, the biscuit is placed in the slot, and the two boards are clamped together; the glue swells the biscuit and locks the joint tight.

Biscuits are predominantly used to join sheet goods such as plywood, particleboard, and medium-density fiberboard. They are sometimes used with solid wood to replace mortise and tenon joinery, since they are much easier and faster to use and nearly as strong. They are also used to align pieces of wood when joined edge to edge in making wider panels.

CAUTION

When using a biscuit joiner, clamp your material to a bench so that you can use both hands to control the tool.

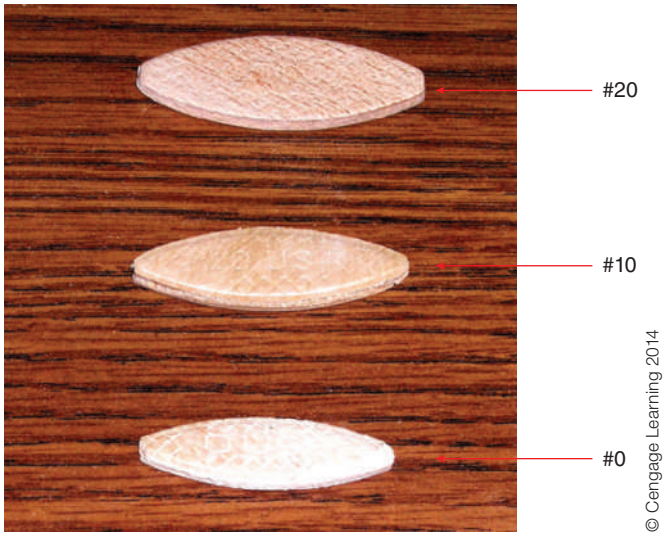
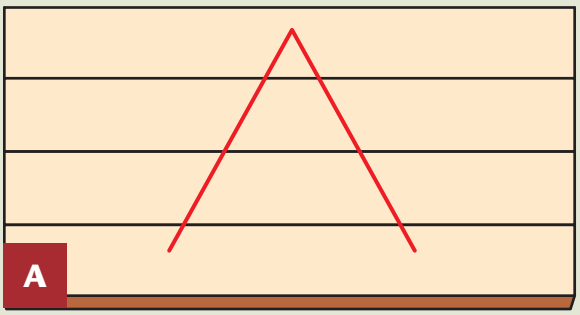


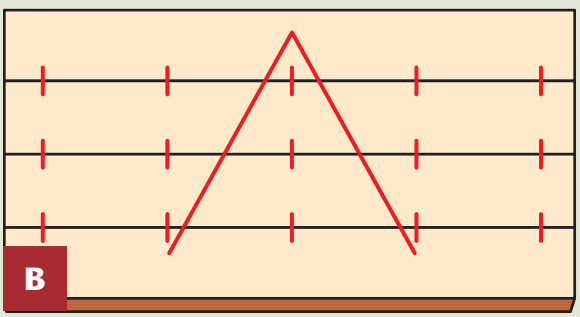
FIGURE 4-50 Biscuits.

PROCEDURE 4-7

Joining Boards Using the Plate Joiner



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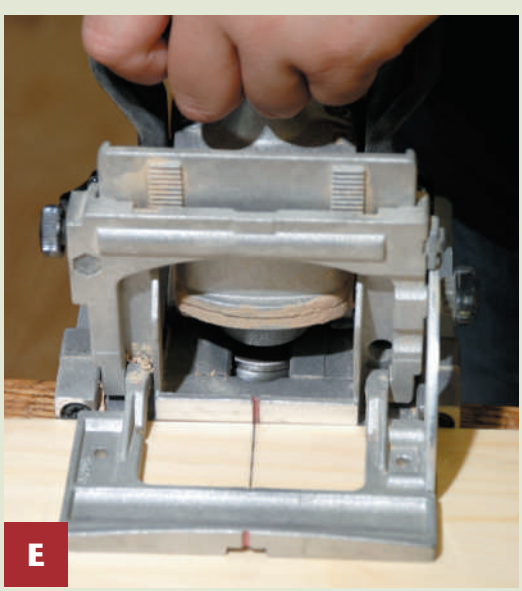
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STEPS

1. Align the boards to be joined and mark them for easy reassembly, as shown in **Figure A**.
2. Mark the centerlines for the biscuit slots across adjacent boards, starting at least 2 inches from each end and spacing them every 6 to 8 inches, as shown in **Figure B**.
3. Adjust the fence on the plate joiner so that the slot will be cut halfway through the thickness of the boards, as shown in **Figure C**.
4. Turn the depth adjustment knob to select the appropriate depth for the biscuit. This governs how deep and wide the slot will be, as shown in **Figure D**.
5. With the board secured to the bench with a slight overhang, align the biscuit joiner so that the center mark on the fence aligns with the mark for the slot, as shown in **Figure E**.



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6. Holding the biscuit joiner with both hands, squeeze the trigger and push the joiner into the board, as seen in **Figure F**. Repeat for all marks.
7. Reassemble the panel and stand all the boards except the last one on edge. Spread glue along the edge of each board and into each slot, inserting biscuits as you go, as shown in **Figure G**.
8. Spread glue over the sides of each biscuit, as shown in **Figure H**.
9. Fit and clamp the boards together as marked, as shown in **Figures I** and **J**.


F

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G

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H

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I

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SELECTION AND CARE OF PORTABLE POWER TOOLS

As with hand tools, it is a good idea to buy the best tools you can afford for the use you will put them to. If it is a tool that you will only use sporadically, you probably do not need a professional quality tool. If, on the other hand, it is a tool that will see constant use, it is wise to buy one that will hold up to that amount of use. Research tools by talking to people who use them regularly, and try them out first if possible. A tool that is comfortable for one user may not be so for another. Going to trade shows is another way to learn about various tools, and often you can try the tool first. Do not overlook trade magazines; most regularly review tools and make recommendations based on quality and price.

Your tools will last to the extent that you take care of them: Store them safely, and keep your bits and blades clean and sharp. It is important to learn to listen to your tools; unusual noises may indicate that the bearings or brushes need to be replaced. Sawdust should not be allowed to build up inside tools, and dust bags or filters should be cleaned regularly. One place that needs to be checked regularly is the collet recess in your router, where dust tends to build up, which could interfere with the collet's ability to hold a bit. Worn collets should be replaced, as should worn or frayed cords on any tool.

It is a good practice to keep the manuals that come with your tools. If you acquire a used tool that no longer has a manual, you can probably find the manual online and download it for free. Manuals should ideally all be kept in the same drawer in the shop for easy reference; they often contain detailed information on how to use the tool, as well as diagrams and parts listings, which will be useful when you need to service the tool.

Bits and blades should be stored carefully, protecting their cutting edges. One of the simplest ways to store router bits is to drill a series of 1/4- or 1/2-inch holes in a piece of scrap material to insert the shank of the bit into (see **Figure 4-51**). Blades may be hung on a wall or kept in the cardboard container they came in; they should not be allowed to bang around against each other, as this is likely to chip the teeth. Router bits with piloted bearings may be sprayed with a bearing lubricant to keep the bearing moving freely.

The guards on saws such as circular or miter saws should be kept in good shape and should move easily. A circular saw guard should never be removed or tied up.



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FIGURE 4-51 A simple way to safely store your router bits.



Summary

Portable power tools can do the work of hand tools in a fraction of the time, so they represent an opportunity for the cabinetmaker to work more quickly and efficiently. Each of the tools we have discussed can quickly accomplish tasks once done solely with hand tools. A modern shop would not be very modern without power saws, drills, routers, sanders, and biscuit joiners. With advances in speed and ease of construction, however, comes a corresponding responsibility. Motorized tools such as those discussed have more moving parts and thus require more in the way of maintenance, as well as respect. An operation that starts to go bad when using hand tools can usually be remedied before much damage is done, but the same cannot be said for portable power tools. It is good practice to try a test cut or two on a

piece of scrap before beginning work on your project. This gives you the chance to ensure that the tool is properly set up, and that it will do what you want it to. Always take the time to make sure that blades and bits are securely held, and any fences used are locked in place. Regularly inspect bits and blades for damage, and keep them clean and sharp. Learn what the tools should sound like, and be sensitive to changes in how they sound; if the tool is laboring, for example, this is a sign that you are trying to do more than the tool is really capable of or that the tool is beginning to wear and may be in need of maintenance. Keep tools clean and check the cords regularly to make sure they are in good repair.



Key Terms

belt sander
bevel
biscuit joiner
biscuits
chuck
circular saw
collet
compound miter cut
compound miter saw
disc sanders
drill
drill bit
fixed-base router
jigsaw
laminate trimmer
miters
miter saws
pad sanders
palm sanders
plate joiner
plates
plunge router
pneumatic tools
router
router table
simple miter saw
sliding compound angle miter saw
sliding miter saw
standard routers



Check Your Knowledge

1. What is the essential difference between a circular saw and a power miter saw?
2. What are the three basic types of miter saws? Which is the most versatile, and why?
3. What saw would you use to cut a curved shape?
4. List three reasons it is a good practice to keep your tool manuals.
5. What are the most important safety rules for portable power tools?
6. Explain this statement: It is important think your way through an operation before actually performing it.



Activities

1. Your shop has been given a grant of $500 to purchase new portable power tools. Working with a group, decide how to get the most for your money. Support your answers.
2. Visit a woodworking shop and observe what portable power tools are a vital part of the operation. If possible, talk to the workers about their preferences in tools in terms of brands and features.
3. Try out a variety of different types of saws, drills, and routers. Which ones seem best for you, and why?



What's Wrong with This Picture?



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BUILD IT!

Tote Box

The completed tote box is shown in **Figure A**.

TOOLS REQUIRED

- measuring tool
- marking tool
- circular saw or power
- miter box
- drill and 5/8″ flat bottom bit
- jigsaw
- sander
- router, 1/4″ straight bit, and 1/4″ round-over bit
- brad or finish nailer

MATERIAL REQUIRED

- 1″ × 6″ × 48″ pine
- 5/8″ dowel, approximately 16″ long
- scrap of 1/4″ plywood, approximately 6″ × 16″

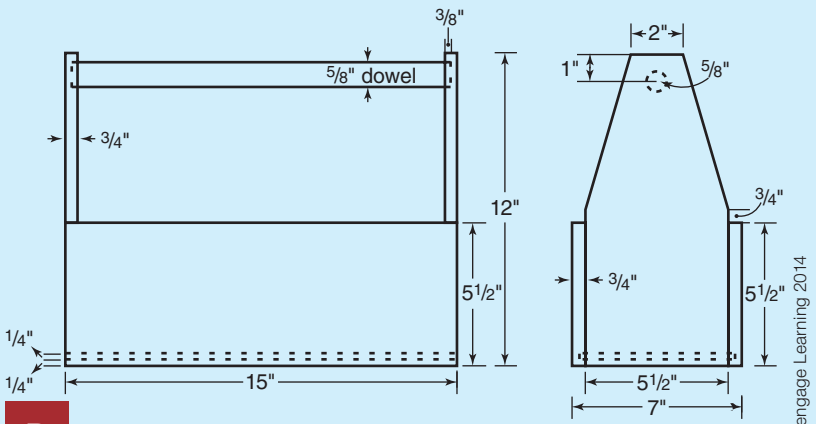
STEPS

1. Using the diagram shown in **Figure B**, lay out your pieces.
2. Using your router and a 1/4″ straight bit, machine a groove in your two side pieces and two end pieces, as shown in **Figure C**.
3. Lay out and drill a stopped 5/8″ hole 3/8″ deep for the handle on the inside faces of both ends, as shown in **Figure D**.



A

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B

Tote box

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C

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D

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E

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F

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G

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4. Lay out the shape of the ends and cut them using a jigsaw, as shown in **Figure E**.
5. Cut the bottom and handle to fit.
6. Before assembling the tote box, sand the inside faces.
7. Assemble and fasten together using a brad or finish nailer, as shown in **Figure F**.
8. Using the 1/4″ round-over bit in the router, ease the outside edges of the tote box, as shown in **Figure G**.
9. Sand the exterior.
10. Finish as desired.

BUILD IT!

PROJECT CHALLENGE

Small Jelly Cupboard

Figure A shows a completed jelly cupboard.

STEPS

1. Referring to the assembly list given in **Figure B**, cut all the parts to size with a circular saw except the door.



A

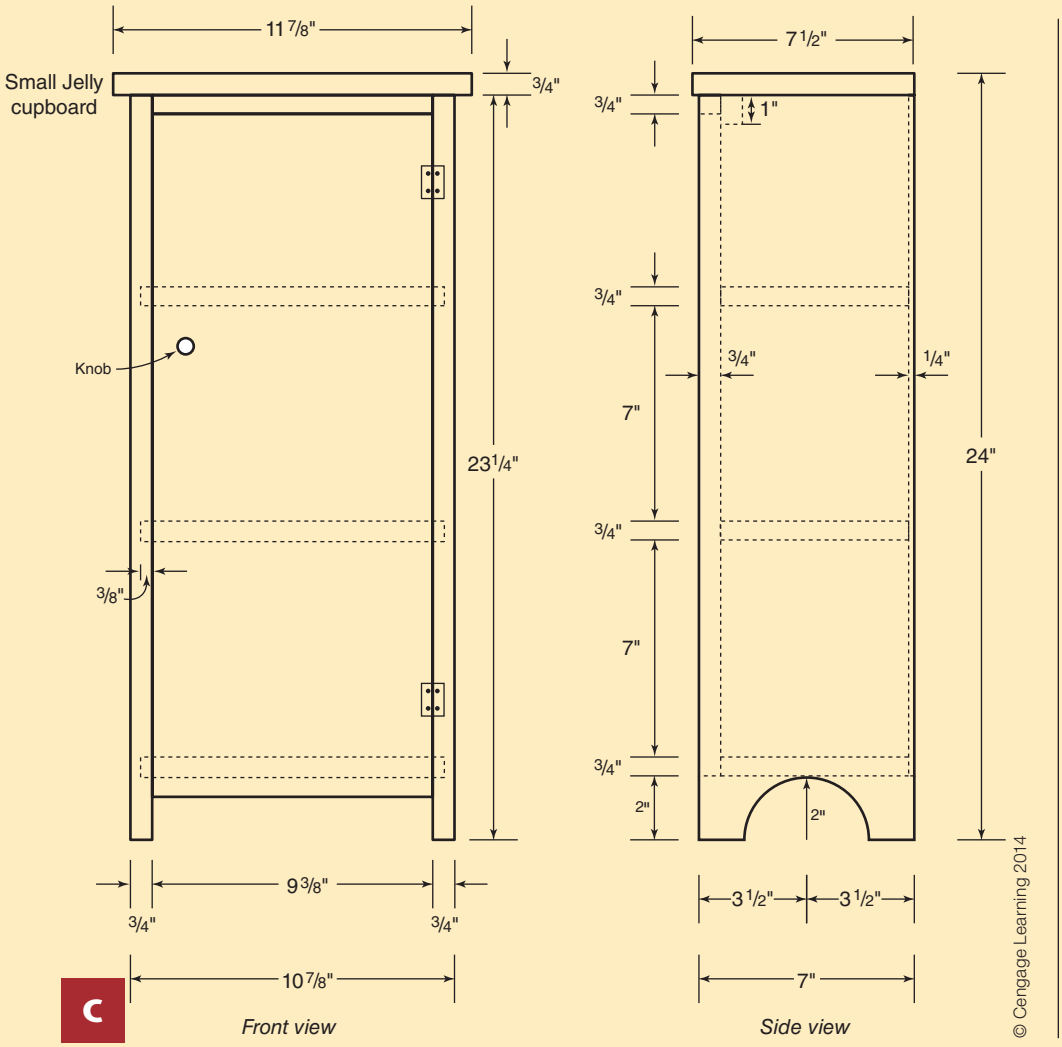
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Assembly list - jelly cupboard

Part	Dimensions (thickness × width × length)	Quantity
1. Sides	$^{3}/_{4}$" × 7" × 23$^{1}/_{4}$"	2
2. Back	$^{1}/_{4}$" × 10$^{1}/_{8}$" × 21$^{1}/_{4}$" plywood	1
3. Shelves	$^{3}/_{4}$" × 6" × 10$^{1}/_{8}$"	3
4. Top	$^{3}/_{4}$" × 7$^{1}/_{2}$" × 11$^{7}/_{8}$"	1
5. Door	$^{3}/_{4}$" × 10" × 22" (oversize)	1
6. Rail	$^{3}/_{4}$" × $^{3}/_{4}$" × 9$^{3}/_{8}$"	1
7. Dust stop	$^{3}/_{4}$" × 1" × 9$^{3}/_{8}$"	1
8. Hinges	$^{1}/_{2}$" × 1"	2
9. Knob	$^{1}/_{2}$" diameter	
10. Finish nails	6d	as needed

B

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C

2. Study the front and side views of the jelly cupboard, as shown in the diagram in **Figure C**. Using a router with a 1/4″ rabbeting bit, machine rabbets 3/8″ deep on the back of the two side pieces, as shown in **Figure D**.
3. Using a 3/4″ straight bit and a straightedge as a guide, machine stopped dados 3/8″ deep for the shelves, as shown in **Figure E**.
4. Square up the stopped end of each dado with a chisel, as shown in **Figure F**.



D



E



F

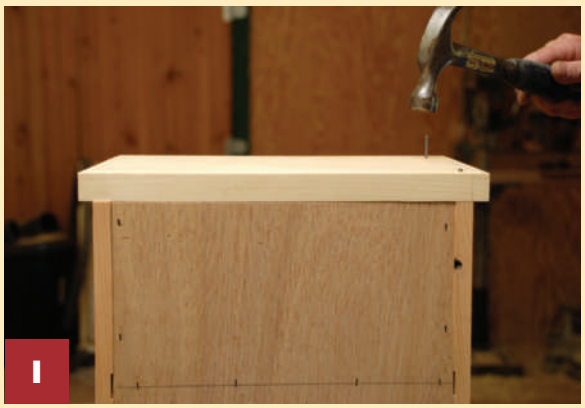
5. Lay out the arc at the bottom of the two side pieces, and cut them out with a jigsaw, as shown in **Figure G** and **Figure H**.
6. Assemble the cupboard with glue and 6d finish nails. Staple on the back, driving staples into the sides and the shelves.
7. Center the top so it is flush with the back and has an equal overhang on each side, as shown in **Figure I**. Set the nails.
8. Glue the rail and dust stop together and attach to the cupboard by nailing through the sides.
9. Measure the opening and cut the door 1/8″ smaller in length and width than the opening.
10. Attach the hinges to the door and cabinet, and check the fit of the door. Trim as necessary.
11. Remove the door, and drill a hole for the knob.
12. Remove the hinges, putty the nail holes, and sand.
13. Finish as desired and reinstall the door. Install the knob.
14. You may wish to install a catch to keep the door closed, as shown in **Figure J**.


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5

Stationary Shop Tools

You'll Learn

After studying the chapter, the student should be able to:

- Correctly identify commonly used stationary shop tools
- Describe the uses of each tool
- Demonstrate knowledge of the safe use of stationary shop tools
- Explain how to select and care for stationary shop tools

INTRODUCTION

Stationary shop tools are the largest and most powerful machines in the shop. They are the workhorses of any production shop. Properly used and maintained, they are capable of performing a tremendous amount of work with relative ease, thereby making a shop more efficient and thus more profitable. Stationary shop tools include table saws, band saws, jointers, planers, lathes, shapers, and a range of stationary sanders. There are also radial arm saws, mortising machines, drill presses, scroll saws, and grinders. And most cabinetmakers feel that the sliding compound miter saw is an indispensable shop tool. Today's woodworker may also use tools that have been programmed by computers to perform various tasks in a highly automated fashion.

If most cabinetmakers were forced to choose only three of the machines listed above to work with, most

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would take the table saw, the jointer, and the planer. These are often considered to be the "big three," forming an important work triangle as stock is shaped into components. We will begin with these tools after first considering some general safety rules for stationary tools.

GENERAL SAFETY RULES

The key safety rule for stationary tools is the same one covered earlier: Be alert! If you pay attention to what you are doing, you have the right attitude with which to approach these potentially dangerous machines. Keep your undivided attention on the work you are doing. Use guards whenever possible, and rely on push sticks, feather boards, and hold-downs to keep your hands a safe distance from blades and cutters. The general rule of thumb is to keep your hands a minimum of 4″ from any cutting action.

Stationary shop tools require spaces bigger than the tools themselves, and in some shops, these spaces are marked out. For example, you need room behind your table saw, as well as in front of it, to run a large piece of material, such as a sheet of plywood or a long piece of stock. The same is true of the jointer and the planer. It is important that you know you have enough room before you begin an operation! Otherwise, you will find yourself in a dangerous situation partway through the task. In shops where lack of adequate space is an issue, tools are often mounted on casters, so they can be moved into a clear spot when being used and out of the way when they are not.

Do not use a tool which you have not been trained to use properly. If you are not comfortable performing an operation on one of the tools, you should not do it without supervision. If you do not understand something, ask for assistance; do not let pride cause an accident, and do not attempt operations that have not been demonstrated to you. When deciding how to do a task that could be performed on a number of machines, consider safety as well as accuracy when making your decision.

If you are working in a multiperson shop, be alert to what others are doing. Keep beds and tables clear of debris, and do not let scraps accumulate on the floor, because they can be tripping hazards. Get in the habit of cleaning up after yourself as you go along; it makes for a safer, neater environment, plus there is less clean-up at the end of the work day.

Other safety procedures common to all woodworking machines include:

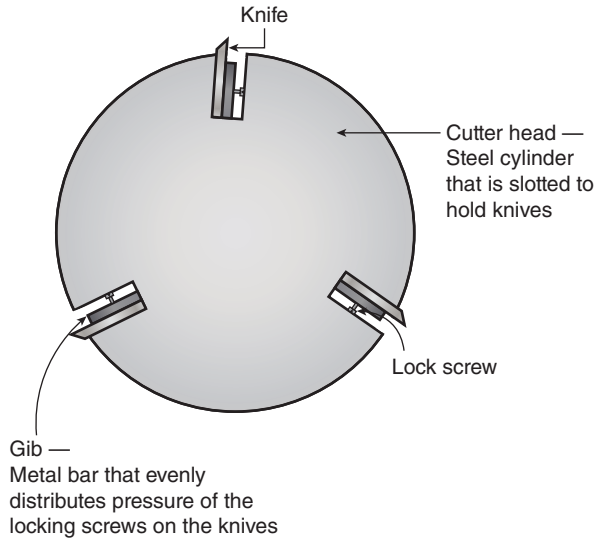
- Always wear safety glasses or goggles.
- Wear a dust mask when required, for example, when cutting materials like medium-density fiberboard (MDF) or particleboards, which create a very fine dust.
- Wear hearing protection when necessary. If you have trouble hearing someone speaking from three feet away, the noise level is high enough that you risk hearing damage if you are not protected.
- Do not wear loose clothing, work gloves, or jewelry that can become entangled with moving parts.
- Make sure the guards on the tool you are using are in good operating condition, and check the condition all other safety devices such as push sticks.
- Make sure you know where the stop and start buttons are and that you can reach them easily.
- Ensure that all blades, knives, bits, and cutters are clean and sharp.
- Inspect stock for nails and other foreign objects prior to jointing, planing, cutting, or shaping them.
- Do not remove scraps from a machine table while the tool is running.
- Avoid awkward hand positions where a slip could cause your hand to move into the cutting part of the tool.
- Turn the power off and unplug the power cord prior to inspecting, changing, cleaning, adjusting, or repairing a blade, bit, cutter, or the machine itself.
- Woodworking machines should be fitted with efficient and well-maintained exhaust ventilation systems to remove the sawdust or chips that are produced by machining.
- Do not leave woodworking machines until the power is turned off and the machine has come to a stop.
- Do not attempt to free a stalled blade before turning the power off.
- Do not distract or startle someone who is using woodworking equipment.
- Do not engage in horseplay in a woodshop.

JOINTERS

The **jointer** is a machine used to produce a flat surface on a board, either on its face or on its edge. Jointers are available in a great range of sizes, from 4-inch tabletop models to industrial models that are 16 inches or more. The jointer consists of two parallel tables, known as the infeed and outfeed tables, a movable *fence,* and a **cutter head**, which is driven by a motor (see **Figure 5-1**).

The **fence** provides a surface to support the work. It is normally set perpendicular to the jointer tables. The cutter head is cylindrical in shape and contains two or more sharp high-speed steel (HSS) knives, which do the actual cutting. The knives are arranged in a radial pattern in the cutter head so that their cutting edges protrude from it (see **Figure 5-2**). In this way they come into contact with the board being cut as the cutter head spins. The cutter head's axis of rotation is parallel to the tables. The knives spin back toward the infeed table and cut into the board opposite the feed direction (see **Figure 5-3**).

Although the straight knife type of cutter head is still the most popular type, there are two other types of cutter heads as well, the spiral and the helical. The terms spiral and helical are often used interchangeably, but there is a small difference between the two. Both types consist of a machined steel head with small square carbide steel cutters arrayed along the



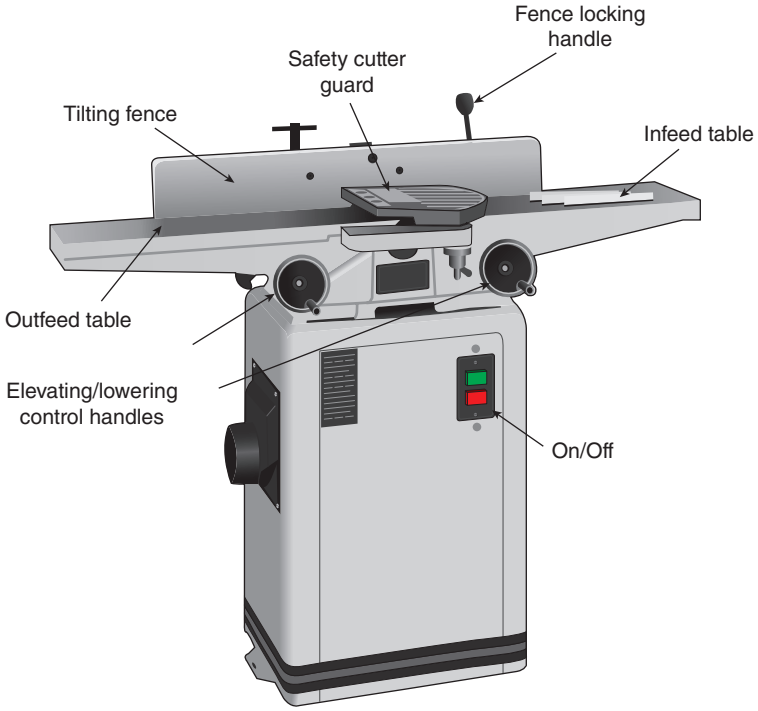
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FIGURE 5-2 Jointer knives are arranged radially in a cylindrical cutter head.



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FIGURE 5-3 Jointer knives cut into the material opposite the feed direction.



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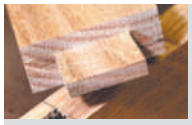
FIGURE 5-1 Diagram of a jointer.

surface in a spiral pattern and screwed in place (see **Figure 5-4**). These small cutters are sharpened on all four sides and can be rotated to expose a sharp cutting edge to the wood. When all the sharpened edges are used up, the cutter is replaced. The difference between the two designs has to do with the orientation of the cutters. Spiral cutter heads position each blade so that its cutting edge is perpendicular to the jointer's feed direction. Helical cutter heads have their cutters positioned at an angle to the feed direction. The straight knives used in most machines are less expensive than the other types, and for the most part they do a fine job, but they are difficult to align with one another after changing and they tend to tear out loose grain. They also dull much more quickly than the carbide cutters, so the quality of cut you get deteriorates faster. The helical and spiral cutter heads both do a good job of overcoming these two issues. They cause less splintering due to the spiral arrangement of the cutters, and the cutters are mounted directly to the cutter head with screws so there are no alignment issues. Additionally, it is possible to rotate a single or several dull or chipped cutters without having to remove a whole blade and sharpen it. Yet another advantage is that carbide cutters allow you to joint manmade materials such as melamine, plastic laminate, and MDF (medium-density fiberboard) that very quickly dull HHS knives. And although they are more expensive initially, by the time you take the cost of multiple sharpenings of steel knives into account, as well as the necessity for a second set of knives to use while the other set is being sharpened, the costs become more comparable. Given the facts that a carbide edge will last at minimum three to five times longer than an HHS edge, and that these carbide inserts have four sharpened sides, you can see that a set of carbide cutters will last 12 to 20 times longer than a set of HSS straight knives before needing to be replaced. A segmented cutter head like the helical or spiral is also significantly quieter than a straight knife cutter head. On the downside, they also require more power and more feed pressure, especially when surfacing stock.



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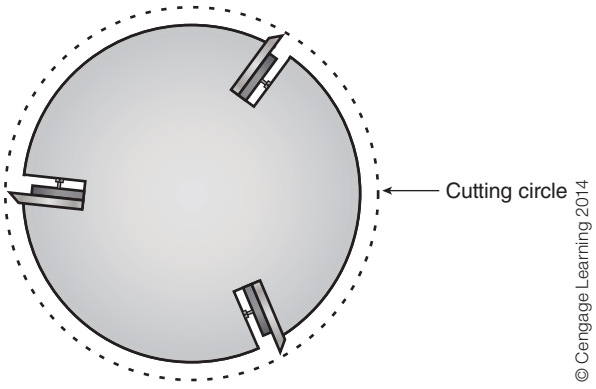
FIGURE 5-4 A helical cutter head has many square or rectangular shaped cutters arrayed around the cutter head in a spiral.



HISTORY FACT

The jointer gets its name from its primary function of producing a flat edge on boards prior to joining them edge to edge to create a wider board. The term probably originates from the name of a type of bench plane, the jointer plane, which was used for the same purpose. ■

The principle behind the jointer is pretty simple: The infeed table is set lower than the **cutting circle**, and the outfeed table is in line with the cutting circle. The infeed and outfeed tables can be raised and lowered independently of one another. The cutting circle is the circle that could be drawn around the outside surface of the knives as they protrude from the cutter head (see **Figure 5-5**). Material is removed from



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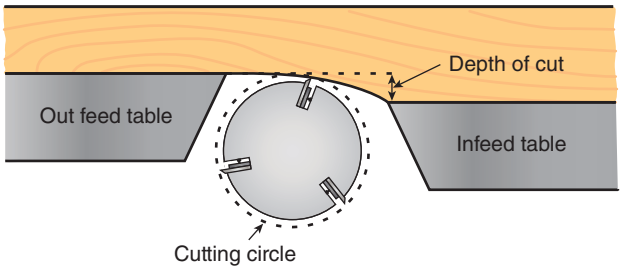
FIGURE 5-5 The cutting circle.

a board in the amount that the infeed table is lower than the cutting circle; this is the depth of cut (see **Figure 5-6**). The board rides against the fence, which can be moved in and out, adjusting the amount of cutter head exposed. Note that there is a guard in the jointer photograph; it covers the knives and pivots to the side, allowing material to be processed, while still covering the parts of the knives that are not being used. The jointer is a very dangerous tool. The guard should be in good working condition and it should be used. There are very few operations on the jointer that require removal of the guard, and these operations can be performed more safely on other machines.

The jointer is sized by the length of its knives. **Figure 5-7** shows an 8-inch jointer, which would be more than adequate for most small shops. The length of the knives determines the width of a board that can be flattened. Flattening a board is also known as *surfacing*. If you use rough-cut lumber, surfacing is a necessary step to make material flat enough to use. Wood that is purchased planed must be checked for flatness.

When using a jointer in a multiperson shop, it is good practice to carry a small square to check the fence to make sure it is square to the table. The cutter head knives should be kept sharp and clean; they can be honed while in the machine, but they should be removed periodically and professionally sharpened.

Do not run dirty or painted material on your jointer. If you must joint sheet goods, such as plywood or other composite panels, and you have HSS knives, it is a good practice to use the innermost part of the knives for this, as the adhesives used to bond these materials are tough on HSS knives and quickly dull them. Always check wood carefully for metal; a buried nail will put a nick in all your knives, which, until pulled and sharpened, will leave a line on your freshly surfaced or jointed board.



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FIGURE 5-6 The jointer works by removing material at a cutting depth equal to the difference between the height of the infeed table and the height of the outfeed table.



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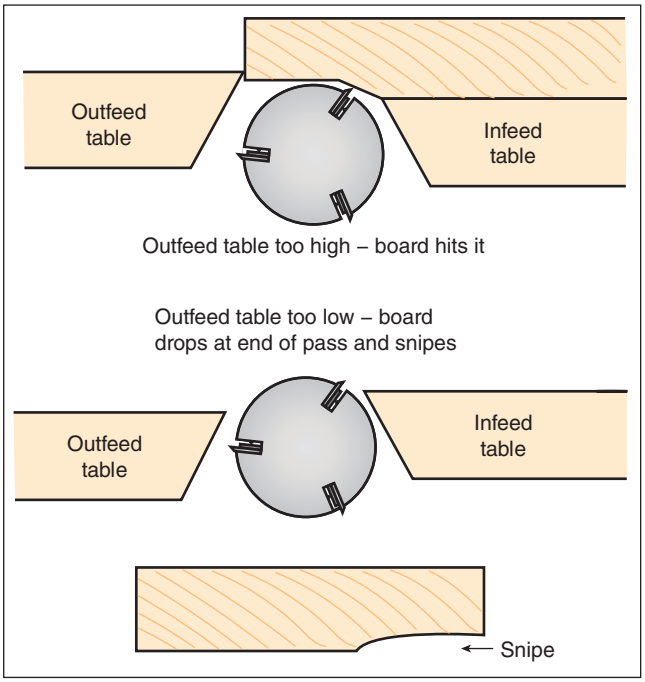
FIGURE 5-7 8″ jointer.

Setting Up the Jointer

The jointer *beds*, which are the infeed and outfeed tables, should be dead flat and parallel to one another. Longer beds allow you to work more easily and accurately with longer stock. Use a true straightedge to check the beds for flatness and to ensure they are parallel with one another. To do this, the infeed and outfeed table locks are loosened, and the two tables are raised until they are in line with one another. The fence should be set as far back as possible. To check for table flatness and parallelism, lay the straightedge across the tables and check to make sure there is no sag in the end of the tables; move the straightedge around to check for flatness across both beds; the straightedge should be touching the tables at all points.

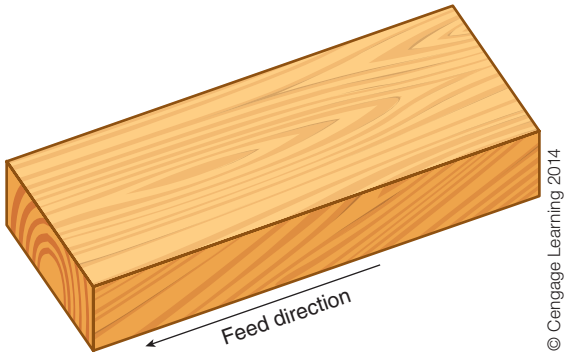
Once you have determined that the tables are properly aligned, adjust the outfeed table so that it is even with the top of the cutting circle. This ensures full support for the workpiece throughout the cut. As you manually rotate the cutter head, the knives should just touch the bottom of a straightedge. If your outfeed table is set too high, a board run through will either hit the outfeed table or result in a board that is tapered along its length. If the outfeed table is set too low, a **snipe** — an extra, stepped cut taken out of the end of the board — will result as the board drops down at the end of the cut (see **Figure 5-8**).

Never sit on a jointer bed or move a jointer by lifting it by its tables. You will remember that the infeed and outfeed tables on the jointer need to be parallel for the machine to work effectively; stressing them can upset this critical alignment.



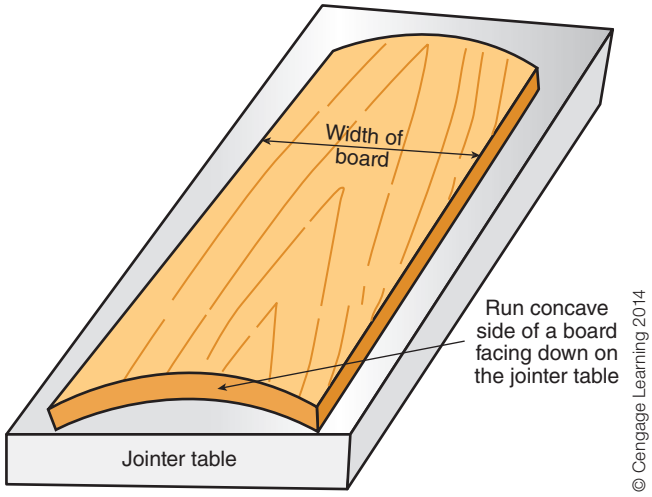
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FIGURE 5-8 An outfeed table set too high hits the board; an outfeed table set too low results in a snipe.



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FIGURE 5-9 Join with the grain to avoid tear-out.



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FIGURE 5-10 When flattening a face, run the concave side of the board down on the jointer table.

Jointer Operations

The jointer can be used to perform a variety of tasks, but its primary uses are for surfacing stock and squaring an edge to a face. Surfacing flattens the face of a board so that next it can accurately be brought to the desired thickness using the planer. Squaring an edge perpendicular to a flat face makes it possible to safely and accurately rip a piece to width using the table saw. Of these two operations, jointing an edge is by far the more common. Other jointer operations include end jointing, chamfering, and beveling.

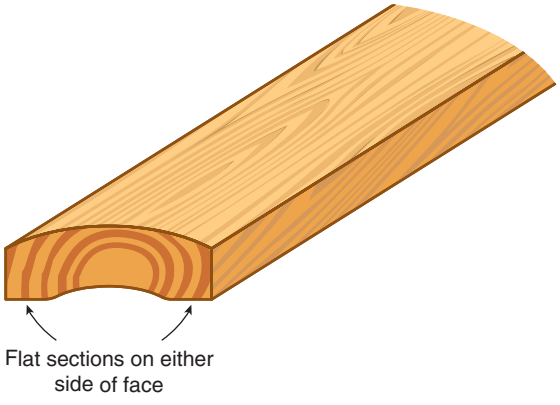
Surfacing:

1. Set the fence to accommodate the width of the workpiece,
2. Set the depth of cut by lowering the infeed table. Do not attempt to make a cut greater than 1/16″ in a single pass.
3. Check to make sure the guard rotates freely.
4. Look at the board to determine grain direction, and run it so that the grain runs back toward you to prevent tear-out (see **Figure 5-9**).
5. If the board is cupped, run it with the concave face down to the tables (see **Figure 5-10**).
6. Turn the jointer on and allow it to come to full speed before starting the cut.
7. Hold down and guide the board with your left hand and advance it through the cutter head with your right, using a push block. Your left hand should be holding the board lightly, with little pressure (see **Figure 5-11**).
8. Feed the board at a steady, moderate rate, keeping your balance at all times.
9. Repeat as needed to achieve the desired result. If the board is going to be taken to the thickness planer, it is only necessary to joint it until it looks like **Figure 5-12**, which will be sufficient to support it while planing the opposite face flat, at which point it is turned over and the first face surfacing can be completed using the planer.



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FIGURE 5-11 Surfacing stock.

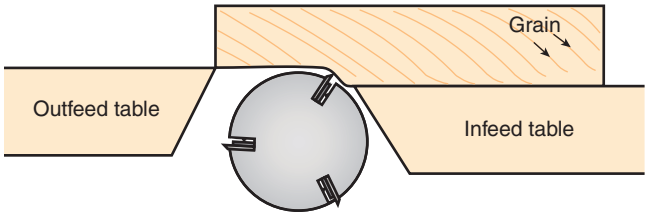


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FIGURE 5-12 With flats established on either side, this board can be taken to the planer.

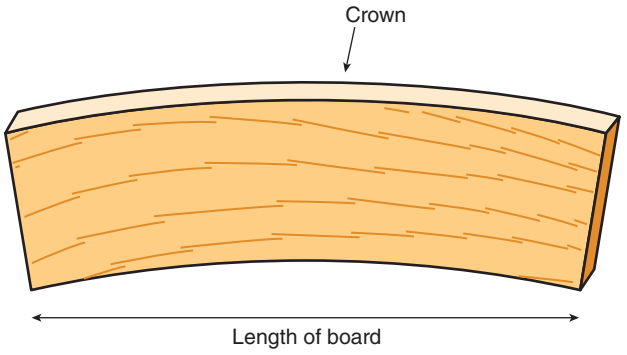
Edge Jointing:

1. Set the depth of cut. Do not attempt to make a cut greater than 1/16″ in a single pass.
2. Check to ensure that the fence is square to the tables.
3. Check to make sure the guard rotates freely.
4. Determine the grain direction of the board, and run it so that the grain looks like the diagram in **Figure 5-13**. You want to joint with the grain to reduce splintering.
5. Check the board to see if it has a crown. The crown of the board is its high point as you sight along the edge (see **Figure 5-14**). You will run your board with the crown up. Successive passes will remove the crown and straighten the edge of the board (see **Figure 5-15**).
6. Make sure that you have a flat face to place against the fence. You are going to straighten the edge so that it is square to this face.
7. Turn the jointer on and allow it to come to full speed before starting the cut.
8. Place the edge of the board firmly on the infeed table and hold it snugly against the fence with



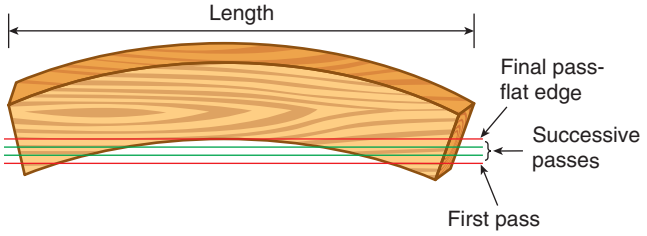
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FIGURE 5-13 The grain should run back toward the infeed table so that you are jointing with the grain.



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FIGURE 5-14 The crown of a board.



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FIGURE 5-15 Successive passes remove the board's crown.

your left hand. Advance the board with your right hand, using a smooth and steady feed rate (see **Figure 5-16**). If the piece is narrower than 3″, use a push stick to advance the board (see **Figure 5-17**).

9. Repeat as needed until the edge is straightened.

WOODWORKING TIP:

Although you checked that the fence was square to the table prior to jointing your board, it is always wise to get feedback from the workpiece, so once you have jointed the board, use a true square to check that it is indeed square.



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FIGURE 5-16 Jointing an edge.



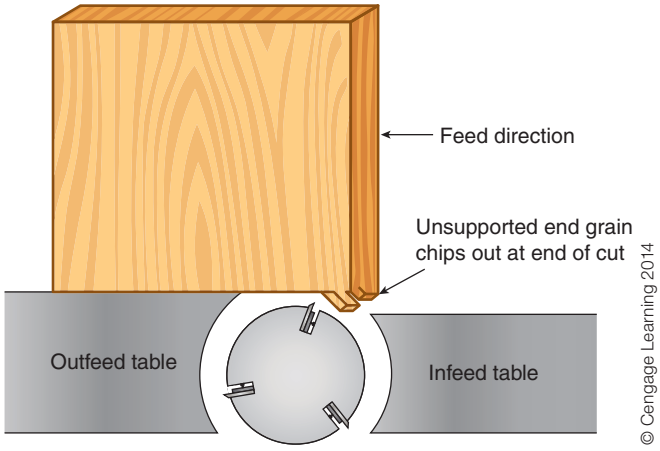
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FIGURE 5-17 Use a push stick when jointing narrow pieces.

End Jointing:

There are times when it is desirable to joint end grain. For example, you may wish to remove a burn mark left from sawing. The difficulty you must overcome is the fact that unsupported end grain will chip out at the end of the cut (see **Figure 5-18**). The remedy for this is to use a procedure called the double-pass method.

1. Set the depth of cut for a light pass, such as 1/32″.
2. Check to ensure that the fence is square to the tables.
3. Check to make sure the guard rotates freely.
4. Hold the board against the fence and down to the table with your left hand, and advance it into the cutter head a distance of about an inch (see **Figure 5-19**).



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FIGURE 5-18 Unsupported end grain chips out at the end of a cut.



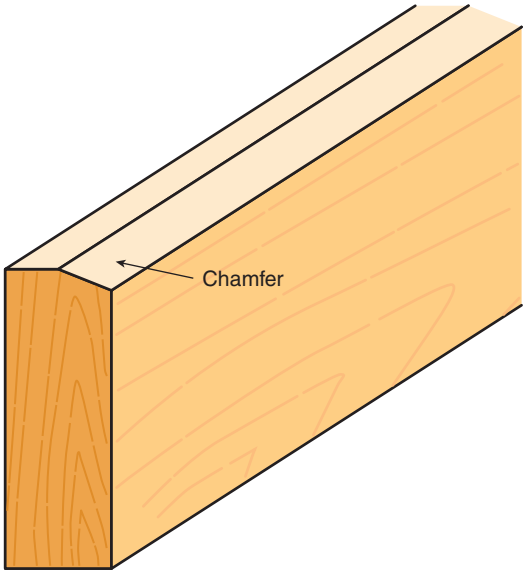
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FIGURE 5-19 First make a cut about an inch long into one end.

5. Lift and turn the workpiece around.
6. Joint the piece, applying pressure to the outfeed table at the end of the cut, when you reach the 1″ section you first jointed.

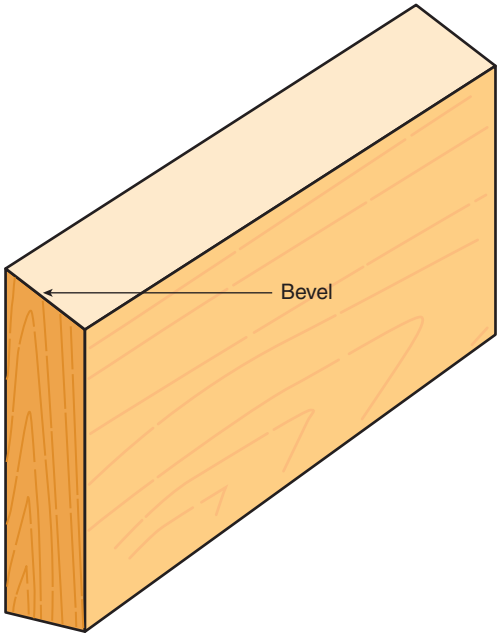
Chamfering and Beveling:

The jointer fence can be tilted up to 45° to create chamfered and beveled cuts. A **chamfer** is an angled cut made *part* way across the edge or end of a board (see **Figure 5-20**). A **bevel** is an angled cut made *all* the way across the edge or end of a board (see **Figure 5-21**). The safest way to make chamfers and bevels is to tilt the fence so that it forms a closed angle with the tables (see **Figure 5-22**). This is because when the fence is tilted back away from the tables, the workpiece has a tendency to slide away from the fence, particularly when the initial cuts are made. If the fence is set this way, it can be made safer by using a beveled guide strip that will hold the board firmly against the fence (see **Figure 5-23**). Chamfers may be made in one pass, depending on the size of chamfer desired; bevel cuts will require multiple passes. The procedure is the same as edge jointing.



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FIGURE 5-20 Chamfer.



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FIGURE 5-21 Bevel.

WOODWORKING TIP:

It is more difficult to surface or joint a very long board accurately than a shorter one, and it is often not necessary. If a project requires pieces than are 600 long, for example, and your board is 1300 long, cut it in two before you take it to the jointer and the work there will be much easier to manage. Also, in the case of a long board with a crown, you will lose less stock in straightening the two halves of the board rather than the one longer one, since the crown will not be as pronounced.

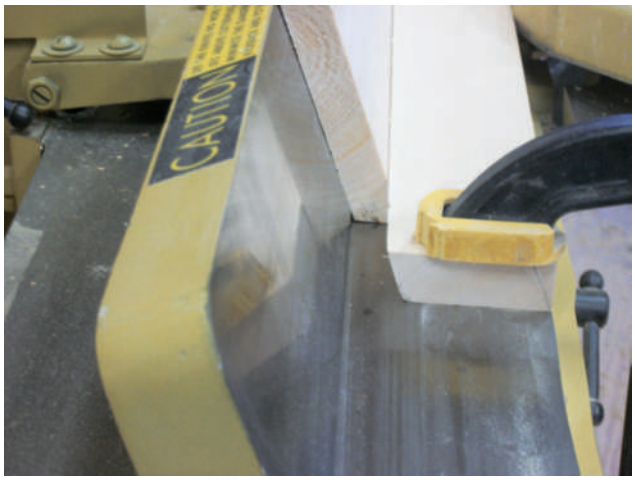
Jointer Safety

The jointer can be an intimidating tool, but you will quickly feel comfortable using it and get good results if you check grain direction and master the proper stance and feed technique. It is important to be well balanced at all times and to make sure to keep material flush on the table and against the fence. Ideally, your hand should not pass directly over the knives, especially when surfacing stock. Material should be held down with push blocks during this operation, particularly at the end of the cut (see **Figure 5-24**). Place pressure only on the infeed and outfeed tables. For good balance, your weight starts off on the infeed table and gradually moves to the outfeed table as you come to the end of the cut. You should be well balanced on your feet at all times, and there should be



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FIGURE 5-22 Tilt the fence into join chamfers and bevels most safely.



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FIGURE 5-23 Use a beveled guide strip to support stock if you tilt the fence away from the table.



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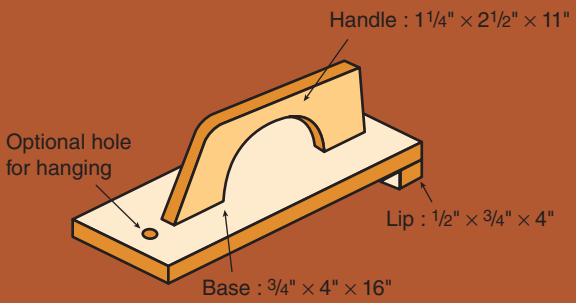
FIGURE 5-24 Use a push block when flattening stock.

no tripping hazards around the machine. The key is to keep the board flat and resting on the tables, both before it hits the cutter head and afterward. Other safety precautions for using the jointer are:

- Never edge joint stock that is less than 1/4″ thick, 3/4″ wide, or 12″ long,
- Never surface plane stock that is less than 1/2″ thick, 3/4″ wide, or 12″ long.
- Do not joint stock less than 3″ wide without a push stick.
- Always have the blade guard in place.
- Stand to one side of the jointer, not directly behind it.
- Allow the cutter head to reach full speed before starting a cut.
- Never feed material with your thumb or fingers on the end of it; keep them on top of the material.
- Check the depth of cut before turning the machine on, and do not make cuts more than 1/16″ deep.
- Use the left hand to hold stock down and the right hand for pushing stock.
- Walk with the board through the cut on long boards.

WOODWORKING TIP:

Make a push block to use when flattening stock on the jointer (see Figure 5-25). Drill countersunk holes in the base and screw up into the handle.



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FIGURE 5-25 How to make a push block.

PROCEDURE 5-1

Edge Jointing a Board



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STEPS

1. Check the board to be jointed for a crown as shown in **Figure A**; run it with the crown up if it has one.
2. Adjust the depth of the cut by lowering or raising the infeed table. Loosen the table lock, adjust as desired, and lock, as shown in **Figure B**.
3. Check the fence to be sure it is perpendicular to the table, as shown in **Figure C**.
4. Check the way the grain runs on the board. It should run back toward the infeed table as you joint it, as shown in **Figure D**.
5. Turn on the jointer and run the board through, keeping it flush to the table and firmly against the fence, as shown in **Figure E**. Begin with pressure on the infeed table and gradually switch it to the outfeed table, keeping your balance at all times.
6. Repeat as necessary, until every part of the edge has met the knives and the board sits completely flat on the table.

Troubleshooting Hints for the Jointer

Snipe — outfeed table is too low

Unwanted taper — outfeed table is too high

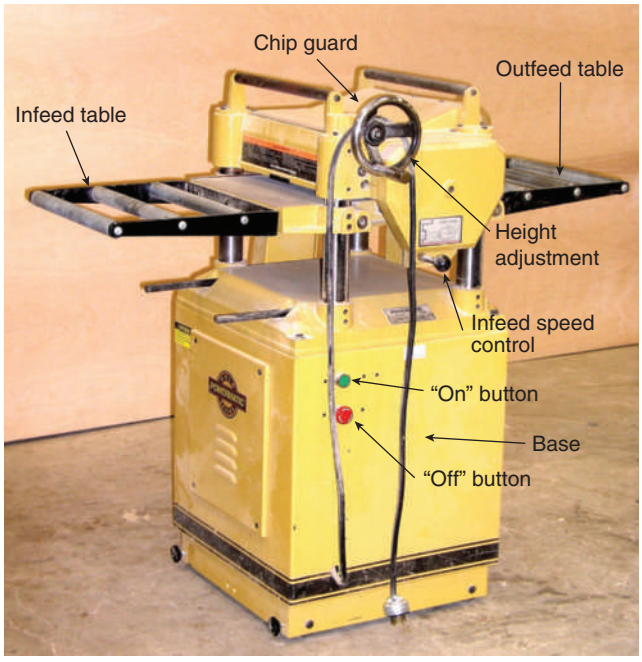
Rippled surface on stock after jointing, called washboarding — stock was fed too quickly or the jointer knives are uneven

Burning — feed rate was too slow or knives are dull

THICKNESS PLANERS

The **thickness planer**, often simply referred to as a *planer,* is a machine used to create boards that are of an even thickness throughout their length. This machine consists of three primary elements: a *cutter head,* which holds two or more knives; a set of infeed and outfeed *rollers;* and an adjustable *table*. **Figure 5-26** shows a 15-inch planer, and **Figure 5-27** illustrates the internal workings of a planer.

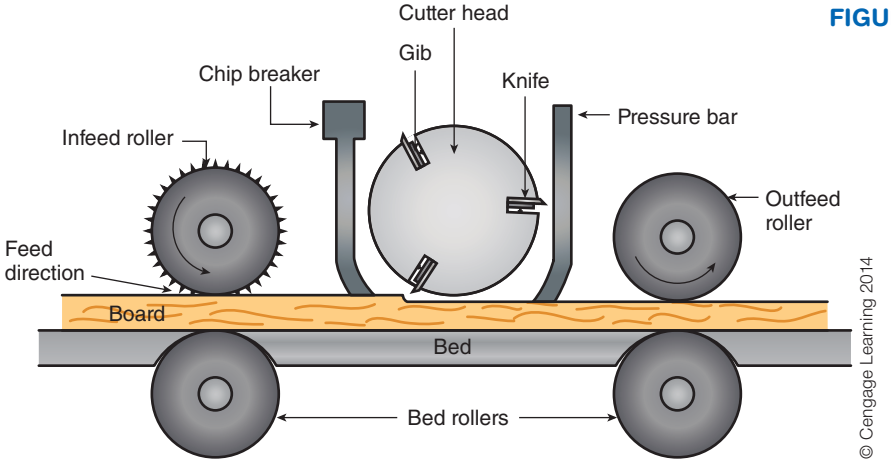
The cutter head holds knives in the same way the jointer cutter head does. And, as with the jointer, your planer may have several single piece HSS knives or it may have a spiral or helical cutter head. The comments made previously about these cutter heads also apply to their use in the planer. The infeed and outfeed rollers draw the board through the machine and past the cutter head. The infeed roller may be solid or in sections, and it is often striated, which helps it grab the lumber better. It is mounted on a spring which allows it to rise when a board is fed into the planer. It is motorized and pulls the stock forward. The infeed roller is set so that the distance between it and the table is slightly (1/32″) lower than the distance from



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FIGURE 5-26 A 15″-thickness planer.

the bottom of the knives in the cutter head to the table. Stock moving through the planer next encounters to the chipbreaker, which is also spring mounted. The chipbreaker, like the rollers, helps hold the stock down to the table and also prevents splintering of the lumber that might be caused by the upward thrust of the knives exiting the stock. Like the infeed roller, it is set 1/32″ below the bottom arc of the knives. As the board passes under the cutter head it is reduced in thickness by the action of the knives. Directly behind the cutter head is the pressure bar, whose function is to hold the board firmly down to the table and thus prevent vibration of the stock. The pressure bar should be set at the same height as the distance



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FIGURE 5-27 Cutting action of a planer.

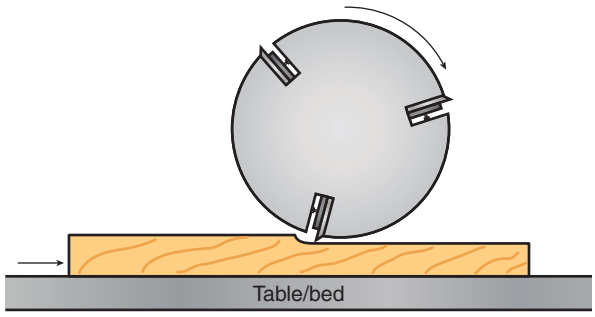
from the bottom arc of the knives to the bed of the planer. Next and last is the outfeed roller, which, like the infeed roller, is mechanized to help pull lumber through the planer. It is set at the same height as the chip breaker and the infeed roller. The outfeed roller, however, is smooth so that lines will not be depressed into the freshly planed board. Most planers have bed rollers, also called table rollers. There are two, both set in the table — one in front of the cutter head and one behind it. Their job is to reduce the friction between the board and the table, and they are set just slightly above the surface of the table (.008″). Unlike the infeed and outfeed rollers, table rollers are not motorized but roll due to the pressure created by the material as it is fed by the upper rollers. Smaller and portable planers may not have bed rollers. The table is raised and lowered relative to the cutter head, determining how much material will be removed. This is how the depth of cut is set. The table is adjusted by means of the table adjusting handwheel.

Much like the jointer and the other stationary shop tools that we will discuss, planers are available in a great range of sizes, powers, and weights. There are good, portable 12-inch planers on the market, which have the advantage of being able to be moved out of the way if space is at a premium in the shop, or taken to a jobsite if needed. Larger, stationary machines are 15 inches and up.

The size of the thickness planer is determined by the length of the knives, and the size of the planer is also the maximum width of stock that can be planed. In this it is similar to the jointer. A planer works in much the same way that a jointer does, but unlike the jointer, the cutting action happens on the top surface of the material, rather than the underside (see **Figure 5-28**). In operation, the table is set to the desired height, and the machine is switched on. The board is fed into the thickness planer until it makes contact with the infeed roller, which grips the board and pulls it into the machine and past the rotating cutter head. The knives remove material from the top of the board, and the outfeed roller pulls the board through and ejects it from the machine at the end of a pass. On many heavier planers, the speed at which the board moves through the machine is adjustable and there is a separate switch for the feed mechanism. The slower the feed rate, the smoother the cut.

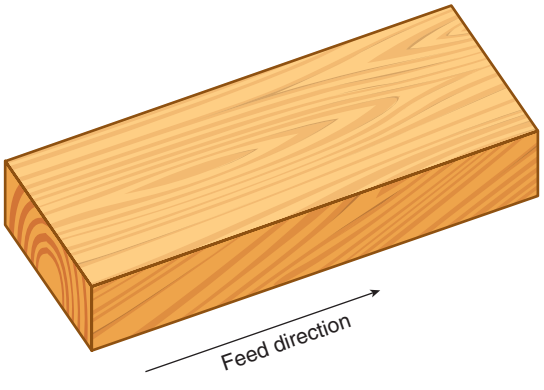
For best results, planer knives must be sharp. Spiral and helical cutters may be rotated to expose new cutting edges, while straight knives will need to be removed and sharpened periodically. As with the jointer, the knives must be re-installed properly for the planer to do the best job. You want to plane with the grain when using the planer, just as you do with the jointer. The difference is that the cutting is being done from above, so in order to cut with the grain, you need to feed the work as diagrammed in **Figure 5-29**.

The job of the thickness planer is to reduce the thickness of the board, while maintaining parallelism between the two faces. In order to achieve this, it is necessary to start with a board that has at least one perfectly flat reference face, because a thickness planer will not flatten a warped or distorted board. Although the rollers that move the board through the planer will temporarily flatten the board and reduce its thickness, it will resume its warped shape once it is out of the planer. Before stock is brought to the planer, one flat surface must be established. In the case of a cupped board, it is sufficient for the two outside edges of the board to be in the same plane, as was illustrated in Figure 5-12. That side will be placed on the bed of the planer, and material will be removed from the top until it is flat. At that point, the board can be turned over and the first side brought to final flatness.



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FIGURE 5-28 The planer removes material from the top of the board.



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FIGURE 5-29 Feed material so you are planing with the grain.

It is important to use a dust collector with your planer, because planers create a large amount of chips; if those chips are not cleared out, they will fall onto the work and be pressed into it, causing dents. As with the jointer, it is not a good idea to send dirty, painted, or used lumber through the planer, particularly if you suspect it has any metal in it, such as old, broken off nails or staples, as these will damage the planer knives.

Long pieces being planed should be well supported, especially on the outfeed side, so that they do not drop at the end of a cut and cause a snipe at the end of a board. Ask a helper to catch material for you, or set up an outfeed roller or table to support long stock as it exits the planer.

Using the Thickness Planer

1. Measure the thickness of the board to be planed.
2. Raise or lower the planer bed to set the depth of cut. Set the table to cutter head distance to be 1/16″ to 1/8″ less than the stock thickness. How much material you can remove at a time depends on how powerful your machine is.
3. Set the feed rate, if your machine has an adjustable feed rate.
4. Look at the board and determine the grain direction so that you can feed with the grain.
5. Make sure the dust collector is connected to the planer and turned on.
6. Turn on the planer and wait for it to come to full speed. Turn on the feed rollers if there is a separate switch for them.
7. With a flat face down on the table, start your board into the planer, releasing it as soon as the infeed roller grabs it.
8. Remove the board as it exits the planer, supporting long stock to prevent sniping.
9. Raise the table and repeat until the desired thickness is reached, removing material from both sides of the board equally.
10. If much material needs to be removed, take heavier, faster passes until you get close to the desired thickness. At that point, slow the feed rate and take lighter passes to get the best possible final results.

Planing Thin Stock

You should not plane stock less than 3/8″ thick. However, it is possible to plane thinner stock if you use a backer board. A backer board is a flat piece of stock that is both longer and wider than the piece you wish to plane, and it must be at least 3/4″ thick. Set the planer's depth of cut to be a maximum of 1/16″ less than the combined thickness of the backer board and the board you wish to plane. Place your piece on the backer board and feed them into the planer together (see **Figure 5-30**).

Planer Safety

- Keep all guards and covers on the machine.
- Remove any bark or loose knots from stock before planing.
- Stand to the side of the planer with the switch rather than directly behind the machine to avoid injury in the event of kickback and to be able to quickly reach the switch.
- Place boards on the bed in such a way that your fingers do not get pinched.
- Release material as soon as the infeed roller grabs it. Do not follow stock with your hands. The planer is self-feeding.
- Do not plane stock shorter than the distance between the infeed and outfeed roller plus 2″. Short pieces can get wedged under the chipbreaker or pressure bar.
- If a board jams in the machine, turn off the planer and lower the table after the machine stops.



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FIGURE 5-30 Use a backer board to plan thin pieces.

- Never reach into the planer with your hand to remove a wedged piece of material. Use a stick after the machine has come to a complete stop and the table has been lowered.
- Always use the dust collector.

Troubleshooting Hints for the Thickness Planer

The most common and visible planer defects are snipe, clip, and washboard (see **Figure 5-31**).

Snipe at front of board only — front bed roller set too high

Snipe at back of board only — rear bed roller set too high

Clip at 3″–6″ from both ends of board — pressure bar set too high and/or bed rollers too high

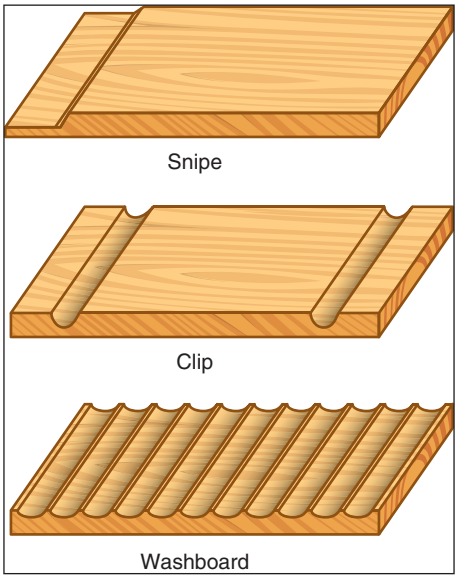
Washboard surface —knives not all set at the same height and/or feed rate too fast

Line on board parallel to feed direction — nick in the knives

Tear-out/splintering — Cutting against the grain and/or chipbreaker set too high and/or feed rate too fast

Board won't feed through — pressure bar too low and/or cut too deep

Motor bogs down — depth of cut too great or feed rate too fast.



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FIGURE 5-31 Planing defects.

CAUTION

Wearing work gloves to protect your hands from splinters is a good idea when handling wood, but never wear gloves when you are operating machinery lest they get caught by rotating blades, bits, or cutters and pull your hands in.

TABLE SAWS

There are woodworkers who would argue that the **table saw** is the most essential of the stationary shop tools. It is the most commonly owned piece of large woodworking equipment. Table saws are sized by the diameter of the largest blade they are designed to take and by the horsepower they can generate. The table saw consists of a circular saw blade that protrudes through a table. The saw blade is mounted on an **arbor**, a metal shaft that is threaded at one end to accept the nut, which secures the blade in place. The arbor is driven by a motor, which causes the blade to turn.

Like the other tools in this chapter, table saws are available in a wide range of models. There are five basic categories of table saws: *benchtop table saws, contractor saws, cabinet saws*, *hybrid saws,* and *European saws*. (see **Figures 5-32**, **5-33**, **5-34**, **5-35**, and **5-36**.).

Benchtop table saws, also known as portable saws, are lightweight (well under 100 pounds) and compact in design. They are made sit on a support, such as a table or bench, although some are available with fold-out legs or legs on wheels. They are easily moved by one person and can be carried to a job site. They commonly have direct-drive motors and typically have a plastic body and an aluminum top. They are the least



Image courtesy of Stanley Black & Decker/ DEWALT

FIGURE 5-32 Benchtop (portable) table saw.



Image courtesy of POWERMATIC® and JET®.

FIGURE 5-33 Contractor saw.



Image courtesy of POWERMATIC® and JET®.

FIGURE 5-34 Cabinet saw.



Image courtesy of rockler.com

FIGURE 5-35 Hybrid tablesaw.

expensive of the three types of saws, and may be fine for small-scale work and occasional heavier use, but these portable saws are not adequate to meet the demands of most woodshops. The small size of their tables makes cutting large stock difficult or impossible,



Image courtesy of Felder USA

FIGURE 5-36 European tablesaw.

and their lack of power prevents ripping thick hardwoods. The universal direct-drive motor is noisy and, combined with their light weight, results in a saw that will produce more vibration and feel less stable to operate than a larger, heavier saw.

Contractor table saws are larger and heavier than benchtop saws, although still relatively lightweight compared to cabinet saws, weighing between 250 and 300 pounds. Contractor saws were originally designed to be portable enough to move from one jobsite to another. They have a base which is open in the rear and an attached, open stand. The top is cast iron, with the extension wings made of stamped metal or cast web work. The induction motor, which is typically 1½ horsepower (HP), is hinged off the rear of the saw, making it easier to remove when transporting the saw. The motor drives the arbor assembly holding the blade by means of a single belt. These saws are more useful than benchtop saws due to their larger tables and greater weight and power, making it possible to rip long pieces of wood and break down sheet goods. While not as portable as benchtop saws, they can also be taken to jobsites, and in fact, that is what they were originally designed to do. The portable saw, which is now the table saw most frequently seen at jobsites, was developed later. A contractor saw has a dual voltage motor that can be wired for either 110 V or 220 V, so it can be set up to run on standard household current (110), or more efficiently on 220 if your shop is wired for it.

Cabinet table saws are the heaviest and most powerful of the table saws, with the exception of some European saws, weighing upwards of 600 pounds. Their mass derives from the large amount of cast iron and steel used in their construction. They are characterized by an enclosed base, which houses the motor. Their greater mass and enclosed motor result in a quieter, more solid saw. The enclosed base also makes

dust collection easier. Cabinet saws have motors in the 3- to 5-HP range, and they require 220 V AC. The blade, mounted on the arbor assembly, is driven by three parallel belts. The motor and arbor assembly are held in place with heavy trunnions, which are bolted to the cabinet base instead of to the table as with the contractor saw, making precision alignment of the blade with the miter gauge slot and the fence much easier than when the trunnions are attached to the table. The increased weight and power of the cabinet saw minimizes vibration when in use, which in turn increases accuracy. Cabinet saws represent a greater investment than portable, contractor, or hybrid saws, but as a rule are manufactured to more exacting standards and built using better components, making them the preferred saw of professional woodworkers and serious amateurs.

Hybrid table saws occupy the middle ground between contractor and cabinet saws. They are a relatively new class of table saw, introduced by DeWalt in 1999. Hybrid saws have an enclosed base in which the motor is mounted; the base may look like that of a cabinet saw or it may have a shorter enclosed base with legs. They are equipped with more substantial trunnions and arbor bearings than most contractor saws, and often a more advanced drive belt system and better gearing. Depending on the manufacturer, the trunnions may be mounted to the base of the saw like cabinet saws, or to the table like contractor saws. Like contractor saws, hybrid saws have motors in the 1½- to 1¾-HP range and can be run on a standard 110 V service. In terms of cost, weight, and overall accuracy, they fall in between contractor and cabinet saws.

European saws take cabinet saws to the next level. They are larger in size, heft, features, and price. The most important differences between the European saw and the traditional American cabinet saw, aside from its greater size, are that European saws include an integral sliding table, a riving knife, and a scoring blade. The sliding table allows the operator to very easily crosscut large workpieces, and the small scoring blade set in front of the main saw blade results in a smoother final cut, especially when cutting veneered sheet goods and products such as melamine. The small scoring blade rotates opposite the main blade and makes a shallow precut. The dust collection system on European saws is a two part system; it collects dust from the base of the machine like the American saws, but it also collects dust at the saw blade guard, which is a very nice feature. The riving knife serves the function of keeping the wood separated after it passes the blade, preventing kickback. Its function is similar to that of the splitter found on American saws. European-style saws are now being manufactured in North American as well as Europe.



HISTORY FACT

SawStop is an American company located in Oregon that was founded in 2005. It is the first table saw to feature a brake, which was invented by Steven Gass, an amateur woodworker with a doctorate in physics who was working as a lawyer. SawStop's patented braking system stops the blade within milliseconds of flesh coming into contact with it, preventing major injury. Touching the blade triggers a spring that releases the brake, which slams into the blade. The blade stops within 5 milliseconds and drops below the table. The operator may suffer a cut, but will not experience a traumatic injury. The blade and brake must both be replaced. SawStop manufactures both contractor and cabinet saws. To see a vivid demonstration of the SawStop in action, go to *www.sawstop.com* and watch the hot dog demo. ■

WOODWORKING TIP:

It has been said that the test of a good table saw is to place a nickel on edge on the table and then use the saw. If the nickel stays in place and doesn't fall over due to vibration, it's a good saw.

Table Saw Anatomy

The exterior parts of a table saw are illustrated in **Figure 5-37**, and **Figure 5-38** shows the saw's internal parts. The saw table is supported by the base, which may be open or closed. Extension wings are bolted to either side of the table, increasing its surface area and making it easier to work with larger stock.

The fence on the table saw is often referred to as a **rip fence**, which supports the stock when **rip cuts** are made. Rip cuts are cuts made with the grain that

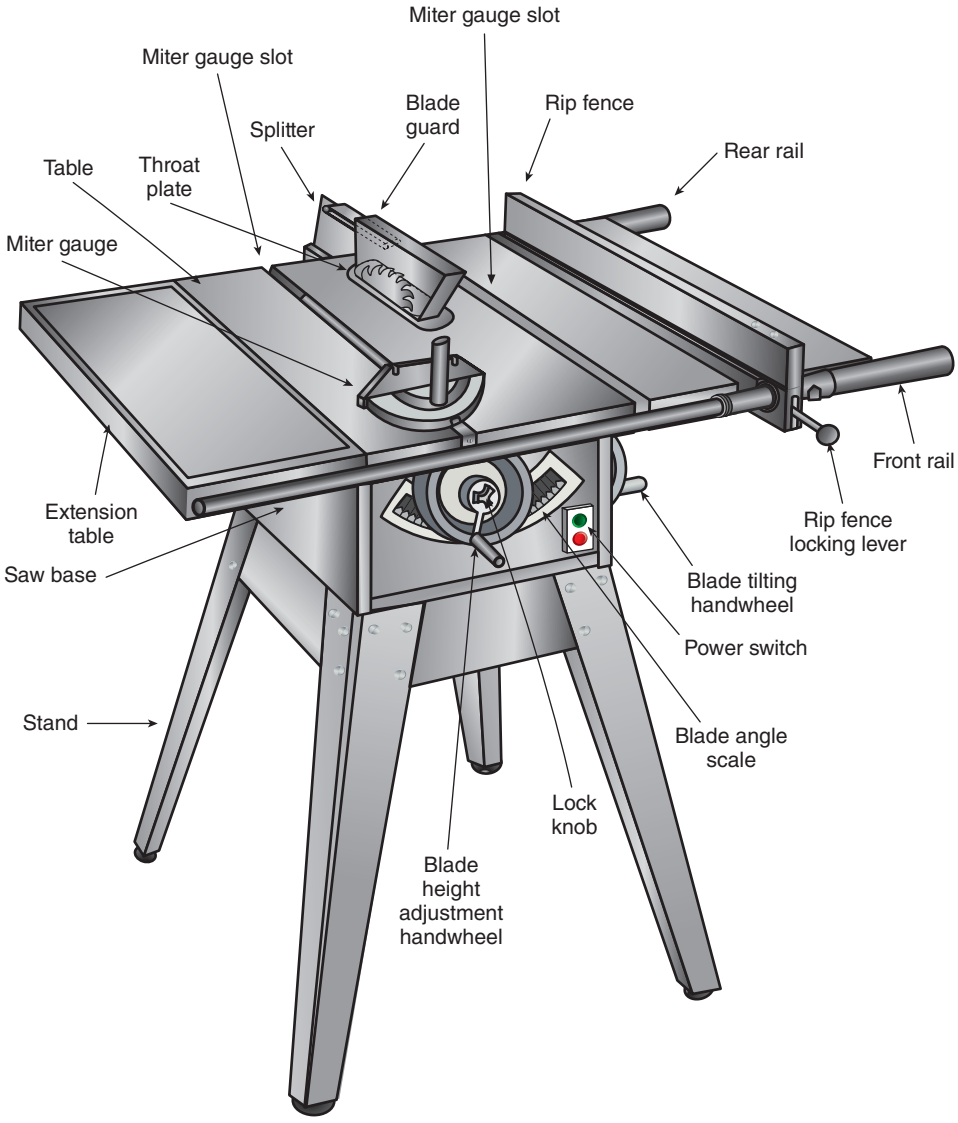


FIGURE 5-37 Diagram of a tablesaw (external).

change the width of a board. The rip fence rides on rails attached to the front and back of the saw.

The **miter-gauge slots** are two 3/8-inch-deep by 3/4-inch-wide grooves milled in the table on either side of and parallel to the blade. They are designed to position and guide a miter gauge, crosscutting sleds, and other jigs. The **miter gauge** consists of a flat piece of metal that rides in the miter gauge slot and an adjustable protractor head that supports the board being crosscut (see **Figure 5-39**). It is usually set at 90° to the blade and is used for making square crosscuts. It can be adjusted to precise angles for making miter cuts. The miter gauge should fit snugly in its slots and slide easily.

WOODWORKING TIP:

The miter gauge should fit snugly yet slide easily in the miter gauge slot. If there is excessive side-to-side play, accuracy is compromised. To fix this, use a center punch to dimple either edge of the bar about every inch along its length. This raises bumps that will result in a tight fit in the slot. If it is too tight, file down the bumps as needed to get a good fit.

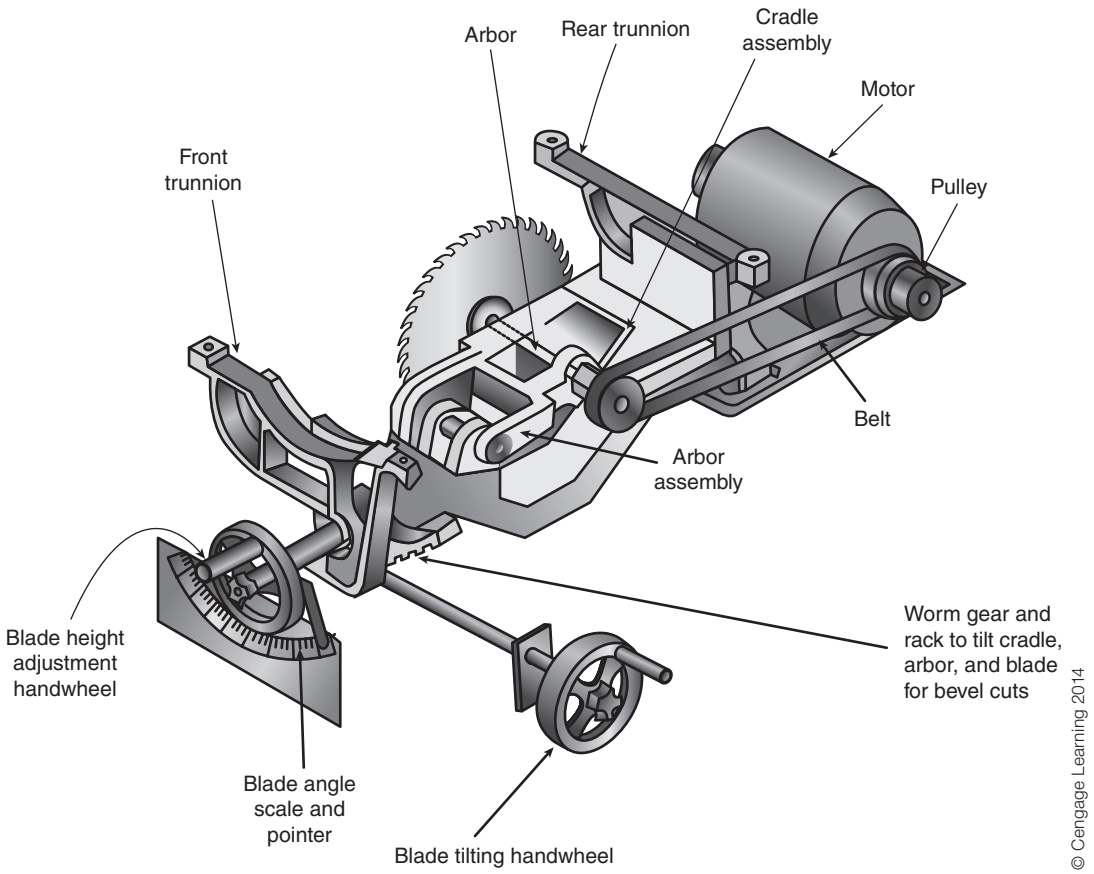


FIGURE 5-38 Diagram of a tablesaw (internal).

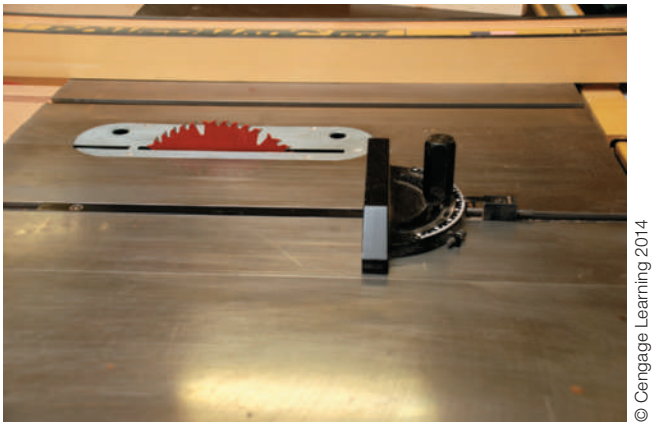


FIGURE 5-39 Miter gauge.

The blade protrudes through the **throat plate**. Also called an *insert,* the throat plate is made of soft metal, wood, or plastic; it has a slot in it for the blade and is removable for blade changes. At the back of the throat plate is an opening for the **splitter** or **riving knife**, which is narrower than the thickness of the saw blade and sits behind the blade and in line with it. The splitter prevents the board being ripped from pinching back together after the cut. The splitter is often part of a unit consisting of the splitter, the blade guard, and a pair of barbed anti-kickback pawls. The splitter tilts with the blade (see **Figure 5-40**). This is the traditional guard system on American table saws and is



FIGURE 5-40 Combination splitter/guard system.

usually bolted to a bracket inside the saw which sits under the throat plate and behind the blade, and to a bracket at the rear of the saw. Another type of guard is table-mounted and does not contain an integral splitter (see **Figure 5-41**). Some, like the one shown, are connected to a dust collection system. This type of guard permits operations such as rabbeting and dadoing, which cannot be performed with a traditional guard in place. A riving knife is standard on European saws, and American saws may be retrofitted with one. The riving knife serves the same function as the splitter, but it rises and falls with the blade as well as tilting with it (see **Figure 5-42**). It is curved to match the curve of the blade and sits just below it, minimizing any gap that might allow kickback. Since it moves vertically with the blade, it does not need to be removed for non-through cuts, unlike the splitter. A riving knife is both more convenient and safer than a splitter.

Also on the outside of the saw are the power switch, the blade height and blade tilting handwheels, and the bevel angle gauge. The height adjustment wheel is on the front of the saw, while the wheel governing blade angle is on the side. Both handwheels have a locking knob to hold the position of the blade once set. Magnetic switches are a good safety device, because after a power interruption they will not automatically come back on when you restore the power, but must be pressed again.

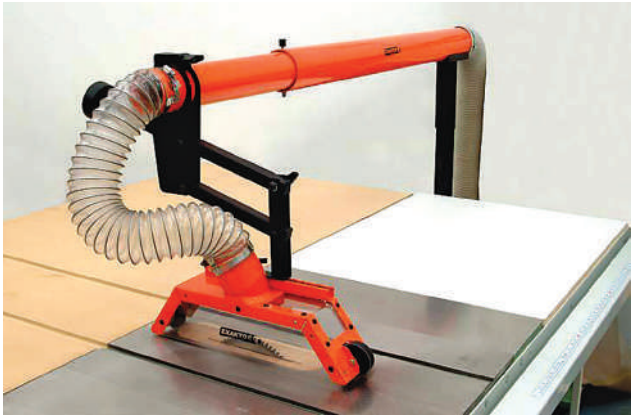


Image courtesy of rockler.com

FIGURE 5-41 Table-mounted guard.

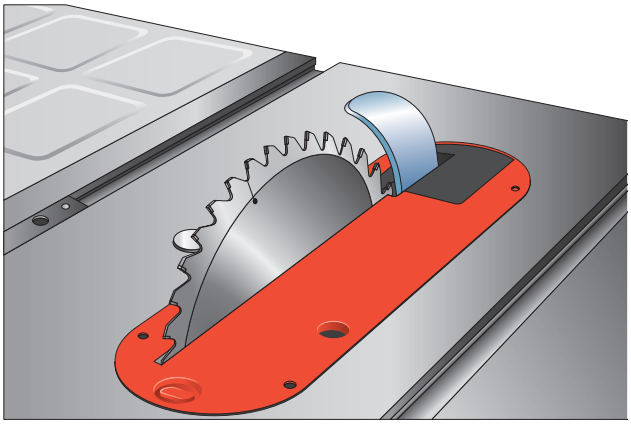


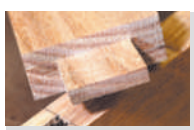
Image courtesy of rockler.com

FIGURE 5-42 Riving knife.

WOODWORKING TIP:

A zero-clearance insert provides better support and decreases chipping. To make a zero-clearance insert, remove the throat plate from the saw and trace its outline onto a piece of stock the same thickness as the throat plate. Cut it out on the band saw and sand it to fit, then drill a hole in it so it can be easily removed from the saw. Lower the saw blade beneath the surface of the table, and put in the new insert. Bring the rip fence over the insert to hold it in place, but make sure it is not over the blade. Turn on the saw and slowly raise the blade through the insert. A slot can be cut in the back of the insert for a splitter.

Within the cabinet of the saw are the trunnions, which are bolted either to the saw's base (cabinet saws) or to the table (contractor saws). The trunnions hang in brackets which permit them to be tilted up to 45°, making bevel cuts possible. A sector gear on the front trunnion meshes with a worm gear on the end of the arbor tilting handwheel. Saws are either left-tilt or right-tilt. Between front and rear trunnions is the cradle, also known as the yoke. The cradle holds the arbor bracket, which consists of the blade arbor and the belts and pulleys that connect it to the motor. The blade is raised and lowered by means of the blade height handwheel, which has a worm gear on the end of it that engages a sector gear on the arbor bracket.



HISTORY FACT

Today's table saws are tilting arbor saws. When we want to cut a bevel, we change the angle of the blade using the arbor tilting handwheel located on the side of the saw. The table remains flat. Tilting arbor saws were developed in the 1930s. Prior to that, the saw tables were tilted to make bevel cuts, while the saw blade remained in a vertical position. ■

Setting Up the Table Saw

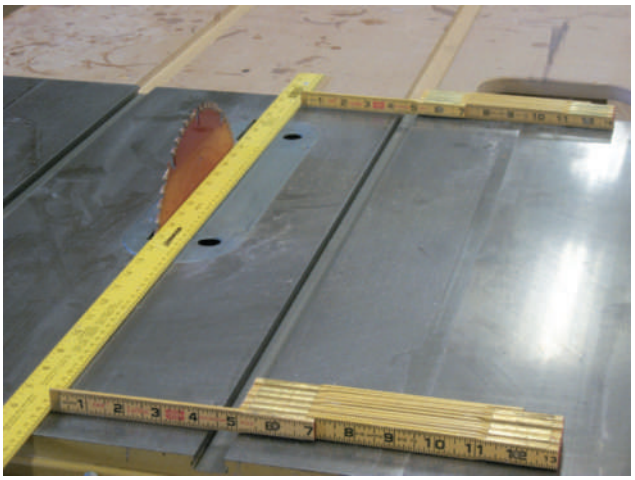
The saw's table saw should be dead flat. Flatness can be checked with a long straightedge by moving the straightedge to different places on the saw table. Check to see if there are any gaps between the straightedge and the table. The extension wings must be flush with the table top. This alignment is also checked with a straightedge. The saw should sit firmly and securely on the floor, with no rocking. If the shop floor is uneven, it may be necessary to shim the base or legs of the saw.

For accurate, safe cuts on the table saw, the miter gauge slots, the blade, and the rip fence must be parallel to one another. First check for parallelism between the blade and miter gauge slots. Unplug the saw and then raise the blade to its full height. Place a straightedge against the blade and measure from the straightedge to the miter gauge slot at the front of the table and again at the rear (see **Figure 5-43**). The measurements should be equal. If they are not, the blade is out of alignment. Follow the specific manufacturer's instructions for adjusting the blade. Typically, this involves loosening three of the four bolts that attach the trunnions to the saw, tapping the assembly into the correct position, and then retightening the bolts. Second, check for parallelism between the blade and the rip fence. Again place a straightedge against the blade at its full height, and measure to the fence at the front and again at the rear of the table. Alternatively, you can simply lock the fence in position and measure from the fence to the miter gauge slot at the front and rear of the saw (see **Figure 5-44**). The measurements should be the same. If they are not, the fence is out of alignment. Consult the owner's manual for instructions on adjusting the fence.

The blade, the fence, and the miter gauge head should be perpendicular to the table. Use a true square to check these relationships. As a further check on the blade angle, raise the blade to its full height and make a crosscut in a thick piece of stock that has been dressed straight and square. Flip one piece over and butt the cut edges together. Any deviation from square will be doubled. Saws include adjustable stops for setting the blade at 90° and also at 45°. Refer to the owner's manual for the location of these stops on your saw and adjust the 90° stop as needed. To check for the accuracy of the 45° stop, tilt the blade over against that stop and make a crosscut. Put the two pieces together to form a corner. If the stop is accurate, you will have a 90° corner. If you don't, adjust the 45° stop.

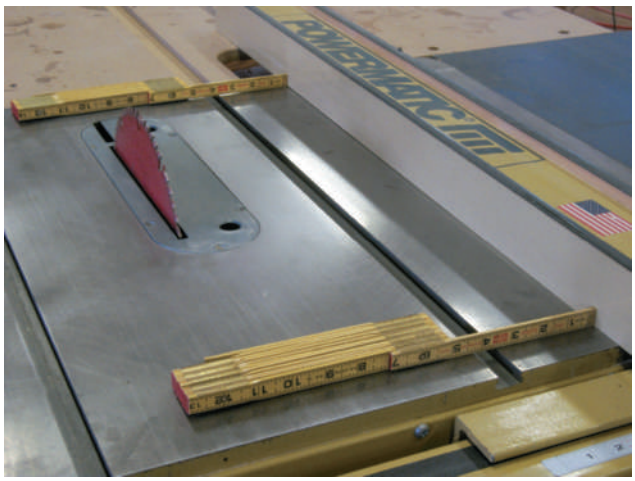
The miter gauge should be square to the blade. Since the blade, fence, and miter gauge slots have already been checked and adjusted for parallelism, you can use a framing square against the miter gauge and either the second miter gauge slot, the blade, or the rip fence to check this alignment (see **Figure 5-45**). Loosen the adjustment handle on the miter gauge and adjust as necessary, and then adjust the 90° stop on the miter gauge. You can use a 45° drafting triangle between the blade and the miter gauge to set the 45° stop.

It is important that the throat plate be level with the table surface. If it sits high, you may need to exert more pressure than you should to move your work forward, and if it is low, stock may catch on the far side, also putting the operator in a potentially dangerous situation. The stock throat plate can be adjusted to be flush with the table using its leveling screws (see **Figure 5-46**).



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FIGURE 5-43 Checking for parallelism between blade and miter gauge slot.



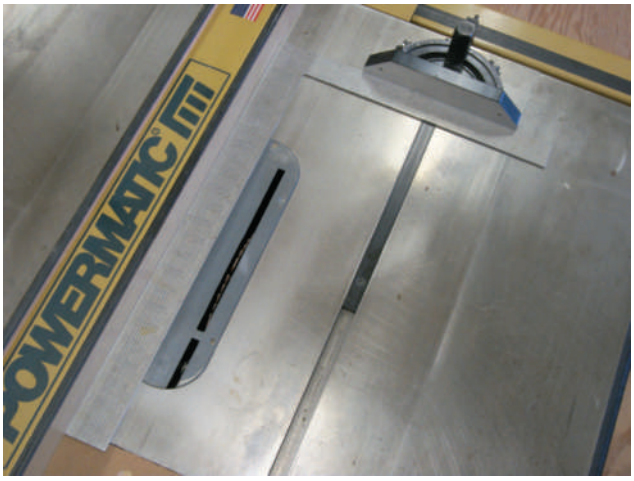
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FIGURE 5-44 Checking for parallelism between the miter gauge slot and the fence.

The splitter must be at 90° to the table and in line with the blade. Use a square to check that it is perpendicular to the table, and check that it is in line by placing straightedges on either side of the blade. The splitter should fall between them without touching either (see **Figure 5-47**).

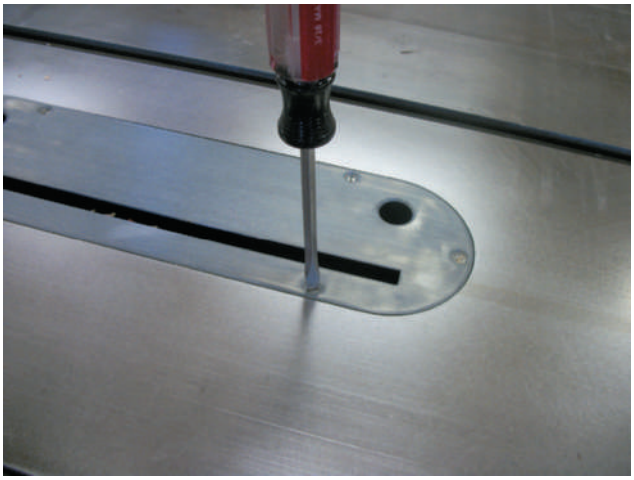
Table Saw Operations

Numerous operations may be performed on the table saw, but its two primary uses are for ripping and crosscutting. **Ripping** is cutting a board in the direction of the grain. It is a cut that affects the width of the workpiece. This operation uses the fence as its guide (see **Figure 5-48**). **Crosscutting** is the other operation commonly performed on the table saw. In this operation the cut is made across the grain and changes the length of the piece. For crosscutting, the board is supported by the miter gauge, as shown in **Figure 5-49**. Other operations performed on the table saw include beveling, mitering, and various types of joinery.



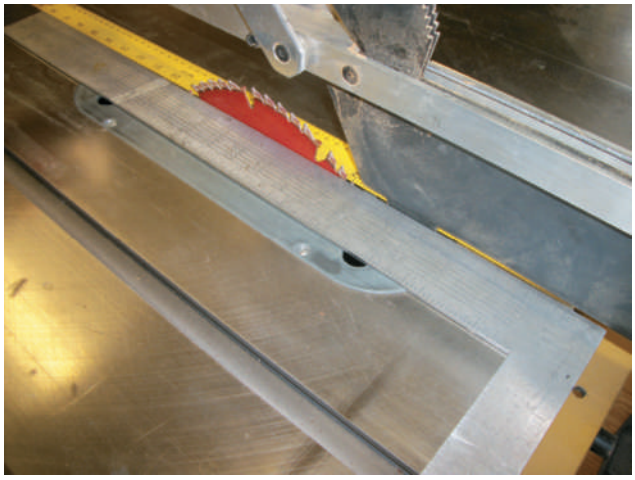
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FIGURE 5-45 Checking for squarness of the miter gauge.



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FIGURE 5-46 The throat plate is adjusted flush to the table.



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FIGURE 5-47 Checking the alignment of the splitter with the blade.



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FIGURE 5-48 Ripping on the tablesaw.



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FIGURE 5-49 Crosscutting on the tablesaw using the miter gauge.

Ripping

1. Install a rip or combination blade in the saw.
2. Make sure that the stock you plan to rip has been surfaced so that it has one flat face and an edge square to that face.
3. Adjust the fence so the distance between the fence and the side of the blade toward the fence is equal to the desired width of cut.
4. Raise the blade by loosening the lock knob and turning the blade raising handwheel so that the blade will clear the stock plus approximately 1/4″. Tighten the lock knob.
5. Place the flat face of the board down on the table and the squared edge against the rip fence.
6. Make sure you have a push stick within easy reach.
7. Turn on the saw and, holding the board down on the table and against the fence with your left hand, feed it forward at a steady rate with your right hand. Once the end of the board has moved past your left hand, remove that hand from the saw table. You should be standing to the left of the blade with your left hip against the front rail. When the trailing end of the board reaches the table, use a push stick if your hand would come any closer than 4″ to the blade.
8. Continue to feed the board through and a couple inches beyond the blade. If your stock is long, set up an outfeed table, outfeed rollers, or have someone catch for you. Do not reach over the blade.

Ripping Narrow Stock

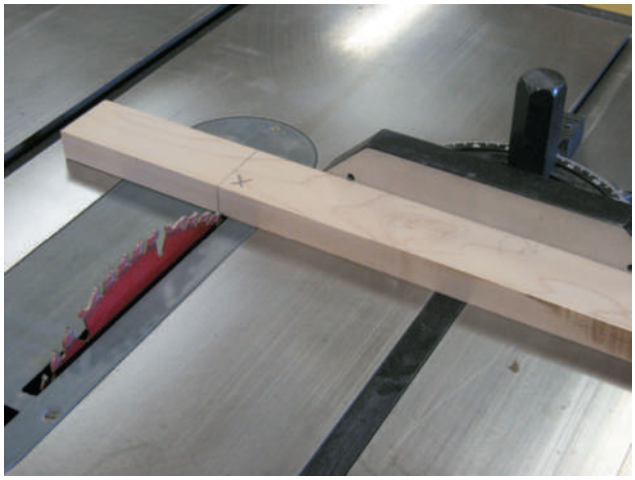
Ripping thin stock may require removal of the guard. A splitter or riving knife should still be used. There is a danger of narrow stock getting caught in the stock throat plate, so it should be replaced with a zero-clearance insert plate. Your push stick should be a little narrower than the finished pieces. It is good practice to joint the edge of the stock that will ridge against the fence between rips, so that you are assured a straight, clean, and smooth edge.

Crosscutting

1. Install a crosscut or combination blade in the saw.
2. Make sure your board is properly prepared with a flat face and a square edge.
3. Set the height of the blade so that it is approximately 1/4″ higher than the thickness of your stock.
4. Place the board to be cut with its flat side down on the table and the square edge against the miter gauge.
5. Holding the board against the miter gauge, *with saw turned off*, slide the miter gauge up to the blade and align your cut mark so that the saw will cut on the waste side of the line (see **Figure 5-50**).
6. Pull the miter gauge and board back well clear of the blade and turn the saw on.
7. Holding the board against the miter gauge head with your left hand, advance the miter gauge at a steady rate with your right.
8. Move the miter gauge forward until the board has completely passed the blade. At this point, still holding the board firmly against the miter gauge, slide the miter gauge back toward you. If the board is not too heavy to do so easily, you may shift the piece slightly away from the blade before bringing the miter gauge back to you to prevent possible splintering.

Crosscutting Long or Large Parts

The miter gauge works well for relatively small parts, but it's not big enough to handle long boards or panels. This is where a table saw with a sliding table is advantageous. If your saw is not equipped with a sliding table, a solution that works well with longer boards is to screw an auxiliary wooden fence to the miter gauge



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FIGURE 5-50 Aligning stock with the blade prior to crosscutting.

PROCEDURE 5-2

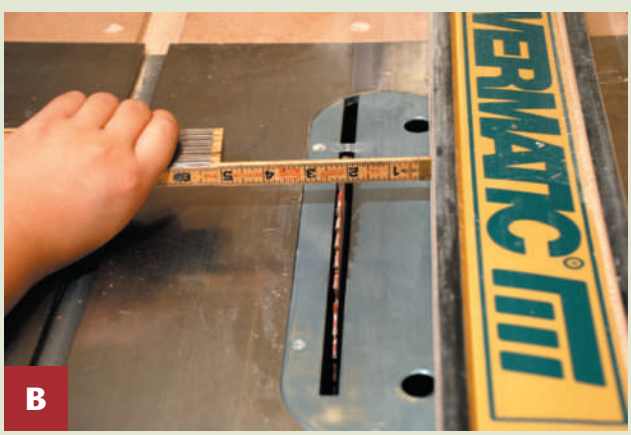
Ripping on the Table Saw

STEPS

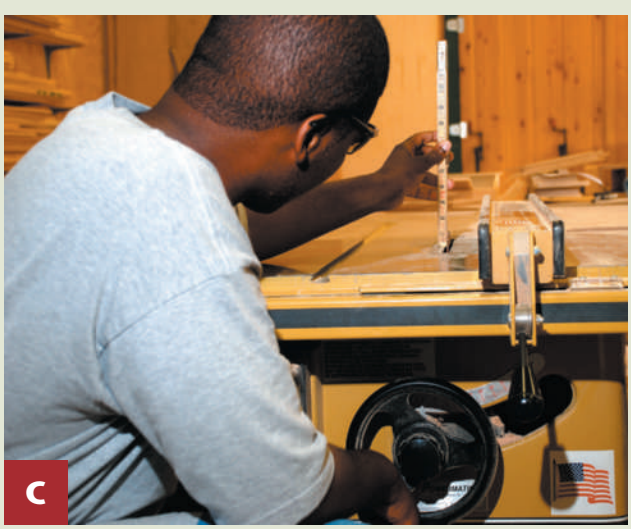
1. Unlock and slide the rip fence for the desired width of cut, as shown in **Figure A**.
2. Lock the fence and check the distance from the fence to the blade to ensure that the distance is correct, as shown in **Figure B**. Adjust if necessary.
3. Unlock the locking hub on the blade height adjustment handwheel, and set the blade height so that one full tooth and part of an adjacent gullet will protrude above the wood, as shown in **Figure C**.


A

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B

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C

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4. Turn on the saw, and butt the edge of the board to be ripped against the fence, as shown in **Figure D**.
5. Standing so that you are not directly in line with the blade, push the board through the blade; keep it down on the table and against the fence, as shown in **Figure E**.
6. Finish the cut using a push stick if the piece is narrower than 6", as shown in **Figure F**. Push it all the way past the blade.

PROCEDURE 5-3

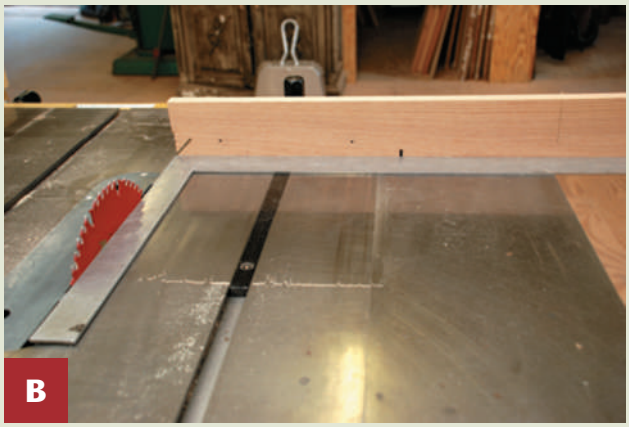
Crosscutting Several Boards to the Same Length

STEPS

1. Attach the face of a straight board to the miter gauge with screws to serve as an auxiliary fence, as shown in **Figure A**.
2. Use a framing square to check that the miter gauge is at 90° to the saw blade, as shown in **Figure B**.
3. On one board, measure and mark the length of the pieces to be cut. Slide the miter gauge up to the blade, and adjust the board so that it will be cut on the waste side of the line, as shown in **Figure C**.



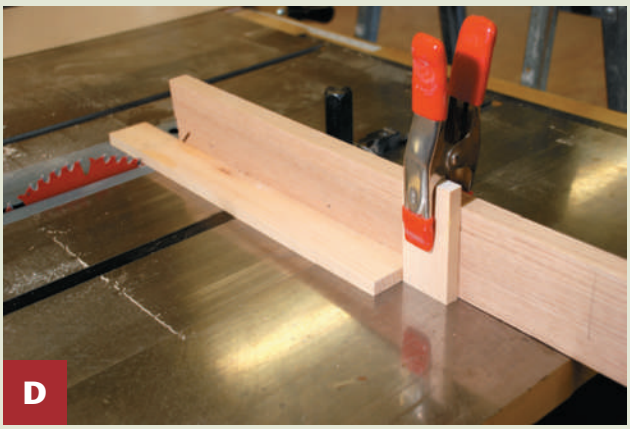
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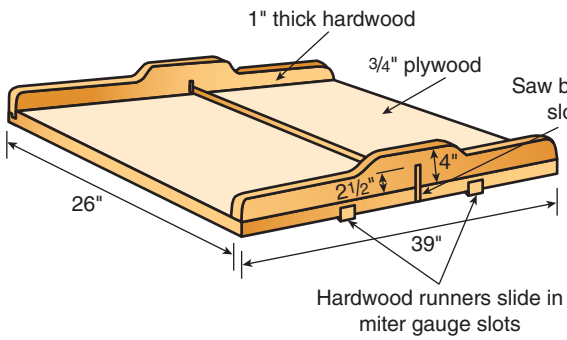
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4. Clamp a stop block on the auxiliary fence to limit the length of the cut, as shown in **Figure D**.
5. Butt the piece to be cut against the stop block. Turn on the saw and, holding the piece against the miter gauge, slide the miter gauge forward and past the blade, as shown in **Figure E**.
6. Check that the cut was made in the proper place, and adjust the stop block if necessary.
7. Make successive cuts of the same length by butting each piece against the stop and pushing it past the blade.

fence, which has holes in it for this purpose. Make sure the board you use is flat and straight. Another solution is to build a crosscutting sled, which rides in the two miter gauge slots and carries the work past the blade. **Figure 5-51** shows one plan for building a crosscutting sled. Using a sled makes crosscutting long, wide, or heavy pieces easier and more accurate.

Repeat Crosscuts

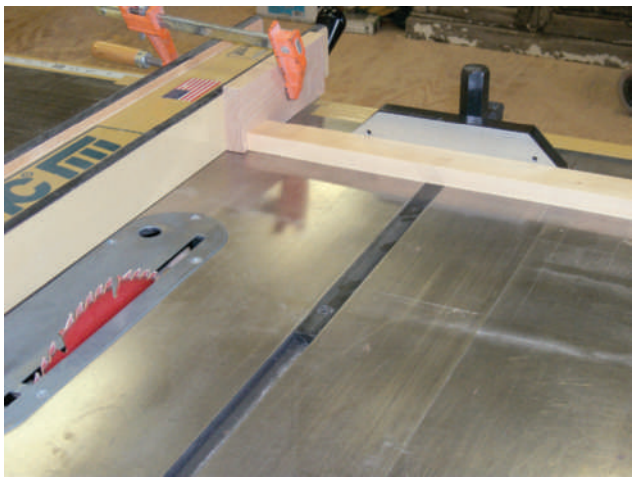
Often a woodworker may need multiple pieces of the same length. Rather than measuring each one individually, we can measure one and then cut them all to the same length. There are two methods for doing this on the table saw. One is to use a stop block attached to the rip fence as a guide. The stop block must be positioned far enough back on the fence that the workpiece will completely clear the stop before it encounters the blade. This is extremely important. The



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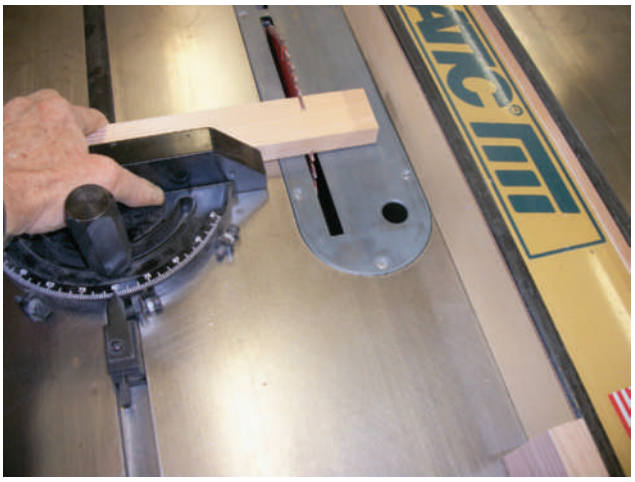
FIGURE 5-51 Tablesaw crosscutting sled.

fence is set so that the cut will be made at the mark. Subsequent pieces are held against the miter gauge, butted to the stop, and run (see **Figure 5-52** and **Figure 5-53**). The second method for cutting multiple pieces to the same length is to attach a stop block to an auxiliary fence screwed to the miter gauge or to



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FIGURE 5-52 Butting material against stop block attached to the fence.



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FIGURE 5-53 Making the cut.

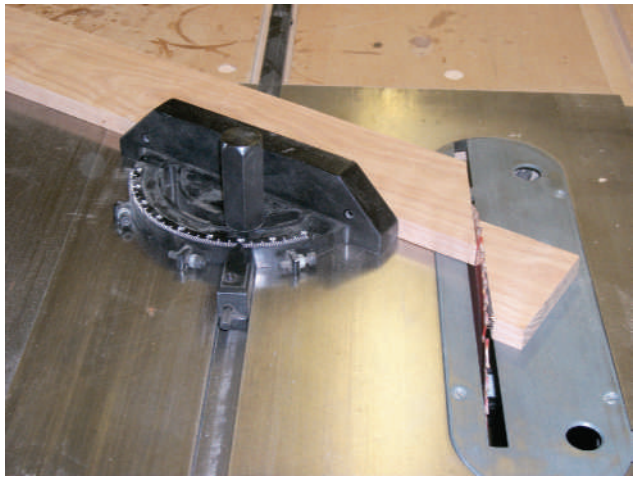
the fence of a crosscut sled. As with the first method, the desired length is marked out on the first piece and the stop is positioned so the cut will yield the desired result. The rest of the pieces simply need to be butted against the stop block and run. Note that one end on all pieces must be squared prior to cutting them to length. Procedure 5-3 details this method.

CAUTION

Make sure that there is enough space around equipment to enable you to safely machine the material you are working on without bumping into other workers or equipment. This is particularly something to be careful of when ripping long stock on the table saw.

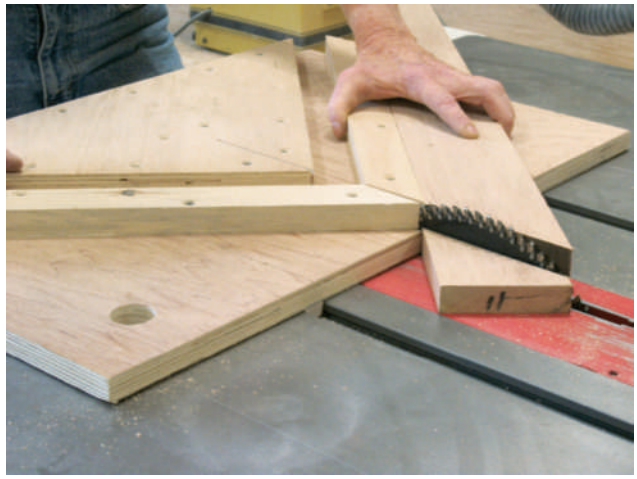
Mitering, Beveling, and Compound Angle Cuts

Miters are cuts made across the face of a board using the miter gauge. They are cuts through the width of the board at an angle to an edge (see **Figure 5-54**). Often, but not always, two 45° angles are cut to form a square 90° corner. The protractor head on the miter gauge is adjusted to the desired angle, the material to be cut is held firmly against the miter gauge, and the material is pushed past the blade in the same manner as with a square crosscut. A crosscutting blade or a combination blade should be used. Longer pieces are better supported with a fence attached to the miter gauge. A dedicated mitering sled similar to the crosscutting sled may be built, such as the one shown in **Figure 5-55**.



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FIGURE 5-54 Miter cut.



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FIGURE 5-55 Mitering sled.

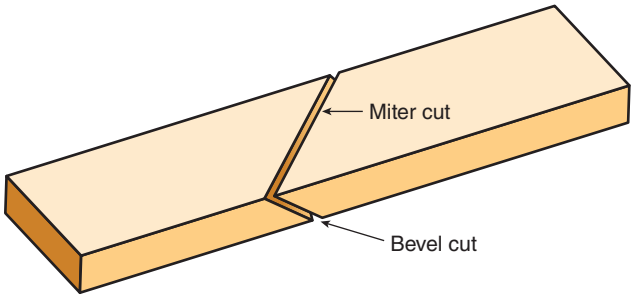
Bevel cuts are made with the blade tilted at an angle other than 90° to the table. They are cuts through the thickness of the board at an angle to the face. A bevel cut may be a rip cut or a crosscut (see **Figure 5-56A** and **Figure 5-56B**). Beveled rips are guided by the rip fence and beveled crosscuts by the miter gauge. In either case, the blade should tilt away from the fence or miter gauge, so that the waste is on the table under the blade. If the blade tilts into the fence or miter gauge, the waste pieces falls on the moving blade and may be kicked back. Table saws are either left-tilt or right-tilt. If you have a right-tilt saw, you will need to move the rip fence to the left side of the blade for bevel ripping.

Compound miters cuts are both miters and bevels at the same time (see **Figure 5-57**). The work, supported by the miter gauge, is pushed through the tilted saw blade at an angle (see **Figure 5-58**).



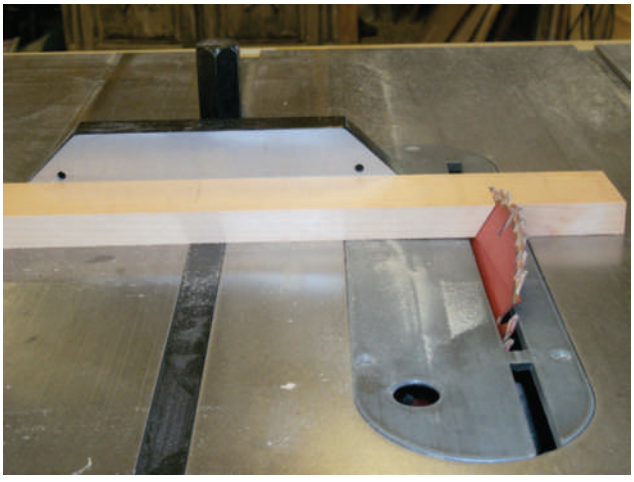
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FIGURE 5-56a Beveled rip cut.



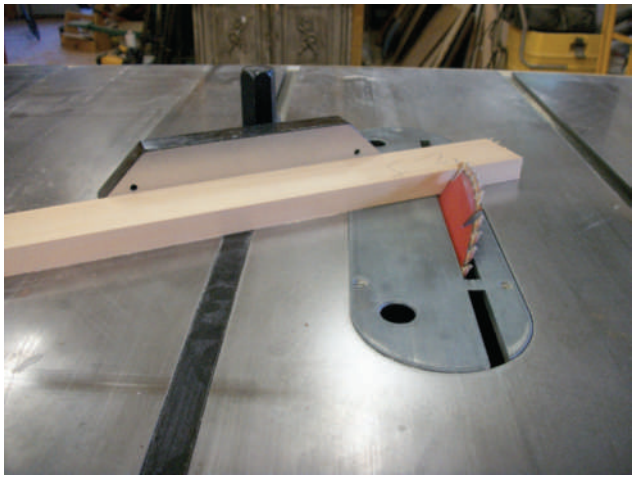
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FIGURE 5-57 Compound miter cut.



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FIGURE 5-56b Beveled crosscut.

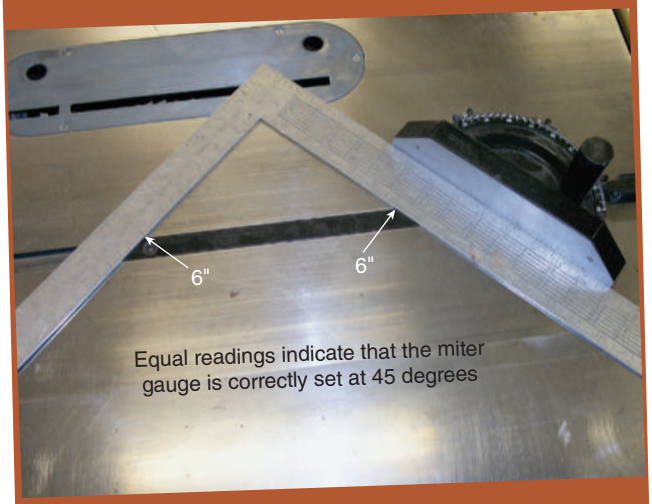


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FIGURE 5-58 Making a compound miter cut.

WOODWORKING TIP:

One quick way to check whether your miter gauge is accurately set to 45° is to use a framing square. Put one side of the square against the miter gauge head and adjust the head until the 60 marks on the inside of the square are both aligned with one side of the miter gauge slot (see **Figure 5-59**).



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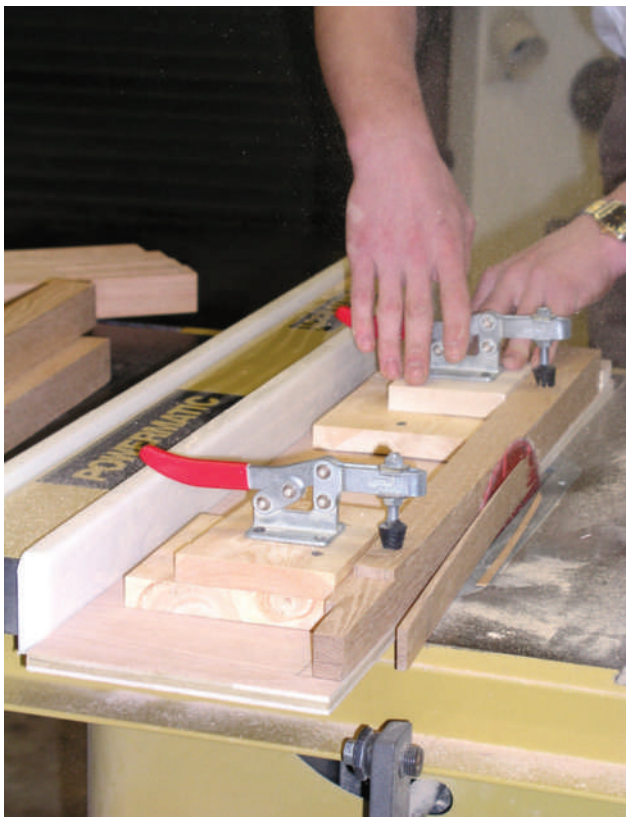
FIGURE 5-59 Checking a mitre gauge for an accurate 45 degree setting.

CAUTION

Move the rip fence out of the way when crosscutting. Never use the fence as a cut-off gauge, because material caught between the blade and the fence can easily twist and be kicked back.

Using Jigs with a Table Saw

The capability of the table saw extends far beyond its ability to rip boards to width and crosscut them to length. With the blade set to a height less than the thickness of the piece being machined, a groove can be cut. This task might be performed to create slots in drawer sides for the drawer bottom, for example. A *tapering jig* can be used to create tapers with a table saw. A **taper** is a gradual reduction in thickness or width from one end of a board to the other (see **Figure 5-60**). A *tenoning jig* can be purchased or constructed to aid in the creation of a **tenon**, which is a tab projecting from a work piece. It can also be used in the creation of half lap joints, which is how it is being used in **Figure 5-61**.



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FIGURE 5-60 Using a tapering jig.



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FIGURE 5-61 Use a tenoning jig to make a half lap joint.

Box joints are attractive and durable joints that can be constructed using a jig on the table saw, as shown in **Figure 5-62**.

Table Saw Safety

More accidents happen with the table saw than any other stationary power tool, either from contact with the blade or from kickback. **Kickback** happens when the blade catches the wood and throws it up and back at the operator. Since the blade is moving at 100 miles per hour or more, you or someone else in the shop can easily be hurt. Kickback can also result in your hand coming into contact with the blade. If the board is thrown and your hand keeps moving, it can move right into the blade. An operator should never stand directly behind the blade, but to one side. If kickback occurs, you will not be right in the line of fire. Causes of kickback are very often the result of a poorly tuned saw, improperly prepared stock, or lack of a splitter. Make sure your critical alignments are in order, that your stock is flat and square, and that your safety equipment is in place. Safety rules general to all tools apply to the table saw, such as wearing personal safety gear, unplugging the machine to make adjustments, making sure the area around the tool is free of clutter, and being attentive. Other safety rules apply more specifically to the table saw:

- Use the blade guard and splitter whenever possible.
- Your hands should never come closer than 4″ to the blade. Make sure you have a push stick at hand before beginning a cut.
- NEVER make a freehand cut, that is, a cut that is not supported in some manner, either by the rip fence, the miter gauge, or some type of jig.
- Make sure the fence is locked after adjusting for width of cut.
- Never back out of a cut.
- Do not use the miter gauge and fence together while crosscutting without a stop block.
- Push your stock completely past the blade.
- Do not reach over the blade while it is spinning.
- Do not remove scraps of wood from the table with your fingers while the blade is moving.
- Use the proper blade for the job and make sure it is sharp and clean.
- Do not work with stock that is too large to handle. Get help or break it down with a circular saw before bringing it to the table saw.
- Make sure your work is adequately supported. Use outfeed tables, a roller, or a helper. The helper should only catch the stock, not pull on it.
- Minimize the blade height so that not more than 1/4″ of blade is above your stock.
- Keep the table top clear, smooth, and waxed so that stock slides easily.



SCIENCE CONNECTION

SawStop saws work because the blade holds a slight electrical charge which is constantly monitored. Touching the blade changes the charge and activates the braking system. ■

CAUTION

After the width of cut has been set, double check to make sure the fence is locked in position. An unlocked rip fence will move while the operator is working and result in an unsupported cut.



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FIGURE 5-62 Box joint jig in use.

Troubleshooting Hints for the Table Saw

Burning — fence misaligned, dirty or dull blade, improper feed rate

Kerf closes after cut — internal stress in the wood; be sure to use splitter

Work moves away from fence — fence misaligned, poor handling of work, edge next to fence is not properly prepared

Kickback — misalignment of fence, poor work handling

Crosscuts aren't square — check alignment of miter gauge

Cut is slightly beveled — blade is not square to table

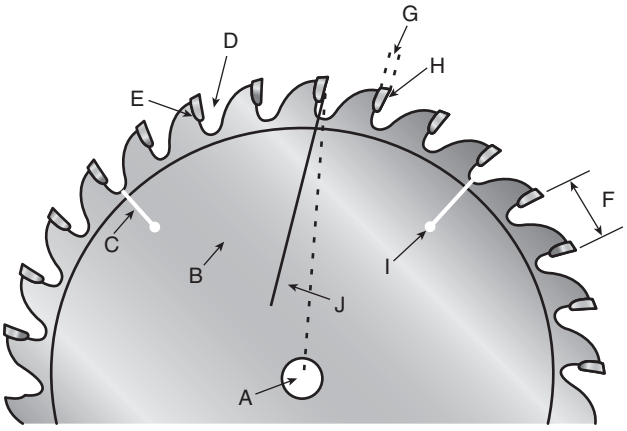
Stalling — feeding work too quickly, dull blade

Saw Blades

Various blades are available for use on the table saw. The best, longest lasting blades are carbide-tipped blades. The anatomy of a carbide-tooth saw blade is illustrated in **Figure 5-63**.

There are different kinds of blades available for use on the table saw. The three most common are the *rip blade,* the *crosscut blade,* and the *combination blade* (see **Figures 5-64**, **5-65**, and **5-66**). A rip blade is designed for ripping, while a crosscut blade excels at cutting across the grain. Combination blades can be used for both ripping and crosscutting.

Rip blades have fewer teeth and a greater hook angle than do crosscut blades, which allows them to cut more efficiently and aggressively. The **hook angle** is the angle of the tooth in relation to the centerline



A: Arbor hole
B: Steel plate
C: Expansion slot
D: Gullet
E: Seat
F: Pitch
G: Tooth thickness
H: Tooth face
I: Expansion hole
J: Hook angle

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FIGURE 5-63 Anatomy of a carbide-tooth saw blade.

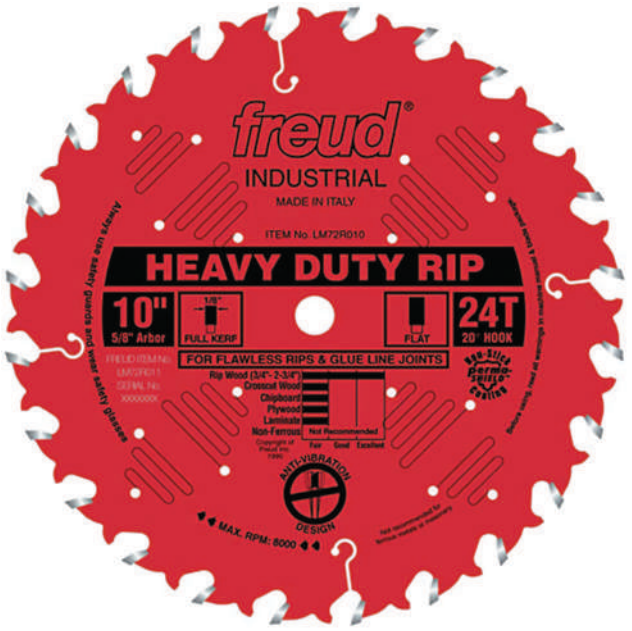


Image courtesy of rockler.com

FIGURE 5-64 Rip blade.

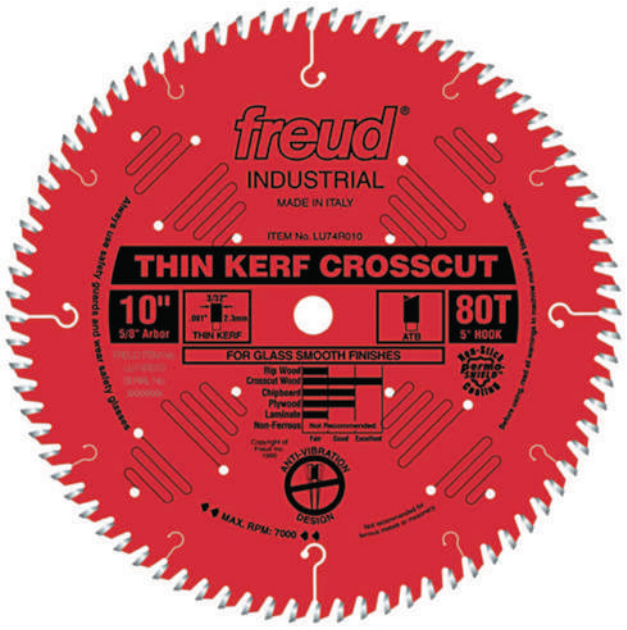


Image courtesy of rockler.com

FIGURE 5-65 Crosscut blade.

of the blade. A rip blade typically has a 20° hook angle, and a 10-inch blade has 24 teeth. The teeth of a rip blade have a flat top grind (FTG). This means that the teeth are ground square across the top (see **Figure 5-67**). The gullets on rip blades are deeper than the gullets on other blades, allowing large amounts of chips and dust to be carried out of the cut.

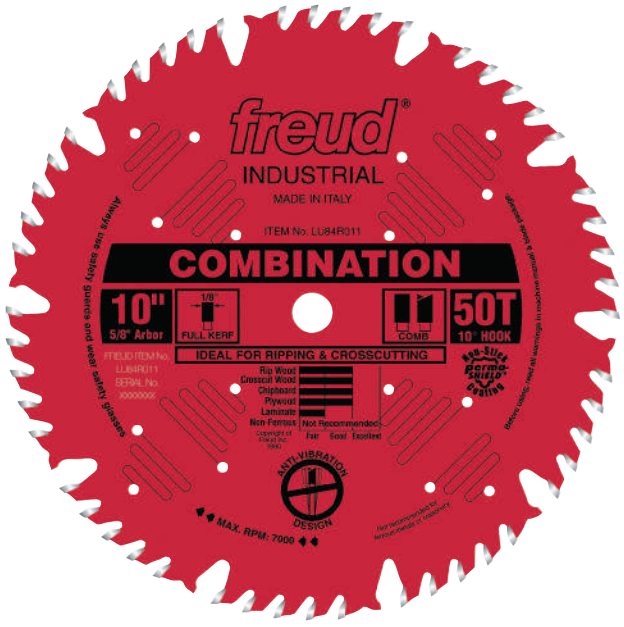
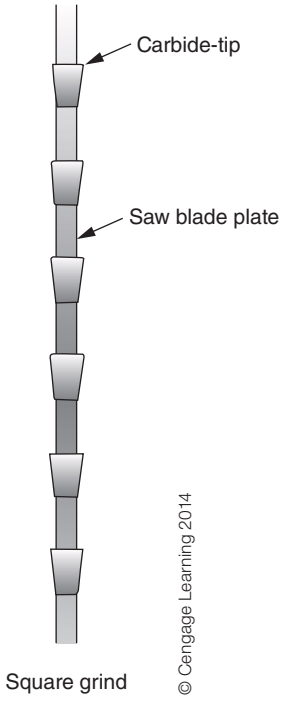


Image courtesy of rockler.com

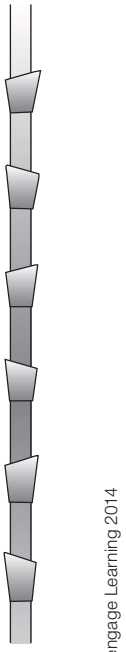
FIGURE 5-66 Combination blade.



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FIGURE 5-67 FTG (flat top grind) teeth make fast, efficient cuts along the grain.

A 10-inch crosscut blade typically has 60 or 80 teeth and a hook angle of 10°. It cuts more slowly than a rip blade, but leaves a much smoother cut when cutting across the grain. The teeth of a crosscut blade have an alternate top bevel grind (ATB), shown in **Figure 5-68**, which slices through the wood.



Alternate bevel

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FIGURE 5-68 ATB (alternate top bevel) teeth cleanly shear wood fibers when crosscutting

Alternate top bevel means that the saw blade teeth alternate between a right- and left-hand bevel. A crosscut blade has shallower gullets than a rip blade.

A combination blade is a compromise between the rip and crosscut blades, and although not the best choice for either crosscutting or ripping, it is ideal in a saw used for both operations because it performs both tasks reasonably well. Combination blades are available in two different configurations. One type has a 10° hook angle and teeth set in groupings of five, for a total of 50 teeth. In each group of five, alternately beveled teeth are followed by a tooth with a flat top grind, called a raker tooth. The abbreviation for this grind is ATB/R (see **Figure 5-69**). Another type of combination blade is a 40-tooth general purpose blade which has evenly spaced, alternately beveled teeth. It is similar to a crosscutting blade, but has fewer teeth and a greater hook angle, typically 13° (see **Figure 5-70**).

Rip, crosscut, and combination blades are available in a standard thickness of 1/8″, and a thin-kerf version of 3/32″. Thin-kerf blades require less energy and are an especially good choice on lower-powered saws, which have a tendency to bog down under heavy loads. Other blades are manufactured that address other types of cutting on the table saw. One blade features an alternate top bevel with a high angle (Hi-ATB)

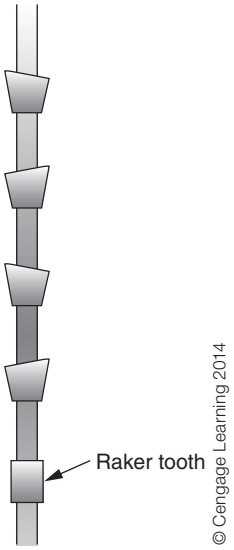


FIGURE 5-69 Combination blade teeth consist of groups of four ATB teeth followed by a raker tooth which has a flat top grind.

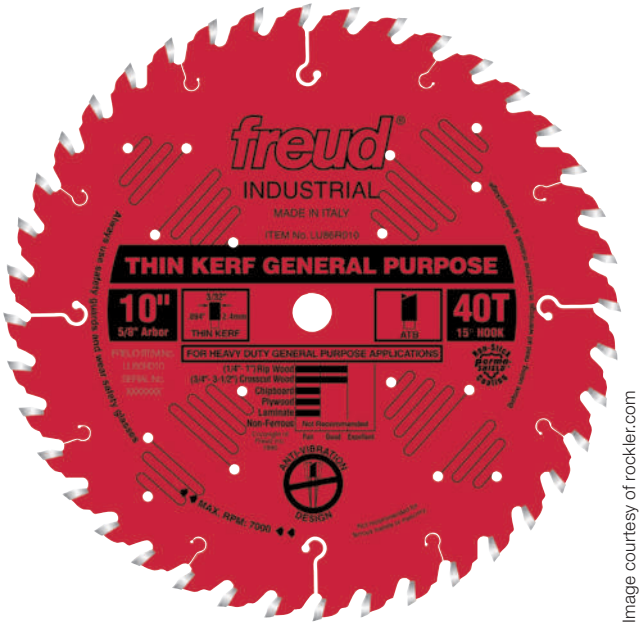


FIGURE 5-70 General purpose blade.

and low hook angle. The bevel angle is steep, 30° to 40°. The high bevel angle cuts very cleanly through melamine and hardwood plywood without tearing their very thin face veneers. Another different tooth design is the triple chip grind (TCG) (see **Figure 5-71**). This tooth, with its corners beveled at 45°, alternates with FTG teeth, and stands a bit higher than they do.

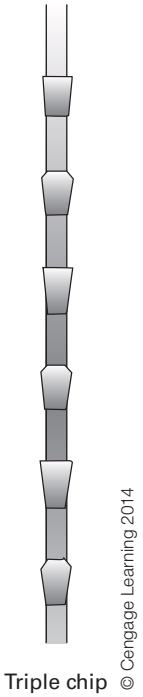


FIGURE 5-71 Triple chip grind tooth design alternates flat top grind teeth with higher teeth with beveled edges

These teeth are very durable and are used on blades designed to cut manufactured materials such as laminates and particleboard, which are highly abrasive. This tooth design is also used on glue-line rip blades. These blades are not designed to rip wood thicker than 1″ and require a slower feed rate than standard FTG rip blades, but they leave cleaner edges that may not require jointing prior to gluing.

A blade often used for doing joinery work on the table saw is the **dado blade**, sometimes referred to as a *dado head*. Dado blades are used to create recesses of various widths. There are two types of dado blades: *stacked dadoes* and *wobble dadoes*. **Stacked dadoes**, or *stack dadoes,* consist of two outer blades and inside blades of different widths, known as **chippers** (see **Figure 5-72**). By varying the number of chippers, different widths can be achieved. Shims are used to fine tune the width of cut. A **wobble dado** blade, sometimes called an *adjustable dado,* is only one blade, set to oscillate back and forth as it spins, thereby creating a recess (see **Figure 5-73**). These blades have generally been considered inferior to stack dado blades. Dado blades require a larger opening in the throat plate. Most saws come with two throat plates: one for a single saw blade and another for dado blades.



Image courtesy of rockler.com

FIGURE 5-72 Stack dado blades.



Image courtesy of Stanley Black & Decker/Oldham.

FIGURE 5-73 Wobble dado blade.

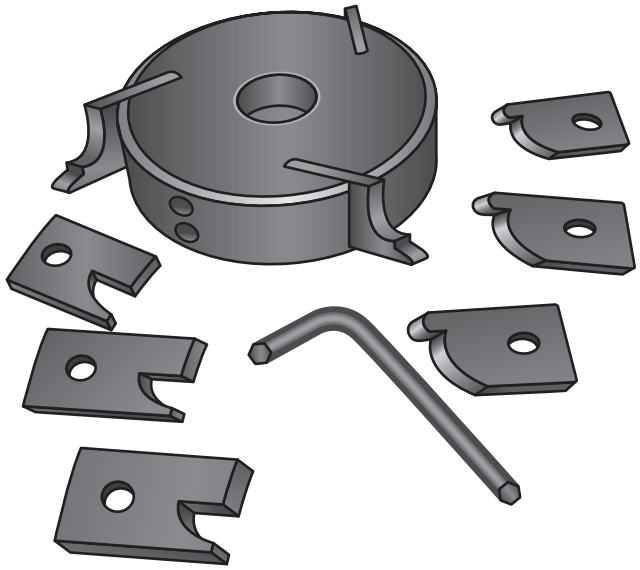
WOODWORKING TIP:

A good practice that increases safety and reduces tear-out is to make up a series of zero-clearance throat plates for various dado blade width combinations to replace the stock throat plate that came with the saw, which is sized so that it can accommodate the widest dado.

Although it is not a blade, another cutting implement that can be used on the table saw is a **molder head**. It is used for doing shaping operations on the table saw. Like a blade, it mounts on the arbor of the saw. It is a cutter head that holds three matching knives. It can be fitted with various knives to create decorative shapes (see **Figure 5-74**). Like the dado blade, it requires a wider opening in the throat plate than a single blade.

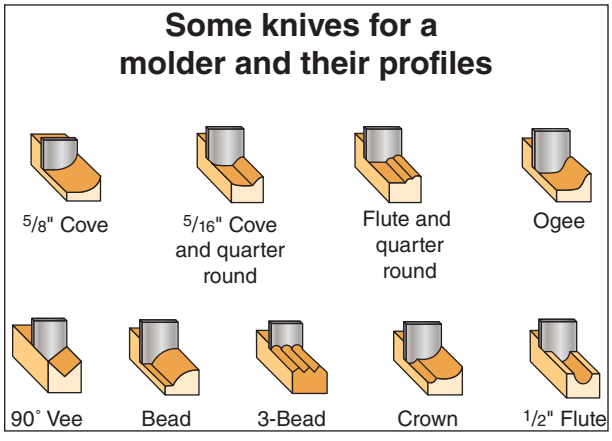
GREEN REMINDERS

Citrus-based solvents work well for cleaning dirty bits, cutters, and blades, and they are environmentally friendly, unlike many solvents.



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FIGURE 5-74a Molder heads can be fitted with various knives to create different profiles.



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FIGURE 5-74b Molder heads can be fitted with various knives to create different profiles.

BAND SAWS

The **band saw** gets its name from its blade, which is a continuous band of toothed metal that rides on two or three wheels, cutting down toward a table (see **Figure 5-75**). Each wheel is rimmed with a rubber or urethane tire that cushions the blade and prevents it from slipping. The band saw is a very versatile tool, as well as one of the safest tools in the shop. The blade cutting downward pushes the material being cut down onto the table, so there is no danger of kickback on this tool, unlike tools in which the blade or cutter is spinning back toward the operator, such as the table saw. See **Figure 5-76** for the external anatomy of a band saw.



Image courtesy of Delta Power Equipment Corporation.

FIGURE 5-75 Band saw.

The band saw excels at cutting lines that are not straight, so its primary use is in cutting curves, but it has other valuable uses as well. It can be used with a fence for ripping or with a miter gauge for crosscutting. It can also **resaw**, which is the operation of cutting a board into thinner pieces. A resaw cut affects the thickness of the board, and because the band saw blade is much thinner than a table saw blade, it creates a smaller kerf, so less material ends up as sawdust. This is an important consideration when resawing; also, you do not have the height limitations that you would have on the table saw, making it possible to resaw much wider pieces. The resaw capacity of a band saw is determined by its **throat depth**, which is the vertical distance from the table to the guide post raised to its highest position. A greater throat depth allows a wider board to be resawed.

Band saws are available in both two-wheel and three-wheel models (see **Figure 5-77**). As with other tools, there are a variety of models available. A band saw may be a *benchtop model, stand-mounted,* or *floor-mounted.* The primary advantage of the three-wheel type is its ability to handle wider pieces, but the two-wheel style is more common. The size of a band saw is typically referred to by its **throat width**,



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FIGURE 5-76 Diagram of a band saw (external).

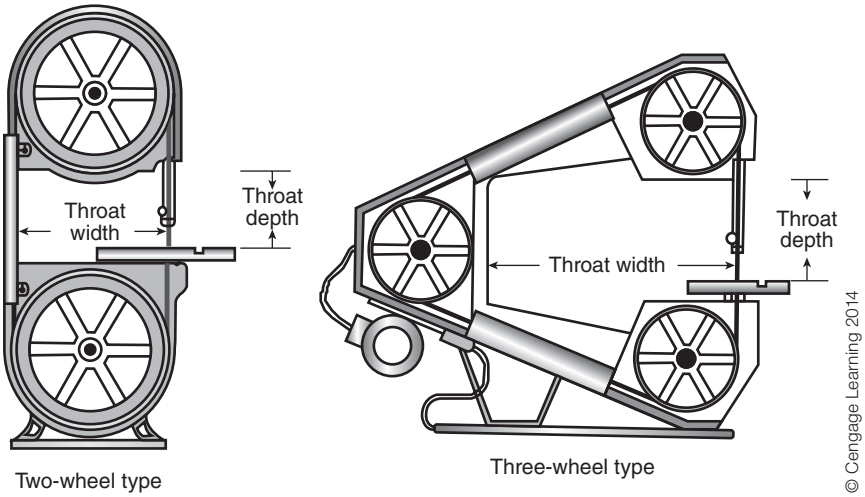


FIGURE 5-77 Two- and three-wheeled band saws.

which is the distance from the blade to the column, or neck; thus, a 14-inch band saw measures 14 inches from the blade to the column.

The table on most band saws tilts, allowing for beveled cuts. The fact that the band saw has a miter gauge slot milled into its table allows for the use of not only a miter gauge but also various jigs, such as the circle-cutting jig shown in **Figures 5-78A** and **5-78B**.

Setting Up the Band Saw

The effectiveness of the band saw depends on how well it is tuned, which in turn depends heavily on the support and tension of the blade, as well as the blade's condition. The blade rides on the wheels and is supported both above and below the table by guide assemblies. The bottom wheel is the drive wheel and the top wheel spins freely. The wheels must be parallel to one another and in the same vertical plane in order for the blade to track correctly. This is checked by tilting the table out of the way, opening both blade covers, and holding a long straightedge against both wheels (see **Figure 5-79**). The straightedge should rest against the top and bottom of both wheels. If it does not, use the tilt knob on the back of the top wheel to adjust the angle of the top wheel until the correct alignment is achieved. In some cases it may be necessary to shim the top wheel with washers. Tension on the blade is achieved by raising and lowering the top wheel via the tension knob or handle. After the blade is tensioned and the tracking is correct, use a square to check that the angle between the blade and the table is 90° (see **Figure 5-80**). If it is not, adjust the table until it is and then reset the pointer on the bevel scale to 0°. The table is adjusted by loosening the table tilt

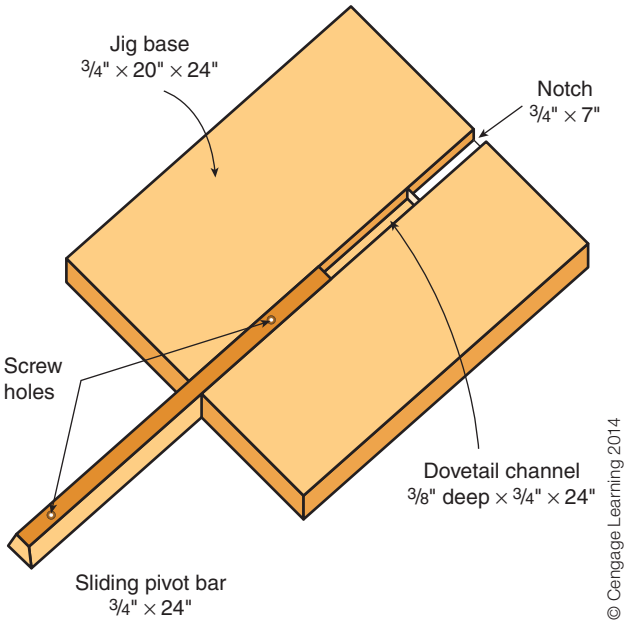


FIGURE 5-78a Circle-cutting jig.

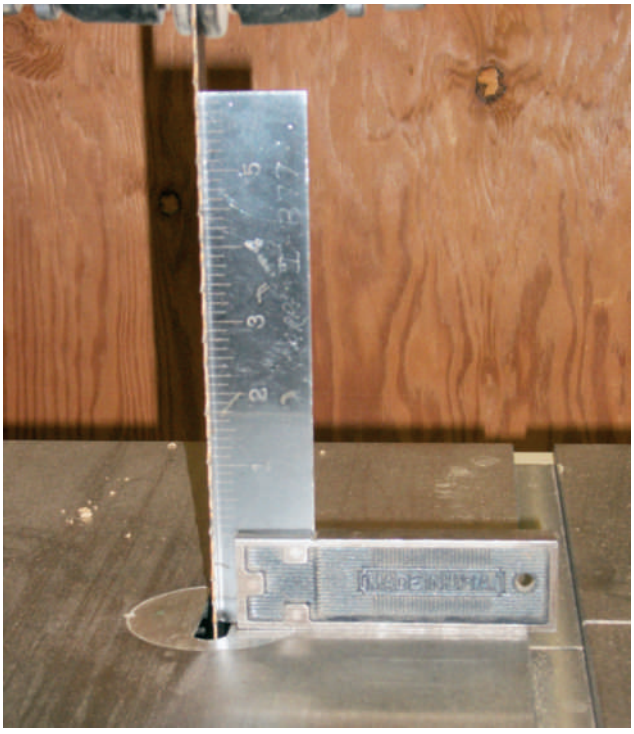


FIGURE 5-78b Circle-cutting jig in use.



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FIGURE 5-79 Check the alignment of the wheels with a straightedge.



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FIGURE 5-80 Use a square to see if the table and blade are square to each other.

knob, moving the table to the desired angle, and then re-tightening the tilt knob.

The guide assemblies are located both above and below the table and are instrumental in preventing blade deflection. The upper guide assembly is on an adjustable post, allowing the assembly to be set just above the work. The guide assemblies consist of a **thrust bearing** and **guide blocks**, or bearings (see **Figure 5-81**). The thrust bearing sits behind the blade and prevents it from walking off the wheels; the guide blocks or bearings prevent the blade from deflecting side to side. The thrust bearing and guide blocks should be set as diagrammed. The guard should be adjusted so that it sits about a quarter inch above the material.

WOODWORKING TIP:

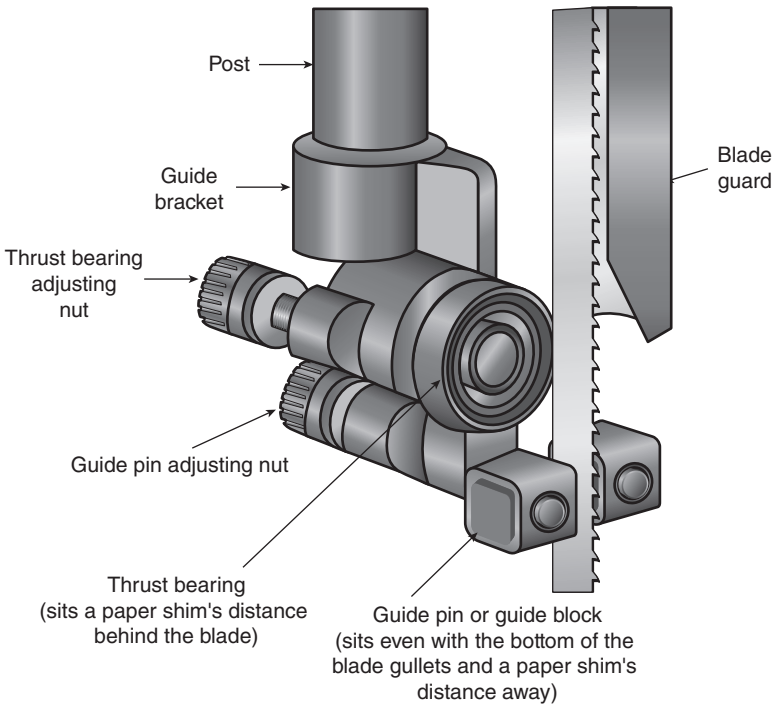
The metal guide blocks that come with band saws are adjusted so that they do not touch the blade, since they will damage the blade if they touch the teeth. Some people choose to replace them with aftermarket blocks made of softer materials that can actually be set right against the blade without danger of damage to the teeth. Another option is to make up hardwood blocks of the correct size. It is important, however, that the faces of the blocks stay flat and square. On blocks made of softer material, this needs to be checked frequently to ensure that the blade is getting the support it needs.

CAUTION

When using the band saw, keep your hands on either side of the blade, not in line with the blade. Use a push stick when removing cut pieces from between the fence and the blade or when your hands are close to the blade.

Band Saw Operations

The band saw excels at cutting curves. The width of the blade governs how tight a turn can be made. In order to avoid having to back out of a cut or finding yourself in a situation where the blade binds, it

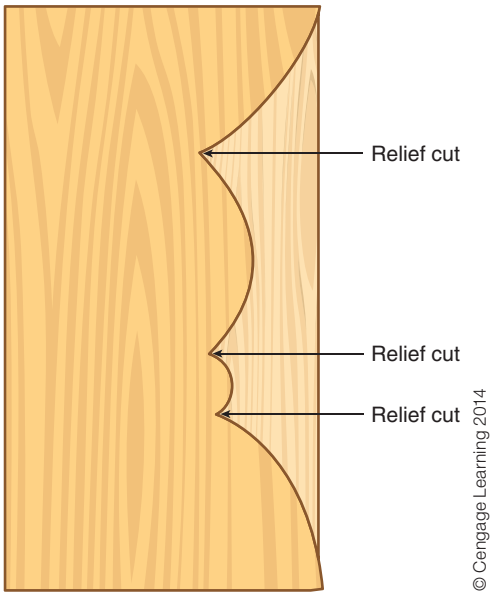


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FIGURE 5-81 Thrust bearings and guide blocks support the band saw blade above and below the table.

is often wise to make relief cuts before making the curved cuts. Relief cuts, also called release cuts, are straight cuts made from the edge of the workpiece to the cutline in places where the curve changes direction (see **Figure 5-82**). They should be made to the tightest point of the curve. Then, when the curved cut is made, the relief cut allows the waste to fall away so the blade can turn more easily. Sometimes you just saw out of a situation where you cannot make the turn you want to. Simply leave the cut line and exit through the waste part of the stock, then reposition the work and continue to saw on your cut line. It is always best to avoid backing out of a cut. A smooth, continuous feed rate yields the best results. Always continue to move the work forward as you pivot it for turns. Be aware of the position of your fingers at all times and keep them out of the path of cut.

The band saw is capable of a great deal more than cutting curves, however. In fact, it is arguably the most versatile cutting tool in the shop. We have been talking about freehand cutting, but we can also make guided cuts on the band saw, using a miter gauge that rides in the miter gauge slot, a fence, or various jigs. The miter gauge is used to make support crosscuts, and can be adjusted to make miter cuts. The fence can be used for supported rip cuts or for resawing. The table tilts, allowing for beveled cuts, which may be curved or straight. Compound angle cuts may be made by tilting the table and adjusting the angle on the miter gauge. Tapers can be cut, either freehand or using jigs. The band saw is also a great tool for joinery, such as dovetail joints. One limitation of the band saw, however, is the size of its table, which is quite



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FIGURE 5-82 Relief cuts are made from the outside of the piece almost to the cut line and allow material to fall away without binding or backing out of the cut.

small. Therefore, if you are working with large stock, you will need to set up rollers or tables, or have someone available to give you a hand supporting material.

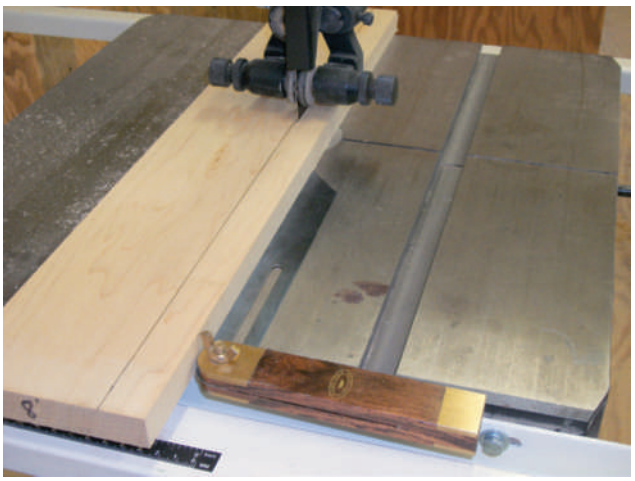
When using the fence, the band saw blade has a tendency to veer to the right or the left. This phenomenon is called band saw blade drift, and in order to get reliable cuts with the fence, it must be compensated for. Take a board with one straight edge that is an inch or so longer than the width of the table. Draw a straight line an inch in from the straight edge. With the fence out of the way, carefully make a freehand cut along the line you just drew, stopping when the leading edge of the board gets to the far side of the table. Hold the board in that position and shut the saw off. Use a sliding T-bevel with its body against the table and its blade against the straight edge of your board to set the angle of drift. Remove your board from the table, put the fence on, and now adjust the fence to the angle set on the sliding T-bevel (see **Figure 5-83A** through **Figure 5-83C**). The adjustment mechanism shown is common but may be different on your saw. Check the owner's manual for directions on how to adjust the fence. Blade drift is only a concern when using the rip fence. Adjust for blade drift each time you put a new blade on the band saw if you intend to use the rip fence.

Resawing can also be done with a pivot block, which allows you to do some adjustments as you feed the stock. A pivot block consists of two pieces of wood joined perpendicularly to one another. The shorter piece is rounded at its end. This assembly is attached to the rip fence and the fence is adjusted for the desired width of cut (see **Figure 5-84**). It is very



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FIGURE 5-83a Cut along the marked line, stopping when the board reaches the end of the table.



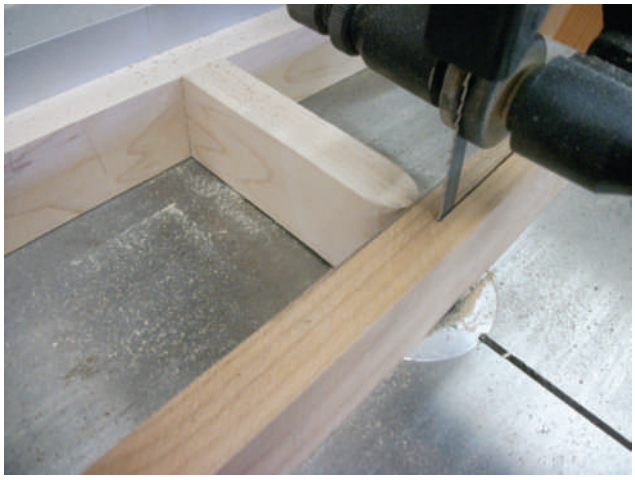
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FIGURE 5-83b Set a sliding T-bevel to the blade drift angle.



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FIGURE 5-83c Adjust the fence to the blade drift angle.



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FIGURE 5-84 Resawing with a pivot block.

important when resawing to use a push stick as you reach the end of the cut.

A pivot block can also be used to make multiple curved pieces. The first curve is cut freehand, and subsequent cuts are made by butting the workpiece against the tip of the pivot block and then feeding it through the blade, keeping it against the pivot block throughout the cut (see **Figure 5-85**).

A variation on the pivot block makes pattern cutting possible on the band saw. It has a notch for the blade, making it a double point rather than a single point fence, and it has a notch underneath to allow the workpiece to slide under it. The template is attached on top of the workpiece, and then the template is guided along the block (see **Figure 5-86**).

Stack sawing is another technique that can be performed on the band saw. It is an effective method for producing multiple copies of the same shape. Two or more layers of material are fastened together and cut at the same time. Not only is this quicker than cutting the pieces individually, it also ensures that the pieces are exactly the same. Pieces may be fastened together using nails through the waste sections, or with two-sided tape or temporary hot-melt adhesive.

Band Saw Blades

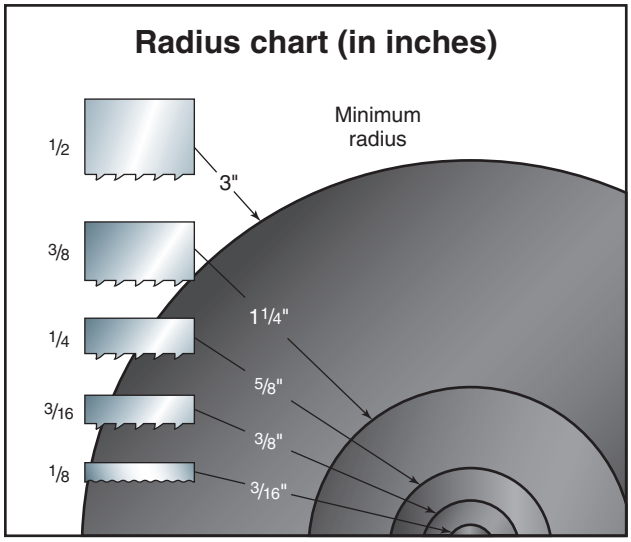
There are different band saw blades that can be used on the saw depending on the work being done. Like circular blades used on table saws, fewer teeth and a greater hook angle are better for faster, rougher cuts, and blades with more teeth will yield a smoother cut but take more time. A consideration with band saw blades is also the width of the blade; narrower blades can cut tighter radiuses and are therefore more appropriate for work requiring tighter curves (see **Figure 5-87**). Wider blades are less likely to deflect under a load and are better suited for straight cuts and resawing. There are different types of band saw blades as well, as seen in **Figure 5-88**.


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FIGURE 5-86 Template cutting on the bandsaw.


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FIGURE 5-85 Making multiple curved pieces using a pivot block.



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FIGURE 5-87 The narrower the band saw blade, the tighter the radius it can cut.

PROCEDURE 5-4

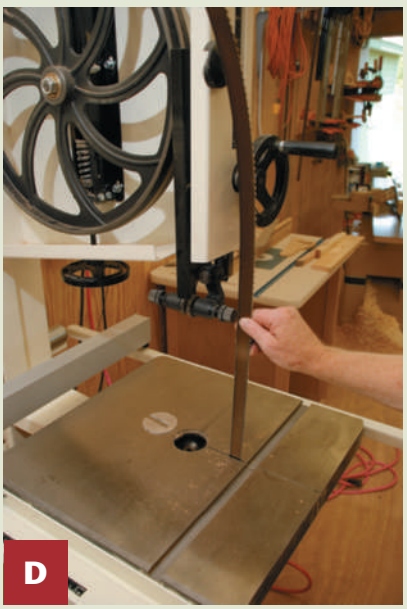
Changing a Band Saw Blade

STEPS

1. Disconnect the power to the saw.
2. Swing aside or remove the upper and lower wheel guards, as shown in **Figure A**.
3. Release the tension on the blade by lowering the top wheel, as shown in **Figure B**.
4. Back off the guide components and the thrust bearings both above and below the table, as shown in **Figure C**.
5. Remove the table insert and table leveling pin and slide the old blade off the wheels and through the slot in the table, as shown in **Figure D**.



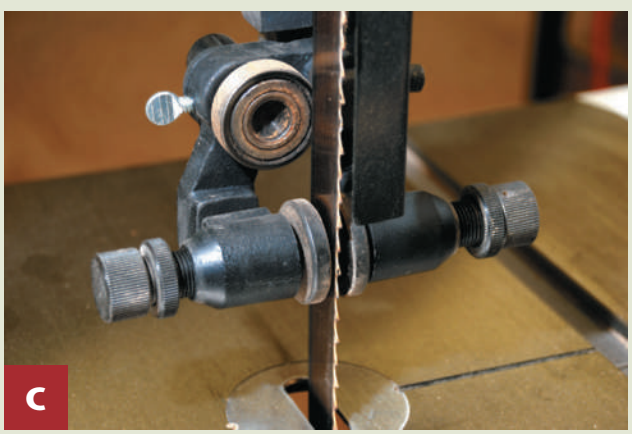
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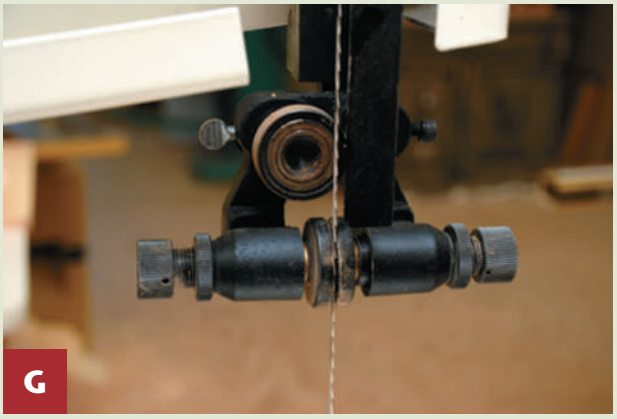


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6. Slide the new blade onto the wheels, making sure the teeth are facing down and toward the front of the saw, as shown in **Figure E**.
7. Different width blades are set to different tensions; reset the tension for the size blade installed using the guide on the back of the saw. Replace the table insert and the table leveling pin (see **Figure F**).
8. Adjust the blade guide components and thrust bearings both above and below the table, as shown in **Figure G**. The guide component should be even with the tooth gullets. Use a slip of paper to set the blade guides and the thrust bearing slightly away from the blade.
9. Spin the blade by hand to make sure it is tracking correctly, as shown in **Figure H**.
10. Replace the wheel guards, reconnect the power, and turn the saw on and then off. Check to see that the blade is tracking correctly.



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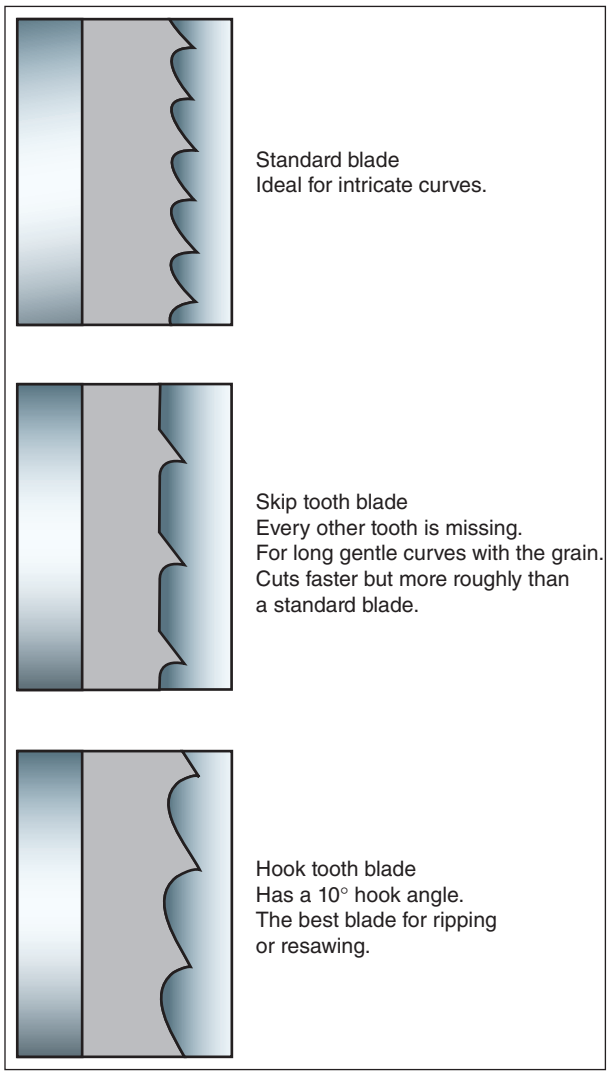


FIGURE 5-88 Types of band saw blades.



FACTS ABOUT WOOD

Black walnut is one of the most highly prized cabinetmaking woods; it machines easily and takes a fine finish. The sapwood of black walnut is whitish and should be avoided. Walnut is also a good carving wood, but be careful: Some people are sensitive to walnut and may be susceptible to rashes or breathing problems when using it. ■

Band Saw Safety

The fact that there is no danger of kickback with the band saw makes is a far safer tool than many of our shop tools. However, it is still very important to be cautious when using it. Most band saw accidents are the result of excessive feed pressure and poor hand position. In addition to the rules that apply to all power tools, observe the following rules:

- Keep your hands on either side of the cut line and away from the blade; use push sticks as necessary.
- Except when changing a blade, keep the wheel covers closed.
- Stand slightly to the left of the blade when cutting. Never stand nor allow anyone else to stand to the right of the blade. If the blade breaks, it will fly to the right.
- If a blade breaks, shut off the power and do not open the wheel covers until the machine has come to a complete stop and you have unplugged it.
- If you hear a rhythmic clicking sound, stop the machine and check the blade for defects.
- Hold the stock firmly down on the table as you cut.
- Make sure the tension is properly adjusted for the blade you are using.
- Lock the upper guide assembly, which includes the guard, about 1/4″ above the work.
- Make relief cuts as necessary; the wider the blade and the tighter the curves, the greater the need for relief cuts.
- Minimize backing out of cuts, since this can pull the blade off the wheels.

Troubleshooting Hints for the Band Saw

Cut isn't square to surface — table to blade angle is not square

Blade binds — making too sharp a turn for the blade width

Blade breaks — forcing a cut; turning too sharply; blade worn or damaged; guide assemblies not correctly aligned

Rough cut — feed rate too fast; finer blade required

DRILL PRESS

The **drill press** is an invaluable tool for accurately drilling holes. It is a fixed drill, consisting of a *base, column, table, spindle,* and *tool head.* The drill press has a set of handles, usually three of them, radiating

from a central hub which, when turned, move the drill spindle vertically, parallel to the axis of the column. **Figure 5-89** shows the anatomy of a typical drill press. The drill bit is held in the **chuck**, which is located at the end of the spindle and is lowered into the work on the table. The chuck is simply a clamping device for holding a drill bit. The table can be raised and lowered to accommodate material of varying thicknesses. It is possible to set the drill depth by using the depth stop; this allows you to drill partway through the material, when drilling holes for shelf supports, for example. The table on most drill presses tilts, allowing the operator to cut holes at various angles.

Drill presses are sized by doubling the distance from the center of the chuck to the column. This distance determines the widest workpiece the press can handle. An 18″ drill press, for example, measures 9″ from the column to the center of the chuck, and is capable of cutting a hole in the center of a board that is 18″ wide. Drill presses may be floor or bench models, and often the only difference between the two is the length of the column.

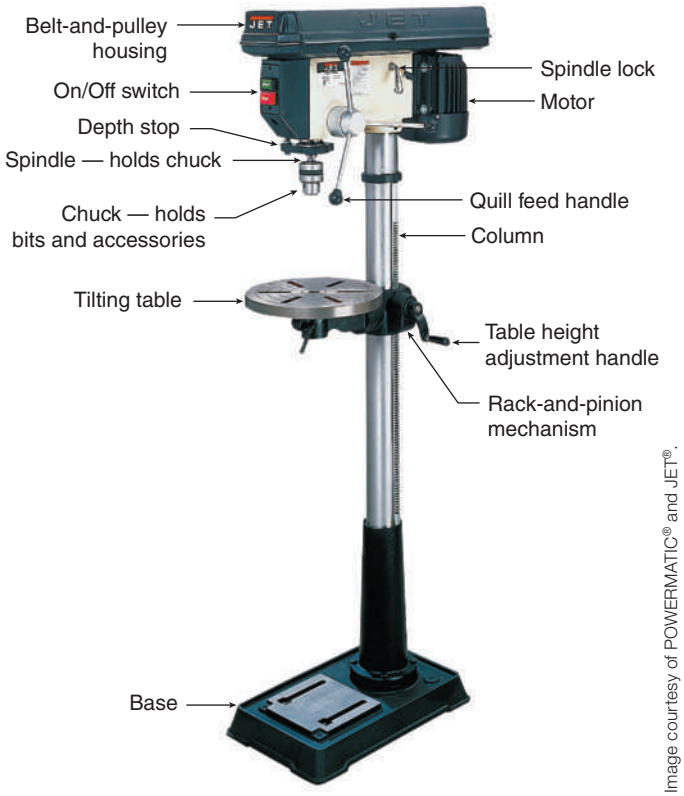


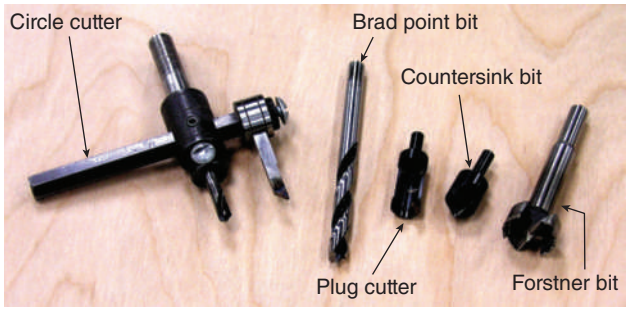
Image courtesy of POWERMATIC® and JET®.

FIGURE 5-89 Diagram of a drill press.

Using Drill Bits and Accessories

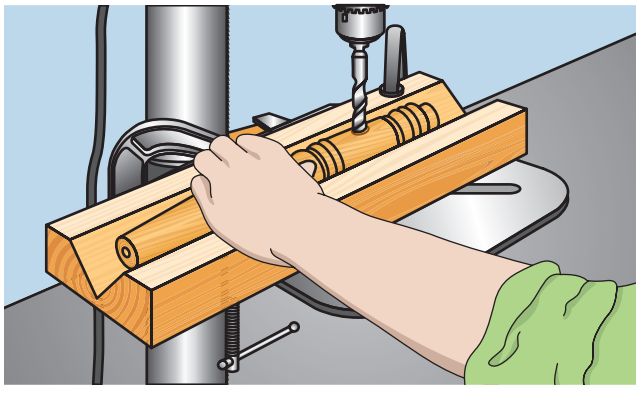
A wide selection of drill bits can be used with the drill press (see **Figure 5-90**). If you are drilling partway through a piece, a flat-bottomed bit, such as a Forstner bit, is a good choice. If you are drilling completely through, it is important to place a backer board underneath the piece being drilled to prevent tear-out on the underside. When drilling, raise smaller bits frequently to clear shavings and prevent heat build-up. With larger bits, make a series of shallow passes, allowing the bit to cool between passes. When drilling cylindrical stock, use a V-block to support the stock and keep it from rolling. The point of the bit should be aligned with the center of the V (see **Figure 5-91**).

Drill presses can also be used for sanding, using drum sanders of various diameters and lengths (see **Figure 5-92**). The spindle is locked in a fixed position for this operation. Rosette cutters, shown in **Figure 5-93**, may also be used in the drill press. Make sure that the material being machined is held securely on the table; this may mean clamping the work down or holding small work with an auxiliary jig, which may be as simple as a hand-screw clamp. If your shop does



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FIGURE 5-90 Drill bits used on a drill press.



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FIGURE 5-91 Use a V-block for support when drilling cylindrical stock.



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FIGURE 5-92 Drum sander on a drill press.



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FIGURE 5-93 Rosette cutter.

not have a mortising machine, an attachment can be purchased that will allow you to make mortises on the drill press, as shown in **Figure 5-94**. Like the band saw, the drill press has a relatively small table, so be careful to adequately support larger stock with auxiliary tables or rollers.



Image courtesy of POWERMATIC® and JET®.

FIGURE 5-94 Mortising attachment for drill press.

Drill presses differ from most other woodworking machine in that their speed is variable. The speed on the drill press is adjusted either by a speed control wheel or by adjusting the belts on the stepped pulleys housed in the head of the press. The larger the diameter of the bit being used, the slower the speed setting on the drill press should be. **Figure 5-95** is a drill press speed chart. If your drill press is one on which you change speed by manually moving the belts on the step pulleys, there may be a speed chart on the inside of the belt guard. If your drill press has a speed control wheel, speed adjustments are made while the drill press is running.

To ensure safety when using a drill press, make sure your speed is appropriate to the situation, the work is securely held in place, and wide sleeves, dangling jewelry, or loose hair are not near the rotating bit. Other safety guidelines when using the drill press include the following:

- Make sure the bit is securely tightened in the chuck.
- Make sure the chuck key has been removed from the chuck before starting the machine.

Recommended operating speeds (RPM)

Accessory	Softwood (pine)	Hardwood (hard maple)
Twist drill bits*		
1/16" – 3/16"	3000	3000
1/4" – 3/8"	3000	1500
7/16" – 5/8"	1500	750
11/16" – 1"	750	500
Brad-point bits*		
1/8"	1800	1200
1/4"	1800	1000
3/8"	1800	750
1/2"	1800	750
5/8"	1800	500
3/4"	1400	250
3/8"	1200	250
1"	1000	250
Forstner bits		
1/4" – 3/8"	2400	700
1/2" – 5/8"	2400	500
3/4" – 1"	1500	500
1 1/8" – 1 1/4"	1000	250
1 3/8" – 2"	500	250
Hole saws*		
1" – 1 1/2"	500	350
1 5/8" – 2"	500	250
2 1/8" – 2 1/2"	250–500	NR

Accessory	Softwood (pine)	Hardwood (hard maple)
Spade bits*		
1/4" – 1/2"	2000	1500
5/8" – 1"	1750	1500
1 1/8" – 1 1/2"	1500	1000
Circle cutters*		
1 1/2" – 3"	500	250
3 1/4" – 6"	250	250
Shear-cutting countersinks		
1/4" – 3/8"	1000	1000
	750	700
Countersinks		
2-flute	1400	1400
5-flute	1000	750
Countersink screw pilot bits		
All sizes	1500	1000
Taper drill bits with countersinks		
All sizes	500	250
Plug cutters		
All sizes	1000	500
Drum sanders		
Hard rubber	750	1500
Soft sleeveless	500	750
3" pneumatic	1750	1750

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FIGURE 5-95 Drill press speed chart.

- Keep hands and fingers at least 4″ away from the moving drill bit at all times.
- Never try to stop the drill press by grabbing the chuck.
- Never use an augur bit with a screw type head in a drill press; the screw points are self-feeding and make it much more difficult for the operator to control the rate of penetration.
- Frequently back the drill out of deep cuts to clean and cool the bit.
- Be careful to support the table when adjusting its height; it is heavy and can cause injury if dropped.
- Don't touch the drill bit immediately after drilling, as it will be hot.
- If the bit binds, turn off the drill press and carefully turn the drill chuck backward by hand to free the bit.

PROCEDURE 5-5

Drilling to Exact Depth

STEPS

1. Mark the depth to which you wish to drill on the side of the piece to be drilled and set it on the drill press table, as shown in **Figure A**.
2. Bring down the bit beside the piece to the depth of the mark, as shown in **Figure B**.
3. Set the depth stop, as shown in **Figure C**.
4. Align the bit where you wish to drill the hole, turn it on, and bring down the feed lever to bring down the drill; it will stop at the preset depth, as shown in **Figure D**.



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WOODWORKING TIP:

Often the shop space we have is more limited than we would like, so it can be difficult to have adequate space around all our tools. One solution is to mount your stationary tools on casters, so that they can be moved around as needed.

SHAPERS

The **shaper** may be thought of as a bigger and stronger sibling of the table-mounted router. **Figure 5-96** shows a shaper. Although it has a different cutting system, it has many of the same uses as the router. It can be used to mill decorative edges on stock, to perform joinery operations, and for template cutting. The shaper consists of a table through which a motorized adjustable spindle projects, and two fences. Like other tools we have looked at, shapers vary in size, speed, weight, and power. **Figure 5-97** diagrams a typical shaper.

Stationary shapers are powerful tools and deserve serious respect. Shapers use **cutters** rather than bits, as routers do. The cutter is locked in place on the spindle by means of a keyed washer and a lock nut. Sometimes collars are used under or over the cutter to help set the cutter height and the depth of cut. The spindle is raised and lowered by means of the spindle raising handwheel to adjust the depth of the cut. The shaper has a miter-gauge groove milled into the table to facilitate cross-grain cuts. Shapers have a split fence, unlike the other tools we have looked at; the fence provides support during the cut. When shaping work that is not straight, the fence cannot be used. There are holes milled in the shaper table to allow the insertion of ***starter pins***, sometimes called ***taper pins***. Starter pins act as a fulcrum point for pivoting curved work into the cutter. They are used in conjunction with collars mounted on the spindle which control the depth of cut.



Image courtesy of POWERMATIC® and JET®.

FIGURE 5-96 Shaper.

CAUTION

Be especially careful when shaping stock that contains cross grains or knots. These may pull the operator's hands into the cutter or cause kickback.

Shaper Cutters

There are several types of cutters manufactured. The safest of them is the solid, three-wing cutter. See **Figure 5-98** for a selection of three-wing cutters. Cutters are available with carbide tips, which allow for multiple resharpenings, but they are also more expensive than steel cutters. A second type of cutter holds removable knives that are gripped in slotted collars. This allows for custom grinding of a particular profile. When using this type of cutter it is imperative that the individual knives be securely attached to the cutter head. Some shaper cutters are sectional. They have two or three separate solid cutters mounted together. By altering the position of these cutters, various shapes can be created. Some sectional cutters are matched sets for particular operations, such as those designed to create the stile and cope cuts used in the assembly of doors. Whatever type of cutter is used, it must be correctly installed on the spindle and securely tightened down. The lock washer must always be placed under the lock nut. The washer has a key that fits into a keyway milled in the spindle, preventing the cutter from loosening the nut and making it safe for the spindle to run in either direction. After assembling and checking to make sure there are no obstructions, turn the shaper on and quickly off again. This allows you to verify the spindle rotation direction, and also to check for any unusual noises.

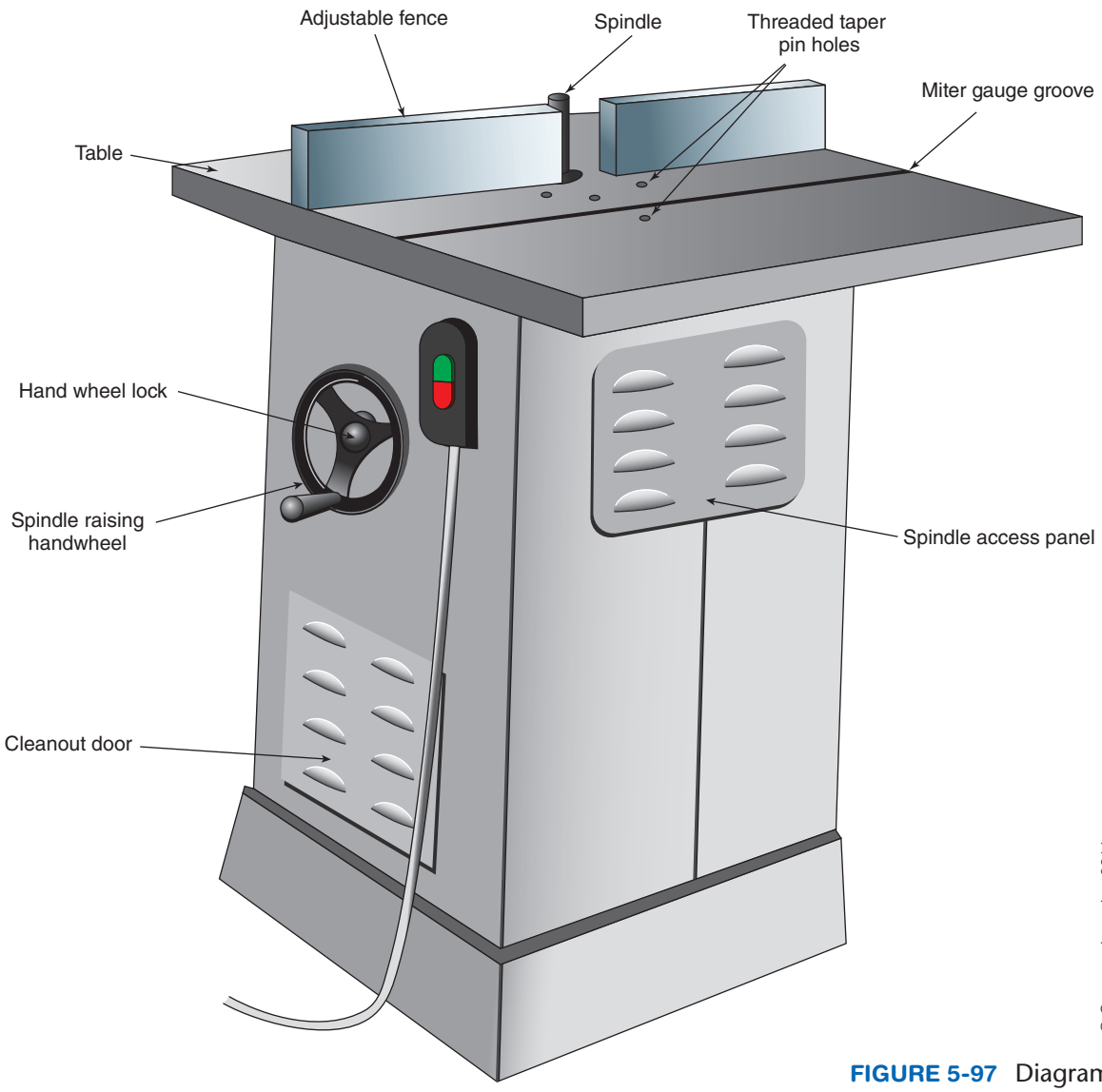


FIGURE 5-97 Diagram of a shaper.



FIGURE 5-98 Three-wing carbide-tipped shaper cutters.

CAUTION

ALWAYS check the rotation of the cutter before running work on the shaper! Work should always be fed *against* the rotation of the cutter.

Setting Up and Using the Shaper

Shapers may be operated using the fences; a miter gauge; a taper pin and collar; a taper pin, collar, and template; and various jigs. Work may be placed flat on the table, or on edge. When it is placed on edge, it may be necessary to attach a tall supplemental fence

to the regular fence in order to ensure that the workpiece has adequate support.

When shaping with the fences, the fences will either be aligned with one another or offset. When the overall dimension of the stock does not change and you are only shaping part of the edge, the infeed and outfeed fences are aligned. When you are shaping the entire edge and the stock dimension does change, the outfeed fence is brought forward so that will support the stock as it exits the cutter (see **Figure 5-99**). If you are shaping all edges of a piece of material or adjacent edges, make your cross-grain cuts first. They have a tendency to tear out at the end of the cut where the grain is unsupported, but will be cleaned up when the final cuts with the grain are made.

When shaping the ends of narrow pieces, use the miter gauge. If the piece is narrower than the opening between the fences, you should have a clamping mechanism on the miter gauge to hold the piece securely in place. To reduce splintering at the end of these cross-grain cuts, use a backer board placed between your stock and the miter gauge, which will support the trailing edge of your piece.

When shaping irregularly shaped pieces, use a starter pin and a collar. Collars are available in different diameters, and may be solid or ball bearing. Solid collars rotate with the spindle, while ball bearing collars rotate independently and are less likely to burn the wood. Install the collar that will give you the desired depth of cut. It is installed above the cutter. There must be enough unshaped work riding against the collar to guide the work. A spindle-mounted guard should be used. The edge of the workpiece to be shaped must be smooth since the collar rides on the workpiece and will follow any imperfections. Thread a taper pin into a hole on the shaper table on the infeed side of the cutter. Remember that which side this is will depend on the direction of spindle rotation. Turn the shaper on and position the workpiece against the starter pin, but not against the cutter. Ease the workpiece into the cutter and start feeding the work after it touches the collar. Keep the workpiece in contact with the collar throughout the cut. When the cut is completed, pull the piece away from the cutter and turn the machine off.

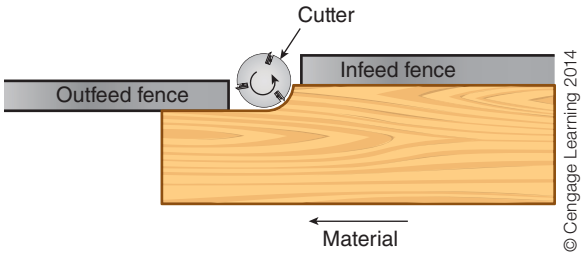


FIGURE 5-99 When shaping changes the dimensions of the stock, the outfeed fence is brought forward so the work is supported throughout the cut.

It is possible to do template or pattern cutting on the shaper, again using the starter pin and a collar mounted above the cutter on the spindle. When using a template, the whole edge may be shaped. Pattern cutting allows the operator to make multiple identical pieces. It is important that the template be smooth and accurate. The material to be shaped is cut to approximate size on the band saw, and then the pattern is attached over it. The template will ride against the collar as you feed the work. The method of running the work is the same as with the collar and starter pin described earlier.

Shaper Safety

One of the most important things to be aware of with the shaper is that the direction in which the spindle turns is reversible. The direction of spin ***must*** be checked prior to running work on the shaper. Usually a switch inside the base of the router sets the direction of the spindle's rotation, and the work must be fed ***against*** the direction of the cutter rotation for safety reasons: As the cutter turns into the work, it helps push it against the fence. When the cutter is turning clockwise, the material must be fed from left to right. When the cutter is turning counterclockwise, the material must be fed from right to left. A cutter that is spinning in the same direction as the operator is feeding material will pull the piece out of the operator's hands and has the potential to pull the operator's hands into the cutter.

The shaper is a dangerous machine, not only because of the reversible spindle rotation, but also because it is difficult to adequately guard the cutter. A good guard to use is a clear plastic spindle guard, which fits on the spindle underneath the washer and rotates with the cutter. The fence should be adjusted so that as little cutter as possible is exposed. It is also desirable to run the work with the cutter underneath the work, rather than above it, when you have the opportunity to do so. This places the work between you and the cutter, increasing your margin of safety, and also eliminates the possibility of the work being damaged should you lift it during a cut. Cutters should be

securely tightened down and the fence locked. Other safety considerations include the following:

- Never allow your hands to come closer than 4" to the cutter.
- Do not shape pieces that are too small or narrow for safe hand positioning; it is often wise to shape a larger piece and then saw off the desired part.
- Inspect your cutters and collars to make sure they are without damage or flaws; keep them clean.
- Do not shape stock less than 12″ long without a jig or other means of support.
- Adjust the two halves of the fence so that the cutter opening is no larger than required for the cutter to clear.
- Revolve the cutter by hand while the power is disconnected to make sure the cutter path is clear.
- Always use the safety locking washer.
- When working against collars, make sure the work has sufficient bearing surface against the collar.
- Do not perform any operation completely freehand; use the fence for straight shaping, the miter gauge for end shaping, and a starter pin and rub collar for curve shaping.
- Use featherboards and hold downs to help control the stock, keeping it down on the table and against the fence.
- Never run a workpiece between the fence and the cutter.
- Make sure that the fence is adjusted so that the stock will have complete support throughout the cut. This is particularly important when making a cut that will change the width of the stock; the outfeed half of the fence must be brought forward to accommodate for this.
- Do not shape stock that has loose knots, is warped, or contains nails or other foreign material.

LATHES

The **lathe** is the stationary shop tool with the longest history. **Figure 5-100** shows an example of a modern lathe. Although the lathe has evolved over time, in principle it is much the same as it was hundreds of years ago. The lathe spins a block of material so that



Image courtesy of POWERMATIC® and JET®.

FIGURE 5-100 Lathe.

when tools are applied to the block, it is shaped to produce an object that is symmetrical around its axis of rotation. Power was provided to early lathes by various means, such as spring poles or apprentice power; today we rely on electricity. **Figure 5-101** shows an example of an early lathe.

There are many models and sizes of lathes, from benchtop models to huge industrial machines, but the basic design is similar on all of them (see **Figure 5-102**). A rigid, horizontal bed supports a stationary **headstock** and a **tailstock** that can be moved to accommodate blanks of various lengths. The headstock is on the left, as the operator faces the lathe. It contains spinning bearings, and rotating within these bearings is a horizontal axle, called a *spindle,* which is parallel to the bed. The spindle is threaded so that faceplates may be attached; good spindles are hollow and tapered to accept drive centers and other accessories. The spindle is powered and imparts the motion to the lathe. Turning tools manipulated by the operator are supported by an adjustable tool rest, which is actually two parts consisting of the base, which slides along the bed of the lathe, and the tool rest itself, which is the ledge that serves as the resting point for the turning tools. This assembly can be moved laterally and vertically; it also pivots. Tool rests are available in different lengths to fit in the same base. The tailstock is on the right side of the bed, and it is moved along the bed to provide auxiliary support to the material. Like the headstock, it has a hollow spindle, also called a quill or a ram, which holds centers and other accessories; unlike the headstock spindle, it

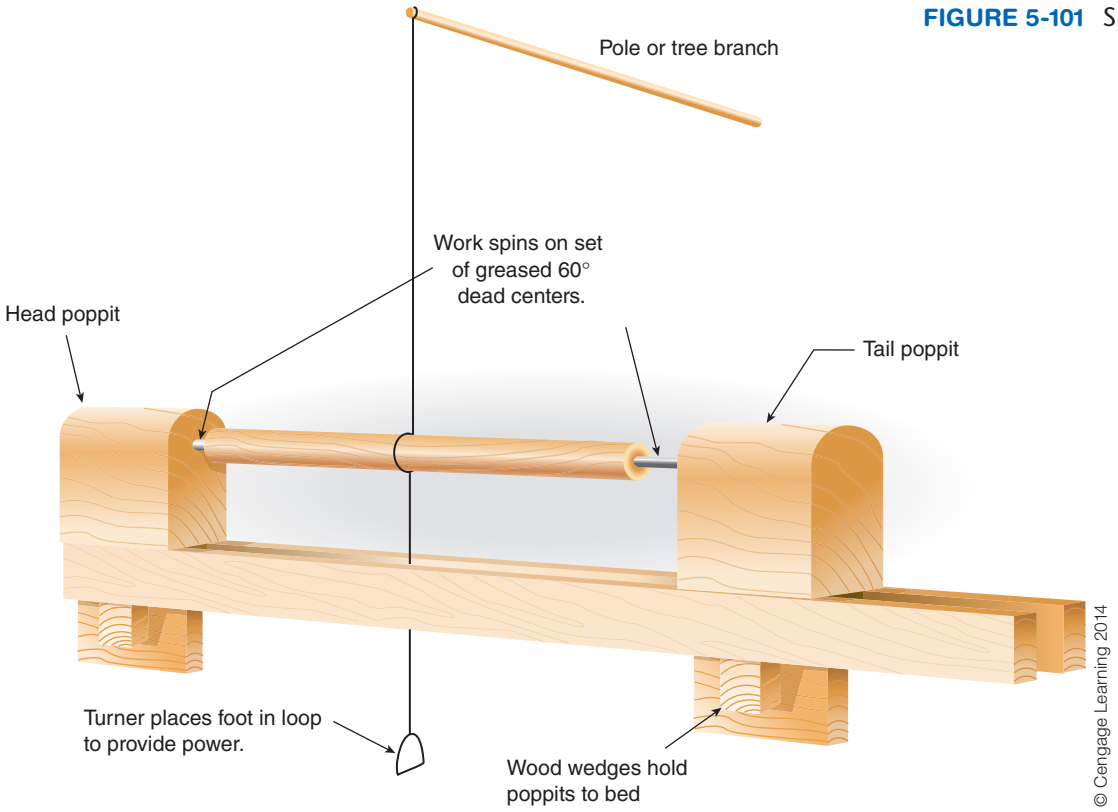


FIGURE 5-101 Spring pole lathe.

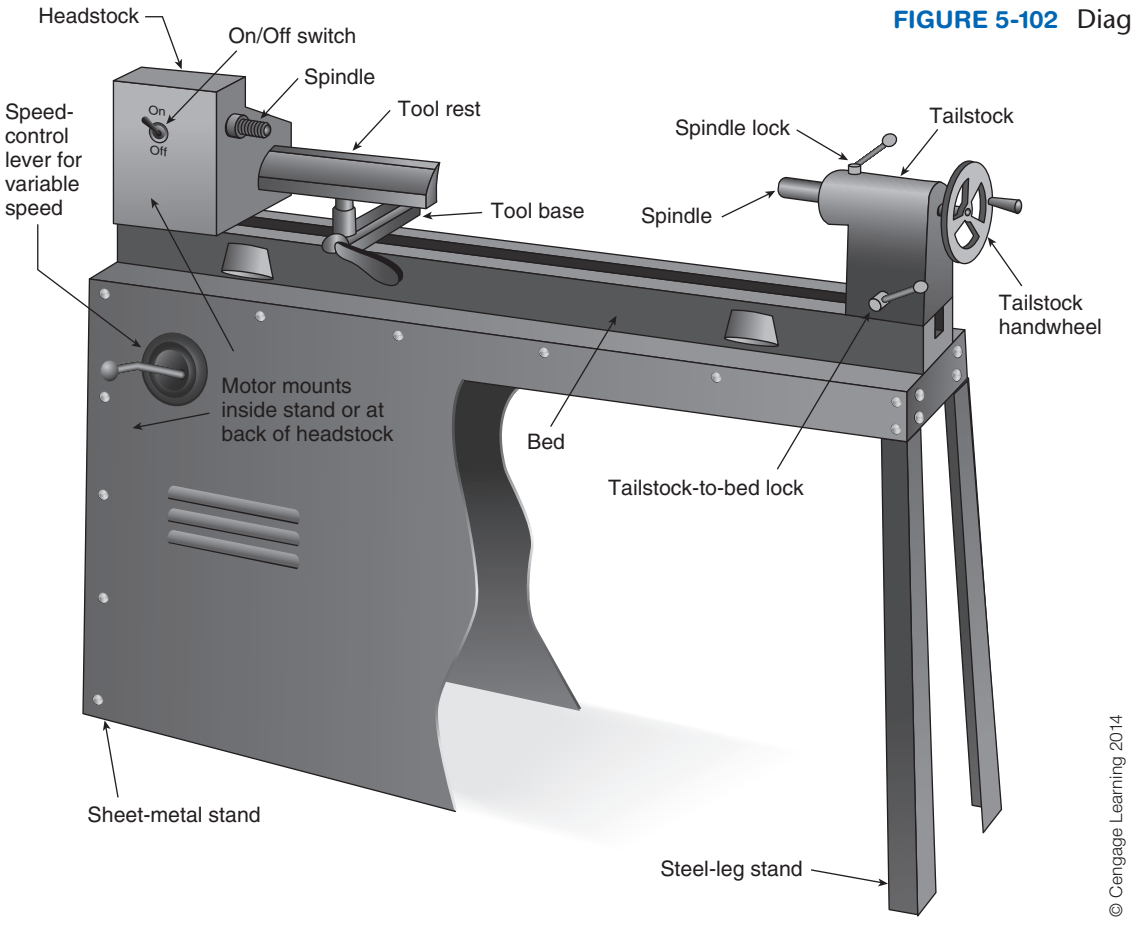


FIGURE 5-102 Diagram of a lathe.

is not powered. The tailstock is brought into position and locked in place; the tailstock handwheel is then turned to bring the tailstock spindle firmly against the work, and then that spindle is locked. The headstock and tailstock spindles are aligned with one another.

Several factors contribute to the sizing of a lathe. One is the maximum distance that can be achieved between the headstock and the tailstock; this is referred to as the *distance between centers*, and it determines the maximum length of a piece that can be turned on that particular lathe. The term *swing* is used to specify the maximum diameter of the piece the lathe can handle. Swing is double the *center height*, which is the distance between the point of a drive center mounted in the spindle and the top of the bed (see **Figure 5-103**).

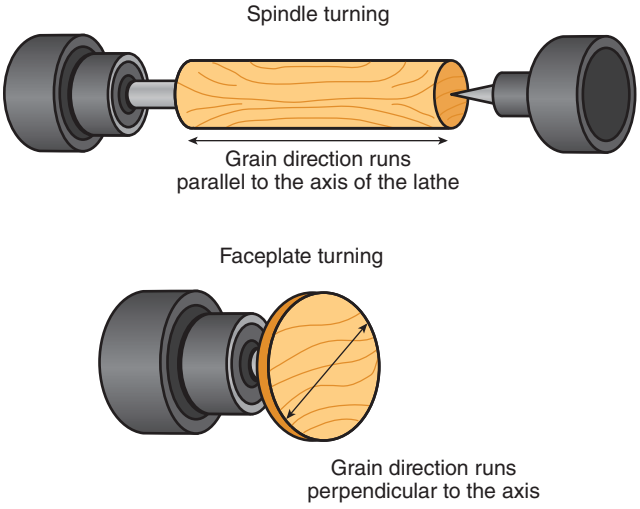
The speed on lathes is adjustable for different types of work, just as on the drill press. And, like the drill press, the larger the diameter of the work being turned, the slower the speed should be. A second variable governing lathe speed relates to the stage of the work. The speed is slower during the roughing cut, faster while shaping, and faster yet when finishing. **Figure 5-104** is a speed chart for the lathe. Lathe speeds are controlled by one of two methods. Variable speed lathes are adjusted by a speed control lever while the lathe is running. Other machines have step pulleys on both the motor and the spindle, and the belt is moved to achieve different speeds. The lathe must be turned off to make speed adjustments with this system, and a narrower range of incremental speeds is available.

Lathe work can be divided into two types: *spindle turning* and *faceplate turning*. The orientation of the grain relative to the bed of the lathe determines the type. In **spindle turning**, the grain runs parallel to the bed. If the grain of the piece being turned runs perpendicular to the lathe bed, it is considered **faceplate turning** (see **Figure 5-105**).

Wood diameter	Roughing cut Revolution per mark	Shaping cut (RPM)	Finishing cut (RPM)
Up to 2"	910	2,590	4,250
2"–4"	810	2,375	3,380
4"–6"	650	1,825	2,375
6"–8"	650	1,200	1,825
8"–10"	650	910	1,025
Over 10"	650	650	650

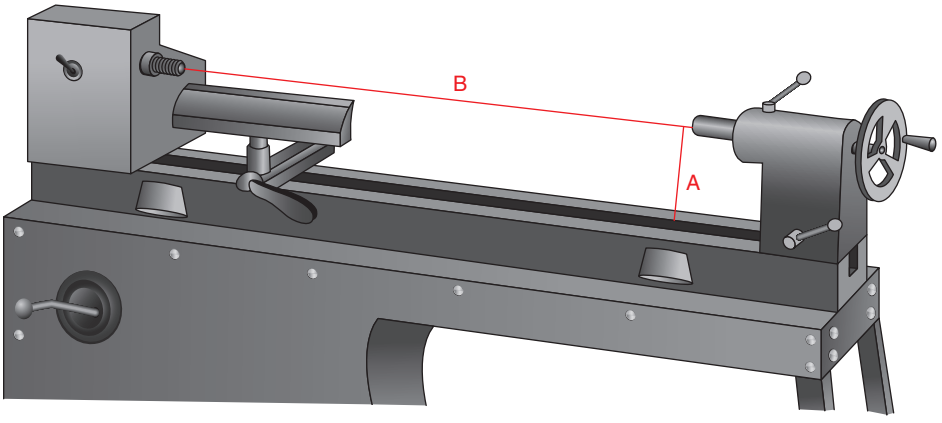
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FIGURE 5-104 Lathe speed chart.



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FIGURE 5-105 Spindle turning and faceplate turning.



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A: Center height: Distance from spindle center to bed.
Swing: Twice center height
B: Distance between centers

FIGURE 5-103 Center height, swing, and distance between centers.

CAUTION

Before the lathe is turned on, make sure the material is securely held and that it can rotate freely without hitting the tool rest.

Using the Lathe

Work is held in the lathe in a number of ways. The simplest and oldest method is to hold the work between centers, one of which is mounted in the headstock and the other in the tailstock. Most spindle work is held this way (see **Figure 5-106**). The centers have a small central point, and the center placed in the headstock is called the *drive center,* because it holds the work and imparts power to it. The drive center is also referred as the *spur center,* because it has two or four spurs that bite into the work. The tailstock center does not have spurs. This center may be a live center or a dead center. A live center is preferable because its point turns with the work, whereas the dead center does not. Dead centers are more likely to loosen or cause burning problems on the stock. Centers are usually attached using a Morse taper, which fits into the tapered hollow in the spindles.

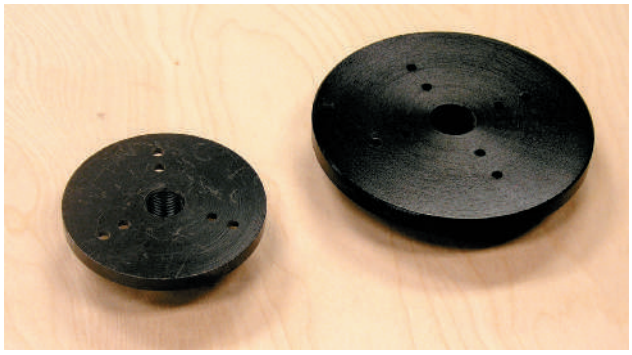
A **faceplate** is a flat metal disc with a threaded hub that screws onto the headstock spindle. Faceplates are available in diameters ranging from about 3″ to 10″ and are used to hold work that cannot be supported by a tailstock (see **Figure 5-107**). The work to be turned is fastened to the faceplate with screws or bolts through the holes around the faceplate. Do not use drywall screws to attach work to a faceplate; they are too brittle and may snap. Sheet metal screws, #12 by 1 inch, are recommended. Screws need to be stout enough to provide security but not so long that they will be in the turner's way. In the initial stages of truing a piece attached to a faceplate, particularly a large piece, the tailstock fitted with a center may be brought up against the stock to provide additional support and an additional measure of safety.

A third common way of holding work in the lathe is by means of a **scroll chuck**, illustrated in **Figure 5-108**. Scroll chucks attach directly to the spindle and hold the work by means of three or, more commonly, four jaws, which open and close in unison. They have the advantage of not leaving screw holes in your work. Other types of chucks include *collet chucks, screw chucks, jam chucks,* and *Jacobs chucks.* Jacobs chucks are drill chucks; they allow you to bore holes into the work held in the lathe. They can also be used to hold small parts. If the Jacobs chuck in your drill press has the same size Morse taper as your lathe, you will be able to use that drill chuck in your lathe.



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FIGURE 5-106 Work held between centers.



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FIGURE 5-107 Faceplates.



Image courtesy of One-way Manufacturing, www.oneway.ca

FIGURE 5-108 Scroll chuck.

Lathe tools are held by the operator using two hands; both hands are required to control and move the tool. Most people hold the handle in their right hand and place their left thumb on top of the tool and the fingers under it. The left hand is also in contact with the tool rest (see **Figure 5-109**). The tool is placed on the tool rest so that the tool is at too high an angle to cut, and then the handle is raised, bringing the cutting edge of the tool down into the spinning material. Depending on how the tool is held in relation to the work, scraping, cutting, or shearing action will occur (see **Figure 5-110**). Scraping is the safest and easiest of the three, and shearing produces the smoothest cut.

Developing lathe skills enables the woodworker to expand the scope of his work, permitting the production of rounded legs, finials, knobs, spindles, and more. Turning can be a very creative process. It is a skill which, like all skills, requires practice and patience. If you enjoy the process, however, it will be well worth your effort.

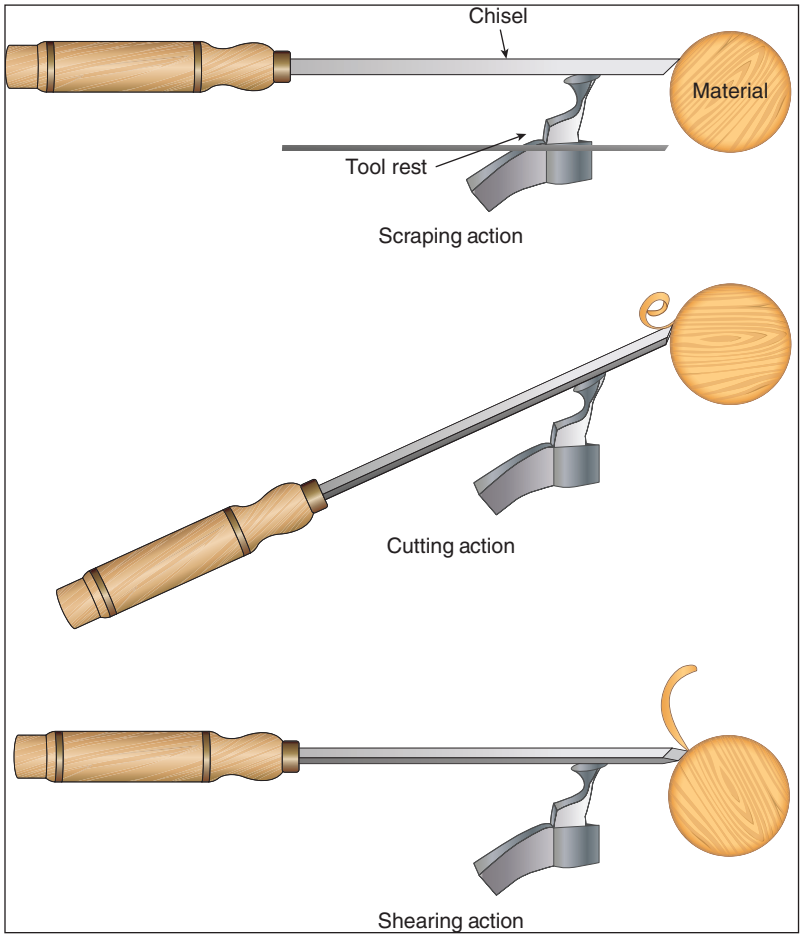


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FIGURE 5-109 Holding a lathe tool.

CAUTION

Use only stock that is free from defects for lathe work. Avoid using material that has splits, cracks, or knots in it.



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FIGURE 5-110 Scraping, cutting, and shearing cuts.

Lathe Tools

The lathe is unique among the shop tools in that the cutting implements are brought toward the spinning work, rather than the work being fed into a stationary blade or cutter. Lathe tools may be divided into two broad categories: *gouges* and *chisels*. A **gouge** is a tool that is similar to a chisel, except that its blade is not flat but curved. There are a great many lathe tools available, but the basic kit is pretty small. It consists of a *roughing-out gouge, a spindle gouge, a skew chisel,* and a *parting tool* (see **Figure 5-111**).

The **roughing-out gouge** is a wide, fluted gouge, which allows rapid removal of material. It is square-ended and has a beveled edge. It is used to do the initial rounding and rough shaping of a spindle. **Spindle gouges** are smaller, shallower, fluted gouges used for cutting details on spindles, such as coves and beads. **Figure 5-112** illustrates a bead and a cove. Spindle gouges are commonly available in 1/4-, 3/8-, and 1/2-inch sizes.

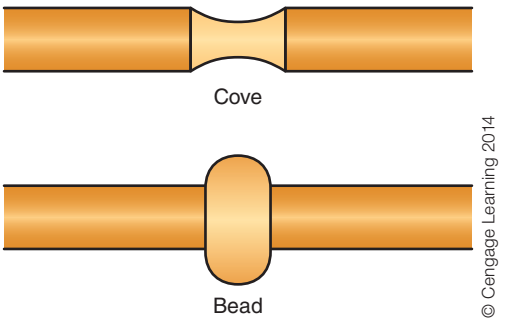
Skew chisels differ from regular woodworking chisels in that they have a bevel on both the top and bottom, and the cutting edge is not square to the shank; it is skewed 15° to 20°. Commonly available in quarter-inch increments, from 1/2-inch to 1 1/4-inch sizes; the larger ones are best for beginners. Skew chisels are good for cutting cylinders, tapers, and gentle curves. They also leave a better finish than any of the other lathe tools.

Parting tools, also known as cutoff tools, are pointed tools, and they are used both to define areas to be cut and to separate, or *part,* the material from the lathe.

Adding a **bowl gouge** or two and a scraper to your kit will allow you to turn bowls and other pieces with recesses. Bowl gouges are deep, fluted gouges used to turn the inside and outside of bowls and vessels. They are available in different sizes (see **Figure 5-113**).


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FIGURE 5-111 Rouging out gouge, spindle gouge, skew chisel, and parting tool.



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FIGURE 5-112 Bead and cove.

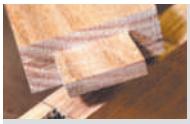

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FIGURE 5-113 Bowl gouges and scrapers.

The lathe is the only shop tool on which a project can be completed from start to finish without ever taking it off the machine. Once turned, sanding can be done rather easily by holding sandpaper to a turning piece; the lathe does the work. After sanding, the project can also be finished on the lathe. A small pad moistened with the finish of your choice can be held to the turning piece. The tool rest should be removed from the lathe during sanding and finishing operations.

CAUTION

Remove the tool rest when sanding or finishing so that you do not run the risk of getting your fingers caught between the work and the tool rest.



HISTORY FACT

Early woodturners in England were called *bodgers*. Bodgers set up camp in the forests of England and, using spring pole lathes, they turned parts that were then taken to the city centers for assembly into furniture, particularly chairs. ■

Lathe Safety

To ensure safe use of the lathe, there are a few rules to keep in mind. First, the work should be securely held so that it cannot come free. Long hair should be tied back, and jewelry that might get caught must be removed; for the same reason, long sleeves should be rolled up. As mentioned, the tool rest should be removed during sanding or finishing on the lathe, lest fingers be caught between the tool rest and the spinning work. Like the drill press, the speed of the lathe is adjustable, and it should be appropriate for the piece being machined. Additionally, the following rules should be observed when using the lathe:

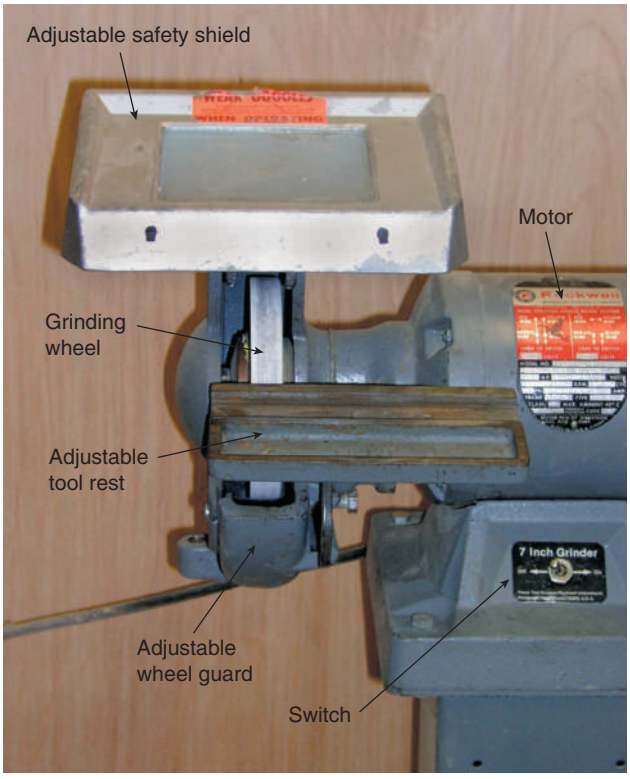
- Do not turn stock that has splits, knots, cracks, checks, or other defects.
- Rotate the stock by hand after mounting and before turning the machine on to ensure that it clears the tool rest.
- The tool rest should be set approximately 1/8″ away from the work and 1/8″ above the center of the work. As material is removed, reset the tool rest.
- Turn the lathe off to move the tool rest.
- Check that the tool rest and tailstock are securely locked before turning on the lathe.
- Make sure the work is securely mounted in the lathe.
- Never bring tools to the material without support from a tool rest.
- Do not lay turning tools on the lathe. They can vibrate off and cause injury.
- Use both hands to hold lathe tools and always use the tool rest when bringing a tool to the work.
- Keep lathe tools sharp both for better turning results and so you do not have to exert excessive pressure.
- Clean up wood shavings often, as they present a fire hazard. This is particularly an issue when turning green wood.
- Consider wearing a full face shield rather than just safety glasses or goggles when turning; turning can produce a lot of flying chips.
- Never use your fingers to check stock for roundness when turning. Stop the machine to check progress.
- Always cut downhill.

GRINDERS

A **grinder** is a machine tool that uses an abrasive wheel as a cutting device. Most grinders have two wheels: one with a coarser grit for roughing cuts, and the other with a finer grit for finishing.

Grinders serve an important function in the shop: They are used for sharpening lathe tools and to square up the edges of damaged plane irons and chisels. They can also be used to rough out the design for a custom-made scraper or to grind down screws that are too long. Most grinders are high-speed grinders, but slower grinders work better in the woodworking shop. Important features to look for in a grinder are the tool rests, safety shields, guards, wheels, and lighting (see **Figure 5-114**). Many come with an attached lamp, which is a real plus.

It is imperative that you wear safety glasses with side shields, goggles, or a face shield when grinding. Grinders must be guarded to keep sparks contained



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FIGURE 5-114 Diagram of a grinder.

and to catch any steel that may come off the surface you are grinding, so that a piece of shrapnel does not go flying across the shop. The guard should be adjusted away from the wheel about a sixteenth of an inch. As the wheel is worn down, the guard needs to be readjusted.

CAUTION

Do not grind on the side of an abrasive wheel.

The wheels that come with most grinders are not meant for the woodshop. They tend to be made of silicon carbide, which grinds too hot for steel. They should be replaced with aluminum oxide wheels, which have a much softer bonding material and do not run as hot. The roughing wheel should be 60 to 80 grit and the finishing wheel 100 to 120 grit. When you first install a new wheel, it is a good idea to stand to the side, turn the grinder on, and leave the room for a few minutes. A defective wheel can disintegrate, and should that happen, you do not want to be nearby. If there is a defect in the wheel, it will generally self-destruct shortly after being mounted. New wheels are rarely perfectly round, but to do the best possible job, they should be. New wheels need to be trued, which is known as *dressing the wheel*. A diamond dresser is the best tool for this job (see **Figure 5-115**). As the grinder is used, the wheels periodically need to be dressed in order to keep them cutting well. If the grinding wheels look glazed, if you can see steel in the wheel, or if it has grooves worn in its surface, it is time to dress it again to bring fresh abrasive particles to the surface.

It is imperative to keep a container of cold water at hand while grinding to quench the tool when it gets hot. Allowing carbon-steel tools to overheat will cause them to lose their temper and render them useless. If you have ever blued a chisel edge, you have taken the temper out of the tool.

You will be less likely to damage your turning tools while grinding if you purchase tools made of high-speed steel (HSS), which maintain their hardness at much higher temperatures. They also hold an edge longer, which means less frequent sharpening.

After grinding, tools need to be honed. The grinder leaves a fairly rough finish, which needs to be refined to a polished edge. There are two honing tools available: whetstones and buffing wheels. Whetstones are the best choice for chisels, and buffing wheels are best for gouges. Buffing compounds — generally a wax, grease, and abrasive mixture — are sold in sticks and are "crayoned" onto the spinning wheel, which may be felt or cloth.



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FIGURE 5-115 Diamond dresser.

WOODWORKING TIP:

Buffing wheels can be set up on a grinder or on the lathe itself.

STATIONARY SANDERS

Stationary sanders include wide-belt sanders, stroke sanders, edge sanders, spindle sanders, drum sanders, narrow-belt sanders, and combination belt/disc sanders. See **Figure 5-116** through **Figure 5-122** for pictures of each. Like all the other machines we have looked at, sanders come in a wide range of sizes, powers, and degrees of sturdiness.

CAUTION

Keep hands away from the abrasive surface of sanding machines. Hold small or thin pieces in a jig or holding device to prevent injuries to the fingers or hands.



Image courtesy of Tannewitz Inc.: Ramco Sanders/Max Ind.

FIGURE 5-116 Wide-belt sander.

The principle behind all of these different sanders is the same: Sanders are fitted with abrasive belts, discs, or sleeves that rotate. When brought into contact with the work, the abrasive grains act like tiny cutting tools to nibble away at the surface.

Sanding machines are utilized for two basic purposes. One is to help shape the work, and the other is to smooth it. The coated abrasives, generally referred to as *sandpaper,* are available in various degrees of coarseness. The degree of coarseness is known as the *grit size:* The lower the grit number, the coarser the



Image courtesy of Delta Power Equipment Corporation.

FIGURE 5-117 Stroke sander.



Image courtesy of Delta Power Equipment Corporation.

FIGURE 5-118 Edge sander.



Image courtesy of POWERMATIC® and JET®.

FIGURE 5-119 Spindle sander.



Image courtesy of POWERMATIC® and JET®.

FIGURE 5-120 Drum sander.



Image courtesy of Grizzly Industrial, Inc.

FIGURE 5-121 Narrow-belt sander.



Image courtesy of POWERMATIC® and JET®.

FIGURE 5-122 Combination belt/disc sander.

abrasive. Lower grits cut more aggressively and therefore remove material more quickly than higher-grit abrasives. Higher grits leave less visible scratches on the surface of your material, but they do not cut as quickly.

Safety with Stationary Sanders

Sanding produces a lot of dust and it is important to protect yourself from it. Use dust collection whenever possible, of course, but even with dust collection

there will be airborne dust, so it is important to wear a mask or respirator. Eye protection is also essential. Remember too that abrasives are cutting tools, and be mindful of getting your hands too close to moving abrasive belts and discs. Additional safety considerations include the following:

- Do not use belts or discs with torn edges; pieces may tear off and cause injury.
- Keep the stock that is being sanded in contact with the table of the machine lest it be pulled out of your hands or pull your hand into the machine.
- Do not use excessive pressure or keep your stock in one position for a long time; this will cause burning and may cause the abrasive paper to tear.
- Replace sandpaper as necessary.
- Be sure to use only the downward traveling half of the disc sander; this will push your work down toward the table. Usually this is the left side of the disc, as most discs will turn in a counterclockwise rotation.
- Make sure the abrasive is securely attached to the machine and tracking correctly before using the machine.
- When using the spindle sander, move your material into the spindle opposite the rotation of the spindle. Feeding with the rotation can kick the piece out and pull your hand into the moving spindle.

RADIAL ARM SAWS

The **radial arm saw**, which is shown in **Figure 5-123**, is first and foremost a cut-off tool, but it has the capability of being much more. It consists of a circular saw blade directly driven by an electric motor, which is held in an adjustable yoke sliding along a horizontal (radial) arm above a horizontal table surface. **Figure 5-124** details the anatomy of a radial arm saw. The arm can be pivoted to make miter cuts, and the arbor can be tilted for beveled cuts. The radial arm is supported by a column at the rear of the machine, and it is cranked up and down on the column to adjust cutting depth. Radial arm saws are sized like table saws: by the maximum diameter blade they are designed to run. The operator makes crosscuts by holding the material to be cut firmly against the fence and pulling the saw blade through the work toward himself (see **Figure 5-125**). The yoke should be returned



Image courtesy of Delta Power Equipment Corporation.

FIGURE 5-123 Radial arm saw.

to the back of the saw at the end of the cut. The blade is spinning toward the operator, which helps hold the material flush to the table and back against the fence, making kickback unlikely.

CAUTION

Do not remove stock from a radial arm saw until the blade has been returned to its resting position at the back of the saw table.

Radial arm saws may be fitted with dado blades to make rabbets and dados, much the same as the table saw; molder heads can be used too. It is also possible to make rip cuts using the radial arm saw. The yoke is turned 90° so that the blade is parallel to the fence, and the width of the cut is set by moving the yoke back and forth on the radial arm (see **Figure 5-126**). When ripping, stock is supported against the fence and should be fed into the machine against the direction that the blade is turning; the bottom teeth are turning toward you.

The radial arm saw has a couple of advantages over the table saw. For one, it is far easier to make crosscuts in long material on the radial arm saw than the table saw. For another, it can be placed against the wall of the shop, requiring less room around it than does the table saw. Thirdly, there is a safety advantage to the fact that the blade is always visible.

The radial arm saw excels at crosscutting, but it is not the best choice of tools for making rip cuts. In many shops, the radial arm saw has been replaced

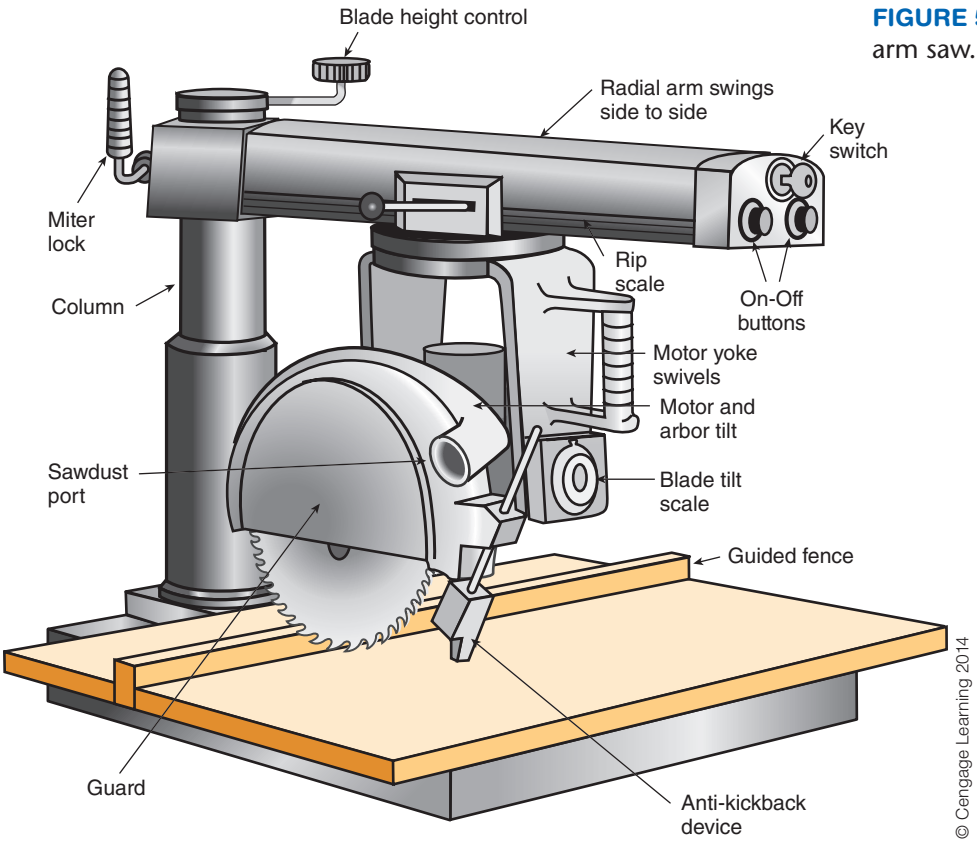


FIGURE 5-124 Diagram of a radial arm saw.

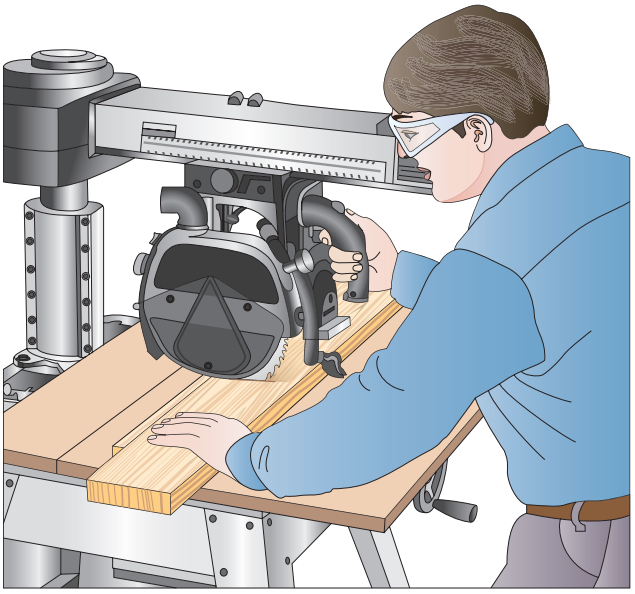


FIGURE 5-125 Crosscutting on the radial arm saw.

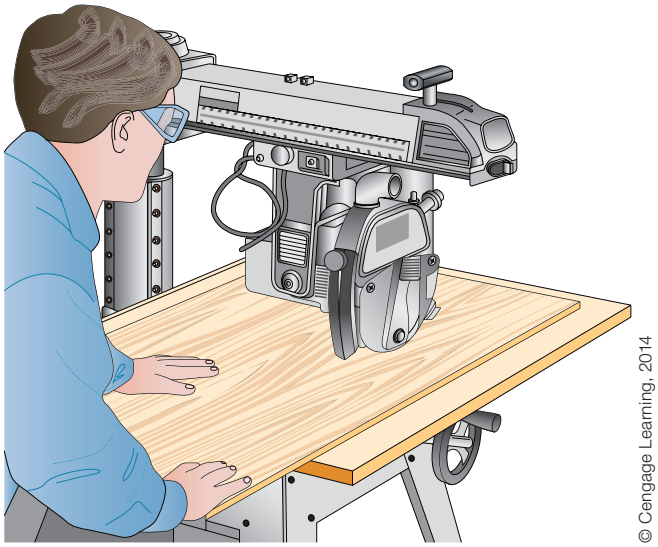


FIGURE 5-126 Ripping on the radial arm saw.

by the sliding compound miter saw, although its crosscutting capacity is often considerably less than the radial arm saw's. However, radial arm saws have a reputation for being difficult to keep properly adjusted, and they do not have the portability of sliding compound miter saws.

Racial Arm Saw Safety Tips

- Before turning on or using the saw, pull the blade out and return it to its starting position to make sure that the blade clears the table and that the guards are working properly. In standard crosscutting operations, the blade is set 1/16″ into the table.
- Make any adjustments to the saw, such as blade height or angle, while the saw is turned off.
- NEVER make a freehand cut on the radial arm saw.
- When crosscutting, hold the work securely against the fence and table with your left hand and pull the saw out with your right hand.
- Always return the saw to the rear of the table after completing a crosscut.
- Keep your hands and fingers a minimum of 4″ away from the blade at all times.
- Keep the table clear of scraps and dust.
- Never turn on the saw when the blade is touching the work.
- The blade has a tendency to "walk," that is, pull itself through the work. This is because the blade is turning in the same direction as the cut. Anticipate this to make a steady, even cut. Using a blade with a 0° or negative hook angle will help to counteract this tendency.
- When ripping, do not stand in line behind the blade, but to one side.



HISTORY FACT

The origin of many types of woodworking machinery is somewhat unclear, but not so with the radial arm saw. Patents for this tool were issued in 1925 to Raymond De Walt of New Jersey. The original design was sold under the name Wonder Worker and was very similar to later radial arm saws. ■

MORTISING MACHINES

The **mortising machine**, also called a *square chisel mortiser* or a *hollow chisel mortiser,* is somewhat similar to a drill press. It is a dedicated machine for making mortises, which are half of one of the most essential joints in woodworking: the mortise and tenon joint. The **mortise** is basically a square or rectangular-shaped recess created to accept the tenon (see **Figure 5-127**).

Figure 5-128 shows a mortising machine. This is a floor model, but smaller, benchtop models are becoming increasingly popular, especially in shops where space is at a premium. Whether a floor or bench model, the general configuration and principles are the same. Some mortisers, such as the one shown, have tables that tilt, while others do not. Mortises are cut with **mortising chisels**, which are available in various sizes (see **Figure 5-129**). This chisel is actually a combination of a drill bit and a square, hollow chisel. The drill bit is tightened into the chuck of the machine, and the chisel is set in place so that 1/16″ to 1/8″ of the bit protrudes beyond the chisel for clearance.. The bit clears out most of the material to be removed, and the chisel ensures that the edges are straight and even.

Depth of cut on the mortising machine is set by raising and lowering the table. The depth should be set so that the chisel will not strike the table at the bottom of the cutting stroke. The work to be mortised is held firmly in place against the fence with a hold-down of some sort, and the bit is brought down into the work, by means of either a foot pedal or a hand-operated lever. When making a mortise, the size of the chisel selected depends on the width of the mortise to be cut. So if your plans call for a mortise that is 3/8″ × 2″ × 4 1/2″, then a 3/8-inch chisel should be used.

When making the mortise, the depth of the cut is set first. This is easily done by marking the depth on the end of the board and adjusting the table until the chisel will cut to the desired depth when it is brought

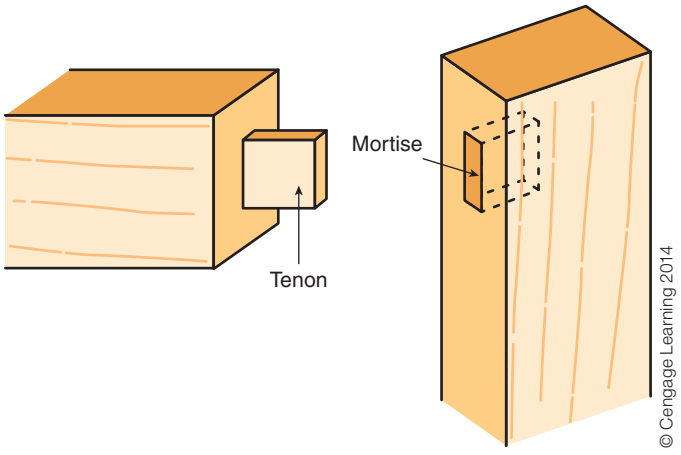


FIGURE 5-127 Mortise and tenon.

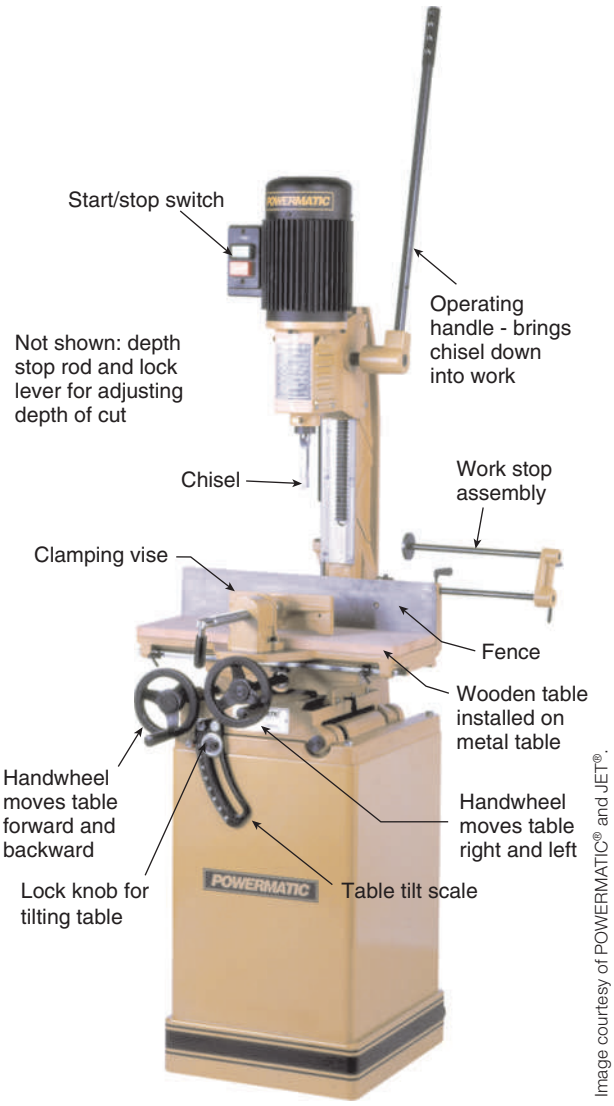


Image courtesy of POWERMATIC® and JET®.

FIGURE 5-128 Diagram of a mortising machine.



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FIGURE 5-129 Mortising chisels.

down (see **Figure 5-130**). The mortising chisel should be situated so that it is parallel to the fence, or a clean, square mortise will not result. The table on the mortising machine can be adjusted in and out so that the mortise may be bored in the proper location. Careful layout will ensure good results. If you have multiple mortises to cut that are all the same — for example, in table legs to accept the tenons that will be machined on the aprons — only one has to be laid out completely; the others will simply need to have the start and stop points of the mortise marked.

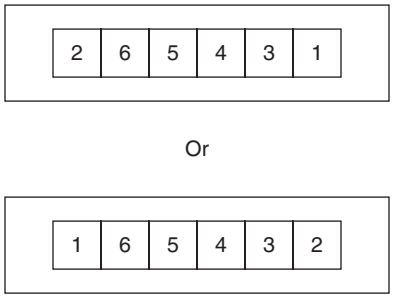
The sequence of making the actual mortise is to define either end of the mortise and then make overlapping passes from one end of the mortise to the other (see **Figure 5-131**). The table is cranked left or right, usually by means of a handwheel, which means that once your work piece is locked tight against the fence, it does not have to be released until the mortise is completed.

As with all tools, the mortising machine should be approached with safety foremost in the operator's mind. Make sure material to be mortised is securely attached to the table with a hold-down or clamp; your hand alone is not sufficient. Keep hands a minimum of 4″ away from the mortising chisel, and maintain a balanced stance at all times.



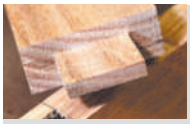
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FIGURE 5-130 Setting depth of cut.



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FIGURE 5-131 Sequence of mortise cuts.



HISTORY FACT

The mortising machine was invented in 1874 by Robert and Ralph Greenlee, founders of the Greenlee Company. ■

SCROLL SAWS

A **scroll saw** is a small electric saw that can cut very intricate patterns and much tighter curves than the band saw. See **Figure 5-132** for an example of scroll saw work. The scroll saw is also the saw of choice for inlay and marquetry work. See **Figure 5-133** for an example of a scroll saw. Unlike the band saw, in which the blade is a continuous loop, scroll saws use blades similar to coping saw blades. The blade extends through the table and is attached to an upper and lower frame arm by blade clamps. There is a tension adjustment mechanism that draws the blade taut. The blade operates through a reciprocating motion. **Figure 5-134** shows the configuration of a typical



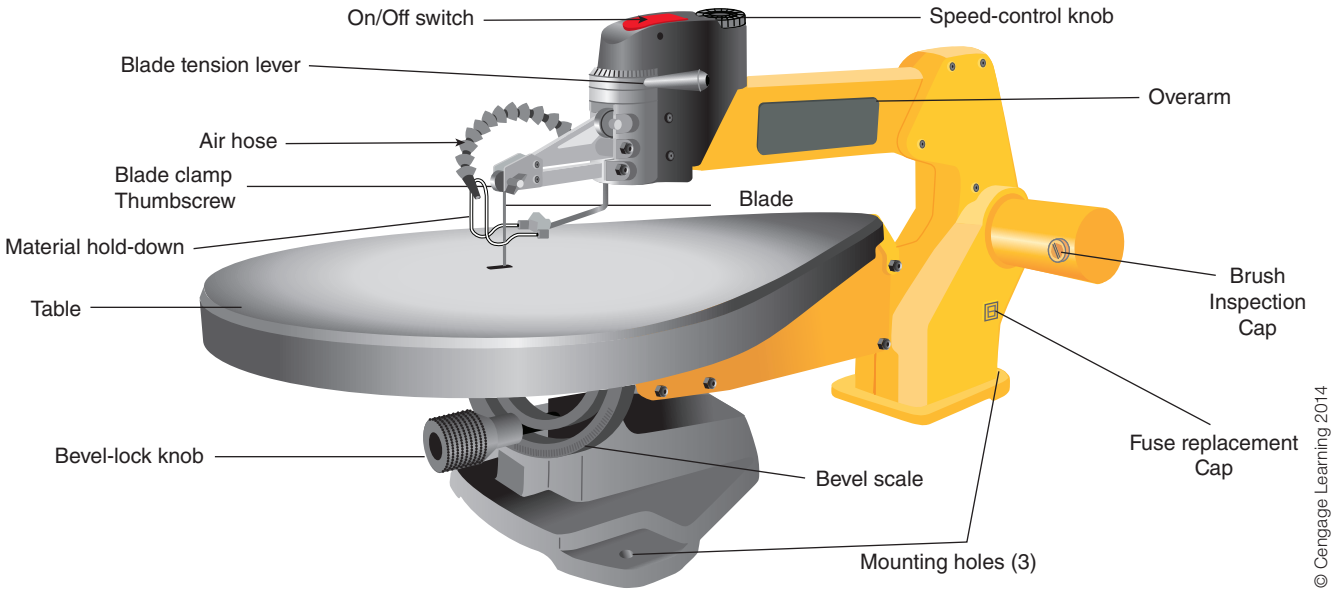
Image courtesy of Boris Radovskiy.

FIGURE 5-132 Scrollsaws can cut intricate curves.



Image courtesy of Stanley Black & Decker/ DEWALT.

FIGURE 5-133 Scroll saw.



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FIGURE 5-134 Diagram of a scroll saw.

scroll saw. There is a hold-down foot that is adjusted to rest lightly on the material being cut, helping hold it down firmly to the table. Many machines also have a blower, which is aimed at the point of operation to remove the sawdust being created and keep the line of cut clearly visible. Because they are relatively light and operate with a reciprocating motion, scroll saws have a tendency to vibrate, which interferes with the tool's accuracy. Mounting the scroll saw to a heavy stand or bench will eliminate this problem.

The size of the scroll saw is determined by the distance from the blade to the back of the overarm. This is called its throat capacity. Most machines are variable speed. Thick and hard materials should be sawn at slower speeds. As with the band saw, relief cuts are recommended to minimize backing out of cuts. If the blade does bind, turn off the saw before backing out of the cut.

The table on many scroll saws tilts, allowing for bevel cuts. The scroll saw can also do interior cutting: A hole that will accept the blade is drilled inside the section to be removed, and the blade is threaded through that opening to make the cut. The blade should be installed with the teeth facing downward, as on the band saw. Scroll saw blades are 5 inches long, and many different blades are available in various widths, number of teeth, and tooth configurations for different types of cutting applications.

The scroll is one of the safest of the shop tools, partly because it cuts quite slowly compared to other tools, but nevertheless it is important to be vigilant when using it and to observe the general safety rules that apply to all tools. In addition:

- Do not reach under the table while the saw is running.
- Keep your hands a minimum of 4″ away from the moving blade at all times.
- Never place your hands or fingers directly in line with the blade, where they might get cut if you slipped.
- Do not start the machine with the blade in contact with the work.
- Hold the work firmly against the table.
- Keep the table clear of scraps; only remove scraps when the saw is stopped.
- Use the proper speed and blade for the work, and maintain the proper blade tension.
- Do not cut a piece that is too small to be safely supported and held onto.
- Do not cut stock that does not have a flat bottom to rest on the table.

CNC MACHINING, AUTOMATION, AND LASER ENGRAVING

CNC stands for computer numerical control. CNC machine tools have revolutionized the manufacturing process by automating tools rather than operating them manually through handwheels and levers. The automation controls production from beginning to end by using computer-aided design (CAD) and computer-aided manufacturing (CAM) programs. These programs produce information, which is essentially a set of instructions, that is conveyed to a CNC machine to manufacture a part. Any machine operated by a computer can be considered a CNC machine. There are CNC machines for drilling and routing. There are CNC lathes. CNC machines speed up the manufacturing process and allow for greater accuracy, reducing production costs at the same time. Once a program has been generated for a certain part or operation, it can be run again and again. Initially, CNC machines were limited to factories and large production shops, but they are now being manufactured on a smaller scale, suitable for smaller shops and even the individual woodworker. Although these tools are not as heavy as their industrial counterparts, they are similar in design and function.

All CNC machines have two or more programmable directions of motion, called axes. These axes are used to help determine where the machine's tools need to be. You might think of a CNC machine as if it were a large plotter which, instead of moving pens around the surface, moves cutters around the surface in *X* and *Y* axes. It also moves them up and down (*Z* axis), which allows the creation of three-dimensional designs. This permits intricate carving. The cutter looks like a drill bit and is spun by a spindle or, in the case of some smaller machines, a router. Virtually any shape can be made. A CNC machine can cut material the same way you would with a saw; it can cut in the *X* direction, the *Y* direction, or on a diagonal. It can cut circles and holes, arcs, curves, and ellipses. These cuts can be made at any depth or at varying depths within the cut. Basically,

any shape that you can draw can be cut. A CNC machine is a multi-purpose tool that can cut, drill, shape, and machine. In short, it can perform the tasks that table saws, band saws, routers, miter saws, drill presses, and lathes do. In theory it could replace all those tools in your shop, performing the same jobs more quickly and more safely than you can manually. When building something with traditional shop tools, you often move from tool to tool, performing a sequence of operations to produce a part. For example, if you were making the side of a bookcase, it would be ripped to width (table saw), cut to length (miter saw), dadoed for the top and bottom and rabbeted for the back (table saw or router), and have a series of holes drilled for adjustable shelf pins (drill press). With CNC machinery, you design the part with its various holes and grooves, load it in the machine, and all the operations are performed right there on the table, and quite quickly compared to you doing it manually. Should you need to produce multiple parts, this is easily accomplished. **Figure 5-135** through **Figure 5-139** show some examples of work done with a small shop CNC machine.

Laser engraving is the technique of marking objects by means of a laser. It does not involve inks or tool bits. Laser engraving machines, like CNC machines, were originally seen only in large commercial shops, but have become more affordable for smaller shop owners. Woodworkers may use them to decorate their work, to make signs or plaques, or to produce a line of craft items. Lasers can also be used to do cutting (see **Figure 5-140** through **Figure 5-142**).



Courtesy of Childwood Products

FIGURE 5-135 CNC produced work.



Courtesy of Brooke M Davis Design

FIGURE 5-136 CNC produced work.



Front 38" × 20"

Courtesy of Phoenix CNC Creations, www.phoenix-cnccreations.com

FIGURE 5-137 CNC produced work.



Courtesy of Phoenix CNC Creations, www.phoenixcnc-creations.com

FIGURE 5-138 CNC produced work.

Laser engraving has three main components: the laser, which does the marking and/or cutting; the surface which is marked or cut; and the controller, usually a computer, which controls the laser.



Courtesy of Phoenix CNC Creations, www.phoenixcnccreations.com

FIGURE 5-139 CNC produced work.



Laser engraved photograph on wood, Courtesy of Touch of Wood Laser Engraving, touchofwood.com

FIGURE 5-140 Laser engraved work.



Laser engraved photograph on wood, Courtesy of Touch of Wood Laser Engraving, touchofwood.com

FIGURE 5-141 Laser engraved work.



Courtesy of lasercutengraving.com

FIGURE 5-142 Laser engraved work.

SELECTION, CARE, AND MAINTENANCE OF STATIONARY SHOP TOOLS

In selecting stationary shop tools, as with all other tools, it is a good idea to do some research before making a purchase. Since tools are expensive, you want to get the most for your money. Do not depend solely on manufacturers' advertisements; their goal is to sell you their tool. You want the best tool you can get at a cost you can afford. As mentioned in the previous chapter, woodworking magazines regularly review tools. The people who do these reviews test the tools thoroughly and then make recommendations, usually in terms of best overall tool and best bargain. It is also desirable to test drive these tools yourself; a tool that is very comfortable and easy to use for one person may not be for another. Another recommendation is not to practice blind brand allegiance; look for the best tool possible for your needs. You may not need one with all the bells and whistles. Consider buying the most essential tools first, and adding to them as you can.

Regular maintenance of your stationary shop tools will pay big dividends. A good stationary shop tool can last indefinitely if properly cared for. Belts should be checked regularly for wear and tear and replaced when necessary. Worn, stretched drive belts cause increased vibration and slippage, and at some point they will break. You may wish to replace the standard belts that came with your machine with link belts

made up of interlocking segments of polyurethane elastomer and multiple plies of polyester fabric, a composition that retains its original shape far better than standard belts. These belts are sold by the foot, and you add and subtract links to get optimal tension, reducing machine vibration.

Vibration results in poorer tool performance and less desirable cuts, so it is a good idea to do what we can to reduce it. One reason for vibration on band saws can be that the rubber tires mounted on the wheel have lost their flexibility and perhaps begun to crack. Replacing them with urethane tires will eliminate this problem, since urethane won't dry out. Any tool that uses a circular blade can have vibration reduced by the use of blade stabilizers.

Machine power cords should be checked regularly and replaced as necessary. Guards should be in place and should operate easily. Keeping blades and cutters clean and sharp will reduce the tool's demand for power, extending the life of the motor. Sawdust should not be allowed to accumulate either on or inside the tools. Using dust collection is a must whenever possible, but even then, the insides of tools such as the table saw and band saw will need periodic vacuuming. Do not get in the habit of cleaning out your tools with compressed air. You are better off using a vacuum, since compressed air will force dirt and dust into the moving parts.

Bearings and moving parts should be lubricated regularly. Newer machines will have sealed bearings that are simply replaced when they go bad. When lubricating the gears of tools, it is wise to use a dry lubricant when possible, such as a silicone spray or graphite. Neither of these will attract dust like oil-based products will. Often the areas requiring lubrication will need a thorough cleaning first to remove built-up residues. Environmentally friendly citrus-based solvents work well and can be used with nylon, brass, or steel brushes. Steel brushes are the most aggressive of the three and can cause scratching, so use them with care on difficult deposits.

Machine beds should be kept clean and lubricated so that miter gauges and material being processed move easily on them. This is one place you do not want to use a silicone spray; if your work picks some of it up while being machined, it is likely to cause finishing problems, because the silicone will prevent adhesion of the finish. Beds can be waxed, talcum power or chalk dust can be used, or products made specifically for this purpose can be purchased. These products will not only make materials and jigs slide easily, they will also inhibit rust, which can be a concern if your shop is in a damp environment. If this is the case, it may be a good idea to invest in a dehumidifier and run it when the environment is damp.

It is good practice to clean out your tools well once a week or so, lubricate them as needed, and rewax the beds. Keeping records of when you do major maintenance is also a good practice. If you are wise, you will keep the manuals that come with your tools; not only will you have a parts list, should you need parts, but many of them also contain troubleshooting information that can help you through a problem.



Summary

Stationary shop tools represent a large investment, but they pay you back handsomely if you take care of them. Many of us do not like to take the time to do this, but it is a necessary evil that saves you time in the long run. There are many stationary shop tools, some with multiple uses, such as the table saw, and others with fairly specific uses, like the mortising machine.

Learn as much as you can about your tools. Reading the manual is usually a pretty good idea. Read trade magazines and learn new techniques. Visit trade shows and dealerships to see what is available. Talk to professionals in the field and ask them about the tools they use and what recommendations they may have.

Stationary shop tools tend to be very powerful machines, and they can quickly perform operations that would take a long time by hand work alone. No modern cabinetmaker would be without them. Do remember, however, that they can be very dangerous and must be treated with respect and a degree of caution.



Key Terms

arbor
band saw
benchtop table saw
bevel
bowl gouge
cabinet table saw
chamfer
chippers
chuck
contractor table saw
crosscutting
crown
cutter
cutter head
cutting circle
dado blade
drill press
faceplate
faceplate turning
fence
gouge
grinder
guide blocks
headstock
hook angle
hybrid table saw
jointer
kickback
lathe
miter gauge
miter-gauge slot
molder head
mortise
mortising chisel
mortising machine
parting tool
radial arm saw
resaw
rip cut
rip fence
ripping
riving knife
roughing-out gouge
scroll chuck
scroll saw
shaper
skew chisel
snipe
spindle gouge
spindle turning
splitter
stacked dado
table saw
tailstock
taper
tenon
thickness planer
throat depth
throat plate
throat width
thrust bearing
wobble dado



Check Your Knowledge

1. What are often considered the "big three" stationary shops tools, and why is this?
2. What advantages does the band saw have over the table saw?
3. List safety concerns for each of the tools covered.
4. How does a shaper differ from a router?
5. Other than the quality of work produced, why is it important to keep blades and cutters sharp and clean?
6. Explain how you should regularly service your tools.
7. What is the danger of moving a jointer by picking it up by its infeed and outfeed tables?
8. What sort of lubricant should never be used on machine beds, and why?
9. Can some operations, such as ripping, for example, be executed on more than one machine? Explain.
10. Given several choices of machines to perform a particular operation, how should you go about deciding which one to use for the task?



Activities

1. Imagine you have been given $5000 to completely equip a shop with all the hand tools, portable power tools, and stationary shop tools you will need for your business. Draw up a list of the tools you would purchase, and justify each purchase.
2. Visit a trade show or home improvement center that offers tool demonstrations.
3. Go on a field trip to a cabinet shop; observe what machines they have and how the shop is arranged for best workflow. If this is not practical, you might visit a furniture or cabinet showroom and talk to the salespeople there about how the pieces are built.
4. Design your own shop layout.



What's Wrong with This Picture?



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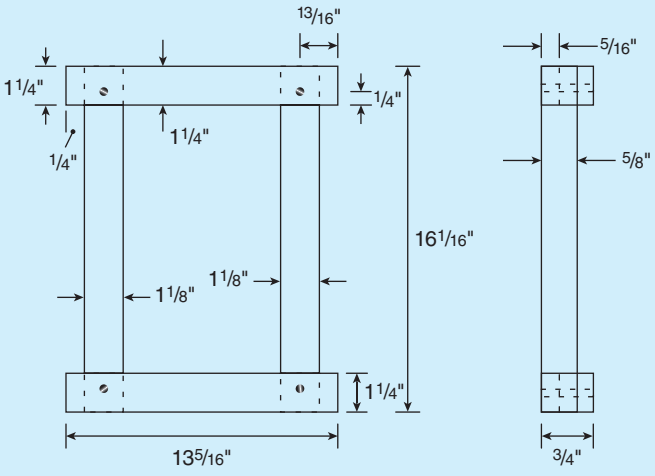
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Craftsman-Style Picture Frame

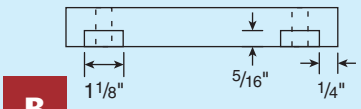


A

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Front view *Side view*



B

End view

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C

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The completed picture frame is shown in **Figure A**.

TOOLS REQUIRED

- Measuring tool
- Marking tool
- Chisel and mallet
- Flush-cut saw
- Jointer
- Planer
- Table saw
- Power miter box
- Drill press and 1/4″ drill bit
- Router and 3/8″ rabbeting bit
- Sander

MATERIAL REQUIRED

- 1″ × 4″ × 36″ stock
- 1/4″ dowel stock, four pieces about 1″ long

STEPS

1. Study the diagram shown in **Figure B**.
2. Crosscut the 1″ × 4″ board into two pieces: one about 20″ long and one other about 16″ long.
3. Joint one side of each board and mark the jointed edge, as shown in **Figure C**.
4. Set the rip fence on the table saw to rip a piece just over 1 1/4″ wide. Set the jointed edge of the shorter board against the rip fence and make a rip cut using a push stick for safety, as shown in **Figure D**.

5. Go back to the jointer with the remainder of the piece you just ripped, and joint the edge that passed by the table saw blade until it is smooth; mark the jointed edge.
6. Go back to the table saw and with the fence at the same setting, rip the piece again.
7. Reset the rip fence so that it will make a rip cut just over 1 1/8" wide. Set the jointed edge of the other, longer board against the fence and make a rip cut, again using a push stick.
8. Take the remainder of this piece and go back to the jointer and joint the edge that passed by the saw blade. Mark the jointed edge.
9. Back at the table saw, with the rip fence at the same setting, make another rip cut.
10. Take all four pieces to the jointer and joint them with the original jointer mark facing up until they are the proper dimensions: Two pieces should be 1 1/4" and two should be 1 1/8". This will get rid of any saw marks.
11. Take the two longer pieces to the planer and plane them down to 5/8" thick.
12. Square one end of each of the four pieces at the miter saw. Mark each squared end, as shown in **Figure E**.
13. Measure from the squared end and cut the two longer pieces to 16 1/16". Cut the two shorter pieces to 13 5/16" lengths.
14. Refer to **Figure F** for making the half-lap joint.



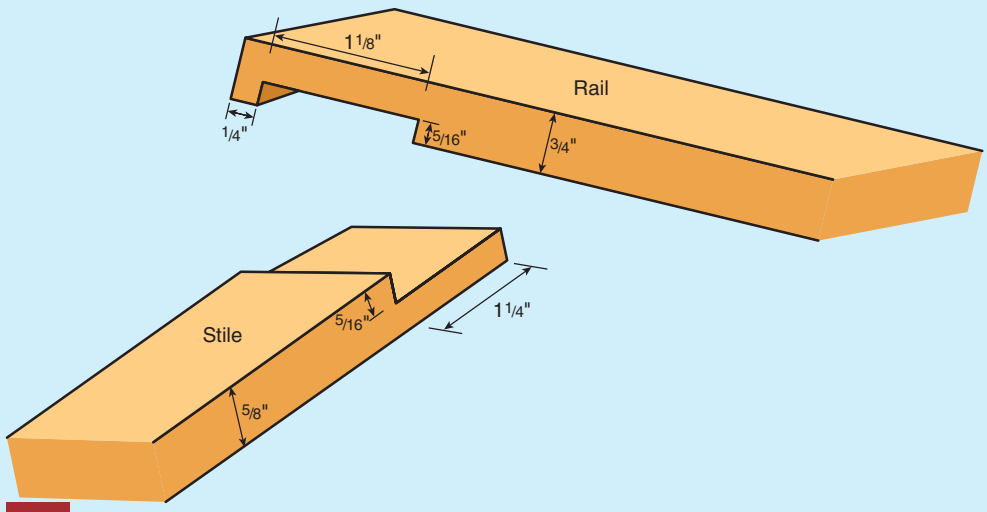
D

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E

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F

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G

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H

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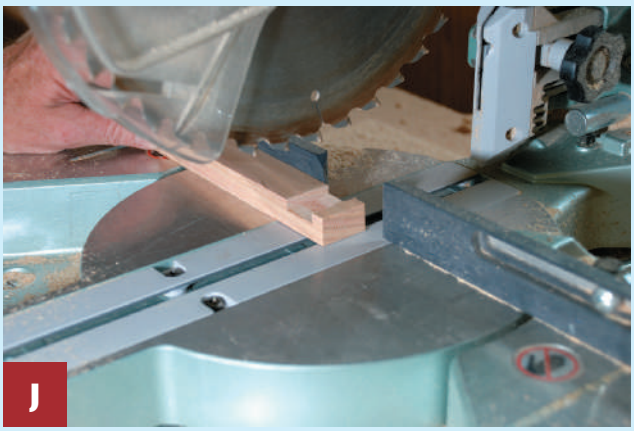


I

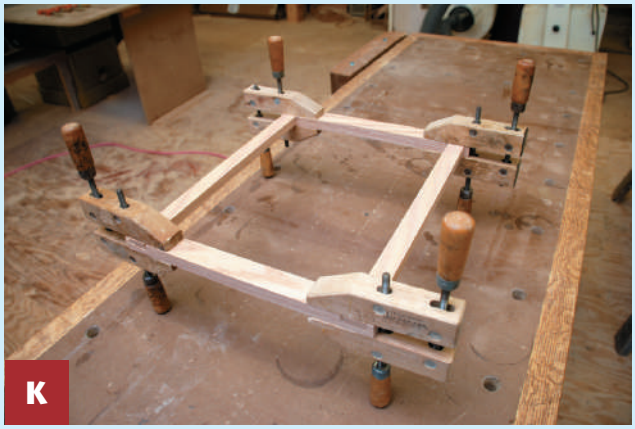
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15. Mark out and machine the half-lap joint on either end of the two stiles. They are the longer pieces, as shown in **Figure G**. You can do this with a dado blade and the miter gauge on the table saw, a straight bit in a table-mounted router, or by setting the depth stop on the miter saw and making multiple passes. Refer to **Figures H**, **I**, and **J**.
16. Mark out and machine the notches on either end of the rails, which are the shorter pieces. Again, you can use the table saw, router, or miter saw. The depth is the same as it was for the half-lap joint you created in the previous step.

17. Clean up the bottoms of the joints with a chisel.
18. Fit the pieces together, then glue and clamp, as shown in **Figure K**.
19. Once the glue is dry, mark out for the dowel.
20. With a quarter-inch bit in the drill press, drill through the frame at the four locations you marked, as shown in **Figure L**.


J

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K

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L

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M

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N

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O

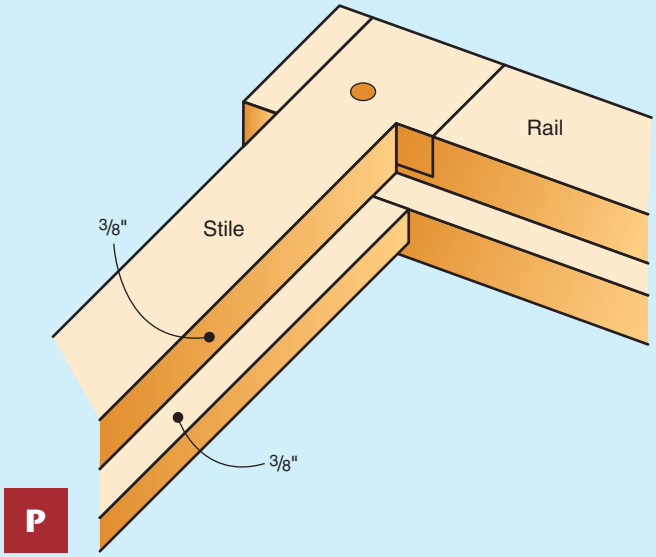
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21. Insert the four dowels with glue on them into the four holes, as shown in **Figure M**.
22. When the glue is dry, trim off the dowels with a flush-cut saw and then plane or sand them flush, as shown in **Figure N** and **Figure O**.

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23. Use a 3/8" rabbeting bit in the router to make a rabbet 3/8" deep on the inside of the frame, as shown in **Figure P** and **Figure Q**. Do this in a couple of passes. Square the corners up with a chisel, as shown in **Figure R**.

24. Sand and finish as desired.



P

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Q

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R

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PROJECT CHALLENGE

Peg Rail with Shelf



A

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Assembly list - Peg rail with shelf

Part	Dimensions (thickness × width × length)	Quantity
1. Bracket	$^3/_4$" × 6" × $9^1/_4$"	2
2. Shelf	$^3/_4$" × 8" × 33"	1
3. Peg rail	$^3/_4$" × 2" × 30"	1
4. Back rail	$^3/_4$" × $1^1/_2$" × 28"	1
5. Pegs	$2^1/_2$" long with $^5/_8$" tenons	6
6. Screws	# 8 × $1^1/_4$" # 8 × $^7/_8$"	10

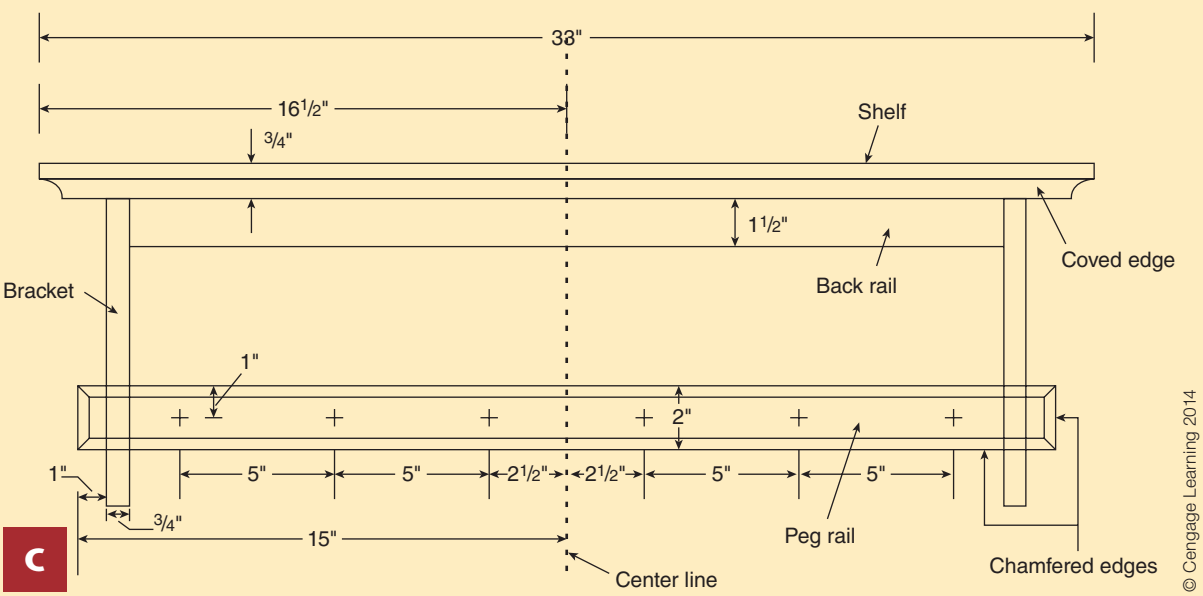
B

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Figure A shows the completed peg rail with shelf.

STEPS

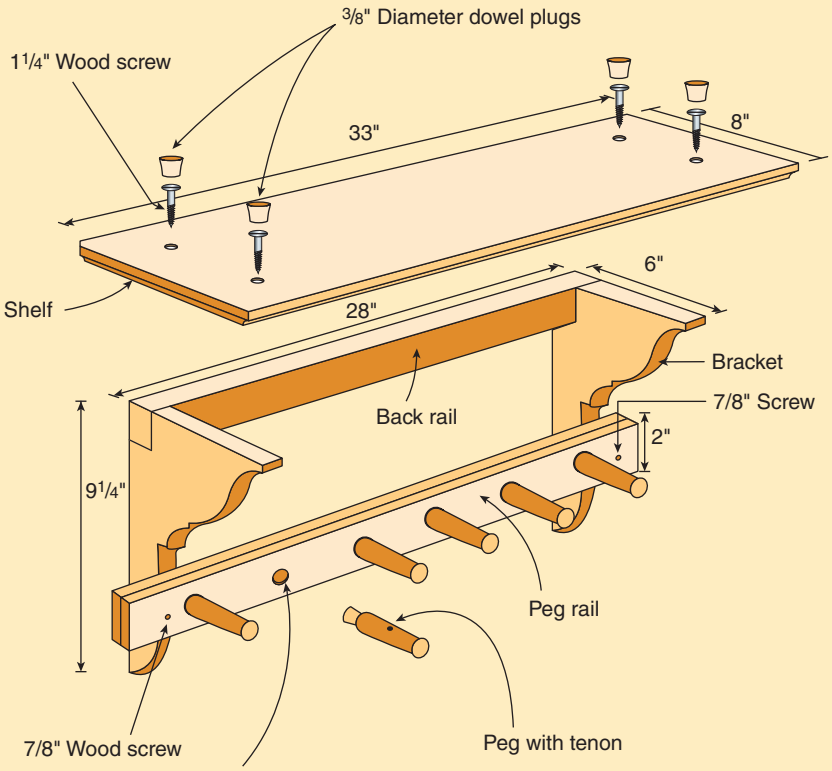
1. Referring to the Assembly List given in **Figure B**, and the diagrams of the peg rail with shelf shown in **Figures C** and D, make a rough layout of your pieces.



C

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2. Joint, rip, and crosscut all pieces to final size except for the brackets.
3. Lay out the holes for the pegs on the peg rail, using the front elevation drawing (**Figure C**) as a guide.



D

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E

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F

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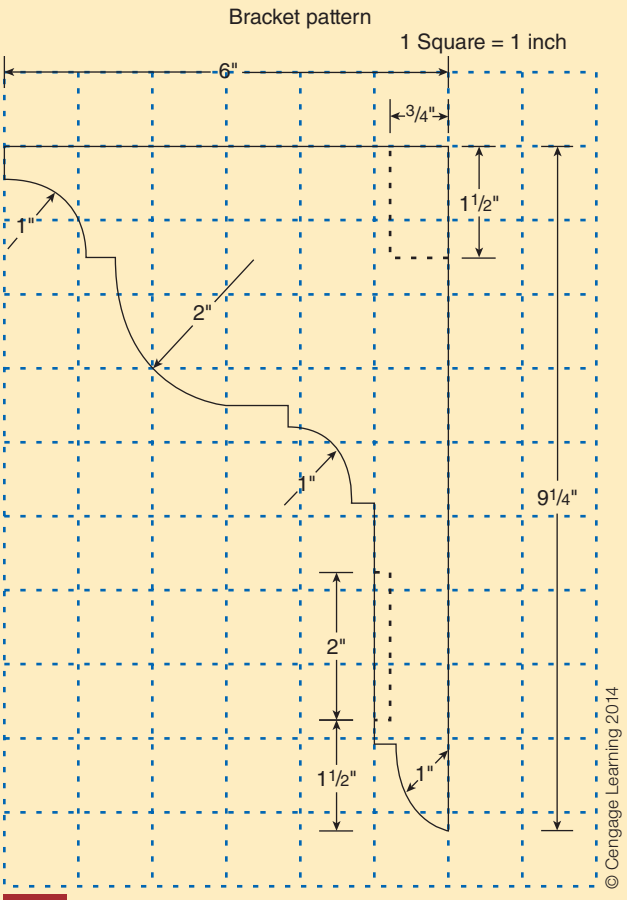
4. Using the drill press, drill 5/8" stopped holes 5/8" deep for the pegs, as shown in **Figure E**.
5. Using a router and a chamfering bit, rout the chamfer on the peg rail, as shown in **Figure F**.

6. Using a router and a half-inch coving bit, rout a cove on the two ends and front of the top piece, as shown in **Figure G**.



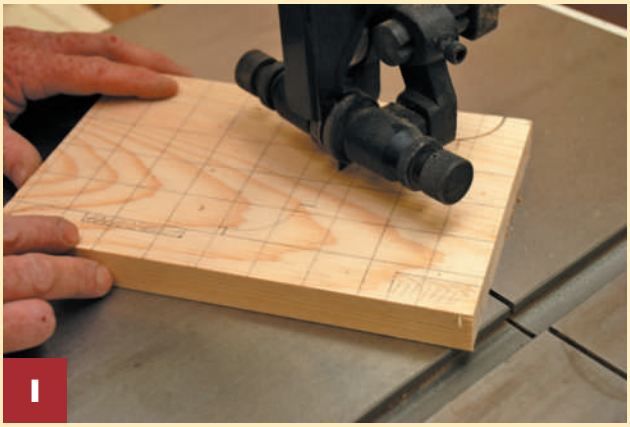
G

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H



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I

7. Lay out a grid on one end piece, and sketch in the shape, as shown in **Figure H**.
8. Cut out the end bracket you laid out on the band saw, as shown in Figure I. Trace it onto the other end blank and cut it out.
9. Dry assemble the rack and mark screw positions on the peg rail and top.
10. Drill 3/8" holes 1/4" deep with a flat-bottomed bit in the screw locations marked.
11. Reassemble the rack and drill 1/8" pilot holes for the screws.
12. Drill pilot holes for attaching the back rail to the brackets and countersink these holes.
13. Sand all the parts and screw the rack together.
14. Glue pegs in the peg holes.
15. Using a 3/8" plug cutter on the drill press make plugs.
16. Glue plugs in the counter-bored holes. When the glue is dry, plane and sand flush.
17. Finish as desired.

SECTION III


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Clamps, Fasteners, and Adhesives


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SUCCESS STORIES

Teresa Jenkins

Title

Owner of Teresa K. Jenkins Design, a studio furniture shop in Woodland Hills, California.

Education

Teresa has a degree in engineering from San Diego State University; she also did a formal apprenticeship with furniture maker Jeffrey Greene.

History

Teresa has always liked designing things — her introduction to woodworking was in a summer school program between eighth and ninth grades. But her first career didn't involve wood so much as metal. As an aerospace engineer for Northrop Grumman, she designed airplanes. When she moved to the East Coast, her options in the field were limited and she came back to the idea of woodworking. In 2003, she began a year-long internship with Jeff Greene, helping him build custom furniture for his clients. In 2004, she moved back to Los Angeles and opened her own design studio. Her nature-inspired, one-of-a-kind consoles and tables sell for $1200 to $1800. She has a few in stores but sells mostly directly.

On the Job

The mother of a young son, Teresa spends 20 to 30 hours per week in the shop. Her process begins with a vision of an item, usually inspired by nature, and then she begins deconstructing it and re-engineering it. She sketches it first, cuts the wood, then lays it out. This is an important step, she says, because "A lot of times you have an idea of what you want to do, but you get to the wood and it tells you what it wants to do instead. The final outcome depends what the wood dictates." She begins sanding and then building, which she finds to be the most laborious parts of the process. It can take her anywhere from a few days to a few weeks to finish a piece.



Image courtesy of Teresa Jenkins.

Best Aspects

"Seeing things from vision through to [the] final product is really cool," says Teresa. "When I first see it in my head, I'm never sure if I can make it work."

Challenges

Finding quality wood can be tough, particularly on the West Coast. Teresa bought most of her stash (300 board feet) in Virginia, where she was able to get more interesting varieties, like wormy maple, for half the price.

Importance of Education

Teresa credits her apprenticeship with giving her a strong foundation in woodworking. Among the lessons she learned there: how to mill to minimize waste; how to lay out patterns and build methodically; how to be safe in the shop; and, most importantly, "how to turn bare wood into beautiful furniture."

Future Opportunities

"I'd love to spend some time developing a number of design ideas I have," says Teresa. She'd also like find some other venues to sell her work, in galleries or design centers.

Words of Advice

"Network!" says Teresa. "Join organizations like the Furniture Society. Groups like this can teach you how to market and sell to galleries and clients."

Story originally written by Margaret Magnarelli, 2008. Interview and photo provided by Teresa Jenkins.



6

Clamps

You'll Learn

After studying the chapter, the student should be able to:

- Discuss the different uses for clamps
- Identify various types of clamps
- Select the appropriate clamps for different situations
- Explain proper clamping techniques
- Indicate the causes of glue stains and methods for avoiding them
- Explain how to clean up glue squeeze-out
- Discuss how to take care of clamps

INTRODUCTION

Woodworking and cabinet shops contain many different kinds of **clamps**. A clamp can be defined simply as a device used to hold one or more objects in a fixed position. Clamps are not an item many woodworkers get very excited about, but no one would argue with the necessity of having as many of them as possible. In this chapter, we will explore the multiple uses for clamps and then investigate some of the various types of clamps that are available for use. The proper use of clamps will be covered, as well as what causes glue stains and how to avoid them.

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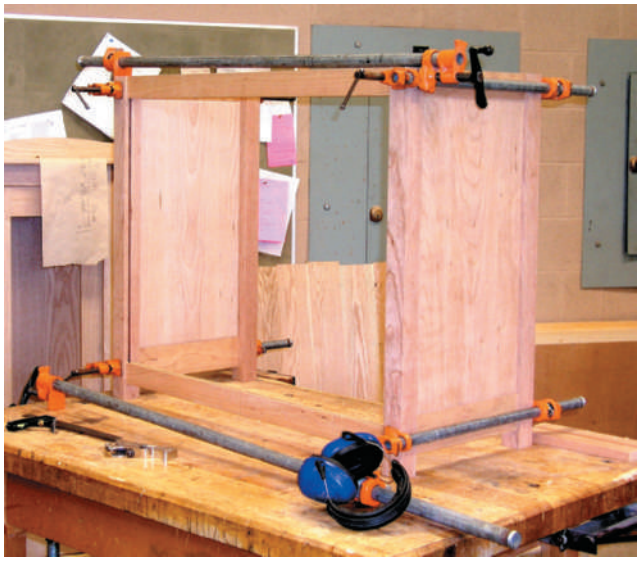
USES FOR CLAMPS

The first use for clamps that probably comes to mind is their primary one, which is to hold glue joints while the glue sets (see **Figures 6-1** and **6-2**).

But clamps are useful for other purposes as well, many of which are safety related. For example, when machining a small part, if it is held in a clamp, it is possible to keep your hands out of the danger zone (see **Figure 6-3**).

Clamps may be used to hold pieces while using hand tools as well (see **Figure 6-4**). Again, this is a safety measure, and it also keeps pieces more securely in place than simply holding the piece by hand. It allows the worker to bring full concentration to the task at hand.

Feather boards and stop blocks are held by clamps as well. **Feather boards** are used to keep work down on a machine table and also against the fence, creating safer and more accurate cuts. **Stop blocks** are used to make repetitive cuts of the same length and to limit cuts. See **Figures 6-5** through **6-7** for examples of feather boards and stop blocks in use.



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FIGURE 6-1 Clamps are used to hold glue joints.



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FIGURE 6-2 Glued and clamped panel.



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FIGURE 6-3 Clamps can be used to hold a small piece during machining.



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FIGURE 6-4 Clamps are useful for holding work while using hand tools.


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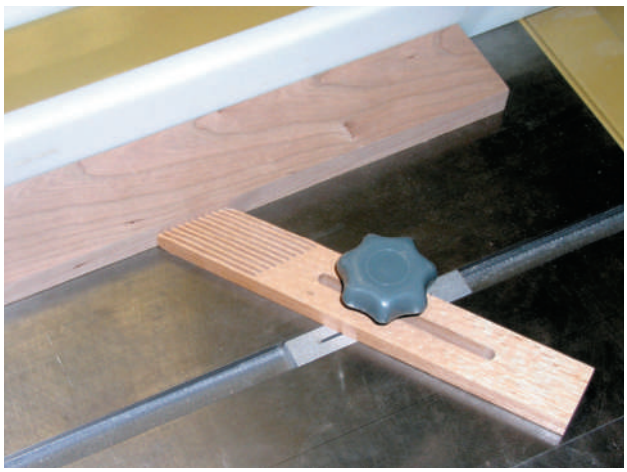

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FIGURE 6-5 Feather boards are used to keep stock down on a machine table and against the fence.


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FIGURE 6-6 Stop block used for repetitive cuts to block.

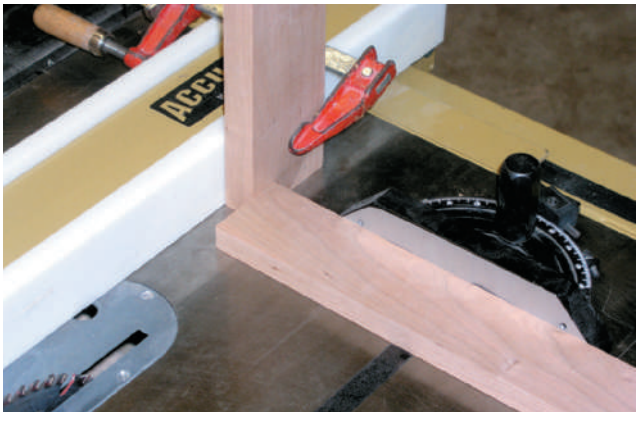
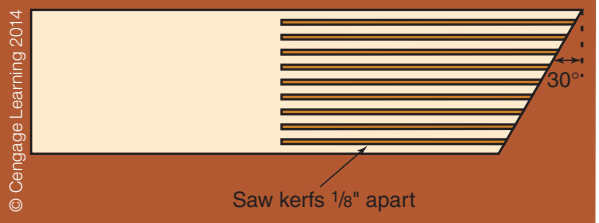

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FIGURE 6-7 Stop block used to limit cuts.

WOODWORKING TIP:

Make your own feather boards. Start with a piece of 1/2″ or 3/4″ solid stock that is 10″ or longer. Using a band saw, make a series of cuts spaced 1/8″ apart about 4″ into the piece. Then cut off the end of the board at a 30° angle, as shown in **Figure 6-8**.



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FIGURE 6-8 Featherboard diagram.

Clamps are also used to hold jigs in place, to secure a fence, or to hold a piece in a jig. They can be used to temporarily hold pieces in place for marking or simply to see how something might look (see **Figures 6-9** through **6-12**). A **jig** is any custom-made accessory that increases the accuracy, speed, or safety of a task. Jigs may be simple or complex.

It is helpful to think of clamps as an extra set of hands. They allow the cabinetmaker to work both more safely and more accurately.

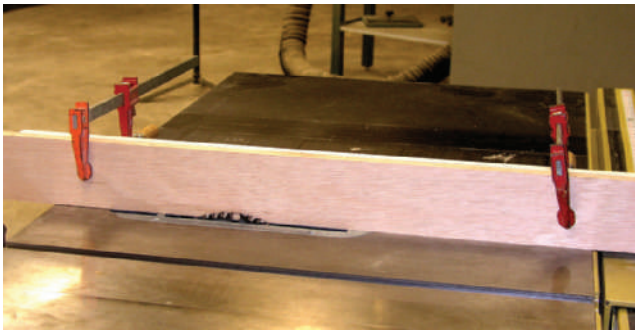
TYPES OF CLAMPS

Clamps come in many shapes and sizes. Some can be used for many situations, but others have very specific uses. Some clamps are expensive; others can



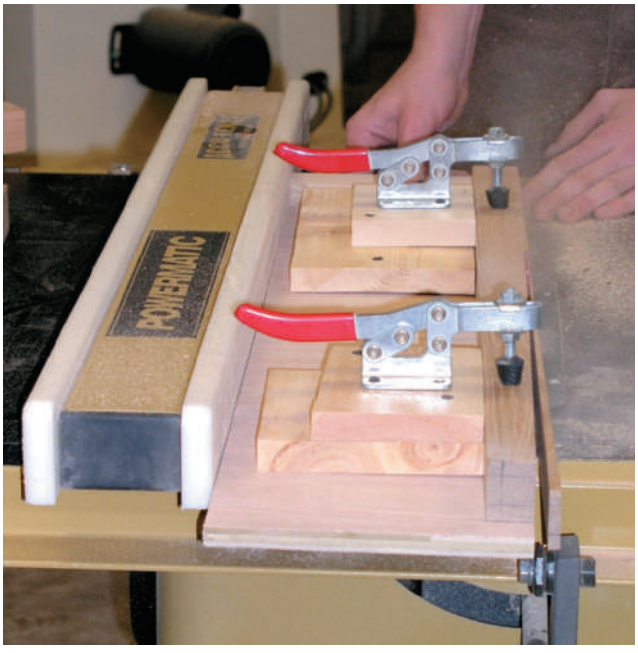
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FIGURE 6-9 Clamps may hold a jig in place.



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FIGURE 6-10 Clamps used to secure a sacrificial fence.



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FIGURE 6-11 Clamps secure a piece to a jig.

be improvised. Different types of clamps include bar clamps, pipe clamps, C-clamps, spring clamps, web clamps, band clamps, toggle clamps, and miter clamps. Other methods of clamping include hand screws, bench vises, bench hold-downs, and vacuum



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FIGURE 6-12 A piece is temporarily held in place with clamps for marking.



Image provided by BESSEY Tools North America

FIGURE 6-13 Bar clamps.

clamping. Clamps that can be built in the shop include cam clamps, wedge clamps, and veneer presses. Improvised clamps can be made from tape, rubber bands, and string.

Steel **bar clamps** are primarily used for edge-to-edge gluing and for assembling cabinets and furniture. Bar clamps consist of a bar with two jaws. Typically, one jaw is connected to a clamp head at one end of the bar and can only be moved a short distance; the other is movable along the whole length of the bar. Common lengths are from 2 to 8 feet. The more movable jaw of the clamp has a friction catch to keep it in the desired location once it is slid into place; the other end has a screw-type mechanism for applying pressure. Lighter-duty bar clamps may have the friction catch and the tightening screw on the same jaw. In this case the other jaw is fixed (see **Figure 6-13**). When using bar clamps, the screw end should be completely retracted and the friction catch brought to bear on the surface

to be clamped. Then pressure is exerted on the joint by tightening the screw. Bar clamps can damage surfaces, and finished surfaces should be protected with scrap placed between the jaws of the clamp and the material. It is also important that the clamping pressure be centered properly on a panel being glued up. This may mean raising the assembly in the clamps (see **Figures 6-14** and **6-15**).

Some light-duty bar clamps have plastic jaws, which help protect surfaces. These clamps work by a ratcheting mechanism, which is activated by squeezing the handle (see **Figure 6-16**).

Pipe clamps are similar to bar clamps except that a steel pipe rather than a bar holds the jaws. The clamp units that fit on pipe clamps are purchased separately and will fit on pipes of any length, making it possible to make clamps of various lengths. Units can be purchased for 3/4 or 1/2-inch diameter pipe. The pipe has to be threaded for a short distance on both ends to take the clamp fixtures (see **Figure 6-19**).

The same cautions about damaging surfaces and properly distributing clamping pressure apply to pipe

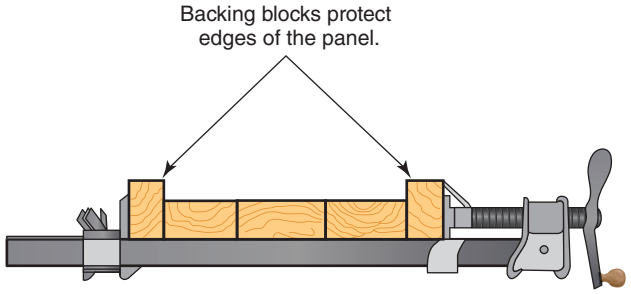


FIGURE 6-14 Protecting surfaces with scrap blocks.

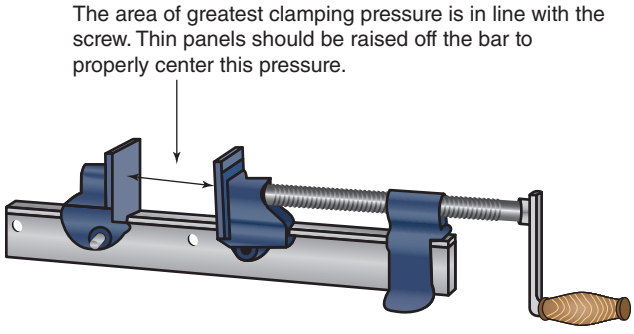


FIGURE 6-15 Clamping pressure should be centered on the panel.



FIGURE 6-16 Light-duty bar clamps with plastic-covered jaws and racheting handle.

WOODWORKING TIP:

A basic jig can aid in clamping frame assemblies so that they are square. The jig has a 3/4" flat panel base to which two cleats are glued and screwed at exactly 90° to one another. Use a framing square to get them precisely positioned. To use, place the frame against the cleats and clamp. A few coats of polyurethane applied to the jig will keep frames from sticking to it. ***Figure 6-17*** *and* ***Figure 6-18*** *show how to build and use this jig.*

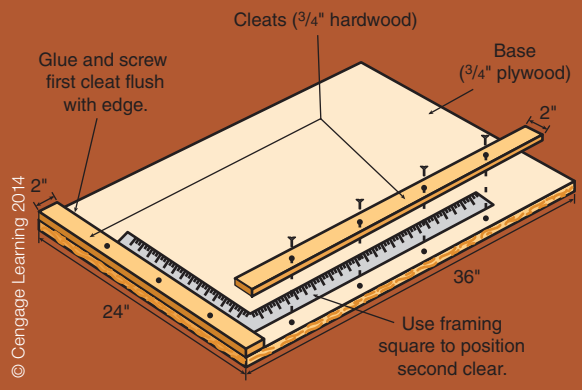


FIGURE 6-17 Frame-squaring jig.



FIGURE 6-18 Using frame-squaring jig.



Image provided by BESSEY Tools North America

FIGURE 6-19 Pipe clamps.

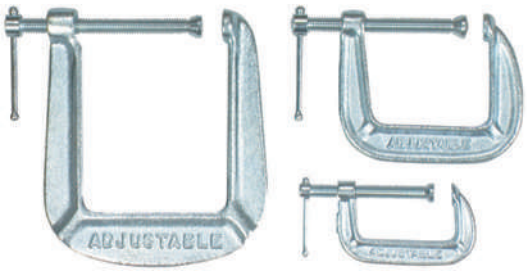
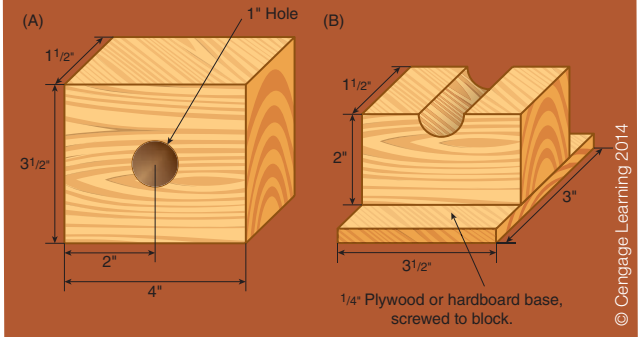


Image courtesy of Adjustable Clamp Company, www.adjustableclamp.com

FIGURE 6-21 Assortment of various sized C-clamps.

WOODWORKING TIP:

Pipe clamps can be frustrating when you are gluing up a panel, because they have a tendency to roll. Making some saddles like the one shown in **Figure 6-20** *solve this problem. To make one pair of the saddles, drill a 1″ diameter hole in the center of a 4″ length of 2″ × 4″ stock and then saw it in half. If you line the notch with a piece of bicycle inner tube, it will keep the clamp from sliding. The attached base lends stability to the saddle.*



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FIGURE 6-20 Pipe clamp saddle.

clamps as they do to bar clamps. Pipe clamps are used for the same functions as bar clamps, but they are less expensive.

C-clamps are metal clamps that are shaped like the letter *C*. They are sometimes called *carriage clamps*. The C-shaped frame has a machine screw, which is tightened to produce the clamping action. C-clamps come in many sizes (see **Figure 6-21**). They have a swiveling foot at the end of the screw that



Image provided by BESSEY Tools North America

FIGURE 6-22 Three-way edging clamp.

will move to allow tight clamping pressure against a slanting surface or an irregularly shaped piece. They can be used to secure jigs or material to benches, as well as for gluing joints. Again, the material should be protected. Another clamp that was developed out of the basic C-clamp is the three-way edging clamp (see **Figure 6-22**). It is useful for gluing edging in place.

CAUTION

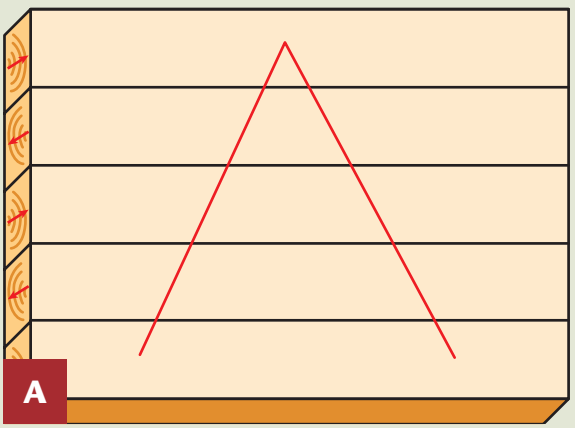
Store clamps that are not in use. Falling clamps can cause injury, and clamps left on the floor create a tripping hazard.

PROCEDURE 6-1

Clamping a Wide Panel

STEPS

1. Rip and joint boards to be used in the panel. Cut 1 or 2 inches longer than the finished length of the panel, and allow extra width as well.
2. Arrange boards in a pleasing pattern with growth rings alternating, and mark for easy reassembly, as shown in **Figure A**.
3. Place bar or pipe clamps on a flat surface and put the boards on it. There should be clamps near either end, spaced 10 to 16 inches apart, as shown in **Figure B**.
4. Turn all the boards but the last one on edge and apply glue, spreading it evenly, as shown in **Figure C**.



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D

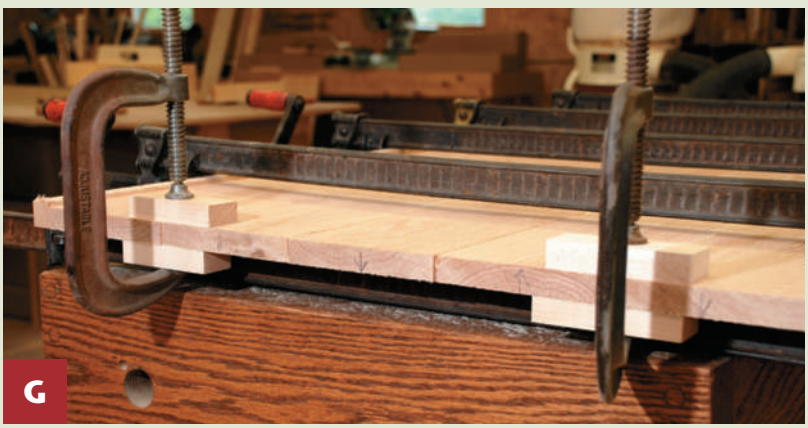
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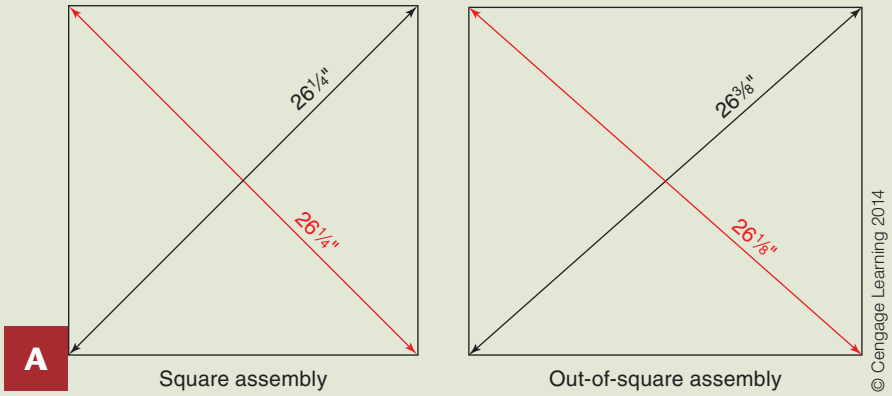
5. Lay the boards back down on the clamps and snug up the clamps, tapping the boards with a mallet if necessary to get them properly aligned. To avoid marring the edges of the panel, use scrap material on either side of the panel, as shown in **Figure D**.
6. Place clamps over the top of the panel, spacing them between the bottom clamps; snug them up, as shown in **Figure E**.
7. Go through and tighten all the clamps. They should all be snug.
8. If any of the joints are not flush, use hand screws on either end of the joints or cauls and C-clamps, as shown in **Figure F** and **Figure G**.

PROCEDURE 6-2

Squaring Up an Assembly

STEPS

1. Check a glued assembly to see if it is square by measuring diagonals. If they are the same, it is square. This is shown in **Figure A**.
2. If the assembly is out of square, place a clamp across the long diagonal. Corners can be protected by using blocks, as shown in **Figure B**.
3. Slowly tighten the clamp, and check the diagonal measurements again. Continue until the assembly is square, as shown in **Figure C**.



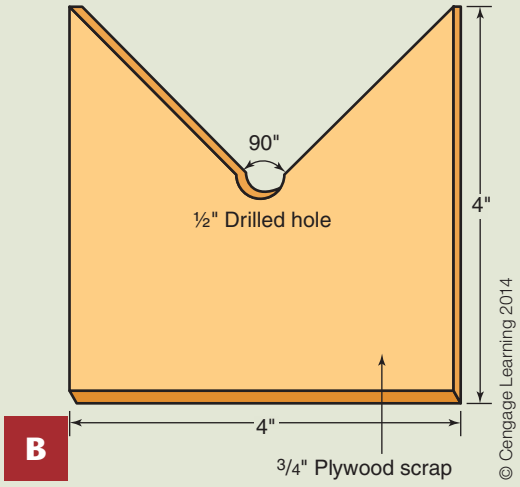






Image provided by BESSEY Tools North America

FIGURE 6-23 Spring clamps of different sizes, with and without plastic caps.



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FIGURE 6-24 Web clamp.



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FIGURE 6-25 Band clamp with 90° corner blocks.

Spring clamps operate like a large clothespin. Clamping pressure is constant, depending on spring tension. They are available in various sizes and are good for clamping on trim or holding thin pieces together. They may have serrated teeth to help them grip objects held at irregular angles; or they may have soft plastic ends to prevent marring. Some clamps have serrated teeth covered by plastic caps that can be removed if gripping pressure is required (see **Figure 6-23**).

Web clamps and band clamps are similar. **Web clamps** are lighter duty than band clamps and use a cloth webbing strap that is an inch wide. **Band clamps** use cloth webbing that is 2 inches wide or a steel band. In either case, pressure is toward the center of the assembly. Both types allow the clamping of items when the surfaces to be clamped are not parallel to each other, when multiple surfaces are involved, or when clamping pressure is required from multiple directions at once. Places where a web or band clamp does a good job are clamping the staves of a barrel or clamping stretchers between the legs of a chair (see **Figure 6-24**). Clamping pressure is applied by a screw or ratchet mechanism, which tightens the web or band.

Some web and band clamps include 90° corner blocks that can be moved to fit around frames. This is an efficient way to clamp up some types of frames, as the band clamp will take the place of several bar or pipe clamps (see **Figure 6-25**).

WOODWORKING TIP:

Before you start spreading glue and beginning to put an assembly together, take the time to get out all the clamps you will need and do a dry fit. This allows you to make sure you have enough clamps and to pre-set them so that they can be put on quickly. It also enables you to spot and correct any problems, like a poorly fitting joint, prior to getting glue on everything.

Toggle clamps are used primarily for holding pieces in jigs while they are machined. Several types are available. All toggle clamps have a quick-release handle of some sort that allows pressure to be applied or released by simply moving the handle to the on or off position. Most come in a few different sizes, offering different degrees of holding ability. Perhaps the most widely used are hold-down clamps (see **Figure 6-26**). These hold-downs can be adjusted in and out on the arm, and the threaded spindle is adjustable for varying thicknesses of material.

These hold-downs greatly increase the safety of operations by securely holding a piece in place and keeping the operator's fingers well out of the way. Different handle configurations are available.

Another type of toggle clamp is a straight-line clamp. These provide a pushing action (see **Figure 6-27**). These clamps are useful in gluing jigs and also in holding pieces for machining. They can be adjusted by moving the hex nut.

Miter clamps are designed specifically for clamping frame miter joints (see **Figure 6-28**). Frame miter joints, the kind used in picture frames, have a tendency to slide out of position when regular bar or pipe clamps are used. Other clamps that are useful for clamping miter joints that will also work with other types of frame joints are shown in **Figures 6-29** and **6-30**.



Image courtesy of MSI-PRO

FIGURE 6-26 Hold down toggle clamp.



Image courtesy of MSI-PRO

FIGURE 6-27 Straight-line toggle clamps.



Image provided by BESSEY Tools North America

FIGURE 6-28 Miter clamp.



Image courtesy of rockler.com

FIGURE 6-29 Frame clamp.



Image courtesy of rockler.com

FIGURE 6-30 Another type of frame clamp.

WOODWORKING TIP:

Figure 6-31 shows shop-made miter clamps in use. Each one was made by cutting a 3/4″-thick block at a 45° angle and then gluing and screwing a 3/4″-wide piece of 1/4″ plywood to it. One of these was clamped to each mitered piece and a clamp was placed across the blocks to draw the joint tight.



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FIGURE 6-31 Shopmade miter clamps.

Hand screws are one of the oldest cabinetmaking clamps. These clamps have parallel wooden jaws, and for this reason are sometimes called *wooden parallel clamps*. The two jaws are connected by two screws, which have wooden handles on their ends. Hand screws have a deep reach, or throat. They are available in a range of sizes, in lengths from 4 to 24 inches, with a maximum opening from 2 to 17 inches. **Figure 6-32** shows the configuration of a hand-screw clamp. This type of clamp can be rapidly opened and closed by swinging the clamp while holding your arms extended; with a simple wrist movement, the jaws of the clamp may be revolved around the threaded spindles.



Image courtesy of Adjustable Clamp Company, www.adjustableclamp.com

FIGURE 6-32 Hand-screw clamp.

When using wooden parallel clamps, it is important to keep the jaws of the clamp parallel to one another for even clamping pressure. They are used for gluing stock face to face, as when a leg blank is being glued up. They are also good for many other clamping jobs. Do not assume that because the jaws are wooden they cannot damage your material. Be careful to check the jaws for dried glue and keep them clean.

Bench vises provide another method of clamping. A bench vise is an integral part of the woodworker's bench (see **Figure 6-33**). It is a mechanical screw apparatus used for holding a piece so that work may be performed on it, such as sawing, planing, or chiseling. A bench vise has two jaws, one of which is fixed; the other moves in relation to the first by means of a screw device. The jaws are either wooden or metal faced with wood to avoid marring the material being worked. The top edges of the jaw are typically flush with the benchtop.

Bench vises are used to secure material being worked on at the bench and can also be used for small clamping jobs by themselves or for larger jobs when



Image courtesy of Lee Valley Tools, Ltd.

FIGURE 6-33 Bench vise.

used in conjunction with **bench dogs**. Bench dogs are small, movable jaw faces that mount in holes in a benchtop to extend the capacity of a vise. They may be round or square, wood or metal. Most bench vises have pop-up dogs designed to be used with bench dogs (see **Figures 6-34A**, **6-34B**, and **6-35**).

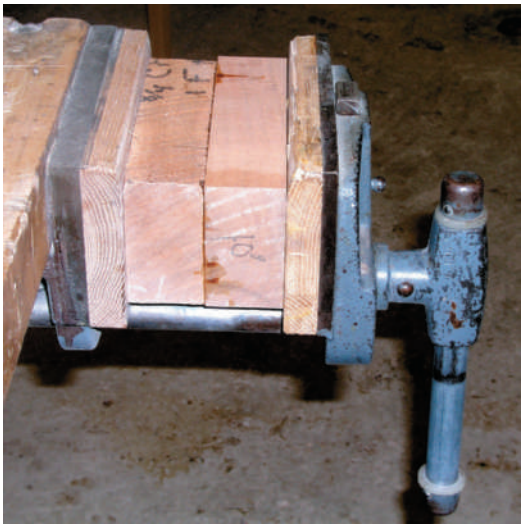
Holdfasts are not used in gluing but are very useful for holding material in place on the workbench. A holdfast has a metal shaft that mounts in a hole in the bench and an arm that is placed over the item to be held. Once positioned, it is struck with a mallet to set it firmly in place (see **Figure 6-36**).

Vacuum clamping is a method of holding material through atmospheric pressure. The air between the workpiece and its support is suctioned out using a vacuum pump, causing immense downward pressure on the work, which holds it securely in place. There are several advantages to vacuum clamping over regular mechanical clamping. It does not mar the work piece, and it is strong. Pressure of up to 1800 pounds per square foot can be exerted; this pressure is even and uniform. Vacuum clamping is faster than regular



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FIGURE 6-34A Bench vises may clamp material being worked on.



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FIGURE 6-34B Bench vises may perform small glue-ups.



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FIGURE 6-35 Using a bench vise with bench dogs allows gluing up larger pieces.



Image courtesy of Lee Valley Tools, Ltd

FIGURE 6-36 Bench holdfasts.

WOODWORKING TIP:

Holes in a workbench may be square or round. If they are round, it is easy to make your own bench dogs. Simply get a length of dowel the same diameter as the holes in the bench, typically 3/4", cut it into 3" or 4" lengths, and cap it with a rubber cane tip. The cane tip will keep the dowel from dropping through the bench and also protect the wood surfaces of your projects.

clamps, since it is either on or off. No time is lost in setting and resetting clamps. This method of clamping is especially useful for template routing, because there are no obstructions; a complete pass can be made without any interference, which also makes it safer. One disadvantage of vacuum clamping is that the piece being worked must have a relatively flat back. **Figure 6-37** shows a vacuum clamp in use.

Vacuum presses are used in veneering work. The concept is the same as with vacuum clamping, but the work is placed in a heavy plastic bag that is completely sealed. Air is suctioned out of the bag with a vacuum pump. Forms can be built that allow the cabinetmaker to veneer curved work (see **Figure 6-38**).

Clamps that can be built in the shop include cam clamps, wedge clamps, and veneer presses. Cam clamps are made up of a *locator board, fence,* and *cams.* The locator board is a flat piece of sheet material with holes drilled through it to accept the pin of the cam. A **cam** is an eccentrically shaped wheel with a pin for placement in a hole in the locator board. In other words, it is not perfectly round. The assembly to be glued is placed against a fence, also secured in the holes on the locator board, and then the cams are inserted and turned to exert pressure against the workpiece into the fence (see **Figure 6-39**).



Image courtesy of M. POWER Tools, Inc.

FIGURE 6-37 Vacuum clamping allow machining without obstruction.



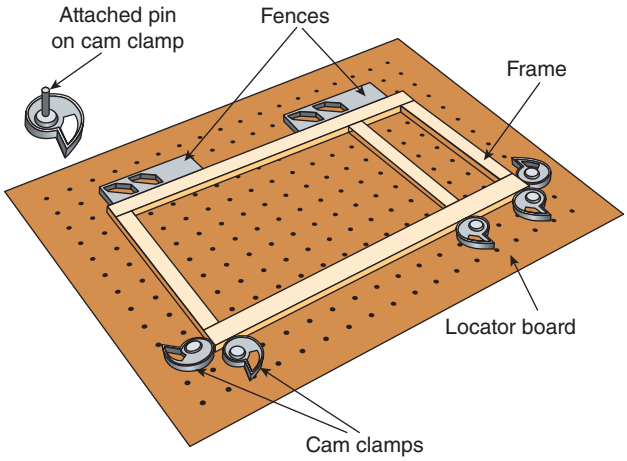
Image courtesy of rockler.com

FIGURE 6-38 Vacuum press.

Wedge clamps work well for clamping frames and can be built to suit whatever size frame is being glued. They consist of fences attached to a bottom board. The bottom board should be laminated or finished and waxed to prevent the frame from sticking to it. The frame is placed inside the fences, and then pairs of wooden wedges are driven past each other to bring the joints of the frame snug (see **Figure 6-40**).

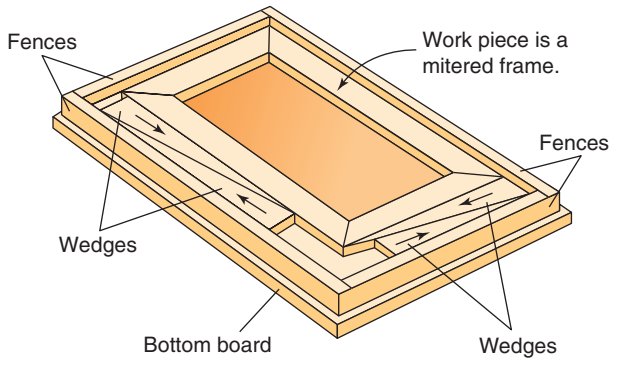
A veneer press is used for attaching veneer to a substrate or to clamp inlaid panels. Press screws are purchased and set into a frame; the material to be clamped is placed between a top board and a bottom board, and the press screws are tightened down. The top board distributes pressure across the assembly. See **Figures 6-41A** and **6-41B** for an illustration of a veneer press and the press screws used in constructing veneer presses.

If you encounter a situation where you do not have the necessary clamps for a job, you may choose to improvise. Improvised clamps can be made from tape, rubber bands, flexible plastic tubing like bicycle inner tubes, rope, and string. If not much pressure is needed to hold items together while glue sets, masking tape works well; duct tape also works. Rubber bands of different sizes are also useful for clamping



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FIGURE 6-39 Cam clamps.



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FIGURE 6-40 Using wedge clamps.



Image courtesy of Adjustable Clamp Company, www.adjustableclamp.com

FIGURE 6-41A Veneer press.



Image courtesy of Adjustable Clamp Company, www.adjustableclamp.com

FIGURE 6-41B Press screw.

small items, and these are especially good for clamping irregular pieces. A stick may be placed so that by turning it, more pressure is brought to bear. Spring-type clothespins may be handy in some situations. Notice that one of the advantages of the improvised clamps described is that they will not mar the wood.

Avoiding Glue Stains

Unsightly glue stains can be a problem when using metal clamps, especially when a water-base glue is used. A reaction occurs between the water in the glue, the iron in the clamps, and the **tannin** in the wood to form a stain, which may be blue, blue black, or green to greenish black. Tannin is a chemical compound found in wood. The higher the tannin content of the wood, the more likely this is to occur; for example, the tannin content of oak is particularly high.

Glue stains can be avoided in a few different ways. One way is to keep the piece being glued out of contact with the body of the clamp. A second way is to spread wax paper between the clamps and the work piece. A third method is to cover the pipe or bar of the clamp with masking tape. Glue stains are primarily a problem with glued-up panels.



HISTORY FACT

Tannins are an important ingredient in the process of tanning animal hides into leather. The word tannin comes from the medieval Latin word *tannum,* which means oak bark. Oak bark has traditionally been the primary source of tannery tannin. ■

Cleaning Up Glue Squeeze-Out

There are three methods for cleaning up the excess glue that is squeezed out of joints by the clamping process. One way is to flush it off while the glue is still wet. The second is to wait until the glue is completely dry and chip it off. The third method is to scrape the glue off when it is partially but not completely set.

If the squeeze-out is flushed off while the glue is still wet, care must be taken to do a thorough job. If the glue is not completely removed but only thinned, it will seal the pores, and problems will be evident when stain or finish is applied.

Waiting until the glue has cured and then chipping it off with a chisel or scraper may cause wood fibers to be torn out along with the excess glue, necessitating a lot of sanding or even repairs.

Perhaps the best way to clean up glue squeeze-out is to wait until the glue has filmed over but not completely hardened. At this point, it will come off fairly easily with a chisel or scraper without taking extra wood with it.

Taking Care of Clamps

The primary issue in taking care of clamps is keeping them clean. Glue buildup should be cleaned off regularly. Heads should slide easily, and screws should turn without undue pressure. Pipe clamps can be bent by over-tightening, and bent pipes should be replaced. Clamps should be stored out of the way, lest they fall and injure either you or a piece you are working on. It is handy to store your clamps in an organized manner so that you can easily access them.

PROCEDURE 6-3

Keeping Assemblies Flat


A

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B

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STEPS

1. Assemblies must be flat as well as square. Clamp up the assembly on a flat surface.
2. Check to see whether the assembly is flat; it should be touching the assembly surface at all points. You can also check for flatness by placing two equal-sized sticks on the top of the assembly and sighting across them horizontally. If the sticks appear parallel, the assembly is flat; this is shown in **Figure A**. These sticks are called *winding sticks*, and if they are contrasting colors, they are easier to use.
3. If the assembly is not flat, clamp it down to the table or weight it down until it is flat. See **Figure B**. Leave the assembly clamped or weighted down until the glue is dry.



Summary

A variety of different types of clamps may be found in a woodshop. Clamps are used for gluing projects together, holding a piece being worked on, and holding jigs and safety devices such as feather boards in place. It is much safer to work on something that is being held securely in place by a clamp or two rather than holding the piece in your hands. You can think of clamps as extra hands, freeing you up to put your entire attention on the job at hand. Different clamps are appropriate for different clamping operations. Keeping your clamps clean and well organized will make your work easier.



Key Terms

band clamps
bar clamps
bench dogs
bench vises
cam
C-clamp
clamps
feather boards
hand screws
holdfasts
miter clamps
pipe clamps
spring clamp
stop blocks
tannin
toggle clamp
vacuum clamping
web clamps

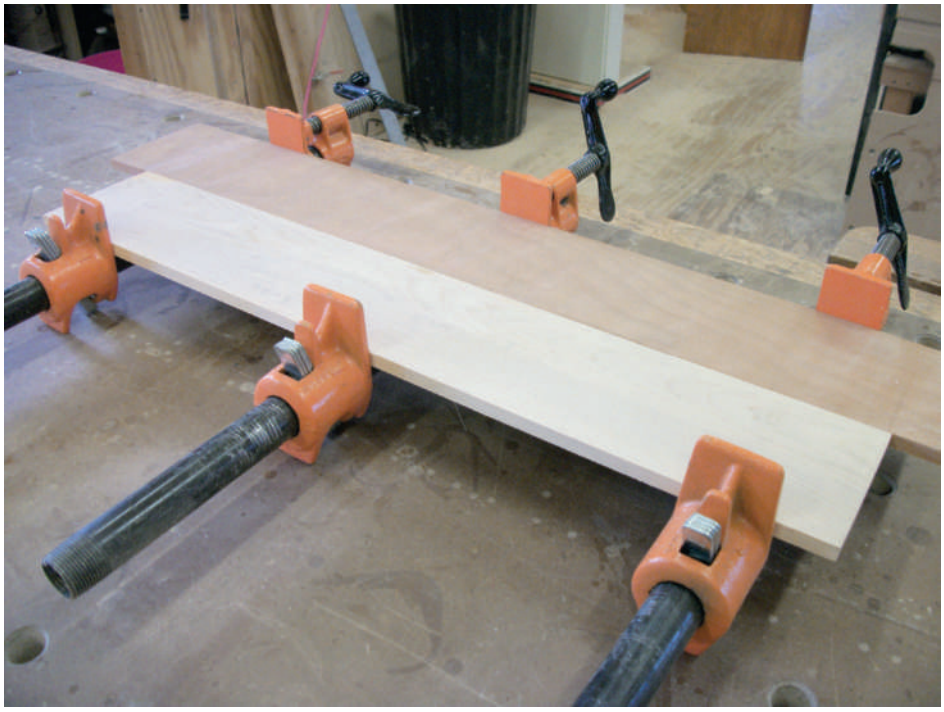


Check Your Knowledge

1. List three things clamps are used for.
2. Name five different kinds of clamps and explain how they differ.
3. How can you avoid marring a workpiece with clamps?
4. When using hand screws, why is it important to keep the jaws parallel to one another?
5. What advantages does vacuum clamping offer?
6. Name a safety device that might be secured with clamps to help keep a workpiece flat on a machine table.
7. Why should you clamp a piece that you are working on to a table?
8. What is the single most important thing you can do to maintain your clamps?
9. Why does keeping your clamps organized make good sense?
10. Discuss the three methods for cleaning up glue squeeze-out.



What's Wrong with This Picture?



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BUILD IT!

C-Clamp Rack

A completed C-clamp rack is shown in **Figure A**. This rack is for 4″ C-clamps, but you can make racks for larger or smaller C-clamps by varying the spacing of the dowels.

TOOLS REQUIRED

- Measuring tool
- Squaring tool
- Drill press, 1/8″ bit, countersink bit, and 3/4″ bit
- Table saw
- Miter saw
- Plane
- Drill

MATERIALS REQUIRED

- Scrap of 3/4″ plywood or solid stock, approximately 4″ × 14″
- Dowel stock 3/4″ × 12″ long
- Screws

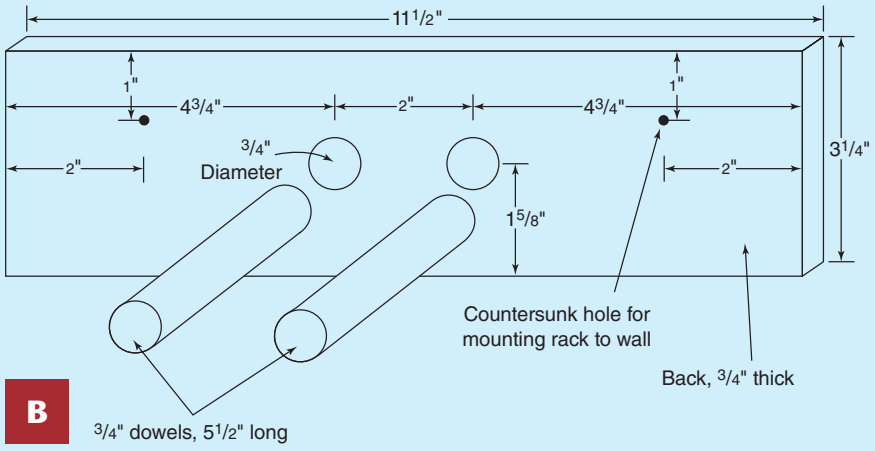
PROCEDURE

1. Using the table saw and the miter saw, size the 3/4″ piece to 3 1/4″ wide by 11 1/2″ long.
2. Lay out the positions for the holes, consulting **Figure B** for the dimensions.



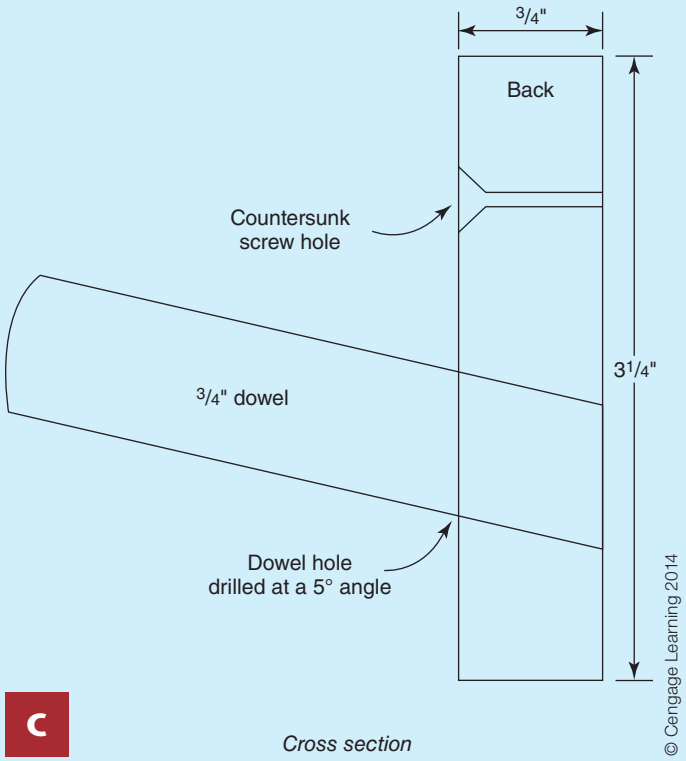
A

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B

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C

Cross section

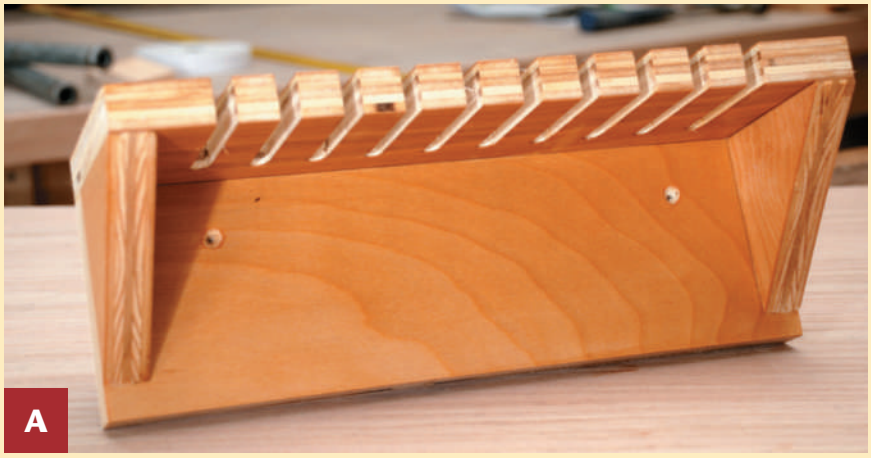
3. Drill the mounting holes using an 1/8" bit and then countersink the holes.
4. Tilt the drill press table to 5° and drill the two 3/4" holes you marked out, as shown in **Figure C**. Make sure you have a backer board beneath the piece you are drilling, and drill all the way through your piece.
5. Cut the dowel into two 5 1/2" lengths.
6. Glue dowels into the board. They will protrude a bit through the back due to the angle at which the holes were drilled.

BUILD IT!

PROJECT CHALLENGE

Clamp Racks for Bar Clamps and Pipe Clamps

The completed racks are shown here: **Figure A** shows the small-bar clamp rack, **Figure B** shows the large-bar clamp rack, and **Figure C** shows the pipe clamp rack.



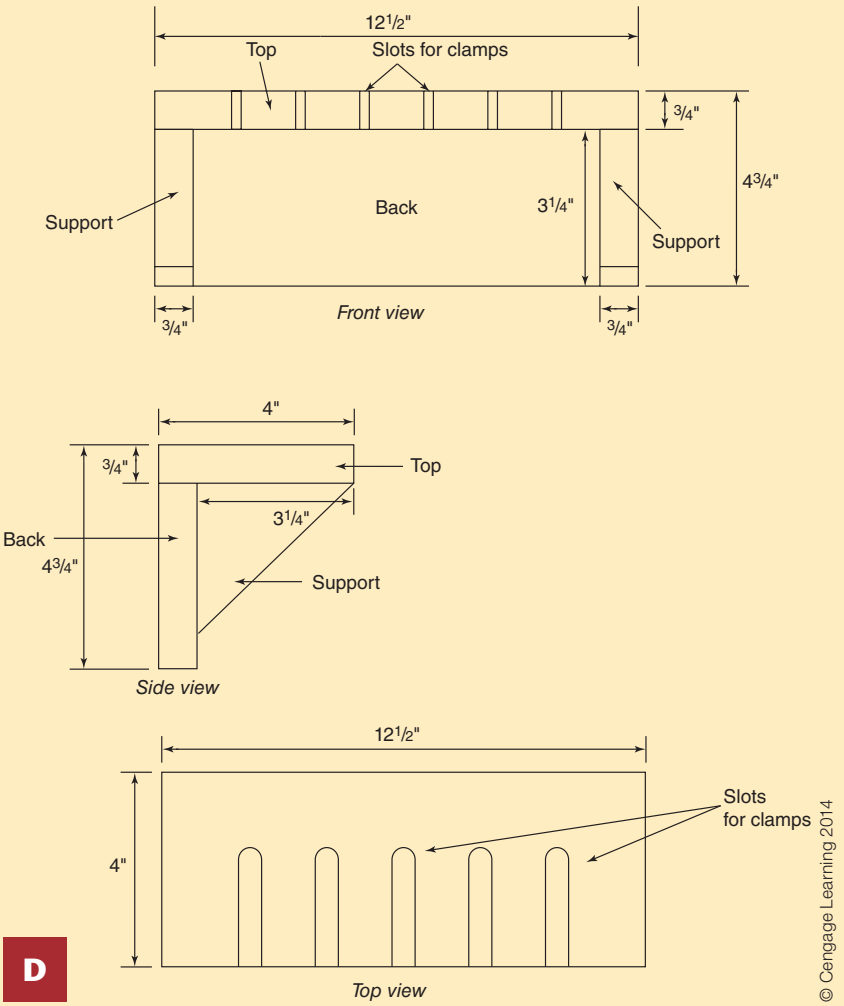
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D

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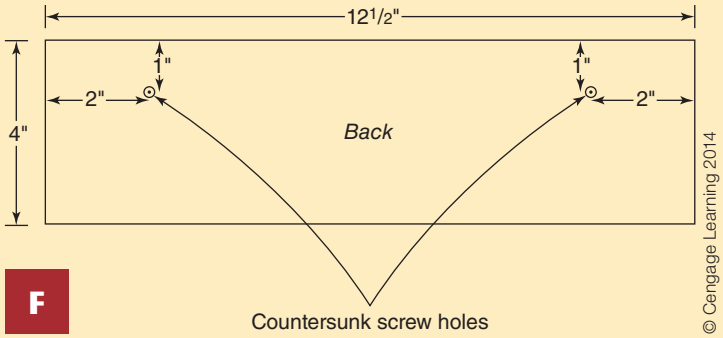
E

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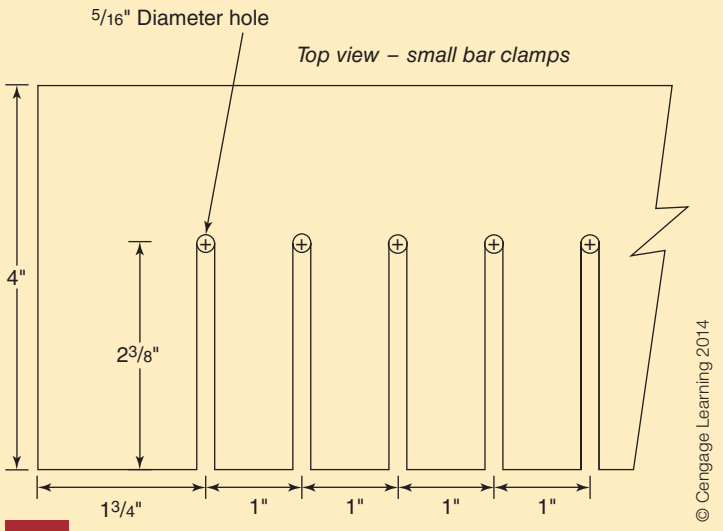
PROCEDURE

1. Either 3/4" plywood scrap or 3/4" solid stock can be used to make these racks. For each rack, you will need two 4" × 12 1/2" pieces. Mill these to size on the table saw and miter saw, as shown in the plan in **Figure D**.
2. Rip another piece of material to a width of 3 1/4" for the supports.
3. Cut the support pieces on the miter saw with the saw set to make 45° cuts (see **Figure E**).

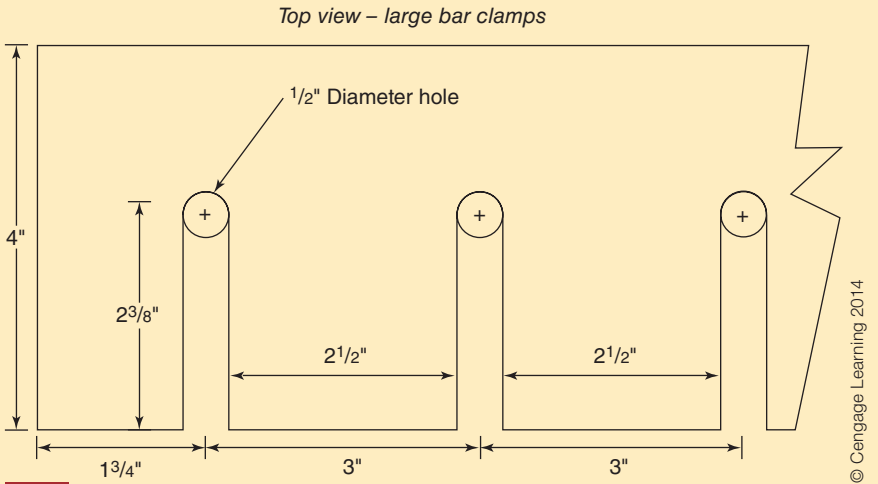
4. Drill 1/8" countersunk holes for mounting the racks to the wall in each back piece, as shown in **Figure F**.
5. Take the top pieces and lay out the slots for the clamps. The size of the slots and their spacing depends on the type of clamp the rack will hold. See **Figures G, H**, and **I** for three common types.



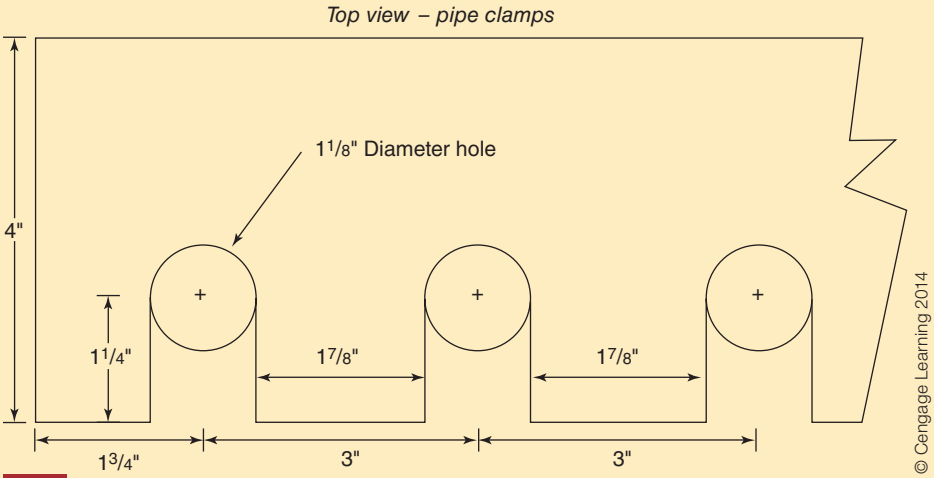
F



G



H



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I



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J



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K

6. Using the drill press, drill holes as indicated by your layout marks.
7. Cut out the waste material using a band saw or a miter gauge on the table saw equipped with a tall, auxiliary fence, as shown in **Figure J**.
8. Glue and nail the rack together. Use a pneumatic finish nailer to make it fast and easy, as shown in **Figure K**.
9. Screw the racks to the wall and hang up your clamps.



7

Fasteners

You'll Learn

After studying the chapter, the student should be able to:

- Explain the purposes fasteners serve in furniture- and cabinetmaking
- Identify the different types of fasteners used in cabinet and furniture construction
- Demonstrate knowledge of the terminology associated with different fasteners
- Understand the proper use, selection, and installation of various fasteners

INTRODUCTION

Although quality furniture uses few metal fasteners, fasteners do have a place in the construction of furniture and cabinets. There are four primary purposes for using fasteners: to fasten two or more objects together, to strengthen a joint, to secure a project in place, and to attach hardware.

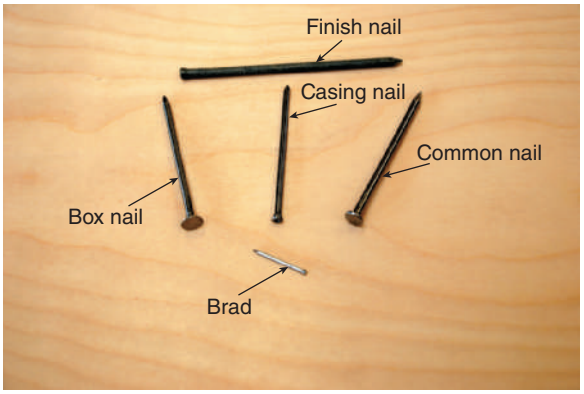
A vast array of fasteners exists for the woodworker to select from. They include nails, screws, staples, joint fasteners, knockdown fasteners, bolts, threaded inserts, and wooden fasteners. Within each category are many different types and sizes of fasteners. In this chapter, we will look at each type of fastener, its various attributes, and the choices that exist when using fasteners.

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NAILS

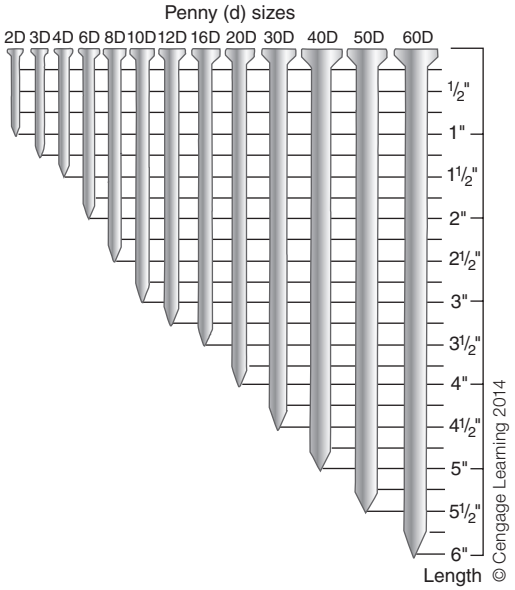
Nails come in a variety of types and sizes. Different types of nails include common, box, casing, and finish nails. Brads are a subset of smaller finish nails (see **Figure 7-1**). Nails are sized by the penny system, abbreviated with a lowercase *d*, which refers to the length of the nail. The larger the number, the longer the nail. A 6d, or 6-penny, nail is 2 inches long; a 16d nail is 3 1/2 inches long. **Figure 7-2** shows the lengths of different sized nails.

Common nails are the stoutest of the nails and are most commonly used in framing. **Box nails** have a thinner cross section and a smaller head than common nails and are used in lighter construction work, such as attaching siding. Both common and box nails have round flat heads and are used in situations where the appearance of the heads will not matter. **Casing nails** have cone-shaped heads and are commonly used where the nail will be set beneath the surface of the wood. They are used for attaching door and window casings and other trim. **Finish nails** are finer than casing nails and are also typically set lower than the surface of the wood. Finish nails have barrel-shaped heads, which, like casing nails, have a recess into which a nail set can be placed for driving the nail below the surface of the wood. **Brads** are smaller, lighter versions of finish nails. Finish nails and brads are the most frequently used nails in cabinet and furniture construction, often used for attaching trim.



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FIGURE 7-1 Common nail, finish nail, casing nail, box nail, and brad.



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FIGURE 7-2 Nail sizes by pennyweight.



HISTORY FACT

The penny system for sizing nails derives from an English system that originated in the fifteenth century. It was used to indicate how much one paid a blacksmith to forge a hundred nails of a certain size. So, for example, one paid 8 pennies for a hundred nails that were 2 1/2 inches long. These are now called *8d nails*. The *d* used as an abbreviation for *penny* comes from a small Roman coin, called a *denarius*. ■

USING NAILS

Using nails involves selecting the proper size nail for the job and driving it. "Driving" the nail simply means hammering it in. The rule of thumb for choosing the length of a nail is that it should be three times longer than the thickness of the top piece (see **Figure 7-3**).

CAUTION

Hitting your finger with a hammer is no laughing matter, but it is not the only danger to beware of when nailing. A nail that is hit with a glancing blow can fly off, presenting a potential danger to the person nailing and to others in the vicinity. For this reason, it is important to wear safety glasses when nailing or when someone around you is nailing.

Nails can be driven straight in, but they have better holding power if they are slightly angled. Nails drive easily into soft wood, but you may want to apply soap or wax to nails driven into harder woods. For very hard woods, it is best to drill a **pilot hole** slightly smaller than

the diameter of the nail. A pilot hole is simply a hole drilled into the wood that makes it easier to drive a nail or screw. More than one nail should not be driven into the same grain line, as it is likely to split the wood (see **Figure 7-4**). Nails should be positioned so that the load placed on them drives them deeper into the wood, rather than pulling them out (see **Figure 7-5**).

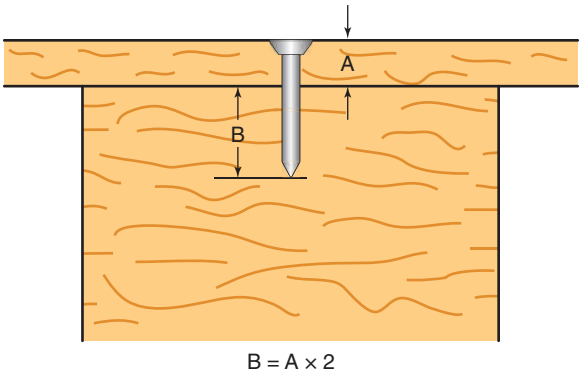


FIGURE 7-3 The nail should be three times longer than the thickness of the top piece.

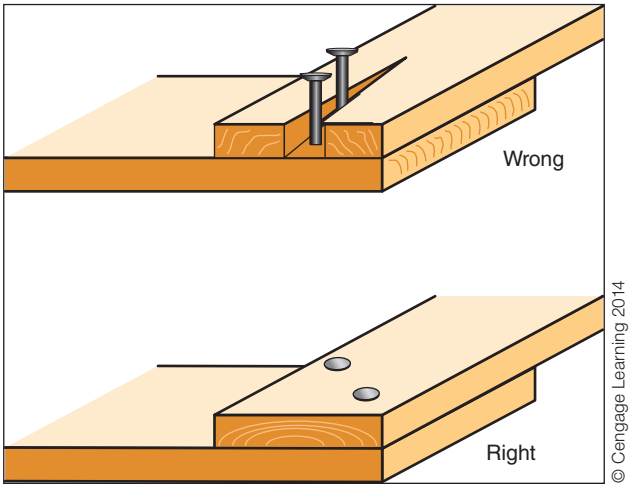


FIGURE 7-4 Do not drive two nails into the same grain line; stagger them.

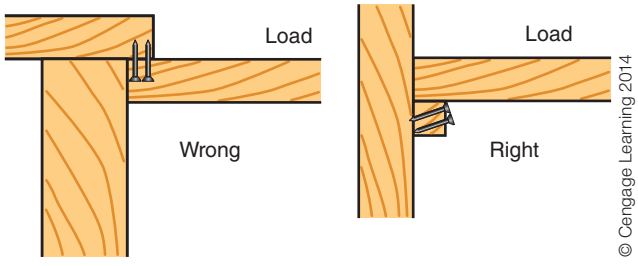


FIGURE 7-5 Nails should be placed so the load reinforces them, rather than pulling them out.

If nails are to be hidden, casing nails, finish nails, or brads should be used. They are driven close to the surface of the wood, and then set into the wood with a **nail set**, also called a *nail punch* (see **Figure 7-6**).

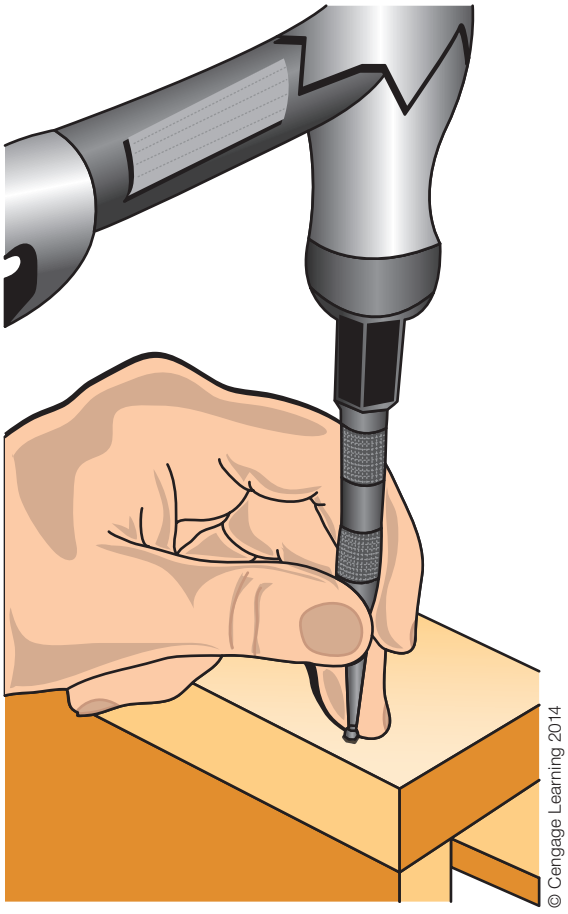


FIGURE 7-6 Setting a nail with a nail set.

WOODWORKING TIP:

*A way to hide finish nails or brads without using putty is to peel a sliver of wood back with a chisel or knife, drive and set the nail, and then glue the sliver of wood back into place (see **Figure 7-7**).*

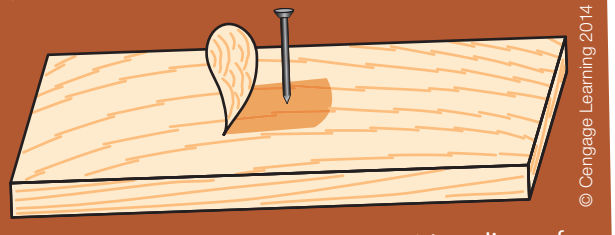


FIGURE 7-7 Concealing a nail with a sliver of wood.

A nail set is a metal punch with a cupped end; it is placed on the nail and then struck with a hammer to set the nail beneath the surface of the wood. Nail sets come in different sizes for setting various sizes of nails. The resulting small nail hole can be filled with wood putty.

Use care when driving nails. You do not want to slip and mar the surface of the wood with your hammer. Use the lightest hammer needed for driving the nail. If the nail starts to bend, take it out and start a new one. When removing a nail, use a scrap block of wood for leverage and to keep from marring the project (see **Figure 7-8**).

Other types of nails used in the furniture and cabinet industry include escutcheon pins, tacks, and upholstery nails, sometimes called *finish tacks* (see **Figure 7-9**). **Escutcheon pins** are small brass nails with round heads that are used for decorative purposes or to attach small hardware. Tacks are upholstery nails used to hold material to a wooden frame.


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FIGURE 7-8 Use a block of wood when removing a nail.

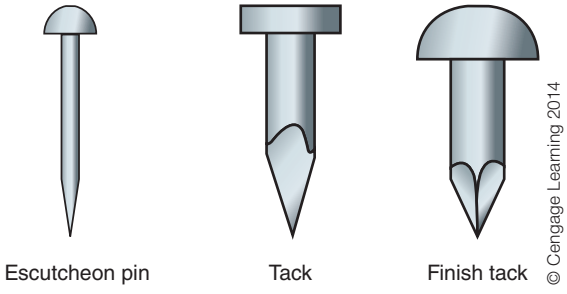


FIGURE 7-9 Esutcheon pin and tacks.

SCREWS

Screws are a type of threaded metal fastener that ends in a sharp point. A groove winds around part or all of the screw's length, allowing it to cut threads into the piece it is fastening. **Figure 7-10** details the anatomy of a screw.

Screws have much more holding power than nails because of their threading. Additionally, they are much more easily removed and replaced without damage. Screws also give a nicer appearance and do not have the same tendency to split the wood. For all these reasons, screws are used far more frequently than nails in furniture and cabinet construction.

Screws vary in length, diameter or *gauge*, head type, and material composition. Most screws used in woodworking are made from mild steel and are usually hidden. If screws will be visible in quality furniture, they should be brass. If screws are used in projects that will be subjected to weather, they should be made of material that will resist rusting, such as brass, stainless steel, aluminum, or copper.

The type of screw used most frequently by the woodworker is the *wood screw*. It is available in lengths from 1/4 inch to 6 inches. The length is measured from the tip of the screw to the base of the head. Screw diameters range from .060 inches, designated as *0*, to .372 inches, designated as *24*. From one gauge to the next, the gauge of the screw increases by .013 inches. Screws that are the same length are available in different gauge sizes. For example, a 1-inch screw may be purchased that is a *6*, which is .138 inches in diameter, or it may be a *10*, which is .190 inches in diameter. A number 10 screw is thicker and stouter than a number 6 screw.

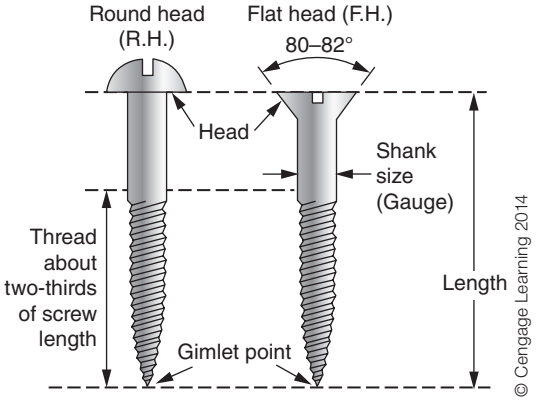


FIGURE 7-10 Screw anatomy.

PROCEDURE 7-1

Driving a Nail

STEPS

1. Hold the nail between your thumb and forefinger, as shown in **Figure A**.
2. Tap the nail with your hammer to get it started, as shown in **Figure B**.
3. Pull back your hand, keep your eye on the nail head, and use your wrist to swing the hammer, as shown in **Figure C**.
4. If the nail is to be set, drive it close to the surface and stop. Place a nail set on the nail head and strike the nail set to drive the nail beneath the surface of the wood, as shown in **Figure D**.


A

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B

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C

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D

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Another choice to be made with screws, along with length and diameter, is the head type. A variety of choices are available (see **Figure 7-11**).

Screws have different slots. Different types of screw slots require different drivers. **Figure 7-12** shows different slot types. Whichever driver is used, it should fit the screw head snugly.

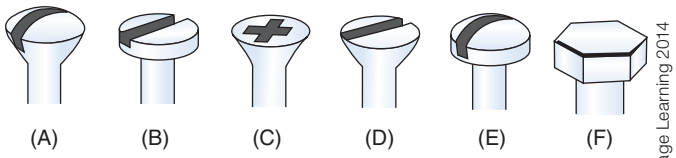
Installing Screws

Several steps are involved in installing screws. A **clearance hole**, also called a *shank hole,* is drilled in the first piece. This should be the same size or slightly larger than the shank of the screw. The clearance hole provides room for the shank of the screw. After the shank hole is drilled in the first piece, the pieces are placed together and a pilot hole is drilled (see **Figure 7-13**).

Pilot-hole size is determined by two factors: One is the *gauge of the screw* that is to be used, and the other is the *type of wood* involved. When screwing softwoods, the pilot hole should be approximately 30 percent smaller than the screw size. In hardwoods, the pilot hole is only 10 percent smaller than the screw size. See **Figure 7-14** for a table of correctly sized pilot holes in softwood and hardwood for various screw sizes. Shank-hole sizes are also provided. The pilot hole in hardwood should be as deep as the screw is long to avoid splitting. In softwood, the pilot hole only needs to be about half as deep as the screw is long.

The third step depends on whether the screw will be flush to the surface or recessed beneath it. If the screw is to be flush to the surface, the last step before driving the screw is to drill a **countersink**, into which the head of the screw will fit (see **Figure 7-15**). A countersink is a tapered hole with a wide outer portion that allows the screw to sit flush with or just below the surface of the surrounding material. Countersink bits are used for this. Both hand countersinks and countersink bits for use in drills or drill presses are available (see **Figure 7-16**).

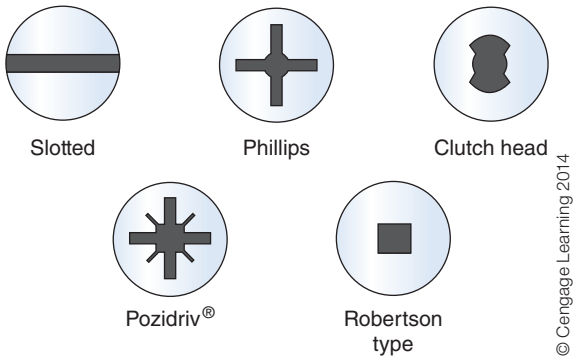
If the screw will be recessed into the material and hidden by a plug or button, a **counterbore** is drilled (see **Figure 7-17**). A counterbore creates a flat-bottomed hole. The diameter of this hole should be close to the size of the screw head and deep enough



Screw-head shapes: (A) Oval, (B) Pan, (C) Bugle, (D) Flat, (E) Round, and (F) Hex.

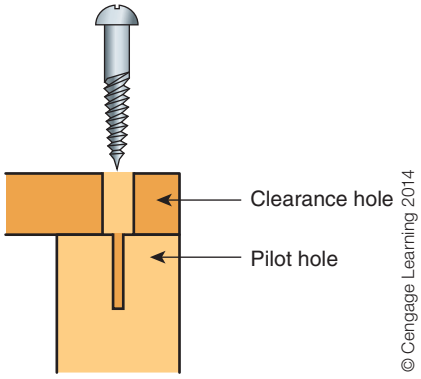
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FIGURE 7-11 Different screw heads.



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FIGURE 7-12 Different screw slots.



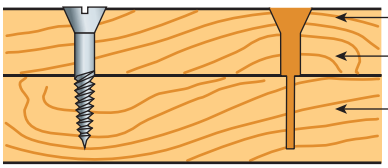
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FIGURE 7-13 Pilot and clearance holes.

Screw gauge	0	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20
Shank hole	1/16	5/64	3/32	7/64	7/64	1/8	9/64	5/32	11/64	3/16	3/16	13/64	7/32	1/4	17/64	19/64	21/64
Pilot hole - softwood	1/64	1/32	1/32	3/64	3/64	1/16	1/16	1/16	5/64	5/64	3/32	3/32	7/64	7/64	9/64	9/64	11/64
Pilot hole - hardwood	1/32	1/32	3/64	1/16	1/16	5/64	5/64	3/32	3/32	7/64	7/64	1/8	1/8	9/64	5/32	3/16	13/64

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FIGURE 7-14 Shank hole and pilot hole sizes for softwoods and hardwoods.



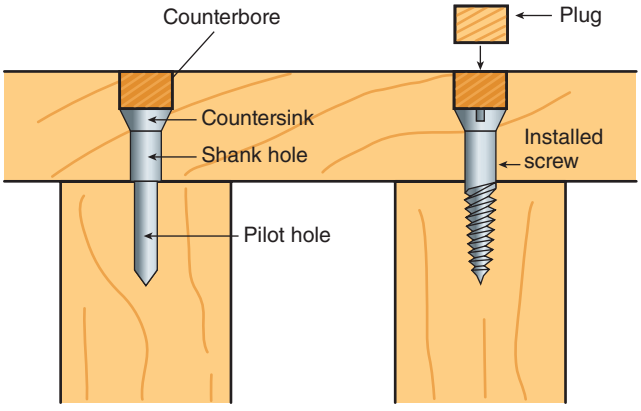
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FIGURE 7-15 Countersinking.



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FIGURE 7-16 Hand countersink and countersink bit.



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FIGURE 7-17 Counterbored screws.

to take a button or plug. Buttons stand proud of the surface and may be either glued or simply pressed into place. **Figure 7-18** shows screw hole buttons. You might choose to use removable buttons if, for example, you were hanging a shelf that you want to be able to move later. Plugs can be purchased or made with a **plug cutter**. **Figure 7-19** shows a plug cutter and plugs it will make. Plug cutters are used in the drill press and come in different sizes: 1/4, 3/8, 1/2, and 5/8 inches are the most common sizes. Making your own plugs often enables you to match the wood more closely, because you can use scrap from the same project to make the plugs. Plugs are glued into



Image courtesy of rockler.com

FIGURE 7-18 Screw hole buttons.



Image courtesy of rockler.com

FIGURE 7-19 Plug cutter and plugs.



Image courtesy of Woodworker's Supply Inc., www.woodworker.com

FIGURE 7-20 These bits will drill the shank hole, pilot hole, and countersink or counterbore, all in one operation.

the counterbore and then planed and sanded flush with the surface.

There are tapered bits sized for specific size screws; these allow you to drill the pilot hole, shank hole, and countersink or counterbore all at once to save time. **Figure 7-20** shows bits that will do this.

When all the preparation work is done, the screw can be set with the proper driver. It is important that

PROCEDURE 7-2

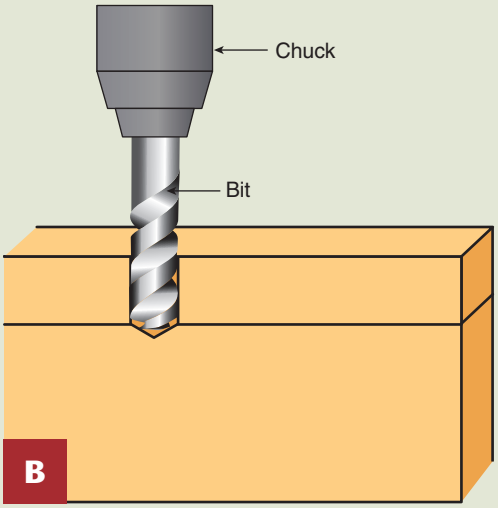
Installing a Countersunk Screw in Hardwood



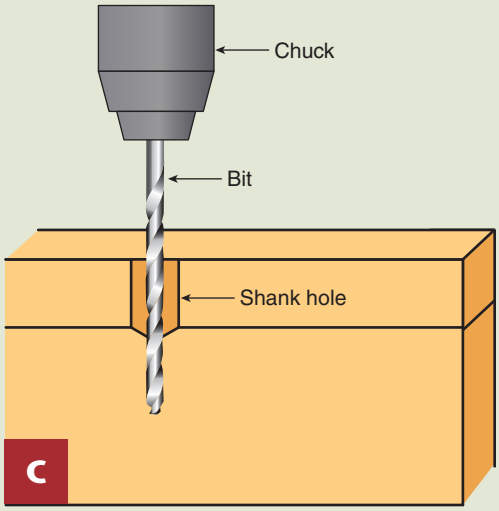
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STEPS

1. Select a screw that is long enough for all of the threaded portion to go into the second member, as shown in **Figure A**. Approximately 2/3 of the screw should be in the lower piece, as shown here. Use a thinner gauge screw for thinner woods and a heavier gauge for thicker materials.
2. Hold the two pieces to be attached to each other together and drill a shank hole equal to or slightly larger than the diameter of the screw; drill all the way through the first piece and just into the second, as shown in **Figure B**. The screw should slip through this hole without pressure.
3. See the chart in Figure 7-14 to select the proper sized bit, and drill a pilot hole the length of the screw, as shown in **Figure C**. If you were installing the screw in soft-wood, the hole would only need to be half as deep as the screw is long.

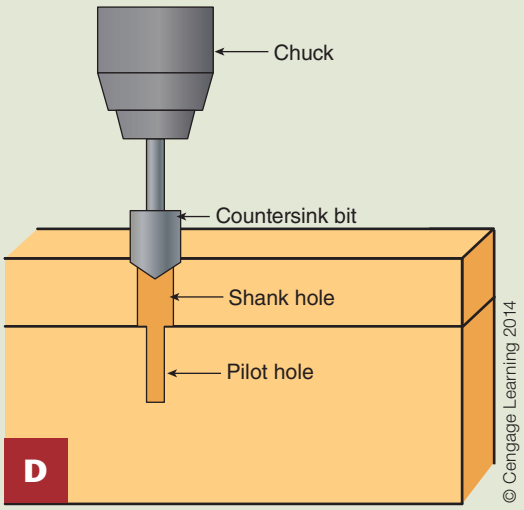


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4. Install a countersink bit in your drill and make the countersink, as shown in **Figure D**.
5. Check the size of the countersink with the head of the screw, as shown in **Figure E**.
6. Drive the screw with the properly sized driver as shown in **Figure F**. When set, it should be flush with the surface of the work.



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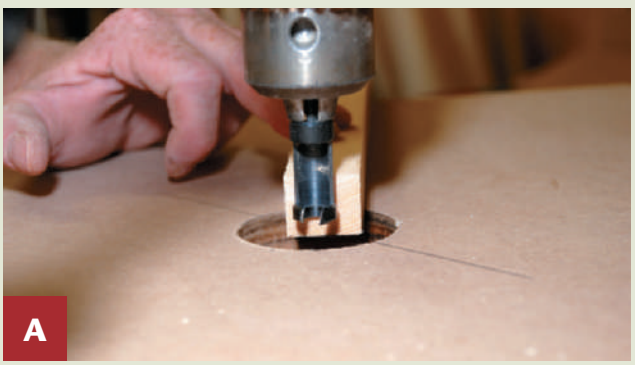
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PROCEDURE 7-3

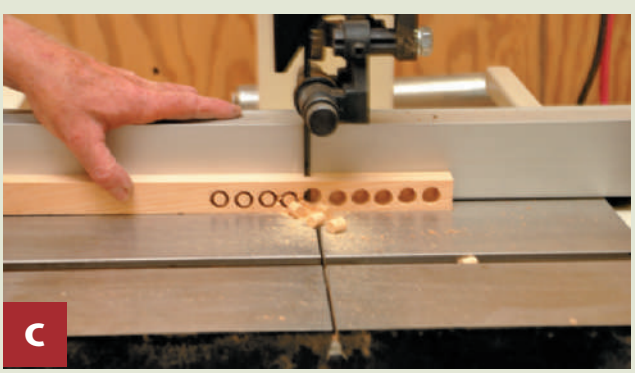
Making and Installing Plugs



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STEPS

1. Install a plug-cutting bit of the proper size for the hole you want to plug in the drill press.
2. Select the piece you will use to make the plugs and place it on the drill press table. Bring down the plug cutter, as shown in **Figure A**, and set the depth stop on the drill press so that you do not cut all the way through the material.
3. Turn on the drill press and bore the plugs, as shown in **Figure B**.
4. Take the material to the band saw and make a resaw cut to free the plugs, as shown in **Figure C**.
5. Install the plug in the hole with glue and tap it in place. Orient the grain direction of the plug so that it matches the grain direction of the workpiece; this makes it less noticeable. The plug will stand above the work piece, as shown in **Figure D**.
6. When the glue is dry, plane, and sand the plug flush with the surrounding material.

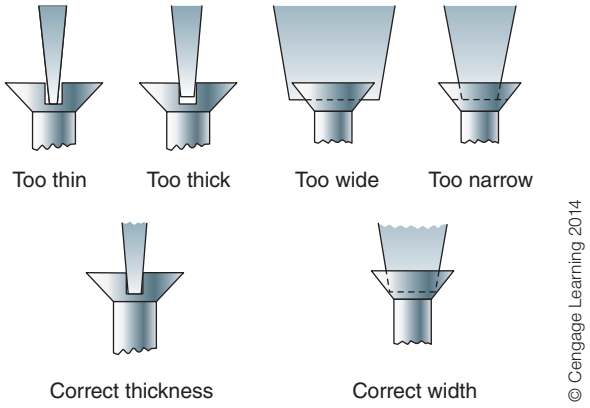
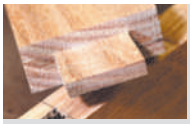


FIGURE 7-21 Select the correct size driver for the screw slot.

the driver fit the screw head snugly (see **Figure 7-21**), and the screw should be driven carefully and relatively slowly. An ill-fitting driver is likely to slip and mar the surface or gouge out the head of the screw, making it impossible to drive completely in.



HISTORY FACT

The square drive screw was patented in 1907 by a Canadian tool salesman named Peter Robinson. He is said to have invented it after he cut his hand with a screwdriver when he was driving a standard slotted woodscrew and the screwdriver slipped. Not only is it possible to get cut when driving a slotted screw, it's also easy to mar your work when the screwdriver slips. Another aggravating thing about both slotted screws and Phillips head screws is their tendency to cam out, which rarely happens with Robertson screws. ■

Besides standard wood screws, there are special screws for different applications. For example, wood screws do not hold particularly well in composite materials such as particleboard or MDF. Screws have been designed for these products that have deeper and sharper threads that are more widely spaced.

WOODWORKING TIP:

Brass screws are both weather resistant and decorative, but they are much softer than steel screws and more likely to break or cam out the screw head. One way to avoid this is to first drive a steel screw of the same size and then remove it and replace it with the brass screw.

Another screw often used, sometimes in place of wood screws, is the *drywall screw.* These screws are threaded all the way up and are available with either coarse or fine threads. They tend to be more brittle than wood screws, so care must be taken in driving them. If over-tightened, the head may snap off.

Another type of screw used in cabinetry is the *pocket screw,* used in pocket hole joinery. Pocket screws come in different lengths and are available with different thread designs for best holding power in various materials. Finely threaded screws are used when working with hardwoods, and coarser threads are better in softwoods. Pocket screws have pan or washer heads and usually a square drive, although Phillips drives are available (see **Figure 7-22**).

Lag screws are used where great strength is required. They are heavy screws with a square or hexagonal bolt head and are driven with a wrench or socket. See **Figure 7-23** for examples of lag screws. Lag screws come in different gauges and lengths.



FIGURE 7-22 Pocket screws.



FIGURE 7-23 Lag screws.

STAPLES

Staples are another mechanical fastener used in woodworking. A staple is a piece of wire in the shape of a square bracket and might be thought of as a U-shaped nail. Staples are used in areas that will not be visible when the project is completed. For example, staples are often used to fasten cabinet backs or drawer bottoms in place (see **Figure 7-24**). Staples are available in various lengths and are typically driven with a pneumatic fastener. Air pressure should be adjusted so that staples are set flush with the finished surface.

JOINT FASTENERS

Joint fasteners include panel connectors, cross dowels and bolts, one-piece connectors, dowel screws, corrugated fasteners, and chevrons. Their function is to fasten a joint together without employing joinery. See **Figure 7-25A** through **7-30** for illustrations of each of these and to see how they are used.

KNOCKDOWN FASTENERS

Knockdown (KD) fasteners are used in the construction of cabinets or furniture that can be assembled or disassembled relatively easily. They are sometimes referred to as *ready-to-assemble (RTA) fasteners,* and they are used in the building of furniture that looks no different from regular furniture, but it can be shipped and transported much more easily than traditional cabinets and furniture and then put together at the site. Knockdown fasteners hold as well as screws or glue. Various types of knockdown fasteners are readily available, and they come in different sizes and styles to suit different applications. Among these are bolt and cam connectors, panel connectors, assembly fittings, plug-and-socket connectors, and snap clips for attaching toe kicks and trim.

Bolt and cam connectors are used for attaching cabinet sides to one another and for fitting shelves in place. Several types are available. Basically, each has



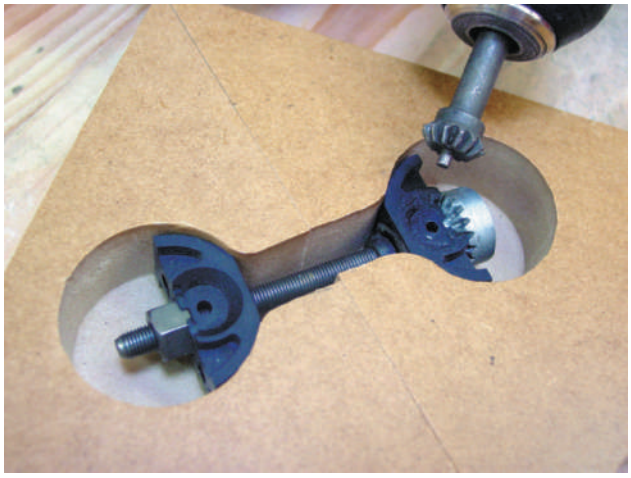
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FIGURE 7-24 Stapling the back on a cabinet.



Image courtesy of Woodcraft Supply, LLC, www.woodcraft.com

FIGURE 7-25A Panel connectors are used to join panels edge to edge.



Zipbolt, Image courtesy of FastCap LLC

FIGURE 7-25B Another panel connector.

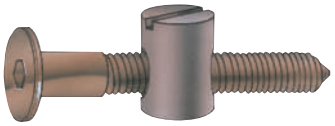


FIGURE 7-26A Cross dowel and bolt.

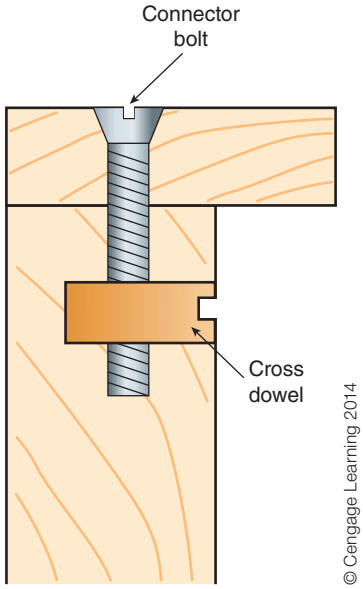


FIGURE 7-26B Cross dowel and bolt fastening a right-angle joint.



FIGURE 7-27A One-piece connector.



FIGURE 7-27B Using one-piece connector.



FIGURE 7-28A Dowel screws are threaded at both ends.

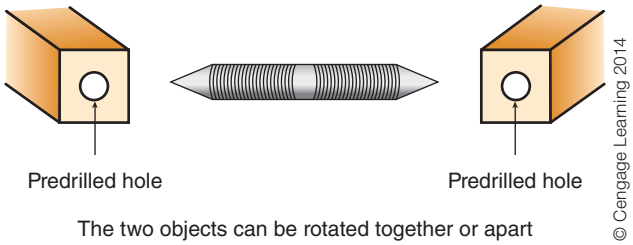


FIGURE 7-28B Dowel screws fit into holes drilled in the matching pieces.



FIGURE 7-29 Corrugated fasteners are driven by pneumatic fasteners.

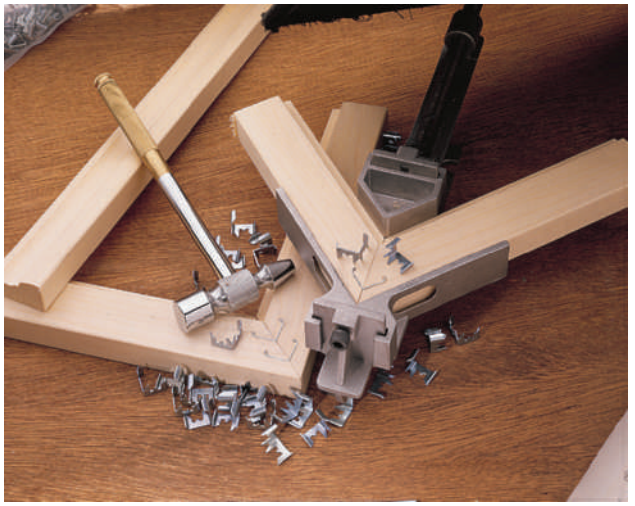


FIGURE 7-30 Chevrons are also used to hold joints together.

a bolt with a special head that is screwed into a predrilled hole in the cabinet. The second key part is a cam, which may be steel or plastic, which is inserted into already-bored holes in the piece to be fastened. The hole in the cam is placed facing out, then the piece with the cam in it is fitted over the bolt. The cam is tightened with a screwdriver or Allen wrench, depending on its head type. This draws the bolt in and brings the two components tightly together. Plastic caps to cover the cam are provided by the manufacturer (see **Figure 7-31** and **Figure 7-32**).

Panel connectors are used to securely hold sections of cabinets together. They are perfect for joining bookcases or entertainment center sections, and they consist of two parts: a *screw* and a *sleeve nut* (see **Figure 7-33**). Mating holes are drilled in the adjacent sections, and the threaded sleeve nut is inserted through both sections. It is shorter than the thickness of the two sections being joined. The screw is threaded into the sleeve nut; as the screw is tightened, the two sections are pulled together (see **Figure 7-34**).

Assembly fittings consist of a *screw pin* and a *cam socket*. The cam socket is inserted into a hole drilled into the cabinet side, and the screw pin is driven into a hole drilled in the mating piece. The protruding pin is placed in the cam, and then the cam is turned to engage the screw pin and draw the joint tight (see **Figure 7-35**).

Plug-and-socket connectors are used in situations where less holding power is needed. The plug is screwed into one part and the socket into the other. The two pieces are simply pushed together to complete the assembly (see **Figure 7-36**).

There are different types of snap clips. One type is used in connection with adjustable cabinet levelers to attach toe kicks to cabinets. A bracket is attached to the toe kick, which then snaps around the leveler leg, holding the toe kick in place (see **Figure 7-37**).

Another type of snap clip has been developed for attaching trim. **Figure 7-38** shows a *surface-mounted clip,* which is screwed to the surface that will receive the molding. A dovetailed groove is machined in the molding, and then it is snapped into place. Clips that are recessed into the main piece are also available.


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FIGURE 7-31 Bolt and cam connector.

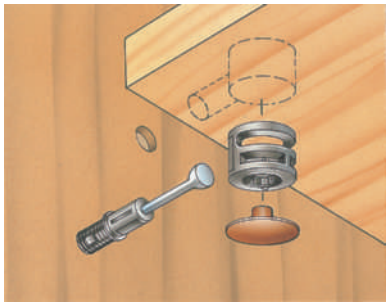
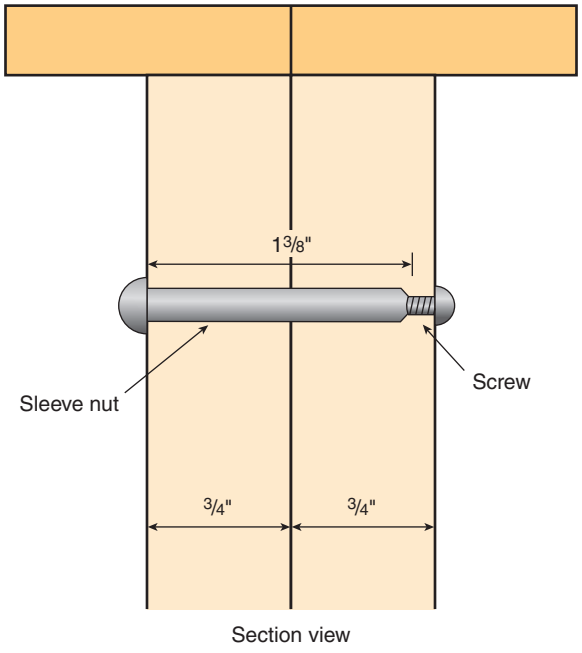

Image courtesy of rockler.com

FIGURE 7-32 Cabinet assembly with bolt and cam connectors.


Image courtesy of rockler.com

FIGURE 7-33 Panel connectors consist of a sleeve nut and screw.



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FIGURE 7-34 Panel connectors are used for joining cabinet sections together.

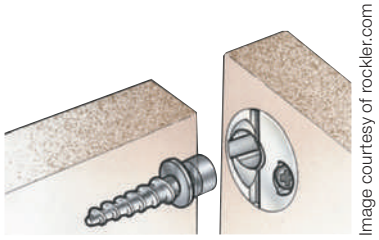

Image courtesy of rockler.com

FIGURE 7-35 Assembly fittings consist of a screw pin and a cam socket.


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FIGURE 7-36 Plug and socket connector.

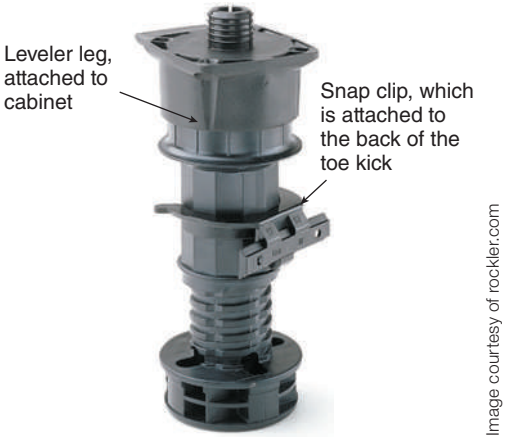


FIGURE 7-37 Snap clip, which would be attached to the toe kick, shown shapped into place around the leveler leg.

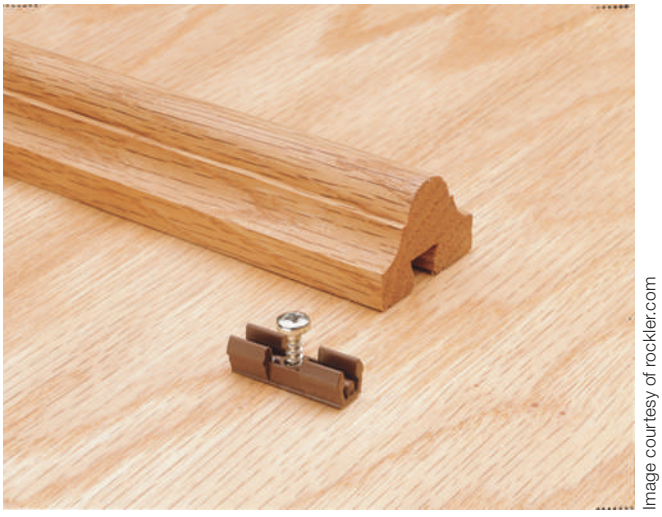


FIGURE 7-38 Snap clip, for attaching trim.

BOLTS

Bolts, like screws, are threaded fasteners. A **bolt** has a head at one end and is designed to be inserted through holes in assembled parts and secured with a nut. Bolts are not widely used in cabinetmaking, but when they are, it is generally in conjunction with insert nuts or T-nuts, which are discussed in the next section. Two exceptions to this are *carriage bolts* and *hanger bolts*.

Carriage bolts have a rounded head with a square shoulder (see **Figure 7-39**). The shoulder is pulled into the wood as the nut is tightened and keeps the bolt from turning in the wood. Carriage bolts come in different sizes and lengths; they are useful fasteners for jigs and fixtures. Using a wing nut or threaded plastic knob or handle makes them very convenient.

Hanger bolts are a cross between a screw and a bolt in that they have a wood screw thread on one end and a metal screw thread on the other (see **Figure 7-40**). Hanger bolts are commonly seen with metal brackets used to attach aprons to table legs. The wood screw end is driven into the leg. The bolt fits through the metal plate, and a nut threaded onto the other end tightens the assembly (see **Figure 7-41**).

THREADED INSERTS

Threaded inserts include insert nuts and T-nuts. They are used with machine screws or bolts. Threaded inserts are very useful in situations in which frequent

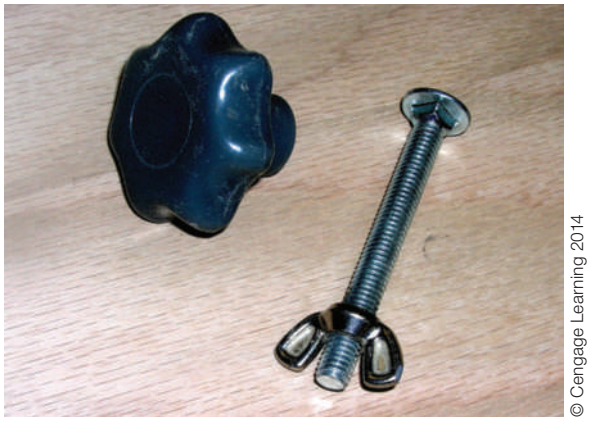

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FIGURE 7-39 Carriage bolt, wing nut, and threaded plastic knob.

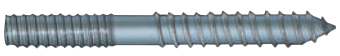


FIGURE 7-40 Hanger bolt.

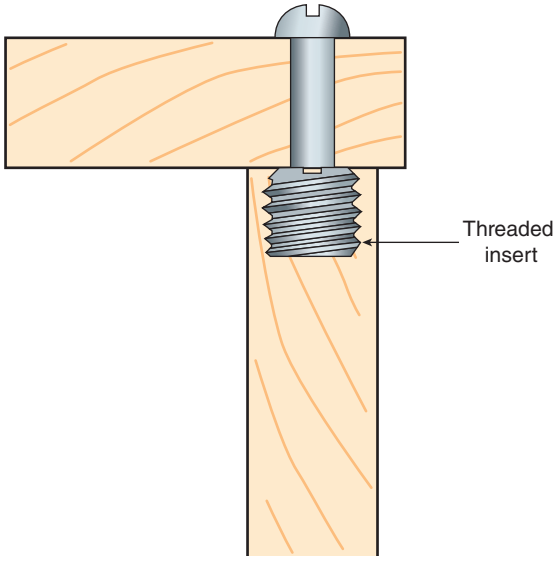
assembly and disassembly may occur. Wood screws that are frequently removed and replaced eventually lose their holding power, because new threads are cut each time they are replaced. Insert nuts and T-nuts are rarely removed once they are in place, so they remain secure. They are also used in weak materials, such as particleboard or MDF, which do not have grain and do not hold screws particularly well.

Insert nuts and T-nuts are installed in the base workpiece. A machine screw or bolt fits through a hole in the connecting piece and is tightened into the insert or T-nut (see **Figure 7-42**).



Image courtesy of Woodcraft Supply, LLC, www.woodcraft.com

FIGURE 7-41 Hanger bolt used in leg-to-apron construction.



Section view

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FIGURE 7-42 Use of insert with machine screw or bolt.

Insert nuts may be a knock-in type or may be threaded. The knock-in type has barbs or fins that hold it in place; it is pushed or tapped into its recess with a mallet. The threaded type is screwed in. T-nuts have prongs. A hole is drilled for the barrel, and then it is hammered into place. **Figures 7-43A** through **7-43C** show these different kinds of inserts.

WOOD FASTENERS

Wood fasteners are different types of dowel pins and biscuits. Dowels are used with a doweling jig to create dowel joinery. A **dowel** is a round wooden pin that fits tightly into corresponding holes to fasten or align to adjacent pieces. **Figure 7-44** shows an example of a self-centering doweling jig. Appropriately sized holes are drilled in each of the mating pieces, and dowels and glue hold them together.

Dowels come in various diameters and lengths. They should be fluted or spiral cut to allow the glue to be evenly distributed (see **Figure 7-45**). Note that the ends of both types are chamfered, allowing them to be inserted more easily.

There have been two recent innovations in dowel pins. One is a pin that is milled oversize and then



Image courtesy of rockler.com

FIGURE 7-43A Threaded insert.



Image courtesy of rockler.com

FIGURE 7-43B Barbed inserts.



Image courtesy of rockler.com

FIGURE 7-43C T-nut.

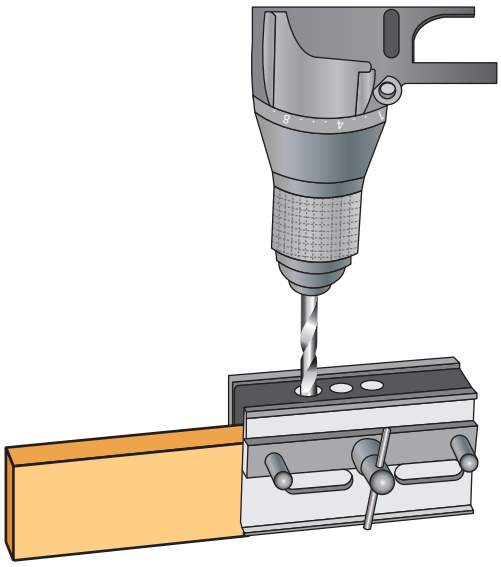

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FIGURE 7-44 Self-centering doweling jig.


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FIGURE 7-45 Dowels may be fluted or spiral cut.

compressed. When a water-based glue is used it expands, resulting in a very tight fit.

A second recently developed dowel pin is a stepped dowel. A stepped hole is drilled with a special stepped bit, glue is applied to the dowel, and the dowel is driven into place with a mallet. These dowels are available in different sizes and different species of wood (see **Figure 7-46**).

Biscuits are used in plate joinery. *Biscuits*, or *plates* as they are sometimes called, are football-shaped wafers made of compressed beech. They come in three standard sizes: *0*, *10*, and *20*, with 0 being the smallest. When used with a water-based glue, these plates expand and lock the joint in place. A biscuit or plate joiner is used to create a recess in each mating piece (see **Figure 7-47**).


Image courtesy of rockler.com

FIGURE 7-46 Stepped dowel pins and stepped bit.

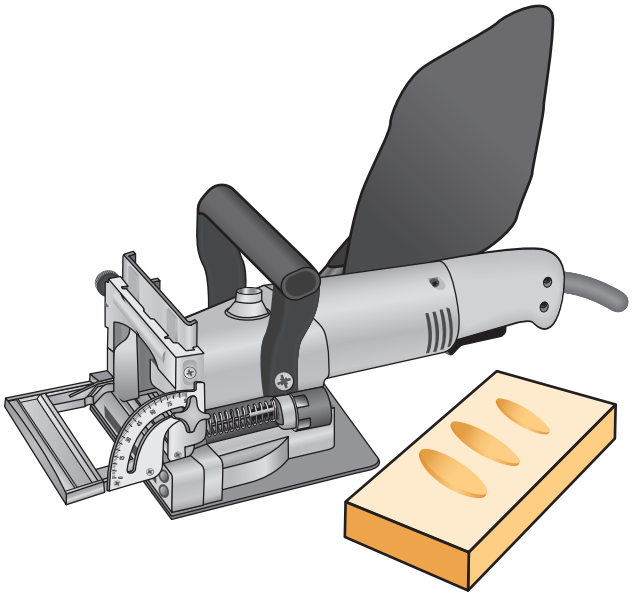

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FIGURE 7-47 Biscuit jointer and biscuits.

ANCHORS

Various **anchors** are used to secure a project in place. Screws are often used to attach cabinets to walls. Cabinet installation screws have an integral washer head (see **Figure 7-48**). Screws can only be used when there is a stud in the proper spot or if blocking has been installed between studs. When a solid attachment area is not present, other types of anchors

have to be used, which are designed to work on gypsum board, hollow concrete blocks, or poured concrete.

One type of anchor is the **toggle bolt**. It consists of a *stove bolt* and a *spring-loaded toggle* and is used to secure objects to hollow walls (see **Figure 7-49**). The bolt fits through the mounted hole in the cabinet, and the toggle head is screwed onto it from the back. A hole slightly larger than the diameter of the toggle head with the wings closed is drilled in the hollow wall. The unit to be mounted is put in place, and the closed wings are pushed through the hole in the wall. Then the stove bolt is tightened from inside the cabinet. The wings of the toggle-head spread and are pulled tight against the inside of the wall, locking the cabinet in place (see **Figure 7-50**).

A variation on the standard toggle bolt is the **plastic toggle** (see **Figure 7-51**). A hole is drilled in the wall, the toggle wings are pulled back, and the toggle is pushed into the hole. As the sheet metal screw is tightened in the anchor, the wings expand and lock against the inside of the hollow wall (see **Figure 7-52**).



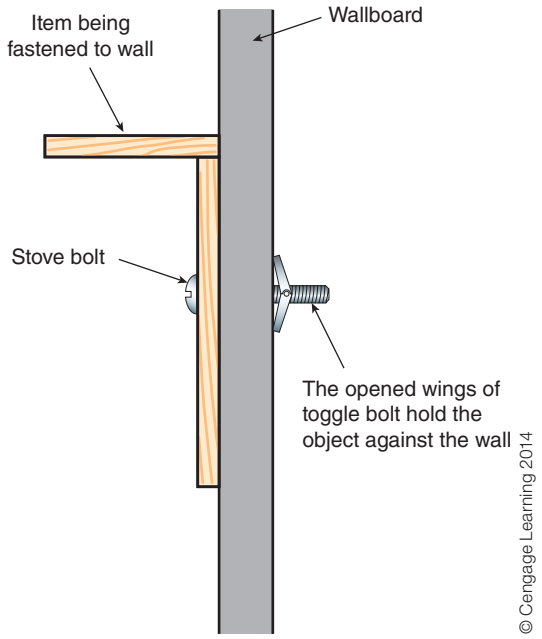
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FIGURE 7-48 Cabinet installation screws have an integral washer head.



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FIGURE 7-49 Toggle bolt.



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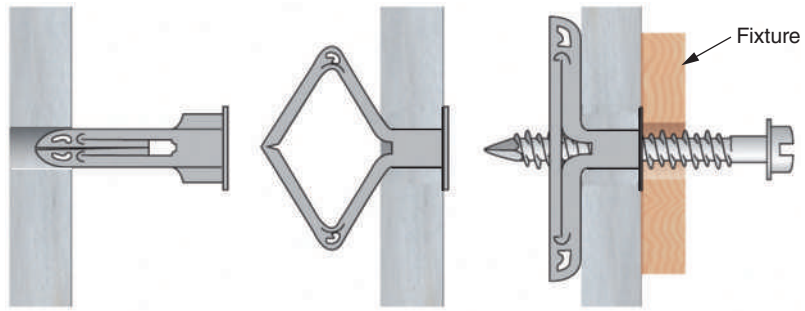
FIGURE 7-50 Toggle bolt in use.



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FIGURE 7-51 Plastic toggle.

Expansion anchors, commonly called **molly screws**, consist of an expandable *sleeve,* a *machine screw,* and a *fiber washer* (see **Figure 7-53**). A hole may or may not have to be drilled in the wall, depending on the type of molly screw used; some have sharp points and may be driven into the wall with a hammer. The expansion anchor is inserted into the wall, and then the screw is tightened to expand the anchor. Once this is done, the screw is removed and placed through a hole in the object to be fastened to the wall and then rethreaded into the anchor. As the screw is tightened, it pulls the object tight against the wall.



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FIGURE 7-52 Installing a plastic toggle.



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FIGURE 7-53 Expansion anchor.



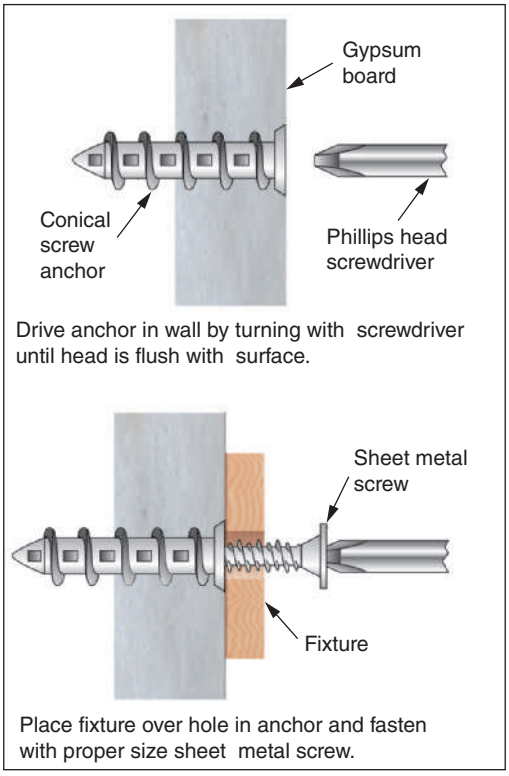
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FIGURE 7-54 Conical screw.

Conical screws are plastic anchors suitable for attaching relatively light objects to a hollow wall. They have deep threads, which allow them to be screwed into the wall (see **Figure 7-54**). **Figure 7-55** illustrates the method for installing and using conical screws.

Another light-duty anchoring device used in hollow walls is a **universal plug** (see **Figure 7-56**). It is made of nylon and is inserted into a drilled hole. When a screw is driven into the plug, it expands to lock in place (see **Figure 7-57**).

Four types of anchors used to attach objects to poured concrete walls are *split-fast anchors, lag shields, lead anchors,* and *plastic anchors.* **Split-fast anchors** are one-piece steel fasteners with two sheared expanded halves at the base. When driven, the halves are compressed and exert great force on the walls of



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FIGURE 7-55 Installing a conical screw.

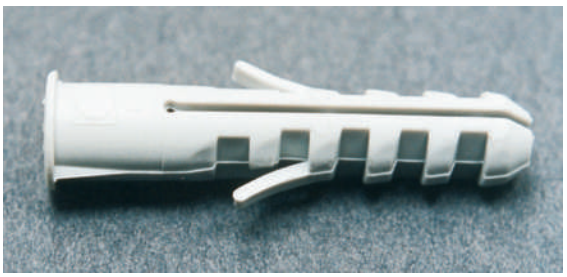
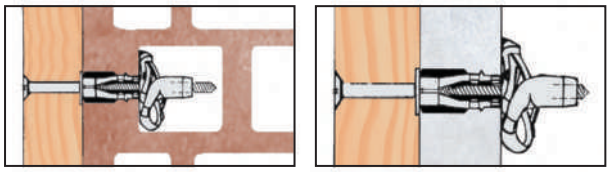

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FIGURE 7-56 Universal plug.



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FIGURE 7-57 Installing a universal plug.

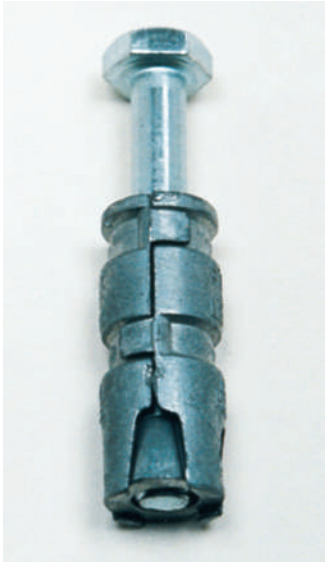
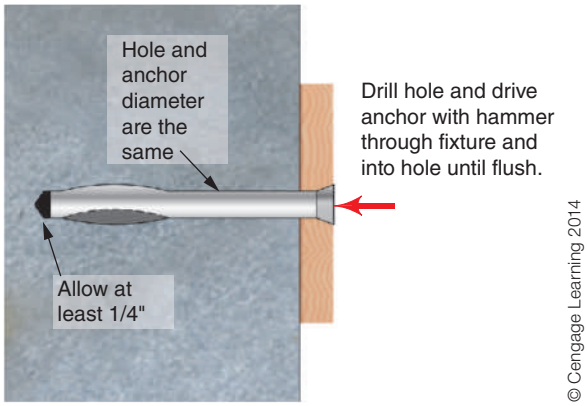

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FIGURE 7-58A Split-fast anchor.

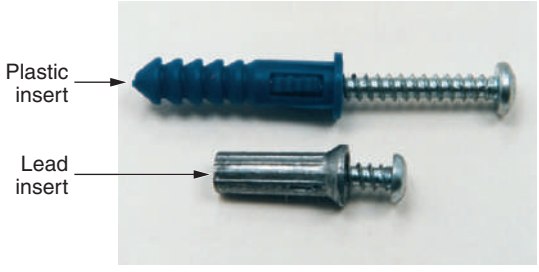


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FIGURE 7-58B Using a split-fast anchor.


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FIGURE 7-59 Lag shields.



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FIGURE 7-60 Lead and plastic anchors.

the hole as they try to regain their original shape (see **Figure 7-58A** and **Figure 7-58B**).

Lag shields are used with lag screws (see **Figure 7-59**). A hole is drilled in the concrete, and the lag shield is inserted. The lag screw is then threaded through the object being attached to the wall and screwed into the anchor.

Lead anchors and **plastic anchors** are also called *inserts* (see **Figure 7-60**). They are only suitable for hanging light objects. These anchors are driven into a hole drilled in the concrete wall, and the screw is inserted through a hole in the object being attached to the wall and then screwed into the anchor. The inside of the anchor is unthreaded and made of a soft material. As the driven screw cuts threads into it, the anchor expands and tightens in the drilled hole.

Another type of anchor is called a chemical anchor, or a resin anchor. These are embedded in a substrate, usually masonry or concrete, using a resin-based adhesive system. They are ideally suited for high load situations, and they are extremely strong.



Summary

Mechanical fasteners come in many different types, sizes, and styles. They are used to fasten parts together, to attach hardware, to reinforce joints, and to secure cabinets or other items to walls. Fasteners include nails of various types, different kind of screws, bolts, inserts, KD fasteners, wood fasteners, and anchors. While traditional quality furniture uses few mechanical fasteners, they nevertheless have a place in woodworking. They speed the construction of more utilitarian kinds of projects, they make it possible to create large pieces that can be easily disassembled, and they have a place in jig making as well. Using the proper fastener in the correct manner determines to a large degree the success of the fastening.



Key Terms

anchors
bolt
box nails
brads
carriage bolts
casing nails
clearance hole
common nails
conical screws
counterbore
countersink
dowel
escutcheon pins
expansion anchors
finish nails
hanger bolts
joint fasteners
knockdown (KD) fasteners
lag screws
lag shields
lead anchors
molly screws
nail set
pilot hole
plastic anchors
plastic toggle
plug cutter
screws
split-fast anchors
staples
threaded inserts
toggle bolt
universal plug



Check Your Knowledge

1. What purposes do fasteners serve in cabinetmaking?
2. How are nails sized?
3. Which nail is more likely to be used in cabinetmaking, a finish nail or a common nail? Why is this?
4. How are wood screws sized?
5. Which screw has a heavier gauge, a 4 or a 10?
6. List four different screw heads that will require different drivers.
7. List three kinds of screws, other than wood screws, and explain what each is used for.
8. What are knockdown (KD) fasteners good for?
9. List several types of KD fasteners.
10. Why is using an insert better than simply using a screw?
11. Name a situation where staples would be used.
12. What are two kinds of wood fasteners?
13. What is a biscuit made of, and how does it work?
14. How can a cabinet be secured to a hollow wall?
15. What anchors could be used to fasten a cabinet to a poured concrete wall?

BUILD IT!

Drawer Dividers for Small Parts Storage



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Figure A shows the completed drawer dividers.

TOOLS REQUIRED

- Measuring tool
- Squaring tool
- Table saw and dado blade
- Miter saw

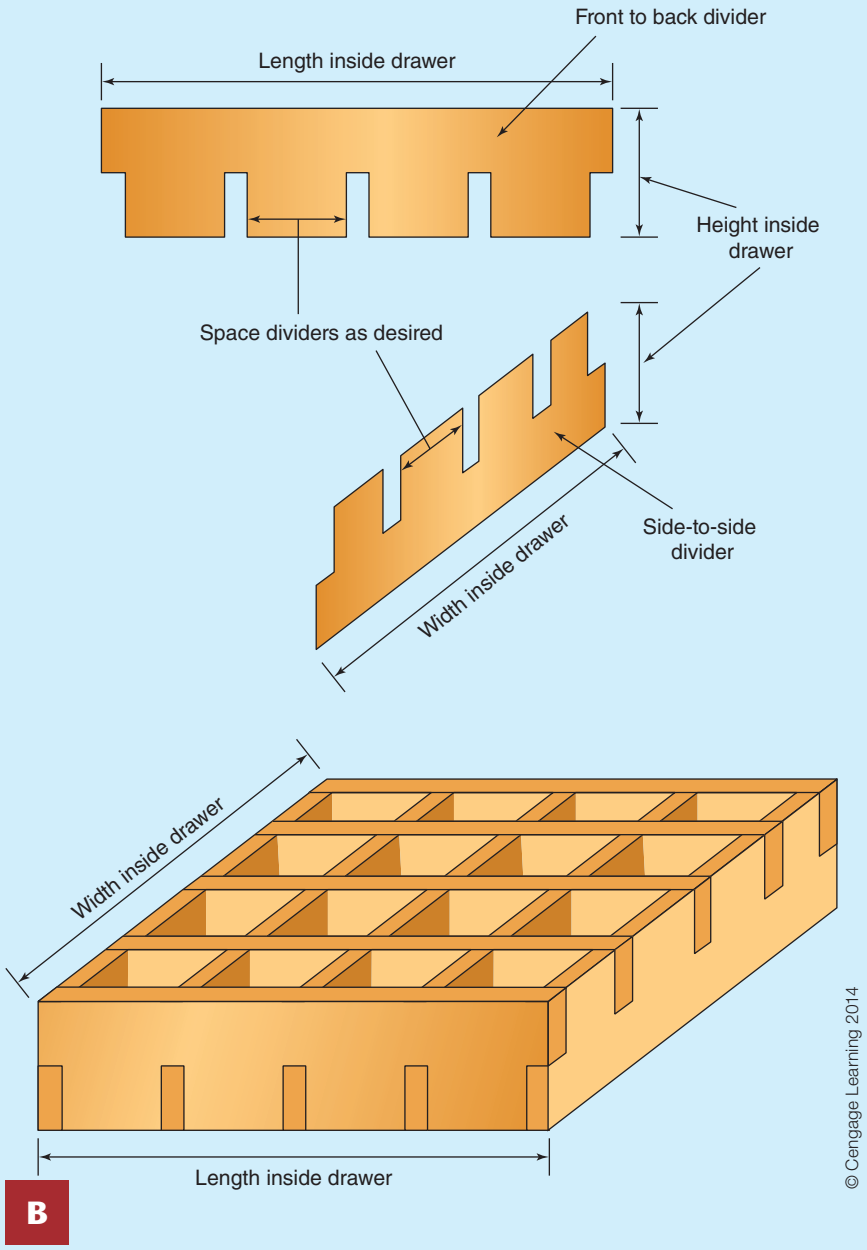
MATERIALS REQUIRED

- 1/4" solid stock; amount depends on drawer size

STEPS

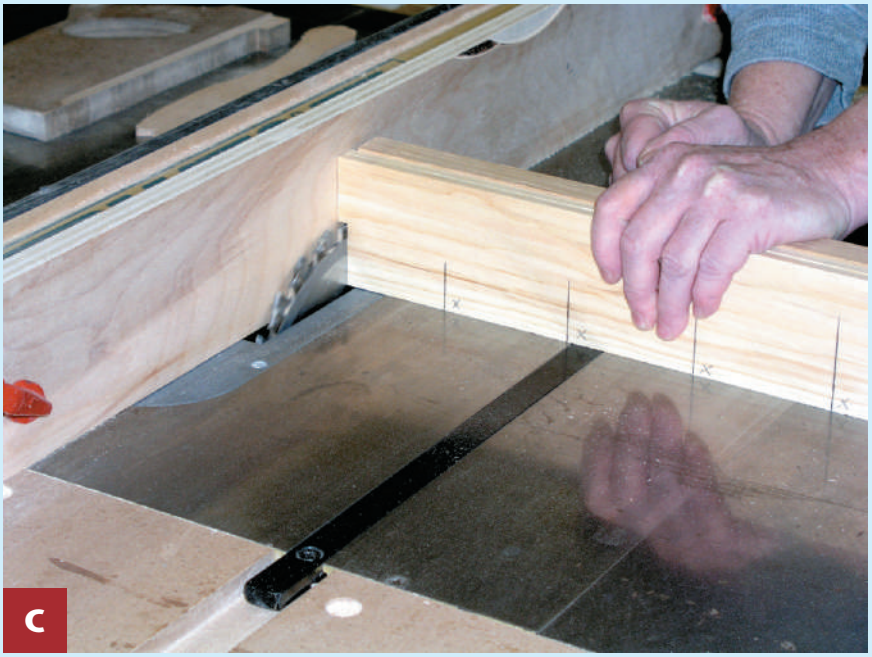
1. Measure the inside length, width, and height of the drawer you wish to divide.
2. Rip to width and crosscut strips. The number you make depends on the size of the drawer and how far apart you want the dividers spaced.

3. Decide the size of the interior spaces, and lay out the pieces for this. **Figure B** shows how the pieces will fit together.
4. Stack the dividers that will run the length of the drawer together and clamp them to a miter gauge equipped with an auxiliary fence.
5. Clamp a sacrificial fence onto your table saw fence.
6. Install a dado blade set for a 1/4"-wide cut on the table saw; raise it so its height is one-half the width of your pieces.



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BUILD IT!



C

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7. Make your first cut with your pieces butted to the sacrificial rip fence, which is set right next to the blade, as shown in **Figure C.** Do the same thing on the other end of the pieces.
8. Slide the rip fence out of the way, as shown in **Figure D**, and make your other cuts as marked.
9. Repeat the process with the pieces that span the width of the drawer.
10. Fit the interlocking pieces inside the drawer.

BUILD IT!

PROJECT CHALLENGE

Stacking Shop Totes

Figure A shows the complete totes.

STEPS

1. Have the storage bins you plan to use on hand. This tote is designed for small bins, but because sizes may vary, you should have the bins on hand to make any necessary adjustments in the plan.
2. Study the assembly list given in **Figure B**. Decide how many totes you want to make, and note how many pieces of each part you will need.
3. Machine pieces to the dimensions given.



A

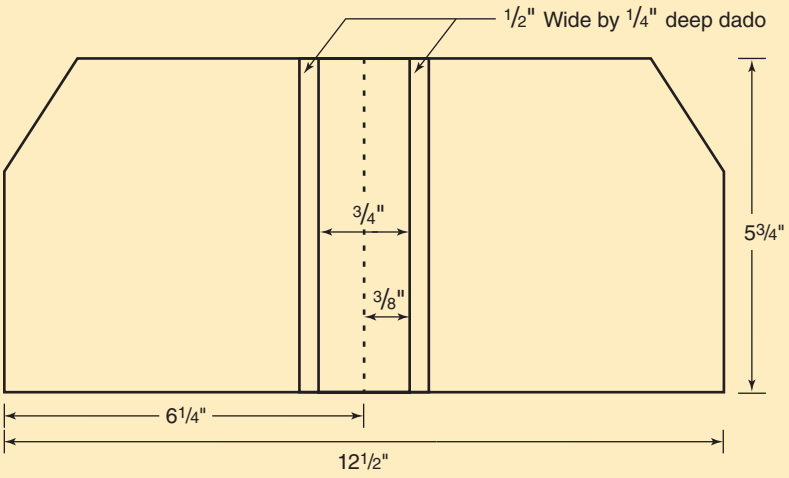
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Assembly list for one tote

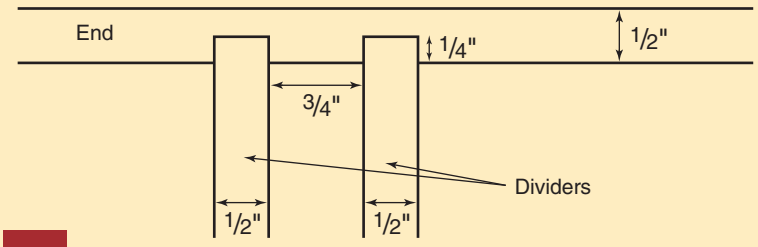
Part	Dimensions (thickness × width × length)	Quantity
1. End	$^1/_2$" × $5^3/_4$" $12^1/_2$"	2
2. Divider	$^1/_2$" × $5^3/_4$" × $17^1/_2$"	2
3. Bottom	$^1/_2$" × $5^5/_8$" × $17^1/_2$"	2
4. Handle	$^3/_4$" × $5^1/_2$" × 17"	1
5. Stop	$^1/_4$" × $^7/_8$" × 17"	2
6. Side (optional)	$^1/_2$" × $2^3/_4$" × 17"	2

B

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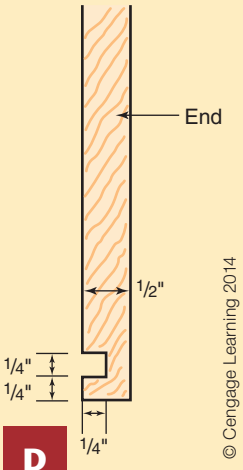
Inside view of end



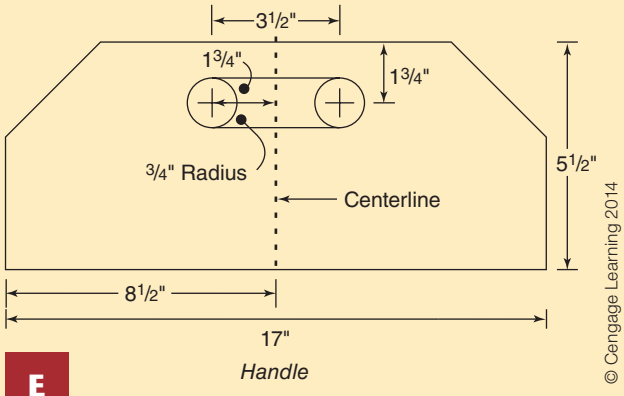
C

Top view

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D



E

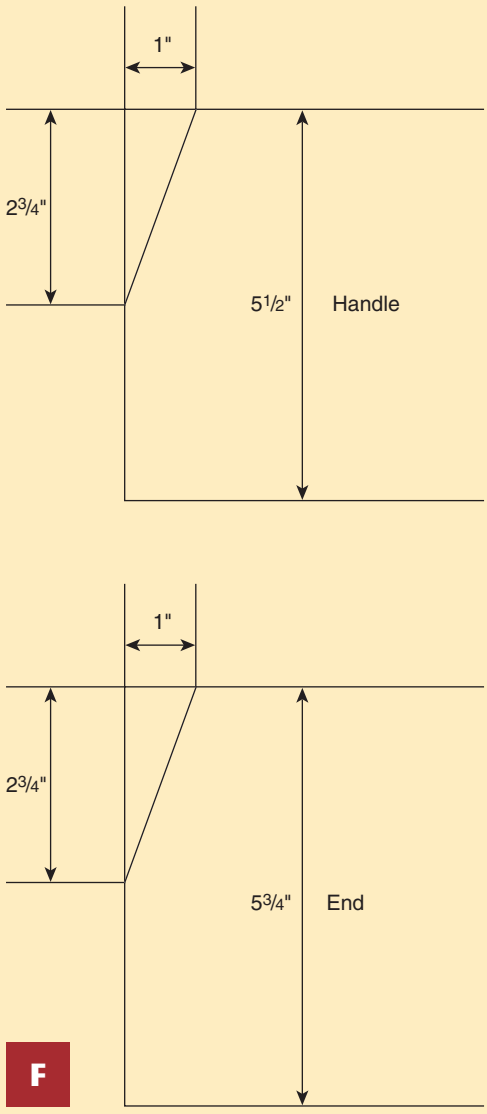
Handle

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4. Find the center of the end pieces; lay out 1/2" wide by 1/4" deep dados 3/8" to either side of the centerline, as shown in **Figure C**. They will accept the dividers. Mill the dados.
5. Cut grooves on the same side of the ends that you milled the dados. The grooves should be 1/4" wide, 1/4" deep, and set up 1/4" from the bottom of the end, as shown in **Figure D**. Do the same thing on the bottom of each divider.
6. On both ends and in one long side of each bottom piece, cut rabbets to fit in the dados.
7. Find the center of the handle and lay out for the opening, as shown in **Figure E**. Drill two 1 1/2" holes and then cut out the waste with a jigsaw.

8. Cut miters on each end piece and on the handle, as diagrammed in **Figure F**.
9. Ease the edges of the cutout in the handle with a 1/8" round-over bit in the router.
10. Before assembling the tote, cut a shallow rabbet on the inside face of each divider, as shown in **Figure G**. This provides a little room for the handle of the tote below.
11. Glue and clamp the tote together.



F

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G

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H

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I

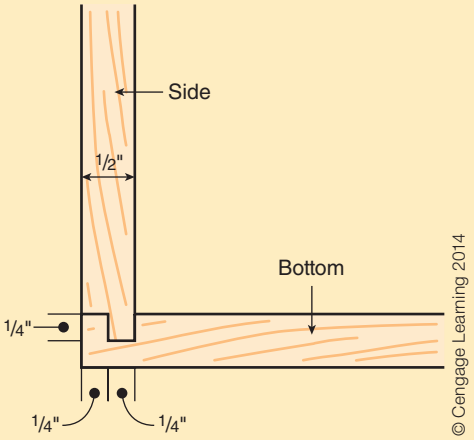
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12. Glue 1/4" hardboard stops 7/8" wide to the front edge of the tote bottoms, as shown in **Figure H**.

13. Sand smooth.

NOTE

If you want to create a tote that has closed sides, like the one shown in **Figure I** for carrying tools, make two 1/2"-thick side pieces that are 2 3/4" × 17". Mill a groove in each bottom piece and a tongue on each side piece, as shown in **Figure J**. The tongue is glued into the groove in the bottom piece and screwed through the side, as shown in **Figure K**.



J

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K

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8

Adhesives

You'll Learn

After studying the chapter, the student should be able to:

- Explain how adhesives work
- List the characteristics of adhesives
- Demonstrate knowledge of how to get a good adhesive bond
- Understand the difference between natural and synthetic adhesives
- List various types of adhesives
- Indicate different situations in which the various adhesives might be used

INTRODUCTION

Adhesives are used by woodworkers to bond materials together. The term *adhesive* includes glues, cements, resins, and mastics. Different adhesives are appropriate for different applications, depending on what is being bonded and what the needs of the project are. For example, a piece that will be used outside requires a different type of adhesive than one used in the house. The various adhesives have different characteristics. Some adhesives used in woodworking are white and yellow glues, polyurethane glue, contact cement, resorcinol resin, epoxies, and hot-melt glues.

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HOW ADHESIVES WORK

Adhesives work by adhering, or sticking, one object to another. There are two types of adhesion: *mechanical adhesion* and *specific adhesion*. **Mechanical adhesion** is the bonding that occurs between the adhesive and the wood fibers; tiny fingers of adhesive penetrate the pores and cell cavities of the wood. **Specific adhesion** is the molecular attraction between the glue and the wood, because glue and wood have opposite electrical charges. Specific adhesion contributes far more to the strength of the bond than does mechanical adhesion.

In addition to adhesion, another factor is the **cohesion** of the glue, or how well the glue sticks to itself; the glue molecules *cohere* to one another.

Adhesion and cohesion and the resulting glue bond are affected by several different factors, including the type of wood used, type of glue used, conditions under which the glue cures, orientation of the wood grain, total area of adjoining surfaces, assembly technique, and fit of the joint. Of these elements, the most important is the fit of the joint. The parts of the joint to be glued should be in close contact with each other. Glue will not fix the problem of a poorly fitting joint. The joint should be snug, but not so tight that it has to be driven together with a mallet.

Characteristics of Adhesives

There are five principal characteristics of adhesives that you will want to consider as you choose which ones you will use for different projects. These characteristics are *water resistance, heat resistance, chemical resistance, gap-filling ability,* and *curing time*. Other characteristics that are important are *shelf life, pot life,* and *set time*. Of course, the type of materials being bonded will also determine the type of adhesive chosen.

Water resistance is the adhesive's ability to withstand wetness. It may be low, in which case the adhesive will not even withstand high humidity. If the adhesive has fair water resistance, it can withstand high humidity but cannot be wet. A water-resistant adhesive can withstand periodic wettings, and a waterproof adhesive can be submerged without danger to the adhesive bond.

Heat resistance refers to how well the adhesive will hold up to heat. This is an issue when sanding a glued joint. Some adhesives are more likely than others to soften, which will clog and quickly load sandpaper.

Chemical resistance is a measure of how the adhesive will stand up to chemical assaults such as finishes, cleaning agents, and alcohol. Also, some adhesives provide better gap-filling ability than others. Gaps may be produced by poor machining or inadequate clamping.

Curing time refers to the length of time it takes for an adhesive to be fully cured. At this point the joint has reached full strength and the solvent in the adhesive has completely evaporated.

Shelf life, sometimes called *storage time,* is how long the adhesive remains usable. Many adhesives come with a date stamped on the container indicating when they were manufactured. Knowing the shelf life tells you how long the adhesive will be effective. It should not be used after this time has elapsed.

Pot life describes the amount of time you have for applying the adhesive. After the pot life has gone by, the glue starts to set. More complicated bonding situations call for a longer pot life to give you more time to get the piece assembled and clamped. Another term used for pot life is **open time**.

Set time also differs from adhesive to adhesive. This is the amount of time it takes for the solvent in the adhesive to evaporate. It is also the length of time that the materials being bonded should be in clamps. It is different from *curing time,* which is the point at which the bond has reached full strength.

The choice of adhesive depends on all of these characteristics as they relate to a particular project. Two primary factors that will guide your choice are the *materials* being bonded and the *conditions* to which the adhesive will be exposed. Certain woods contain oily extracts, which prevent some glues from bonding well.

Getting a Good Bond

No matter what adhesive is chosen for a project, a good bond between the pieces to be joined is extremely important. Glue will not overcome the problem of a poorly fitting joint. Producing well-prepared, snug-fitting joints is essential. Of course, a great deal of this has to do with the precision with which the joinery is machined. It is also important to have clean cuts. This means using blades, bits, knives, and cutters that are sharp and clean. Dirty or dull cutting tools produce surfaces that may be burned or polished, either of which will cause a lack of adhesion. In addition, you should never sand a surface that is to be bonded. This may polish the surface and result in an inadequate glue bond. If a surface needs to be reduced to achieve a proper fit, it should be planed rather than sanded.

WOODWORKING TIP:

Surfaces to be bonded should be glued as soon as possible after machining is complete. If the pieces sit around for some time, they collect dust and oil, which may interfere with the efficacy of the glue joint. If much time has elapsed, the surfaces to be joined should be very lightly hand sanded before gluing.

Types of Adhesives

Adhesives may be divided into two broad categories: *natural* and *synthetic*. **Natural adhesives** were the first adhesives used and have been around for thousands of years. They are made from materials such as bones, blood, hides, eggs, milk, and vegetables. All these substances contain protein, which is the important chemical component of natural adhesives. Natural adhesives still in use today include animal glues, starch glues, and casein.

Synthetic adhesives were developed in the 1940s, during World War II. They are called *synthetics* because they are generated through a chemical process. Most adhesives used today are synthetic adhesives, which can be further broken down into two categories, *thermoplastic* and *thermosetting*. **Thermoplastic** adhesives are dispersed through a water system; because they are water based, they clean up with water. **Thermosetting** adhesives cure through a chemical reaction. Synthetic adhesives used in the cabinetmaking industry today include polyvinyl acetate, aliphatic resin, polyurethane, plastic resin, resorcinol resin, epoxy, cyanoacrylate, contact cement, and hot-melt adhesives.

Natural Adhesives

Animal glue, often called **hide glue**, is manufactured from the hooves, hides, and bones of animals. It is available in liquid form or as flakes (see **Figure 8-1** and **Figure 8-2**). Different types of flakes yield different strengths of glue. Stronger glues, such as granular hide glues, have a very short open time or pot life of 3–5 minutes. The hide purchased in liquid form has a much longer open time of 15–30 minutes. You'll remember that open time is the amount of time you have between applying the glue and when clamps must be in place. Animal glues that are not as strong, such as pearl hide glues, give the woodworker more open time to work before the glue begins to set up. The flakes are soaked in water overnight to dissolve, and then the glue is heated in an electric glue pot or double boiler. For this reason, animal glue is also sometimes called *hot glue*. Hide glue flakes are popular with antique restorers.

Hide glue is nontoxic, very durable for interior use, and cleans up with water. It sands easily and does not clog abrasives, unlike most other adhesives. The major drawback to animal glues is that they have low moisture resistance. Even prolonged exposure to high humidity may loosen glue joints. However, this disadvantage may also be seen as an advantage: The joint can be taken apart with water or, better yet, steam. Should repairs be necessary, the joint can be disassembled without destroying it. Most antiques that



Image courtesy of Titebond Wood Glues

FIGURE 8-1 Hide glue is available in liquid form.



Image courtesy of Lee Valley Tools, Ltd.

FIGURE 8-2 Granular and pearl hide glue flakes.

have been restored were originally built with animal glues.

Starch or vegetable glue is made from cassava starch and water. The starch powder is mixed with water to form a thick paste. This glue has a long pot life, allowing plenty of assembly time, but the set time is very slow. Disadvantages are low moisture resistance and a slight staining of the wood.

Casein is formulated from milk curds. It comes as a powder that is mixed with water, and it has good gap-filling properties and moderate moisture resistance. On the negative side, it has a tendency to stain, a short pot life, and a dulling effect on cutter knives when glued pieces are machined. Other natural adhesives are made from soybeans, blood, and fish (see **Figure 8-3**).

Synthetic Adhesives

Synthetic adhesives are much more popular and more widely used than are natural adhesives.

Polyvinyl acetate (PVA) is a thermoplastic adhesive. It is white in color, so it is often referred to as *white glue,* and it dries clear (see **Figure 8-4**). It is readily available, nonstaining, and odorless. It has good strength and gap-filling abilities, is nontoxic, and has a long shelf life. However, it has low moisture, heat, and chemical resistance. It has an open time of 5–10 minutes, and a set time of an hour. Curing time is 24 hours. Due to its low heat resistance, it has a tendency to gum up and clog abrasives. Its low resistance to chemicals may cause problems with some finishes.



Image courtesy of Lee Valley Tools, Ltd.

FIGURE 8-3 Fish glue.

Aliphatic resin is also a thermoplastic glue. It is a type of PVA that is yellowish in color and thicker than white glue, so it runs less (see **Figure 8-5**). It is also stronger. Although the water resistance of the original aliphatic resin glues is low, newer resins have medium to high heat resistance and high chemical resistance and have better tack than white glue, which means that they are more instantly sticky. Aliphatic resin has a fairly short shelf life of about a year, and tends to get stringy when old. Like white glue, it has an open time of 5–10 minutes, but it sets in 30 minutes, meaning that is doesn't have to be in clamps as long as white glue. Its cure time is also a day, and it also cleans up with water; it is probably the most commonly used adhesive in general woodworking. Since all PVA glues are water based, they must be stored where they cannot freeze. If they get



Image courtesy of Elmers Products, Inc., www.elmers.com

FIGURE 8-4 White PVA glue.



Image courtesy of Titebond Wood Glues

FIGURE 8-5 Aliphatic resin is a type of PVA.

frozen, they must be discarded as they are no longer viable.

Aliphatic resin glues have been developed for exterior work. See **Figure 8-6** for an example of an exterior type that is highly water resistant and appropriate for outdoor projects. Recently, a type of aliphatic resin glue has come out on the market that meets even more stringent water-resistance standards. It is effectively waterproof, although it should not be used beneath the water line (see **Figure 8-7**).

Polyurethane glues are relatively new thermoset adhesives. The essential component of polyurethane adhesives is *diphenylmethane di-isocyanate* (MDI). Polyurethane glue is highly water and heat resistant.



Image courtesy of Titebond Wood Glues

FIGURE 8-6 Aliphatic resin for exterior work.

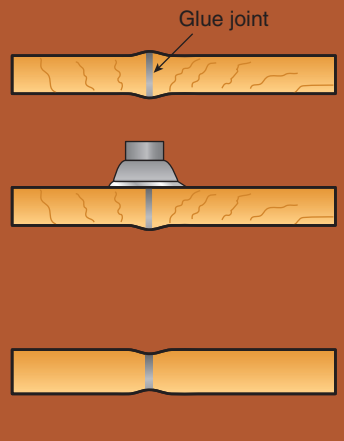


Image courtesy of Titebond Wood Glues

FIGURE 8-7 Highly water-resistant aliphatic resin.

WOODWORKING TIP:

When using a water-based glue, such as white or yellow glue, it is necessary to wait until the joint is fully cured before machining it. The reason for this is that the water in the glue swells the wood fibers around the joint. If this area is sanded or planed before the water has completely evaporated, you will be left with what is called a sunken joint when it does evaporate, like the one shown in **Figure 8-8**.



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FIGURE 8-8 Sunken joints will result from sanding or planing a joint bonded with a water-based glue before it is completely dry.

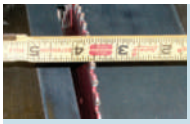
This is true of all thermoset adhesives, whose water resistance makes them a good choice for exterior woodwork. Polyurethane glues are extremely strong and will bond dissimilar materials (see **Figure 8-9**). They have an open time of 10–15 minutes, a set time



Image courtesy of The Gorilla Glue Company

FIGURE 8-9 Polyurethane glue.

of 1–2 hours, and take 24 hours to fully cure. When using polyurethane glues, first lightly moisten the surfaces to be bonded together. A plant mister works well. This step is necessary because the glue cures by reacting with moisture. Then apply the glue and clamp the assembly. This glue foams to three times its original volume as it cures, but after it has set, the foam is dry and can be easily removed with a chisel or scraper. Lower-foaming polyurethane glues are becoming increasingly available. Note that polyurethane glue will react to the moisture in your skin and stick to it, so it's best to wear gloves when working with polyurethane glues.



SCIENCE CONNECTION

Polyurethane glues foam as they cure due to a chemical reaction that releases carbon dioxide. ■

Plastic resin adhesive is also called *urea,* or *urea formaldehyde.* It is a thermosetting glue comprised of urea resins and provides a very strong bond. It comes as a powder that is mixed with water to form an adhesive that is the consistency of heavy cream. It is nonstaining but has very poor gap-filling capabilities, so joints must fit tightly. Uncured glue is toxic and can be absorbed through the skin, so it is important to wear gloves. Additionally, the powder produced from sanding dried glue joints is toxic, so it is very important to wear a mask when sanding. Plastic resin adhesive is used for bonding plywood veneers and for cabinetwork, especially veneering, and complex assemblies that require a long open time (see **Figure 8-10**). Urea has a relatively long pot life of 10–30 minutes, and a long set time of 12–14 hours. It is fully cured after 24 hours.



Image courtesy of Woodcraft Supply, LLC, www.woodcraft.com

FIGURE 8-10 Plastic resin adhesive.

Resorcinal resin is a two-part adhesive. A red, liquid resin is mixed with a tan, powdered catalyst, which acts as a hardener. When mixed, resorcinol resin is dark brown. Its pot life is about 15 minutes. You should not mix more than is needed, as any excess will set and will have to be thrown away. Set time is 1–2 hours and cure time is less than other adhesives at 10–12 hours. Resorcinal resin is completely waterproof and so makes an excellent choice for projects that will be exposed to the weather, and it has good gap-filling properties. It resists salt water as well as fresh water and is often used by boat builders. One major disadvantage of resorcinol resin is that it leaves a dark glue line, which may make it unsuitable for use with light-colored woods. Another concern with resorcinol resin is that, like plastic resin glue, uncured glue is toxic, as is the sanding dust. Therefore, the necessary precautions must be taken when working with this glue.

WOODWORKING TIP:

Acid brushes used by plumbers make inexpensive glue applicators. They are available in a couple of different widths. When water-based glues are used, the brushes can easily be rinsed and used again (see **Figure 8-11***).*



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FIGURE 8-11 Acid brushes made inexpensive glue applicators.

Epoxy cement is another two-part thermosetting adhesive that is mixed just prior to use (see **Figure 8-12**). It produces a very strong joint, but it is expensive and not often used by woodworkers except on small-scale projects. Like polyurethane glues, epoxies will bond dissimilar objects. Epoxy



Quick Cure 5-Minute Epoxy, Image courtesy of System Three Resins, Inc.

FIGURE 8-12 Epoxy.



Image courtesy of Elmers Products, Inc., www.elmers.com

FIGURE 8-13 Commonly available cyanacrylate.

cement is waterproof, and it sets and cures very quickly; little or no clamping time is required. It has an open time of 5 minutes or less, and a set time of 5 minutes. It reaches full strength in 12–24 hours. Slow-set epoxies are also available; these have an open time of 30 to 60 minutes, a set time of 2–4 hours, and a curing time of 12–24 hours. Uncured glue is toxic, so gloves should be worn when using it. In addition, the fumes given off by mixed epoxies are toxic, so it is important to work in a well-ventilated area. Epoxy cements have better gap-filling ability than other glues, due to the fact that they do not shrink as they dry. Polyurethane glues were developed as an alternative to epoxies and are more commonly used today.

Cyanoacrylate is often called *superglue*. Like epoxy cement, it is expensive and only practical for small gluing jobs. It is categorized as an acrylic resin, but unlike two-part resin glues, it doesn't require a separate hardener. **Figure 8-13** shows an example of a readily available cyanoacrylate. Like epoxy, it will bond unlike materials, dries very quickly, and offers tremendous strength. Since it dries almost instantly, it is great for quick repairs or situations where clamping would be awkward. Although low in toxicity, care must be taken in using it, because it will bond the skin to anything it touches. In addition, the fumes can be irritating to the eyes and other sensitive tissue.

Cyanoacrylate is sometimes referred to as *CA* glue; since the advent of these superglues, they have been adopted by and perfected for woodworkers (see **Figure 8-14**). Cyanoacrylate is available in three



Image courtesy of rockler.com

FIGURE 8-14 CA glues developed for woodworkers are available in various thicknesses.

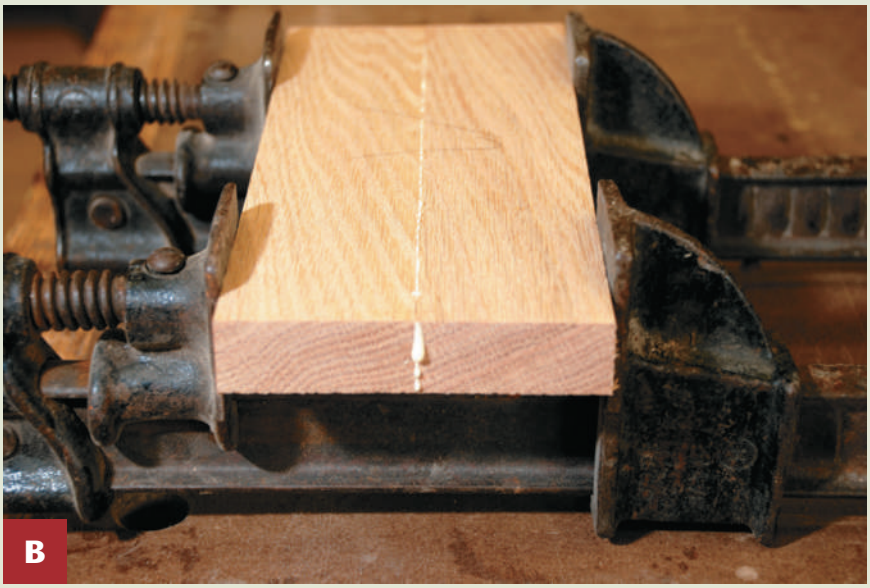
different viscosities: thin, medium, and thick. Each is suitable for different uses. The thin type is ideal for sealing cracks, while the thicker formulations are better for repairs and inlays. CA glues are particularly favored by turners. Two other products associated with CA glues are also seen in **Figure 8-14**. One is an accelerator, which is applied as a mist to the parts prior to the glue being applied. It makes the bond instantaneous. The other product is a de-bonder, a solvent that dissolves the glue quickly. Since the glue bonds so quickly, it is possible to accidentally glue a finger to a part or to another finger, so it is good to have the de-bonder handy. Acetone also works as a cleanup for cyanoacrylate, but it is not as effective.

PROCEDURE 8-1

Using Adhesives



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STEPS

1. Fit your assembly together before gluing. This is called *dry assembly.* Get out the clamps you will need and actually clamp up the project to ensure that it will go together without any problem. If you discover a poorly fitting joint, fix it before proceeding.
2. Release the clamps and leave them handy. Wipe any dust or debris off the pieces.
3. Apply glue in thin, even coats to the surfaces to be joined. Spread it evenly with a small brush, scrap of wood, or your finger (see **Figure A**). You are working on what is called an *open assembly.*
4. Clamp the assembly. It is now referred to as a *closed assembly.* With the exception of epoxies, contact cement, and cyanoacrylate glue, wood glues must cure under pressure to form a strong bond. Small beads of glue should ooze from the joint, as shown in **Figure B**; this tells you that sufficient glue was used.

Contact cement is a liquid adhesive that serves many purposes. It will bond almost anything, whether similar or dissimilar, porous or not. It does not require clamping. Contact cement is different from other adhesives in that it is applied to both surfaces to be bonded, and then each surface is allowed to dry. The cemented surfaces are then brought into contact with each other, and an immediate bond is formed. Contact cement may be applied by brushing, rolling, troweling, or spraying.

There are two basic categories of contact cement, *high solvent* and *neoprene based,* the difference between them being the solvent in which the cement is suspended. This affects the toxicity, flammability, and cleanup of each type.

High-solvent contact cements come in two types, one for spraying and the other for brushing (see **Figure 8-15**). They set quickly and make a very strong bond, but they are highly flammable and toxic. Because the fumes pose a health risk, these cements must be applied only in well-ventilated areas while wearing proper safety equipment. They are undesirable from an environmental point of view, because they release high levels of volatile organic compounds (VOCs), which deplete the ozone in the atmosphere. Cleanup is messy and difficult.

Neoprene-based contact cements are nonflammable and nontoxic, so they do not pose the health hazards that the other types do, nor do they emit dangerous VOCs. They clean up with warm soapy water (see **Figure 8-16**). The only real disadvantage to this type of contact cement is that it has a much longer cure time — up to an hour — compared to 5 to 10 minutes for a high-solvent–based contact cement.



Image courtesy of Titebond Wood Glues

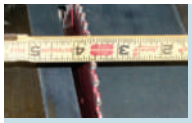
FIGURE 8-15 High-solvent contact cement.



Image courtesy of Titebond Wood Glues

FIGURE 8-16 Neoprene-based contact cement.

Contact cements are primarily used by woodworkers to attach plastic laminates to a core, such as particleboard, plywood, or MDF.



SCIENCE CONNECTION

VOC is an acronym for volatile organic compounds. VOCs are emitted as gases from certain liquids or solids. They include a variety of naturally occurring and human-made chemicals, some of which are known to have long-term adverse health effects and are hazardous to the environment. ■

GREEN REMINDERS

Given the choice, choose to use products that are less hazardous to you and to the environment.

The two types of adhesives that remain to be discussed are both used primarily as temporary adhesives. They are hot-melt adhesives and spray adhesives. Hot-melt adhesives will bond many dissimilar types of materials. The adhesive comes in a solid form, usually a stick, and is applied with a special applicator, often called a glue gun, which melts the stick (see **Figure 8-17**).

The melted glue is applied to one surface, and the item to be bonded to it is immediately placed against



Image courtesy of Adhesive Technologies, Inc.

FIGURE 8-17 Hot-melt stick and glue gun.

it. The bonding time is very quick, so clamping time is short, if it is needed at all. Often hand pressure for a few seconds or minutes is sufficient. **Hot-melt adhesives** leave a wide glue line and do not offer much strength, but they are useful to the cabinetmaker for temporarily bonding one object to another.

CAUTION

When working with any type of adhesive, read the instructions on the container carefully; they include both safety information and clean-up directions. Some adhesives are toxic or flammable, so special precautions must be taken when working with them.

WOODWORKING TIP:

We often use wood blocks between clamps and our work to protect the workpiece from being marred by the clamps. In the midst of the glue-up, it can be difficult to keep everything in place. Using a hot-melt adhesive to attach the blocks to the clamp jaws simplifies the process.

Historically, hot-melt adhesives have been used by woodworkers for temporary bonding, but now there is a hot-melt system that utilizes a polyurethane glue stick that is meant for permanent bonding (see **Figure 8-18**).

Spray adhesives will also bond dissimilar materials. They come in an aerosol can. They are ideal for temporarily bonding patterns to wood, for example, in scroll saw work (see **Figure 8-19**). Stronger spray adhesives are available for permanently bonding materials, such as a leather insert on a writing desk.



Image courtesy of rockler.com

FIGURE 8-18 Polyurethane hot-melt adhesive forms a permanent bond.



Courtesy of DAP Products, Inc.

FIGURE 8-19 Spray adhesive.



Summary

Adhesives are an important part of the woodworking and cabinetmaking trades. Many different choices are available to today's craftsman. All adhesives may be categorized as either natural or synthetic. Natural adhesives include animal glues, starch glues, and casein. Most cabinetmakers today use synthetic glues, which are either thermoplastic or thermosetting. Thermoplastic glues include polyvinyl acetate, aliphatic resin, and hot melts. Thermosetting glues include polyurethane glues, plastic resin, urea formaldehyde, resorcinol resin, epoxy, and cyanoacrylate. Contact cement is another adhesive used by cabinetmakers, primarily for bonding plastic laminates to substrates.

Each type of adhesive has its own advantages and disadvantages. Things to consider in choosing an adhesive are the materials to be bonded and the conditions to which the final project will be exposed. The various adhesives have different properties in terms of water, heat, and chemical resistance. They also vary in set times, cure times, and pot life. It is a very good practice to carefully read the instructions for use and clean-up directions printed on the adhesive container.



Key Terms

aliphatic resin
animal glue
chemical resistance
cohesion
contact cement
curing time
cyanoacrylate
epoxy cement
heat resistance
hide glue
high-solvent contact cements
hot-melt adhesives
mechanical adhesion
natural adhesives
neoprene-based contact cements
open time
plastic resin adhesive
polyurethane glues
polyvinyl acetate
pot life
resorcinal resin
set time
shelf life
specific adhesion
synthetic adhesives
thermoplastic
thermosetting
water resistance



Check Your Knowledge

1. How do adhesives work?
2. What is the difference between mechanical adhesion and specific adhesion? Which contributes more to the glue bond?
3. What are the characteristics of adhesives, and why is it important to be familiar with them?
4. What are the two main categories of adhesives, and how do they differ?
5. Give two examples from each of the two main categories.
6. Name a natural adhesive with low water resistance. How might this seeming disadvantage become an advantage?
7. How does a thermoplastic adhesive differ from a thermosetting adhesive? Give an example of each type.
8. Name two adhesives that would be good choices for exterior projects.
9. What is a one-part adhesive? What is a two-part adhesive? Why should you only mix as much adhesive as you will use?
10. What are the three main types of contact cement and how do they differ?
11. What is the primary application for contact cement for the woodworker?
12. Name an adhesive that would be good for temporarily bonding items.

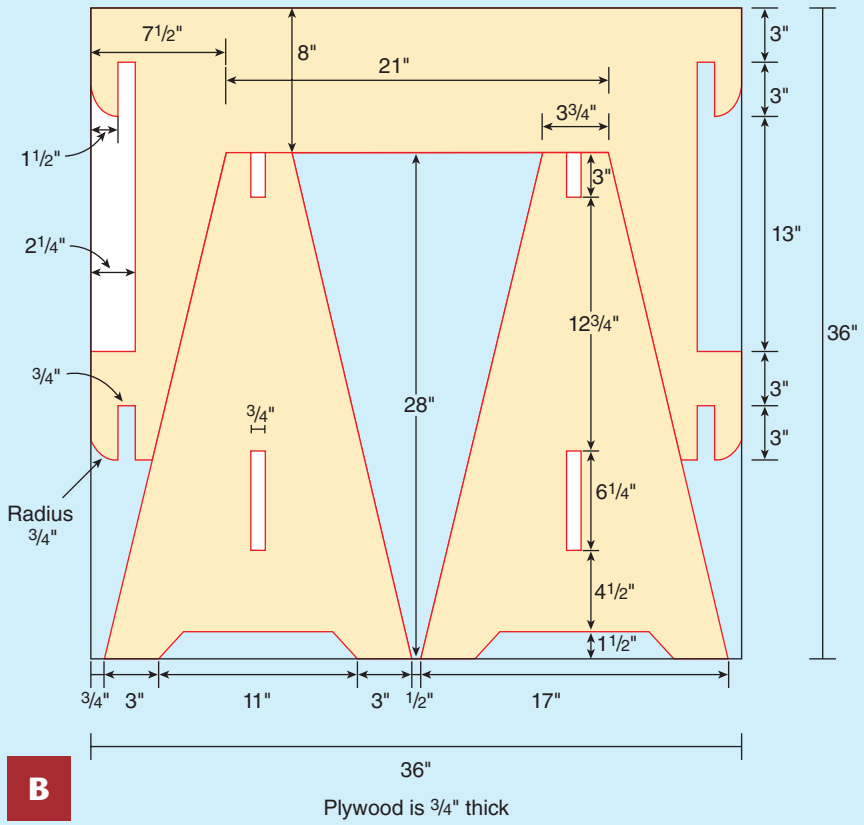
BUILD IT!

KNOCKDOWN SAWHORSE



A

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B

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Figure A shows a completed knockdown sawhorse.

TOOLS REQUIRED

- Measuring tool
- Marking tool
- Drill, 3/4" bit, 1/8" bit, and countersink bit
- Jigsaw
- Sander

MATERIALS REQUIRED

- 3/4" × 36" × 36" plywood
- 1" × 6" × 36" solid stock

STEPS

1. Carefully lay out the pattern shown in **Figure B**.
2. Drill 3/4" holes at either end of the leg slots and at the bottom of all the other open-ended slots.
3. Use a jigsaw to cut out the parts.
4. Ease the rough edges of all the parts with a sander.
5. Fit the pieces together to form the sawhorse.

6. Put a screw through each end to secure the parts as shown in **Figure C**. Drill a 1/8″ pilot hole and a countersink first.
7. Attach the 1″ × 6″ piece to the top with screws, again drilling a 1/8″ pilot hole and countersinking the screws, as shown in **Figure D**. This top can be replaced if it gets chewed up as the sawhorses are used.


C

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D

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BUILD IT!

PROJECT CHALLENGE

Traditional Sawhorse



A

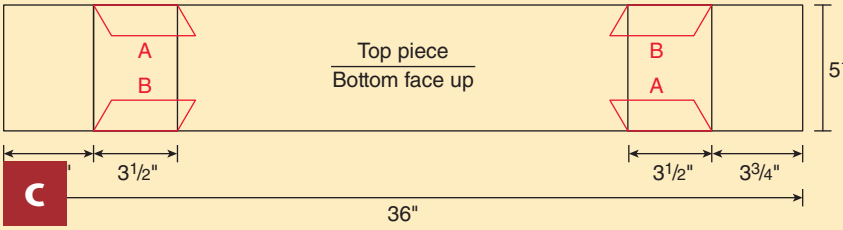
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Assembly list - sawhorse

Part	Dimensions (thickness × width × length)	Quantity
1. Top	$1\frac{1}{2}$" × $5\frac{1}{4}$" × 36"	1
2. Legs	$1\frac{1}{2}$" × $3\frac{1}{2}$" × 34" rough length	4
3. Stretchers	$\frac{3}{4}$" × $3\frac{1}{2}$" × 40" rough length	2
4. Gussets	$\frac{3}{4}$" × 7" × 10" rough dimensions	2
	#8 × $2\frac{1}{2}$" wood screws	12
	#8 × $1\frac{3}{4}$" wood screws	12
	#8 × $1\frac{1}{4}$" wood screws	16

B

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C

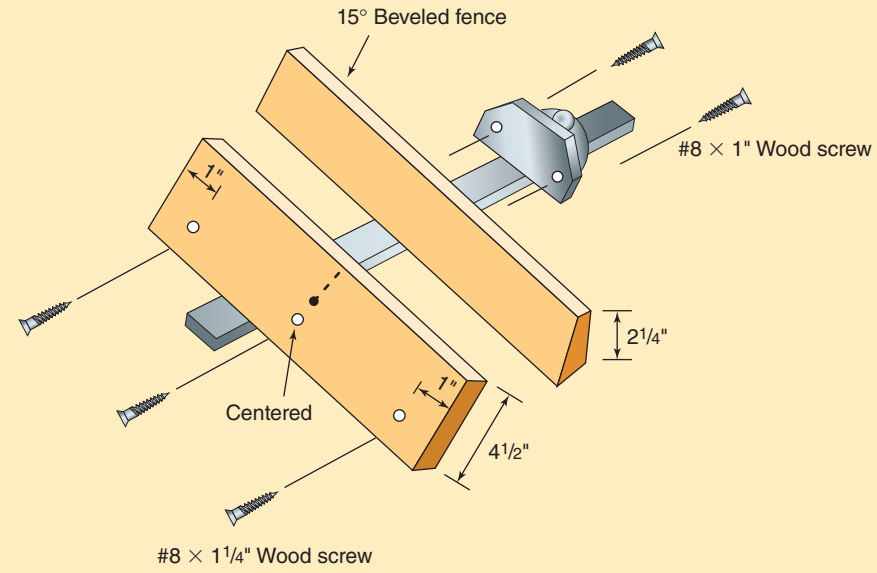
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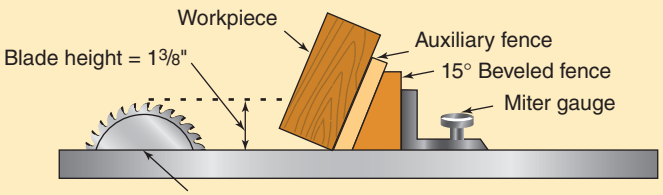
A completed traditional sawhorse is shown in **Figure A**.

STEPS

1. Referring to the assembly list given in **Figure B**, cut the pieces to size.
2. Lay out and label the leg mortises on the bottom of the top piece, as shown in **Figure C**. The angles just need to be sketched in.

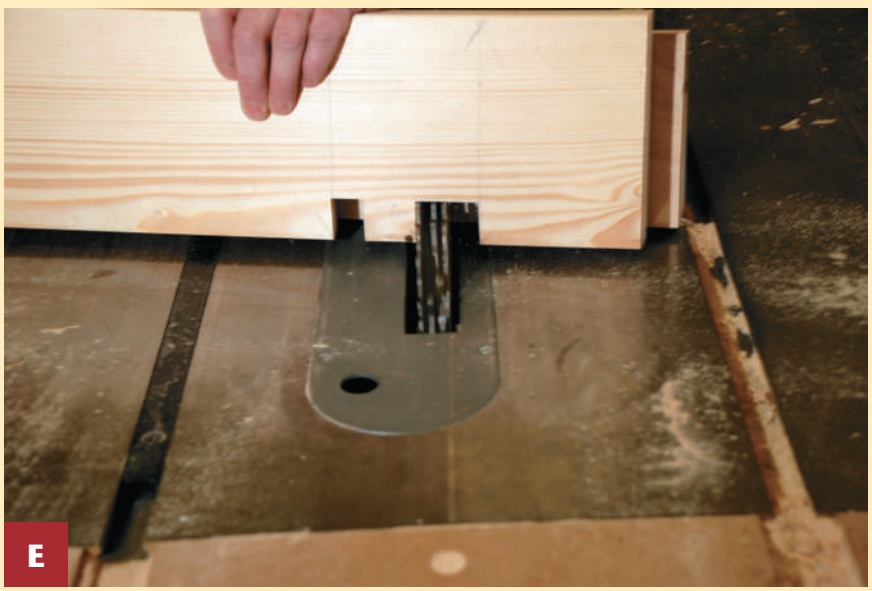
3. The legs of the sawhorse are angled in two directions for stability. This means that the mortises in the top need to be cut at a compound angle. This is done on the table saw using a jig on the miter gauge. Rip a 24″-long piece of 2 by 4 at a 15° angle to 2 1/4″ wide, and screw it to the miter gauge. Screw a piece of 3/4″ × 4 1/2″ × 24″ piece of plywood to this, as shown in **Figure D**.
4. Put a dado blade on the saw, set for the widest cut, and raise it to a height of 1 3/8″.
5. Place the miter-gauge jig in the *right* miter gauge slot, and set the miter gauge to 10° to the right. Cut the mortises labeled *A:* First cut the layout lines on either side, and then remove the waste in the center, as shown in **Figure E**.





D

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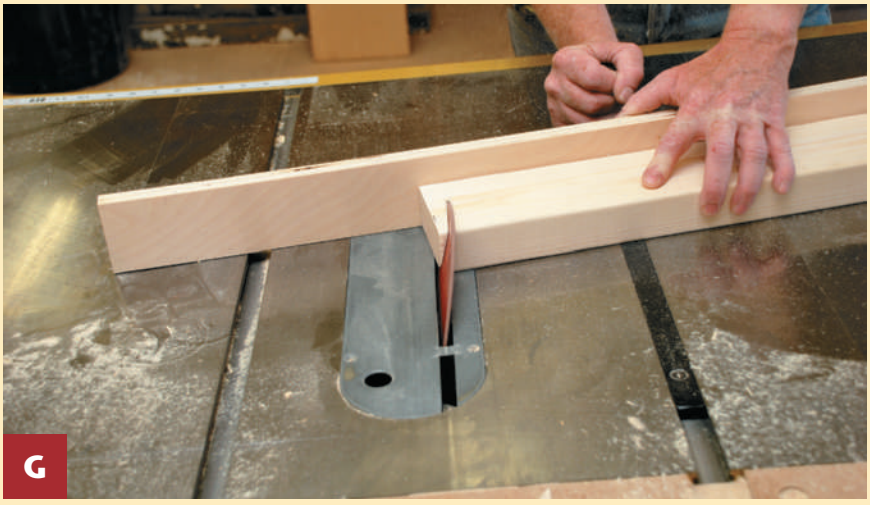


E

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F

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G

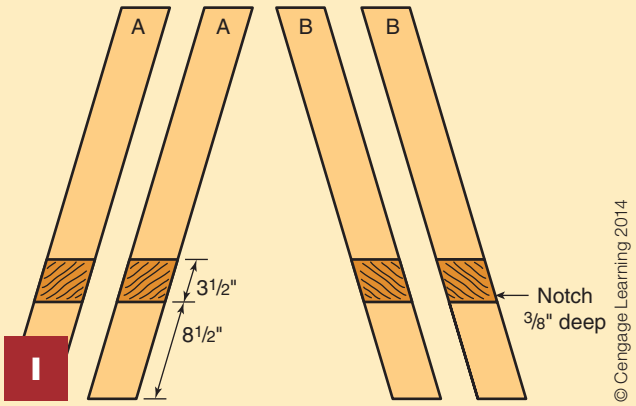
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6. Move the miter gauge jig to the *left* miter gauge slot, and change the miter-gauge setting to the opposite 10° setting. Cut the *B* mortises, as shown in **Figure F**.
7. Rout a 1/8" chamfer on the top and bottom edges of the top piece.
8. Remove the dado blade from the table saw, and replace it with a combination blade. Tilt the blade to 15°.
9. Remove the jig from the miter gauge and attach a 34" plywood fence to the miter gauge. Set the miter gauge for a 10° angle, and cut one end of each of the legs, as shown in **Figure G**.
10. Change the miter gauge to the opposite 10° setting. Measure 31" and mark one leg. Set the leg to cut in the right place and clamp a stop block on the miter fence; by doing this, you will avoid having to measure the other legs, and they will all come out the same length. Cut each of the legs to length, as shown in **Figure H**.

11. Lay out the legs as shown in **Figure I**, and label them as noted. Measure and lay out for the notches that will hold the stretchers. Use a sliding T-bevel set to 10°, as shown in **Figure J**.
12. Install a dado blade in the table saw, set for its widest cut, and raise it to a height of 3/8". Tilt the miter gauge to a 10° angle. See **Figure K**: When you cut the notches for the stretchers, note that the angle of the miter gauge should be parallel to the cuts at the end of the legs. This means that the 10° miter-gauge setting will be opposite for legs *A* and *B*. Define the outside of the cuts and then remove the waste.



I

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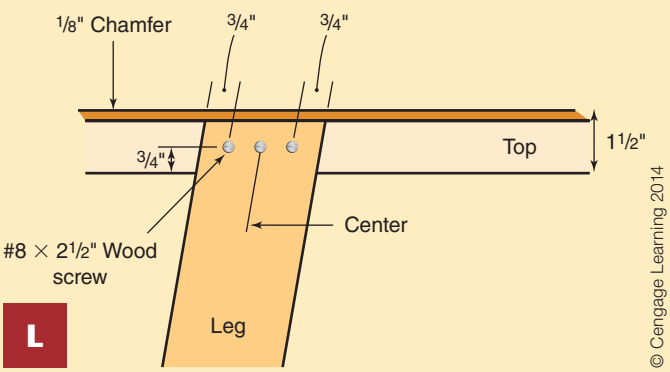

K(a)

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K(b)

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L

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M(a)

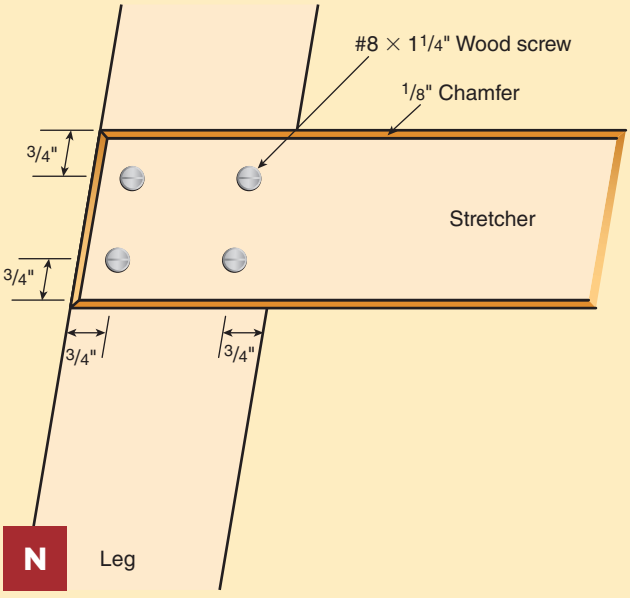
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13. Glue and screw the legs into the top as detailed in **Figure L**.
14. Lay out and cut a 10° angle on one end of each stretcher, as shown in **Figure M**.
15. Fit the stretchers into the notches on the legs so that the end you just cut is flush with one leg. Mark the other ends to length. Cut to size as marked.

16. Rout a 1/8" chamfer along the outer edges of the stretchers, and then glue and screw in place as shown in **Figure N**.
17. Cut a 10° bevel on one long side of each gusset. This allows the gusset to fit tightly against the bottom of the top piece, as shown in **Figure O**.
18. Place the beveled side of the gusset against the table saw fence and rip the gusset to a finished width of 6".

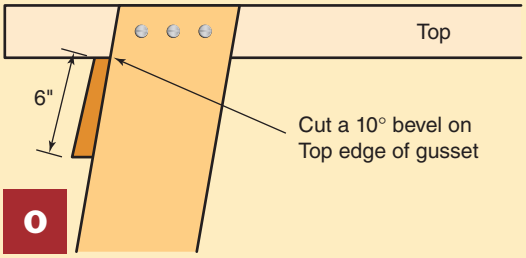

M(b)

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N

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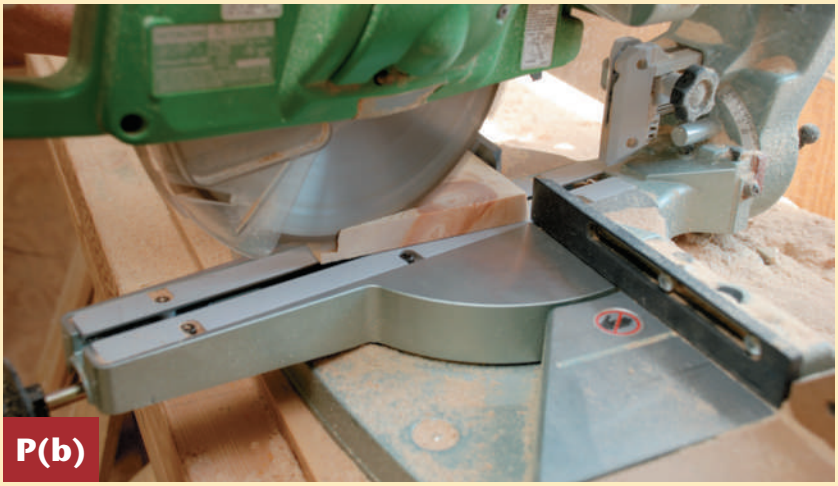
O

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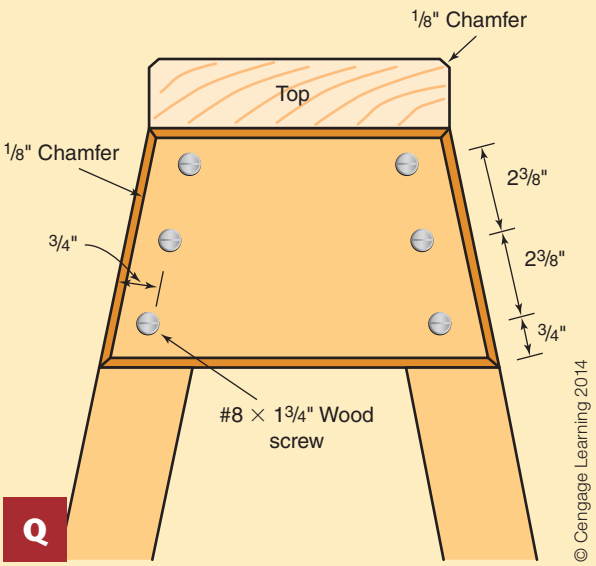
P(a)

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P(b)

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Q

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19. Lay out and cut a 10° angle on one side of each gusset, as shown in **Figure P**.
20. Hold the gussets in place with the end you just cut flush with the leg, mark the other side, and then cut to size.
21. Rout a 1/8" chamfer along the outer sides and bottom edge of the gussets, and then glue and screw them in place, as shown in **Figure Q**.

SECTION IV


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Woodworking Materials


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SUCCESS STORY

Julie Godfrey

Title

Owner of Godfrey Woodworking, a studio furniture maker and marquetry specialist in Shelburne Falls, Massachusetts; instructor at the Center for Furniture Craftsmanship in Rockport, Maine.

Education

In 1990, Julie got a degree from Brown University in visual arts, and a few years later, she matriculated at the prestigious College of the Redwoods woodworking program. She followed her education with an informal apprenticeship with Silas Kopf.

History

There were many experiences that inspired Julie during her undergraduate studies. Among them: taking a class from a wood sculptor, falling in love with some Frank Lloyd Wright chairs at a gallery, and seeing her first marquetry in Florence, Italy. So it was a natural move for her to pursue her interest in woodworking at the College of the Redwoods. While there, she learned marquetry from some older students — and knew that it was what she wanted to do. "It felt like a way to bring freedom and creativity to the meticulous work of cabinetry."

After graduating, she returned to the East Coast and set up a shop down the hall from renowned marquetry artist Silas Kopf. Over the next seven years, she worked with him on projects and learned from him, while also taking on her own commissions. During that time, she developed her own style — mostly high realism, with flowers and animals, showcasing the wood grain. Now she's on her own, doing one to two pieces per year, mostly commissions, getting business mostly via word of mouth. One of the pieces she's most proud of: an ark for Torah scrolls for a Jewish synagogue.



Image courtesy of Paul Franz (Greenfield, MA)

On the Job

A mother of three young kids, Julie works part time, 25 to 30 hours a week, from when the kids go to school until they come home. She builds two to three pieces a year — though they sell for as much as $2,000 to $40,000 each. Since much of her work is commissions, she has quite a bit of interaction with clients. First she creates a drawing that she will run past them, then she does a full-scale model to see how the marquetry will affect the balance and proportions, and then, the real thing.

Best Aspects

Julie finds great satisfaction in designing one-of-a-kind pieces. An outgoing, social person, she also likes collaborative work. She's just completed a memorial board for a synagogue with a stained glass artist and a silk artist.

Challenges

"It's hard not having consistent income," she says. "Sometimes it could be six months before I get paid, and that requires us to budget carefully. I've learned to be patient and ride the highs and the lows of the patterns of work. Even when I've thought I had no more work ahead, something always comes along. It takes a great deal of trust. "

Importance of Education

"It's really important to get training in good joinery and hand skills, as it's better to learn good habits that refine your craftsmanship before you have a chance to develop the bad habits. It saves a lot of grief and frustration learning how to do things by hand, with care, and with a sense of craftsmanship."

Future Opportunities

Julie says she just hopes to continue having a steady stream of interesting commissions — particularly those that have meaning. She's now trying to raise money to build a sacred table for a local interfaith council, one that would include symbols from many religious groups and help begin a dialogue.

Words of Advice

"Always be a person who cares about what they do, and do it the best that you can. You'll have both the most pleasure and the greatest reward."

Story originally written by Margaret Magnarelli, 2008. Interview and photo provided by Julie Godfrey.



9

Wood

You'll Learn

After studying the chapter, the student should be able to:

- Correctly identify the differences between hardwood and softwood trees
- Discuss the processing of the wood from tree to board in sequential order
- Recognize standard molding patterns
- Name and describe common lumber defects
- Describe how the production, grading, and sale of hardwood and softwood lumber differ
- Calculate board feet
- Identify different types of grain and explain how they affect the appearance of wood
- Describe wood movement and how it affects woodworking practices
- Identify various woods and their individual characteristics
- Identify sources for acquiring wood

INTRODUCTION

Trees are one of our greatest natural resources: They cool the environment through water transpiration, they give us shade and prevent erosion of the soil, and they are the source of abundant materials. Virtually every part of the tree can be turned

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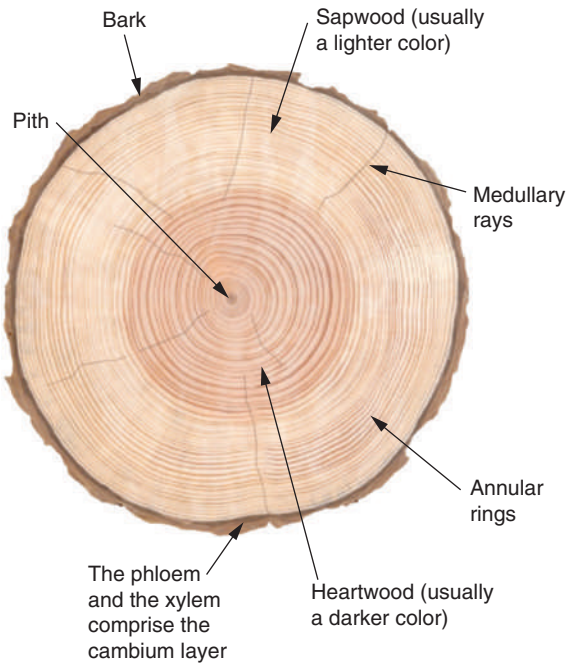
to our use. Trees provide the materials used to build and furnish our homes. State and national parks, which provide numerous recreational opportunities, would not be what they are without their trees. Forests provide important habitat for wildlife and other organisms that are important to the ecological balance of the earth.

Trees contribute to our lives in many ways that we do not think too much about. It is both interesting and instructive to consider the variety of ways we benefit from our forests. Here, as cabinetmakers and woodworkers, we will look at the different kinds of trees.

HARDWOODS AND SOFTWOODS

Trees can be divided into two main categories: **hardwoods** and **softwoods**. These names are somewhat misleading, as there are hardwoods that are relatively soft and softwoods that are actually harder and stronger than some hardwoods. It is more accurate to use the term **deciduous** in referring to hardwoods and **coniferous** for softwoods. Deciduous trees lose their leaves each year; coniferous trees have cones (see **Figure 9-1**).

As the earth developed, conifers were the first trees. They are simpler in structure than deciduous trees, which evolved later, and they reproduce themselves by means of the seeds in their cones. Deciduous trees, on the other hand, reproduce by means of encased nuts and seeds.

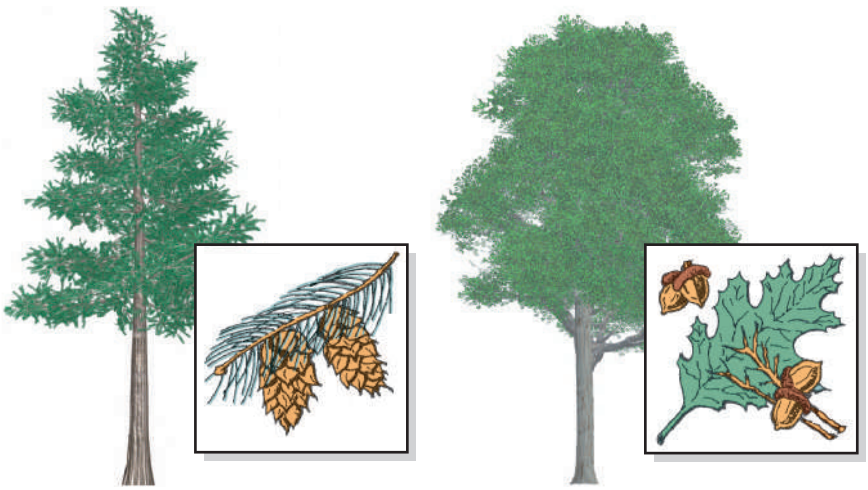


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FIGURE 9-2 Cross section of the tree showing its structure.

All trees, both deciduous and coniferous, share certain characteristics. Let us consider a cross section of a tree, shown in **Figure 9-2**.

The **pith** is at the center of the tree. The circular rings surrounding the pith are the **annual rings**. Every annual ring represents one year's growth in the life of the tree. Each annual ring is made up of two parts, the **earlywood** and the **latewood**. The earlywood is sometimes called **springwood**, because that is when it is added, and the latewood is sometimes referred to as **summerwood** for the same reason. Some trees, such



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FIGURE 9-1 Conifers have needles and cones. Deciduous trees shed their leaves annually and have seeds or nuts, as seen in the oak on the right.

as oak and ash, exhibit very clear differences between the growth that occurs early and that which comes later. In other trees the distinction is not as dramatic.

The outside layer of the tree is the **bark**. Its function is to protect the living part of the tree. Just inside the bark is a microscopic layer called the **cambium**. This is where all the new growth in the tree takes place each year. The cambium has two parts: The outer part is the **phloem**; its job is to produce more bark cells for the tree. The inner part of the cambium is called the **xylem**, which makes the cells that increase the circumference of the tree and creates the **sapwood**, which is the living part of the inside of the tree; its purpose is to carry water and nutrients to feed the tree. Over time, the older sapwood turns to **heartwood**. The heartwood is comprised of dead cells that store minerals and extractives. It acts like a spine, providing the structural support of the tree. In some species, there is a distinct color difference between the sapwood and the heartwood. Cherry and walnut are two examples (see **Figure 9-3**). In other woods the difference between the sapwood and the heartwood is not so obvious. Generally, the heartwood is the more desirable part of the tree to the woodworker, although there are exceptions to this, notably maple, in which the sapwood is considered more valuable.

The **medullary rays** of the tree run horizontally across the face of the cross section. Think of the rays as spokes on a wheel with the pith as the hub. Their function is to carry water and nutrients across the transverse section of the tree. Depending on the species of wood and the way it is cut, the rays may be a striking visual element in a board.



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FIGURE 9-3 Both walnut (top) and cherry (bottom) exhibit a striking difference in color between their heartwood and sapwood.



FACTS ABOUT WOOD

Sycamore, *Platanus occidentalis,* has a fine, even texture, usually with a straight grain. It is pale brown in color and has darker rays, which create a striking look when a sycamore log is quartersawn. ■

From the Forest to the Shop

Foresters and loggers select trees to be cut for lumber. The trees are cut down and their limbs are removed. The trunks are bundled together and transported to a sawmill for processing. Once the logs reach the mill, they are sorted by species (see **Figure 9-4** and **Figure 9-5**). The very best logs are set aside to be processed into cabinet-grade **veneer**.



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FIGURE 9-4 Logs are transported to a sawmill for processing.



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FIGURE 9-5 Logs are sorted by species to await processing after delivery to the sawmill.



Image courtesy of The A. Johnson Co., LLC

FIGURE 9-6 Logs are debarked.

Logs that will become lumber now begin their transformation. First, the bark is stripped off by a debarking machine (see **Figure 9-6**). Next, the log goes through a metal detector to sort out logs containing metal, because hitting metal can damage saw blades, stop production, and cause injury. The majority of logs that are processed into lumber are then squared up by cutting a flat face on each side of the log using a **head saw**, a large circular saw 48 inches or more in diameter. Some mills use a band saw rather than a head saw for this operation, as shown in **Figure 9-7**, which results in less waste, due to the fact that a band saw blade is thinner than the teeth on a head saw. The squared-up log is called a **cant**, and the wood that was cut off to create the cant is known as **slab wood**; it is set aside to be sold as is or to be processed further (see **Figure 9-8**). The cants are moved along to the next stage (see **Figure 9-9**), where they are sawn into boards, as shown in **Figure 9-10**; boards sawn in this way are called **plainsawn** or **flatsawn**.

A less common sawing method is to cut the logs into four quarters and then cut boards from each quarter. The lumber produced by this method is known as *quartersawn lumber.* The appearance of lumber that has been quartersawn is very different from lumber that is plainsawn (see **Figure 9-11**).

Many commercial sawmills use band saws, rather than large circular saws, to cut the boards. This is a much more efficient use of the log, because a band saw blade is much thinner than a circular saw blade,



Image courtesy of The A. Johnson Co., LLC

FIGURE 9-7 Cant being cut from a log on a band saw.

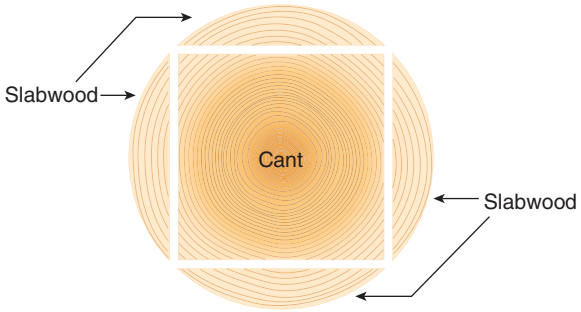


Image courtesy of The A. Johnson Co., LLC

FIGURE 9-8 A cant and slabwood are cut from each log.



Image courtesy of The A. Johnson Co., LLC

FIGURE 9-9 Cants being transported to the next stage of operation.



Image courtesy of The A. Johnson Co., LLC

FIGURE 9-10 Band saw cutting a cant into boards.



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FIGURE 9-11 Plainsaw and quartersawn lumber have a very different appearance.

and so less of the log becomes sawdust. The entire processing operation is largely computerized, and many of the saws use laser technology to maximize the yield.

Once the log has been cut into boards, the edges are trimmed off to produce a board of uniform width, and the boards are cut to length. Next, the newly sawn boards go the **grader** (see **Figure 9-12**). The grader is a person who has been trained to distinguish the different grades of wood and sorts them accordingly. Some mills have a computer system that allows them to do



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FIGURE 9-12 The grader.

some sorting before the boards get to the grader, as shown in **Figure 9-13**, making the grading process faster and more efficient. After grading, the boards are packaged for drying: They are stacked with evenly spaced sticks between them to allow air circulation on all sides of each board. Lumber must be dried evenly, or its quality will be compromised. The drying process seasons the wood so that we can use it. There are two main methods for drying lumber: *air drying* and *kiln drying* (see **Figure 9-14** and **Figure 9-15**). The air-drying method allows the wood to season naturally, but it takes considerably longer than kiln drying. The length of time it takes wood to season varies, depending on the species of wood and the thickness of the material being dried.

Most commercial mills dry their lumber in kilns. This enables them to process lumber far more quickly and also to control the drying process carefully. As the wood is kiln dried, it is constantly monitored and checked regularly, and steam is periodically injected into the kiln to prevent the lumber from drying too rapidly. **Figure 9-16** shows a worker monitoring the moisture content of the wood in the kiln. If the drying is not done carefully and correctly, the final product will not be the highest quality possible. Wood that has


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FIGURE 9-13 Computer sorting the boards before sending them to the grader.


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FIGURE 9-14 Drying lumber in the air.

been kiln dried is considered by many woodworkers to be superior to air-dried wood.

At this point we have **roughsawn** lumber. Depending on the tools we have available to us, we may purchase lumber of this type. Lumber not sold as roughsawn is surfaced. **Figure 9-17** shows roughsawn and surfaced wood. *Surfacing* means planing the lumber to a standard thickness. The board may be *surfaced two sides* (S2S), *three sides* (S3S), or *four sides* (S4S). Each step requires more processing, which makes the board more expensive. Once the board is surfaced, the appearance of the wood is much clearer. Most of the lumber purchased by cabinetmakers is S2S.


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FIGURE 9-15 Drying lumber in a kiln.


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FIGURE 9-16 Monitoring the moisture content of wood being dried in a kiln.

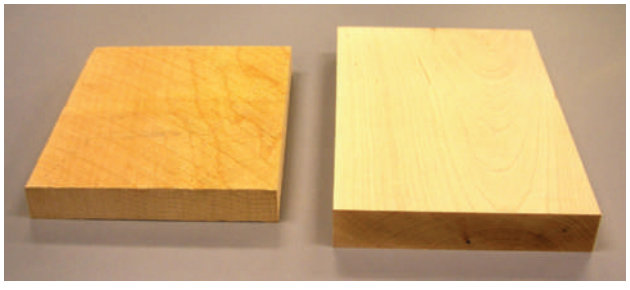

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FIGURE 9-17 Hard maple before and after surfacing; roughsawn and S2S.



SCIENCE CONNECTION

Trees clean the air as they grow. A tree uses 1.47 pounds of carbon dioxide to grow one pound of wood, and it gives off 1.07 pounds of oxygen in the process. Each of us breathes a pound of oxygen a day. We literally need trees to survive. ■

MOLDINGS

Many sawmills make moldings as well as turn logs into lumber. These moldings are wood pieces with shaped edges that are used cover transitions between surfaces or act as decorative elements. Moldings are used in home construction to decorate the edges of doors and windows, and at floor/wall and wall/ceiling intersections. In cabinet and furniture making we use moldings to decorate products and create visual interest. **Figure 9-18** shows some standard molding patterns. They are available in different sizes. There are two grades of molding produced, N-grade and P-grade. N-grade molding is suitable for clear finishes, which allows the grain of the wood to show, while P-grade has more defects and is meant to be painted.

Molding is purchased by the type, size, grade, and length. Lengths start at 4 feet and continue in 2 feet increments.

LUMBER DEFECTS

Lumber is prone to certain defects that affect its quality and the way we work with it. Some occur in the growth of the tree; others happen as a result of the drying process. Before defining these defects, let us look at three terms that will make visualizing them easier: the *face*, the *edge*, and the *end* of the board (see **Figure 9-19**).

You are likely to see both natural defects and drying defects as you work with wood. Some common defects you are likely to see are illustrated in **Figure 9-20**.

Other defects include the following:

knot: A portion of a branch that was part of the tree at one time. Knots may be further categorized; for example, they may be tight or loose, sound or unsound, and may look different depending on the size of the branch and its orientation to the sawn board.

blue stain: A discoloration caused by a mold or fungus. It occurs after the log is cut and left in an area of high humidity before processing. Certain woods, such as white pine and sycamore, are prone to blue stain.

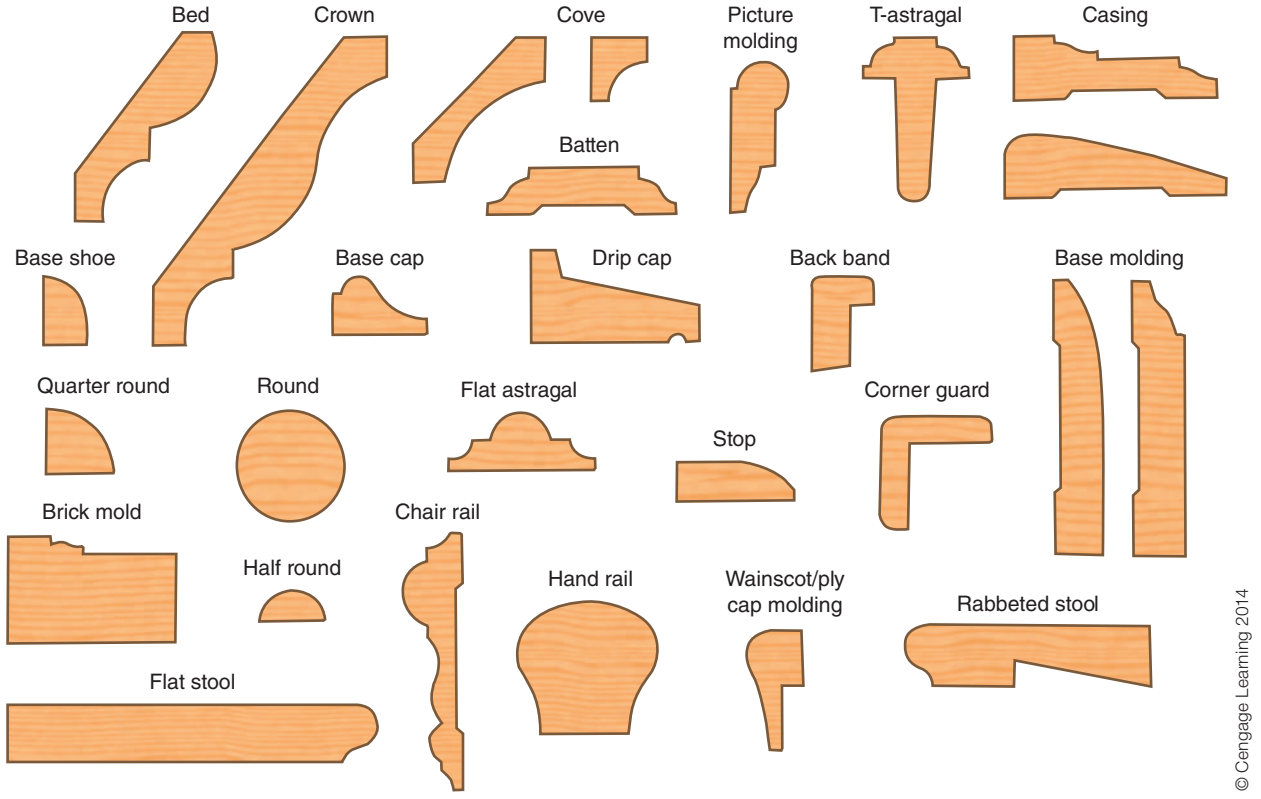
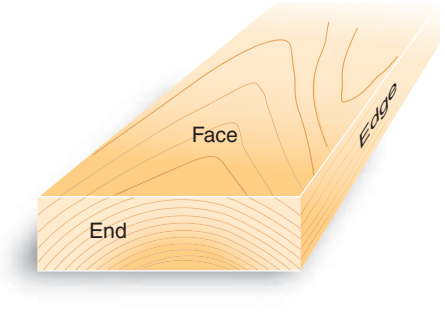


FIGURE 9-18 Standard molding patterns.



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FIGURE 9-19 Terms used to describe the parts of a board.



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FIGURE 9-20 Common natural wood defects.

pitch pocket: An opening in the wood containing resin, which may be solid or liquid; it is found in some softwoods, such as pine.

bark pocket: Bark material that was enclosed as the tree grew.

Other wood defects occur in the milling and drying of lumber. They include:

warp: Any deviation from a true plane surface that results from uneven shrinkage. Warp is a general term and includes bow, crook, cup, twist, and kink. Figure 9-21 illustrates the different types of warp.

bow: A curve along the face of a board from end to end.

crook: A curve along the edge of the board, sometimes referred to as the *crown* of the board.

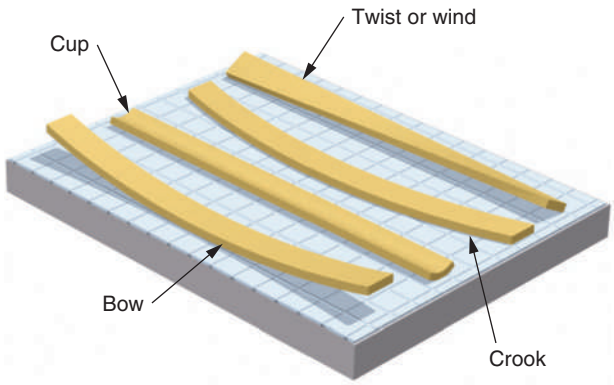
cup: A curve across the width of the board.

twist: A board that looks as though it is spiraling; also called **wind**.

kink: A deviation along the board caused by a knot or irregular grain pattern.

wane: The presence of bark or absence of wood on corners or edges.

split: A crack caused by a separation of wood fibers along the grain traveling the length of the wood. It is perpendicular to the growth rings.



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FIGURE 9-21 Wood defects that may occur as the wood is dried.

check: A crack like a split, also caused by a separation of wood fibers along the grain but shorter and found at the ends of seasoned boards.

shake: A crack caused by a separation between the annual growth rings.

case hardening: The inside of the board is under tension and will react unpredictably when cut; this is caused by improper drying.

honeycombing: A severe case of case hardening. The tension between the inside and surface of the board becomes so great that cracks develop in the core, which may or may not be evident from the outside.

Lumber Grades

Softwoods and hardwoods are graded differently. Softwood lumber grades are based on standards set by associations of lumber producers, such as the Western Wood Products Association. Each association that sets softwood grading standards must conform to the guidelines of the American Softwood Lumber Standard PS 20-70 established by the U.S. Department of Commerce.

For purposes of grading, softwood lumber may first be divided into two broad categories: construction and remanufacture. Remanufacture lumber will be further processed; for example, it may be used in making ladders, or pencils, or molding. Industrial operations are the typical users of this type of lumber. Construction lumber, as its name suggests, is intended for general construction purposes and is what is commonly available to us as consumers. It can be further subdivided into stress-graded, nonstress-graded, and appearance categories. The structural integrity of the wood is the primary requirement in grading stress-graded and nonstress-graded lumber, although

appearance is also considered when evaluating nonstress-graded wood. The most important criterion in grading wood in the appearance category is the way it looks. Stress-graded lumber is wood than is nominally 2 or more inches thick, is used in framing, and is infrequently used by cabinetmakers. We are more likely to buy and use nonstress-graded or appearance grade lumber. The grades we see used within these are select (sometimes called finish), common, and shop. Select grade has the fewest defects, and shop grade the most. Each of these grades may be further subdivided. Select grades may be designated A, B, C, or D, with the A grade being the highest. Grades A and B are often combined into one grade known as B and better (B&BTR). There are also different common grades, designated as No. 1, No. 2, No. 3, and No. 4, in descending order of quality. Shop grade is also divided into categories by the numbers 1, 2, and 3. Because different associations of lumber producers use somewhat different terminology in identifying the various grades of softwood, and because of the vast and differing uses for softwoods, interpreting and understanding its grading can be confusing.

Hardwood is graded by standards established by the National Hardwood Lumber Association (NHLA). These standard grades form the framework by which all American hardwoods are traded. They are more consistent and easier to understand than the softwood grading practices. Grading of hardwoods is based on the amount of clear wood that can be cut from each board, and the size of the clear cuttings. The table below lists the criteria for the different grades. The best grade of hardwood is FAS, which stands for *first and seconds*. Both sides of the board must meet the minimum requirements. Next is a grade called FAS One Face, abbreviated as F1F. F1F has the same requirement as FAS on one side, but its poorer side only needs to meet the requirements of the Number 1 Common grade. Below F1F is the Select grade, which has the same requirements that F1F does, except that the minimum board size requirements are smaller. Number 1 Common grade, abbreviated No.1C and sometimes referred to as Cabinet grade, is the grade below Select. Both faces of the board must meet the requirements. Below No.1C is Number 2A Common (No.2AC), which is sometimes called Economy grade. Its poorer face must meet the requirements. No.2AC is the grade of choice for the U.S. hardwood flooring industry. There is also a Number 3 Common grade, which allows more defects and has a smaller required minimum clear yield.



FACTS ABOUT WOOD

Birch, *Betula papyrifera,* is a tough, heavy hardwood that grows in the United States and Canada. It was widely used by Native Americans for building canoes, so it is sometimes called *canoe birch.* It has a straight grain, a creamy white sapwood, and a pale brown heartwood. It is relatively inexpensive compared to other hardwoods, and it works and finishes well. Widely used for turning domestic utensils, dowels, toothpicks, spools, and toys, it is also frequently used as an interior ply in the production of hardwood plywood. ■

	FAS	Select	No. 1C	No. 2AC
Minimum Board Width	6″	4″	3″	3″
Minimum Board Length	8′	6′	4′	4′
Minimum clear cut size	3″ × 7′	3″ × 7′	3″ × 3′	3″ × 2′
	4″ × 5′	4″ × 5′	4″ × 2′	
Minimum clear yield	83.3%	83.3%	66.7%	50%

Nominal Size (inches)	Actual Size (inches)
1 × 4	3/4 × 3 1/2
1 × 6	3/4 × 5 1/2
1 × 8	3/4 × 7 1/4
1 × 10	3/4 × 9 1/4
1 × 12	3/4 × 11 1/4
2 × 4	1 1/2 × 3 1/2
2 × 6	1 1/2 × 5 1/2
2 × 8	1 1/2 × 7 1/4
2 × 10	1 1/2 × 9 1/4
2 × 12	1 1/2 × 11 1/4

Estimating and Purchasing Lumber

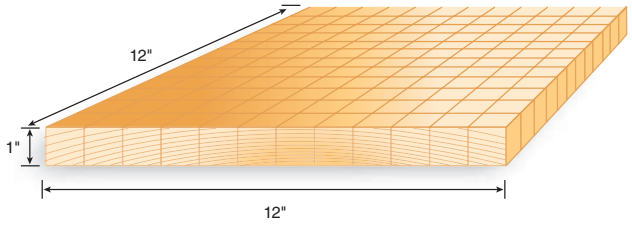
Softwoods and hardwoods are not only graded according to different standards, they are also estimated and sold differently. The great majority of all softwood is sold in standard thicknesses, widths, and lengths. It is ordered by its **nominal size**. Its **actual size** differs in thickness and width, and the length is actually what you get. For example, a 1 × 8 × 10 is actually 3/4 inch thick, 7 1/4 inches wide, and 10 feet long. Softwood lumber is cut in lengths from 8 feet up, in 2-foot increments. Lengths up to 24 feet are available, although you may have to place a special order to get lengths over 16 feet. Softwood lumber is sold by the individual piece. The table above gives the nominal and actual sizes for commonly used softwood boards. Since the nominal and actual lengths are the same, the chart just shows thickness and width.

Hardwoods are estimated and sold by the board foot, rather than by the piece. Widths and lengths are not standardized as they are with softwoods. This is because, as the log was cut, the sawyer tried to maximize the yield and get the best cuts possible, resulting in boards of varying widths and lengths. The terminology for thickness is also different. Instead of specifying the thickness of the piece in whole inches, the hardwood industry indicates thickness by the quarter of an inch. So a 4/4 piece is nominally an inch thick. Actual thickness of a 4/4 piece that has been planed on two sides (S2S) is 13/16 inches. The majority of hardwood lumber is milled to a 4/4 thickness, but 5/4 through 12/4 — in quarter-inch intervals — is not hard to find; and it can be thicker. Thicker pieces are particularly desirable for turning and carving.

A cabinetmaker buying material for a project may buy one piece that is 4/4 thick, 8 inches wide, and 11 feet long and another that is 8/4 thick, 5 inches wide, but only 7 feet long. The unit of measurement for calculating hardwood is the *board foot*. A **board foot** is a unit of volume measurement equivalent to a piece of wood measuring 12 inches wide, 12 inches long, and 1 inch thick (see **Figure 9-22**). Since board footage is a volume measurement, one board foot can have many different shapes, as shown in **Figure 9-23**.

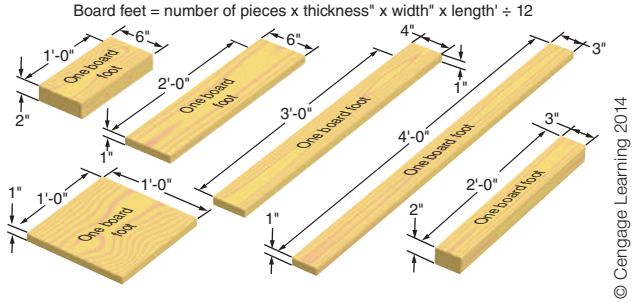
Calculating Board Feet

The volume of one board foot is 144 cubic inches. Volume is determined by multiplying width by length by thickness. So by knowing the width, length, and



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FIGURE 9-22 A *board foot* is the unit of measurement used to estimate hardwood. One board foot is equal to 144 cubic inches.



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FIGURE 9-23 One board foot of lumber can have many shapes.

PROCEDURE 9-1

Calculating Board Footage

STEPS

1. Say a cabinetmaker buys one board that is 4/4 thick, 8 inches wide, and 11 feet long and another that is 8/4 thick, 5 inches wide, and 7 feet long. He needs to determine how many cubic inches of material each piece contains.
2. The width of each piece in inches is multiplied by its length in inches and also its thickness to give the total number of cubic inches. So, the 4/4 is 1 inch thick, and 8 inches wide is fine as is. And 11 feet is 132 inches, so the first piece is 1 inch (thickness) by 8 inches (width) by 132 inches (length), which equals 1056 cubic inches (see **Figure A**).
3. To convert cubic inches to board feet, divide by 144, which is the number of cubic inches in one board foot (see **Figure B**).
4. The second piece purchased by the cabinetmaker was 8/4 by 5 inches by 7 feet. 8/4 tells us the piece is 2 inches thick. 7 feet is 84 inches. **Figure C** shows the steps for calculating the board feet of this piece.
5. The board footage for each board can now be added together to determine the total board footage of material the cabinetmaking is buying (see **Figure D**).
6. This number is rounded off and multiplied by the price per board foot to calculate the cost. Lumber prices fluctuate due to demand and availability.

Note: An alternative formula to calculate board feet is [Thickness (in inches) × Width (in inches) × Length (in feet)] divided by 12.

A

Thickness × Width × Length (in inches)

$1 \times 8 \times 132 = 1056$ cubic inches

B

$$\frac{\text{Cubic inches}}{1 \text{ board foot}}$$

$$\frac{1056}{144} = 7.33 \text{ board feet}$$

C

$2 \times 5 \times 84 = 840$ cubic inches

$$\frac{840}{144} = 5.83 \text{ board feet}$$

D

$7.33 + 5.83 = 13.16$ total board feet

thickness of a given piece of hardwood lumber, we can calculate how many board feet each piece contains. Knowing that, and the price per board foot, you can calculate what the trip to the lumber yard is going to cost.

Grain

The grain of the wood is determined by several factors including the species of the tree, the conditions under which it grew, and the way the wood is cut into boards. The term *grain* is used most often in describing the appearance of a board. From different perspectives, the appearance of the board differs, as shown in **Figure 9-24**. Looking at the faces, edges, and ends of a board reveals different grains, which are determined by where this board was located in the original tree trunk.

But grain is not just about how the wood looks: The strength of any wooden component will also be determined by its grain and how that grain is oriented on the furniture component. Grain also affects the stability of the material, gluing properties, and finishing. The cabinetmaker's understanding of grain affects his work not only aesthetically but also structurally. Perhaps this is why it is said that cabinetmaking is both an art and a science.

Types of Grain

There are six terms used when discussing grain: *end grain, longitudinal grain, edge grain, face grain, radial grain,* and *tangential grain*.

End grain appears at the ends of boards. Whenever a board is cut across its width, end grain is exposed.



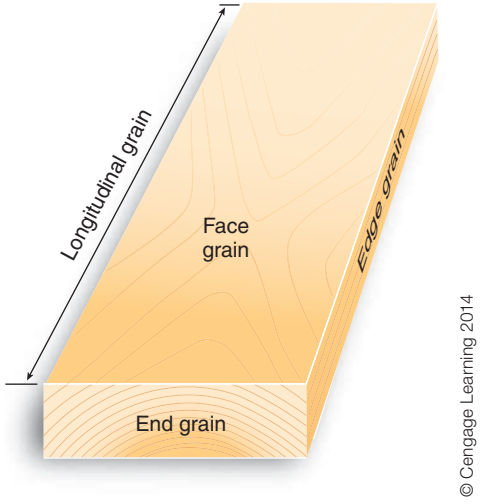
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FIGURE 9-24 The grain of a board may look quite different when viewed from different perspectives.

The ends of a board show a partial cross section of the tree from which it came. **Longitudinal grain** refers to the grain running the length of the piece from end to end.

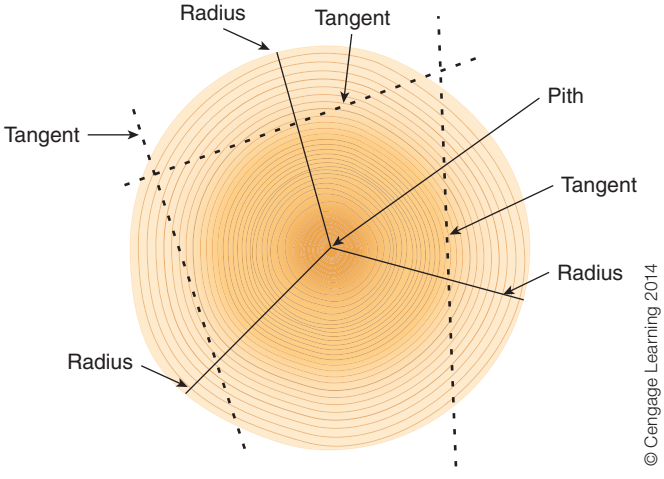
Edge grain refers to the grain on the edges of a board, and **face grain** refers to the grain appearing on the faces of a board. Face and edge grains are classified as either tangential or radial, depending on how the board was cut in relation to the tree's growth rings (see **Figure 9-25**).

Tangential grain and radial grain refer to orientation of the growth rings in a board and are best understood by viewing a cross section of the tree (see **Figure 9-26**), which reveals a circle made up of smaller circles. At the center of the circle is the pith, and each concentric circle represents one year's growth. The circumference of the circle increases as the tree grows;



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FIGURE 9-25 End, edge, longitudinal, and face grains.



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FIGURE 9-26 Tangential and radial grain.

a radius can be drawn from the center of the circle to any point on its circumference, just as the rays radiate out from the pith. Similarly, a tangent can be drawn at any point tangent to the circumference of the tree.

A board exhibiting **radial grain** on its face was cut along a radius running from the center of the tree outward (see **Figure 9-27**). The grain appears straight. A number of years of growth rings can be observed by looking at the end grain. Quartersawing produces lumber that displays radial grain on its face; this grain is straight, and in some species the tree rays are highly visible. This is especially striking in some woods: White oak is more valuable when cut in this manner.

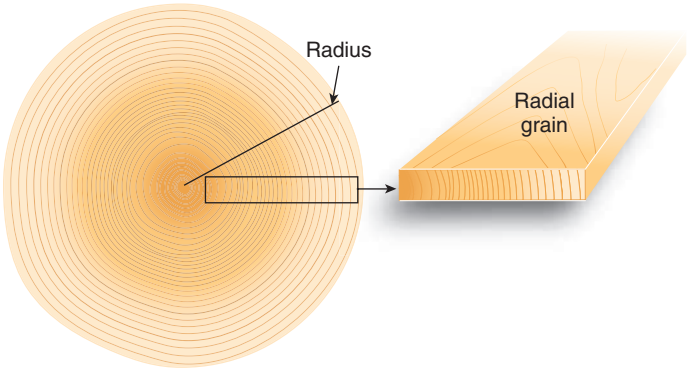
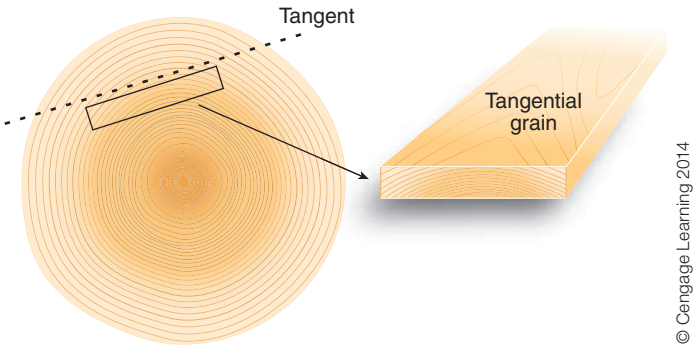


FIGURE 9-27 A board exhibiting radial grain on its face was cut along a radius running from the center of the tree outward.



Image courtesy of L. & J. G. Stickley, Inc., www.stickley.com

FIGURE 9-28 This piece built in the Mission style was built using quartersawn white oak. Note the prominent ray figure.



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FIGURE 9-29 A board showing tangential grain on its face was cut tangent to the growth rings of the tree.

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FIGURE 9-30 Wood cut tangent to the annual rings shows a cathedral figure.

Furniture built in the Arts and Crafts, Craftsman, and Mission styles is all traditionally made of quartersawn white oak (see **Figure 9-28**).

A board cut tangent to the growth rings of the tree shows **tangential grain** on its face (see **Figure 9-29**). The end grain reveals that this board represents fewer years of growth. The springwood and summerwood are much more visible in a board cut tangent to the tree's growth rings (see **Figure 9-30**). The face grain often appears as a series of inverted *V*s. This is sometimes referred to as a *cathedral figure* because of its soaring shape. The effect is highlighted by the contrast between the springwood and summerwood, and

the pattern is more dramatic in some woods than in others. Logs that have been plainsawn produce lumber that shows tangential grain on its face.

The appearance of the wood is a primary consideration for the woodworker, but it is not the only one. The physical properties of the wood — such as strength, elasticity, ease of machining, and gluing and finishing qualities — are also considered when choosing material for a project. There is one key consideration of wood besides its appearance that we should look at here, and that is wood movement, which is directly related to our study of grain.

Wood Movement

Wood is not a static material: It is dynamic. Because of its unique physical structure, it expands and contracts in response to changes in the **relative humidity**, which is the ratio of actual moisture in the air to the maximum amount of water the air will hold at its current temperature. The actual moisture in the air is the **absolute humidity**, and when we talk about the weather being humid, it is absolute humidity we are referring to, not relative humidity.

A living tree has a lot of moisture in it, most of it in the form of sap; this is known as **free water**, and it fills the cell cavities of the tree. Free water accounts for 72 percent of the tree's total moisture content. The remaining 28 percent saturates the wood fibers inside the cell walls; this is called **bound water** (see **Figure 9-31**).

The free water begins to evaporate as soon as the tree is cut, and the wood does not move much until the free water is gone. Once it is gone, the moisture content of the log is at 28 percent. This is called the **fiber saturation point**. The fibers are as full of moisture as they can possibly be, and the moisture content will never again exceed 28 percent, unless the wood is immersed in water.

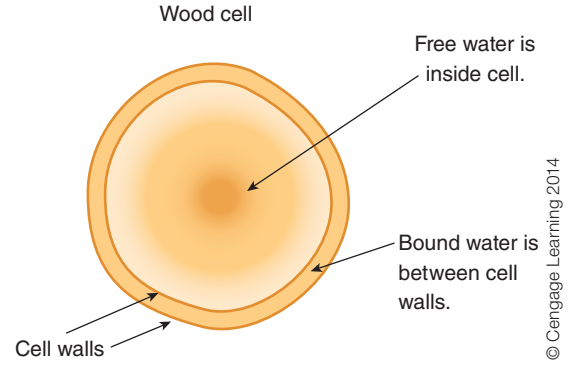


FIGURE 9-31 Free water and bound water.

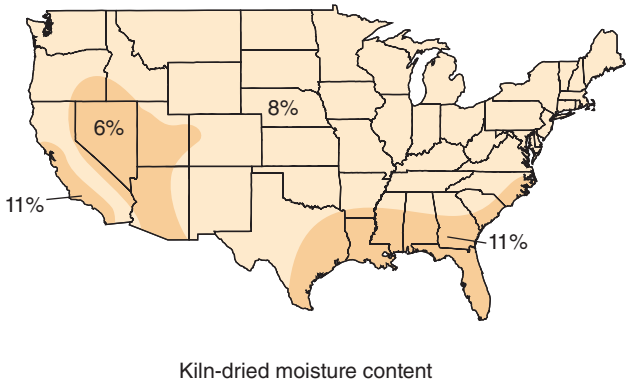
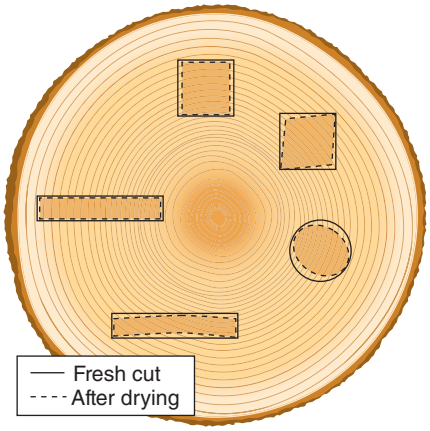


FIGURE 9-32 Kiln-dried moisture content in the United States.

Next, the bound water starts evaporating. As the moisture leaves the previously saturated fibers, the wood continues to dry and begins to shrink. There is still too much moisture in the wood for us to use it. It will be ready when the **equilibrium moisture content (EMC)** has been reached, which is when the moisture content of the wood is equal to the moisture content of the surrounding air. Wood that is air-dried will eventually reach EMC, and the drying process can be accelerated by baking the wood in a kiln. Wood is kiln-dried to different moisture percentages in different parts of the country, because the average relative humidity varies regionally (see **Figure 9-32**).

Changes in the relative humidity will cause the wood to move, even after it has been dried. As the relative humidity increases, the wood takes on moisture from the surrounding environment and swells. As it decreases, the wood shrinks. Many of the finishes used in woodworking will slow down this process, but they will not stop it. As we build furniture, we have to allow for this movement.

Wood is an **anisotropic** material, which means that it changes dimension differently in different directions. The way the wood moves is directly related to grain, and the greatest amount of movement takes place tangent to the grain. The movement radiant to the grain is much smaller, and the longitudinal movement is negligible. On average, wood will shrink 8 percent tangentially, 4 percent radially, and .01 percent longitudinally, as it is seasoned from green to dry. What this means in practical terms is that a



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FIGURE 9-33 Because of the difference between radial movement and tangential movement, boards change shape as they expand and contract. The way they change depends on how they were cut from the tree.



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FIGURE 9-34 Moisture meters are used to check the moisture content of wood.

board exhibiting tangential grain on its face will expand and contract most across its width. It will also have more of a tendency to cup in the opposite direction of the growth rings, because the outside face, which is the face farthest from the pith, shrinks a little faster than the inside face (see **Figure 9-33**).

A board whose faces display radial grain will experience significantly less movement across its width, making it much more dimensionally stable and flat. The greatest percentage of movement this type of board experiences affects its thickness.

Whether the face grain is tangential or radial, the movement along the length of the board, or longitudinal movement, is too small to be a concern.

Since most of the wood produced is plainsawn, the majority of the wood you will work with will show tangential grain on its faces. You need to allow, therefore, for wood movement across the board's width, and need to be especially careful with panels made up of plainsawn boards. One example would be a tabletop: As the relative humidity changes during the year, the top will expand and shrink across its width. The tabletop has to be attached to the table in a way that will allow it to move. If it is secured in such a way that it cannot move, it will experience tremendous tension as it tries to move and may warp or even crack. A second example is a solid wood panel in a door. The panel typically rides in grooves machined in the door frame. The panel should "float" in the frame. If the panel is tight in these grooves when the relative humidity increases, the door will warp. If the panel is not floating free in the frame — for example, if it is glued to the frame — it will crack. These are two common examples of why you need to be aware of wood movement as you build.

Since wood will take on moisture even after it has dried, before a project is begun it is wise to check its moisture content, especially if it has been stored in a damp basement or other environment where the humidity fluctuates. To do this you will use a moisture meter (see **Figure 9-34**).

WOODWORKING TIP:

To easily and accurately divide a board into equal-width pieces, hold a measuring tool across it from edge to edge, adjust until you read a multiple of the width desired, and then mark it off at each multiple (see **Figure 9-35**).



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FIGURE 9-35 Dividing a board into equal-width pieces.

Wood Species

There are thousands and thousands of different species of wood, many of which are used by woodworkers. The goal of this section is to introduce you to some of the more commonly used North American woods and to identify some of their important characteristics. Further information about various types of wood is scattered throughout the text in the FACTS ABOUT WOOD boxes.

The chart shown in **Figure 9-36** evaluates each wood in terms of its specific gravity, type (hardwood or softwood), hardness, strength, workability with hand and power tools, and gluing and finishing characteristics. Specific gravity is the standard measure of density, which describes weight per unit of volume. The higher the specific gravity of a wood, the heavier it is. So, for example, ash (specific gravity .60) is a heavier wood than cherry (specific gravity .50). Notice that some woods work differently with hand and power tools. Woods that are weak are not suitable for projects that must withstand a lot of stress, like chairs, but are fine for items that are not subjected to stress. Some woods glue more easily than others and others finish more easily. The pictures of woods shown in **Figures 9-37** through **9-54** represent those listed in the chart, with the exception of soft maple, also called red maple. Visually, it is not quite as light in color as hard maple, which has a creamy white to paper white color that is quite consistent. Instead, soft maple exhibits more shades, ranging from bright white to tan with pink and gray casts. The two types should not be

	Specific Gravity	Type	Hardness	Strength	Hand Tools Workability	Power Tools Workability	Gluing Ability	Finishing Ability
Alder, Red	.41	Hardwood	Very soft	Weak	Difficult	Difficult	Good	Good
Ash	.49	Hardwood	Hard	Strong	Very easy	Easy	Excellent	Excellent
Basswood	.37	Hardwood	Very soft	Weak	Very easy	Easy	Excellent	Excellent
Beech	.64	Hardwood	Hard	Strong	Easy	Easy	Excellent	Excellent
Birch, yellow	.62	Hardwood	Hard	Very strong	Easy	Moderate	Good	Excellent
Butternut	.38	Hardwood	Very soft	Weak	Very easy	Very easy	Excellent	Excellent
Cedar, Western Red	.32	Softwood	Very soft	Very weak	Very easy	Very easy	Excellent	Good
Cherry	50	Hardwood	Medium	Medium	Very easy	Easy	Excellent	Excellent
Hickory	.72	Hardwood	Very hard	Very strong	Very difficult	Difficult	Excellent	Excellent
Maple, Hard	.63	Hardwood	Hard	Very strong	Difficult	Easy	Adequate	Excellent
Maple, soft	.54	Hardwood	Medium	Strong	Difficult	Easy	Good	Excellent
Oak, Red	.62	Hardwood	Very hard	Strong	Easy	Easy	Good	Excellent
Oak, White	.62	Hardwood	Very hard	Very strong	Easy	Easy	Good	Good
Pine, Yellow	.35	Softwood	Very soft	Weak	Very easy	Very easy	Good	Excellent
Poplar, Yellow	.42	Hardwood	Soft	Medium	Very easy	Very easy	Excellent	Good
Sycamore	.49	Hardwood	Soft	Medium	Difficult	Difficult	Excellent	Good
Walnut	.55	Hardwood	Medium	Strong	Very easy	Very easy	Good	Excellent

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FIGURE 9-36 Wood Properties.



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FIGURE 9-37 Red alder has a fine texture with little difference between the sapwood and heartwood. It stains easily to match more expensive hardwoods such as cherry and walnut.



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FIGURE 9-39 Basswood has a fine even grain and is highly prized by carvers.



© iStockphoto/rusm

FIGURE 9-38 Ash is a coarse textured wood with a relatively straight grain that has excellent bending characteristics.



© Ilepet/www.Shutterstock.com

FIGURE 9-40 Beech bends well and is highly resistant to abrasive wear but it is prone to warping. It is sometimes substituted for hard maple due to its similar appearance.



© Elena Elisseeva/www.Shutterstock.com

FIGURE 9-41 Yellow birch is also sometimes substituted for hard maple due to its similar appearance and it also bends well. It is a straight-grained wood with a fine, even texture.



© iStockphoto/Nancy Nehring

FIGURE 9-42 Butternut is a coarse textured wood with a straight grain that carves well. It is sometimes called white walnut.



© iStockphoto/Nancy Nehring

FIGURE 9-43 Western red cedar is a decay resistant wood that is appropriate for outdoor furniture. Some people are sensitive to its sawdust.



© iStockphoto/Bill Noll

FIGURE 9-44 Cherry is a fine textured wood with a straight grain that is regarded as one of the top furniture woods.



© Christopher David Howells/www.Shutterstock.com

FIGURE 9-45 Hickory has a coarse texture and a straight grain that is similar in appearance to ash. It is the toughest of the American woods and is used for tool handles, sports equipment, and chairs.



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FIGURE 9-46 Hard maple, also called sugar maple or rock maple, is a premium furniture wood with a fine texture. Unlike most hardwoods, the sapwood is the desirable part of the tree rather than the heartwood.



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FIGURE 9-47 Curly maple.



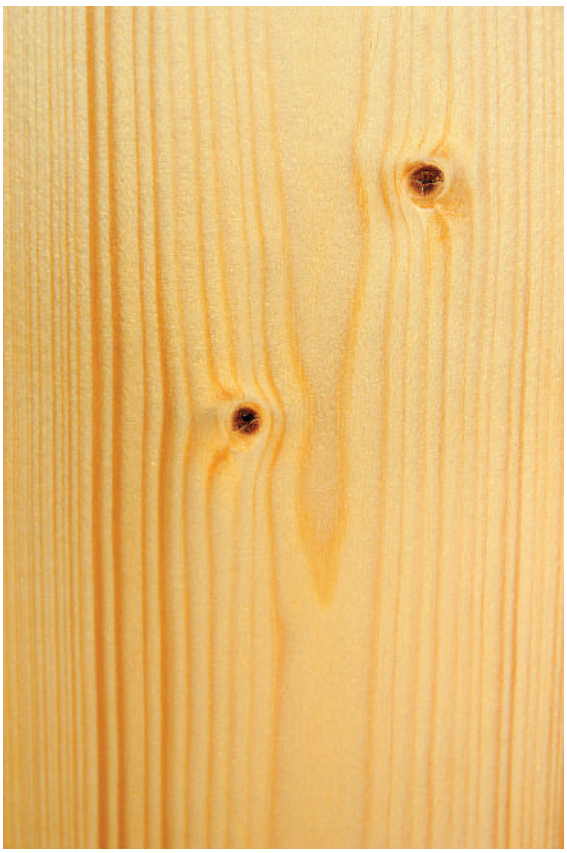
© iStockphoto/Nancy Nehring

FIGURE 9-48 Birdseye maple.



© iStockphoto/Oksana Struk

FIGURE 9-49 Red oak is a very popular furniture wood that is coarse-texture, straight-grained, and has good bending properties that is. Its sawdust is an irritant to some people.



© Sony Ho/www.Shutterstock.com

FIGURE 9-51 Yellow pine, also called Eastern white pine, has a fine texture and straight grain.



© iStockphoto/rusm

FIGURE 9-50 White oak is similar in texture and grain to red oak, but is brownish rather than reddish, and unlike red oak it is decay resistant. Its sawdust is also an irritant to some people.



© iStockphoto/Roel Smart

FIGURE 9-52 Poplar, also called tulipwood, is fine textured and straight-grained. It has a white to yellowish sapwood, and the heartwood is straw brown to green with occasional purple streaks. It is inexpensive and it often used as a secondary wood; i.e. for project parts that are not highly visible.

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FIGURE 9-53 Sycamore is a fine-textured wood with a straight grain that when quartersawn, as in this example, exhibits a lacy pattern. It is often used for veneer.



© iStockphoto/Bill Noll

FIGURE 9-54 Walnut is a premium furniture wood that has an even but rather coarse texture with a straight grain. It is the most valuable furniture and cabinet timber in the U.S. Its dust is a potential irritant.

mixed. Curly figure is seen in both types of maple, as is birdseye figure.

Sources of Wood

Woodworkers are always on the lookout for material. Obvious places to acquire it are home centers and retail lumber stores. Many hardwood mills have wood for sale. Buying wood that has already been sawn into boards and dried is the easiest way to acquire material, but it can be expensive. You can have trees of your own cut and milled by a portable band saw mill. You may be able to salvage wood from structures slated for demolition. Ask around. You may find someone who has had wood stored in a garage or attic for years. That person may be willing to sell it to you at a price much lower than you would pay if you were buying retail.

Other sources of wood are local road crews and power companies that must keep their lines clear. After a big storm that takes down trees, you may be able to acquire wood in exchange for cleaning up the mess. Of course, if the wood you acquire is green, you must wait for it to dry or make arrangements to have it dried.

GREEN REMINDERS

Using wood that has been salvaged from buildings that are being demolished is not only ecologically wise, but it may enable the woodworker to work with woods such as chestnut and elm that are no longer commercially available.

Wood is also available by mail order and online. This is a bit risky, since you do not have the opportunity to inspect it prior to purchasing, but it may be a good way to get wood that is not available to you locally. Remember, however, that wood is heavy, and shipping charges may be high. Wherever you acquire wood, take care of it; bring it into your shop, and do not work with it until its moisture content has reached equilibrium with the relative humidity in the shop. Your wood should be kept dry, and in the best of all worlds, your shop's temperature and relative humidity should be constant. Consider the grain of each piece you use, not only for its looks, but also in terms of its potential movement.



Summary

Wood is a beautiful yet complex material. Understanding how it grew and was milled and seasoned are vital tools for working with it successfully, and is every bit as important as the hand and power tools we use. The appearance of the wood and its behavior relative to the surrounding environment are both determined to a large extent by the roles the wood played in the original tree.



Key Terms

absolute humidity
actual size
anisotropic
annual rings
bark
bark pocket
blue stain
board foot
bound water
bow
cambium
cant
case hardening
check
coniferous
crook
cup
deciduous
earlywood
edge grain
end grain
equilibrium moisture content (EMC)
face grain
fiber saturation point
flatsawn
free water
grader
hardwood
head saw
heartwood
honeycombing
kink
knot
latewood
longitudinal grain
medullary rays
nominal size
phloem
pitch pocket
pith
plainsawn
radial grain
relative humidity
roughsawn
sapwood
shake
slab wood
softwood
split
springwood
summerwood
tangential grain
twist
veneer
wane
warp
wind
xylem



Check Your Knowledge

1. What are the proper terms for identifying hardwoods and softwoods, and how are they different from one another?
2. Describe the process of converting a tree to lumber.
3. What methods of sawing are employed to produce plainsawn and quartersawn boards? Which of these is most common?
4. Are drying defects avoidable? Explain.
5. What kind of trees are sold by the piece?
6. What is meant by a *board foot*?
7. How many board feet are there in three 4/4 boards, if one is 5 inches wide and 6 feet long, one is 7 inches wide and 9 feet long, and the third 9 inches wide and 5 feet long?
8. How does the production and sale of softwood differ from that of hardwood?
9. What does *EMC* stand for? When is it reached?

10. Sketch the end grain view of a board displaying tangential grain on its face. In what direction will this board experience the greatest degree of movement?
11. Why is it important to consider wood movement in designing furniture and cabinetry?
12. What are a few alternatives for acquiring lumber?



What's Wrong with This Picture?



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BUILD IT!

Paper Towel Roller



A

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Assembly list-paper towel roller

Part	Dimensions (thickness × width × length)	Quantity
1. Roller stock	$1\frac{1}{4}$" × $1\frac{1}{4}$" × $12\frac{7}{8}$" dowel	1
2. Sides	$\frac{3}{4}$" × 6" × 10"	2
3. Back	$\frac{1}{2}$" × $7\frac{1}{4}$" × $13\frac{1}{2}$"	1
	#8 × $1\frac{1}{4}$"wood screws	4

B

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Figure A shows the completed paper towel roller.

TOOLS REQUIRED

- Measuring tool
- Marking tool
- Compass
- Table-mounted router and 5/8-inch straight bit
- Drill, 1/8-inch bit, and countersink bit
- Band saw or jigsaw
- Table saw and dado blade
- Miter saw
- Planer
- Sander

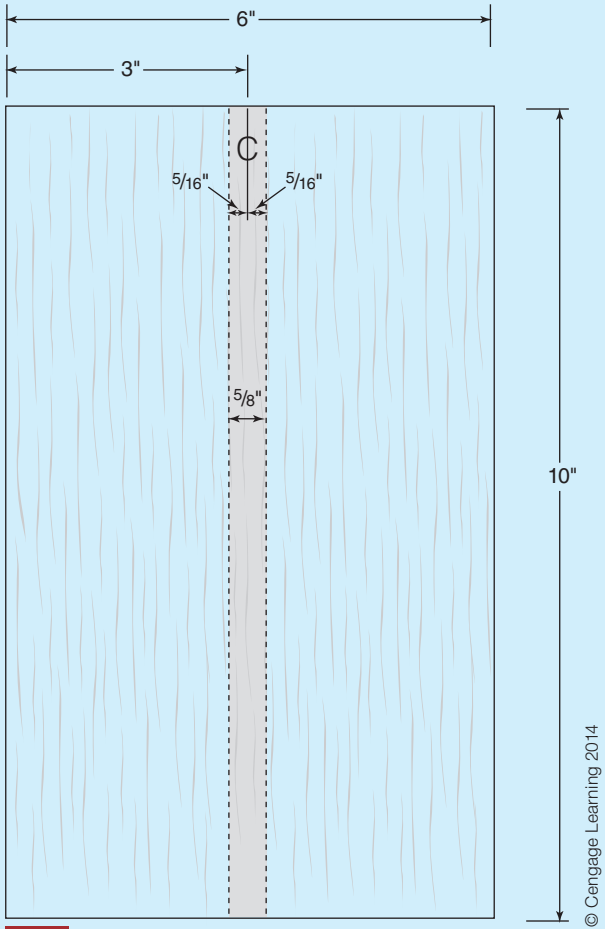
MATERIALS REQUIRED

- 1 × 8 stock, 36 inches long
- 1 1/4-inch dowel, approximately 15 inches long
- #8 × 1 1/4-inch screws

STEPS

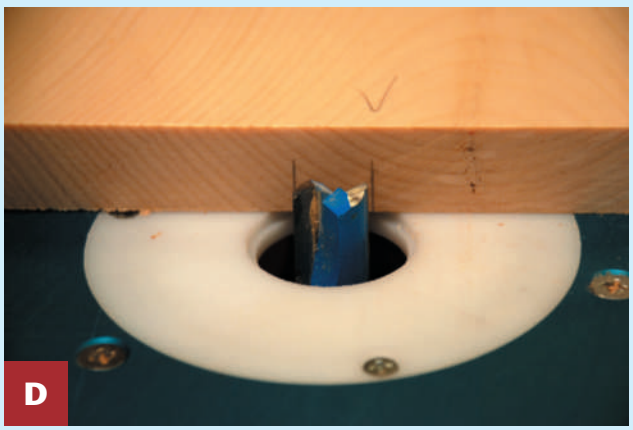
1. Consult the assembly list given in **Figure B** and cut the sides and back to size.
2. Plane the back piece to a finished thickness of 1/2".

3. Measuring across the end of one of the side pieces, mark the center, and then lay out two lines 5/16" to either side of the center, as shown in **Figure C**.
4. Set up the router in a router table with a 5/8" straight bit and set it for a height of 1/2".
5. Using the end piece you marked as a guide, set the router-table fence so that the bit will cut between your two marks, as shown in **Figure D**.
6. Measure from the end of a side down 3 3/8"; square a line across.



C

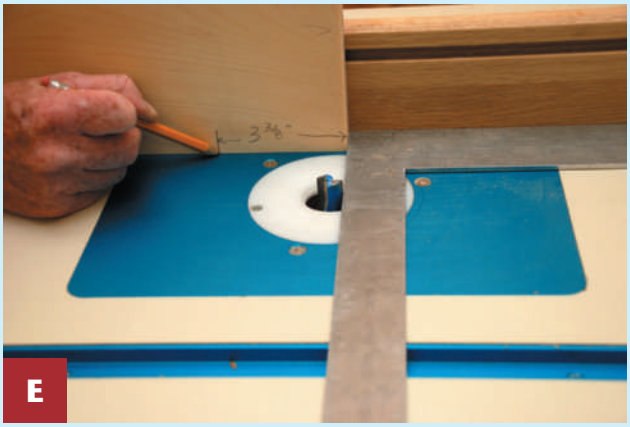
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D

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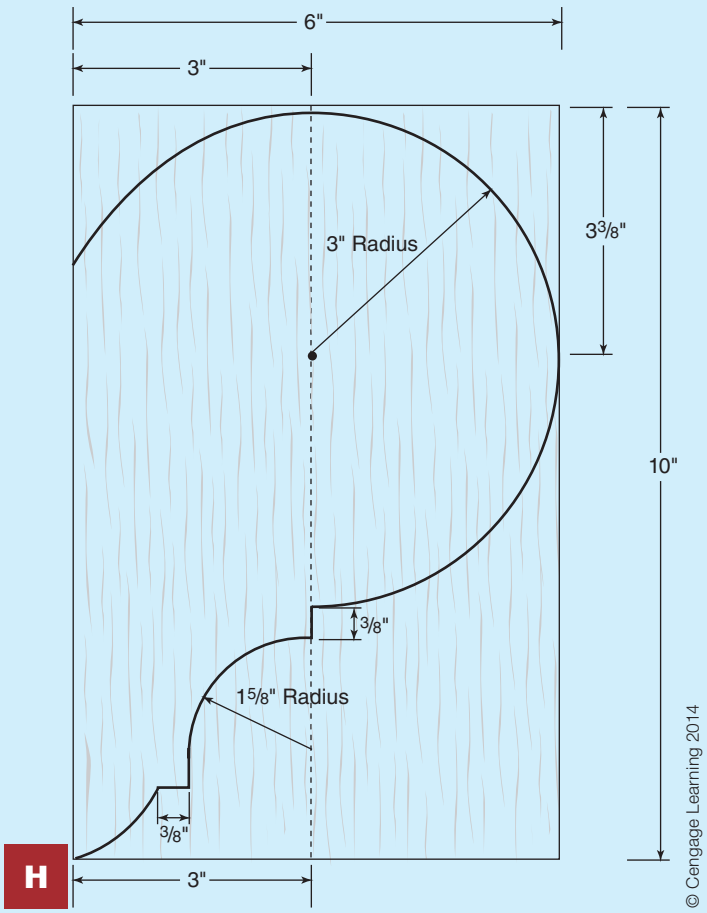


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7. Place a square against the router table fence with the square's blade running back and just touching the right side of the bit. Place the side piece with its back against the fence, and make a mark on the router table where the line is; it should be 3 3/8" from the right side of the router bit, as shown in **Figure E**.
8. Remove the piece, square the line on the table back to the fence, and clamp a stop to the fence, as shown in **Figure F**.
9. Rout the dado on the two side pieces, lifting the piece when it gets to the stop, as shown in **Figure G**.

BUILD IT!

10. Using **Figure H** as a guide, lay out one side piece and cut it on the band saw or with a jigsaw.
11. Lay the piece you just cut on top of the other side, trace it, and cut it out.
12. Cut the dowel to length.
13. Set up a dado blade on the table saw with a width of 3/4"; set the blade height at just a bit under 3/8".
14. Clamp a sacrificial fence to the table saw fence, and bring it over so it is just barely touching the blade.
15. With the miter gauge set at 90° to the blade, place the dowel against the miter gauge and slide it over to butt against the sacrificial rip fence, as shown in **Figure I**.
16. Make the first cut, then rotate the dowel slightly and make another cut. Continue to do this until a tenon is formed on the end of the dowel. Repeat on the other end, as shown in **Figure J**.
17. Sand all the parts.
18. Drill and countersink 1/8" holes in the back for mounting the project to the wall.
19. Attach the back to the sides with two screws on each side. Drill a 1/8" pilot hole and a countersink for each screw.
20. Finish as desired.



H

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I

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J

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BUILD IT!

PROJECT CHALLENGE

Corner Shelf



A

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Assembly list – corner shelf

Part	Dimensions (thickness × width × length)	Quantity
1. Right side	$^1/_2$" × $8^1/_2$" × 25"	1
2. Left side	$^1/_2$" × 9" × 25"	1
3. Bottom shelf	$^1/_2$" × $8^1/_2$" × $8^1/_2$"	1
4. Middle shelves	$^1/_2$" × $5^1/_8$" × $5^1/_8$"	2
5. Top shelf	$^1/_2$" × $3^1/_2$" × $3^1/_2$"	1
	4d finish nails	as needed

B

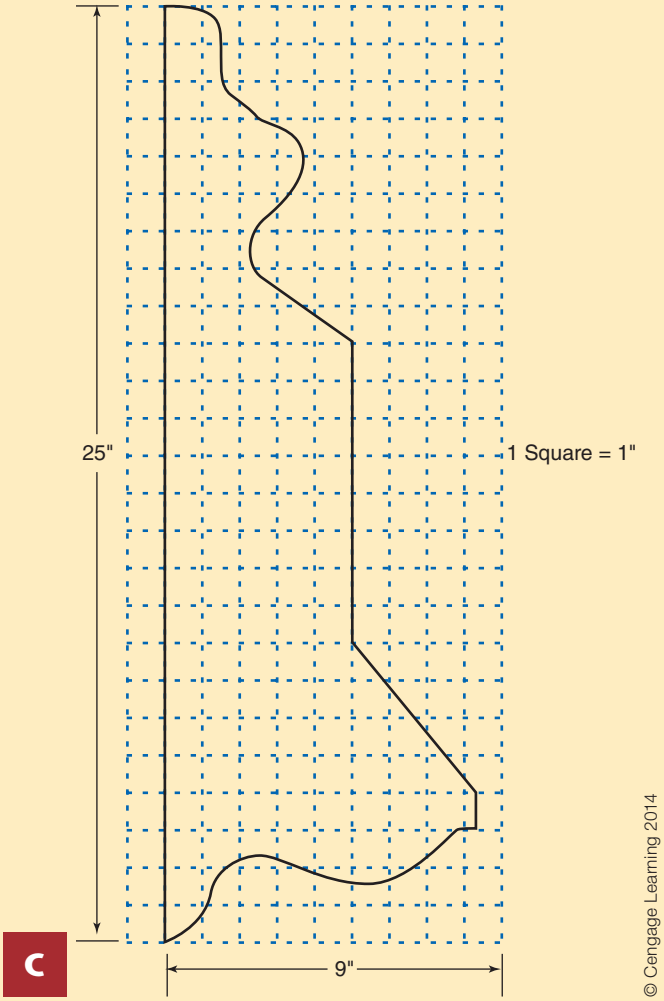
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Figure A shows the completed corner shelf.

STEPS

1. Review the assembly list given in **Figure B**, then lay out and cut the pieces to size, planing to a 1/2" thickness if necessary.

2. Use a piece of poster paper to make a pattern for the sides. Lay out a grid of 1″ squares; using **Figure C** as a reference, lay out the pattern.
3. Cut out the pattern with scissors, and then copy it onto the narrower of the two side pieces.
4. Take the wider side piece and place the pattern on it 1/2″ over from the edge, as shown in **Figure D**. Again, copy the pattern.
5. Cut out the two side pieces using a band saw, jigsaw, or coping saw.



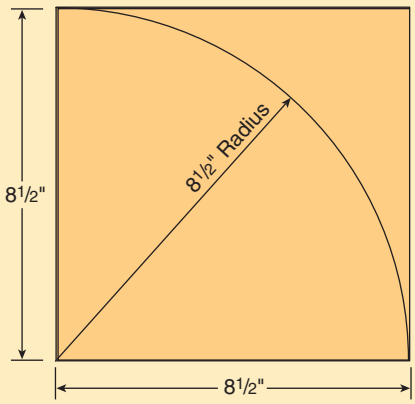
C

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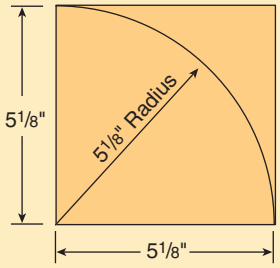


D

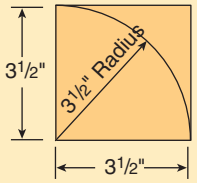
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Bottom shelf



Middle shelves



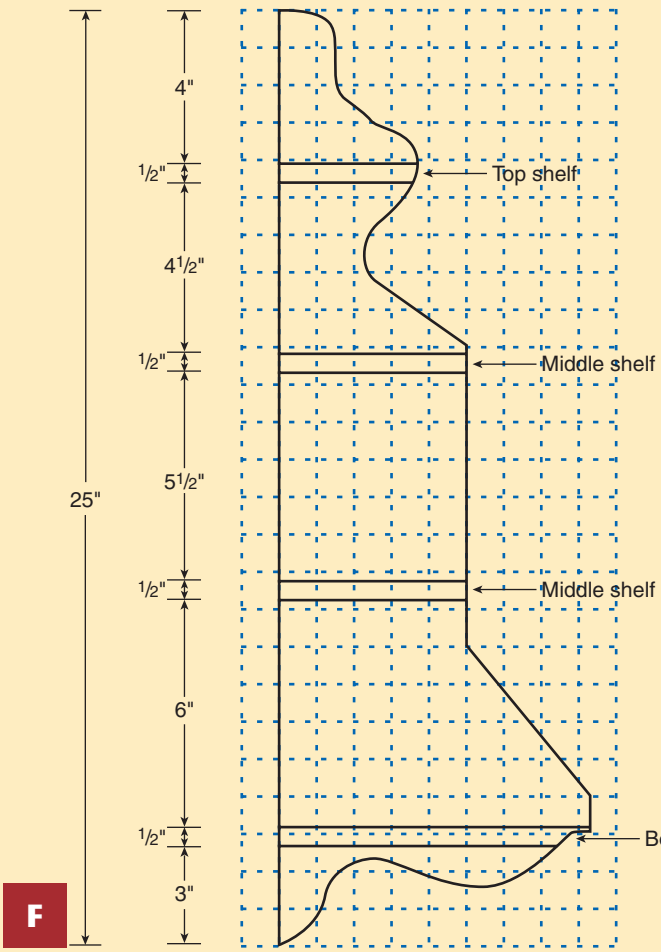
Top shelf

E

6. Lay out the arcs on the shelves, using a compass, dividers, or a beam compass. Refer to **Figure E**.
7. Cut out the shelves using a band saw, jigsaw, or coping saw.
8. Sand all the parts.
9. Lay out the shelf locations on the inside of both sides, as shown in **Figure F**.

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Side



F

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10. Glue and fasten the two sides together with 4d finish nails, nailing through the wider piece into the narrower one, as shown in **Figure G**.
11. Install the bottom shelf, driving 4d finish nails through the sides.
12. Install the remaining shelves, as shown in **Figure H**.
13. Do any final sanding and finish as desired.


G

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H

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10

Panel Products

You'll Learn

After studying the chapter, the student should be able to:

- Identify the different types of panel products
- Understand the composition of the various panel products
- Explain the advantages and disadvantages of using panel products

INTRODUCTION

Manufactured panel products are important building materials in today's construction of cabinetry and furniture. Frequently used panel products are plywood, fiberboard, particleboard, and melamine.

Each of these products has the advantage of being able to create large surfaces quickly. They all reduce production time compared to using solid lumber. Additionally, they are all more stable than solid lumber, because they do not have a continuous grain pattern. This lack of continuous grain pattern minimizes distortion.

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PLYWOOD

Cabinet-grade plywood may replace lumber in cabinets or furniture. It provides the look of solid wood but is less time consuming to work and therefore less expensive to use. It is fabricated with fine veneer faces over a core. **Figure 10-1** shows an example of cabinet plywood faced with cherry veneer.

Different cores are used to create cabinet-grade plywood. Lumber core, veneer core, medium-density fiberboard (MDF) core, and particleboard cores are available (see **Figure 10-2**).

The type of core used in the plywood determines both its degree of stability and its ability to hold fasteners. Lumber core holds fasteners the best of the three core types, but since its core is solid wood, it is most subject to distortion.

Veneer core plywood is comprised of alternating layers of veneer, typically 1/8 inch thick, which are glued together perpendicular to one another. Since there is less continuous grain, it is less likely to distort, but it is not as stable as panel cores that have no grain direction at all. Veneer core plywood holds fasteners well.

Plywood with a particleboard or MDF core is the most stable of the plywoods, but its ability to hold fasteners is much less than either lumber core or veneer core. Plywood comes in different size sheets and in a selection of thicknesses. Sheets 4 feet by 8 feet are most common; commonly available thicknesses are 1/4, 1/2, and 3/4 inches.

Different grades of cabinet plywood are available. Each sheet has a *face grade*, which appears on the front of the sheet: A, B, C, or D, with A being the highest grade. The back of the sheet is graded 1, 2, 3, or 4, with 1 the highest grade.

The veneer that is placed on the front and back of the sheet is cut in one of three ways. The cut is named according to how the veneer was taken from the log, and it affects the way the veneer looks. These three types are called *plain sliced*, *quarter sliced*, and *rotary cut* (see **Figure 10-3**).

It is possible to buy cabinet plywood that has already been finished. This saves a step in the construction process, which naturally makes things go faster.

CAUTION

Carry a pair of work gloves in your toolbox or truck. When sorting lumber or unloading a truck, wearing gloves will prevent splinters. It is also a good idea to have a supply of thin plastic gloves, such as surgical gloves, to use when you are finishing, which will prevent these materials from being absorbed into your skin.



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FIGURE 10-1 Cabinet grade plywood.

FIBERBOARD

Fiberboard is created by mixing wood fibers with resin and bonding them together by radio-frequency adhesion or heat. There is no grain at all, which makes it a very stable material. Fiberboard comes in high, medium, and low densities. **High-density fiberboard** is often referred to as **hardboard** (see **Figure 10-4**).

High-density fiberboard is a good choice for drawer bottoms and cabinet backs. It is an extremely rugged material. It comes in sheets 4 feet by 8 feet and is commonly available in 1/8- and 1/4-inch thicknesses.



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FIGURE 10-2 Lumber core, particleboard core, and veneer core plywoods.







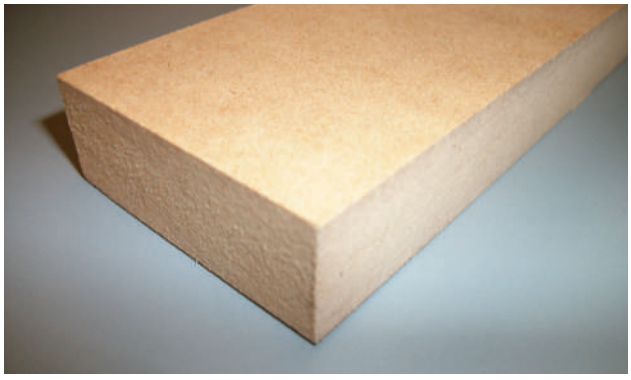
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FIGURE 10-3 Veneer faces are rotary cut, plain sliced, or quarter sliced.



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FIGURE 10-4 High-density fiberboard, or hardboard.



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FIGURE 10-5 Medium-density fiberboard (MDF).

Medium-density fiberboard is usually referred to by the acronym *MDF* (see **Figure 10-5**). Like high-density fiberboard, it provides a very smooth and stable surface. It is an excellent choice for jig material and comes in thicknesses from 3/8 to 1 3/4 inches in 1/8-inch increments. It is a great base material for stained, printed, painted, or laminated applications. It is commonly used for furniture tops, drawer fronts, moldings, and shelving. It can be worked using regular woodworking tools, although the resins that act as bonding agents tend to dull blades, knives, cutters, and bits more quickly than lumber does, so carbide-tipped tools are a good investment when doing much work with this material. It can be shaped easily and makes nice moldings. Since there is no grain, you do not encounter the tear-out problems that you can with solid wood. However, machining MDF creates a very fine dust, and it is important to wear protective safety gear when working with it. While not attractive in itself, it takes paint very well and is also a very good substrate for veneer and plastic laminates.

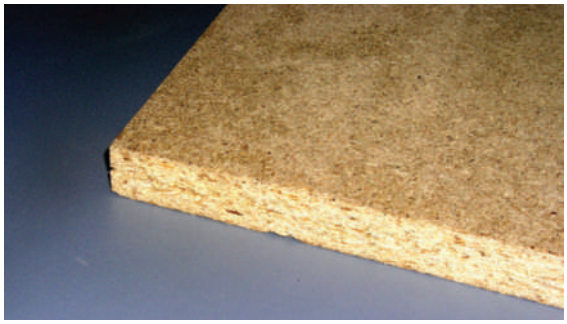
MDF has three drawbacks besides than the dust it produces. It is very heavy, and it should not come into contact with water; it will absorb the water and swell. Therefore, while it is a good choice for ceiling molding, it is not a good choice for a baseboard material. Third, it does not hold fasteners particularly well. Specialty fasteners have been developed to use with MDF.

Low-density fiberboard is not really used by cabinetmakers. Its primary use is in the upholstery industry.

PARTICLEBOARD

Particleboard is not as dense as either hardboard or MDF, but it is an adequate and less expensive alternative. Particleboard is composed of small wood flakes, chips, and shavings bonded together with adhesives.

Like MDF, particleboard is often used as a substrate for laminates. It is a frequently used material for plastic laminate countertops (see **Figure 10-6**). Like fiberboard, particleboard is hard on the cutting edges of tools. It, too, is heavy and does not hold fasteners well.



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FIGURE 10-6 Particleboard.

GREEN REMINDERS

Particleboard has traditionally been fabricated from wood fibers that are bonded together with urea formaldehyde resins. A new type of particleboard is now being manufactured that uses wheat straw rather than wood fibers, using an abundant agricultural waste product and arguably reducing forest exploitation. The wheat straw is bonded together with a formaldehyde-free resin, making it less noxious to machine. It is also lighter in weight, making it easier to handle.

MELAMINE

Melamine is a thermally fused, resin-saturated paper finish applied over a particleboard or MDF core. It has the advantages of being highly stain and mar resistant, and it comes in a wide variety of colors and wood grain looks (see **Figure 10-7**).

Melamine is commonly used for "carcass" construction, and is often the major component of inexpensive furniture. Melamine has the advantage of requiring no finishing, as the resin-saturated paper acts as a finished surface. Since it has a particleboard or MDF core, its disadvantages are the same as those of particleboard and MDF.

Advantages and Disadvantages of Panel Products

Some of the advantages of using panel products have already been mentioned, namely their stability and the way they reduce production time in building cabinets. Additionally, their use makes good ecological sense.

The great disadvantage that all panel products share is that the edges of the sheets must be covered. This can be accomplished using **veneer tape** or by attaching solid lumber. Veneer tape is produced in different widths to accommodate the thickness of the panel product, and it is matched to the face veneer of the panel, so that the final product has the look of a solid board (see **Figure 10-8**). Using solid wood as edges allows you to machine a profile on the edge, which the veneer tape does not.

Fastener-holding ability varies among the panel products, as has been discussed. Specialty fasteners have been developed for use with MDF and particleboard.

Some panel products, such as melamine, are more mar and scratch resistant than others. None of them, however, has more than a thin veneer covering its core. Therefore, deep scratches on any of them will reveal their core and give away the fact that they are not solid lumber.

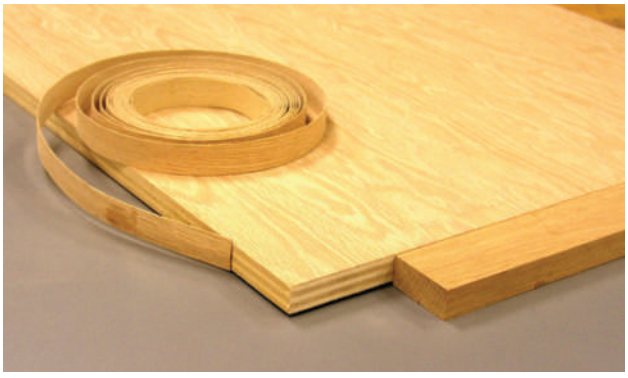
WOODWORKING TIP:

You can make your own edge banding by cutting thin strips of solid wood on the table saw. Make the strip slightly wider and longer than needed. Secure the panel you are edge banding in a vise and apply a bead of glue along the edge. Put the edge banding you made in place and tape it securely at about two-inch intervals. When the glue is dry, you can trim the banding to size using a flush trim bit in a laminate trimmer.



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FIGURE 10-7 Melamine.



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FIGURE 10-8 Edges are covered with veneer tape or solid lumber.

PROCEDURE 10-1

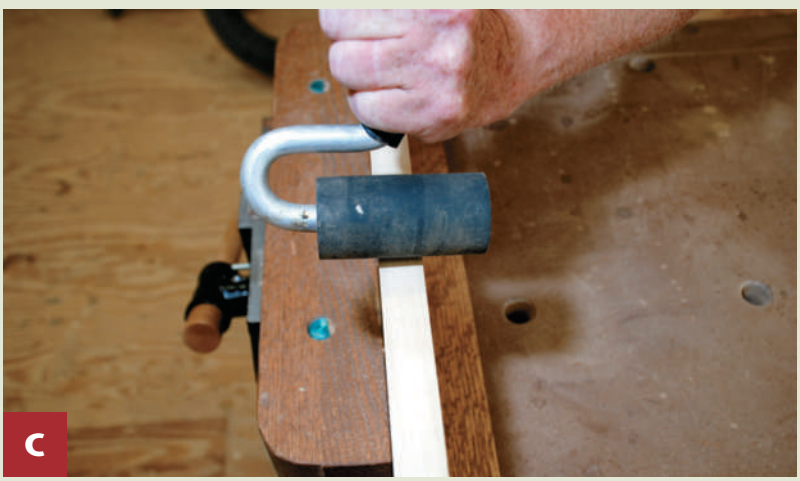
Applying Adhesive-Backed Edge Banding



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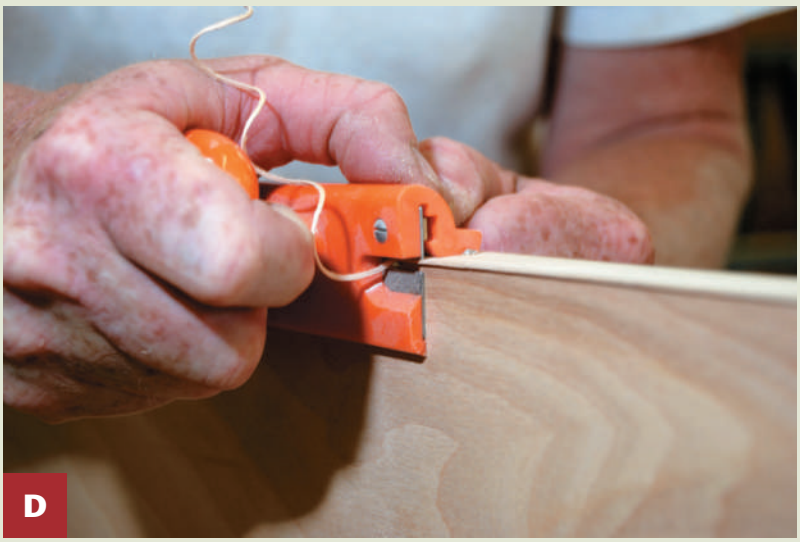


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STEPS

1. Using scissors or a knife, cut a length of edge banding slightly longer than needed to cover the edge.
2. Secure the piece to be banded in a vise or in some other manner so that the edge to be covered is facing up, as shown in **Figure A**.
3. Place the edge banding on the edge of the panel product so that it is centered, with the end overhanging slightly.
4. Holding the edge banding in place with one hand, apply heat to it with a household iron or an edge banding iron, as shown in **Figure B**.
5. Move the heating device back and forth over the edge banding without stopping in any one spot. This activates the glue on the bottom of the edge banding.
6. Once the edge banding begins to stick, take away the heat and use a roller or a block of wood to vigorously rub the banding in place, as shown in **Figure C**.

7. Trim the projecting ends, and then use an edge trimmer to trim the veneer flush with the sides of the panel, as shown in **Figure D**.
8. Lightly sand the edges of the veneer by hand to blend it in with the panel surfaces. **Figure E** shows the completed product.



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Summary

Manufactured panel products are widely used in the cabinet- and furniture-building industries. Panel products include cabinet-grade plywood, fiberboard, particleboard, and melamine. Panel products are far more stable than solid wood, and they allow for much more rapid construction than the use of solid wood does. Some, such as melamine, are already finished, so the finishing step of cabinet construction has also been eliminated. Plywood is also available prefinished. The primary drawback to manufactured panel products is that the core is visible on the ends and edges of the panels and must be covered, either with a matching tape or with solid wood.



Key Terms

cabinet-grade plywood
fiberboard
hardboard
high-density fiberboard
medium-density fiberboard
melamine
particleboard
veneer tape



Check Your Knowledge

1. What are three different cores used in cabinet-grade plywood, and what are the advantages and disadvantages of each?
2. List two advantages of panel products in general.
3. List two disadvantages of panel products.
4. What are the three types of fiberboard?
5. Give an example of what each type of fiberboard is used for.
6. In what way are fiberboard and particleboard superior to plywood?
7. What is melamine?



Activities

1. Research the manufacture of cabinet-grade plywood. Hint: visit *http://www.cpfwood.com,* the Web site for Columbia Forest Products, which is North America's largest producer of hardwood plywood.
2. Visit a manufacturing plant that produces any of the panel products discussed in this chapter.

BUILD IT!

Knockdown Coffee Table

Figure A shows a completed coffee table.

TOOLS REQUIRED

- Measuring tool
- Square
- Straightedge
- Compass
- Table saw or circular saw
- Miter saw
- Drill and 3/4" bit
- Jigsaw
- Router and 1/8" round-over bit
- Sander

MATERIALS REQUIRED

- 4" × 4" piece of 3/4" MDF
- 1 1/4" finish nails or brads
- Primer and paint, or polyurethane.

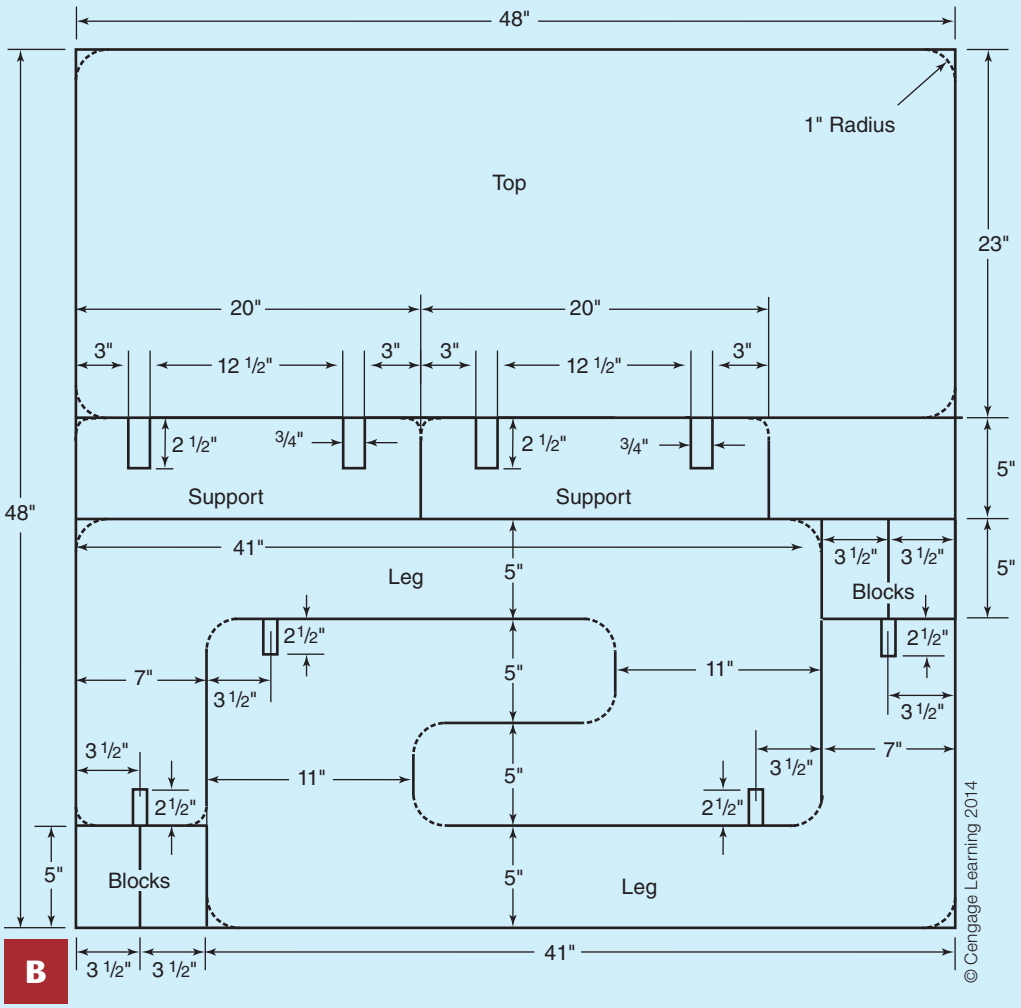
STEPS

1. Referring to **Figure B**, lay out the pieces of the coffee table.
2. Rip off the top piece on the table saw or with a circular saw and straightedge.



A

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B

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C

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D

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3. Make a second 5”-wide rip cut to cut off the two top supports; cut them to length on the miter saw.
4. Use a drill with a 3/4” bit to drill a hole at the bottom of each of the slots.
5. Cut out the remaining pieces with a jigsaw.
6. Use the jigsaw to cut the rounded corners on the top piece and the supports.
7. Put a 1/8” round-over bit in a router or laminate trimmer and round over the top and bottom edges of the top.
8. Using the same router setup, round over both sides of the ends and bottom of the support pieces. Do not round over the slots.
9. Again using the same setup, round over both sides of the legs, except for the bottom of each, as shown in **Figure C**. Do not round over the slots.
10. Place the top face down on a bench; slot together the legs and supports so that the table is upside down on the bench.
11. Center the leg and support assembly on the top.
12. Mark the inside corners where the legs and supports meet, as shown in **Figure D**.

BUILD IT!

13. Remove the legs and supports from the top and glue and nail the blocks in place, as shown in **Figure E**. The blocks will keep the top in place on the table's support structure.
14. Sand, paying most attention to the edges.
15. Prime and paint as desired or finish with polyurethane.
16. Reassemble for use.



E

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BUILD IT!

PROJECT CHALLENGE

Study Carrel and Seat



A

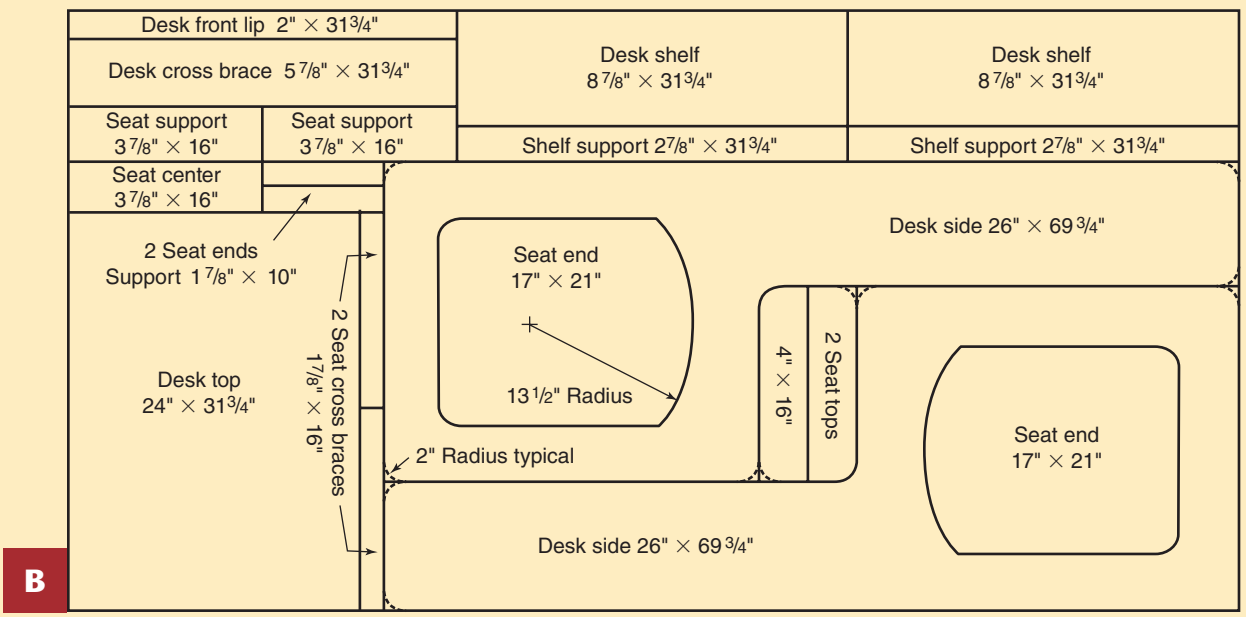
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Figure A shows a completed study carrel and seat.

NOTE: This project does not call for edge banding to cover the plywood edges. If you prefer, skip rounding over the edges and apply edge banding instead, following the steps outlined in Procedure 10-1.

STEPS

1. Using **Figure B** as a guide, carefully lay out the pieces for the carrel and seat on a 4″ × 8″ sheet of 3/4″ veneered plywood.
2. Set up the table saw to make an 11 7/8″ rip cut, cutting off the part of the sheet that will be used for the desk shelves, shelf supports, desk front lip, cross brace, and seat supports. Use a triple-chip grind blade on the table saw if you have one, or a crosscut blade to minimize chipping. A zero-clearance insert plate will also help minimize tear-out.



B

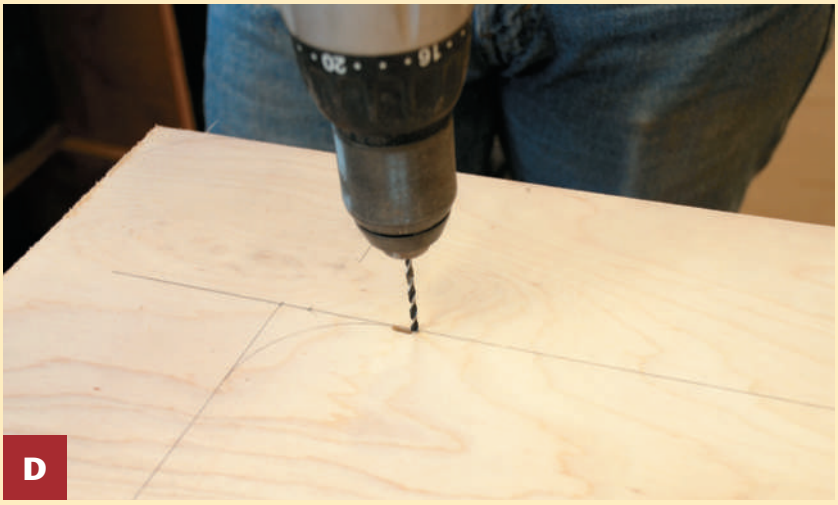
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3. Make a crosscut to free the shelves and shelf supports from the other pieces.
4. Take the longer piece and make a second crosscut to make the two shelves.
5. Back at the table saw, set the rip fence at 8 7/8" to rip the shelves from the shelf supports. Set them aside.
6. Go back to the piece that was left from the first crosscut. Take it to the table saw and make the rip cuts for the desk front lip, cross brace, and seat supports.
7. Cut the pieces you just ripped to finished length.
8. Use a circular saw and a straightedge to make a crosscut to separate the desktop, seat cross braces, seat center, and seat end supports from the rest of the large piece, as shown in **Figure C**. Set the larger piece aside.
9. Using the table saw or a circular saw and straightedge, make a cut to separate the seat center and seat end supports from the rest of the piece.
10. Take the smaller piece to the miter saw and make a cross cut to separate the seat center from the seat end supports. Set this piece aside.
11. Rip the seat end supports to finished width. Set aside.



C

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D

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E

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F

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12. Rip the desktop to finished width. Set aside.
13. Cut the seat cross braces to finished length. Set aside.
14. Go to the remaining large piece. Drill a series of small holes in a line along the edges of the seat ends so that you can insert a jigsaw blade, as shown in **Figure D**.
15. Use a jigsaw to cut out the two seat ends, as shown in **Figure E**.
16. Use a jigsaw to cut out the desk sides and seat tops.
17. Sand the edges of all the pieces smooth.
18. Arrange the pieces for the desk on your bench, setting aside the seat parts for now. Determine what edge will be visible when the desk is assembled.
19. Insert a 1/8" or 1/4" round-over bit in a router and round over the visible edges, as shown in **Figure F**.

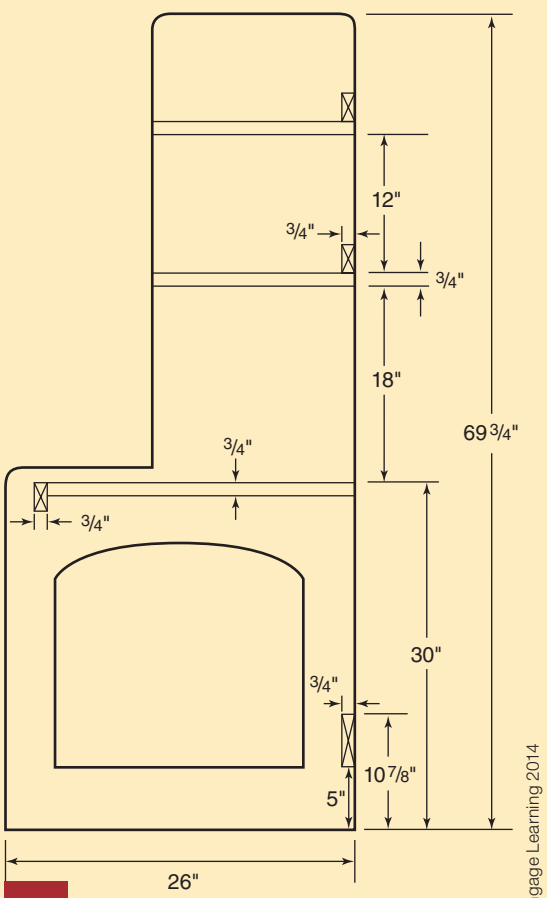
20. Biscuit, glue, and clamp the shelves and shelf supports together, using #20 biscuits spaced about 6" apart. Do the same thing with the desk lip and desktop, as shown in **Figure G**.

21. On the desk sides, lay out the positions for the shelves, desk cross brace, and desktop, as shown in **Figure H**.



G

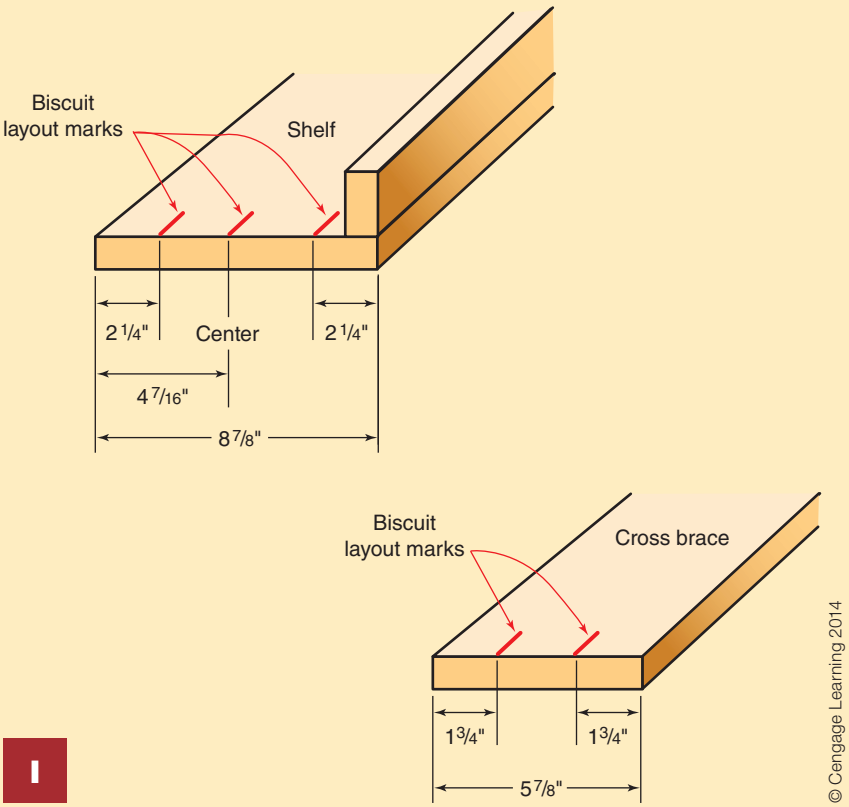
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H

Section view

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I

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J

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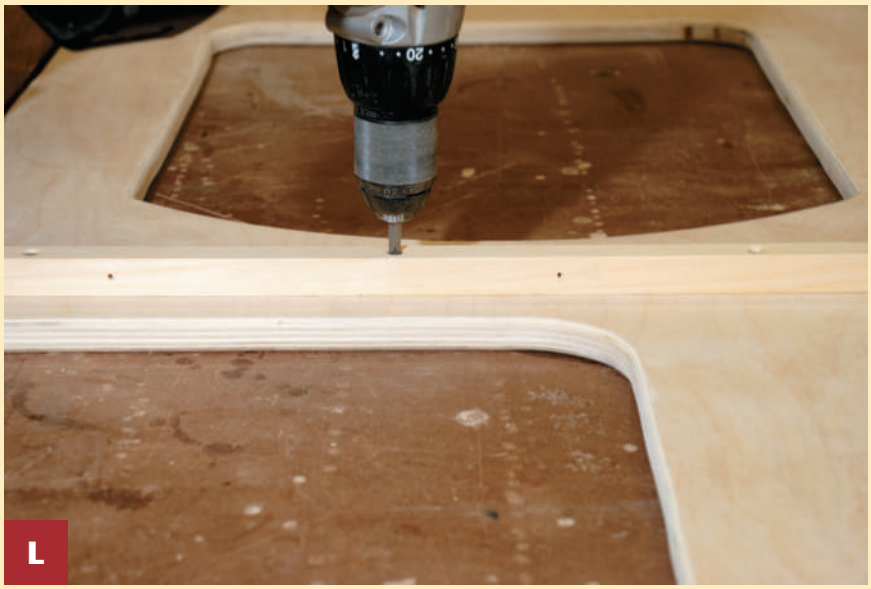
22. Use a biscuit jointer to make three slots at either end of the two shelves. Use three #20 biscuits, centering one on the shelf and setting the others in 2 1/4" from either side, as shown in **Figure I**. Use two #10 biscuits on either end of the desk cross brace, setting each biscuit in 1 3/4" from each side.

23. Hold the shelves upright on the desk sides; transfer the biscuit layout marks to the sides, as shown in **Figure J**. Do the same thing with the desk cross brace.

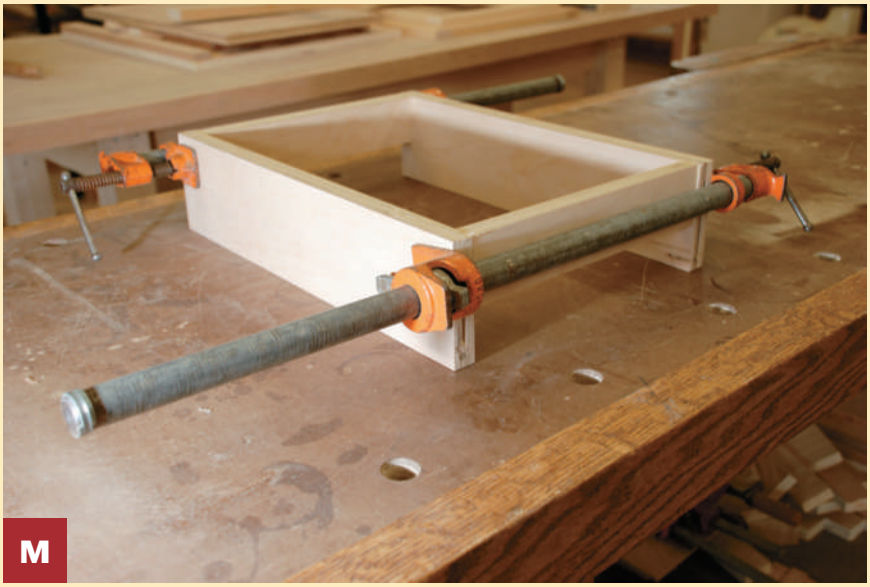
24. Holding the biscuit jointer against the shelf line on the side, make slots at the biscuit layout marks you just transferred from the shelves, as shown in **Figure K**. Repeat for the desk cross brace. Clamping a straight edge along the line helps keep the biscuit jointer in the proper position.
25. Glue and screw a 3/4" × 3/4" strip of solid stock to each side to support the desktop, as shown in **Figure L**.
26. Assemble the desk sides, shelves, and cross brace with biscuits and glue and clamp in place.
27. Put a bead of glue along the desktop supports and drop the desktop in place. Screw up through the supports to secure the desktop, taking care not to screw through the desktop. Drill 1/8" pilot holes and countersink them. Use 1 1/4" screws.
28. When the glue has set, the clamps can be removed. Any glue residue should be cleaned up, and then the desk is ready for finishing.
29. Take the pieces you prepared for the seat and decide what pieces will be visible; round over the edges of those pieces, following the same procedure as on the desk.


K

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L

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M

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N

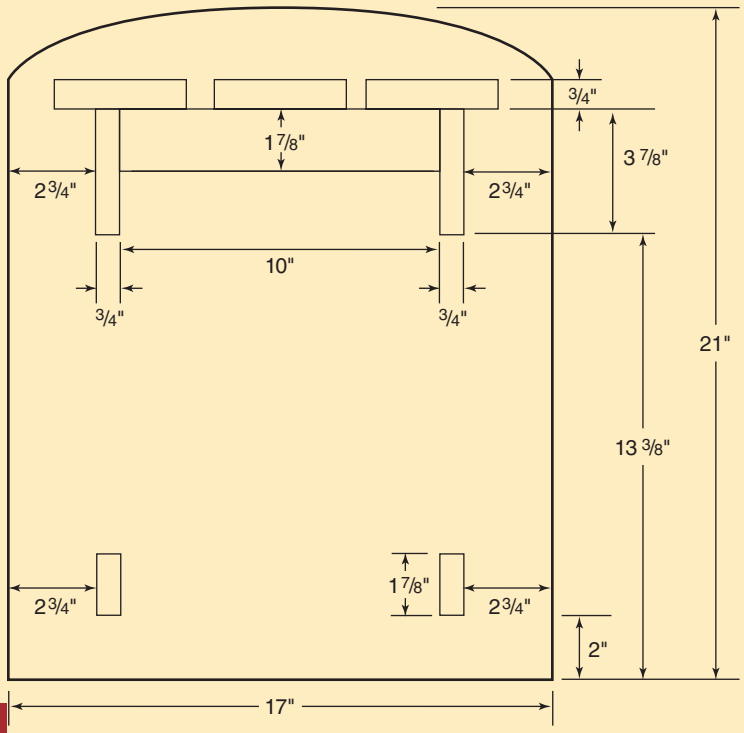
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30. Assemble the seat by first biscuiting the seat supports and seat ends together, using one #20 biscuit centered on each of the seat end supports. Insert biscuits and glue and clamp up, as shown in **Figure M**.
31. Glue and nail the seat tops to the seat support assembly as shown in **Figure N**, using 8d finish nails.
32. Center and machine #10 biscuit slots in the end of each seat cross brace.
33. Center and machine #20 biscuit slots in the ends of the two seat supports.

34. Mark out the seat ends for the seat and seat cross braces, as shown in **Figure O**.

35. Place the seat assembly and seat cross braces in position on the seat ends; transfer the biscuit layout marks to the seat ends, as shown in **Figure P**.

36. Make biscuit slots in the seat ends that you just laid out.



O

Section view

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P

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Q

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37. Glue, biscuit, and clamp together the seat ends, seat assembly, and seat cross braces. Refer to **Figure Q**.
38. When the glue has set, remove the clamps, clean up any glue residue, and finish as desired.



11

Veneer

You'll Learn

After studying the chapter, the student should be able to:

- Define veneer
- Discuss the production of veneer
- List the different methods of cutting veneer
- Identify the different types of veneer
- Explain the different thicknesses of veneer and what they are used for

INTRODUCTION

A **veneer** is a thin slice of a log or timber. Veneers have been used for thousands of years. Examples of veneer work have been found in Egyptian tombs, and possession of furniture created using beautiful and exotic veneers was a symbol of great status in ancient Rome.

A great deal of the classic furniture of the eighteenth and nineteenth centuries used veneers extensively (see **Figure 11-1** and **Figure 11-2**). These veneers were sawn. Since that time, the use of veneer has expanded greatly with the advent of more sophisticated methods of producing veneer. Today veneers are used in the production of manufactured panel products and curved shapes, and to enhance plain surfaces. **Figure 11-3** and **Figure 11-4** show examples of veneers.

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Image courtesy of Bob Stevenson, Stevenson Classic Woodworking, Chula Vista, California.

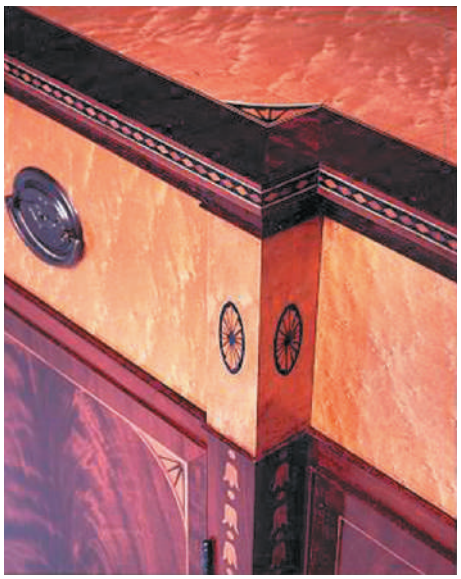


Image courtesy of Bob Stevenson, Stevenson Classic Woodworking, Chula Vista, California.

FIGURE 11-1 Federal Period Sideboard.



Image courtesy of Bob Stevenson, Stevenson Classic Woodworking, Chula Vista, California.



Image courtesy of Bob Stevenson, Stevenson Classic Woodworking, Chula Vista, California.

FIGURE 11-2 Federal Period Game Table.



Image courtesy of rockler.com

FIGURE 11-3 Sample veneers.

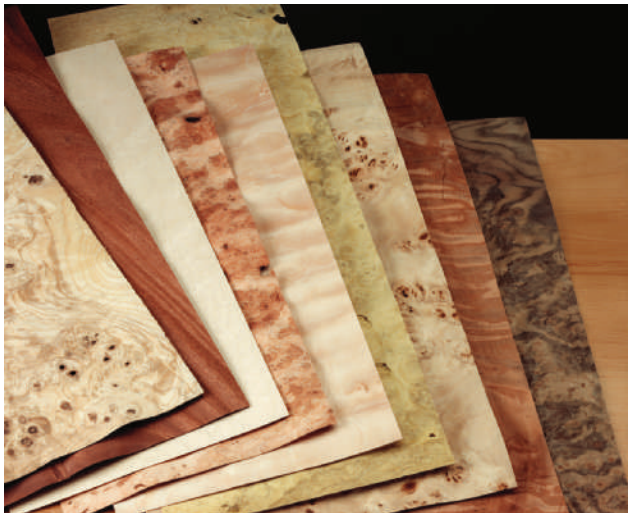
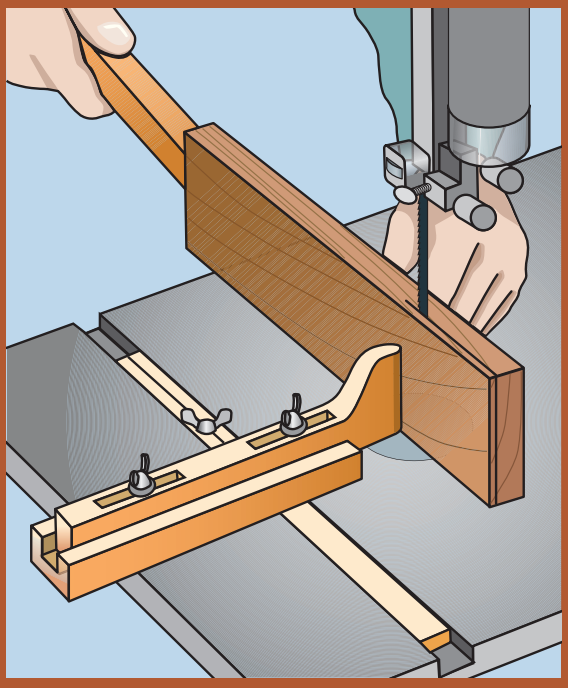


Image courtesy of Woodcraft Supply, LLC, www.woodcraft.com

FIGURE 11-4 Figured veneers.

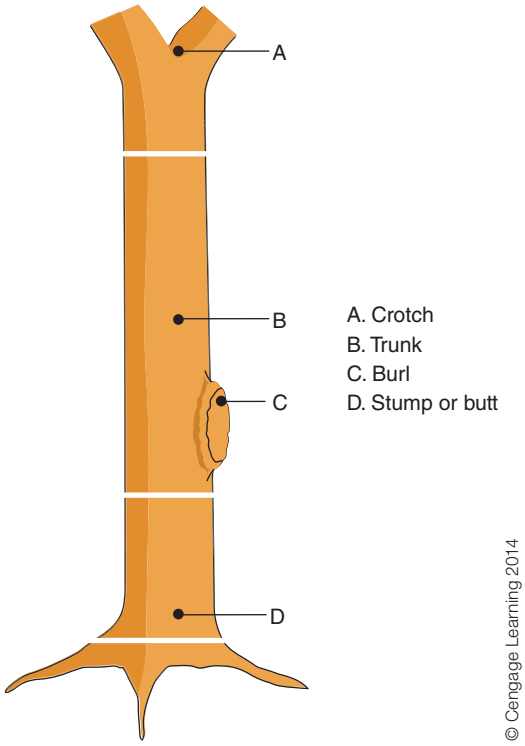
WOODWORKING TIP:

You can cut your own veneer on the band saw using a point fence, as shown in **Figure 11-5**.



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FIGURE 11-5 Cutting your own veneer on the band saw using the point fence.



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FIGURE 11-6 Veneer cut from burl, crotch, and stump material is highly decorative.

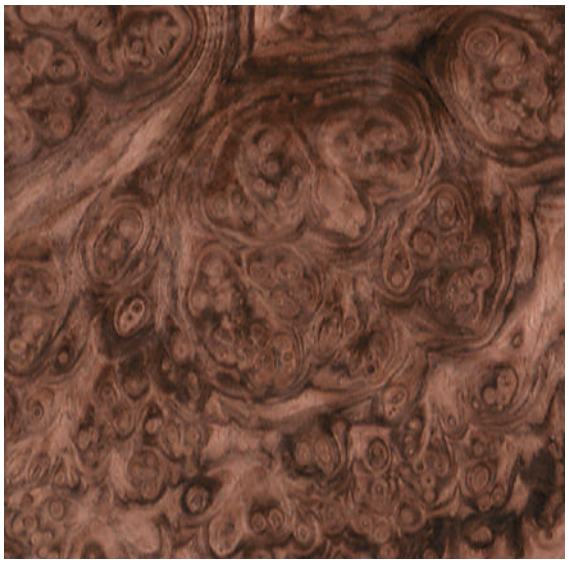


Image courtesy of Herzog Veneers, Inc.; www.veneeronline.com

FIGURE 11-7 Walnut burl veneer.

VENEER PRODUCTION

The best logs that are cut, called *select logs*, are sold for veneer production. Select logs have very few defects and bring a higher price than logs that go for lumber. Veneer logs are first debarked, cut to length, and then softened by immersion in hot water or by steaming. The length of time they are soaked or steamed depends on the type and hardness of the wood and the thickness of veneer that is to be cut. These are called **peeler blocks**.

Highly decorative veneers are also cut from **burl**, **crotch**, and **butt**, or *stump*, wood (see **Figure 11-6**). A burl is a lump on a tree that is formed by new growth generated to heal an injury. Burls follow the pattern created by the injury and veneer cut from burls has a circling, wavy, knotty pattern. **Figure 11-7** and **Figure 11-8** show examples of burl veneers.

A crotch is found where branches separate from the main trunk of a tree. The wood found in this section of the tree exhibits a highly figured V-grain, sometimes called a *flame pattern*. **Figure 11-9** and **Figure 11-10** show crotch veneers. Butt wood is found at the base of the tree. Veneer cut from the stump has a wrinkled line pattern due to the weight of the tree compressing the wood cells that formed it.



Image courtesy of Herzog Veneers, Inc.; www.veneeronline.com

FIGURE 11-8 Oak burl veneer.



Image courtesy of Herzog Veneers, Inc.; www.veneeronline.com

FIGURE 11-9 Walnut crotch veneer.



Image courtesy of Herzog Veneers, Inc.; www.veneeronline.com

FIGURE 11-10 Mahogany crotch veneer.

The appearance of veneer depends on its grain pattern, which is determined by the way it is cut from the peeler block. There are three ways of cutting veneer from the peeler block: *rotary cutting*, *slicing*, and *stay-log cutting*.

GREEN REMINDERS

Using veneer is a good green practice, as it is such a remarkably efficient method of utilizing wood.

In **rotary cutting** the log is turned on a lathe and rotated against a stationary knife (see **Figure 11-11**). This is the fastest method of cutting veneer and produces the greatest amount of veneer from any given log. Ninety percent of all veneer is made using the rotary method, and the vast majority of it is used for the plies in plywood. However, very little cabinet-grade hardwood veneer is cut this way, as it does not yield a very attractive grain pattern. One exception is birdseye maple, where this method will produce the greatest density of bird's eyes. **Figure 11-12** shows maple birdseye veneer. Another hardwood that is cut by the rotary method for the best effects is quilted maple (see **Figure 11-13**).

Slicing is the method by which most hardwood veneer is cut. There are two types of slicing: *flat slicing*, also called *plain slicing*, and *quarter slicing*. In **flat slicing**, the peeler block is cut in half lengthwise. The two halves are known as **flitches**. A flitch is attached to a flitch table, which moves up and down against a stationary knife (see **Figure 11-14**). Flat slicing is the

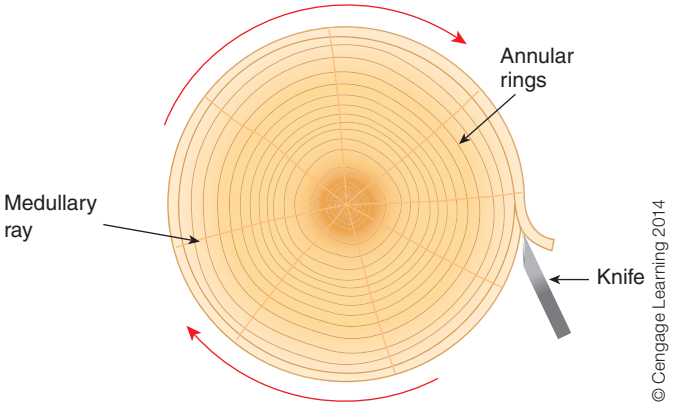


FIGURE 11-11 Rotary cutting veneer.


Image courtesy of Herzog Veneers, Inc.; www.veneeronline.com

FIGURE 11-12 Maple bird's eye veneer is produced by rotary cutting.


Image courtesy of Herzog Veneers, Inc.; www.veneeronline.com

FIGURE 11-13 Quilted maple veneer is also produced by rotary cutting.

most popular method of cutting hardwood veneer. **Figure 11-15** shows red oak veneer cut by the flat-slicing method. Notice the inverted V pattern, which is characteristic of flat-sliced veneer, just as it is characteristic of flatsawn lumber. In both cases the cut has been made tangent to the tree's growth rings.

Quarter slicing uses the same method as flat slicing, in which the flitch is moved against a stationary knife (see **Figure 11-16**). The difference is that the log is quartered rather than halved, so you have four flitches. Since the log is quartered, cuts are made at right angles to the annual rings, resulting in a far different look than plain slicing produces. **Figure 11-17** shows

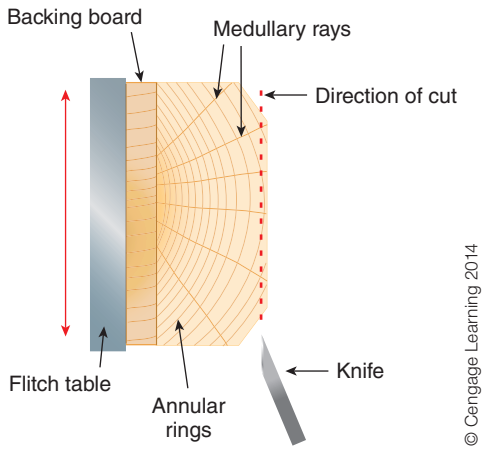


FIGURE 11-14 Flat slicing veneer.


Image courtesy of Herzog Veneers, Inc.; www.veneeronline.com

FIGURE 11-15 Red oak veneer produced by flat slicing.

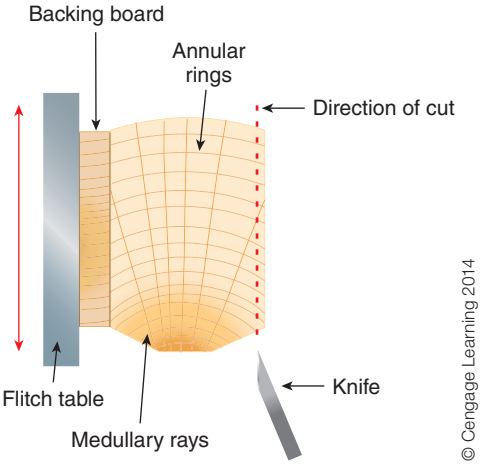


FIGURE 11-16 Quarter slicing veneer.

a red oak veneer that was cut using the quarter-slicing method. Notice the ray flake pattern, which is not visible in the red oak veneer produced by flat slicing.

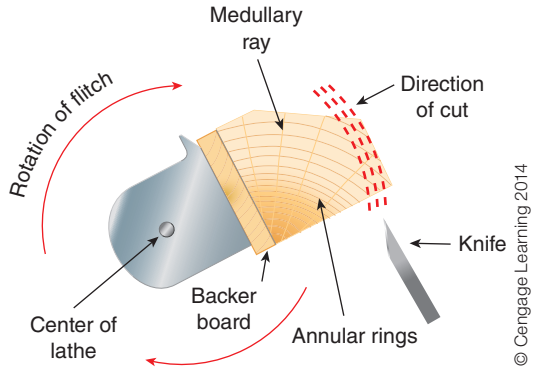
Stay-log cutting is the third method of cutting veneer from the peeler block. In this method, the log may or may not be cut into flitches first. Then either the log or the flitch is mounted on a lathe with an eccentric chuck and then swung against the knife. Three different patterns may be produced by stay-log cutting: *rift*, *half round*, and *back-cut*.

Rift cutting is cutting at a 45° angle to the annual rings (see **Figure 11-18**). The log is first quartered into four flitches. Rift cutting is sometimes called *comb cutting*, and it results in a very straight-grained veneer. **Figure 11-19** shows red oak veneer produced by rift cutting. Compare it to the red oak veneer produced by flat slicing and quarter slicing. Notice that while you have the very straight grain pattern seen in the quarter-sliced example, you do not have the ray flake pattern.



Image courtesy of Herzog Veneers, Inc.; www.veneeronline.com

FIGURE 11-17 Red oak veneer produced by quarter slicing.



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FIGURE 11-18 Stay-log rift-cut veneer cutting.

Half-round cuts produce a large U-patterned grain. The peeler block is halved, and cuts are made from the rounded side of the flitch (see **Figure 11-20**).

Back cutting is the third method of stay-log cutting. Again, the peeler block is cut in half lengthwise, but in this case the cuts are taken from the flat part of the flitch (see **Figure 11-21**). This produces a grain pattern very similar to that found in flat-sliced veneer.

Whether the veneer is sliced or cut by the stay-log method, as each slice is removed, it is stacked consecutively in the way that it came off the flitch. Each piece that is cut is called a **leaf**, and the consecutively stacked leaves are also called a flitch. Within a flitch, the leaves have a similar grain and color.

CAUTION

Extension cords can pose a safety hazard in the shop. The best-case scenario is to have enough outlets that the need for cords is eliminated. Cords snaking across the floor present a tripping hazard. However, most of us will need to use extension cords. Use the shortest cord possible and try to place it so it will not be a danger to yourself or others. Your cords should be periodically inspected; if frayed or worn, they should be repaired or replaced. Long cords also steal power from electric motors, which is another reason to use shorter cords. Also, use the largest wire gauge cord available, because this will also minimize voltage drop.



Image courtesy of Herzog Veneers, Inc.; www.veneeronline.com

FIGURE 11-19 Red oak veneer produced by rift cutting.

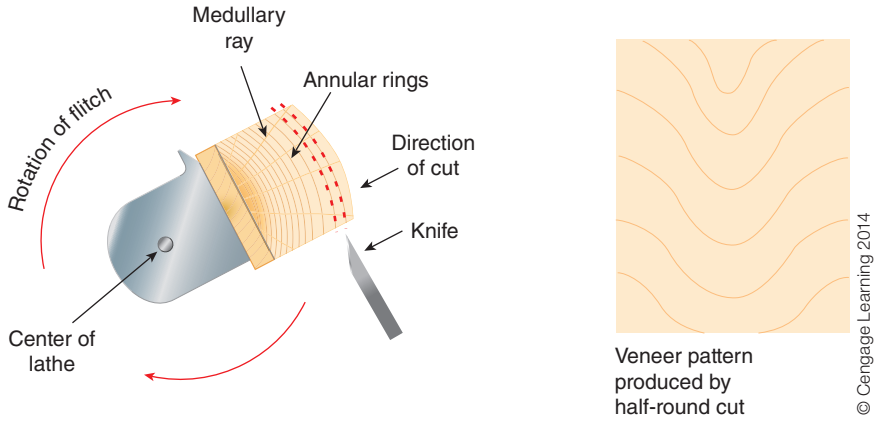


FIGURE 11-20 Stay-log half-round veneer cutting.

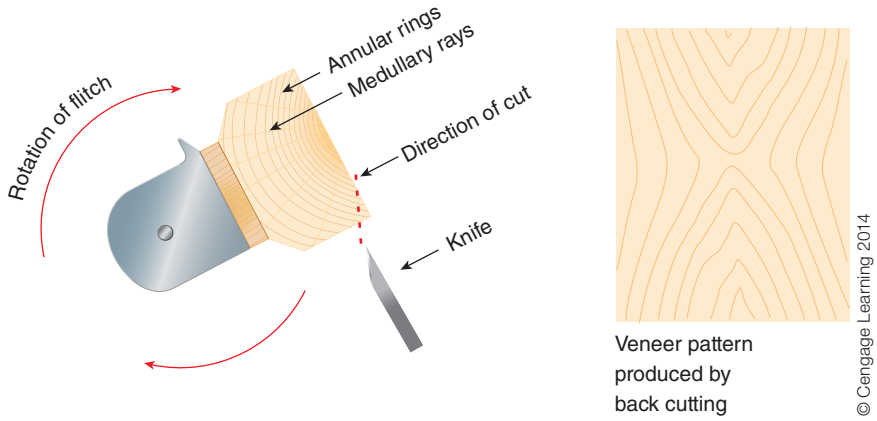


FIGURE 11-21 Stay-log back cutting.

After the veneer has been cut, it is clipped to various widths, and defects are cut out. Next, the veneer is dried to less than 10 percent moisture content; once dry, it is clipped to length.

GREEN REMINDERS

When purchasing veneer, look for a supplier that carries veneer certified by the Forest Stewardship Council (FSC), whose mission is "to promote environmentally appropriate, socially beneficial, and economically viable management of the world's forests."

Veneer Grading

Veneer is graded based on its appearance and the number of defects it has. The highest grade of veneer is AA, also called architectural grade. The next grade is A, which is also a premium grade, but not quite as perfect as AA. Next is B grade, which allows some knots and color variation; below that is C grade, which has the greatest allowance for defects and color variations.

Veneer Thicknesses

There are several standard thicknesses of veneer. The thickest of the veneers, 1/10 inches to 3/16 inches, are cut to be used as plies in plywood.

Veneers 1/28 inches to 1/40 inches thick are called *common veneers*. They are used to enhance plain surfaces or used as face and back veneers in the production of cabinet plywood.

WOODWORKING TIP:

When veneers are purchased, they will come either flat or rolled. Rolled pieces should be allowed to flatten gradually in a safe place. Veneer is a fragile material and therefore vulnerable to splits. Splits tend to start in the ends and progress along the veneer's length. To prevent this, the ends can be taped with masking or veneer tape. Veneers should be stored horizontally and maintained in a flat position in a dark, dry place. They should be stored off the ground, covered, and kept clean.



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FIGURE 11-22 Peel-and-stick veneer.

The thinnest of the veneers, 1/40 to 1/100 inches thick, are used to make reinforced veneers. They are also called *flexible veneers*. These extremely thin slices of veneer are bonded to a variety of backing materials. Among them is nonwoven fiber backing. This is paper-backed veneer. Another backing is a pressure-sensitive adhesive backing. This is a peel-and-stick veneer (see **Figure 11-22**). A third backing is paper and foil and paper under the face veneer. Cloth-backed veneer is produced for use over drywall and plaster, and some veneer is used in the production of edge banding (see **Figure 11-23**).



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FIGURE 11-23 Veneer edge banding.



Summary

Veneer is a thin slice of wood ranging in thickness from 1/100 to 3/16 of an inch. Veneer is produced from the highest-quality logs that are harvested. It has been used since ancient times to enhance plain wood and to make the greatest possible use of rare or unusual woods. Today veneer is cut by one of three methods: *rotary cutting, slicing,* or *stay-log cutting*. Depending on the method and the manner in which the flitch is placed and cut different patterns are made. Veneer that is sliced or stay-log cut is stacked in consecutive leaves, which together make up a flitch. Veneer is sliced in different thicknesses for different applications.



Key Terms

back cutting
burl
butt
crotch
flat slicing
flitch
half-round cutting
leaf
peeler blocks
quarter slicing
rift cutting
rotary cutting
stay-log cutting
veneer



Check Your Knowledge

1. What are the three methods of cutting veneer?
2. What is the most frequently used method for cutting hardwood veneer? Be specific.
3. What is the process for turning a log into veneer?
4. Name one hardwood that is best cut by the rotary method.
5. What is another name for reinforced veneer?
6. What are the thickest veneers most commonly used for?
7. Why are leaves stacked consecutively as they are cut?

BUILD IT!

Coasters



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Figure A shows completed coasters.

TOOLS REQUIRED

- Measuring tool
- Square
- Table saw
- Miter saw
- Band saw or jigsaw
- Sharp knife or veneer saw
- Metal edge or straightedge
- Roller

MATERIALS REQUIRED

- 1/4" hardboard, roughly 4" × 8"
- Veneer, roughly 8" × 16"
- White glue
- Two pieces of scrap 3/4" MDF or plywood, each about 4" × 8"
- Wax paper
- Spray varnish

STEPS

1. Rip and crosscut the hardboard into two pieces 3 3/4" square.
2. Trace around a quarter to lay out rounded corners, as shown in **Figure B**.
3. Cut the rounded corners and sand them smooth.

4. Take one hardboard piece, place it on the veneer, and trace around it. Do this four times. You will use two pieces of veneer for each coaster. See **Figure C**.
5. Use a sharp knife or veneer saw and metal straightedge to cut out the veneer. Cut about 1/8" outside your lines, as shown in **Figure D**.
6. Spread white glue on the two hardboard pieces, as shown in **Figure E**.
7. Allow five minutes for the glue to get tacky, and then place the boards glue side down on two of the veneer pieces you cut.


C

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F

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G

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8. Turn the pieces over so the veneer side is up; roll them to ensure a good bond between the hardboard and the veneer, as shown in **Figure F**.
9. Place the two veneered pieces between two pieces of 3/4" MDF or plywood with a piece of waxed paper between the veneer and the stock. Place some weight on it, as shown in **Figure G**, and leave it overnight.
10. Take the veneered panels, place them veneer side down, and trim off the overhanging veneer with a sharp knife, as shown in **Figure H**. Do not try to cut all the way through in a single pass.
11. Repeat the process to veneer the other side of the panels.
12. Lightly sand the edges.
13. Finish with several coats of spray varnish.

BUILD IT!

PROJECT CHALLENGE

Veneered Picture or Mirror Frame

Figure A shows the completed frame.

STEPS

1. Consult the assembly list given in **Figure B** and size the pieces that will serve as the frame.
2. With a sharp knife or veneer saw and a metal straightedge, cuts strips of veneer slightly wider than the 3/4" frame pieces, as shown in **Figure C**.
3. Apply contact cement to both the 3/4" side of frame pieces and the veneer; allow it to dry.



A

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Assembly list-frame

Part	Dimensions (thickness x width x length)	Quantity
1. Stile	$^{7}/_{8}$" x $^{3}/_{4}$" x 12"	2
2. Rail	$^{7}/_{8}$" x $^{3}/_{4}$" x 8"	2

B

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C

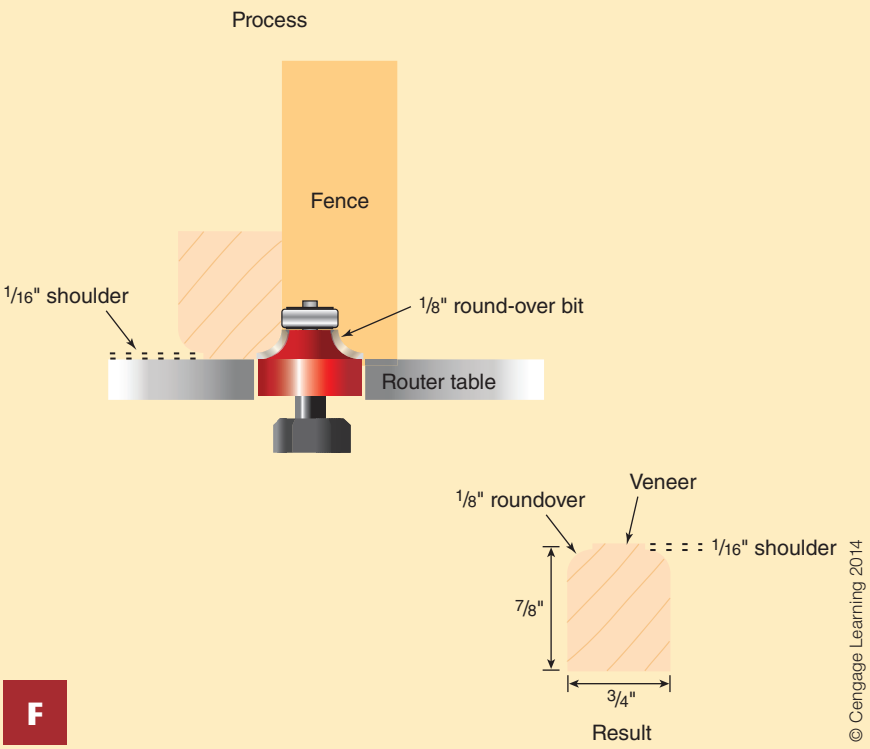
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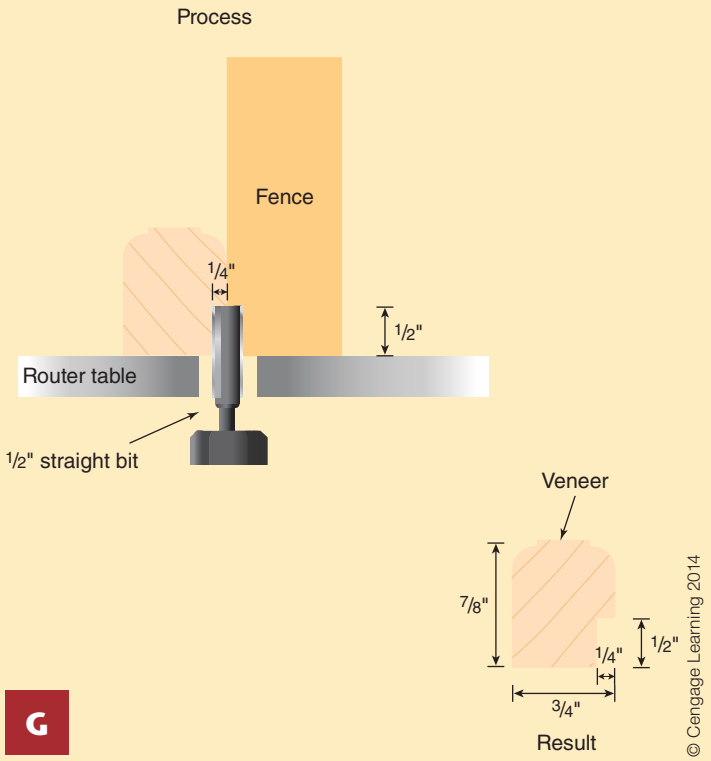
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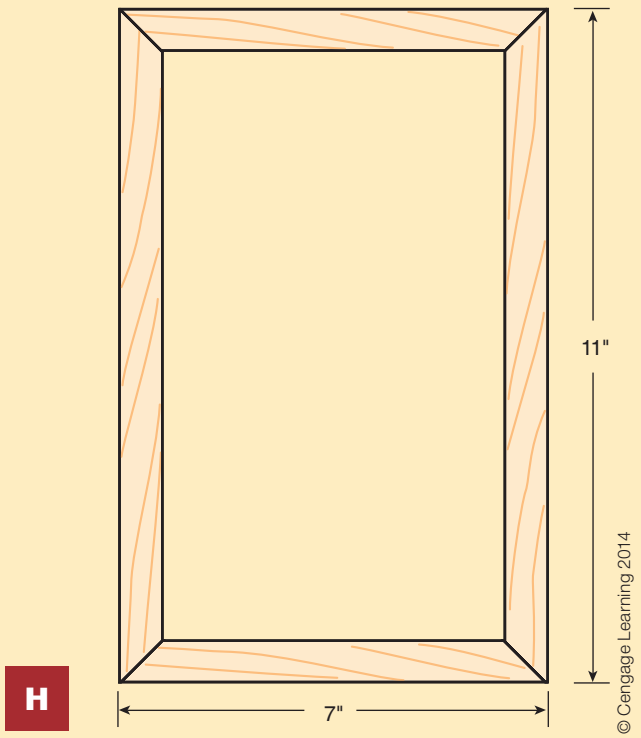
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4. Carefully place the veneer on the frame pieces and roll the veneer, as shown in **Figure D**.
5. Trim the edges of the veneer flush with the frame pieces, as shown in **Figure E**. You can do this with a knife or veneer saw, or you can use a piloted, flush trim bit in a router or laminate trimmer.
6. Set up a 1/8" round-over bit in a router table, as shown in **Figure F**, and rout both sides of the frame pieces with the veneered side face down on the router table.

7. Replace the round-over bit with a 1/2" straight bit; make a rabbet on the back of each frame piece, as shown in **Figure G**. Make this cut in several passes, raising the bit each time.
8. Cut opposing miters on each end of the frame pieces, cutting them to final size at the same time, as shown in **Figure H**.



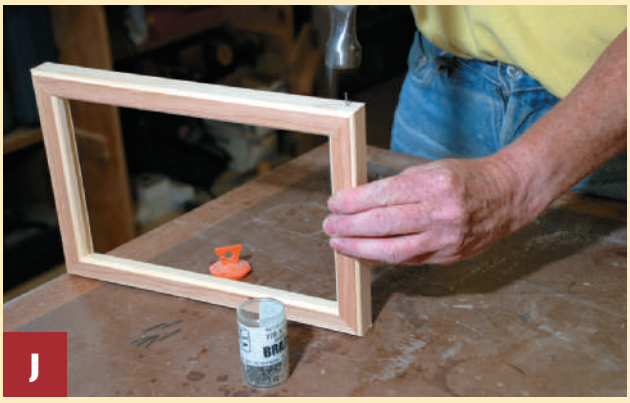
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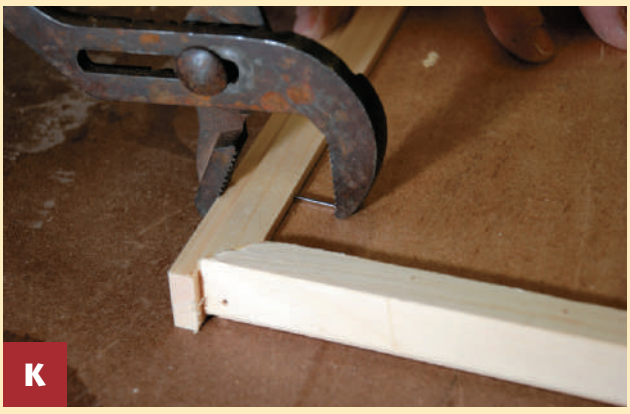
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I

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9. Glue and clamp up the frame, as shown in **Figure I**.
10. Nail brads though the sides of the frame to strengthen the joint, as shown in **Figure J**.
11. Sand and finish as desired.
12. Insert a mirror or 1/8" glass and picture from the back of the frame into the rabbet.
13. Cut a scrap piece of 1/4" plywood or hardboard to fit into the back of the frame. Corrugated cardboard can also be used.
14. Secure in place with small brads and channel lock pliers, as shown in **Figure K** (note that the outside edge of the frame is being protected with a wood scrap); or use a picture-framing tool designed specifically for this purpose, illustrated in **Figure L**.
15. Install a picture hanger.



12

Synthetic Materials

You'll Learn

After studying the chapter, the student should be able to:

- Explain the composition of plastic laminates
- Identify the advantages and disadvantages of plastic laminates
- List the types of plastic laminates and what each is used for
- Describe solid surface materials
- Explain how solid surface materials and plastic laminates differ
- Identify the advantages and disadvantages of solid surface materials

INTRODUCTION

Plastic laminates and solid surface materials are both manufactured synthetic products. Both are tough and durable. This has made them popular materials for fabricating countertops, among other things. Both of these synthetic materials are used widely in residential and commercial construction.

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PLASTIC LAMINATES

Plastic laminates are similar to veneers, but they are synthetic rather than natural and are much tougher materials. Plastic laminates are waterproof and highly resistant to chemicals, stains, and wear. Like veneers, they are attached to a substrate such as plywood, MDF, or particleboard.

The core and back of plastic laminates are made up of multiple layers of Kraft paper impregnated with phenolic resin, which is a durable plastic. Above the core is the decorative layer, which is printed with a color and/or a decorative design. It is impregnated with a clear melamine resin. On top are a couple of thin clear layers that protect the decorative layer (see **Figure 12-1**).

The layers of the laminate are bound together by a hydraulic press under heat and pressure. The back of the laminate is roughened for easier adhesion to the substrate. The top finish may be gloss, satin, low glare, or textured.

Plastic laminates are available in large sheets of various sizes, from 24 to 48 inches wide and up to 12 feet long. They may be rigid or flexible. Rigid laminates are frequently referred to as *high-pressure laminates*. A wide array of colors and patterns are available, as shown in **Figure 12-2**.

Types of Plastic Laminates

There are five types of laminates that are commonly available. **General-purpose laminates** are designed for surfaces that will have a great deal of use, such as countertops. They are 1/16″ thick.



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FIGURE 12-2 Examples of plastic laminates.

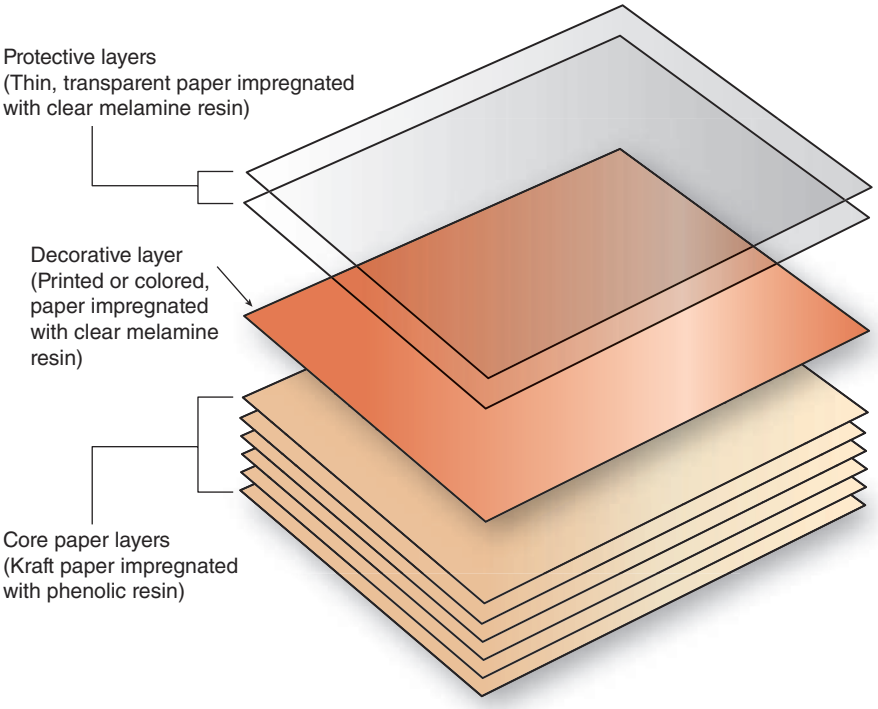


FIGURE 12-1 Plastic laminate composition.

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Vertical-surface laminates are 1/32″ thick and are used for the sides and other outside surfaces of cabinets that are subject to less wear than countertops.

Post-forming laminates are no more than 1/32″ thick. They are made with flexible resins that allow them to be bent around curved surfaces. These laminates are typically heated before bending to allow them to form curves (see **Figure 12-3**).

Backing laminates and **liner laminates** are similar. Both are only 1/50" thick. Backing laminates do not come in colors or designs. They are applied to the backs of panels to control warping. Liner laminates are available in colors and are used to line the interiors of cabinets. Flexible plastic bandings, similar to veneer tape, are available for covered edges of corners of panels.

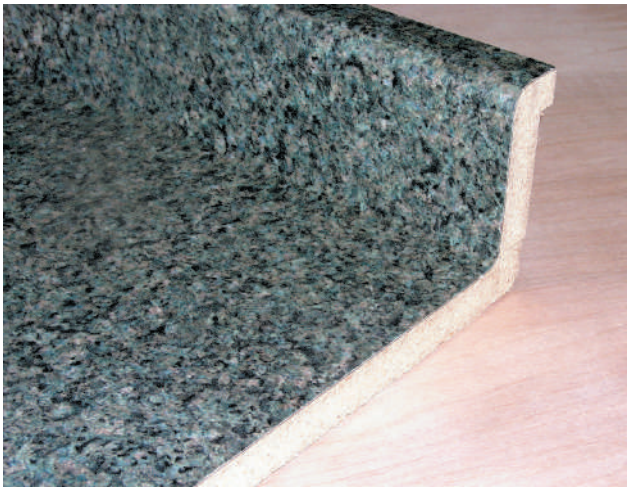


HISTORY FACT

Plastic laminate was invented in 1912 by Daniel O'Conor and Herbert Faber, who were then working for Westinghouse Corporation. The original purpose of the material was for use as an electrical insulator. They started their own company, Formica, in 1913, named after their invention, which had been conceived to be used in place of mica, hence the name "for mica." The range of surfacing laminates we have now were first developed in the late 1920s. ■

Advantages and Disadvantages of Plastic Laminates

The advantages of plastic laminates are many. They are tough and durable materials that are waterproof and stain and chemical resistant. A wide array of colors and patterns are available. The main disadvantage of plastic laminates is similar to that of wood veneers: The color and pattern layer of the laminate is very thin, with the result that scratches will reveal the underlying layers, which are not colored or patterned. These scratches are not repairable and can detract from the overall beauty of the finished surface. Another disadvantage is that plastic laminate is not particularly heat resistant, and a hot pan from the stove will burn through the top layer of the laminate, leaving an unsightly burn mark. A third disadvantage to plastic laminate is aesthetic: It is simply not as attractive to most people as solid surface material and can appear "cheap" in comparison.



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FIGURE 12-3 Post-forming laminate.

CAUTION

Some workshop accidents are caused by slippery floors. One inexpensive way to create nonslip surfaces in front of machines such as the lathe is to paint the area with a rubber-type adhesive and to sprinkle it with dry sand; wait for it to cure, and sweep up the excess.

SOLID SURFACE MATERIALS

Solid surface material is an acrylic material that is manufactured into flat sheets. Unlike plastic laminates, it is not applied to a substrate. It is a thicker material, most commonly seen in half-inch thicknesses. It is designed for use in both interior and exterior applications and is suitable for a wide variety of applications, including kitchen countertops and bathroom vanities. It may be applied horizontally or vertically. Solid surface material is available in a wide variety of colors and patterns; a few are shown in **Figure 12-4**.

Most solid surface materials are a combination of two main ingredients: a *filler* and a *binder*. The filler and binder are combined and then cast in a curing process that results in a sheet or shape.

The filler used in the production of solid surface is a natural mineral. The most commonly used mineral is *alumina trihydrate*, or *ATH*. A sheet of solid surface material may be up to 75 percent ATH, which is refined from bauxite ore, a form of clay.

The binder used in the creation of solid surface materials is a resin. Two main resins used in the

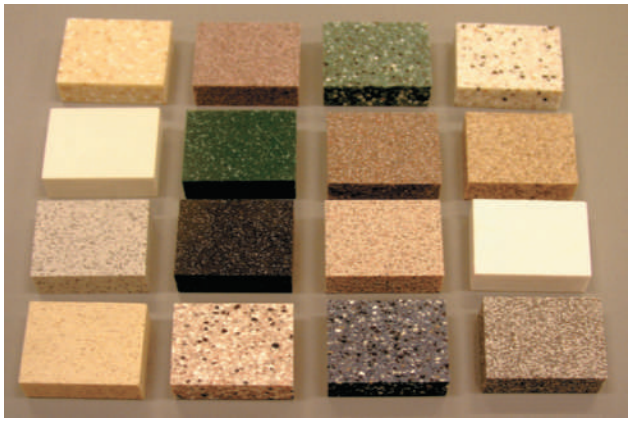

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FIGURE 12-4 Examples of solid surface materials.


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FIGURE 12-5 Solid surface edges may be profiled.

manufacturing process are *acrylic* and *polyester*. A purely acrylic-based resin yields a sheet that is *thermoformable,* which means that it can be heated, bent into a new shape, and cooled without any loss of performance characteristics. Polyester resins, including those that are mixed with acrylic, are used in demanding or high-strength applications. Additives to give the sheets color are mixed in. With the addition of a catalyst, usually peroxide, the sheets are then cast and cured.

Advantages and Disadvantages of Solid Surface

Solid surface is an amazing material. It is chemical, stain, water, and heat resistant. It is hard enough to have impact resistance, but soft enough to be workable with standard woodworking tools, and it is stable and nonporous.

Solid surface sheets may be bonded to one another by using color-matched fusion adhesives to create a continuous, seamless appearance. This is one of its most desirable attributes—one that plastic laminates cannot claim. Also unlike plastic laminates, its edges may be profiled (see **Figure 12-5**).

Solid surface material may be inlaid with another color or pattern of solid surface to create visual interest (see **Figure 12-6**).

Another great advantage that solid surface has over plastic laminates is that it is a renewable surface. Scratches, cuts, and burns can be sanded away, because solid surface is the same material throughout its thickness. Compared to plastic laminate, it is aesthetically more appealing, with what might be described as a richer, stronger-looking appearance.

The primary disadvantage of solid surface material as compared to plastic laminates is its substantially higher cost. Additionally, in order to purchase solid surface material, the buyer must usually be certified by the manufacturer. However, this is not a particularly onerous process.


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FIGURE 12-6 Inlaid solid surface.



HISTORY FACT

Solid surface material was invented by a DuPont chemist named Donald Slocum and first appeared as a consumer product in the 1960s. It experienced phenomenal expansion into the commercial and residential market in the 1980s, and with the introduction of color-matched fusion adhesives and an ever-increasing array of color and pattern choices, industry growth continued through the 1990s at a double-digit rate. ■



Summary

Both plastic laminates and solid surface materials are synthetic products that see wide use both residentially and commercially. They are both tough products that will take a lot of abuse, which has made them popular as countertop material. Plastic laminates come in five different types or grades: *general purpose, vertical-surface, post-forming, backing*, and *liner laminates*. The various types have different applications. Plastic laminates are relatively thin and are glued to a substrate such as MDF, particleboard, or plywood.

Solid surface materials are formed in sheets that are a combination of a natural mineral, usually a refined type of bauxite ore, and a resin that is either acrylic, polyester, or a combination of the two. Various additives give the sheets their color. Solid surface materials have the same advantages that plastic laminates do, in that they are waterproof and stain and chemical resistant. Additionally, they are heat resistant; plastic laminates are not. Perhaps best of all, solid surface materials are a renewable surface: a scratch in a plastic laminate reveals the core, which is without color or pattern; the color of solid surface material is consistent throughout its thickness. Solid surface materials can be bonded together for a seamless appearance, and because they are solid, they may be inlaid or profiled.



Key Terms

backing laminates
general-purpose laminates
liner laminates
plastic laminates
post-forming laminates
solid surface material
vertical-surface laminates



Check Your Knowledge

1. What are the two synthetic materials discussed in this chapter, and what are their applications?
2. How is plastic laminate made?
3. What are the five types of plastic laminate and how do they differ?
4. List two advantages and two disadvantages of plastic laminates.
5. What are the two main ingredients of solid surface material?
6. What thickness does solid surface material commonly come in? Is it glued to a substrate?
7. What are two advantages solid surface materials have that plastic laminates do not?
8. Does working with solid surface material require special tools not typically found in a woodworking shop?
9. What is the primary drawback to using solid surface material instead of plastic laminate?



Activities

1. Visit a cabinet shop that works with plastic laminates or solid surface materials.
2. See what you can learn about the manufacturing of plastic laminates and solid surface materials, either by visiting a manufacturing facility or doing some research online. Sources include ISSFA, the International Solid Surface Fabricators Association, found at *http://www.issfa.net,* **and** *http://www.owenscorning.com.*

BUILD IT!

Drawing Board

Figure A shows a completed drawing board.

TOOLS REQUIRED

- Measuring tool
- Square
- Compass
- Table saw
- Jigsaw
- Sander
- Roller
- Laminate trimmer or router, piloted flush cut bit, 1/8" round-over bit
- Drill press and 1" bit
- Mill file

MATERIALS REQUIRED

- Luan plywood, MDF, or cabinet-grade plywood, 3/4" × 16" × 24"
- Plastic laminate, 17" × 25"
- Contact cement
- Polyurethane

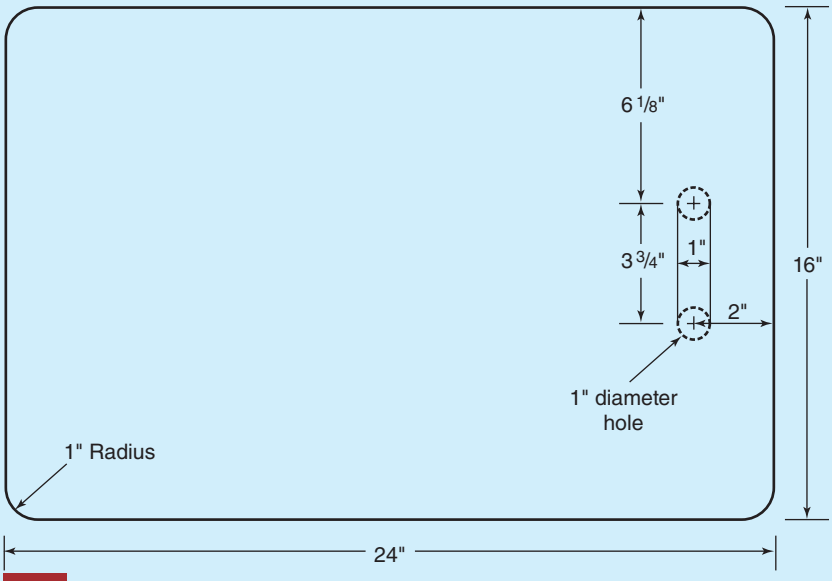
STEPS

1. Cut the plywood to finish size on the table saw; lay out the rounded corners as shown in **Figure B**.
2. Use a jigsaw to cut the rounded corners and sand them smooth.



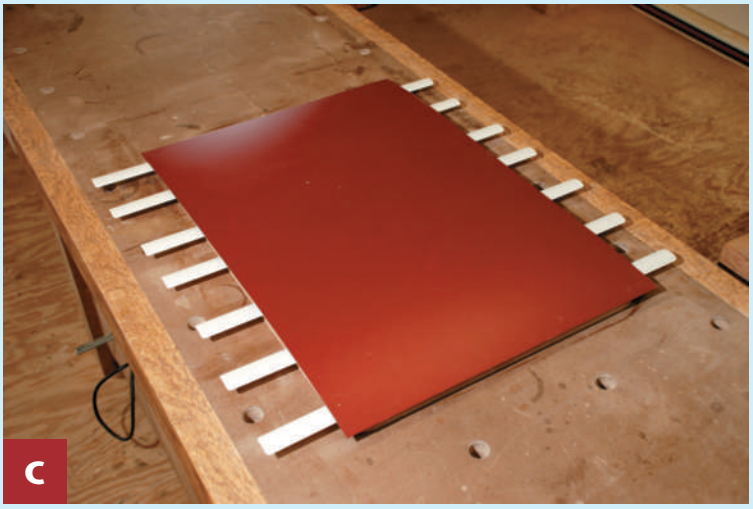
A

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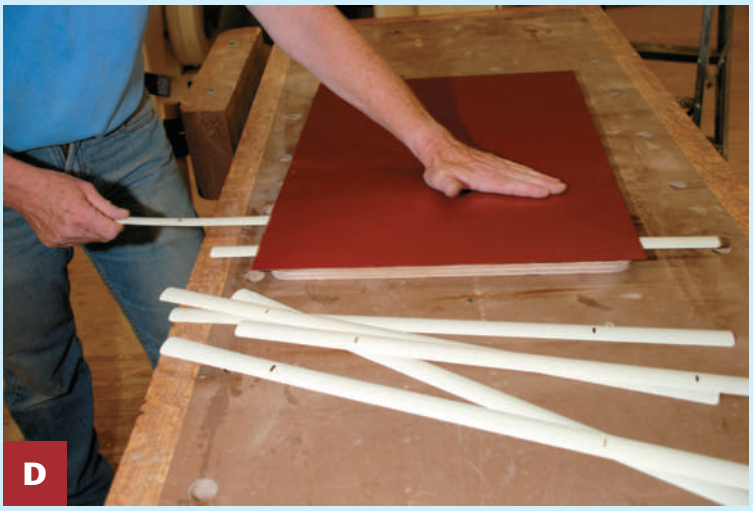


B

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C

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D

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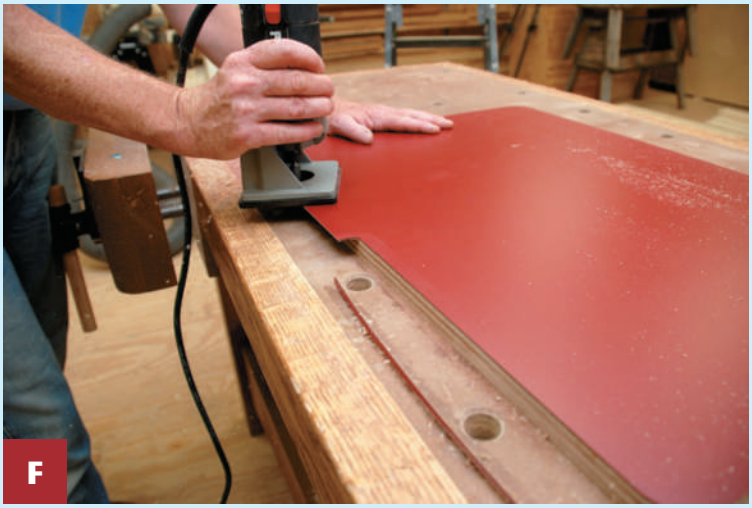

E

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3. Place the laminate face down on the bench; lay the plywood face up. Make sure both surfaces are clean and apply contact cement to both surfaces.
4. Allow the contact cement to dry. It will no longer be glossy when dry. Lay clean, thin lengths of wood, dowel, or old blinds across the plywood and carefully lay the laminate, glued face down, over them. Position it so there is an overhang on all sides, as shown in **Figure C**.
5. Starting from the center, pull out each spacer and press down the laminate to the plywood, as shown in **Figure D**.
6. Using the roller, make overlapping passes to securely fasten the laminate to the plywood. See **Figure E**.

BUILD IT!

7. With a piloted, flush-cut bit mounted in a laminate trimmer or router, remove the overhanging laminate, as shown in **Figure F**.
8. Use a mill file to smooth the edges of the laminate, as shown in **Figure G**.
9. Referring again to the diagram in Figure B, lay out the handle cutout.
10. Drill 1" holes at either end of the cutout, as shown in **Figure H**.


F

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G

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H

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BUILD IT!



I

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J

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11. Remove the waste between the two holes with a jigsaw, as shown in **Figure I**.
12. Install the 1/8" round-over bit in a laminate trimmer or router; round over the back side of the drawing board and both sides of the handle cut-out, as shown in **Figure J**.
13. Brush two coats of polyurethane on the exposed wooden parts of the board.

BUILD IT!

PROJECT CHALLENGE

Lap Desk

Figure A shows a completed lap desk.

STEPS

1. Consult the materials list in **Figure B** and cut the pieces to size.



A

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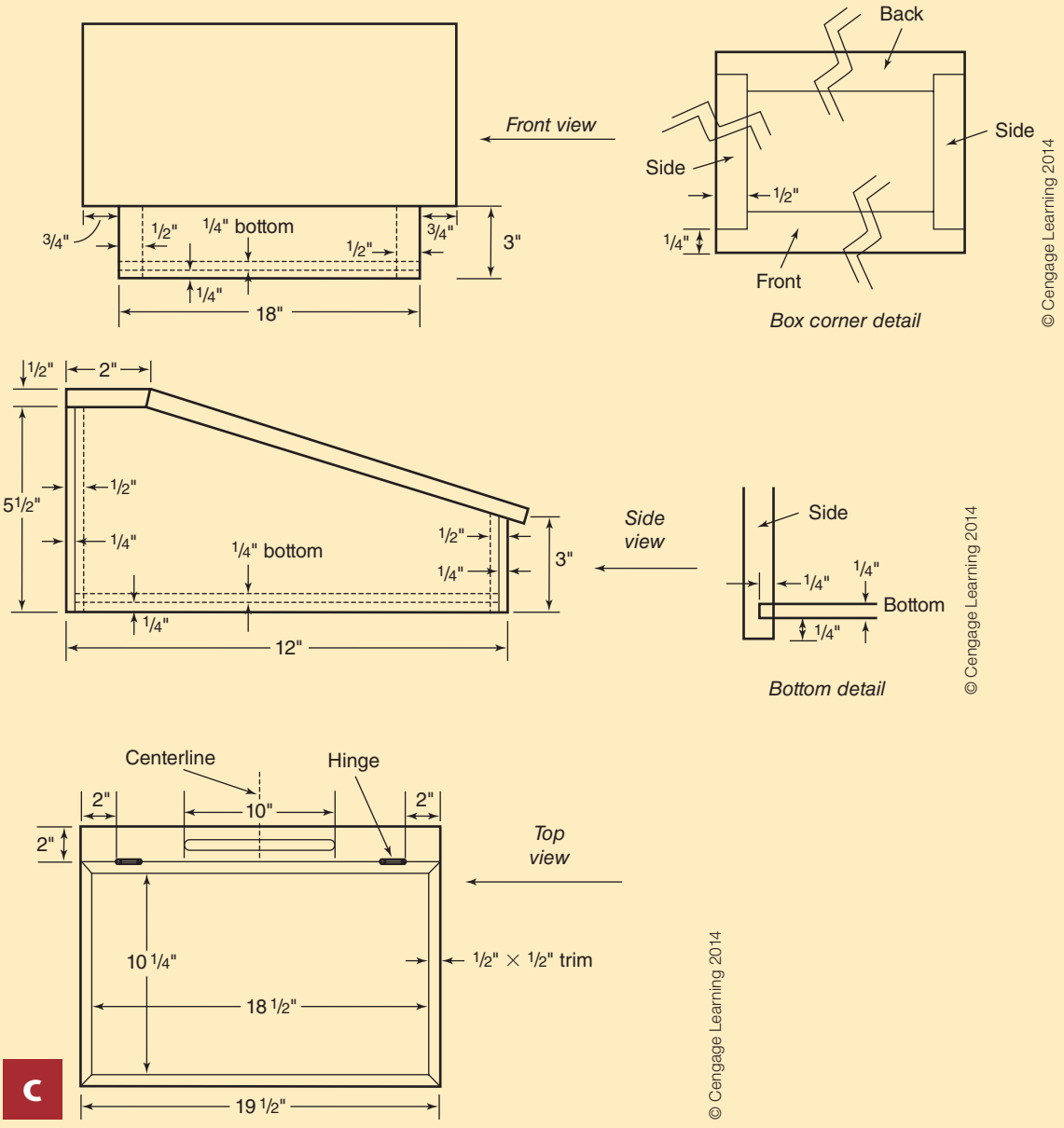
Assembly list – lap desk

Part	Dimensions (thickness × width × length)	Quantity
1. Front	$^1/_2$" × 3" × 18"	1
2. Sides	$^1/_2$" × $5^1/_2$" × $11^1/_2$"	2
3. Back	$^1/_2$" × $5^1/_2$" × 18"	1
4. Bottom	$^1/_4$" × $11^1/_2$" × $17^1/_2$" plywood	1
5. Top	$^1/_2$" × 2" × $19^1/_2$"	1
6. Desk surface	$^1/_2$" × $10^1/_4$" × $18^1/_2$" plywood or MDF	1
7. Trim	$^1/_2$" × $^1/_2$" × 64" rough	
8. Plastic laminate	$11^1/_4$" × $19^1/_2$"	

B

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2. Study the lap desk drawings shown in **Figure C**, and then machine the groove for the bottom on the inside of the front and back and two side pieces.

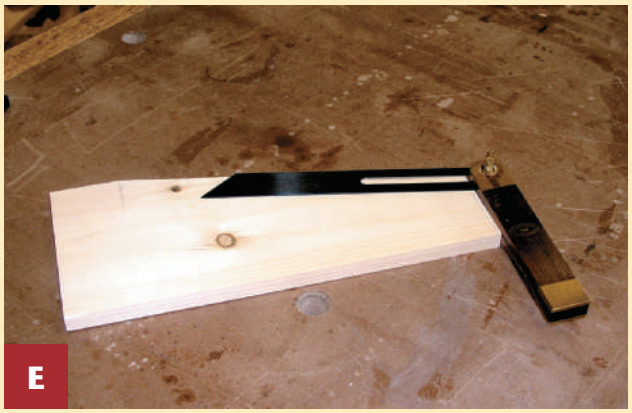


C

3. Machine 1/2″-wide rabbets 1/4″ deep on the inside of both ends of the front and back, using the table saw and a dado blade or a table-mounted router and a straight bit. Refer to **Figure D**.
4. Cut the angle on the two side pieces using a band saw or jigsaw and plane smooth.
5. Use a sliding T-bevel to transfer the angle from the sides to the front piece, as shown in **Figure E** and **Figure F**.


D

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E

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F

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G

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H(a)

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H(b)

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6. Plane the angle on the front piece, as shown in **Figure G**.
7. Sand the inside faces of the bottom, sides, front, and back.
8. Assemble the box. The bottom fits in the groove without glue. The sides, front, and back are glued and nailed in place, as shown in **Figure H**.

9. Use a 1/2″ core box bit on the router table to make the pencil groove on the top piece. This is a dropped stop cut. Refer to **Figure I** and **Figure J**.
10. Nail the top piece in place, as shown in **Figure K**. The overhang on each side should be equal.
11. Apply the laminate to the desk surface. Trim off the overhanging laminate using a flush trim bit.


I

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J

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K

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L

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M

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N

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12. Miter, glue, and nail the trim to the desk surface, as shown in **Figure L**.
13. Lay the desk surface on the box, butting it up against the top piece. Determine the angle required for a flush fit between the top and the desk surface, and plane the desk surface to fit against the top piece. See **Figure M**.
14. Install the hinges as shown in **Figure N**.
15. Remove the hinges, putty the nail holes, sand the outside surface smooth, and apply finish. When the finish is dry, reinstall the hinges.

SECTION V


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Joinery and Assembly


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SUCCESS STORIES

Judy Ditmer

Title

Owner of her own woodturning business in Piqua, Ohio; author of Turning Wooden Jewelry and *Basic Bowl Turning with Judy Ditmer.*

Education

After high school, Judy attended an art school where every first-year student had to take a woodshop orientation. There she learned to use a band saw, jointer, sander, and other tools. "I'd never done anything like that, and it really grabbed me," she says. Several years later, she attended a woodturning workshop in Gatlinburg, Tennessee.

History

For Judy, it wasn't a direct path to woodworking, despite her early interest in it. She pursued a few different careers in the years that followed, including owning a food co-op. "But I wasn't happy," she recalls. Remembering the class from art school, she bought herself a Shopsmith, a multipurpose woodworking machine, and began playing around with it. She started reading woodworking publications and saw an ad for a woodturning workshop in Gatlinburg, Tennessee. "At that point, I didn't know anything about turning, except that people said it was the most creative part of woodworking," says Judy. But the class solidified things for her, and she left knowing what

she wanted to do. She says, "When I started turning, it was like coming home. I got it right away." Two years later, she was turning full time. Today, she makes functional pieces — bottle stoppers, jewelry boxes — as well as some larger artistic pieces. Mostly, she sells wholesale to stores and galleries, but occasionally she attends craft fairs.

On the Job

"*No* day is typical," says Judy, with a laugh. Ideally, she'd work in the shop through early afternoon, then use the rest of the day for errands. But often she doesn't make it to the shop at all because of the administrative necessities of running her own business. She photographs her own work, creates her own brochures, applies for shows, balances her books, and orders supplies. "Unfortunately, there are not eight turning hours in a workday, or five turning days in a workweek."

Best Aspects

"There's a saying that someone who works with her hands is a laborer, a person who works with her head and hands is a craftsman, and a person who works with her head, hands, and heart is an artist," says Judy. "And with turning, I really feel that's true."

Challenges

While the self-described introvert loves working by herself, she says that it also has its drawbacks. For instance, only she is responsible for the success of her business. She must think toward the future, and she must be good at prioritizing.

Importance of Education

Judy advises those who want to go into turning to get some kind of instruction in a school program, an apprenticeship, or even just a good book. For one thing, there is potential for serious injury when you're cutting wood that's spinning on the lathe, so proper guidance is important.



Image courtesy of Judy Ditmer.

But one must also master the technical aspects before turning can become artistry. She says it's important to learn the theory behind what you're doing, because that makes it easier to put it all together.

Future Opportunities

For now, Judy needs to work on the smaller functional items, because these are the bread and butter of her business. But she'd like to get to the point where she can focus on high-end, one-of-a-kind pieces.

Words of Advice

Understand that it takes time — anywhere from a few months to a few years — to become a good turner, one who can execute a vision and turn 12 feet in an hour. Judy suggests that those interested in doing what she does not go into business for themselves straightaway, but rather go into an established architectural turning shop, where you can get decent teaching and decent money. That way, you can master the basics while working on things like porch columns and stair spindles. "Learn to do it right, not fast," she says.

Story originally written by Margaret Magnarelli, 2008. Interview and photo provided by Judy Ditmer.



13

Construction Methods

You'll Learn

After studying the chapter, the student should be able to:

- Describe the three construction methods for cabinets and furniture
- Understand how the methods differ from one another
- Explain the advantages and disadvantages of each method

INTRODUCTION

There are three main methods for building cabinets and other types of furniture. Each one is different from the others and has different advantages and disadvantages. One choice is to use solid wood. A second is to use manufactured panel products. The third choice is to employ frame-and-panel construction (see **Figure 13-1**, **Figure 13-2**, and **Figure 13-3**).



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FIGURE 13-1 Solid wood construction.

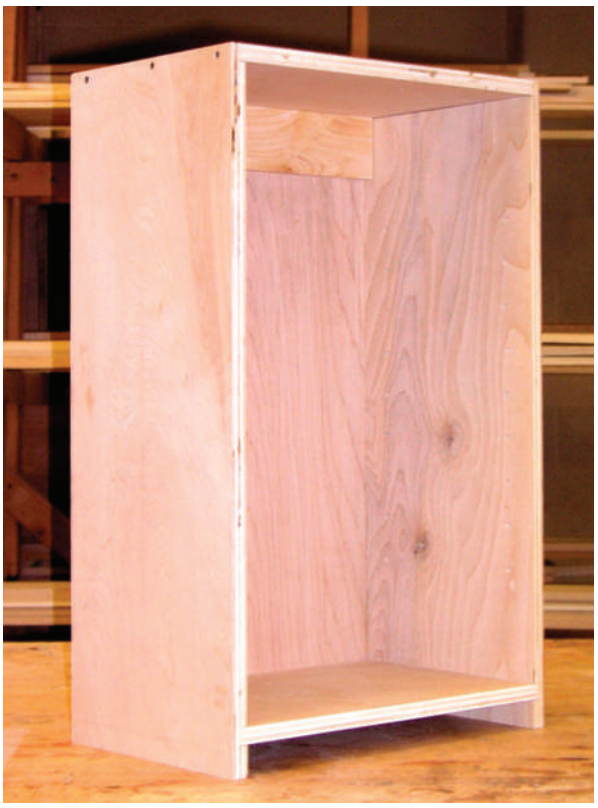

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FIGURE 13-2A Manufactured panel products used to build a wall cabinet.


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FIGURE 13-2B The same wall cabinet with an attached solid wood face frame.

SOLID WOOD CONSTRUCTION

Solid wood construction is the most ancient of the three building methods. As the name implies, solid wood is used throughout the project. The advantages of using solid wood construction are many. Solid wood can be turned on the lathe. It can be carved. Profiles can be milled into it. It is the same throughout, so that if the piece is dented or deeply scratched, more of the same material is revealed. It is beautiful and takes finish well. It is strong and durable. And of the literally thousands of different types of wood, many are suitable for furniture construction.

The primary disadvantage of solid wood construction is that wood is not a static material; it changes in response to seasonal changes in humidity. Therefore, when building, you must allow for this movement. This is why, for example, when attaching a solid wood tabletop, it is attached in such a manner that it can move without damage to itself or the rest of the table. A project that does not take wood movement into account is a project that will not be durable over the long term.

Using solid wood can also be time consuming. A wide panel must be glued up from several narrower boards (see **Figure 13-4**). Each of these pieces must be jointed, ripped, and rejointed. After the panel has been glued and clamped and the glue has cured, the panel must be brought to final thickness, and cut to size.

Additionally, some woods have become or are in the process of becoming scarce. This makes their use expensive, unfeasible, and possibly even unethical from an ecological point of view.



FACTS ABOUT WOOD

White oak, *Quercus alba*, is harvested in the United States and Canada. It is straight-grained, tan in color, and has a fairly coarse texture. It has the distinction of being impervious to water, which means it is a suitable wood to use for exterior projects. For this reason, it was long a chosen wood for making barrels. It is also used for furniture. When quartersawn or riftsawn, white oak displays a very distinct and attractive ray pattern. Quartersawn white oak is the wood most associated with the Craftsman furniture movement. ■


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FIGURE 13-3 Frame-and-panel construction.


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FIGURE 13-4 A solid wood wide panel must be glued up from several narrower boards.

PANEL PRODUCTS

Manufactured panel products are materials such as plywood, particleboard, fiberboard, and melamine. Panel products were discussed in greater detail in Chapter 10. For now, we will just consider panel construction that imitates the look of solid wood, which includes panel products that have been covered, or veneered, with a very thin layer of solid wood (see **Figure 13-5**), although most of the comments apply equally to panel products with other types of faces, such as the paper found in melamine. The panel product we are discussing looks like solid wood but is in fact almost entirely manmade. Many choices of face veneers are available, although the selection is not as wide as that of solid wood.

There are two great advantages of panel products: One is the speed with which projects may be constructed using them. No time is spent gluing up large panels, as must be done with solid wood. The second great advantage is that because such a small amount of actual wood is used, the need to consider wood movement is virtually eliminated. Some of you will no doubt be thinking that plywood is actually all wood, and this is true. However, plywood is made of thin layers (plies) glued up perpendicular to one another, which diminishes wood movement to such a great extent that it is no longer taken into consideration. Panels with cores of particleboard and MDF do not have any grain at all so there is no wood movement at all.

GREEN REMINDERS

Using panel products rather than solid wood uses far less solid lumber and is therefore an attractive option from an ecological viewpoint.


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FIGURE 13-5 Panel products are faced with a very thin veneer.

There are disadvantages to panel construction. One is that the edge of the panel is unattractive and so must be covered somehow, either with veneer tape made specifically for that purpose or by attaching solid wood to the edges. If solid wood of sufficient width is attached, profiles may be milled onto the edge; otherwise they cannot.

Panel products are strong, but not as strong as solid wood in certain situations, such as shelves. The length of panel-product shelves must be limited, or they must be somehow reinforced to strengthen them. The human eye will pick up as little as 1/32″ of sag per foot. Veneer core panels are less likely to sag than either particleboard or MDF core panels, but when designing a cabinet that will have shelves, the builder should always consult a table like the one shown in **Figure 13-6**.

Another disadvantage to using manmade panels is that the face veneer, which gives the illusion of solid wood, is very thin. If dented or scratched, the unattractive substrate may show through. One must also be very careful when sanding panel products. Again, the veneer is so thin that it is relatively easy to sand through it, so care must be taken not to go too far.

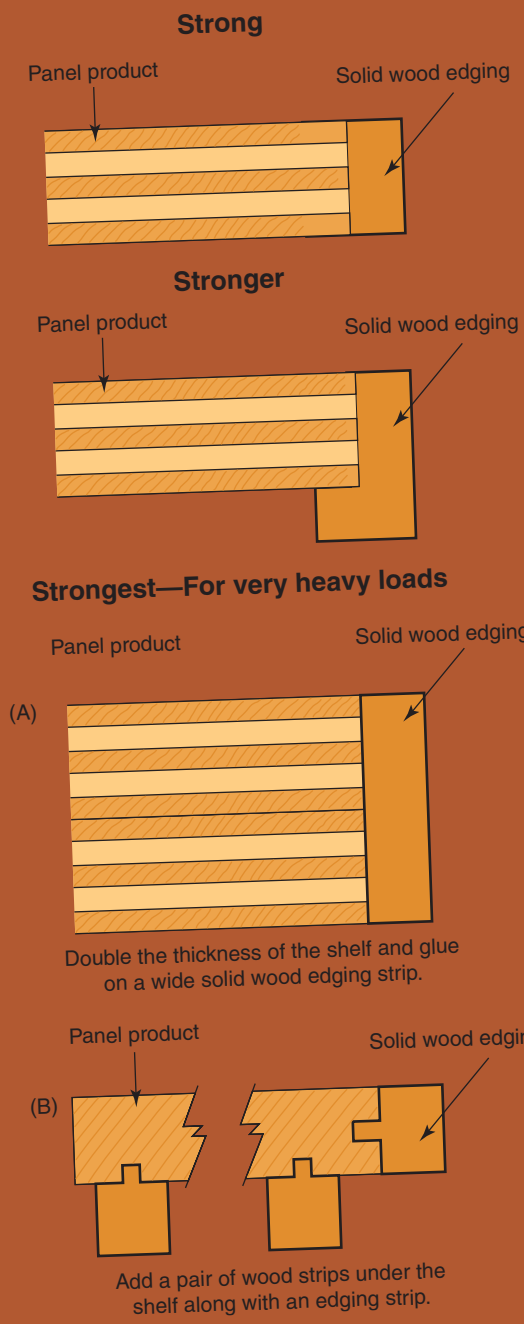
Material	Maximum Span
Plywood, ¾″	32″
MDF, ¾″	28″
Particleboard, ¾″	24″
Softwood, ¾″	36″
Softwood, 1″	48″
Softwood, 1 ½″	63″
Hardwood, ¾″	42″
Hardwood, 1″	48″
Hardwood, 1 ½″	66″

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FIGURE 13-6 The maximum length between supports for a moderate load (20 lb. per foot) on a 10″ wide shelf.

WOODWORKING TIP:

Shelves constructed of plywood, particleboard, or MDF that are longer than 32″ should be reinforced to prevent sagging under a load. Four methods of reinforcing shelves are illustrated in **Figure 13-7**.



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FIGURE 13-7 Methods of reinforcing panel-product shelves.

WOODWORKING TIP:

If you are cutting panel products on the table saw, the good side should be face up to minimize splintering on the face side of the panel. If you are using a circular saw to cut panel products, the good face of the panel should be down, for the same reason.

FRAME-AND-PANEL CONSTRUCTION

Frame-and-panel construction was developed to deal with the wood movement problem of solid wood. Basically, panels are created using solid wood as a frame that encloses a panel, which may be either solid wood or a manufactured panel product (see **Figure 13-8**).

As with the other two methods, there are both advantages and disadvantages to panel construction, although it could certainly be argued that this type of construction can be utilized to maximize the advantages of each of the other two. If panel products are used for the panel in frame-and-panel construction, these pieces can be quickly made. The solid wood frame allows for profiles to be milled on the edges; **Figure 13-9** shows some examples. The unattractive edge of the panel product is hidden in the solid wood frame.

A more interesting look can be achieved with frame-and-panel construction, since by its nature it shows depth, which neither of the other two methods do. This can add great visual interest to a piece. This is especially true if the panel is made of solid wood, since then it can have a profile milled into it, a shown in **Figure 13-10**.

WOODWORKING TIP:

When making a frame for frame-and-panel construction, an easy way to mill centered grooves in a piece of solid wood is to run the piece through the table saw on edge and then flip it end for end and run it again. The panel can be tested for fit, and the fence may be adjusted as necessary. It is a very good idea to use a scrap piece of stock the same thickness as your finished piece to check this setup.

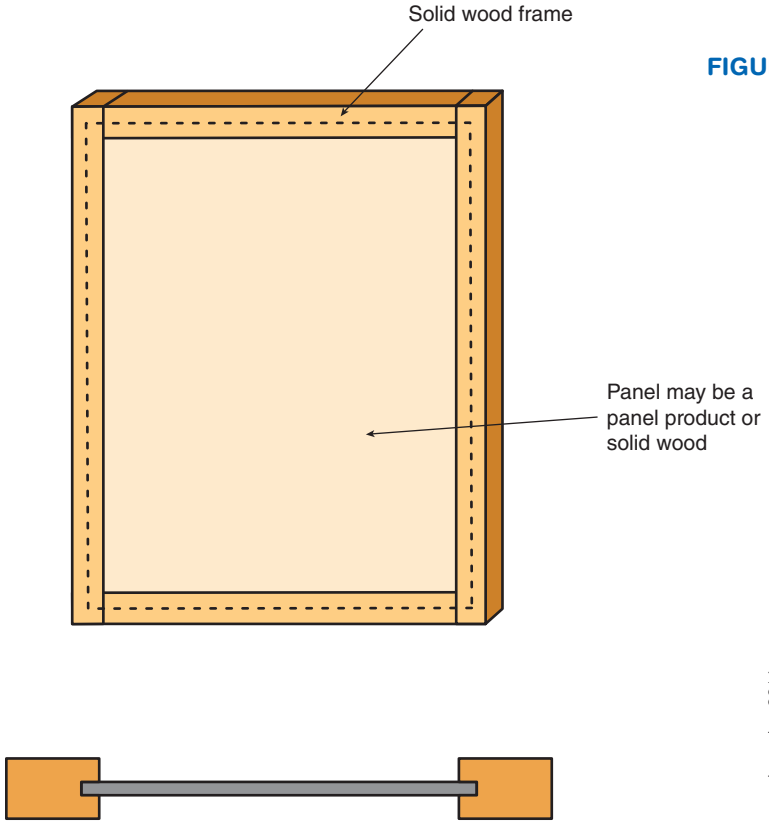
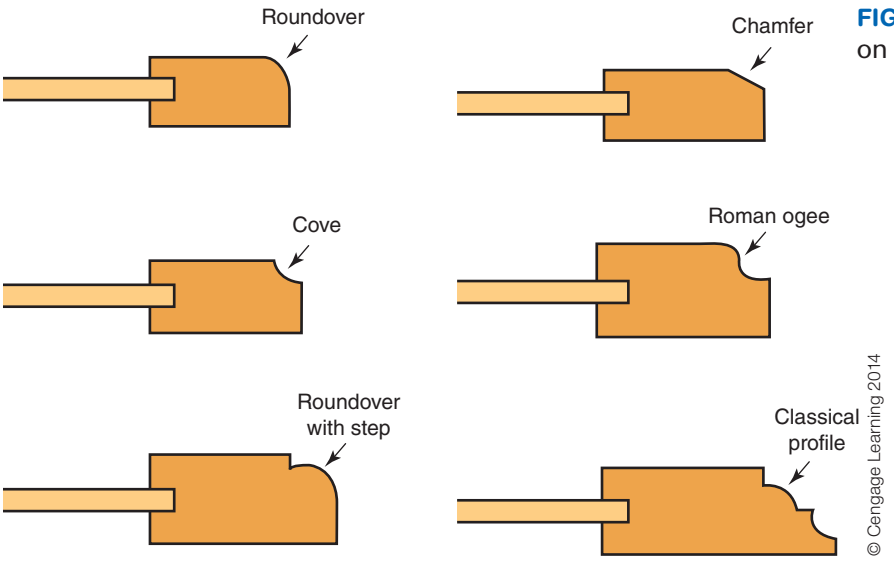


FIGURE 13-8 A solid wood frame encloses a panel.

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FIGURE 13-9 A profile can be milled on a solid wood frame.

Frame-and-panel construction is lighter in weight than either solid wood construction or manufactured panel construction; but it is relatively laborious, which is a real disadvantage, because it is expensive to produce due to the labor involved.



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FIGURE 13-10 Frame and panel construction adds visual interest.



Summary

Solid wood, panel products, and frame-and-panel construction are the three basic methods of cabinet and furniture construction. Each has its own advantages and disadvantages, which must be carefully weighed in deciding which method to use. Any of the three can be used to create attractive pieces of furniture, provided the attributes of each are taken into consideration.



Key Term

frame-and-panel construction



Check Your Knowledge

1. What are the three basic methods of cabinet construction?
2. If you want to quickly assemble a project, which method is fastest?
3. What is the problem that must be addressed with solid wood construction?
4. What are two advantages to solid wood construction?
5. What are two drawbacks to manufactured panel product construction?
6. Which construction method allows the builder to incorporate a feeling of depth?
7. How can manufactured panel product construction be modified to allow for profiled edges?

BUILD IT!

Step Stool



A

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Assembly list – step stool

Part	Dimensions (thickness × width × length)	Quantity
1. Long leg	$^3/_4$" × 8" × 42"	1
2. Short leg	$^3/_4$" × 8" × 12"	1
3. Sides	$^3/_4$" × 3" × 15"	2
4. Top	$^3/_4$" × 10" × 15"	1

B

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Figure A shows a completed step stool.

TOOLS REQUIRED

- Measuring tool
- Marking tool
- Table saw
- Miter saw
- Drill with 3/4", 3/8", and 1/8" bits
- Drill press and 3/8" plug cutter
- Jigsaw or band saw
- Router and 1/4" round-over bit
- Sander

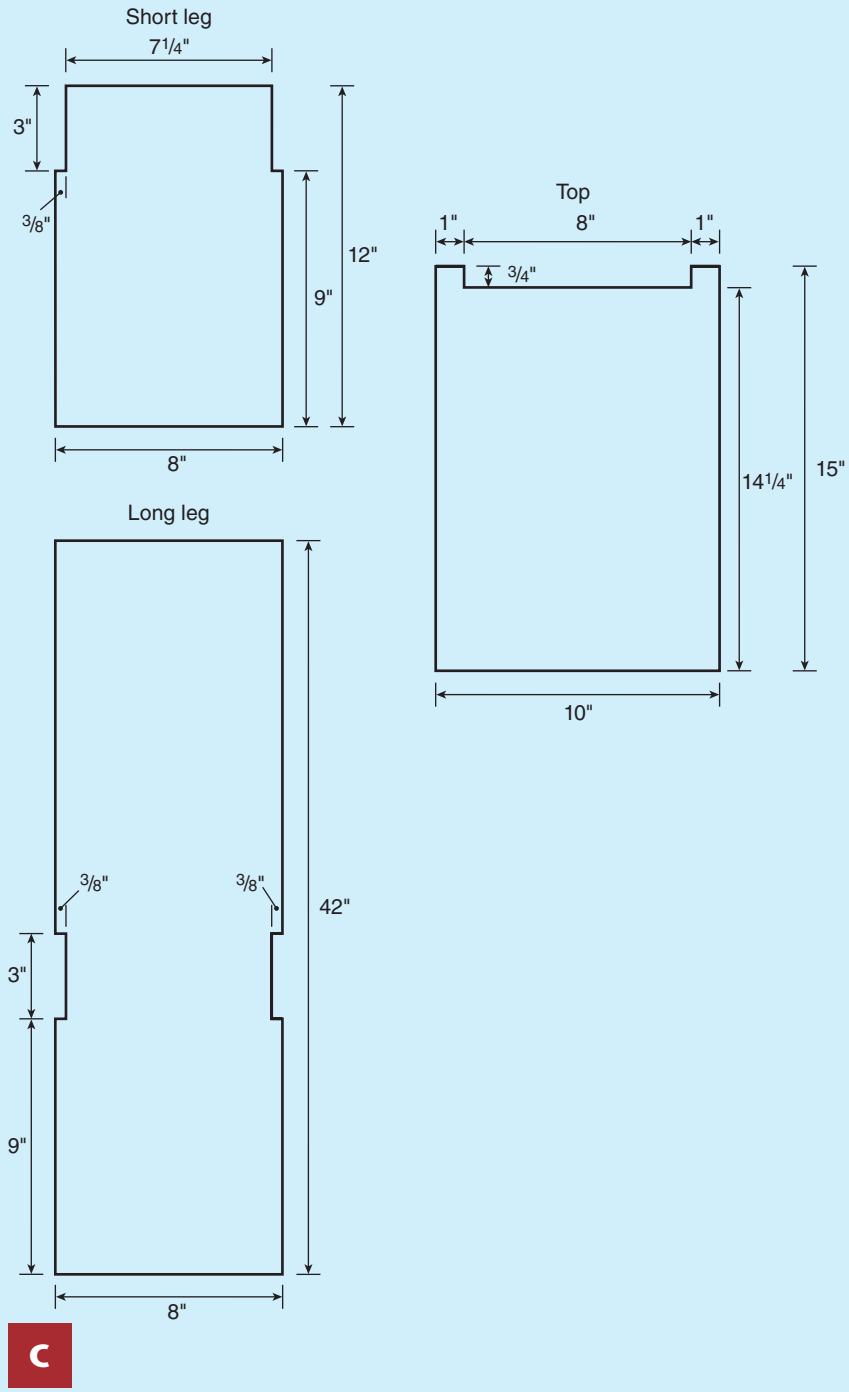
MATERIALS REQUIRED

- 3/4" × 8" × 60" hardwood stock
- 3/4" × 3" × 32" thick hardwood stock
- 3/4" × 10" × 16" hardwood stock
- 1 1/4" screws

STEPS

1. Review the assembly list given in **Figure B** and cut all pieces to size.

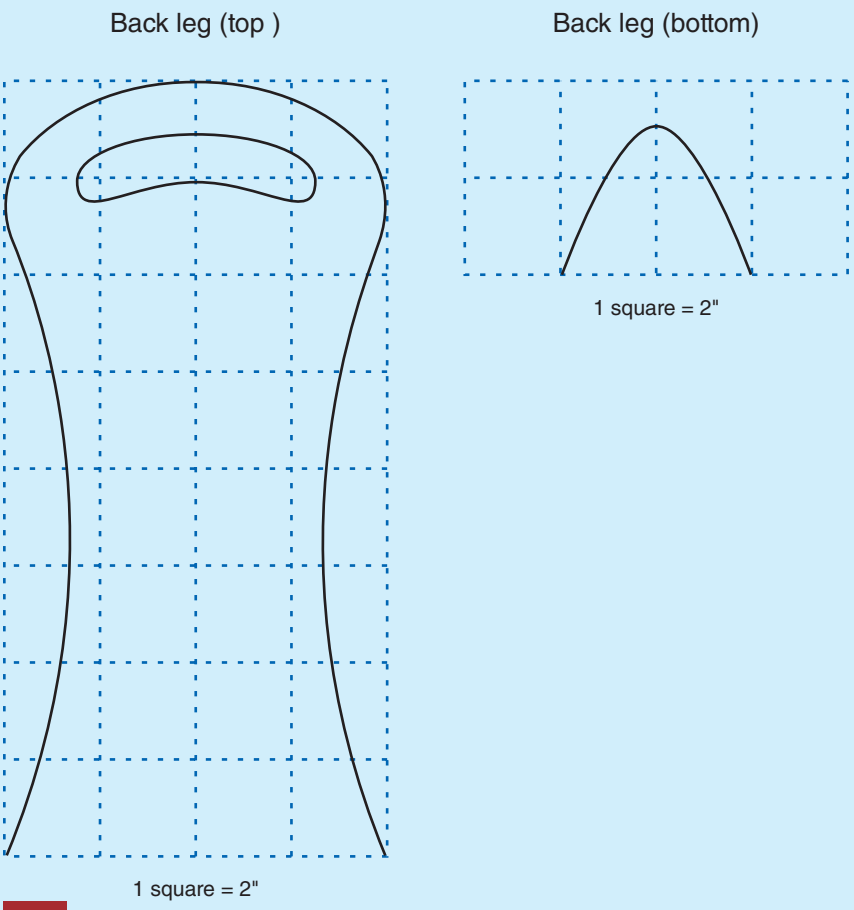
2. Cut notches in the legs and top as indicated in the layout in **Figure C**.



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D

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3. Take the back leg and lay out a grid of 2″ squares 16″ down from the top and 4″ up from the bottom. Lay out the cutout for the handle, the bottom cut, and the curve on the top and sides as shown in **Figure D**.
4. Drill a hole through the handle cutout with a 3/4″ bit; use a jigsaw to create the handle hole. Cut the curve on the bottom, top, and sides with a jigsaw or on the band saw.
5. Copy the bottom cut from the back leg to the front one, as shown in **Figure E**, and cut it out.

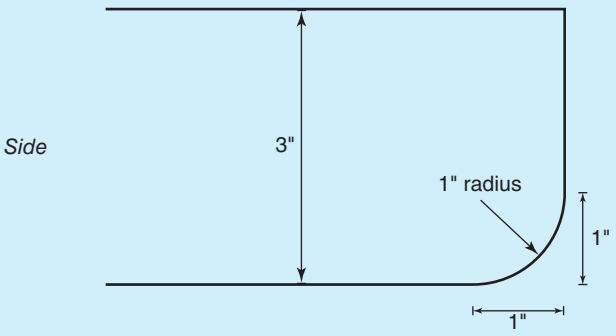
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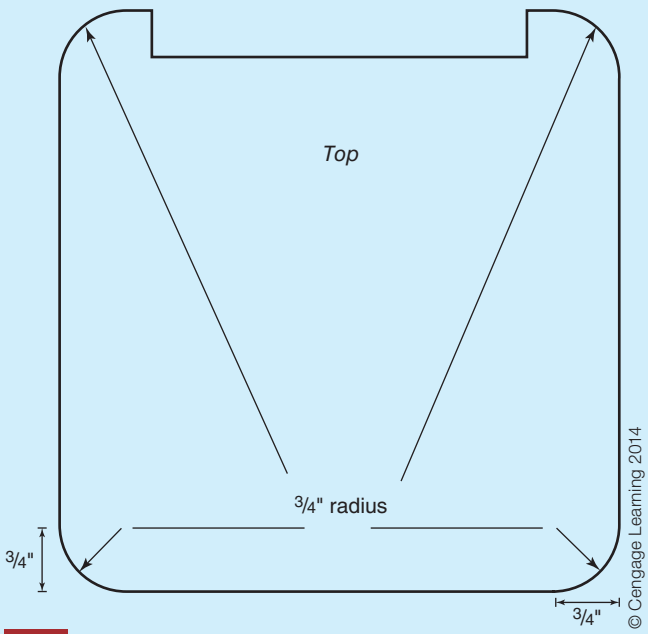
6. Use a 1/4" round-over bit in a router to round over both sides of the handle cutout (see **Figure F**).
7. Lay out the rounded edges on the four corners of the top and one corner of the two sides, as shown in **Figure G**.
8. Cut the rounded edges you just laid out on the top and sides.



F

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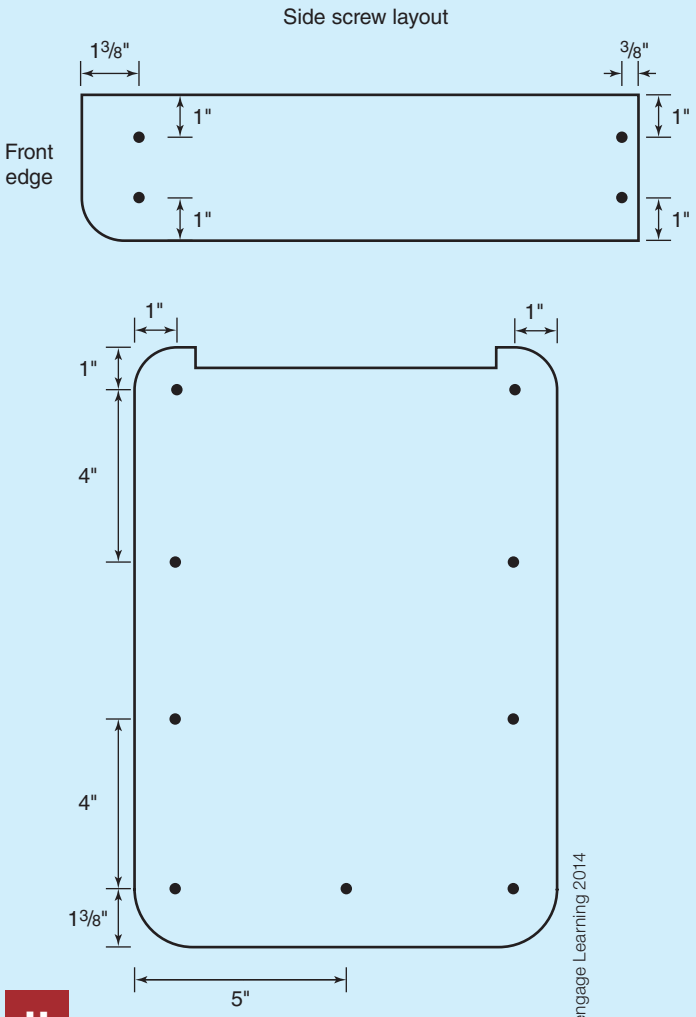




G

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BUILD IT!



H

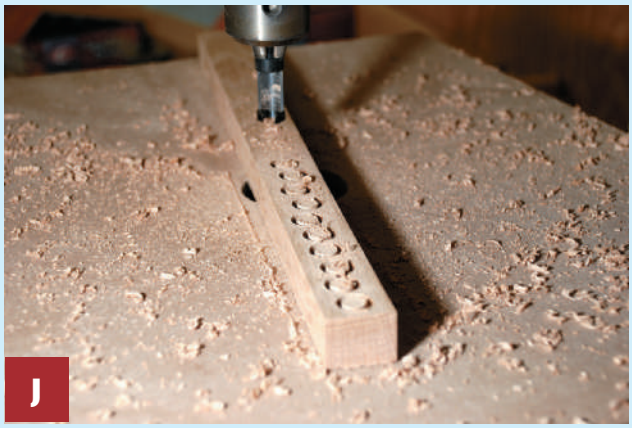


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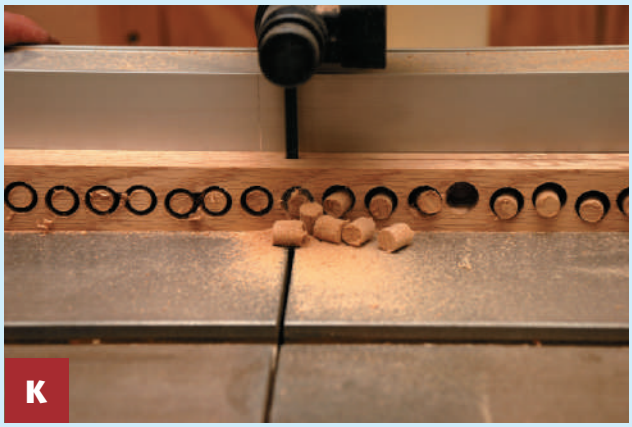
9. Use the router to machine a 1/4" roundover around the top edge of the top and along the front end and bottom edge of the sides. Do not round over the notch cut in the top.
10. Lay out the sides, back leg, and top for screws, as shown in **Figure H**.
11. Drill 3/8" holes 3/8" deep at each screw location, then drill the rest of the way through the piece with an1/8" bit.
12. Assemble the stool and drill 1/8" pilot holes. Then glue it and screw the stool together, as shown in **Figure I**.

BUILD IT!

13. Use the drill press and 3/8" plug cutter to make plugs and cut them free on the bandsaw, as shown in **Figure J** and **Figure K**.
14. Glue the plugs in place, as shown in **Figure L**. Be careful that the grain of the plugs is parallel to the grain of the piece so that the plugs will be less noticeable.
15. Plane and sand the plugs flush.
16. Sand the stool, easing any sharp edges.
17. Finish as desired.


J

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K

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L

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PROJECT CHALLENGE

Hanging Bookcase



A

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Figure A shows a completed hanging bookcase.

STEPS

1. Referring to the assembly list given in **Figure B**, cut the plywood pieces to size.

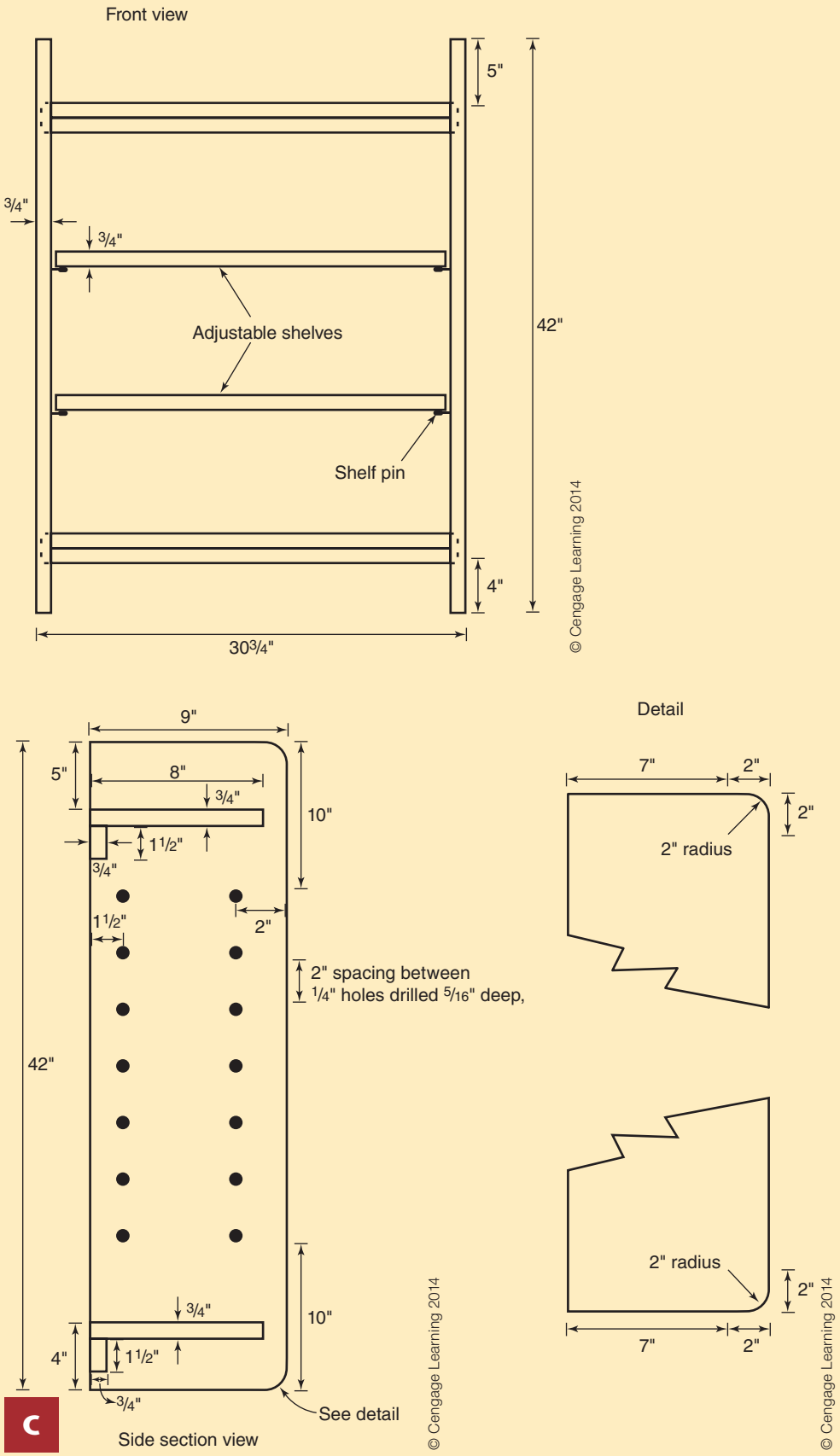
Assembly list-hanging bookcase

Part	Dimensions (thickness × width × length)	Quantity
1. Sides	$^3/_4$" × 9" × 42" plywood	2
2. Top shelf	$^3/_4$" × 8" × 30" plywood	1
3. Bottom shelf	$^3/_4$" × 8" × 30" plywood	1
4. Adjustable shelves	$^3/_4$" × 8" × 29" plywood	2
5. Supports	$^3/_4$" × $1^1/_2$" × 30" solid stock	2
6. Shelf pins		8
7. Iron-on veneer to match plywood		17'
8. Biscuits	20	12
9. Finish nails	8d	8

B

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2. Review the plan given in **Figure C**.




D

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E

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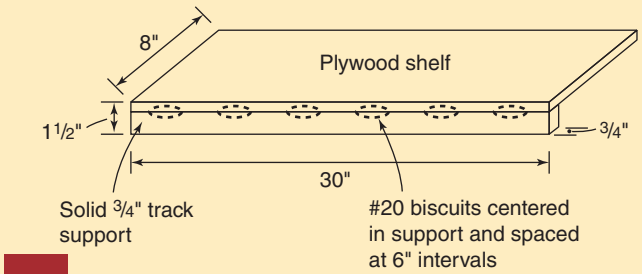


F

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3. Use a router with a straight bit and guide to machine the stopped dados for the top and bottom shelves, as shown in **Figure D**. They are 3/8" deep.
4. Square up the stopped end of each dado with a chisel, as shown in **Figure E**.
5. Make the 3/8" deep recesses in the back of each side piece for the support pieces, as shown in **Figure F**. Lay out the notches and score them with a knife. Most of the waste can be removed with a router equipped with a straight bit. Clean out the rest with a chisel.
6. Use the drill press and a 1/4" flat-bottomed bit to drill a series of 5/16"-deep holes on the inside of each side for the adjustable shelves. These holes will hold the pins that support the shelves.
7. Lay out and cut the curve at the top and bottom of each side.

8. Use #20 biscuits spaced every 6 inches to attach the back support to the top and bottom shelves, as shown in **Figure G**. Glue and clamp supports to shelves.
9. Apply edge banding to the sides and fronts of the four shelves with a household iron or a veneering iron. Roll to ensure adhesion, as shown in **Figure H**.
10. Trim the edge banding flush with the plywood and sand the edges lightly by hand.
11. Glue and clamp together the sides and top and bottom shelves with attached supports. Check to make sure the assembly is square by checking diagonal measurements. They should be the same (see **Figure I**).
12. Drill pilot holes, and then drive two 8d finish nails through the back of each support into the side pieces, as shown in **Figure J**.
13. Sand and finish as desired.
14. The shelf is attached to a wall through the support pieces.

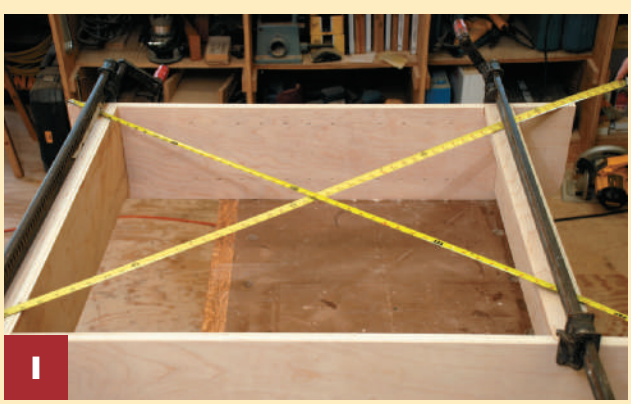


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14

Stock Preparation

You'll Learn

After studying the chapter, the student should be able to:

- Describe the sequence of operations performed in creating a flat, square work piece
- Understand the methods used in forming a flat, square workpiece
- Explain the terms *flattening, squaring, ripping,* and *crosscutting*
- Describe the importance of following a set pattern in creating a flat, square workpiece
- Understand how to make this process as efficient as possible

INTRODUCTION

For a piece of furniture or a cabinet to be a success, all its component parts must fit together well. To achieve this goal, the building blocks we start with must be milled flat and square. If they are not, the joinery that is created will not fit well and the result will be a product that does not meet your expectations. Therefore, at the beginning of the process, we must make sure that the components that make up the final product are perfectly flat and square. To do this, a set sequence of steps must be followed.

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SELECTING STOCK

First we select the stock we will use. It must be somewhat longer and wider than our finished components will be. It is helpful to do a **rough layout** of the components needed on the stock. A rough layout marks out the pieces larger than they will be once they are machined (see **Figure 14-1**).

Next, the stock is cut into workable lengths. It is neither necessary nor efficient to try to run a 10-foot piece over the jointer unless you will need pieces that are 10 feet long.

WOODWORKING TIP:

When doing a rough layout on stock before cutting the board to a rough length, chalk can be a helpful marking tool. Should you change your mind about the layout, chalk marks are much easier to remove than pencil marks.

Flattening a Face

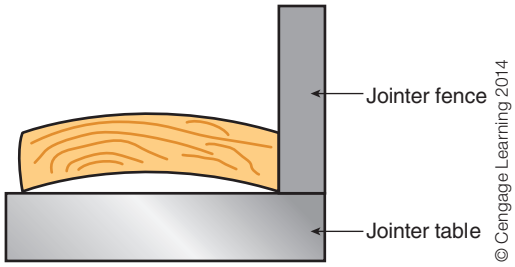
The second step in the process is to flatten one face of the stock. This will be an essential step if you are working with roughsawn lumber. If your stock is **S2S** (surfaced two sides), this step may not be necessary, assuming the piece you are working with is flat. You can determine whether or not it is flat by placing it on a known flat surface, such as the table saw, and sighting along it. If it sits completely flat on a known flat surface, this step can be eliminated.

Material that is not flat is flattened on the jointer. If there is a concave face, material is run with the concave face down, as shown in **Figure 14-2**. A series of passes are made until the board is flat, or at least until flat spots are established on either side of the face, as shown in **Figure 14-3**. For your safety, it is important that you use a push block when flattening stock (see **Figure 14-4**).



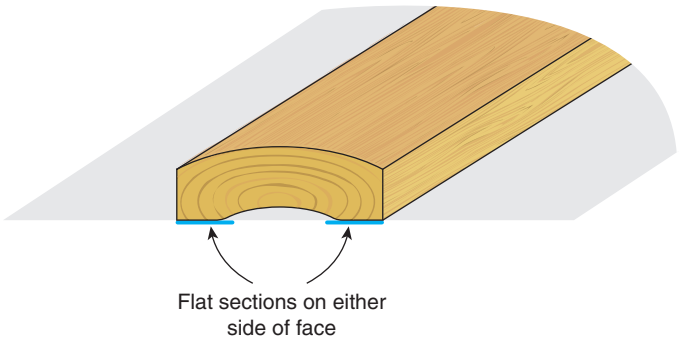
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FIGURE 14-1 Rough layout on stock.



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FIGURE 14-2 Material is surfaced on the jointer with the concave face down.



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FIGURE 14-3 Flat spots have been established on both sides of the face.



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FIGURE 14-4 It is critical to use a push block when surfacing material.

The maximum width piece that you can flatten is determined by the size of your jointer, because the jointer size is determined by the length of its knives; this will be the maximum width of stock you can surface. If you are starting out with stock that is wider than the jointer can surface, it will have to be reduced in width. The safest way to do this with stock that has not yet been milled flat and square is on the band saw or with a circular saw.

CAUTION

NEVER attempt to rip warped stock on the table saw! It is an invitation for kickback.

CAUTION

A push block is a very important safety device to use when flattening stock on the jointer, and it is easy to make one, as seen in Figure 14-5.

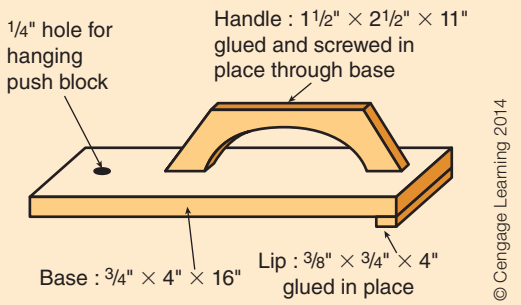


FIGURE 14-5 Push block diagram.

Planing to Thickness

The next step is to plane the material to its desired final thickness on the planer. Since the planer cuts from above, the work is fed into it with the face you flattened on the jointer down on the planer table (see **Figure 14-6**). The job of the planer is to bring material to the desired thickness while maintaining the parallelism of the two faces. As you take successive passes to bring the material to its final thickness, it is a good practice to alternate faces and to remove an even amount of material from each side of the board. You may be wondering why we did not just go to the planer in the first place. The reason for this is that unless we first have one flat face, we will end up with a board that is planed, but not flat, and this will cause problems later on.



FIGURE 14-6 Planing to thickness.

GREEN REMINDERS

A hallmark of green woodworking is to use material as efficiently and with as little waste as possible. Good planning and careful layout promote this practice.

Squaring an Edge

The next step takes us back to the jointer. We need to create an edge that is square to the face of the board. Sight along the edge of the board, and if it has a crown, run it with the crown up (see **Figure 14-7**). If possible, you also want to joint with the grain, to avoid tear-out. Before running your stock, use your square to make sure that the jointer fence is square to the table, because otherwise you will not get a square edge. It is a good practice to mark the edge you square. See **Figure 14-8** and **Figure 14-9**.

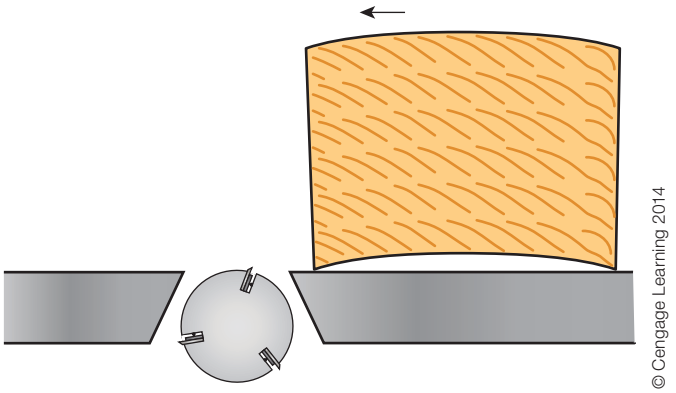


FIGURE 14-7 Joint an edge with the crown up.



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FIGURE 14-8 Squaring an edge.



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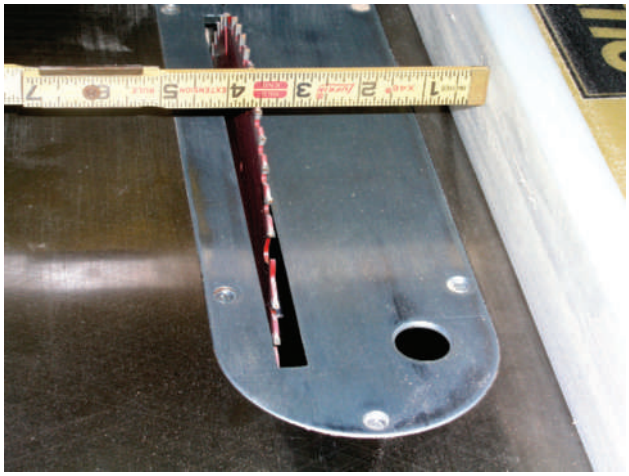
FIGURE 14-9 It is a good practice to mark the edge you joint.

Ripping to Width

Now that the board is flat, milled to desired thickness, and has a square edge, it is taken to the table saw. Set the rip fence to the final width of your workpiece plus enough to allow you to go back to the jointer and make a clean-up pass on the side of the board that passed the saw blade, removing any burns or saw marks left on it. Check the distance from the fence to the blade, as shown in **Figure 14-10**, remembering that the scale on the saw may not be totally accurate.

CAUTION

Always make sure the table saw's rip fence is locked before beginning a rip cut.



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FIGURE 14-10 Check the distance from the fence to the blade.

Place the edge that was jointed square against the rip fence and make the rip cut, using a push stick if necessary. The stock should be fully supported by the fence throughout the cut, as shown in **Figure 14-11**.

Now go back to the jointer and make a clean-up pass on the edge that just passed by the saw blade, bringing your piece to its finished width.

Crosscutting to Length

The final step is to crosscut the workpiece to finished length. First cut one end square; then, measuring from the end you just squared, measure and mark the length desired. Now your final cut can be made (see **Figure 14-12**). This cut can be made on the radial arm saw, the table saw, or the miter saw. It is important that whichever saw you have chosen to use is cutting squarely, and that it be adjusted if it is not.



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FIGURE 14-11 Rip to width.

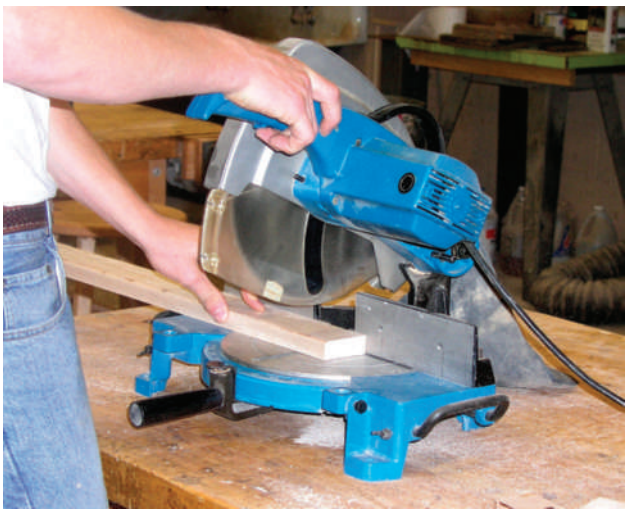

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FIGURE 14-12 Crosscut to length.

A simple **test cut** and check will determine this. A test cut is a cut made to check the setup of a machine. In this case, a test cut would be made on a piece of scrap and then checked with a true square.



FACTS ABOUT WOOD

Hickory, *Carya illinoensis*, is a nut-bearing tree of relatively large size. Found primarily in the eastern United States, it is a ring-porous hardwood like oak and ash. It normally has a straight grain, so it is often used in handles for striking tools, such as hammers, hatchets, and axes. It has very good bending properties and is also used for sporting equipment and bentwood furniture. Hickory wood chips are often using in smoking meat. ■

Working Efficiently

Most projects consist of multiple pieces, and often several pieces that are exactly the same are required. It would be laborious and time consuming to go through the process, from flattening to cutting to final length, one piece at a time. It would be inefficient, and it could lead to errors. To save time and energy and to reduce the chance of error, it is advisable to gang as much of this work together as possible. So when the first rough layout is done, lay out all the necessary pieces. If the stock needs to be flattened, do all the flattening at once before moving on to the planer to bring the material to final thickness. As you plane, send through all your material at one setting prior to raising the planer table to take the next pass. This will ensure that your final pieces are all exactly the same thickness. Then take all your stock to the jointer and joint one edge square on each piece, remembering to mark the jointed edge as you go. Next is the ripping step. Chances are that a number of pieces will need to be cut to the same width. For example, multiple pieces that are two inches wide may be required. Set up for this rip, and cut all the pieces that need to be that width. When you go back to the jointer to make your clean-up pass, count how many passes it takes to get to the finished width on the first piece, and then make the same number of passes on all subsequent pieces of the same width.

When the crosscutting to length is done, square all the ends first, stacking them as you cut them so that all the square ends are together. Duplicate lengths may very well be needed. In this case, rather than measuring and cutting each piece to the same length, possibly making a mistake as you go, carefully measure and mark one piece, and then set up a stop block on the fence of the saw so that as many pieces as needed can be cut to the same length (see **Figure 14-13**).

It is important to label pieces as they are produced, keeping like pieces together. Good organization will make the task at hand, and those to come, easier. It is also good practice to mill a bit of additional material, which can be used for testing setups in the joinery phase of the project or to replace pieces on which mistakes were made.


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FIGURE 14-13 Use a stop block to cut multiple pieces to the same length.



Summary

A successful project is built upon a careful beginning. This requires a measure of patience and precision, as well as a willingness to do the work involved in a careful way. Each component piece that makes up the final project must start out flat, square, and cut to the proper length. This is achieved by following a set procedure, which involves flattening on the jointer, planing to thickness, jointing an edge square, ripping and jointing to final width, and finally squaring and cutting to final length. This process can be made efficient by thinking ahead and cutting all like pieces at the same time.



Key Terms

crosscutting
flattening
planing
squaring
ripping
rough layout
S2S
test cut



Check Your Knowledge

1. Why is it important that individual pieces of a given project be carefully prepared?
2. List the proper sequence of operations involved in preparing these pieces.
3. When flattening a cupped piece of stock, what machine is used? Should the cup face up or down?
4. When jointing the edge of a piece square to its face, should the crown be up or down?
5. What are two machines that could be used to cut a piece of stock to final length?
6. What step should be taken prior to measuring and cutting stock to its final length?
7. Why is it a good idea to rip all pieces that need to be a certain width at the same time?
8. How can a person easily cut numerous pieces to exactly the same length without measuring and marking each one?
9. What machine is used to bring stock to its final thickness?
10. Why is it a good idea to mill a little extra material?

BUILD IT!

Cutting Board



A

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Figure A shows a completed cutting board.

TOOLS REQUIRED

- Measuring tool
- Marking tool
- Compass
- Chisel
- Table saw
- Miter saw
- Planer
- Drill press and 1 1/4" bit
- Router and 1/4" round-over bit
- Sander

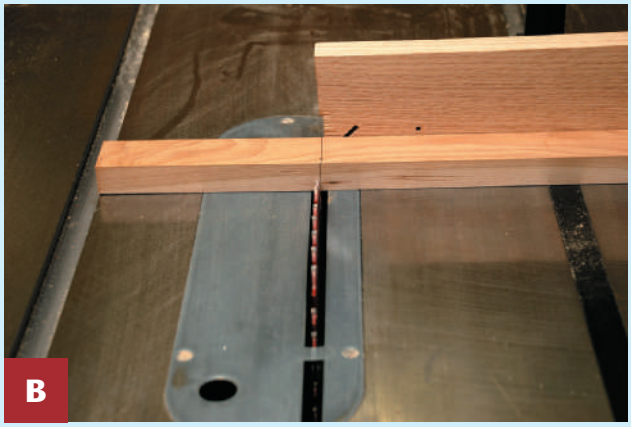
MATERIALS REQUIRED

- Miscellaneous scrap hard wood pieces 1 1/2" wide and 17" long. Thicknesses may vary. You will need enough pieces to make a board approximately 13" wide. Close-grained hardwoods, such as maple, cherry, and beech, work best.

STEPS

1. Joint and mark one edge of each piece.
2. Rip pieces to a width of 1 3/8". Place the marked jointed edge against the fence and use a push stick when ripping these narrow pieces.
3. Square one end of each piece.

4. Lay out for a 16 3/4" cut on one piece. Place the stock against the miter gauge on the table saw and move it until it will be cut right at 16 3/4" (see **Figure B**).
5. Clamp a stop block on the miter gauge fence, as shown in **Figure C**, so that when the marked piece is butted to it, the cut will be made at 16 3/4".
6. Cut all the pieces to length, butting the squared end against the stop.
7. Arrange the pieces in a pleasing pattern so that they are standing as shown in **Figure D**.


B

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C

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E

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F

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G

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8. Spread glue on one face of each piece except the first one, as shown in **Figure E**.
9. Clamp up as shown in **Figure F**, using two clamps on the bottom and one on the top. Do your best to keep all the pieces in line and level with each other.
10. Before the glue is completely dry, skim off the excess with a chisel, as shown in **Figure G**. Do both sides of the glue-up.
11. When the glue has thoroughly cured, remove the assembly from the clamps and clean up any glue squeeze-out you may have missed.
12. Send the board you have created through the planer until both sides are smooth, taking small cuts.
13. Joint one edge of the assembly, as shown in **Figure H**.
14. On the table saw, rip the board to just over a foot, placing the side you just jointed against the fence.


H

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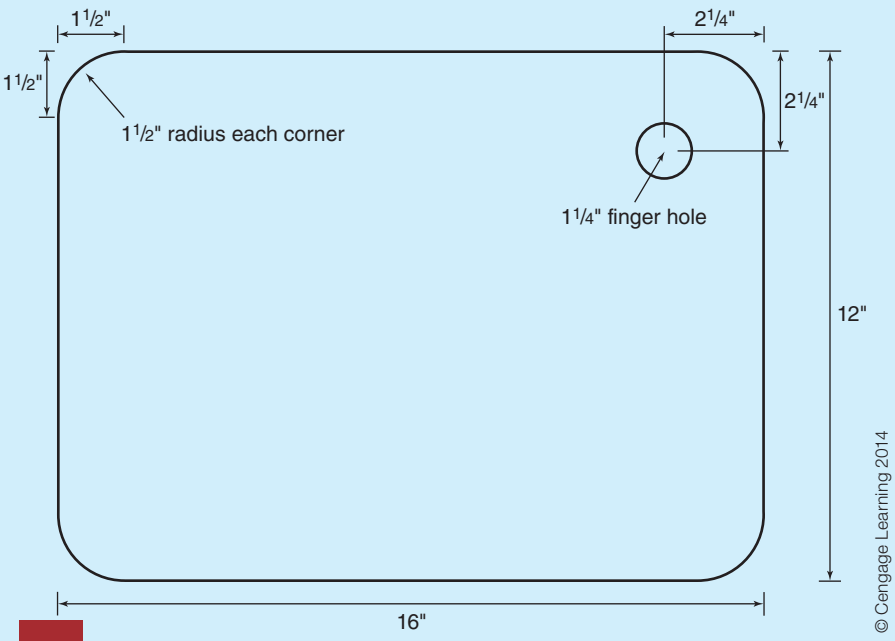
BUILD IT!

15. Make as many jointer passes as needed to bring the board to a finished width of 12". The side that was ripped should be down on the jointer table.
16. Square one end of the board on the miter saw or table saw using the miter gauge with an extension fence attached to it, as shown in **Figure I**.
17. Measure 16" from the squared edge and make a second cut.
18. Lay out the curves at the corners and lay out the position of the finger hole as shown in the diagram in **Figure J**.
19. Drill a 1 1/4" hole in the position indicated, as shown in **Figure K**.
20. Cut the curves on the band saw or with a jigsaw and sand smooth.
21. Use a router with a 1/4" round-over bit to round over both sides of the board and the finger hole.
22. Sand and finish with a nontoxic finish, such as vegetable or mineral oil.



I

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J

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K

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BUILD IT!

PROJECT CHALLENGE

Shaker Plant Stand



A

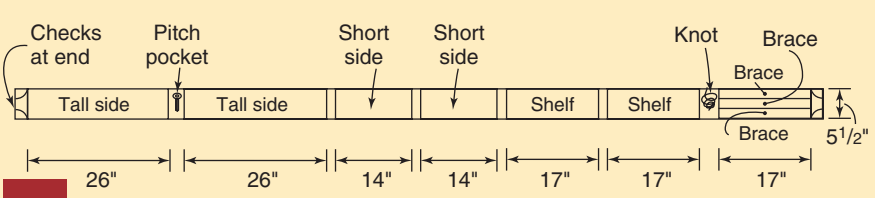
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Assembly list - shaker plant stand

Part	Dimensions (thickness × width × length)	Quantity
1. Tall side section	$^3/_4$" × 5" × 25"	2
2. Short side section	$^3/_4$" × 5" × 12$^1/_2$"	2
3. Shelf	$^3/_4$" × 5" × 16"	2
4. Brace	$^3/_4$" × 1$^5/_8$" × 16"	3
5. 6d finish nails		

B

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Figure A shows a completed Shaker plant stand.

STEPS

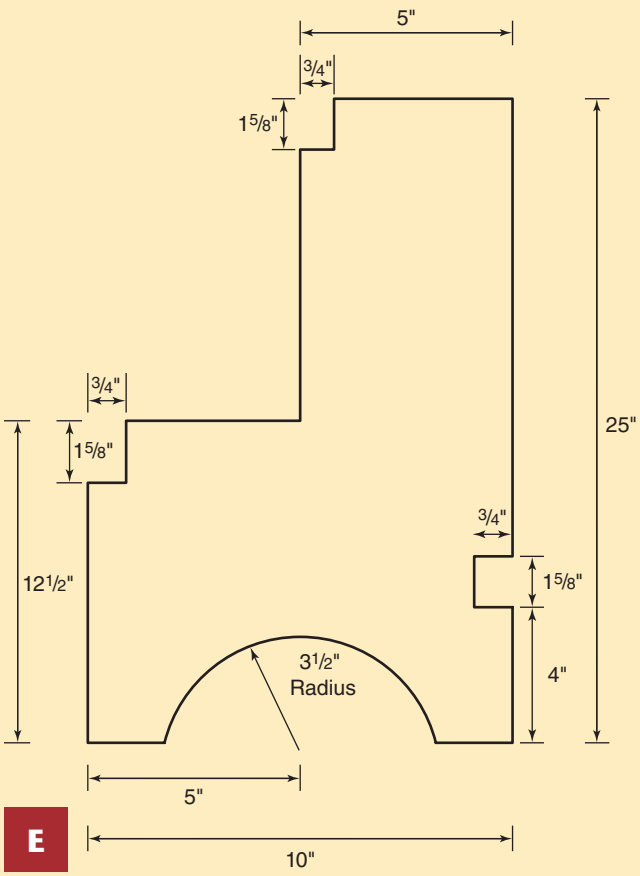
1. Consulting the assembly list given in **Figure B**, do a rough layout on 1" × 6" pine. Pieces should be oversized. **Figure C** shows an example of how this might be done.
2. Make crosscuts to divide the boards you laid out into rough lengths.
3. At the jointer, check each piece for a crown; joint it with the crown up and with the grain running back toward you. Mark each jointed edge.
4. Go to the table saw with your jointed pieces. Set the rip fence for just over 5" and rip both tall side sections, both short side sections, and both shelves, running the jointed edge against the fence.
5. Set the fence so the distance between it and the blade is just over 1 5/8".

6. Place the jointed edge of the board marked for the braces against the rip fence; make one rip cut, and set the piece you just cut aside.
7. Take the remainder of this piece back to the jointer and make a pass with the sawn side down on the table. Mark the edge you just jointed.
8. Go back to the table saw with this piece and make a second rip cut with the fence unmoved from your last rip cut.
9. Repeat the process for the third brace.
10. Gather up all your ripped pieces and go back to the jointer.
11. Take one of the 5" pieces and joint the sawn edge until it is exactly 5". Count the number of passes it takes. Then take the same number of passes on each of the other 5" pieces, always with the sawn edge down. Remember that the edge that was already jointed is marked, so be sure to work on the opposite edge.
12. Use the same process outlined in the previous step to bring all of the braces to the desired 1 5/8" width.
13. Square one end of each piece and then cut all pieces to final length.
14. Glue and clamp the short side pieces to the long side pieces, keeping their bottom edges flush, as shown in **Figure D**.
15. Lay out the notches and cut-out in each side as diagrammed in **Figure E**.



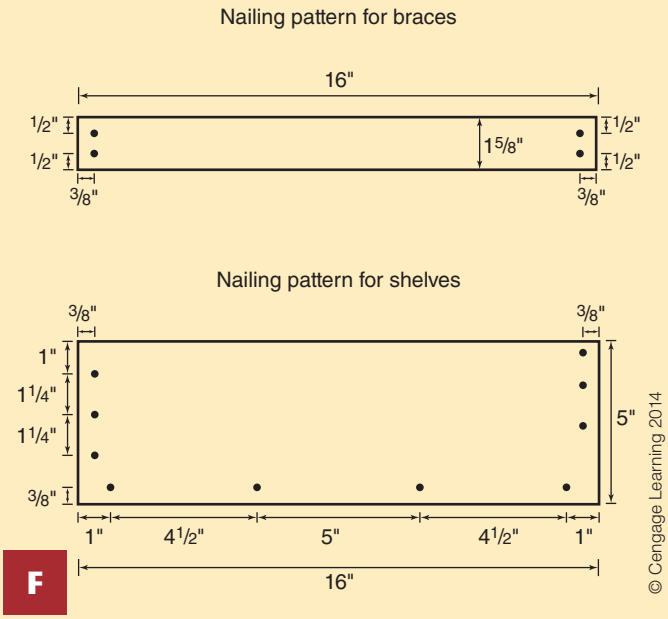
D

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E

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F

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16. Use a jigsaw to cut out the notches and cut-out in each side.
17. Sand all the pieces.
18. Assemble with glue and 6d finish nails, nailing as shown in **Figure F**. Set the nails as shown in **Figure G**.
19. Putty the nail holes if desired, as shown in **Figure H**.
20. Give the piece a final sanding, rounding over the sharp edges slightly.
21. Either prime and paint, finish with a clear finish, or stain with the stain of your choice, and then follow with a clear finish once the stain is dry.



G

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H

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15

Case Joints

You'll Learn

After studying the chapter, the student should be able to:

- Define a case joint
- List different types of case joints
- Discuss the advantages and disadvantages of various case joints
- Describe methods of constructing different case joints

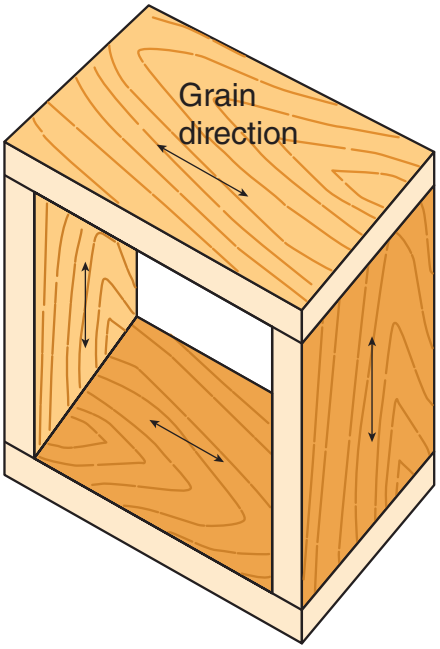
INTRODUCTION

A joint used to build boxes is a **case joint**. Wood is joined together end to end across its width, joining end grain to face grain (see **Figure 15-1**). Notice that the grain is all running in the same direction, since the box pieces are joined across their width. This is visually attractive as well as structurally important when working with solid wood, since expansion and contraction happen across the grain. If one of these pieces were turned 90 degrees, they would not all expand and contract in the same direction, and the integrity of the joint would be compromised.

A great deal of furniture and all cabinetry is comprised of boxes of various shapes and sizes. This is called **casework**, and any enclosed structure built using case joints is considered casework.

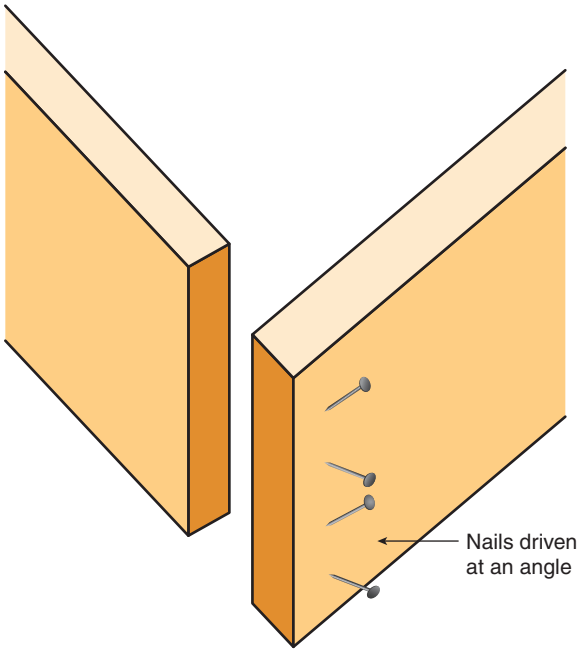
The strength of case joints comes from two potential sources. One is the mechanical interlocking of

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FIGURE 15-1 Boards are joined end to end to form a box, or case. The face grain of one board is connected to the end grain of the next board.



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FIGURE 15-2 Driving nails at a slight angle increases their holding power.

pieces and glue; the other is fasteners. Strength is usually not a big issue with case joinery, as case furniture typically stands unmoving, supporting itself and whatever is stored inside. In large cases, racking stress can be an issue, but interior dividers, backs, and face frames add the necessary stiffness to offset **racking loads**, which are those loads that would move a case or box out of square.

We will examine six different types of case joints in this chapter. They are the *butt, rabbet, dado-and-rabbet, miter, box,* and *dovetail joints.*

BUTT JOINT

The **butted case joint** is the simplest and most basic of all case joints. It is called a *butt joint* because one board is simply butted against another. Because end grain is being joined to face grain, however, fasteners or reinforcement of some kind is required. A glue joint that joins end grain to face grain is not a good glue joint. Therefore, it must be reinforced. Fasteners such as nails or screws can be used. If nails are used, they should be driven at a slight angle, as shown in **Figure 15-2**, to give greater strength to the joint.

Screws used as fasteners are superior to nails. They offer much greater holding ability, and they have the advantage of being easy to remove should the case ever need to be taken apart. Screws may be used in a manner similar to nails, where they are driven through the face of one piece into the end of another piece, as shown in **Figure 15-3**. Alternatively, a technique known as pocket hole joinery may be used to assemble the corner. Pocket hole joinery uses screws driven at an angle through the side of one piece into the face of the other. A special jig and bit are used to



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FIGURE 15-3 Screwed butt joint.

drill the holes, and the joint is pulled together with screws designed specifically for this type of joinery. See **Figure 15-4**.

Using either nails or screws has the disadvantage of leaving visible marks on the boards nailed or screwed together. Small nail holes can be filled with wood putty. Screw holes are larger and more noticeable. They can be recessed and covered with wood plugs bought or cut to match or with removable wood buttons. Plugs machined to cover pocket holes can also be purchased (see **Figure 15-5**, **Figure 15-6**, and **Figure 15-7**).

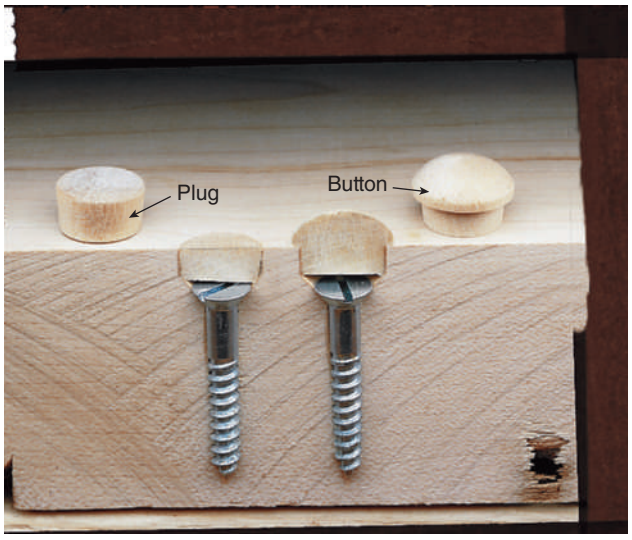
Fastened butt joints can also be difficult to assemble well, because they must be held together perfectly as the fastener is driven into place. If there is room, a clamp can be used to hold the joint while nailing or screwing it together. Butt joints can also be constructed without using nails or screws. Dowels, splines, or biscuits can reinforce a butt joint and simplify the assembly process by helping align the two pieces being fastened together.

Dowel joints may be through joints or blind. A **spline** is a strip of wood that fits into two matching grooves, one machined in each adjoining piece. Biscuits fit into mating slots cut in the two pieces. See



Image courtesy of rockler.com

FIGURE 15-4 Butt joint assembled with pocket screws.



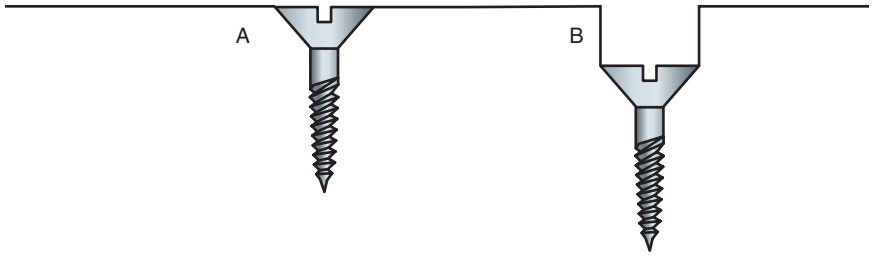
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FIGURE 15-6 Wood plugs and buttons.



Image courtesy of rockler.com

FIGURE 15-7 Pocket screw hole plugs.



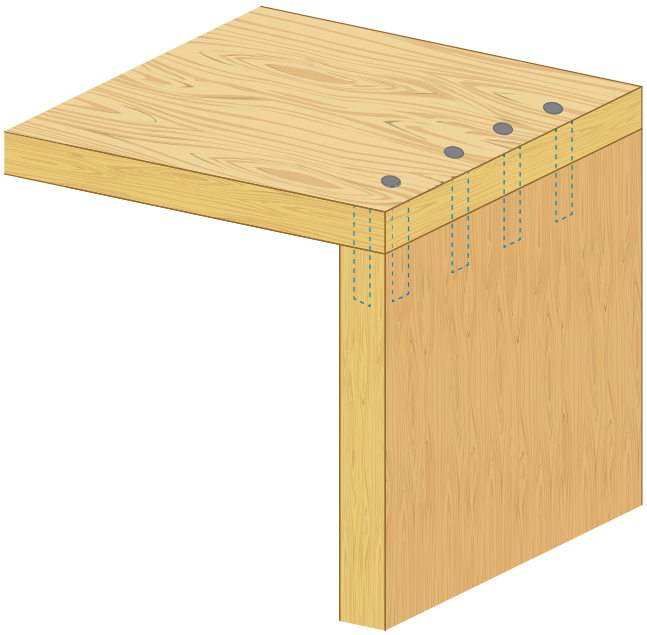
A: Screw is countersunk and flush with wood
B: Screw is counterbored and can be plugged

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FIGURE 15-5 Screws set flush with the surface are very visible (A); recessed screws can be concealed (B).

Figures 15-8 through **15-11** for examples of reinforced butt joints.

The use of dowels, biscuits, or splines increases the strength of the butt joint considerably. In addition, blind dowels and biscuits have the advantage of being invisible once the case is assembled, and splines are nearly so.

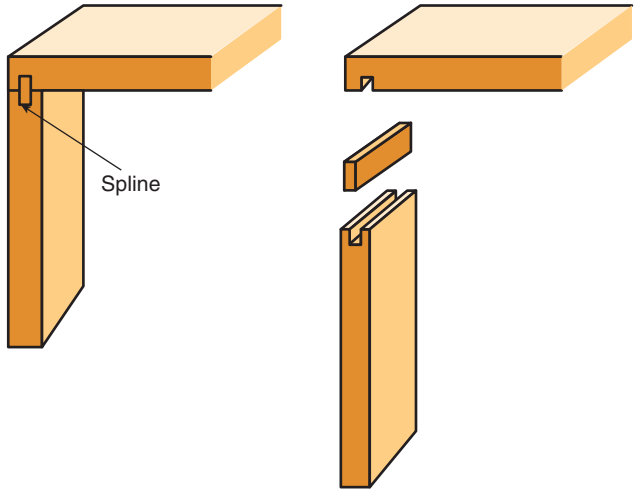


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FIGURE 15-8 Dowled butt joint.

Another way to reinforce a butt joint is to use **glue blocks**, triangular or square pieces of wood used to strengthen and support two adjoining surfaces. They may be continuous or intermittent (see **Figure 15-12**). Glue blocks are often used in conjunction with nails.

Butt joints have the disadvantage of exposing end grain. If sheet goods are used, this edge can be covered with veneer tape. Solid wood end grain is not as unattractive as sheet good edges, but it does absorb stain and finish differently than face and edge grain, which may be undesirable.



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FIGURE 15-10 Splined butt joint.

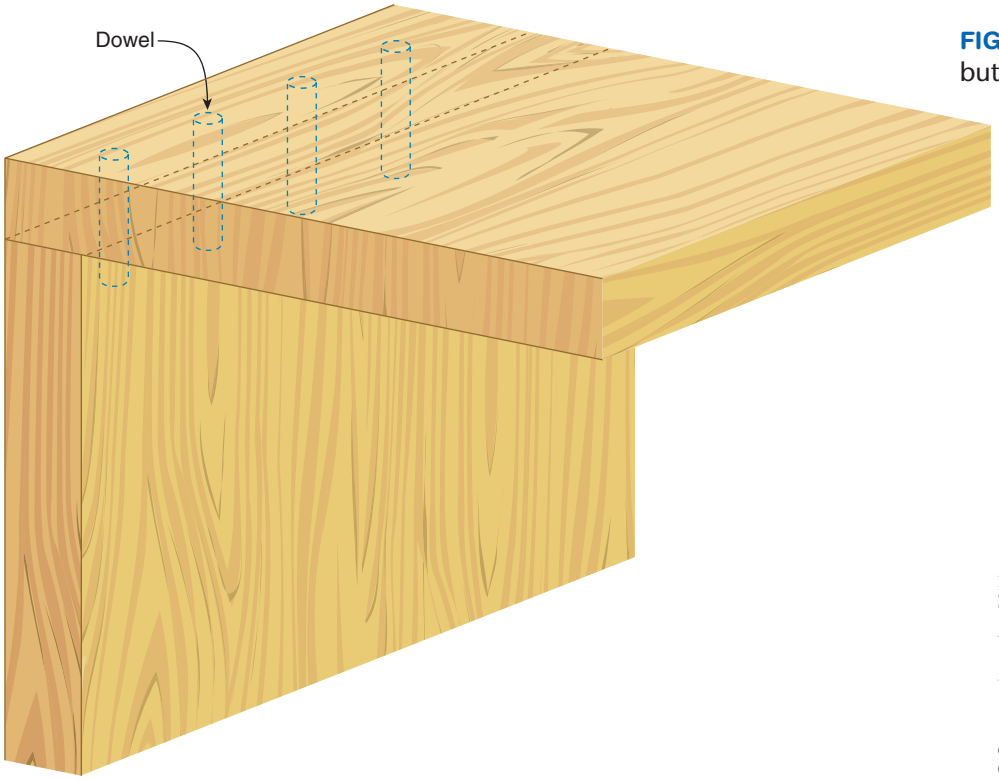
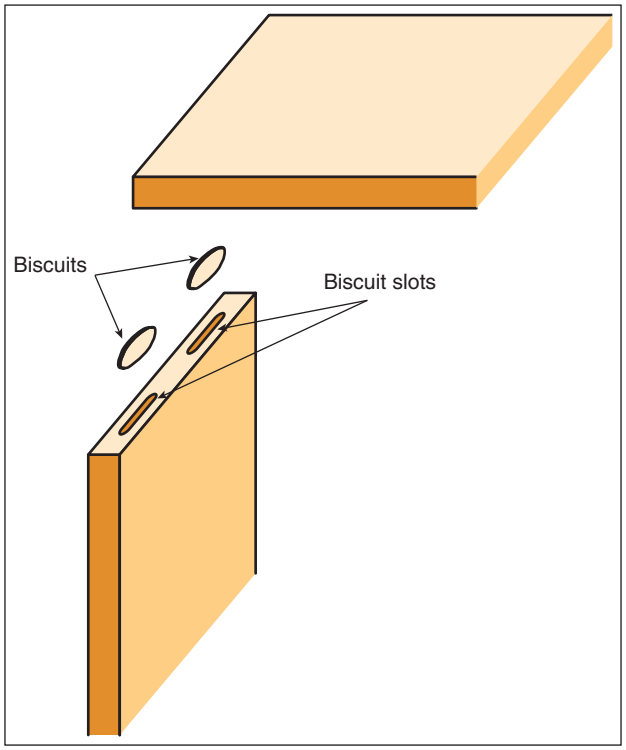


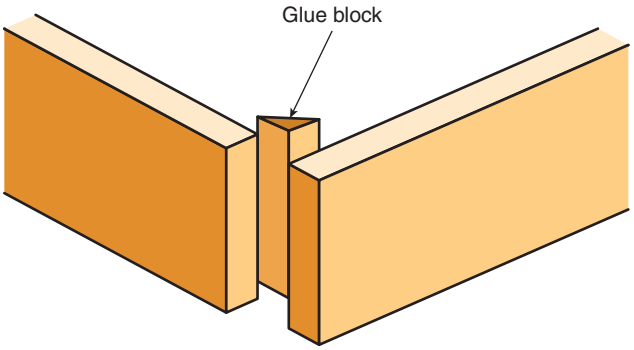
FIGURE 15-9 Blind doweled butt joint.

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FIGURE 15-11 Biscuited butt joint.



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FIGURE 15-12 A glue block.

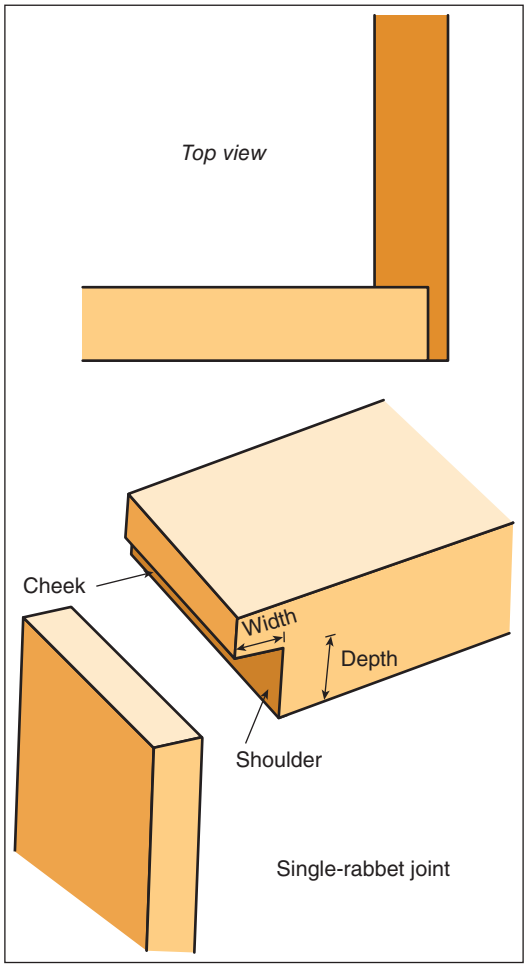
CAUTION

When using nail guns, remember that a nail is being fired at high speed with a lot of pressure. Keep your fingers away from the surface you are nailing to avoid injury.

RABBET JOINT

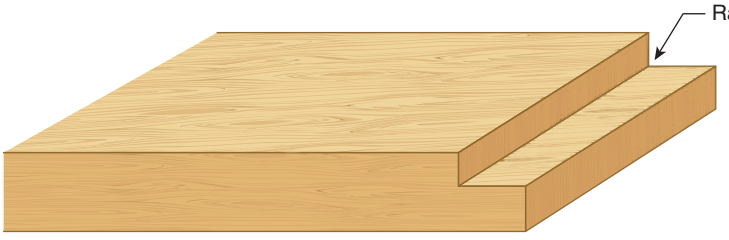
A **rabbet** is a two-sided groove along the edge or end of a workpiece (see **Figure 15-13**). Rabbets can be used as case joints.

There are two common types of rabbet joints used in case construction: the *single-rabbet joint* and the *double-rabbet joint*. A **single-rabbet joint** creates a case corner in which one member rabbeted and the other butts into it (see **Figure 15-14**). The single-rabbet joint



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FIGURE 15-14 Single-rabbet joint.



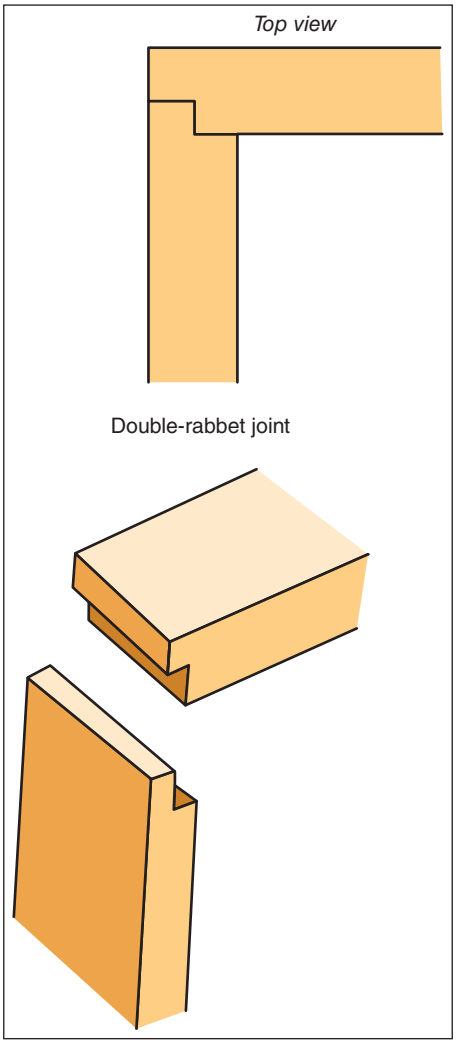
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FIGURE 15-13 Rabbet.

is stronger than a butt joint because it offers a small section that will glue acceptably between the shoulder of the rabbeted piece and the face of the butted piece, but this joint still requires reinforcement.

In the **double-rabbet joint**, both adjoining members are rabbeted (see **Figure 15-15**). This type of rabbet joint also needs reinforcement, unless the case is very small.

Rabbet joints are superior to butt joints in several ways. First, they do offer some good gluing surface, although not enough to obviate the need for fasteners. Second, less end grain is left exposed. Perhaps the most important aspect of the rabbet joint, however, is that it makes case assembly easier. Whether a single rabbet or a double rabbet is used, the corner is easier to keep in place as it is fastened due to the ledge created by the rabbet. Rabbet joints may be made with a dado blade on the table saw, a straight bit in a router table, or a rabbeting bit in a handheld router (see **Figure 15-16**, **Figure 15-17**, and **Figure 15-18**).



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FIGURE 15-15 Double-rabbet joint.



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FIGURE 15-16 Rabbet joint created on the table saw with a dado blade.



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FIGURE 15-17 Rabbet joint created with a straight bit on the router table.



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FIGURE 15-18 Rabbetting bit used in a handheld router to create a rabbet.

PROCEDURE 15-1

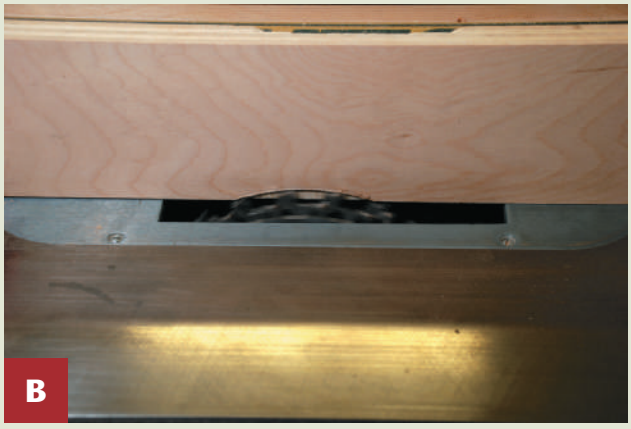
Making a Rabbet Joint on the Table Saw

STEPS

1. Install a dado blade on the saw; set it up for the width of the rabbet you want to make or a bit wider.
2. Clamp a sacrificial fence to the table saw fence, and bring the fence over next to the blade, as shown in **Figure A**.
3. Raise the dado blade to the height desired. If the blade width is wider than the desired width of the rabbet, the blade needs to be raised into the sacrificial fence with the saw turned on, as shown in **Figure B**.
4. With the fence in the correct position and the blade at the proper height, run a test piece with the thickness of the material you will be working with; support it with the miter gauge, as shown in **Figure C**.


A

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B

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5. Check the test piece against the piece it will butt into to check the fit, as shown in **Figure D**.
6. Adjust the fence position and blade height as needed, and keep running test pieces until the proper size rabbet has been achieved, and then run all pieces to be rabbeted.



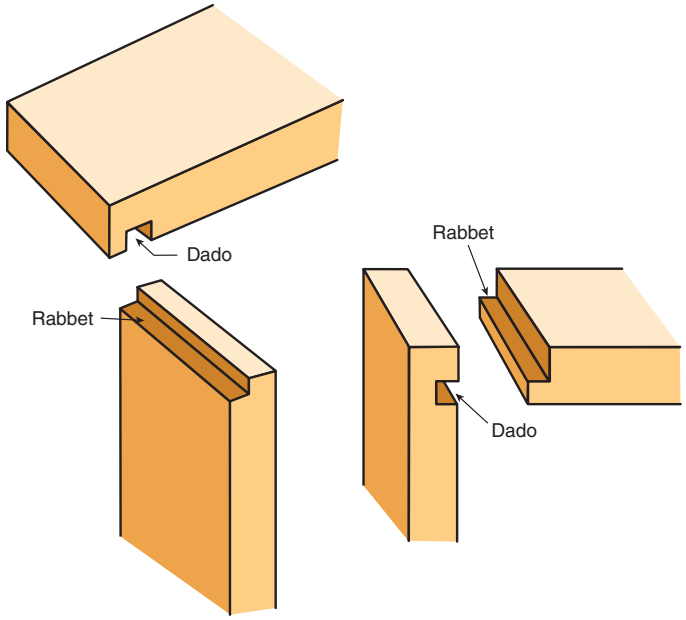
FACTS ABOUT WOOD

Red alder, *Alnus rubra*, is harvested on the Pacific coast of North America. It is sometimes called *Western alder* or *Oregon alder.* It works easily with both hand and power tools and takes finishes well. It is pale yellow to reddish brown in color and is used for turning, furniture, carving, plywood, and veneers. ■

DADO-AND-RABBET JOINT

The **dado-and-rabbet joint** is another case joint (see **Figure 15-19**). A rabbet cut on one member fits into a dado cut in the adjoining member. A **dado** is a three-sided groove.

This joint does not offer much good gluing surface but will in fact glue quite well if the fit between the dado and the rabbet is good, in which case fasteners are not necessary. Again, the problem of visible end grain is an issue, but if the joint is oriented so that the end grain of the side piece ends up on the top of a vertical case, it may not be obvious. Of course, if trim is to be added, this will not be a concern. As with the rabbet joint, assembly is easier than with butt joints.



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FIGURE 15-19 Dado-and-rabbet joint.

MITER JOINT

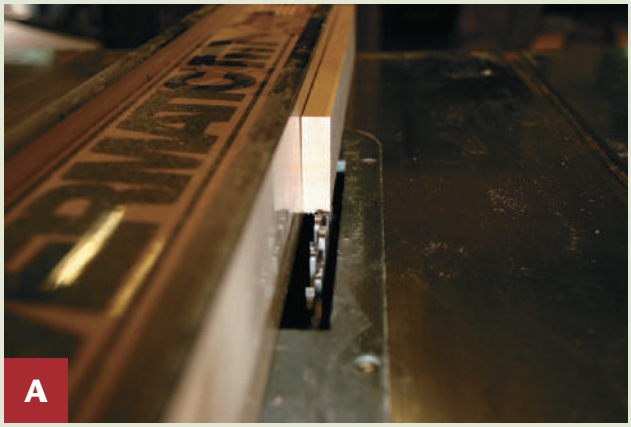
There are several kinds of miter joints that can serve as case joints. A mitered case joint is sometimes called a *plain miter* or a *carcass miter;* **carcass** is another term for a case. A **mitered case joint** consists of two adjacent pieces, each of which has its end beveled, typically at a 45° angle. There are *simple miters, splined miters, biscuited miters, miters with keys,* and *lock miters.* The attractive thing about all miter joints is that the end grain of the joining pieces is completely hidden.

PROCEDURE 15-2

Machining a Dado-and-Rabbet Joint

STEPS

1. Install the dado blade on the table saw with its width set for the dado width desired.
2. Set the blade height for the depth of the dado desired.
3. Slide the rip fence over to act as a stop for the dado joint you will make. This is safe because you are not cutting all the way through the piece and creating a scrap that could get caught between the fence and the blade. The distance from the fence to the far side of the blade should be the thickness of the piece to be rabbeted, as shown in **Figure A**.
4. Using the miter gauge to support the workpiece, make a test dado, as shown in **Figure B**. Check the depth and placement of the dado, and adjust the blade height and fence position until you are satisfied. At this point, you can mill the dado in your finish stock.
5. Next the rabbet is cut. Follow the steps outlined in Procedure 15-1. Again, make test cuts until you have a rabbet that fits snugly into the dado, as shown in **Figure C**.



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Simple miters are the most basic of the miter joints. The ends of each piece are cut at a 45° angle and butted together. As with the other case joints, end grain is involved, so it does not offer a good gluing surface and therefore should be reinforced, usually with finish nails or brads. It can be somewhat difficult to assemble, as the pieces tend to slide past one another. **Figure 15-20** illustrates a simple miter joint and how it should be fastened together. It is wise to pre-drill for the nails to keep from splitting the stock, especially in hardwood.

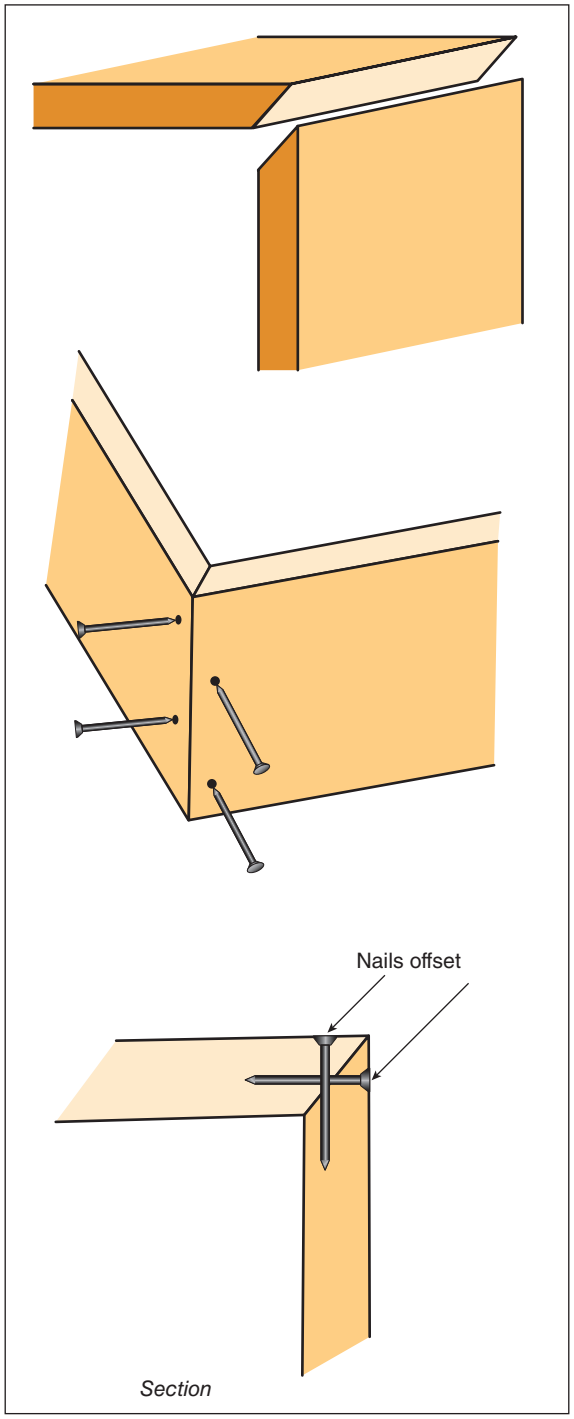


FIGURE 15-20 Simple miter joint and fastening with nails.

Splined miters are a step up from simple miters. First a simple miter joint is machined, and then a groove is milled into each adjoining part, into which a spline is fit and glued up with the corner (see **Figure 15-21**). The slot that accepts the spline can run all the way through the joint or only partway, in which case it is called a *blind-splined miter* (see **Figure 15-22**).

The groove for the spline should be placed close to the inside corner, so that it can be as deep as possible. It is also important that the grain of the spline run parallel to the grain of the mating parts if solid

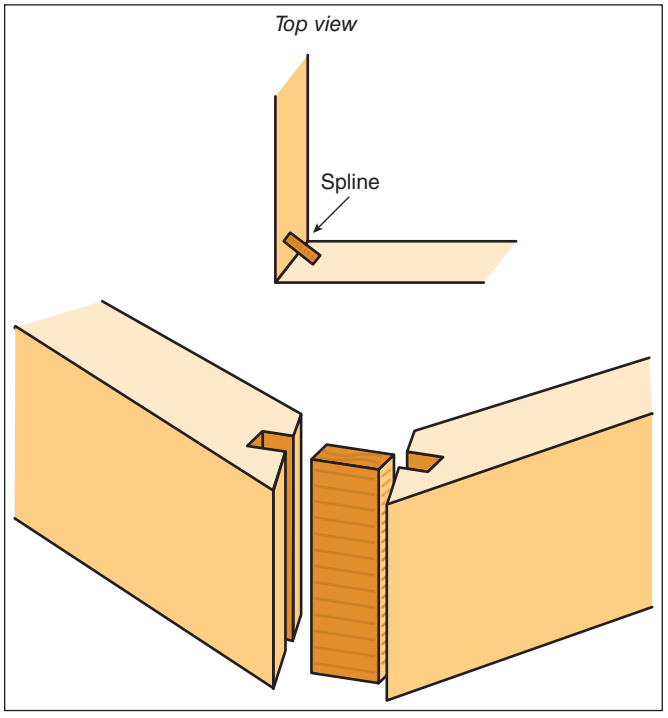


FIGURE 15-21 Splined miter.

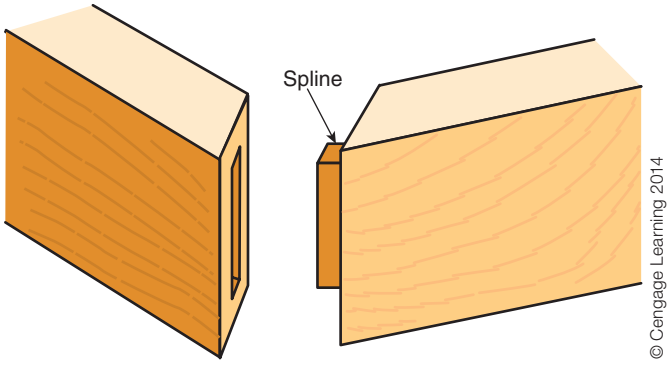
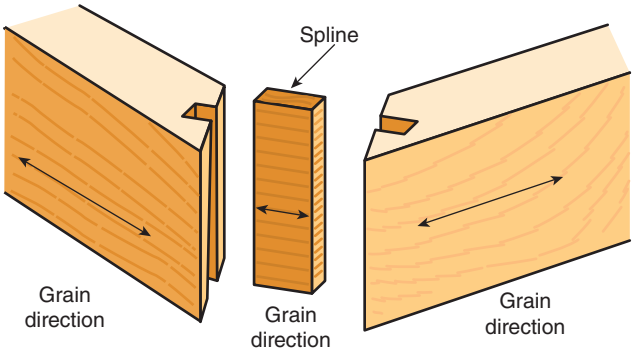


FIGURE 15-22 Blind-splined miter.

wood is used, so that the expansion and contraction of the spline is in the same direction as that of the mating parts. In long case pieces, this means that a series of small splines will need to be used (see **Figure 15-23**). Alternatively, eighth-inch hardboard can be used, avoiding the problem of grain direction orientation.

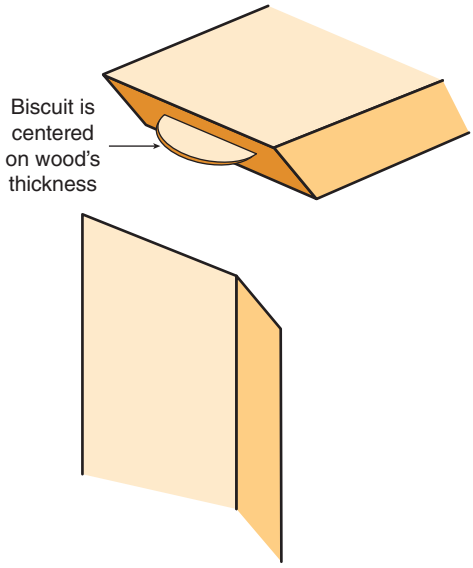
Biscuited miters are a relative of splined miters and work much the same way. The biscuit slots are cut intermittently along the joint of a simple miter (see **Figure 15-24**). Biscuit cuts should be made in the middle of the joint.

Keyed miters are another way to strengthen what starts out as a simple miter joint. These are strong joints and can be highly decorative as well. There are three types of keys: *spline keys*, *dovetail keys*, and *feather keys*. In each case, a simple mitered corner is cut, assembled, and glued up. Then slots are cut into the miter from the outside. Keys are machined to fit the slots and are then glued in place. See **Figure 15-25** through **Figure 15-27** for depictions of spline keys,



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FIGURE 15-23 The grain of solid wood splines should run in the same direction as the grain of the joining pieces.

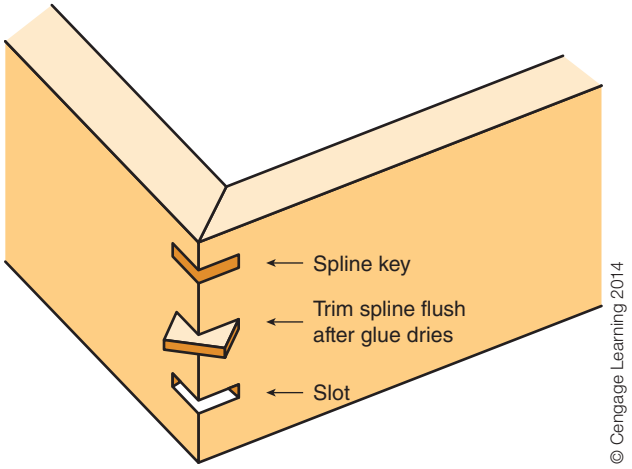


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FIGURE 15-24 Biscuited miter.


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FIGURE 15-25A Miter with spline keys.

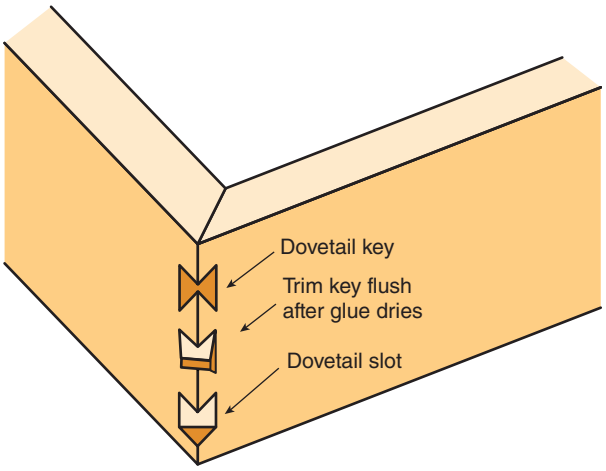


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FIGURE 15-25B Miter with spline keys.

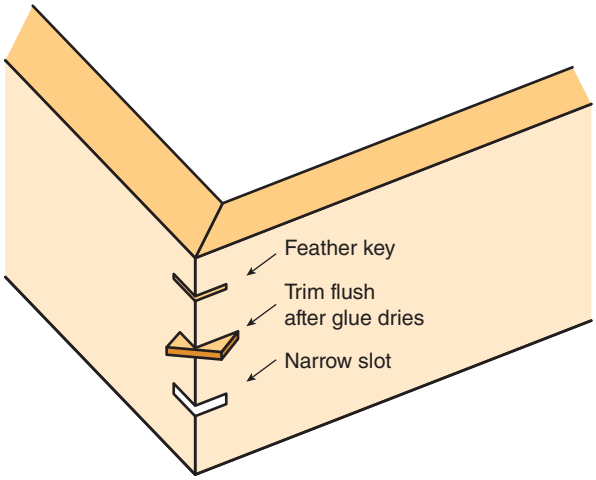

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FIGURE 15-26A Miter with dovetail keys.



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FIGURE 15-26B Miter with dovetail keys.



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FIGURE 15-27B Miter with feather keys.



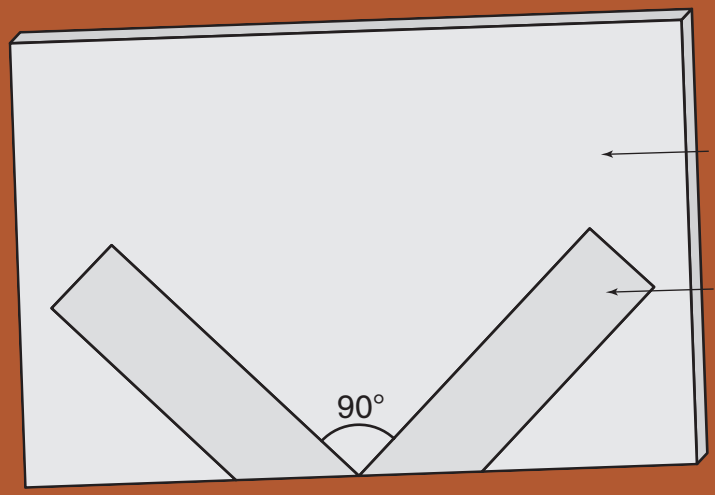
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FIGURE 15-27A Miter with feather keys.

dovetail keys, and feather keys. The only difference between spline and feather keys is that spline keys are made of thicker material than feather keys, which may be as thin as veneer.

WOODWORKING TIP:

A simple jig can easily be constructed to make slots for spline keys on the table saw (see **Figure 15-28**). *The box is placed in the jig, which is run against the fence of the table saw over the blade; the blade is set*



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FIGURE 15-28 Jig for keying miters.

at a height to cut into but not through the box (see Figure 15-29). A similar jig can be used on the router table with a dovetail bit in the router to create recesses for dovetail keys.

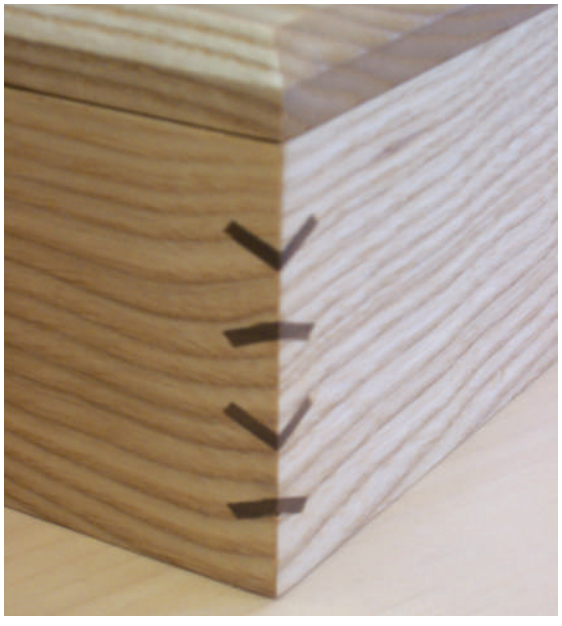


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FIGURE 15-29 Using the jig.

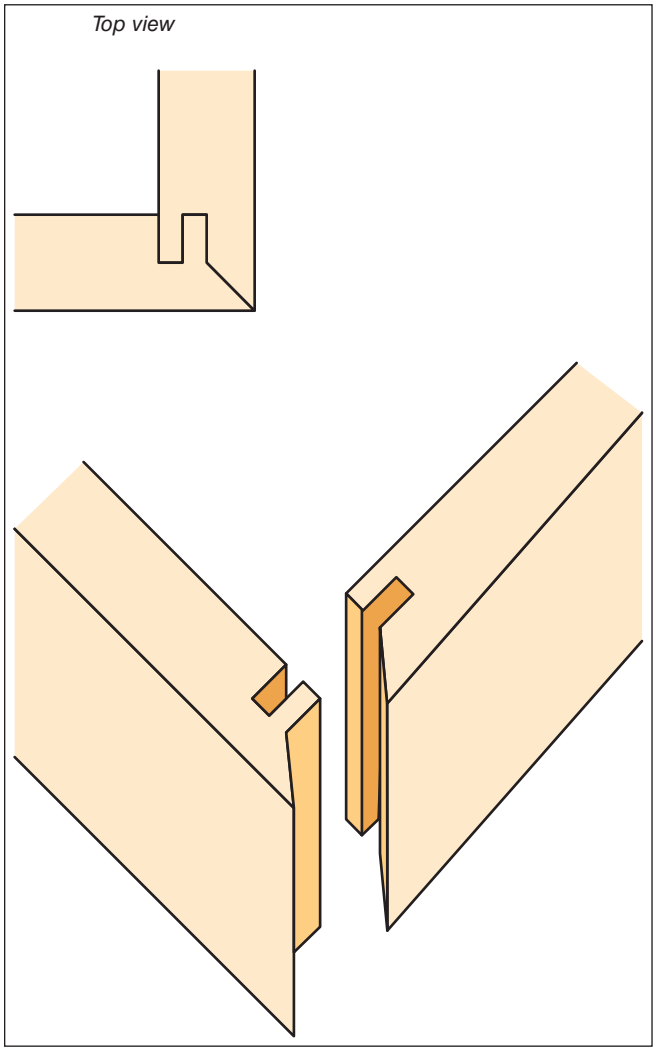
Keys are cut to fit snugly in the slots that are milled for them. They are long when glued in and then trimmed flush once the glue is dry. The cuts that take the keys may be straight or angled, as shown in **Figure 15-30**. A contrasting wood can be used for a nice effect. The more keys that are used, the stronger the joint will be.

The **lock miter** joint is an excellent joint, because it combines the appearance of a miter joint with the strength of a rabbet-and-dado joint. It has a built-in locking action, hence its name, and it offers good gluing surface as well (see **Figure 15-31**).



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FIGURE 15-30 These angled spline keys were cut by tilting the blade on the tablesaw.



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FIGURE 15-31 Lock miter joint.

PROCEDURE 15-3

Making a Splined Miter Joint



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STEPS

1. Cut the mitered corners that will be joined as shown in **Figure A** using the table saw or miter saw.
2. Tilt the table saw blade to 45°. The blade should tilt away from the fence. If necessary, move the fence to the other side of blade.
3. Using one of your mitered pieces as a guide, set the fence so that the blade will be cutting into the inside third of the miter, as shown in **Figure B**.
4. Adjust the blade height so that it will cut approximately halfway through the mitered stock.
5. With the point of the miter against the fence and the workpiece supported by the miter gauge, make a cut in a test piece, as shown in **Figure C**. Adjust the fence position and blade height as needed, and continue to test the setup until you are satisfied, and then run the pieces for your project.
6. Bring the table saw blade back to its normal position at 90° to the table, and rip a strip of eighth-inch hardboard that is just slightly less than twice the depth of the mitered slot you just cut.
7. Check the fit of the spline, as shown in **Figure D**.
8. Cut the spline to length.
9. Apply glue to the spline, insert it into the mitered grooves of the mating corner, and clamp.

The lock miter joint is typically milled either on the shaper with a lock miter cutter or on the router table with a lock miter bit (see **Figure 15-32**). It can be a bit tricky and time consuming to set this up correctly, but it yields an excellent result if care is taken with the setup. One piece is run flat on the machine table, and its mate is run upright against the fence of the machine (see **Figure 15-33**).



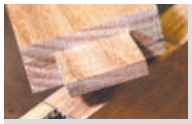
Images courtesy of Freud America, Inc.

FIGURE 15-32 Lock miter shaper cutter and lock miter router bit.

BOX JOINT

The **box joint**, also called a *finger joint* or *comb joint,* is another case joint. Box joints are interlocking tenons and notches cut in the ends of adjoining boards (see **Figure 15-34**). These tenons and notches are called *pins and sockets.*

The box joint is a very strong joint due to its large amount of gluing surface. Like the other joints that have been discussed, its integrity depends greatly on achieving a good fit between the interlocking fingers. The size and spacing of the fingers in a box joint is a matter of personal preference, but typically each of the joining pieces has an alternating pattern of equally sized fingers and slots. Often the width of the fingers is equal to the stock thickness. Box joints can be cut by hand, but they are usually a machined joint. A box joint can be created using a fairly simple jig on the table saw with a dado blade or similar jig and a straight bit in a table-mounted router (see **Figure 15-35**).



HISTORY FACT

Prior to the advent of corrugated cardboard boxes, boxes were made out of wood. The joint of choice for constructing these boxes was the box joint, hence its name. This joint was used extensively in mass-produced items of the nineteenth and early twentieth centuries. Not only was it used in building boxes of all sizes for packing; it was also widely used in the construction of coffee grinders and telephones. ■

The fingers of the joint should be milled 1/32″ to 1/16″ longer than the stock is thick. When the case is assembled, the fingers will project that amount and can be planed or sanded flush. Using a box joint as a case joint gives a checkerboard appearance, which may be considered either an advantage or a disadvantage.

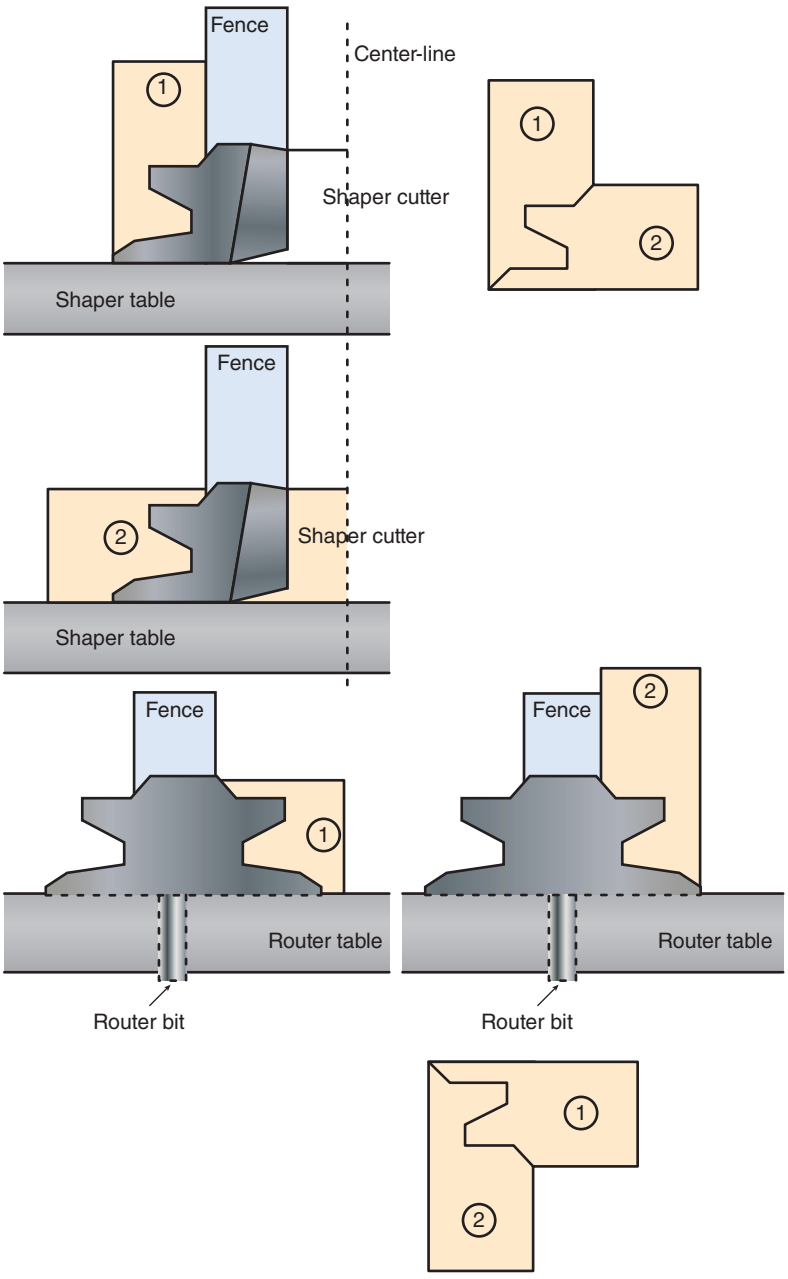


FIGURE 15-33 One side of lock miter joint is run flat on the table, and the other is run upright against the fence.



FIGURE 15-34A Box joint.

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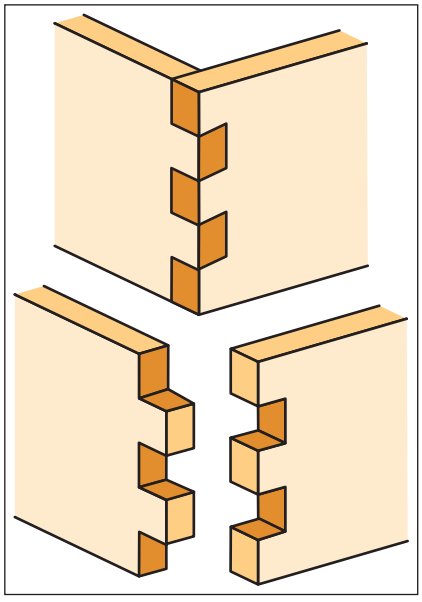


FIGURE 15-34B Box joint.

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FIGURE 15-35 Creating a box joint on the table saw.

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WOODWORKING TIP:

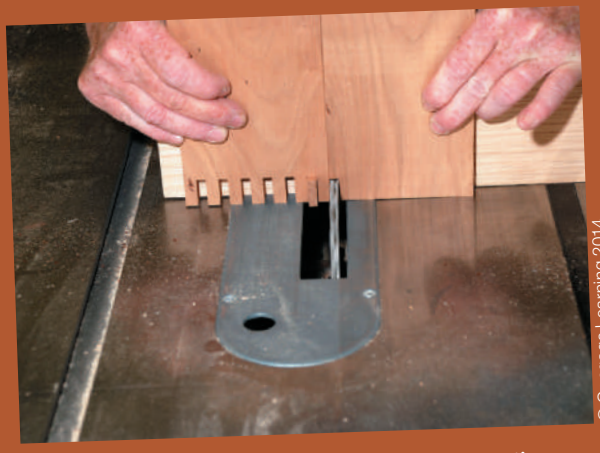
Making a simple box-joint jig is not complicated, but it does require precision and some willingness to fuss with it until a good fit is achieved. To this end, it is important to have test pieces on hand of the same thickness as the stock you are working with. **Figure 15-36** *illustrates the features of a simple finger-joint jig.* **Figure 15-37** *shows the steps in using the jig, and* **Figure 15-38** *details how to adjust the jig to correct the fit of the joint.*



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FIGURE 15-36 Finger-joint jig. The blade kerf, the spline glued into the jig, and the distance between the two are equal.

(C)



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FIGURE 15-37C Steps in using a finger-joint jig.

(A)



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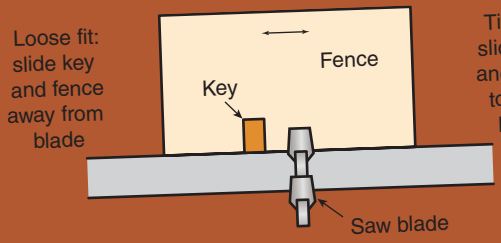
FIGURE 15-37A Steps in using a finger-joint jig.

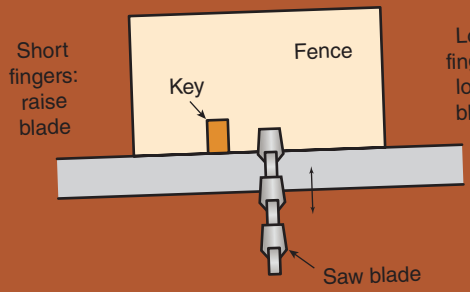
(B)



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FIGURE 15-37B Steps in using a finger-joint jig.





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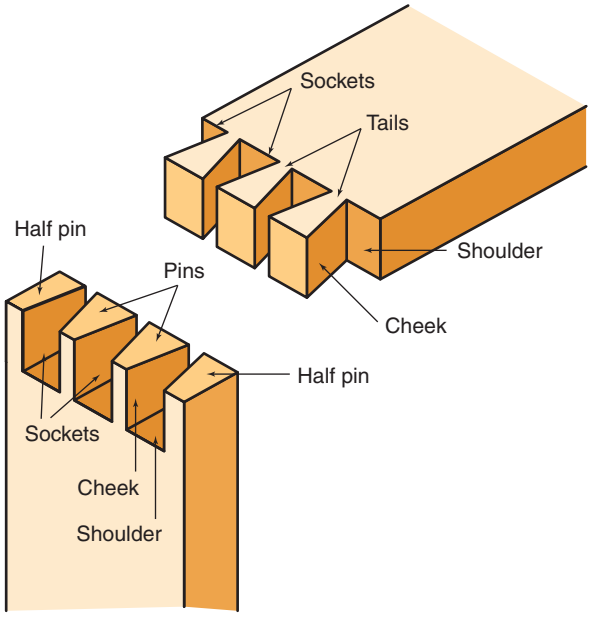
FIGURE 15-38 Correcting the fit of a finger joint.

DOVETAIL JOINT

The **dovetail joint** is the quintessential case joint. Some consider the hand-cut dovetail joint the holy grail of woodworking. It consists of angled tenons, called **tails** on one piece and **pins** on the other piece. Both the tails and pins fit into the recesses on the mating pieces. These recesses are called **sockets**. The dovetail joint is somewhat similar to the box joint, in that it has a great deal of glue surface, but it is even stronger due to the angled nature of its component parts: it actually locks together, and it can only be pulled apart in one direction. The dovetail joint is a very utilitarian joint, developed before reliable glues and inexpensive fasteners were available. See **Figure 15-39** for an illustration of a dovetail joint.

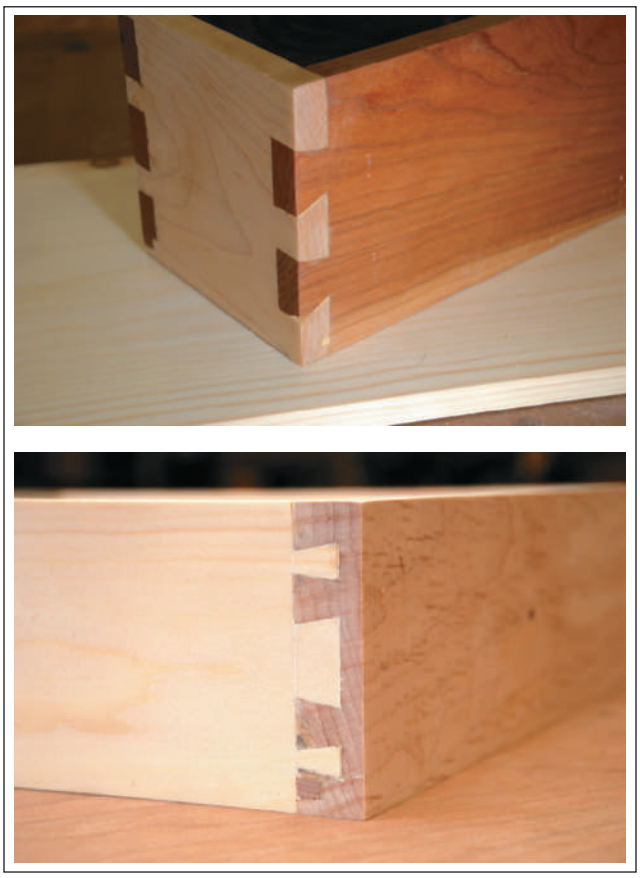
There are various types of dovetail joints, but by far the most common are **through dovetails** and **half-blind dovetails**. On through dovetails, the socket that the tail fits into is cut all the way through the adjoining board so that the joint is visible when looking at either of the two boards that comprise it. With half-blind dovetails, the sockets that the tails fit into are cut only partway through the adjoining board, with the result that the joint can only be seen from one side (see **Figure 15-40**). Half-blind dovetails are often used on drawers.

Dovetails may be either cut by hand or milled with a router and dovetail jig. Jigs can also be built to cut dovetails on the table saw or band saw, but the most common method is to use a router and some kind of jig. There are various readily available jigs. The least expensive cuts a half-blind dovetail joint, milling the tails and sockets at the same time (see **Figure 15-41**).



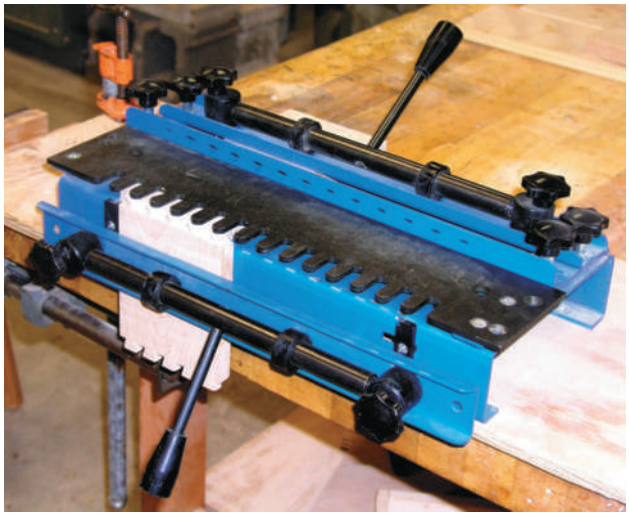
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FIGURE 15-39 Dovetail joint.



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FIGURE 15-40 Through dovetails and half-blind dovetails.



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FIGURE 15-41 A half-blind dovetail jig mills the tails and sockets at the same time.

A dovetail bit is used in the router with a guide bushing that is guided in and out of the jig's template (see **Figure 15-42**). Half-blind dovetails are most often used in drawer construction. Tails are milled into the drawer sides, and sockets are milled into the drawer front. Due to the interlocking nature of the joint, the drawer cannot be pulled apart from the front.

Other jigs are available to cut through dovetail joints. Typically, two different templates are used and two different router bits. First the tails are cut using the tail jig and a dovetail bit, and then the pins are cut using the pin jig and a straight bit. These bits are used with guide bushings or equipped with bearings that ride along the ins and outs of the template (see **Figure 15-43**).

When dovetail jigs are properly set up, they create excellent joints; but the great majority of them can only cut evenly spaced and uniformly sized dovetails. Varying the spacing and size of the dovetails can be much more visually interesting. There are some high-priced jigs on the market that do allow the user to customize the spacing and size of the dovetails, but you can also experiment with the aesthetics of the dovetail joint by learning to cut it by hand. Cutting a through dovetail joint by hand gives the craftsperson the opportunity to vary the spacing and size of the tails and pins. It is also an opportunity to develop and sharpen one's hand skills. It takes some practice but is by no means the mysterious task that it is sometimes made out to be. There are many schools of thought about the best way to do it. Some people prefer to cut the tails first, and others cut the pins first.



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FIGURE 15-42 A dovetail bit sits inside a guide bushing mounted to the router base plate which rides against the dovetail jig.



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FIGURE 15-43 Through dovetail jig and bits with bearings.

WOODWORKING TIP:

When marking out a dovetail joint that will be cut by hand, it is a good practice to shade the area that will be cut out. It is easy to get confused (see **Figure 15-44***).*



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FIGURE 15-44 Mark out the waste by shading the area to be removed.

WOODWORKING TIP:

A simple dovetail gauge can aid in both the layout and cutting of dovetails. It is built to the desired slope and can be used as a cutting guide (see **Figure 15-45**, **Figure 15-46**, *and* **Figure 15-47**).

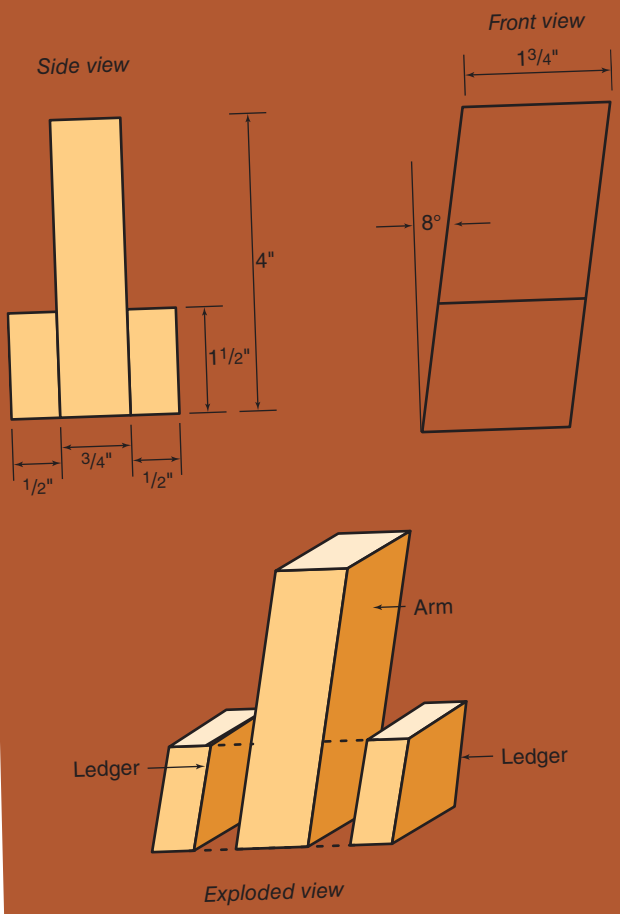


FIGURE 15-45 Dovetail marking gauge and saw guide.



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FIGURE 15-46 Laying dovetails with the dovetail gauge.

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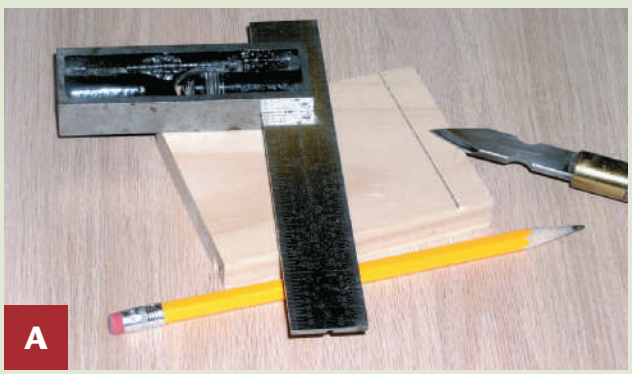
FIGURE 15-47 Using the dovetail gauge to guide cuts.

PROCEDURE 15-4

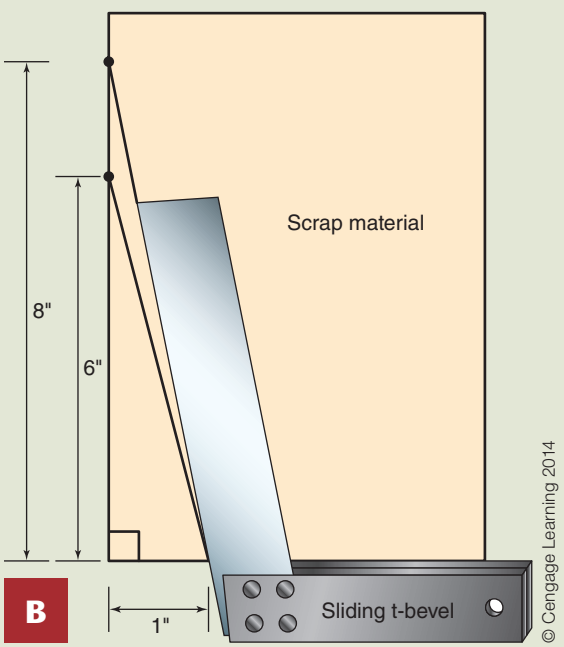
Cutting a Dovetail Joint by Hand

STEPS

1. Select good, straight-grained stock; it is easiest to work. You will need four pieces that are the same width. Cut the ends square.
2. Mark the shoulder on both ends of all four pieces. The shoulder is set over from the end of the board the distance of the board's thickness plus a bit. These are best scribed with a marking gauge or sharp marking knife and square, as shown in **Figure A**. Running a sharp pencil along the scribed line makes it more visible.
3. Lay out the tails. A gauge for doing this can be made or purchased, or a sliding bevel square can be used. The slope of the tails should be somewhere between 1:6 and 1:8. Less slope is commonly used with softwoods, and a higher slope is used with hardwoods. See **Figure B** for setting a sliding bevel square. Using your bevel square set to the proper angle or a dovetail gauge, mark out the tails on both ends of the two tail boards, sizing and spacing them according to your preference, as shown in **Figure C**. Lay out tails on both ends of each end piece.
4. Secure the tail board in a vise, and carefully cut down each sloped line. A fine-toothed saw such as a dovetail or dozuki saw should be used (see **Figure D**). Cut the rest of the tails.



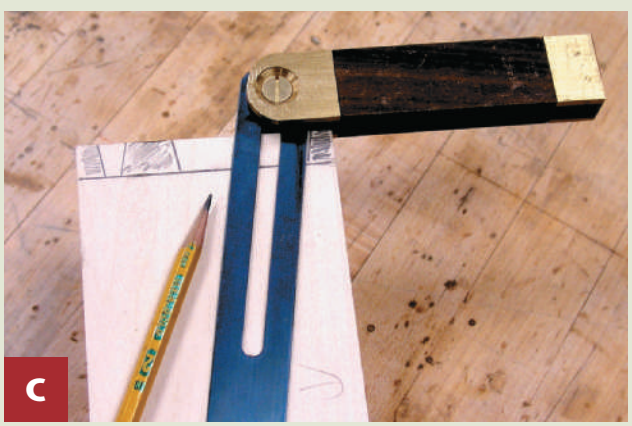
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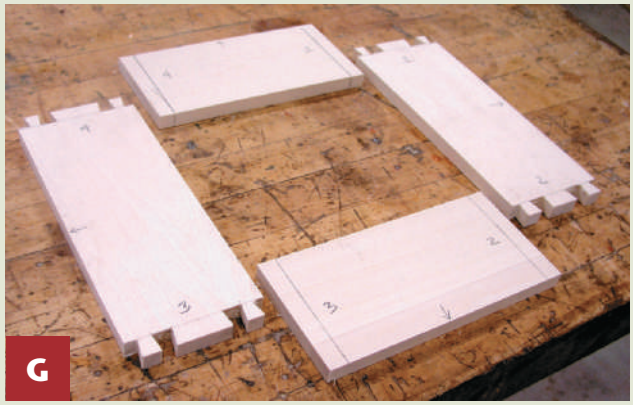


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5. After all the angled cuts for the tails have been made, secure the tailboard with the flat face down to the bench, and with an appropriately sized chisel, chop down into the scribed shoulder line; then come in horizontally from the end, and split out the waste. Do this a bit at a time, until you are about halfway through, and then turn the board over and finish from the other side, as shown in **Figure E** and **Figure F**.
6. After the tails have been cut out, the pin boards are laid out. Lay out your box on the bench as it will go together, and mark each corner. See **Figure G**.

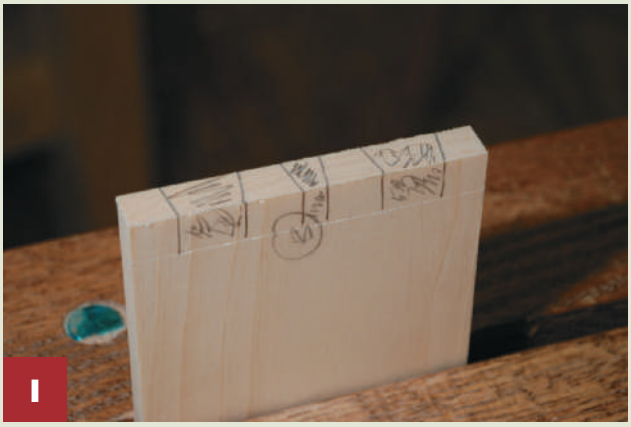


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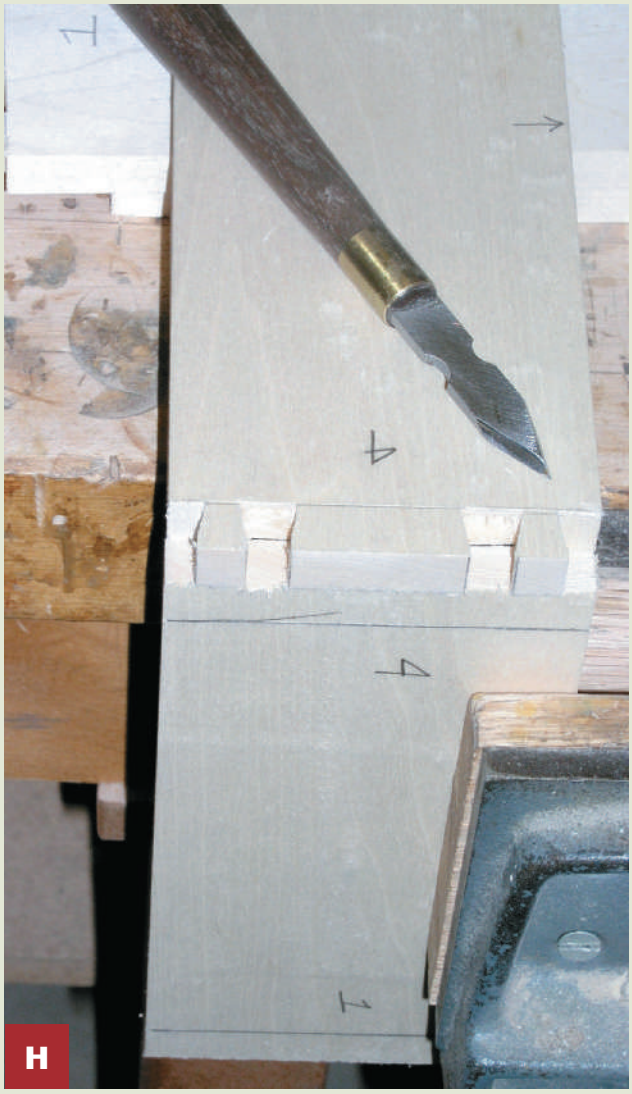


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7. The pins for each corner are laid out from the tails. You will notice that where the slope on the tails was on the face of the board, the pins are sloped on the ends (see **Figure H**).
8. With the pins laid out across the ends, lines are squared down to the shoulder line (see **Figure I**).
9. Now these are cut and cleaned out in the same manner as the tails. Be careful to cut to the waste side of the line.
10. When the pins are cut, test the joint for fit. It may require some trimming, and it will probably take some practice before you are completely satisfied with your results.


I

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Summary

Casework is the art and science of building boxes, and various case joints are used in box construction. These range from the lowly butt joint to the exquisitely laid out and cut dovetail joint. Some joints, such as the butt and rabbet, must be reinforced. Others provide enough gluing surface that this is not necessary. The dovetail joint actually locks in one direction, making it the strongest of the case joints. The miter joint has the advantage of hiding all end grain. Depending on the case, different joints are appropriate for different applications. Whichever joint is used, the cabinetmaker should strive to make it fit as well as possible.



Key Terms

biscuited miter
box joint
butted case joint
carcass
case joint
casework
dado
dado-and-rabbet joint
double-rabbet joint
dovetail joint
glue blocks
half-blind dovetail
keyed miter
lock miter
mitered case joint
pin
rabbet
racking loads
simple miter
single-rabbet joint
socket
spline
splined miter
tail
through dovetail

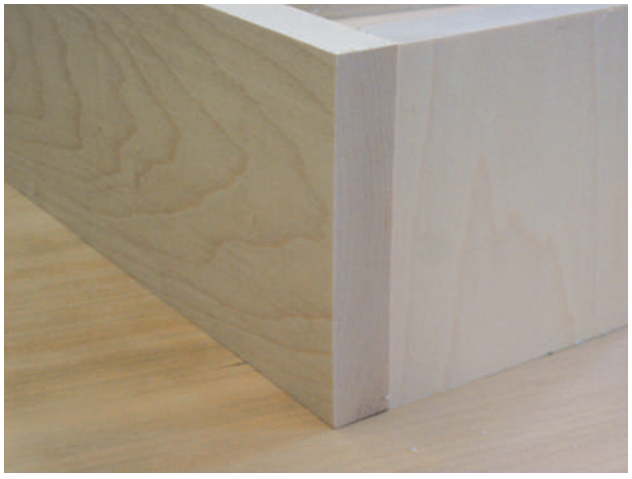


Check Your Knowledge

1. List the case joints covered in this chapter.
2. Which is the simplest of the case joints?
3. Which is the most complicated and strongest?
4. What advantage does the miter joint have?
5. Why are rabbet case joints easier to assemble than butt joints?
6. List the different miter joints.
7. Which miter joint is cut with a special cutter or bit?
8. What are the different keys that can be used to strengthen miter joints, and how can they be decorative?
9. What is the difference between a splined miter joint and a biscuited miter joint?
10. How can a box joint be cut?
11. What is the great advantage of the box joint?
12. How does a dovetail joint differ from a box joint?
13. What is the difference between a through dovetail joint and a half-blind dovetail joint?
14. Where are you likely to see a half-blind dovetail joint used?
15. What advantage does hand cutting a dovetail joint have over most dovetail router jigs?



What's Wrong with This Feature



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Mitered Box with Spline Keys

A finished miter box with spline keys is shown in **Figure A**.

TOOLS REQUIRED

- Measuring tool
- Squaring tool
- Table saw
- Band saw
- Planer
- Miter saw
- Dovetail or dozuki saw
- Splining jig
- Masking tape

MATERIALS REQUIRED

- Two pieces of S2S 3/4″ solid stock, each one about 4″ wide and 15″ long. Using contrasting species makes an attractive box.

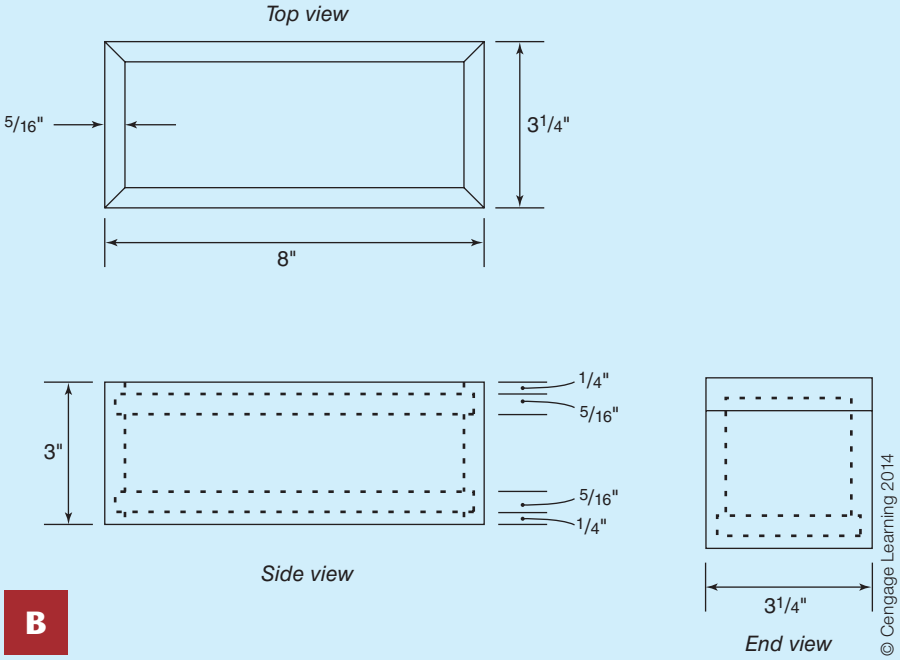
STEPS

1. Review the plan shown in **Figure B**.
2. Choose one piece of stock to use for the box sides and ends. The other piece will be used for the top, bottom, and splines.
3. Joint, rip to just over width, and joint to final width the piece chosen for the box.



A

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B

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C

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D

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E

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4. Joint one edge of the pieces that will be used for the top and bottom.
5. Resaw both pieces in half on the band saw, as shown in **Figure C**, placing the jointed edge down on the band saw table.
6. Plane both pieces smooth. They should now be between 1/4″ and 5/16″ thick. Set aside the pieces that will be used for the top and bottom of the box.
7. Take the two resawn pieces that will be the ends and sides of the box and mill a groove on the table saw 1/4″ down from the top and bottom edge of each piece. The groove should be wide enough to accept the top and bottom pieces, and its depth should be about halfway through the stock, as shown in **Figure D**.
8. Using the miter saw, cut one end and one side from each piece. These are miter cuts made at 45°, as shown in **Figure E**.
9. Cut a bottom and a top to fit. They should be the same size. Save the long waste pieces.

BUILD IT!

10. Take one end of the box and, using a thin-kerf saw, such as a dovetail or dozuki saw, carefully crosscut it at the bottom of the top groove (see **Figure F**). Set the small piece aside.
11. Glue up the sides of the box with the bottom trapped in place. Do not glue the bottom in. Tape the box up using masking tape, pulling the miter joints tight, as shown in **Figure G**.
12. Slide the top in the end that you crosscut. Take the small cutoff and see where it should go. Slide the top out and glue and tape this piece in place, as shown in **Figure H**.


F

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G

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H

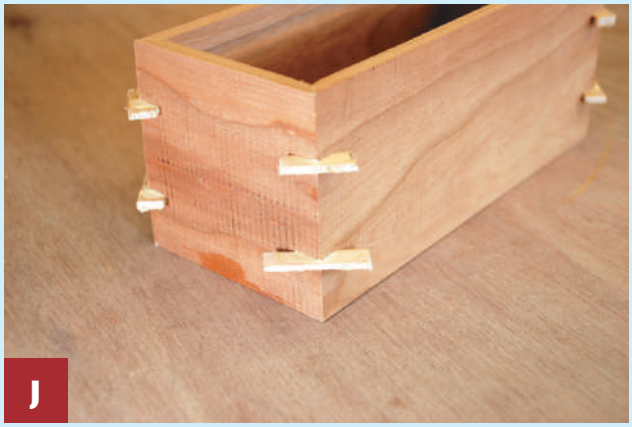
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13. When the glue is dry, remove the tape.
14. Make cuts in the corners of the box with a splining jig, as shown in **Figure I**. Cut at least two splines per corner, being careful not to cut into the bottom or into the slot that the top will fit into.
15. Using the leftover stock from the top and bottom pieces, mill it to fit snugly into the kerfs you made with the splining jig. Cut these pieces longer than necessary, and glue them into the slots, as shown in **Figure J**.
16. When the glue is dry, trim and plane the splines flush.
17. Sand and finish the box.
18. See how many people can figure out how to open it.

BUILD IT!

PROJECT CHALLENGE

Hand-Dovetailed Box

A completed hand-dovetailed box is shown in **Figure A**.

STEPS

1. Select straight-grained stock and mill all the pieces except for the top to size according to the assembly list given in **Figure B**.



A

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Assembly list – dovetailed box

Part	Dimensions (thickness × width × length)	Quantity
Side	$^1/_2$" × 4" × 10"	2
End	$^1/_2$" × 4" × 5"	2
Bottom	$^1/_4$" × 4$^1/_2$" × 9$^1/_2$" plywood	1
Top	$^3/_4$" × 4" × 10"	1

B

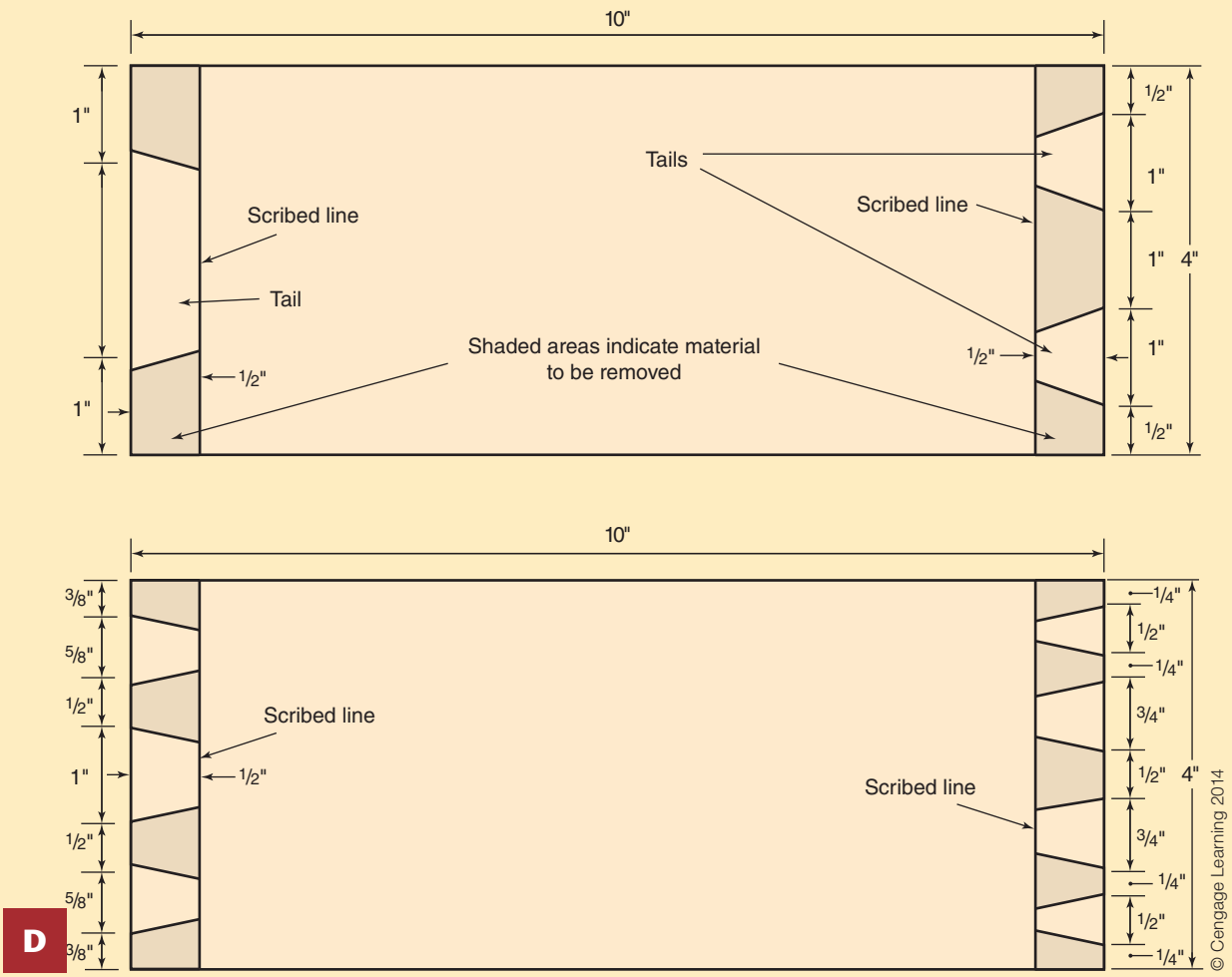
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C

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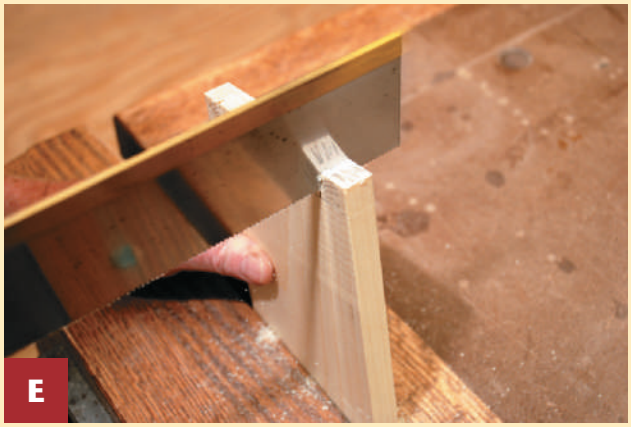
2. Review Procedure 15-4. Score a line around the ends of each of your four box pieces using a marking gauge at 1/2″ in from each end, as shown in **Figure C**. A square and knife may also be used.
3. Take the two long pieces, and lay out the tails, as shown in **Figure D** using a sliding T-bevel or a dovetail gauge. The layout shown is just a suggestion; feel free to vary the spacing and size of your tails. Mark the area to be removed.



D

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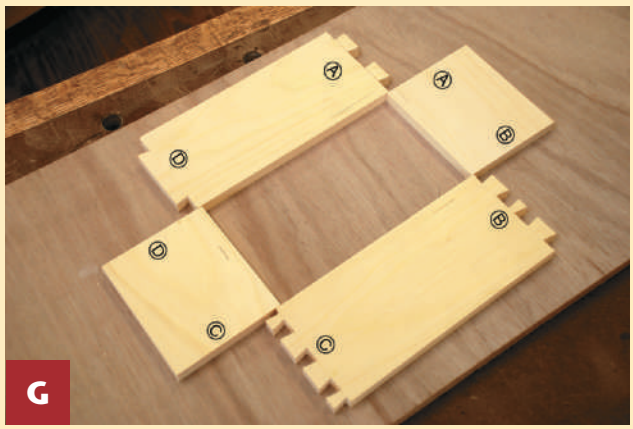
4. Square the lines you just made across the end of the board and again shade the area to be removed.
5. Turn the board on its side and use the saw to cut out the waste on the edge. Repeat for the other side.
6. Use a dovetail or dozuki saw to cut along the lines just marked, as shown in **Figure E**. You can tilt your piece in the vise so you are cutting straight down. Make the cut on one side of each tail, and then tilt the board the other way and make the second cut on each tail.
7. Secure each piece to the bench in turn, and chop out the waste, as shown in **Figure F**. Remove half the waste from one side, then flip the board over and remove the rest from the other side.
8. When all the dovetails are cut, arrange the box pieces on the bench, marking each corner, as shown in **Figure G**.


E

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F

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G

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H

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I

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J

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9. Carefully trace the tails of each side onto the end of each adjacent piece, as shown in **Figure H**. Shade the area to be removed.
10. Square down the lines marked on the ends of the pieces you just laid out to the scored line. Again, shade the area to be removed (see **Figure I**).
11. Using the same procedure as when you cut the tails, make the cuts on the end pieces and remove the waste.
12. Check the fit of each corner, paring to fit as necessary.
13. Use the table saw to mill a 1/4″ × 1/4″ groove 1/4″ up from the bottom of the box for the bottom.
14. Sand the inside of the pieces and the bottom, and glue and clamp the box together. Make sure it is square.
15. Make 1/4″ × 1/4″ plugs for the holes, where the groove for the bottom shows on the sides. Cut long and glue in place, as shown in **Figure J**.

16. Measure the outside dimensions of the box and mill the top to that size.
17. Select a profiling router bit that you like, and rout that profile on the top piece, as shown in **Figure K**.
18. Create a rabbet on the bottom of the top piece that is just over 1/2″ wide and 1/4″ deep, as shown in **Figure L**. This can be done on the table saw with a dadoing blade and a sacrificial fence or on the router table with a straight bit.
19. Check the fit of the top. If it will not quite fit or is too snug, widen the rabbet on the bottom slightly and try again until the fit is good.
20. Cut off the protruding plugs, sand the box and the top, and finish as desired.


K

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L

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16

Frame Joints

You'll Learn

After studying the chapter, the student should be able to:

- Define a frame joint
- Identify the uses for frame joints
- List the various types of frame joints
- Discuss the advantages and disadvantages of the different frame joints

INTRODUCTION

Joints used in the construction of frames are called **frame joints**, which are typically built by joining boards end to edge. This means that the end of one board is being connected to the edge of another, so two different types of grain, end grain and edge grain, are coming together. Frames are built to be used as face frames, in frame-and-panel construction, and as web frames. Frames are also built to serve as picture and mirror frames. Types of frame joints include butt, miter, half-lap, groove-and-stub tenon, cope-and-stick, slip, and various mortise-and-tenon joints.

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USES FOR FRAMES

Frames have three main uses in cabinet construction. For one, they serve as **face frames**, which are used to finish the front of a case, both stiffening it and setting off areas for doors and drawers (see **Figure 16-1**).

Second, frames are used in frame-and-panel construction. Frames are built to hold panels, which may be flat or raised. These frame-and-panel constructions may serve as case elements, which are the sides, backs, or tops of cabinets. They are also very commonly used as doors for such cases (see **Figure 16-2**).

The third use of frames is as **web frames**. Web frames are installed inside a case, tying the case together and supporting and separating drawers. Their most common use is in chests of drawers (see **Figure 16-3**).

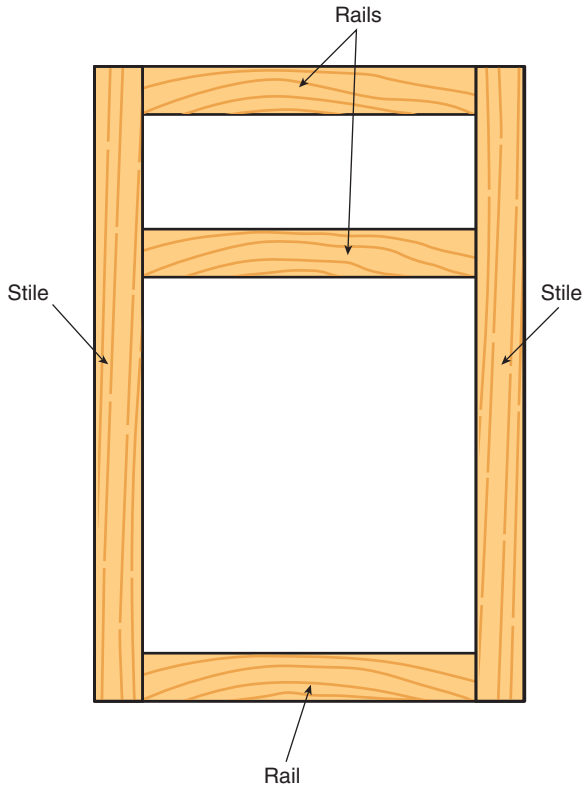


FIGURE 16-1 Face frame.

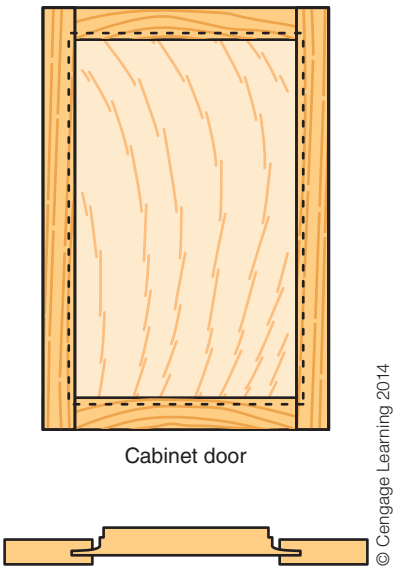


FIGURE 16-2 Frame-and-panel construction.

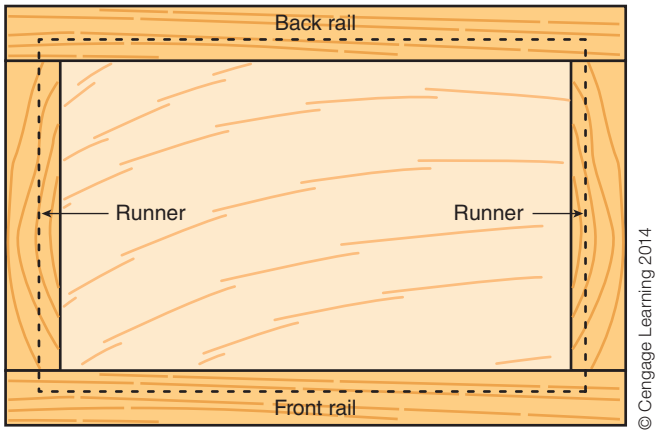


FIGURE 16-3 Web frame.

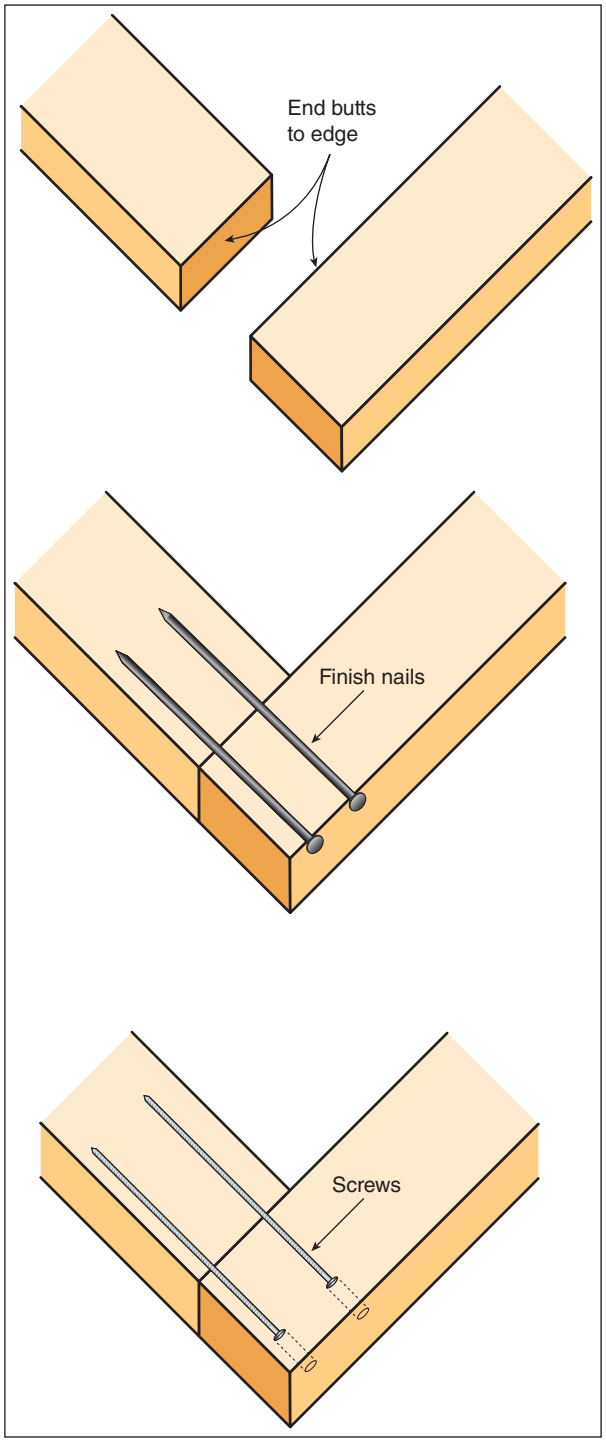
TYPES OF FRAME JOINTS

Types of frame joints range from the humble butt joint to the mighty mortise-and-tenon joint. In this section, we will look at a series of frame joints, starting with the butt joint.

Butt Joint

A **frame butt joint** joins the end of one piece to the edge of another. It requires reinforcement of some

kind. This reinforcement may include fasteners, such as nails or screws (see **Figure 16-4**). A **pocket-hole joint** is another type of butt joint reinforced by screws, which are installed from the back of the frame (see **Figure 16-5**). Alternatively, a butt joint may be reinforced by dowels or biscuits, as shown in **Figure 16-6**.



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FIGURE 16-4 A butt joint may be reinforced with fasteners, such as nails or screws. If counterbores are drilled, the screws can be hidden with plugs.

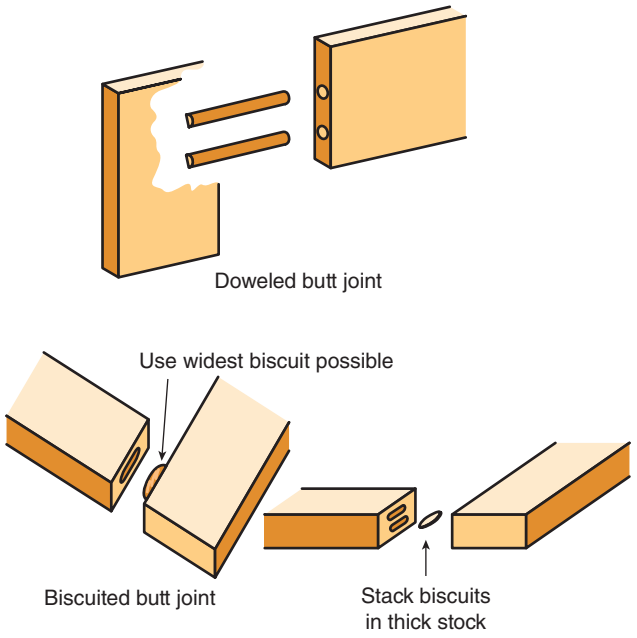
Miter Joint

Mitered frame joints form a neat right-angle corner, and if they fit well, the seam is almost indiscernible. Adjoining members are each cut at a 45° angle. They have the advantage of leaving no end grain exposed. They also differ from butt joints in that where butt



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FIGURE 16-5 Pocket-hole joint. Rear: Viewed from back. Front: Viewed from front.



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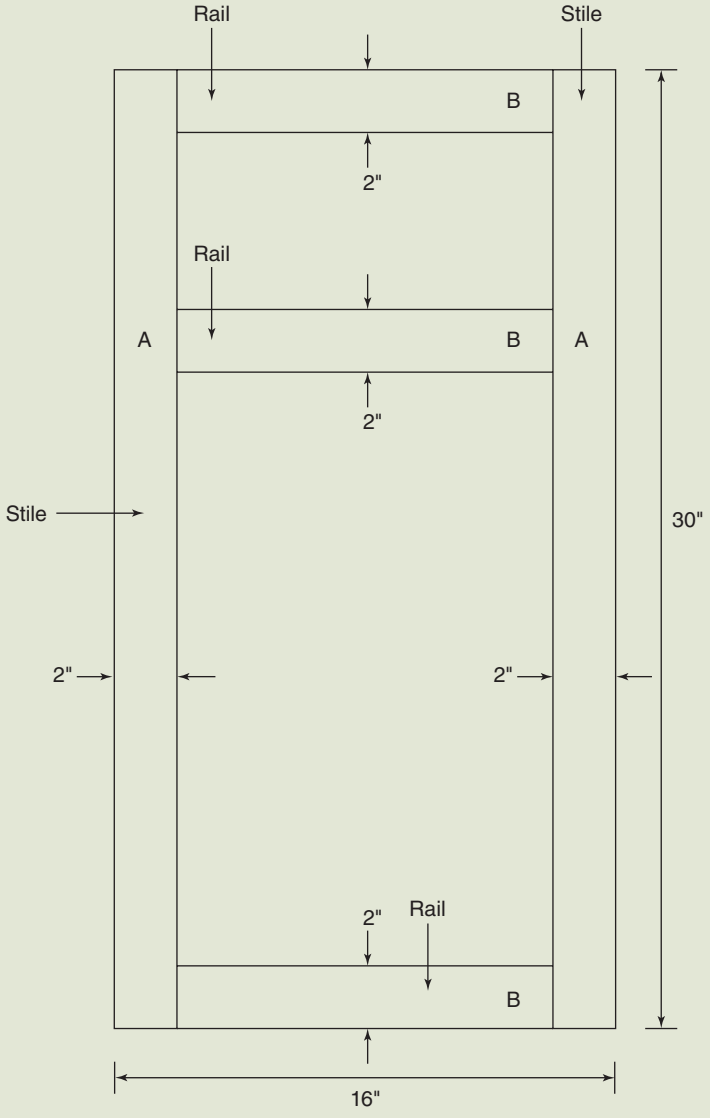
FIGURE 16-6 Dowels or biscuits can be used to reinforce a butt joint.

PROCEDURE 16-1

Creating a Pocket Joint

STEPS

1. Cut the frame pieces to size. Since this is a butt joint, no extra material is required. See **Figure A** for example.

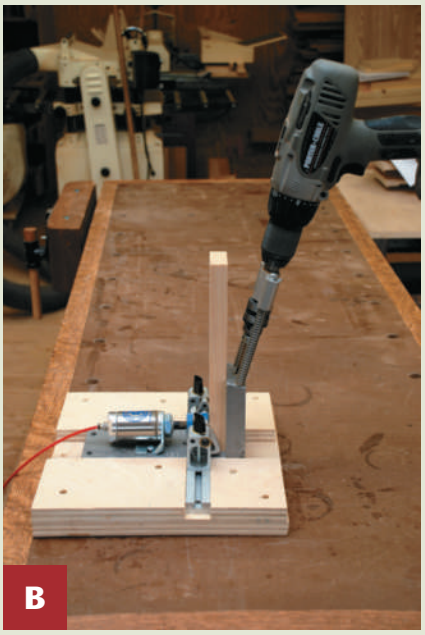


Stiles (A) = Frame length
= 30"

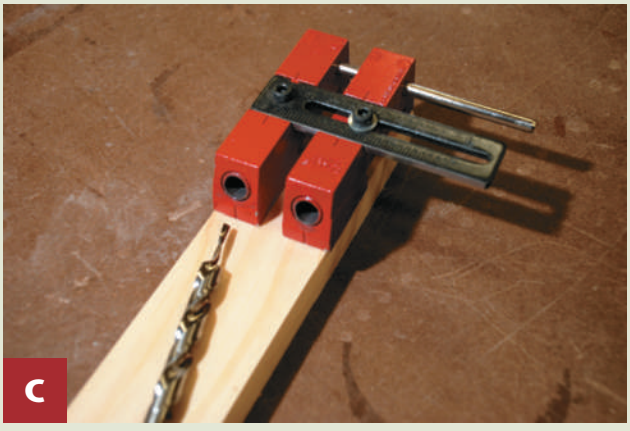
Rails (B) = Frame width − (Stile width × 2)
= 16" − (2 × 2")
= 16" − 4"
= 12"

A

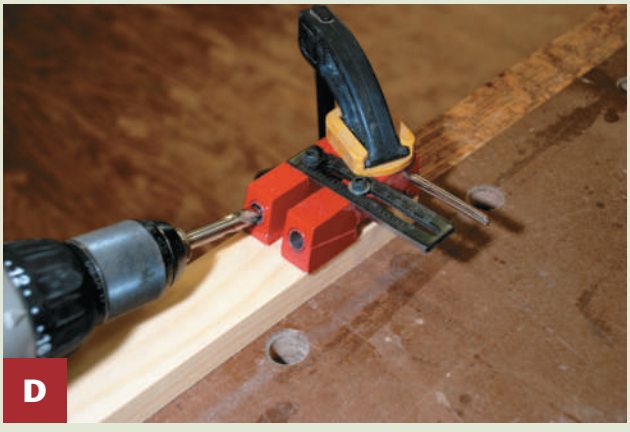
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2. Place the piece through which the screws will be driven into the jig, or attach the jig to that piece. Pocket-hole jigs differ. **Figure B** and **Figure C** show two types of pocket-hole jigs.
3. With the special stepped drill bit that comes with the jig, drill two holes through the piece mounted in the jig, as shown in **Figure D**. This bit drills a pilot hole and a recess for the screw head, as well as creating room for the drill bit that drives the screw.

4. Place the two pieces to be joined on a flat surface and clamp. Clamps have been developed specifically for this purpose, as shown in **Figure E**.
5. Drive self-tapping pan-head pocket-hole screws through the piece you drilled into the mating piece, as shown in **Figure F**. Note that you need a long driver to do this.



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joints join end grain to edge grain, the grain seen in frame miter joints is midway between end grain and edge grain on both pieces. **Figure 16-7** shows a frame miter joint, sometimes called a *flat miter.* The flat miter is the joint most often used when building picture frames.

Miter joints, like butt joints, have the disadvantage of being structurally weak. They are also difficult to assemble, because a mitered corner starts to slide out of line when you apply clamping pressure to it. Miter joints can be reinforced with nails, dowels, pocket screw joinery, biscuits, splines, or various types of keys. Keys are very effective and can be decorative. **Figure 16-8** through **Figure 16-16** illustrate different reinforcement methods for miter joints. Corrugated fasteners and chevrons, covered in Chapter 7, can also be used to reinforce frame miter joints.

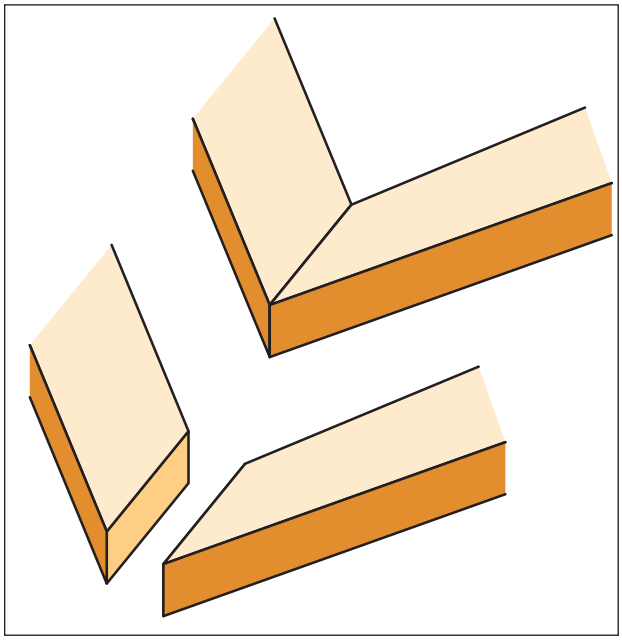
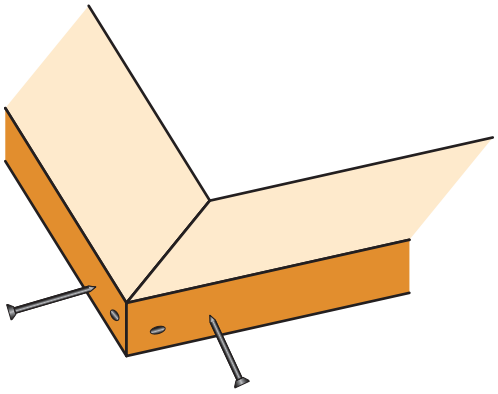
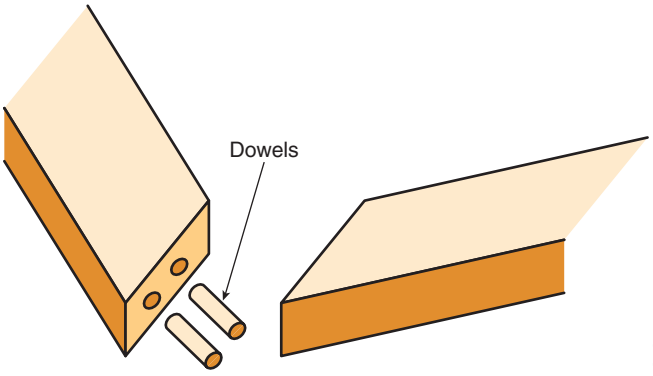

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FIGURE 16-7 Miter joint.



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FIGURE 16-8 Nailed miter joint.



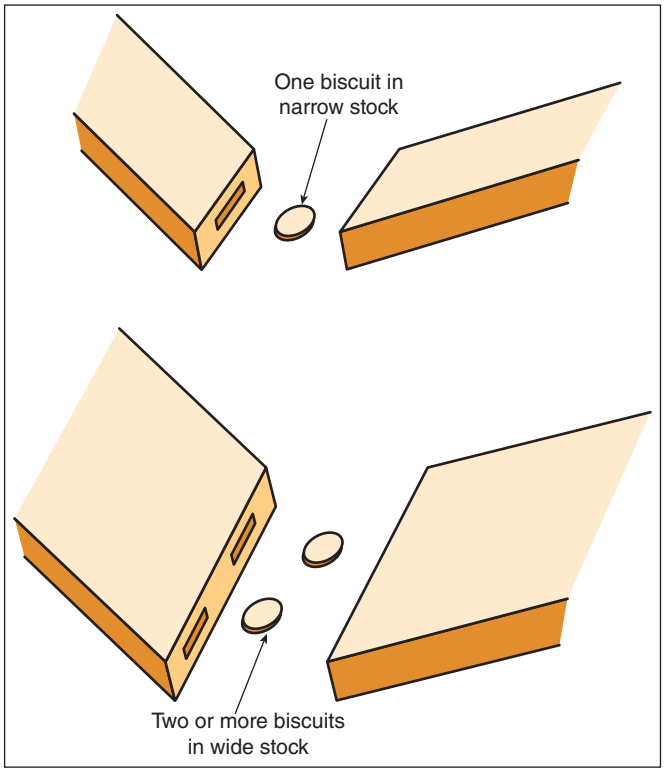
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FIGURE 16-9 Dowelled miter joint.



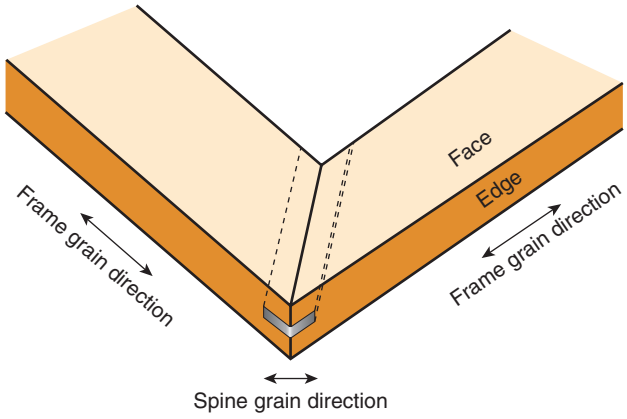
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FIGURE 16-10 Miter joint reinforced with pocket hole joinery.



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FIGURE 16-11 Miter joint reinforced with biscuits.



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FIGURE 16-12 Splined miter joint.

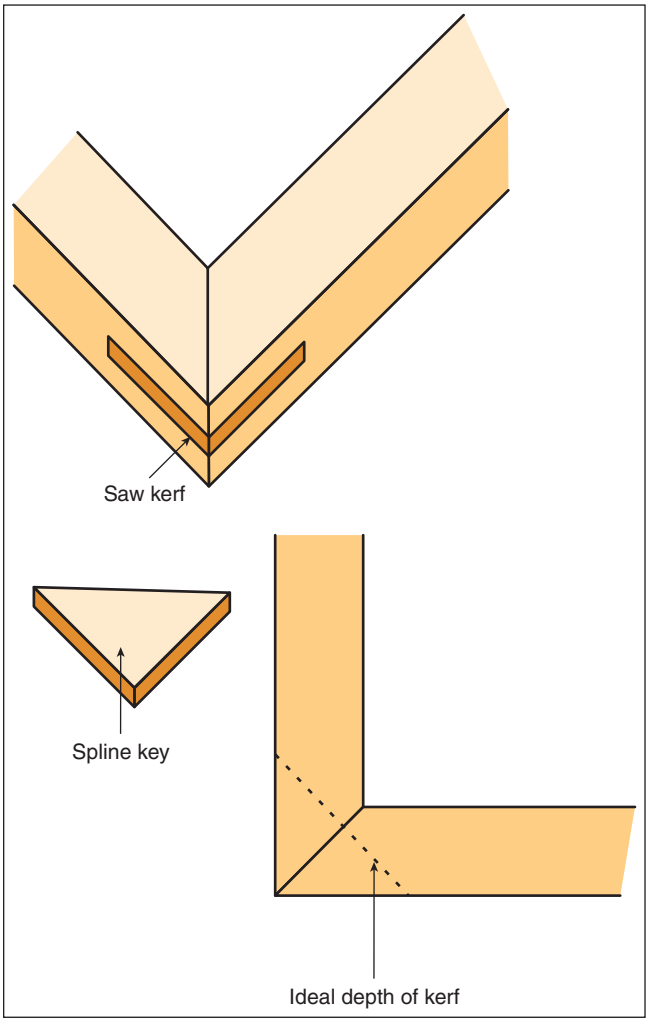


FIGURE 16-13 Miter with spline key.

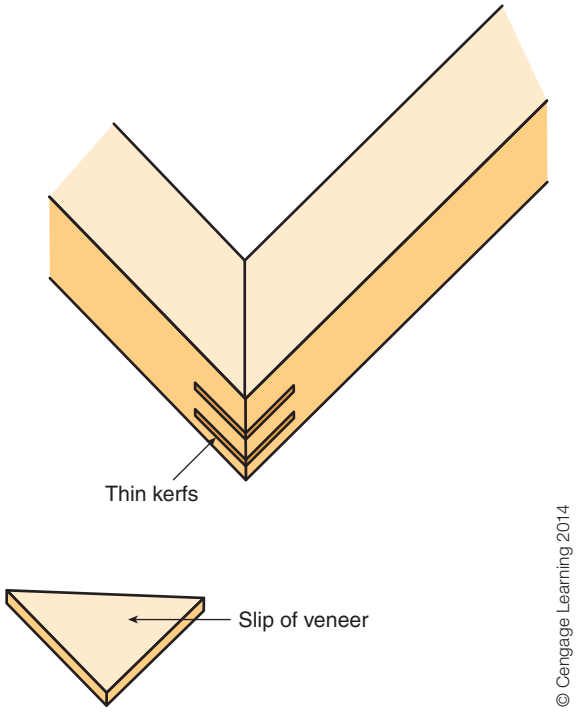


FIGURE 16-15 Miter with feather keys.

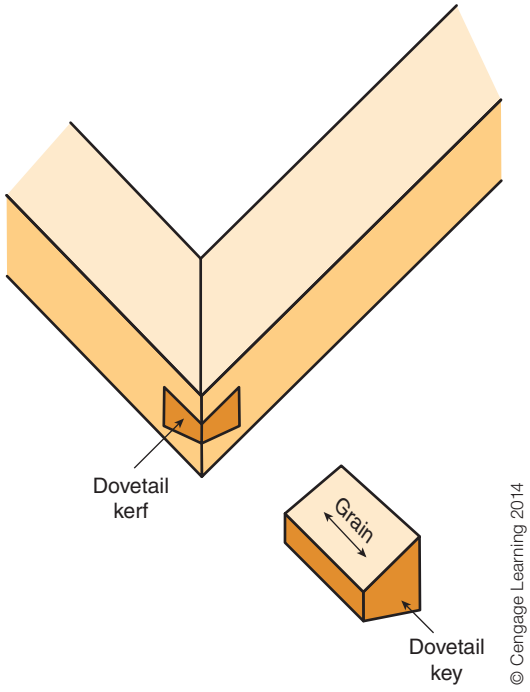


FIGURE 16-14 Miter with dovetail key.

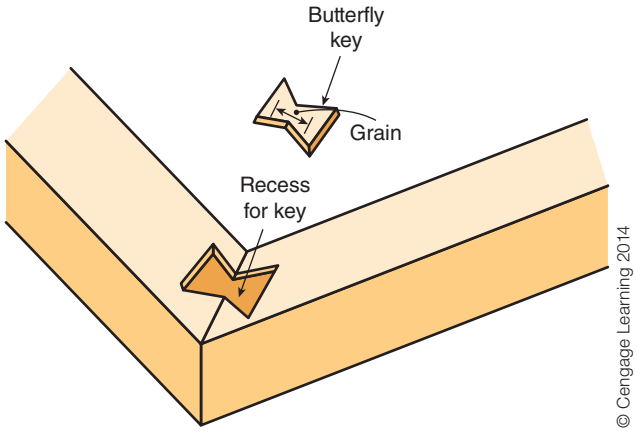


FIGURE 16-16 Miter with butterfly key.

WOODWORKING TIP:

Miter joints can be cut on the miter saw, but they can also be cut very effectively on the table saw. A sled made for this purpose ensures good square miter joints every time (see **Figure 16-17**). *Each piece is cut by placing it flat on the sled and moving the sled past the saw blade, which is set at 90° to the table. Stops can be clamped to the sled fences for cutting multiple pieces the same length.*

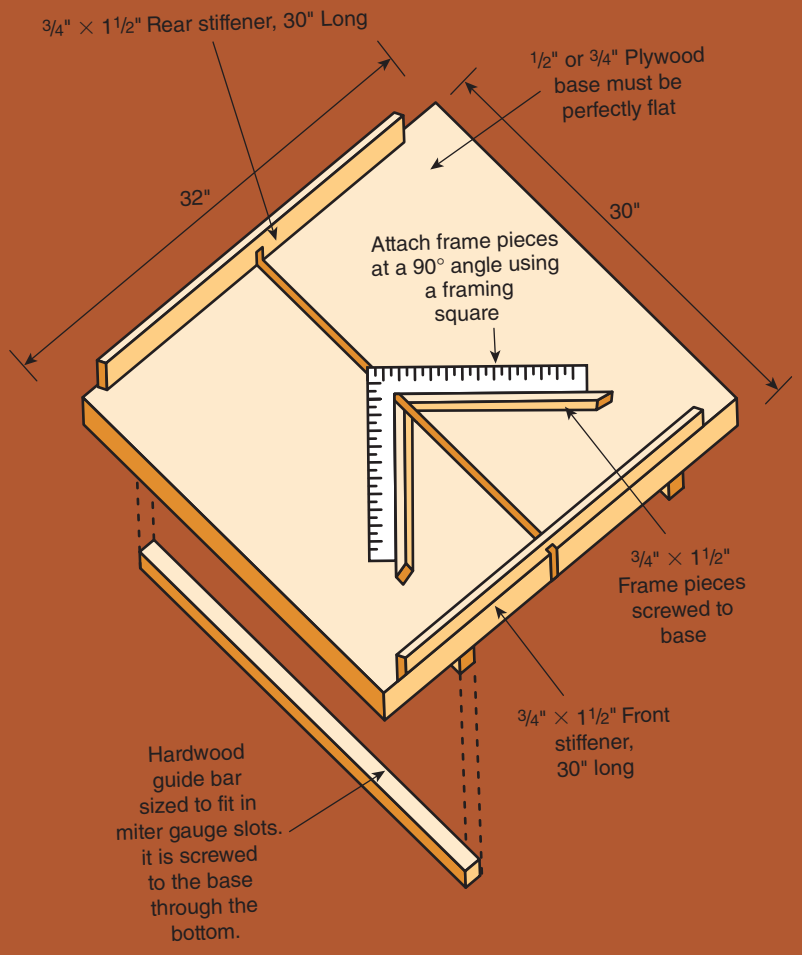
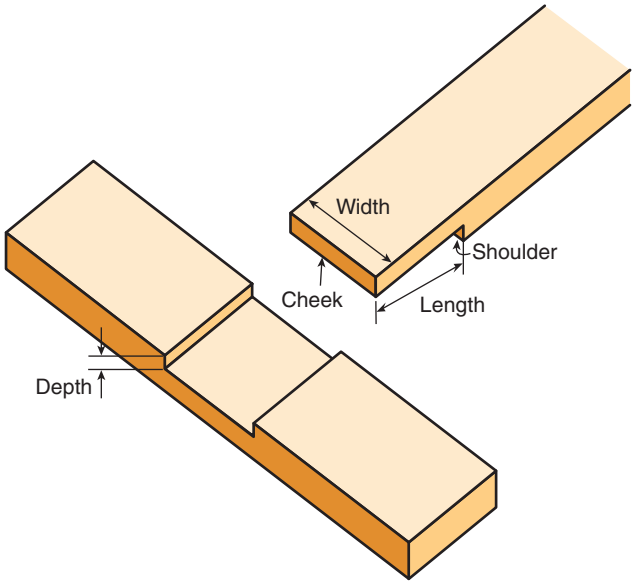


FIGURE 16-17 Mitering sled for table saw.

Half-Lap Joint

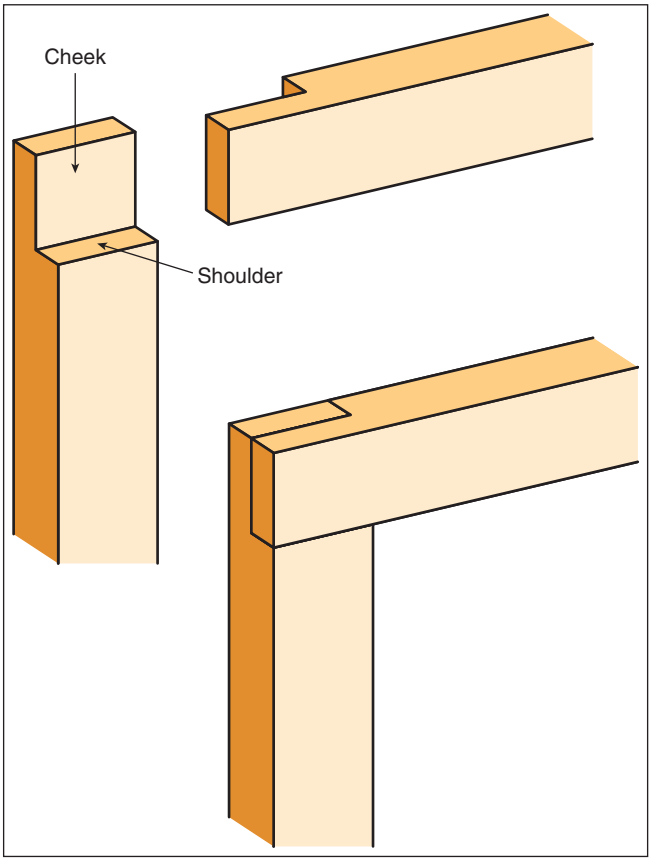
The **half-lap joint** is another frame joint. Each member is notched to accept the other. Half the thickness of the material is removed from the face of one piece and from the back of the other (see **Figure 16-18**).

Lap joints are quite simple, but they can be very strong if properly made. Care must be taken in their construction so that the assembled joint is flush. Lap joints may meet to form an L, a T, or an X. An L shape is an end lap (see **Figure 16-19**, **Figure 16-20**, and **Figure 16-21**).



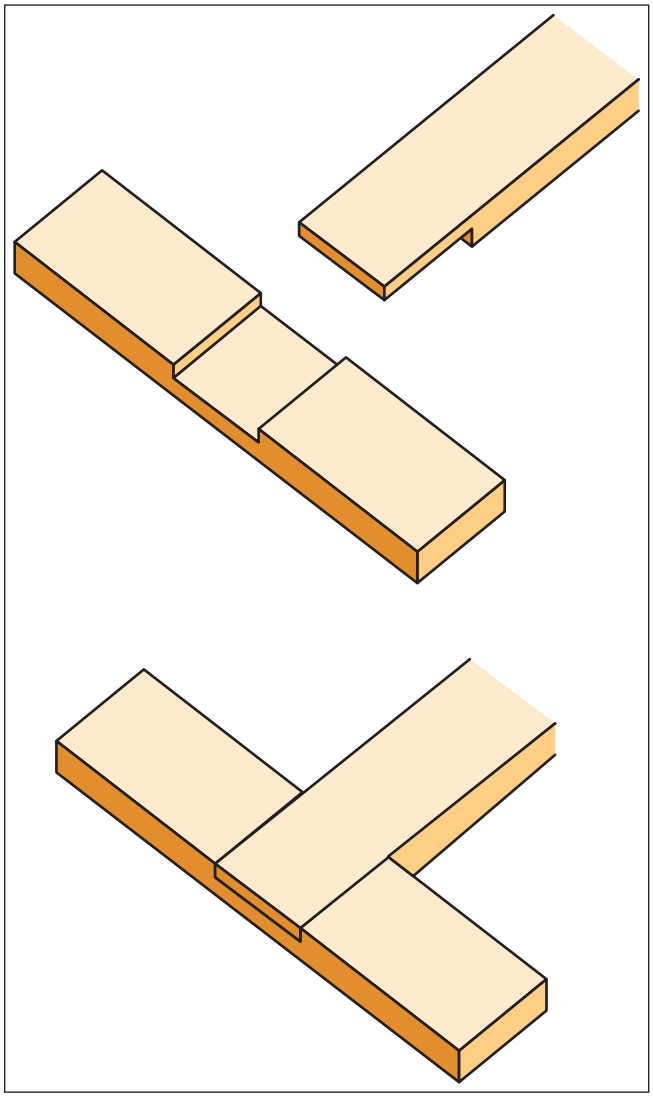
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FIGURE 16-18 Half-lap joint.



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FIGURE 16-19 End, or L lap.



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FIGURE 16-20 T lap.

CAUTION

Never reach over a spinning saw blade to remove cutoffs. Wait until the blade has stopped turning, and then push scraps off the table with a stick.

Another lap joint that gives the appearance of a flat miter but offers the strength of a lap joint is the **mitered half lap** (see **Figure 16-22**).

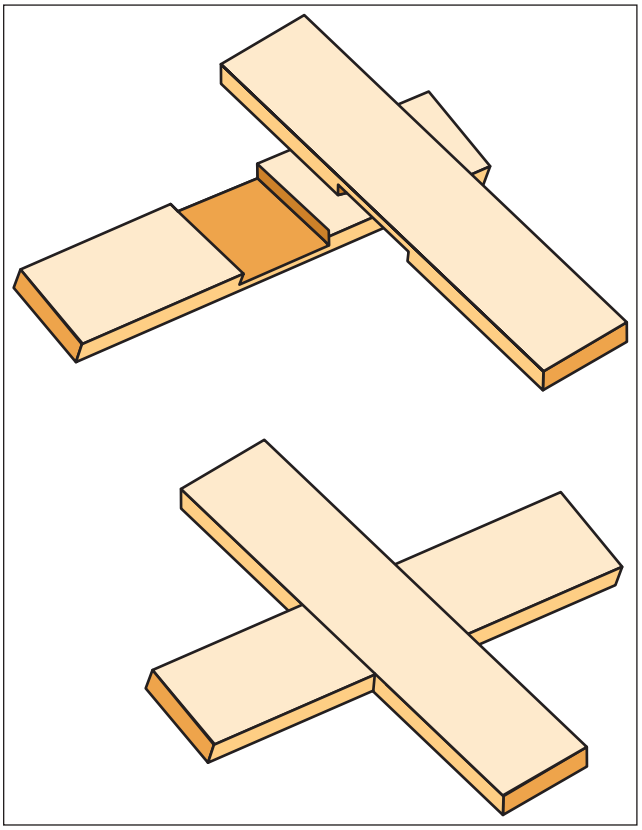

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FIGURE 16-21 X, or cross lap.

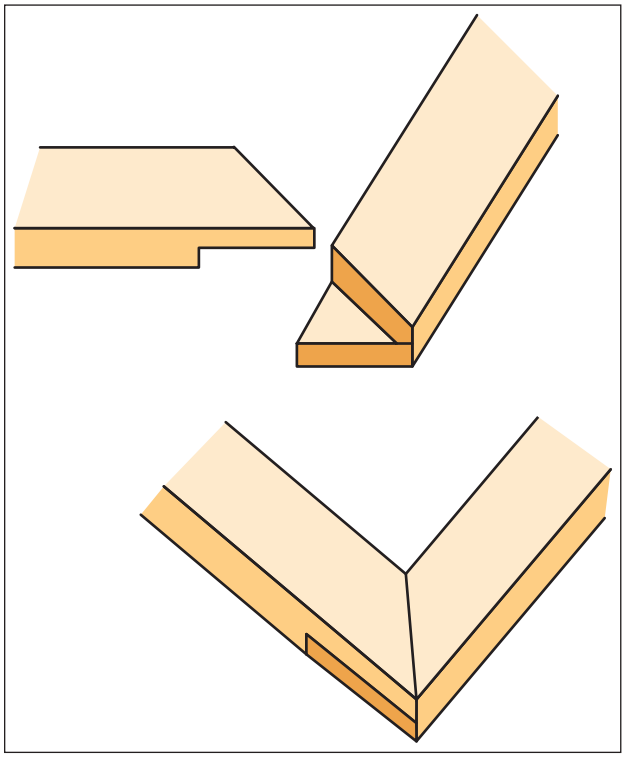

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FIGURE 16-22 Mitered half-lap.

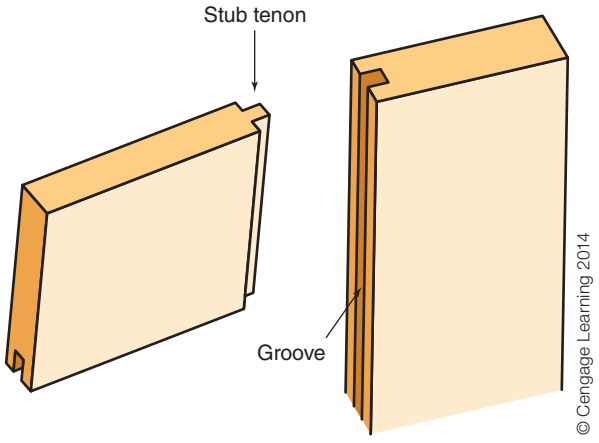
Groove-and-Stub Tenon Joint

The **groove-and-stub tenon joint** is a fairly light-duty joint, appropriate for building frames that will be part of a case, or for cabinet doors that are not subject to a lot of stress. A short tenon is milled in one piece to fit into a groove machined in the mating piece, as shown in **Figure 16-23**.



FACTS ABOUT WOOD

Poplar, *Liriodendron tulipfera,* is found primarily in the eastern United States and Canada. It is also called *American whitewood, canoe wood, tulip poplar,* and *yellow poplar.* It has a straight grain and a fine, even texture. The sapwood is white, and the heartwood is pale brown with green or dark brown streaks. It works easily and finishes well and is used for furniture and cabinetwork, carving, and musical instruments. ■



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FIGURE 16-23 Groove-and-stub tenon.

Cope-and-Stick Joint

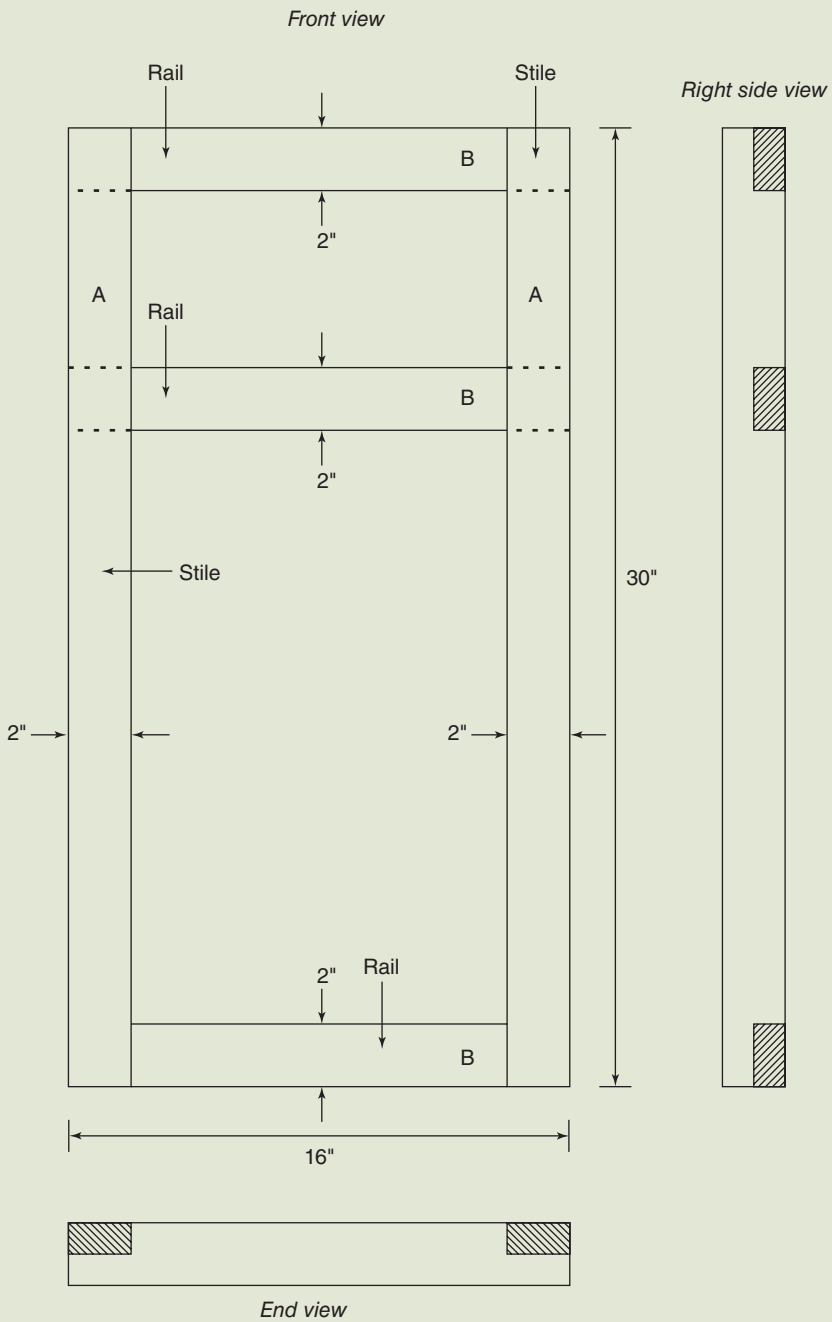
The **cope-and-stick joint** is a more elegant version of the groove-and-stub tenon joint, and a stronger one because it offers more gluing surface. Like the groove-and-stub tenon joint, it is typically used in frames for frame-and-panel construction. The cope-and-stick joint requires special router bits that are used in a router table or special cutters for the shaper.

PROCEDURE 16-2

Machining a Half-Lap Joint

STEPS

1. Cut the pieces to the sizes required. This joint requires more material than a simple butt joint. **Figure A** shows how to compute component sizes.
2. Lap joints can be made in a number of different ways: using a table saw and tenoning jig, with a router and straight bit, with a dado blade, on the band saw, by making multiple passes on a miter saw, or with a handsaw. The method demonstrated here uses a dado blade on the table saw. Mount a dado blade set for its greatest width on the table saw, and raise it so the amount of blade protruding from the table is equal to one-half the thickness of the material being machined.



Stiles (A) = Frame length
30"
Rails (B) = Frame width
16"

A

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3. Lay out the joint carefully on a test piece. If the width of all the component pieces is the same, this will only need to be done on one piece, as shown in **Figure B**.
4. Adjust the rip fence so that the far side of the blade will cut just inside your layout line, when the board is butted against the fence (See **Figure C**).
5. Support the test piece with the miter gauge and run it (see **Figure D**). After making one pass, move the piece to the left and run it again. Continue to do this until you reach the end of the piece, as shown in **Figure E**.
6. Repeat Step 5 with a second test piece, and then check the fit of the two pieces. They should be flush with each other and meet squarely at the ends, as shown in **Figure F**. Adjust the fence if the two pieces do not match at the ends, and adjust the blade height if they are not flush. Continue to run test pieces until you are satisfied with the fit, and then run your finish pieces.



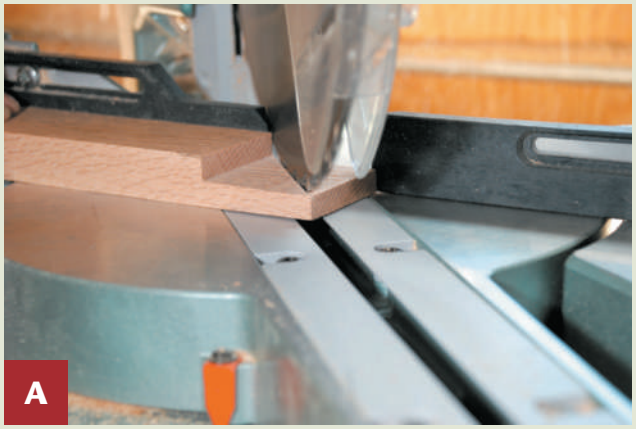
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PROCEDURE 16-3

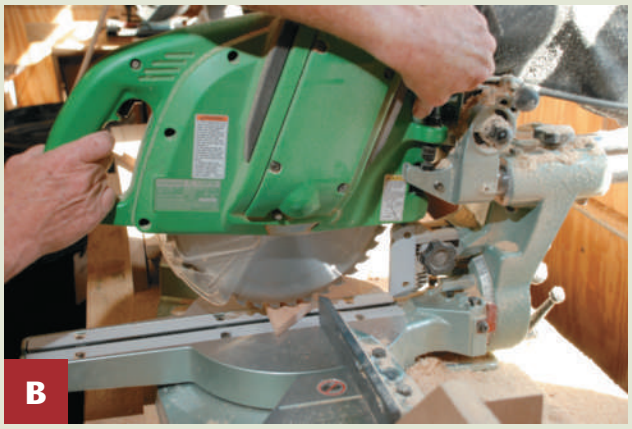
Making a Mitered Half-Lap Joint

STEPS

1. Set up the table saw as if you were going to make a half-lap joint. Refer to Procedure 16-2.
2. Take one of the two pieces that will form the corner and mill a half lap on it.
3. Take the piece that you just machined to the miter saw and cut a miter on the same end that you created the half lap, as shown in **Figure A**.
4. Using the piece with the half lap as a guide, set the depth stop on the miter saw so that the saw will only cut down as far as that half lap, as shown in **Figure B**.
5. Take the other piece that will form the corner to the miter saw; swing the saw so that it will cut the mating miter to the first piece. Make the miter from the corner, as shown in **Figure C**.



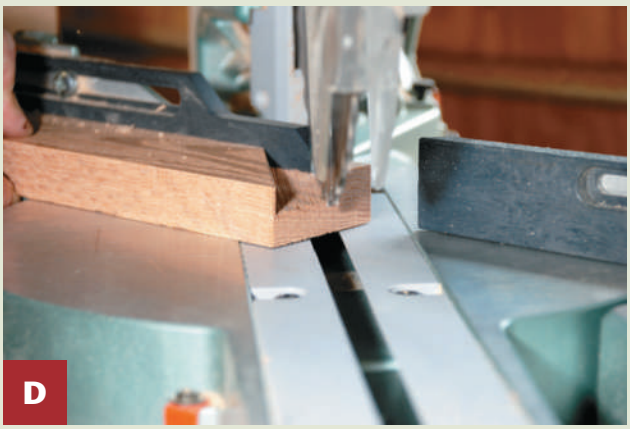
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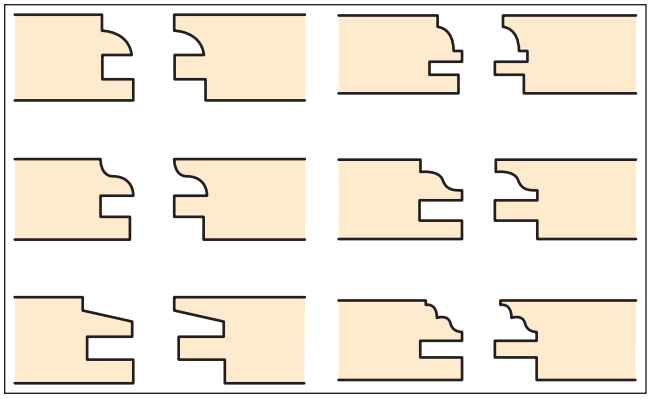
6. Remove the rest of the material by moving the piece and taking successive cuts on the miter saw, as shown in **Figure D**.
7. Use a chisel to remove any ridges left by the miter saw, and check the fit of the joint. If necessary, adjust the depth stop on the miter saw until you get the desired fit, as shown in **Figure E**.

A groove and decorative edge are milled on all the frame pieces using the same setup. The **rails**, the horizontal members of the frame, receive a second cut on their ends, which requires a different bit or cutter. This cut forms a tongue and a reverse of the decorative profile. With the proper setup, this tongue will fit perfectly into the groove on the **stile**, and the rail end will conform exactly to the profile, as shown in **Figure 16-24**. **Figure 16-25** illustrates various cope-and-stick profiles.



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FIGURE 16-24 Two different cope-and-stick joints.



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FIGURE 16-25 Some cope-and-stick profiles.

PROCEDURE 16-4

Machining a Groove-and-Stub Tenon Joint

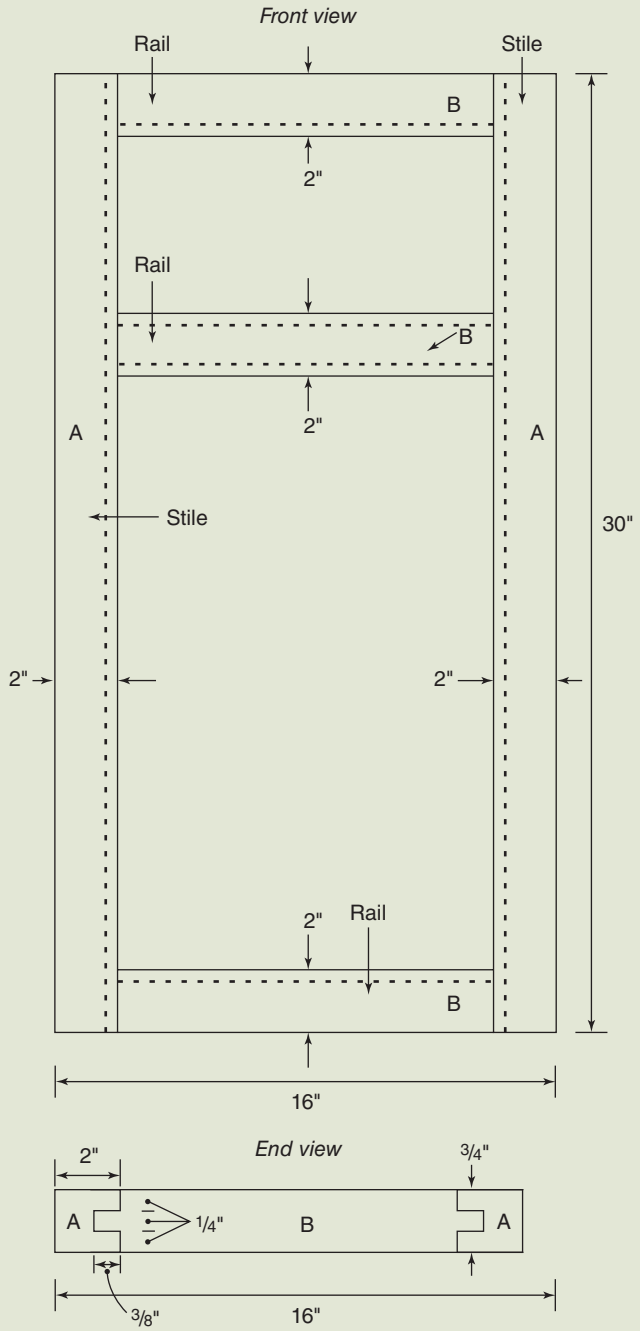
STEPS

1. Determine the sizes of the component pieces. **Figure A** shows one example.
2. Make a centered groove on a test piece that is the same thickness as your finish pieces. Raise the blade of the table saw to the desired groove depth. Mark the center of the piece's thickness, and set the rip fence so that the blade will cut just on the side of your mark (see **Figure B**).



B

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Stiles (A) = Frame length
= 30"

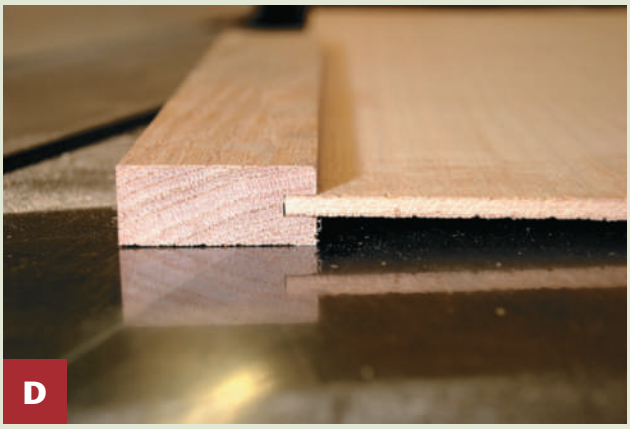
Rails (B) = (Frame width − 2 stiles) + 2 tenons
= 16" − (2 × A) + (2 × 3/8")
= 16" − (2 × 2) + 3/4"
= (16" − 4) + 3/4"
= 12 + 3/4"
= 12 3/4"

A

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3. Run the piece; flip it so that the opposite face is against the fence, and run it again (see **Figure C**). Check the depth of the groove and adjust the blade height as needed. Now check the width of the groove. Do this by testing it with the material that will be used for the panel. The fit should be snug, but not overly tight (see **Figure D**). If the fit is too loose, move the fence slightly toward the blade. If too tight, move it slightly away from the blade. Remember that every bit you move the fence is doubled in the groove, because two passes are made. Once you are satisfied, run the grooves on the inside of the two stiles and the top and bottom rails. If there is a middle rail, as in the example shown in Figure A, it gets grooves on both edges.
4. Cut your final correct test piece in half. You will use it for the next setup. Put a dado blade on the table saw, setting its width so that it is the same as the depth of the groove. In our example, the groove is 3/8" deep, so we will use a 3/8"-wide dado blade. Use one of the test pieces as a gauge to set the height of the blade, as shown in **Figure E**. The blade height is set so that it is just shy of cutting into the groove.

5. Clamp a sacrificial fence to the rip fence, and bring the fence right over next to the blade.
6. Using one of the test pieces supported by the miter gauge, and with its end against the fence, make a cut. Then flip it over and make a second cut (see **Figure F**).
7. Check the fit of the resulting stub tenon in the groove of the other test piece. The tenon should bottom out in the groove, and the joint should pull tight (see **Figure G**). If the tenon is too long, move the fence in toward the blade. If it is too short, move the fence away from the blade. The fit of the tenon in the groove should be snug. If it is too tight, raise the blade a bit. Remember that you are taking equal amounts off each side. If the fit is too loose, lower the blade. Keep testing until you have a good fit, and then machine all the pieces that require tenons.


F

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G

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WOODWORKING TIP:

Properly setting up bits or cutters for a cope-and-stick joint takes time. Once you have test pieces that fit well, mark them as templates. Then, each time you set up for this joint in the future for the same thickness of material, you can use these template pieces to speed the set-up process.

Slip Joint

There are two basic kinds of slip joints. When the end of one piece is joined to the end of another piece, it is called a **slip joint**. When the end of one piece is joined to the middle of another piece, it is called a **bridle joint**. In each case, a recess is milled into one piece, and the other piece has material removed so that what remains slips into a recess machined in the other piece. This joint offers a great deal of gluing surface and is very strong. **Figure 16-26** and **Figure 16-27** show illustrations of slip and bridle joints.

CAUTION

Avoid distractions when using woodworking tools. Keep your eyes and attention on the task you are performing.

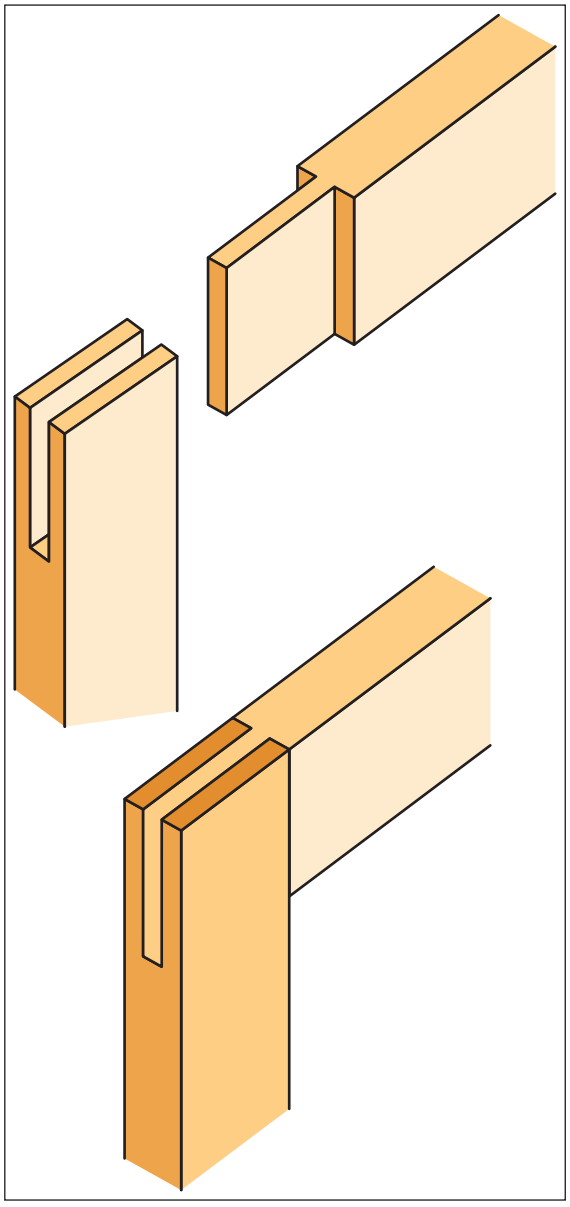

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FIGURE 16-26 Slip joint.

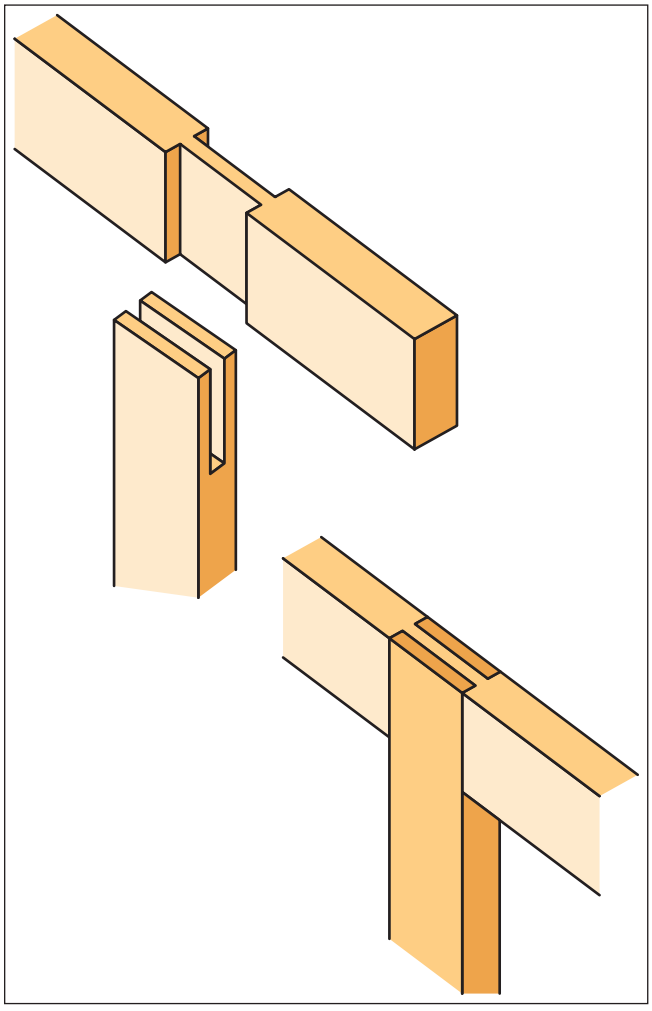
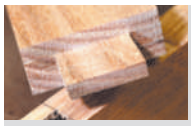

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FIGURE 16-27 Bridle joint.

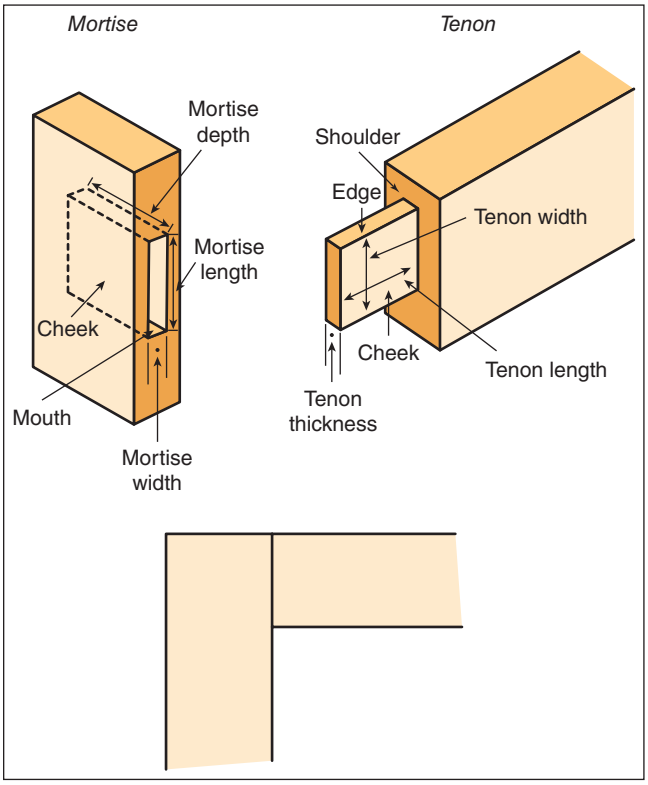
Mortise-and-Tenon Joint

The **mortise-and-tenon joint** is woodworking's essential frame joint, in the same way that the dovetail joint is the ultimate case joint. The mortise-and-tenon is an exceptionally strong joint and also a very ancient one. It has many variations, some of which will be explored here. In each instance, however, the basic components are the same. The mortise is a hole, which may be round, square, or rectangular. The tenon is a tongue milled on the end of the joining member to fit inside the mortise. The names for some parts of the joint are derived from the human body, as you can see in **Figure 16-28**, which depicts the anatomy of a mortise-and-tenon joint.



HISTORY FACT

Mortise-and-tenon joinery has been used for thousands of years, and not just in woodworking. Stone masons, blacksmiths, and machinists have also made use of this joint. Ancient examples of the mortise and tenon can be observed at Stonehenge, which is over 4500 years old, and in the ruins of ships dating back to 4800 B.C. The Khufu ship found in the Giza pyramid complex, built around 2500 B.C., also shows evidence of mortise–and-tenon joinery. ■



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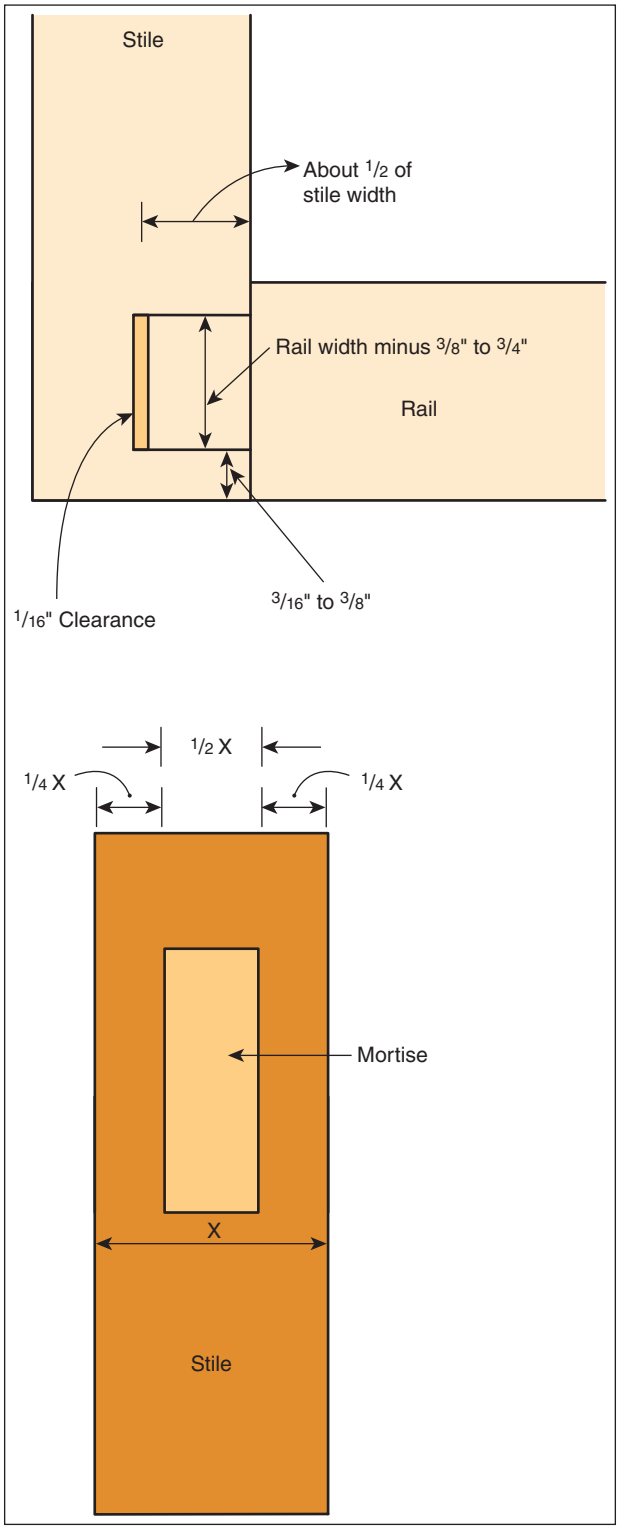
FIGURE 16-28 Blind mortise and tenon.

The mortise-and-tenon joint shown in Figure 16-28 is called a **blind mortise and tenon** or a *stopped mortise and tenon*. Once the tenon is glued into the mortise, there is no sign of the joinery used to construct the corner, and it actually looks like a butt joint. This is the most frequently used of the mortise-and-tenon joints.

Certain guidelines are followed in sizing blind mortise-and-tenon joints. These will give optimum strength to the joint. The length of the tenon is typically half the width of the stock it will be fit into. The tenon should be as wide as possible, but not more than five times the stock thickness, because expansion and contraction across the grain may cause joint failure. When a very wide tenon is needed, two tenons should be made. The thickness of the tenon is typically one-half the thickness of the stock. The mortise should be made about 1/16" deeper than the tenon is long (see **Figure 16-29**).

When creating a mortise-and-tenon joint, it is good practice to make the mortise first, and then fit the tenon to it. The mating surfaces should be as smooth as possible for the best glue bond. The fit of the tenon to the mortise should be snug but not overly tight, to allow some room for glue.

Mortises are best made on a dedicated mortising machine, but mortising chisels can be adapted to the drill press. Alternatively, a series of holes can be



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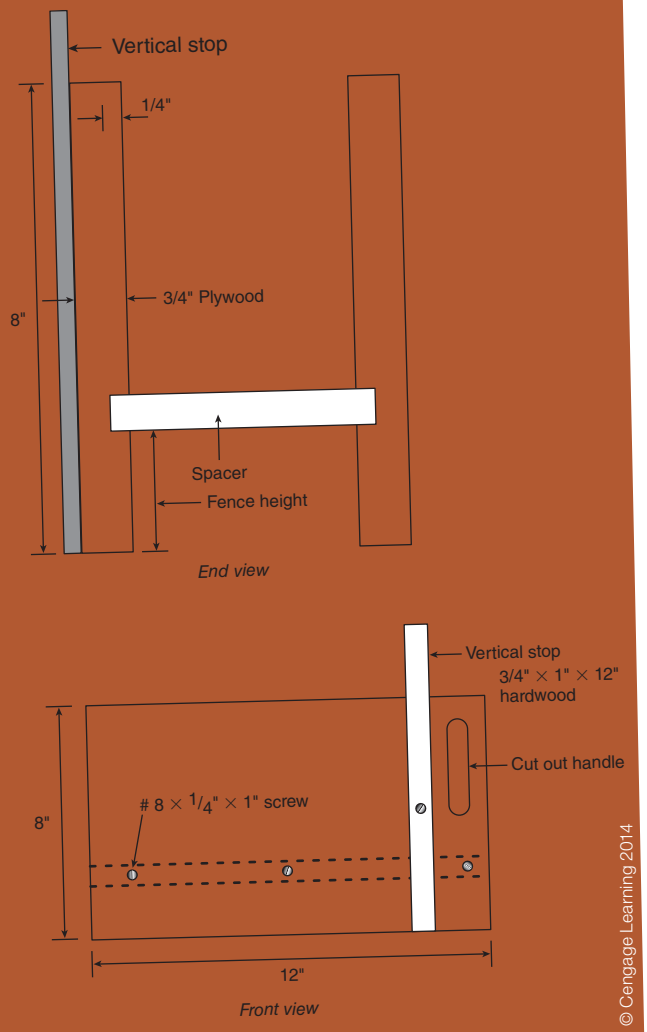
FIGURE 16-29 Mortise-and-tenon guidelines.

drilled in the stock using the drill press, and then the mortise can be squared up with chisels. Tenons are easily made on the table saw with a **tenoning jig**. This jig holds the work piece in a vertical position as the cheek cuts are made. Tenoning jigs may be purchased or made in the shop. Commercial tenoning jigs are

constructed so that they ride in the table saw's miter gauge slot (see **Figure 16-30**). Shop-made tenoning jigs are usually built to butt against or straddle the rip fence (see **Figure 16-31**).

WOODWORKING TIP:

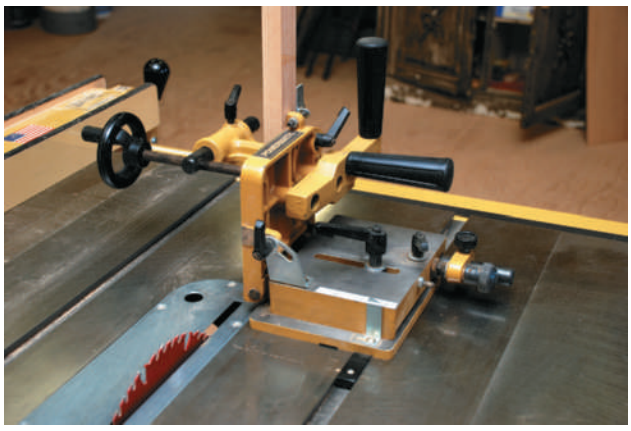
A shop-built tenoning jig is illustrated in **Figure 16-32**.



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FIGURE 16-32 Illustration of a shop-built tenoning jig.

As mentioned earlier, there are many variations on the basic mortise-and-tenon joint. In addition to the blind mortise and tenon, there are *through, haunched, loose, wedged,* and *pegged* mortise-and-tenon joints. The **through mortise and tenon** has a mortise that goes all the way through the stile from edge to edge. In other words, the mortise is open at both ends (see **Figure 16-33**).



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FIGURE 16-30 Commercial tenoning jigs ride in the table saw's miter gauge slot.



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FIGURE 16-31 A shop-built tenoning jig that straddles the rip fence.

CAUTION

Never remove small scraps from the table saw with your fingers. Use a stick to push away small scraps that accumulate near the blade.

A **haunched mortise and tenon** has a tongue that projects from the tenon's shoulder between the edge of the tenon and the edge of the rail. This haunch fits into a through groove milled on the stile. This mortise-and-tenon variation allows the frame maker to run grooves all the way through the stiles instead of making stopped cuts. **Figure 16-34** illustrates a haunched mortise-and-tenon joint.

In a **loose mortise and tenon**, mortises are milled in both pieces to be joined. The tenon is a separate piece of wood. This is a joint most commonly constructed

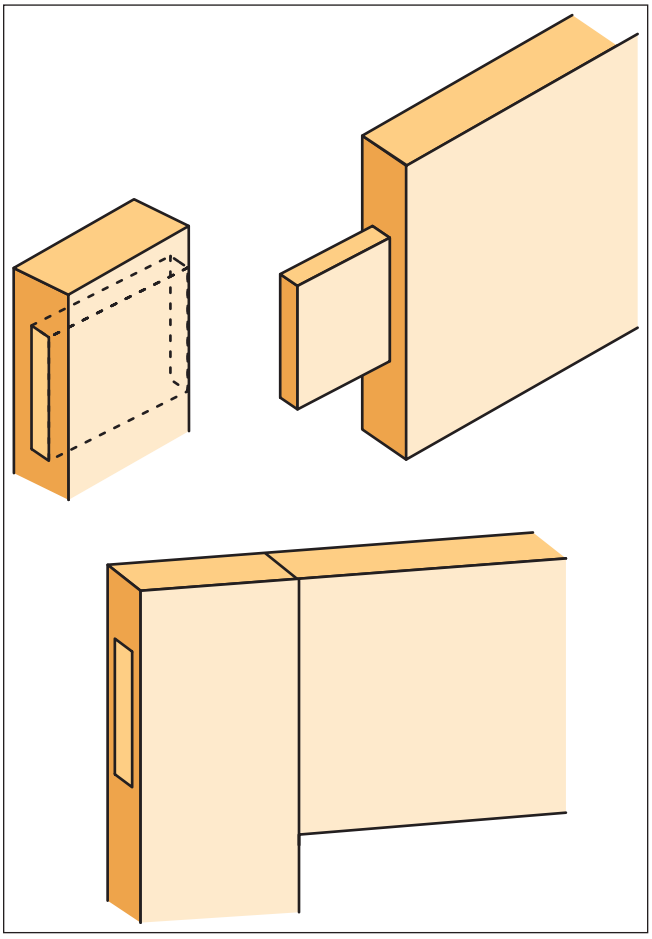
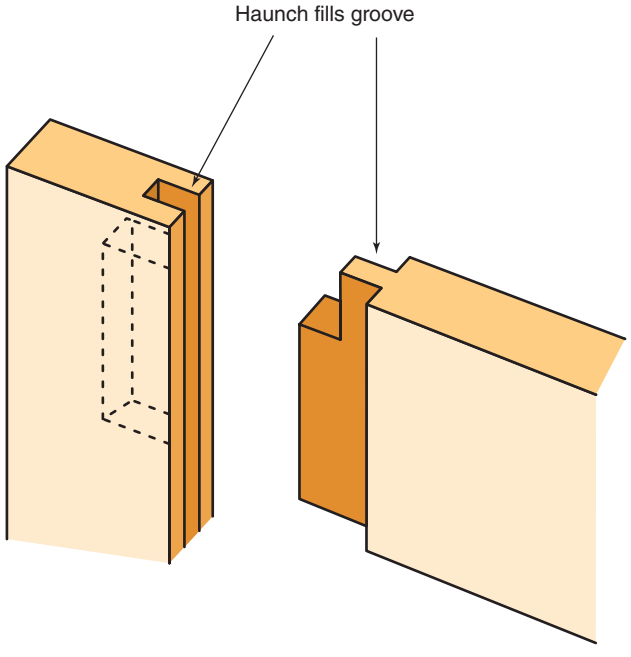

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FIGURE 16-33 Through mortise and tenon.



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FIGURE 16-34 Haunched mortise and tenon.

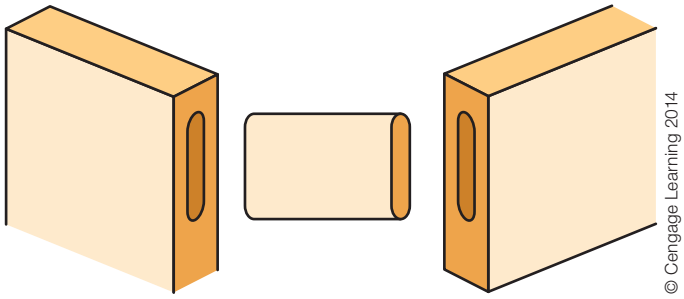
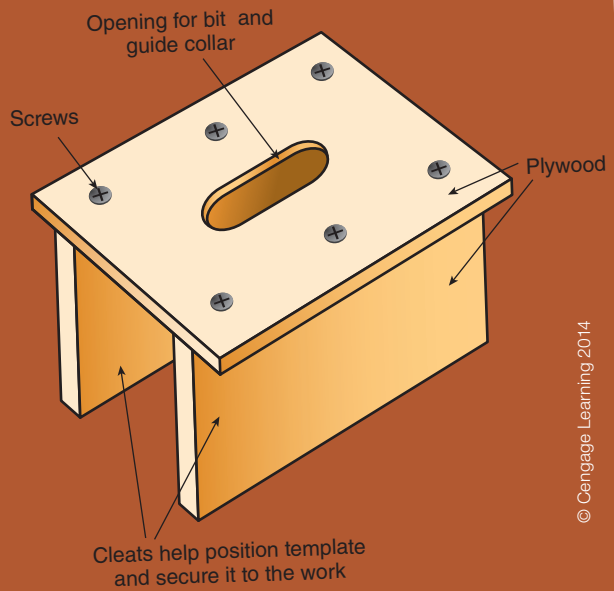

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FIGURE 16-35 Loose mortise and tenon.

with a plunge router and jig (see **Figure 16-35**). The plunge router leaves slightly rounded ends on the mortise, and the loose tenon can be rounded to fit nicely.

WOODWORKING TIP:

*A mortising jig to use with a plunge router can be easily made (see **Figure 16-36**). To use the jig, clamp it to your workpiece and make a series of passes, lowering the straight bit a little each time, taking care that the mortise does not clog up with debris. You will note that the mortise has rounded ends. Loose tenon material can be planed to thickness and ripped to width, and the edges can be rounded over with a table-mounted router and a round-over bit. Then the tenon stock can be cut to the necessary length.*



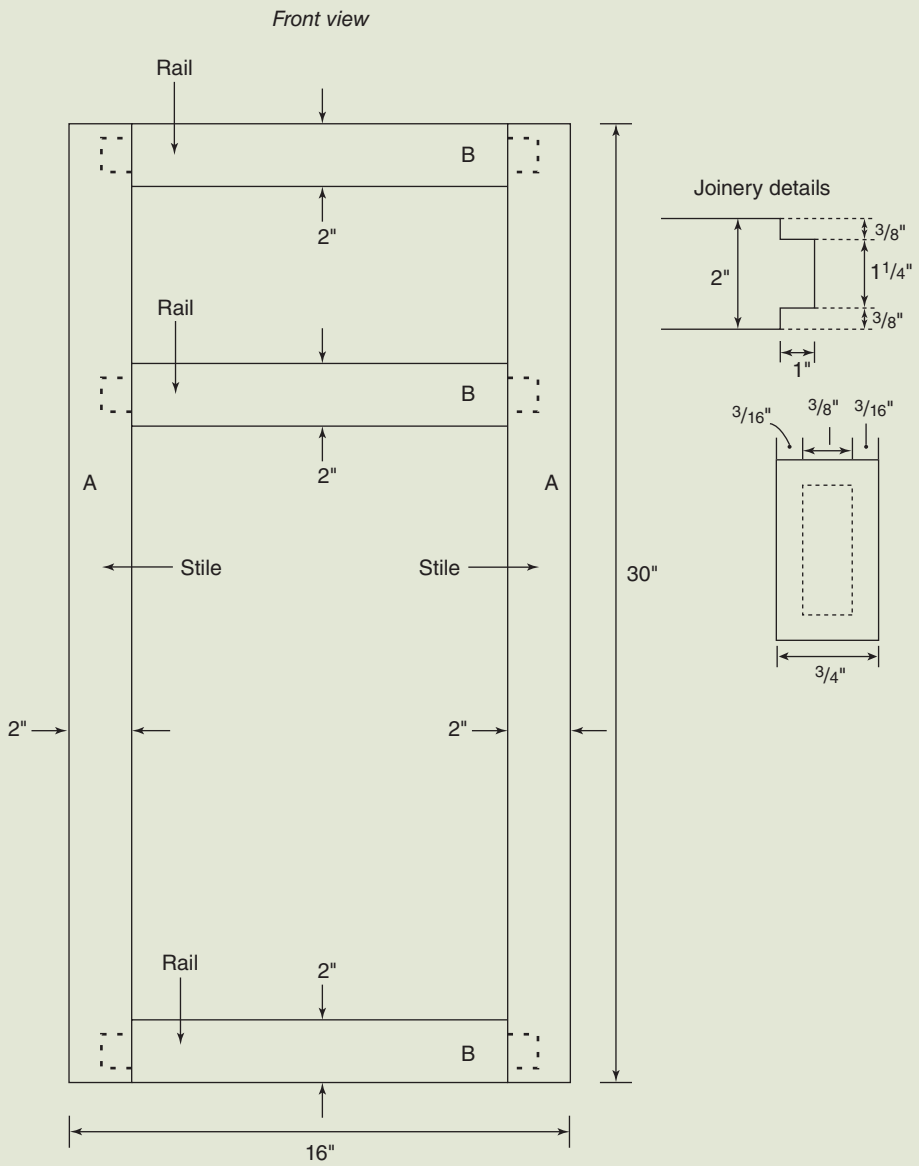
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Sizing opening:
Total length = (Collar diameter – Bit diameter) + Length desired
Total width = (Collar diameter – Bit diameter) + Width desired

FIGURE 16-36 Mortising jig for plunge router.

PROCEDURE 16-5

Creating a Blind Mortise-and-Tenon Joint



Stiles (A) = Frame length
= 30"

Rails (B) = (Frame width − 2 stile widths) + 2 tenon lengths
= 16" − (2 × 2") + (2 × 1")
= (16" − 4) + 2"
= 12" + 2"
= 14"

A

STEPS

1. Determine the sizes of the component pieces. **Figure A** shows one example.

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2. Refer to your plans. We will use the example given in Figure A for sizing the mortise and tenon. Carefully lay out one mortise. Mark the depth of the mortise on the end of this piece. The depth of the mortise is the length of the tenon plus 1/16", as shown in **Figure B**.
3. Transfer the beginning and end marks of the mortise from the piece you just laid out to all the other places that will get mortises, as shown in **Figure C**.
4. Install the proper size mortising chisel in the mortising machine.
5. Clamp the piece with the completely laid-out mortise into the mortising machine in such a way that you will be able to set the table height for the depth of cut, as shown in **Figure D**.
6. Reclamp your piece and bring it under the mortising chisel. Adjust the table so that the chisel will come down in the proper spot, as shown in **Figure E**.


B

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C

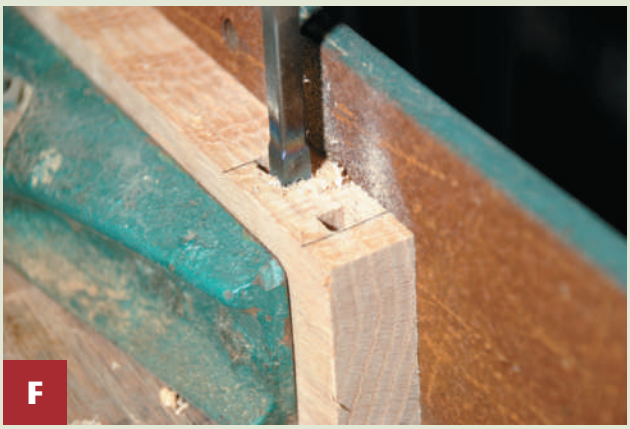
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E

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D

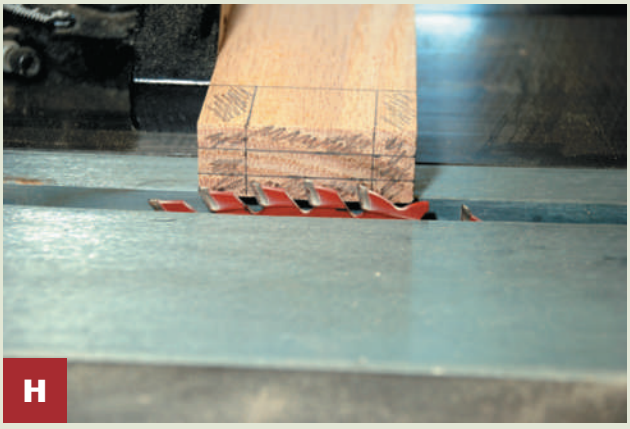
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F

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G

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H

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7. Make the mortise, making cuts at the beginning and end of the laid-out mortise, and then take overlapping passes to remove the rest of the waste, as shown in **Figure F**. Repeat for other mortises. Now that the table is set in the correct position relative to the mortising chisel, you just need the start and stop lines that you laid out for each mortise.
8. Set the mortised pieces aside, and carefully lay out one of the tenons, as shown in **Figure G**.
9. At the table saw, using the piece you just marked out as a guide, set the blade height so that it will cut just to your line, as shown in **Figure H**.
10. Slide the rip fence over so that your cut will be made just inside the layout line, as shown in **Figure I**.
11. Supporting the piece with the miter gauge and butting it against the fence, make your first cut, and then flip the piece over and make a second cut. Refer to **Figure J**, and repeat for all other tenons.

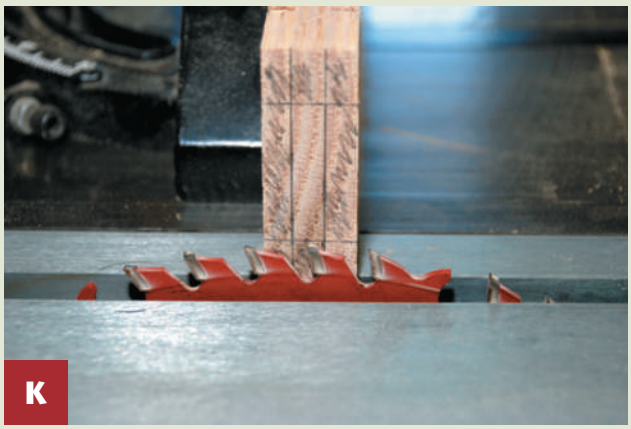

I

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J

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12. Without moving the rip fence, place your piece on edge and raise the blade height so that it will cut on the layout line, as shown in **Figure K**. Again butting the piece against the fence and supporting it with the miter gauge, make a cut and then flip the piece over and make a second cut, as shown in **Figure L**. Repeat for all tenons. You have now defined the shoulders of each tenon.
13. Slide the rip fence out of the way. Set your piece on end on the saw table, and raise the blade until it will cut just into the kerf created earlier, as shown in **Figure M**.
14. Clamp your piece into the tenoning jig, and adjust the jig so that you will cut just inside the layout line on the edge of your piece, as shown in **Figure N**.


K

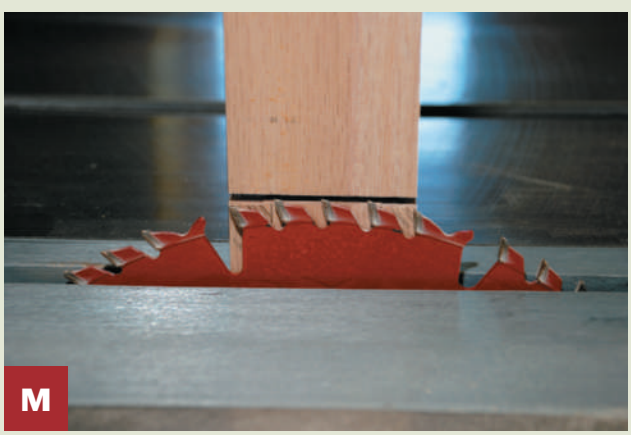
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L

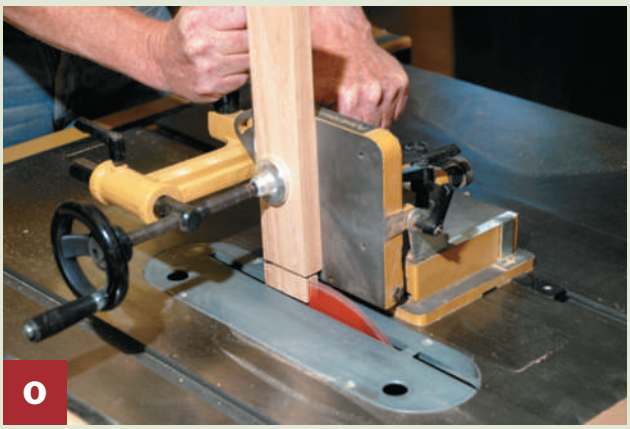
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N

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M

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O

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P

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Q

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15. Turn on the saw and move the jig past the blade. Remove your piece, turn it around, and run it again, as shown in **Figure O**. Check the fit of the tenon in a mortise, and adjust the jig as needed. Repeat for each tenon. You have now defined the cheeks of the tenons.
16. Square the two lines that remain on the end of your piece up onto the tenon cheeks, as shown in **Figure P**.
17. Carefully cut down these lines to the shoulder of the tenon, using a handsaw or band saw. If you use the band saw, you can set the fence to help guide the cut, and you will only have to lay out one piece. See **Figure Q**, and repeat for all tenons.
18. Clean out any debris in each mortise, and use a chisel or rabbeting plane to do any fine-tuning of the tenon. You have now completed the mortise and tenon, as shown in **Figure R**. Make a final check for fit prior to gluing, as shown in **Figure S**.
19. Glue and clamp the joint.


R

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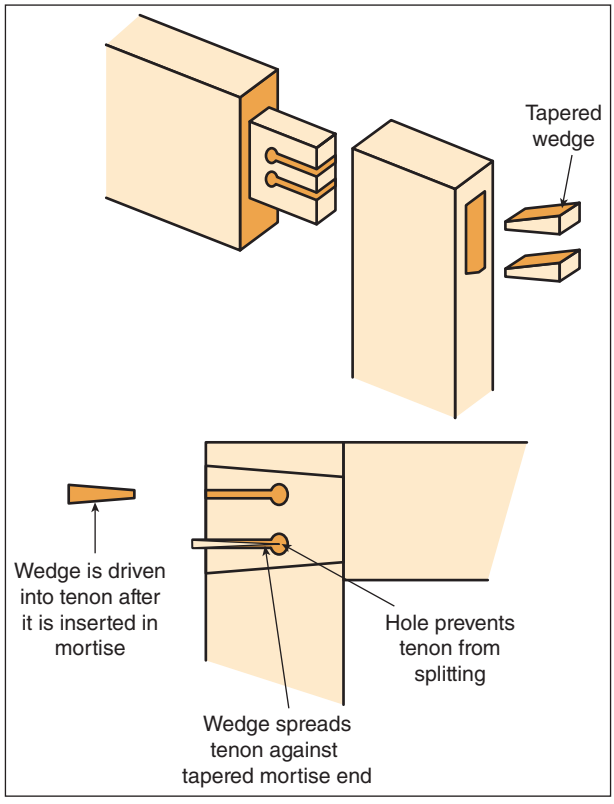


FIGURE 16-37 Wedged through mortise and tenon.

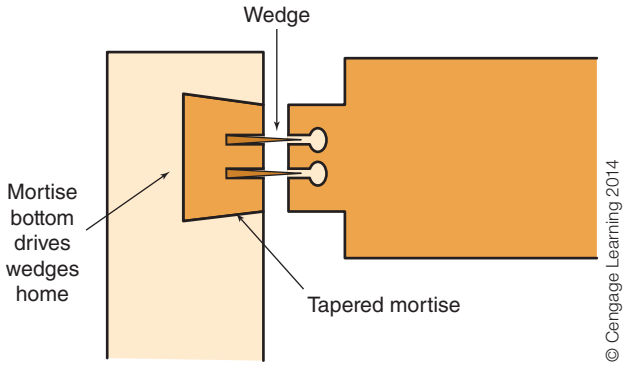


FIGURE 16-38 Fox-wedged mortise and tenon.

There are two types of **wedged mortise and tenon**: *visible* and *hidden*. The one that can be seen is the *wedged* through mortise and tenon (see **Figure 16-37**). The invisible joint is called a *fox-wedged* mortise and tenon (see **Figure 16-38**).

Wedged mortise and tenons work best when the mortise is tapered and the wedges spread the tenon into a dovetail shape. Properly crafted, they are so effective that glue is unnecessary. The fox-wedged joint is very difficult to construct, as everything must be absolutely perfect. If it is, the resulting joint will be very strong. However, if the assembled joint is not quite right, it will not be possible to disassemble it to make adjustments.

The **pegged mortise and tenon** is a blind or through mortise-and-tenon joint that is further reinforced with pins, so it is sometimes referred to as a pinned mortise and tenon. The joint is crafted, glued, assembled, and clamped. Once the glue has cured, a hole is drilled through the joint, and a dowel or peg is driven in. This peg may be made of a contrasting wood for a decorative effect, and a single or double pin can be used (see **Figure 16-39**). The advantage of the pegged mortise and tenon, other than aesthetics, is that should the glue fail, the joint will still hold together because of the peg.

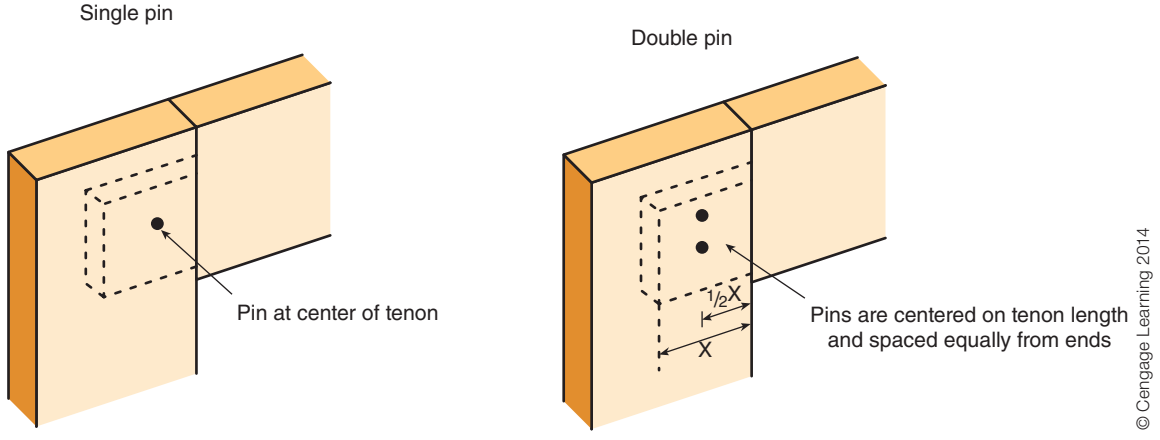


FIGURE 16-39 Pegged mortise and tenon.



Summary

Frame joints join the end of one piece to the edge of another, and are used to create frames. Frames are built to be used as face frames, for frame and panel assemblies, and as web frames, as well as for picture and mirror frames. There are many frame joints to choose from and variations on many of these. The mortise-and-tenon joint is the essential frame joint, but other joints can be effective as well. Butt joints must be reinforced. Miter joints also need reinforcement of some kind, but have the advantage over all the others discussed in that all end grain is hidden. No matter what joint is chosen for a project, it is important to be painstaking in creating it. A joint that fits well and is properly glued and clamped will be both durable and attractive.



Key Terms

blind mortise and tenon
bridle joint
cope-and-stick joint
face frames
frame butt joint
frame joints
groove-and-stub tenon joint
half-lap joint
haunched mortise and tenon
loose mortise and tenon
mitered frame joints
mitered half lap
mortise-and-tenon joint
pegged mortise and tenon
pocket-hole joint
rails
slip joint
stile
tenoning jig
through mortise and tenon
web frames
wedged mortise and tenon



Check Your Knowledge

1. Why does a butt joint need to be reinforced, and what are three methods for doing this?
2. What is the advantage of a miter joint?
3. What makes a miter joint difficult to assemble?
4. How can a miter joint be reinforced in a way that adds decorative detail to the frame?
5. What is a lap joint?
6. What are the three ways lap joints can meet?
7. Define or sketch a groove-and-stub tenon joint.
8. What machines can be used to mill a cope-and-stick joint?
9. What is a slip joint?
10. When a slip joint falls in the middle rather than the end of a piece, what is it called?
11. Regarding the mortise-and-tenon joint, define what a mortise is and what a tenon is.
12. List four variations of the mortise-and-tenon joint.

BUILD IT!

Mirror Frame

Figure A shows the completed mirror frame.

TOOLS REQUIRED

- Measuring tool
- Squaring tool
- Table saw and dado blade or tenoning jig
- Jointer
- Miter saw
- Router, router table, rabbeting bit, and decorative bit(s)
- Chisel and mallet

MATERIAL REQUIRED

- 3/4" solid stock
- 1/4" luan plywood or hardboard
- Mirror

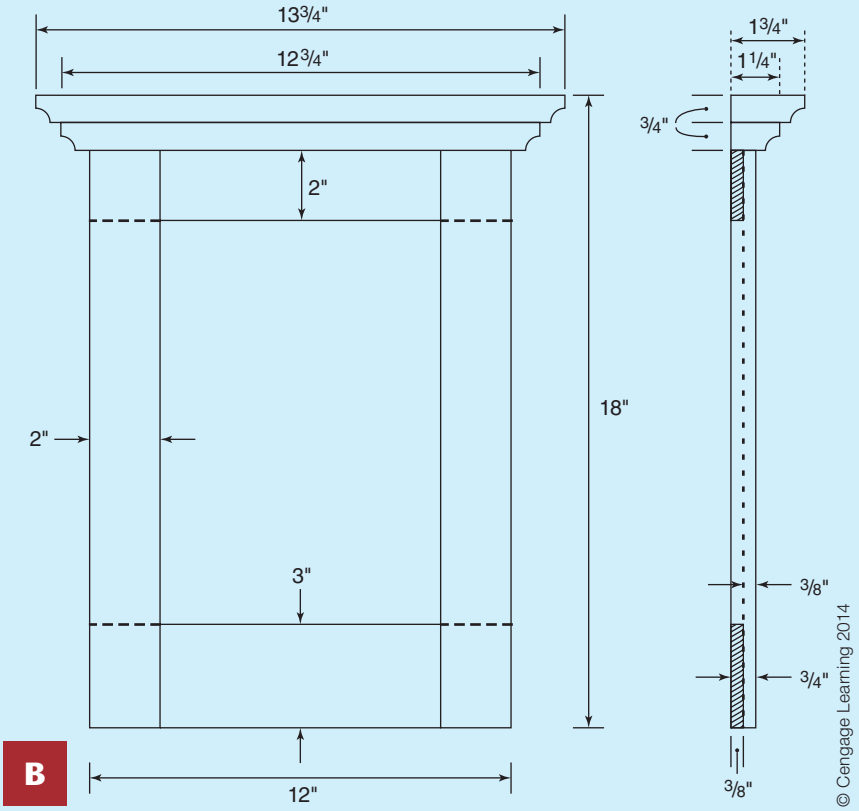
STEPS

1. Review the plan shown in **Figure B** to determine the size of the frame's stiles and rails.
2. Mill pieces to size.
3. Lay out pieces for best appearance and label each, noting also the front and back of each.



A

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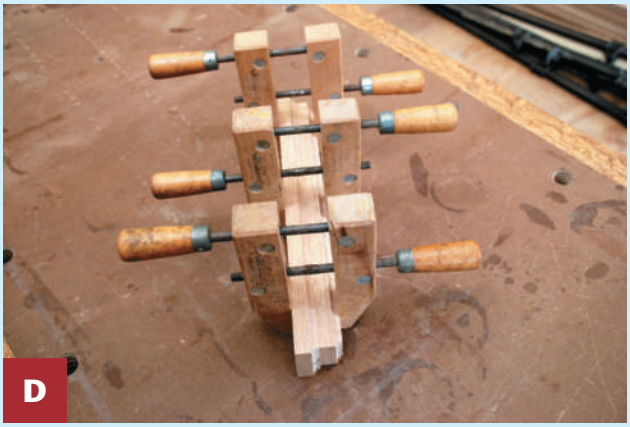


B

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C

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D

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E

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4. Mill half-lap joints for each corner, remembering that the joint will be cut on the back of the stiles and the front of the rails. Use a dado blade in the table saw, and make multiple passes, or make the shoulder cut with a single blade in the table saw, and use a tenoning jig to make the cheek cut. In either case, set the fence to define the length of the cut, and use the miter gauge to support the piece you are crosscutting (see **Figure C**).
5. Glue up the frame, clamping each corner securely.
6. Mill the stock for the top trim pieces. Using a table-mounted router, machine a decorative profile on the front edge and both ends of each piece.
7. Glue and clamp the top trim pieces together, as shown in **Figure D**.
8. When the frame is dry, use a piloted rabbet bit to rout a 3/8″ × 3/8″ rabbet on the inside of the frame for the mirror and backing board, as shown in **Figure E**. It is advisable to do this in several passes.

BUILD IT!

9. Chisel the corners of the recess you just routed square, as shown in **Figure F**.
10. Glue and clamp the top trim pieces to the mirror frame, as shown in **Figure G**.
11. Measure inside rabbets to determine the size of mirror needed. Make it a bit smaller than the opening, so it will go in easily if the frame is out of square.
12. Cut the 1/4" sheet goods to be used for the backing board to fit inside the rabbet ledge. Set aside.
13. Sand and finish as desired.
14. Once the finishing is done and the mirror has been acquired, it is placed inside the rabbets, and the backer board is placed over it. It can be held in place with glazing points or fender washers screwed into the frame with small screws to hold it in place. You may want to recess these so they are flush with the back of the frame, as shown in **Figure H**.
15. Attach picture wire and your mirror is ready to hang.


F

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G

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H

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PROJECT CHALLENGE

Display Cabinet



A

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The completed display cabinet is shown in **Figure A**.

STEPS

1. Consult the assembly list given in **Figure B**, and lay out and cut the plywood for the case sides, top, bottom, and shelves.

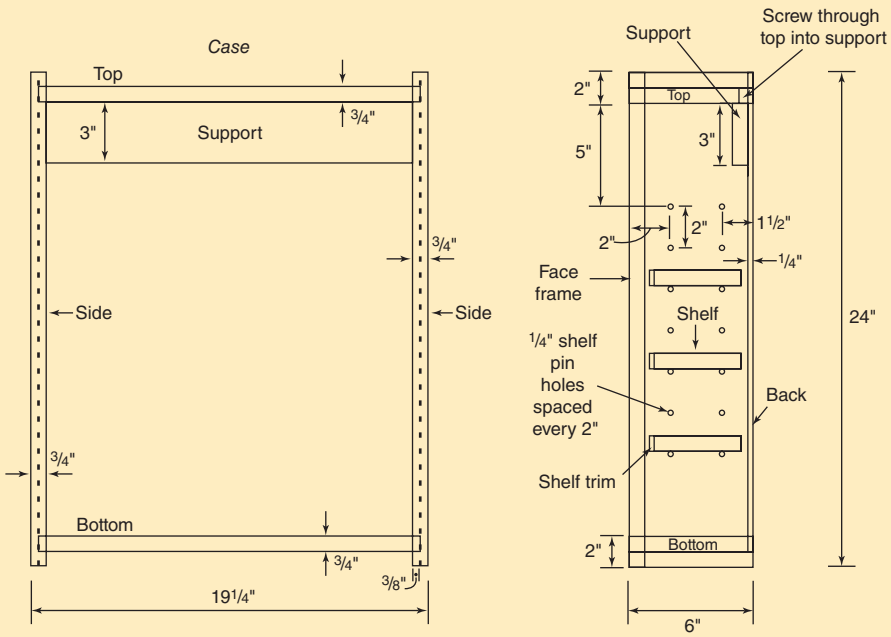
Assembly list — display cabinet

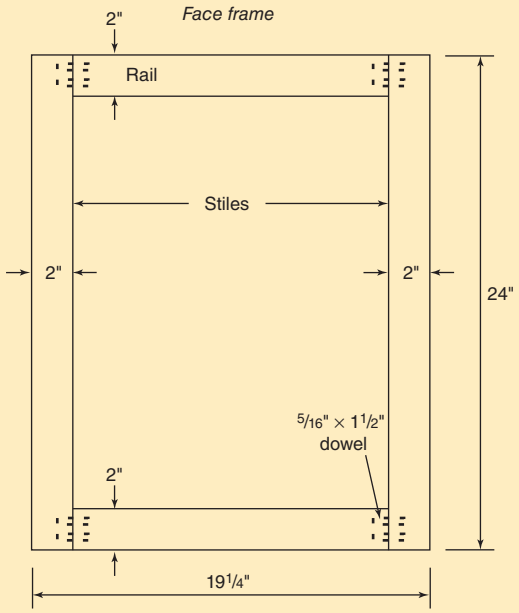
Part	Dimensions (thickness × width × length)	Quantity
Side	$^3/_4$" × $5^1/_4$" × 24" plywood	2
Top	$^3/_4$" × 5" × $18^1/_2$" plywood	1
Bottom	$^3/_4$" × 5" × $18^1/_2$" plywood	1
Support	$^3/_4$" × 3" × $17^3/_4$"	1
Back	$^1/_4$" × $18^1/_2$" × $21^1/_2$" plywood	1
Shelf	$^3/_4$" × $4^3/_8$" × $17^1/_2$"	3
Shelf trim	$^1/_2$" × $^3/_4$" × $17^1/_2$"	3
Face frame stile	$^3/_4$" × 2" × 24"	2
Face frame rail	$^3/_4$" × 2" × $15^1/_4$"	2
Door stile	$^3/_4$" × $1^7/_8$" × $20^5/_8$"	2
Door rail	$^3/_4$" × $1^7/_8$" × $15^{13}/_{16}$"	2
Dowels	$^5/_{16}$" × $1^1/_2$"	8
$^3/_8$" Inset hinges		1 pair
Knob or handle		1
Shelf pins		12
Door panel glass retaining clips or silicon caulk	$^1/_8$" glass to fit	1

B

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2. Referring to the plan given in **Figure C**, lay out and cut the dados on the case sides for the top and bottom.
3. Lay out the holes for the shelf support pins. Use a 1/4" flat-bottom bit in the drill press, and drill these holes 5/16" deep.
4. Machine a 1/4"-wide by 3/8"-deep rabbet on the inside back of the two side pieces. You can use a dado blade on the table saw and a sacrificial fence, or use a straight bit and fence with a table-mounted router (see **Figure D**).





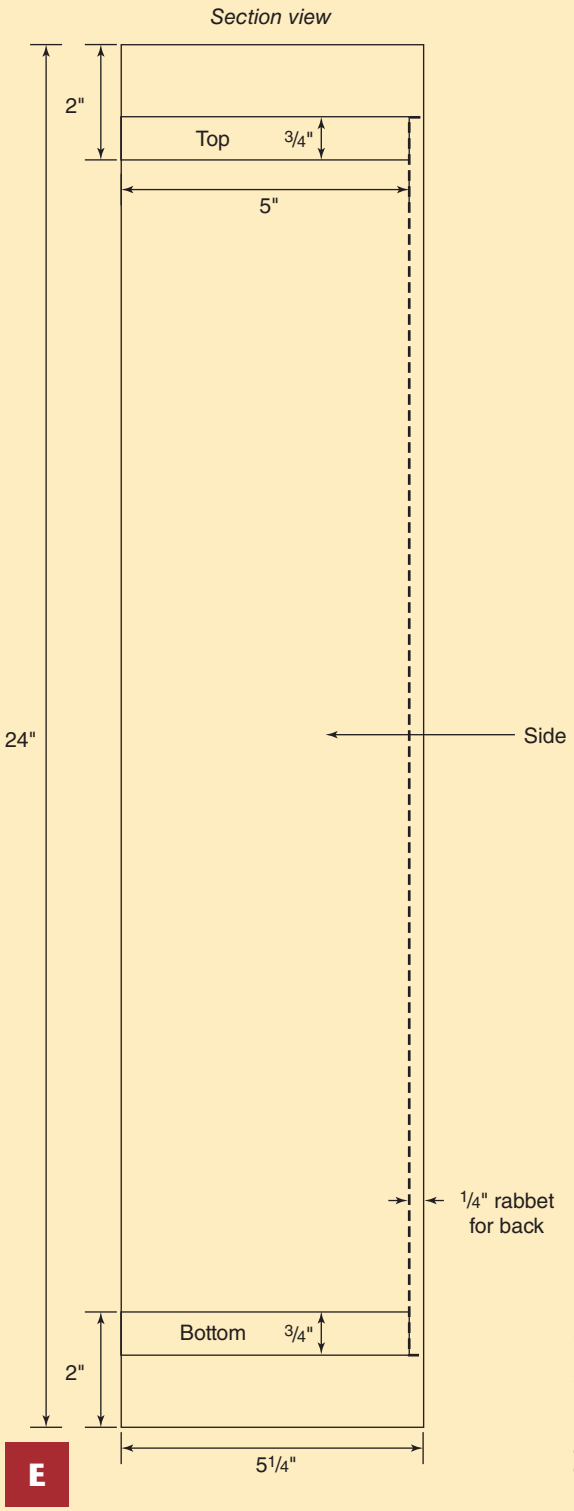
C

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D

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E

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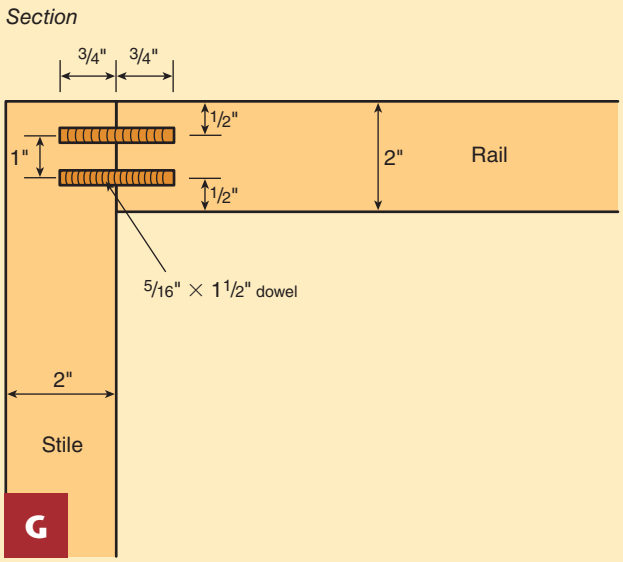
5. Sand the inside faces of the sides, top, and bottom, and glue and clamp the case together, keeping the front edges flush as shown in **Figure E**.
6. Determine the exact size of the back and attach it to the rabbets in the sides and to the top and bottom. Check to make sure the case is square and adjust as necessary.
7. Place the support inside the cabinet and drive nails through the sides into the support. Then drill pilot holes and countersink and drive three screws through the top into the support, as shown in **Figure F**.
8. Next we will build a face frame for the cabinet. Referring to the assembly list, mill the stiles and rails to size.



F

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9. The face frame is built using a doweled butt joint. Assemble each corner and lay out for the dowel joints as shown in **Figure G**. Two 5/16" dowels 1 1/2" long will be used in each corner.
10. Turn the stiles on edge; set up the doweling jig so that the 5/16" hole is lined up with the first layout mark, and tighten the jig to the stile, as shown in **Figure H**. The jig is self-centering, so the hole will be centered across the thickness of the stile.
11. Insert a 5/16" bit in a drill and set a stop collar or a piece of tape so that a hole 13/16" deep will be drilled. Remember to account for the jig. Refer to **Figure I**.



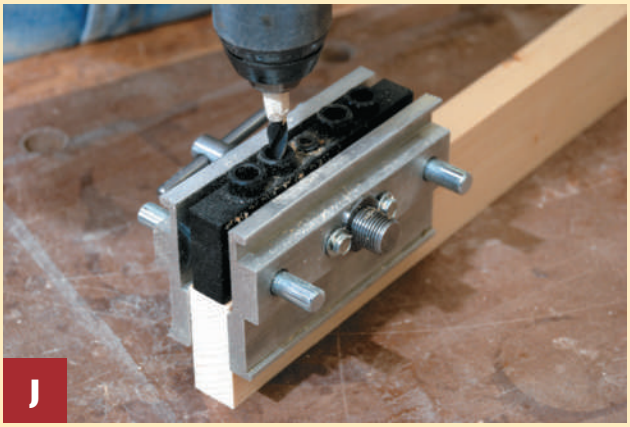
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J

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K

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L

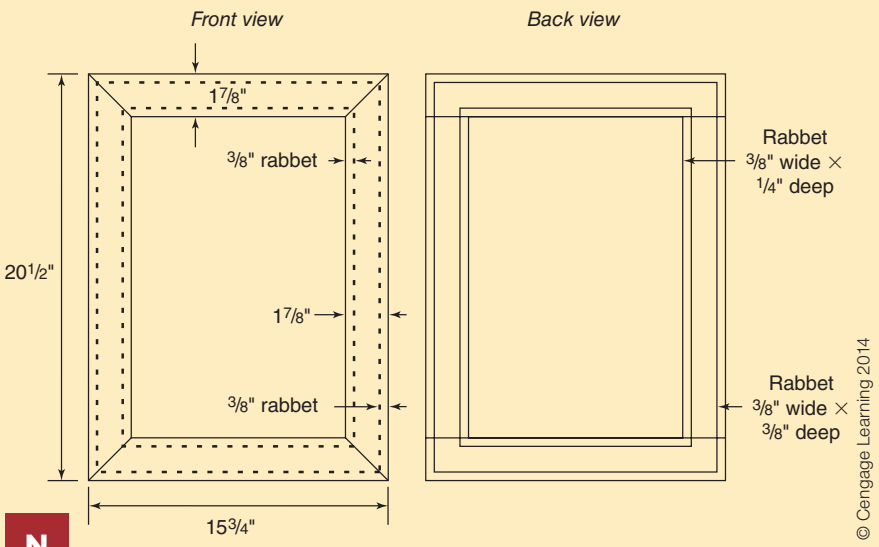
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12. Drill the first hole, and then move the jig to do all the others in the two stiles, as shown in **Figure J**.
13. Clamp the first rail upright in the bench vise, and align and clamp down the doweling jig over the end of the rail. Drill the first hole, as shown in **Figure K**.
14. Drill the remaining holes in the ends of the rails.
15. Assemble the stiles, rails, and dowels with glue and clamp. Check the frame to make sure it is square.
16. When the glue has cured, clean up and sand the face frame, and brad nail it to the case. Refer to **Figure L**. The top of the bottom rail should be flush with the top of the bottom, and the stiles should be flush with the outside of the box. If the stiles do overhang the sides a bit, they can be routed flush later with a piloted flush trim bit.
17. Put shelf pins in place, and measure the length of the shelves. Determine their width, which is slightly less than the distance from the back of the cabinet to the back of the face frame.
18. Cut the shelves to length from 3/4" plywood, and rip them 1/2" less than the width determined.

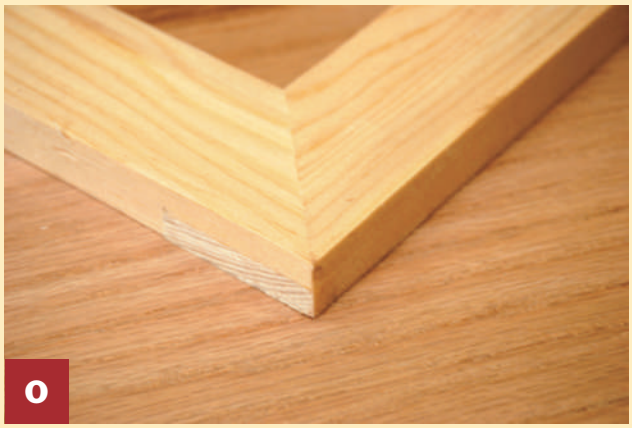
19. Rip 1/2" strips from 3/4" stock; glue and brad nail these to front edge of shelves, as shown in **Figure M**.
20. Now build the frame for the door. Measure the length and width of the opening between the rails and stiles of the face frame. The door we are building is an inlay door, partially overlaying the face frame, so add 1/2" to both the length and width dimensions determined in the preceding step. Cut two door stiles and two door rails from 3/4" stock. Make them 1 7/8" wide.
21. Referring to Procedure 16-3 earlier in this chapter, machine mitered half-lap joints for the four corners of the door frame. See also **Figure N** and **Figure O**.
22. After cutting the mitered half-lap joints, glue and clamp up the door frame. Once the glue in the door frame has set, use a router and a rabbeting bit to mill a 3/8"-wide by 1/4"-deep rabbet on the inside face of the door frame for the glass, as detailed in Figure N.
23. Rout a 3/8"-wide by 3/8"-deep rabbet on the inside face of the outside edge of the door.
24. Sand the door and install the inset hinges and a knob or handle.
25. Remove hinges and knob or handle and finish the door and the cabinet. When finishing is complete, install the glass in the door using silicone caulk or glass retaining clips, then reinstall the knob or handle and the hinges. The cabinet is ready to hang.



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Mitered half lap joint used on door corners.



17

Rail Joints

You'll Learn

After studying the chapter, the student should be able to:

- Explain where rail joints are used
- List various types of rail joints
- Explain the advantages and disadvantages of different rail joints

INTRODUCTION

In leg-and-apron constructions, **rail joints** are used; these are often seen in table construction. Rail joints are also used in post-and-rail construction, an example of which is bed construction. Another place rail joints are used is in chair building. Rail joints are similar to frame joints, in that end grain is being joined to long grain. Unlike frame construction, however, the members being joined are usually not the same thickness. Legs are thicker, for example, than the aprons that are attached to them. Most of the joints that will be covered under the heading of rail joints are joints that are also used in frame construction. Rail joints include the mortise-and-tenon, slip, lap, dovetail, dowel, pocket-hole, and bolted joints.

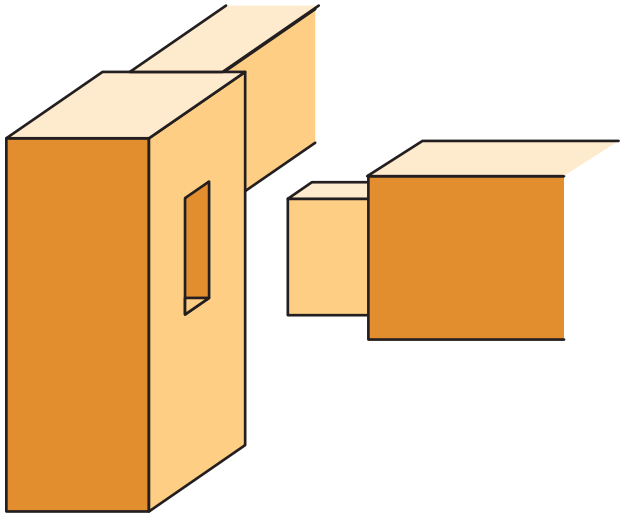
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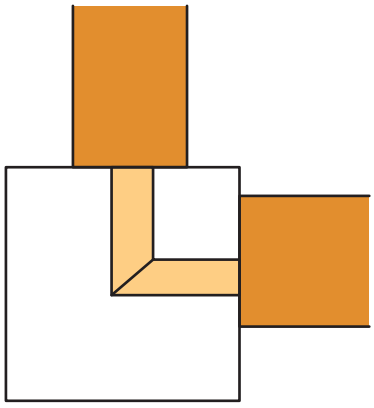
MORTISE-AND-TENON JOINT

The fundamentals of the mortise-and-tenon joint covered in the previous chapter apply here as well. The mortise-and-tenon forms most common to rail joinery are illustrated in **Figure 17-1** through **Figure 17-5**.

There are three other types of mortise-and-tenon joints that occur in rail joinery that should be mentioned: the *multiple tenon*, the *tusk tenon*, and the *twin tenon*. The multiple tenon is also used in frame joinery; the tusk tenon and twin tenon joints are unique to rail joinery.

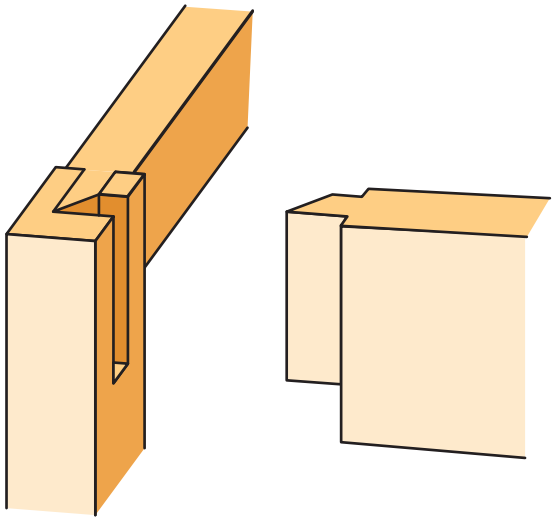
The **multiple-tenon joint**, consisting of two or more tenons and corresponding mortises, is used on wide rails to counteract the expansion and contraction that would occur with a single wide tenon (see **Figure 17-6**).





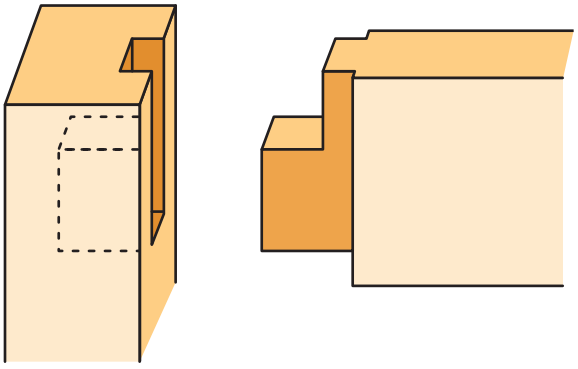
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FIGURE 17-1 Mitered tenon.



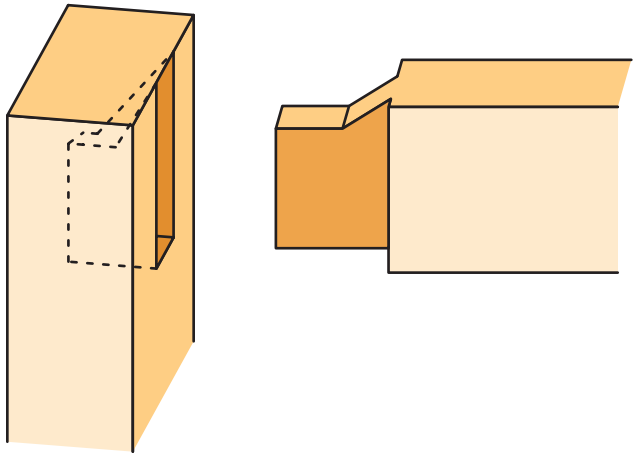
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FIGURE 17-2 Full-height mitered tenon.



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FIGURE 17-3 Haunched tenon.

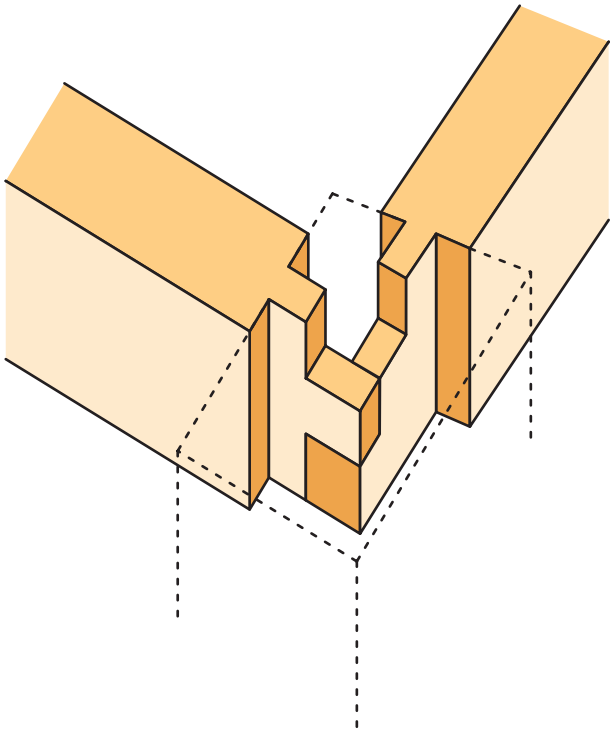


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FIGURE 17-4 Mitered haunched tenon.

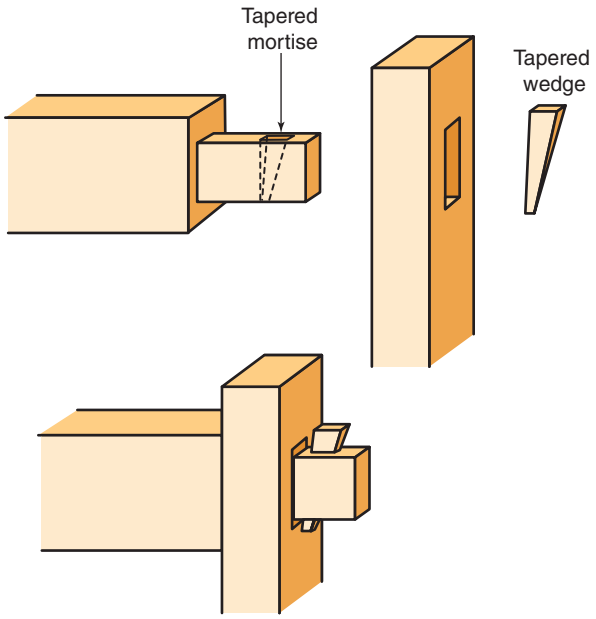
The **tusk-tenon joint** is a very functional joint in furniture that needs to be disassembled occasionally. It is a knockdown joint commonly used in trestle tables and beds. A tusk tenon extends through its mortise and beyond. The tenon itself has a mortise through it, which allows the insertion of a removable wedge that locks the joint together (see **Figure 17-7**).

Twin-tenon joints are used to join a drawer rail to a leg (see **Figure 17-8**).



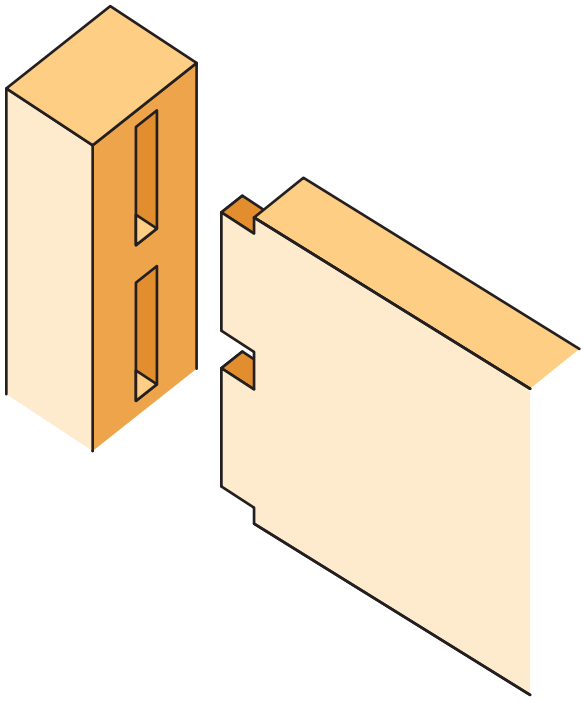
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FIGURE 17-5 Lapped tenons.



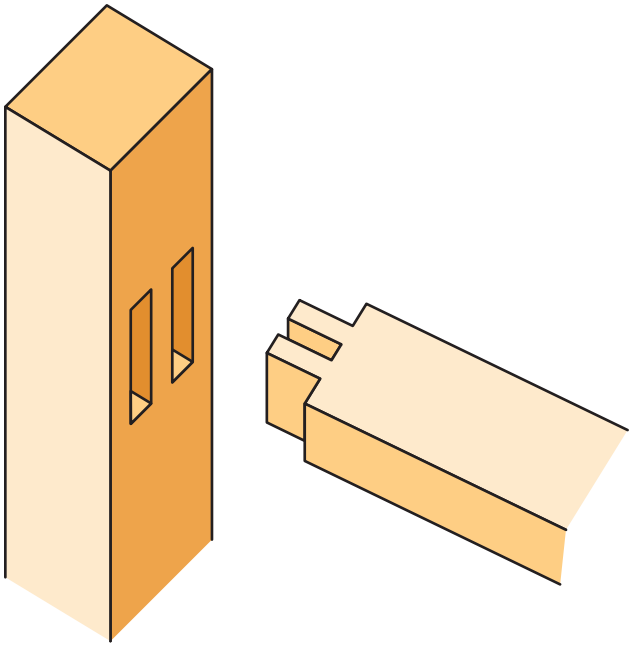
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FIGURE 17-7 Tusk tenon.



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FIGURE 17-6 Multiple tenon joint.



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FIGURE 17-8 Twin mortise and tenon.

CAUTION

When crosscutting on the table saw, the miter gauge or a sled should support and guide the stock. Never use the rip fence as a stop when making a through cut. The piece between the blade and the fence can easily be grabbed by the blade and kicked back at you. It is fine to use the rip fence as a stop if you are not cutting all the way through. If you are making a through cut, you can still use the fence as a stop provided that you attach a half fence to it (see Figure 17-9). The stock being crosscut is butted against the half fence, but by the time the cut is made, the stock is beyond the half fence and cannot get jammed between the fence and the blade.

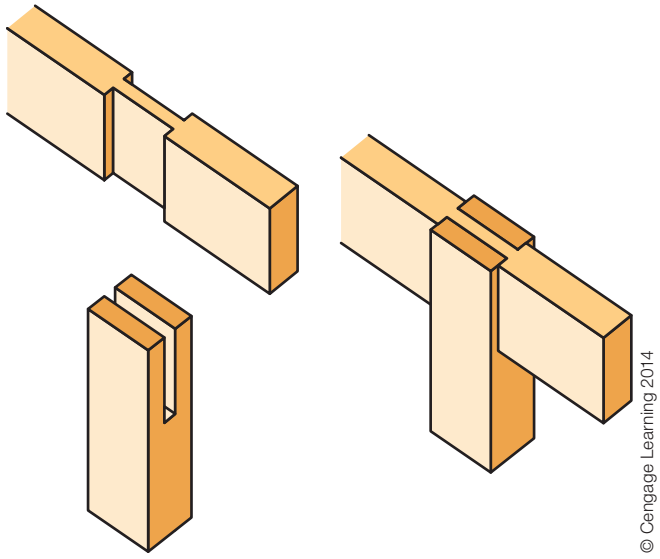


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FIGURE 17-9 A half fence allows you to use the fence as a stop when making crosscuts on the table saw without the danger of having the cut-off get caught between the rip fence and blade and thrown back at the operator.

SLIP JOINT

Slip joints are mostly used in frame construction, but one form of the slip joint, the bridle joint, is very good in rail joinery as well. **Figure 17-10** shows an example of what a bridle joint looks like. The bridle joint is most often seen in rail construction for tables that have curved aprons. If a leg needs to be added along the curve, the bridle joint allows the builder to make a joint that does not break the continuity of the curve.



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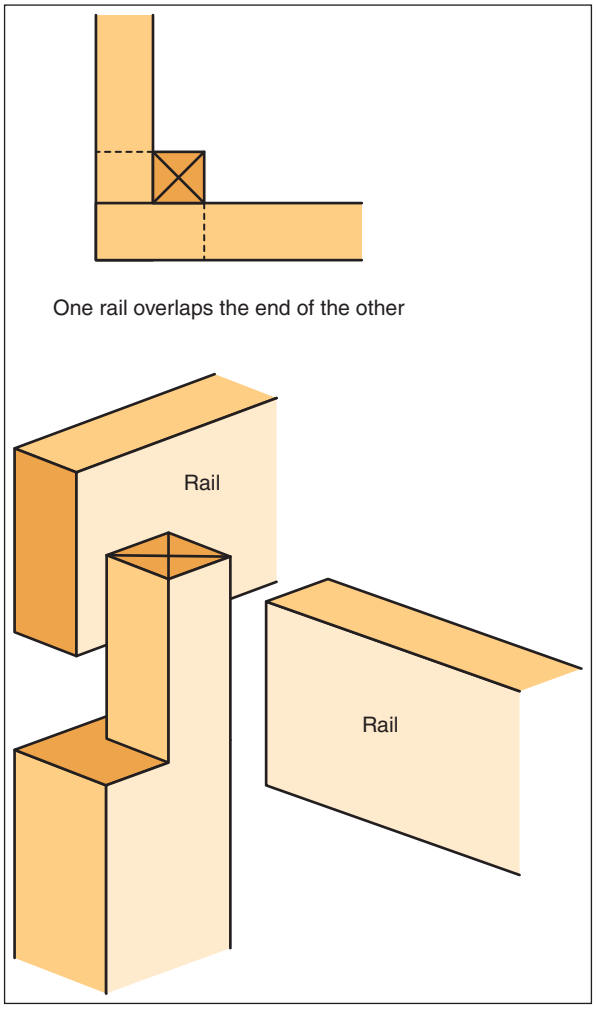
FIGURE 17-10 Bridle joint.

LAP JOINT

The lap joint used in rail joinery is not a particularly attractive joint, so it is most often used on heavy-duty post-and-rail structures, such as workbenches. Although not especially good looking, it is a very sturdy joint. We discussed half-lap joints in the chapter on frame joints; rail-lap joints are full-lap or edge-lap joints.

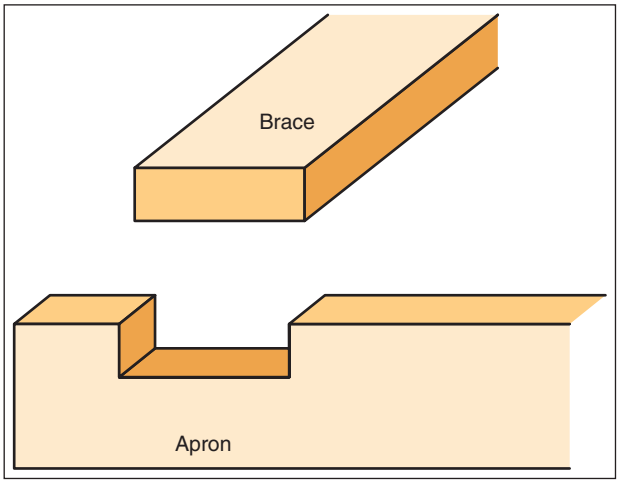
The **full-lap joint** only has material removed from one member, unlike the half lap, in which half the thickness of the material is removed from each mating piece. Two examples of full-lap joints used in rail joinery are shown in **Figure 17-11** and **Figure 17-12**. The full-lap joint illustrated in Figure 17-11 shows rails being joined to a post. Since not much gluing surface is available, this joint should be reinforced with fasteners. The full-lap joint seen in Figure 17-12 illustrates a brace being joined to an apron. In this situation, fasteners are not needed.

The **edge-lap joint** has a notch cut in the edge of each of the adjoining members, allowing them to interlock (see **Figure 17-13**). The edge-lap joint in rail construction is used primarily to link stretchers that cross.



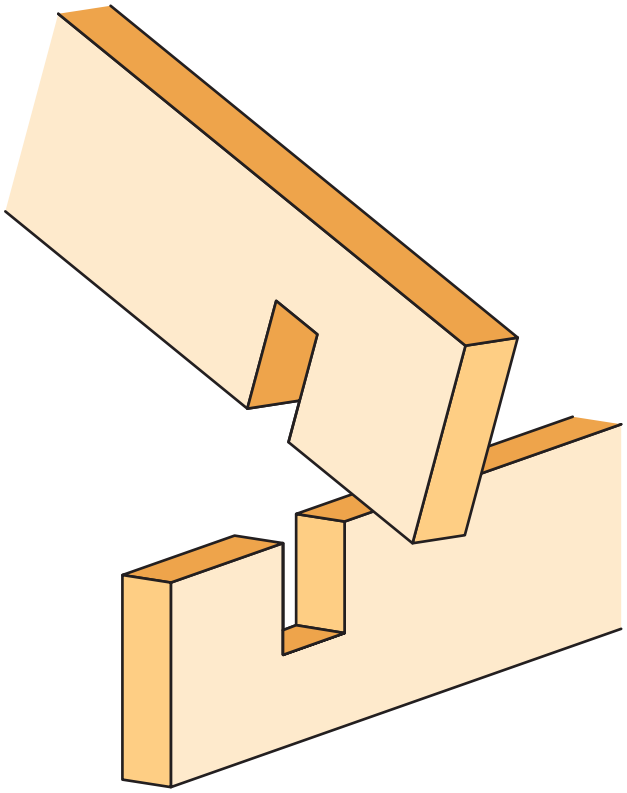
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FIGURE 17-11 Full-lap joint on a post and rails.



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FIGURE 17-12 Full-lap joint on a brace and apron.



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FIGURE 17-13 Edge-lap joint.

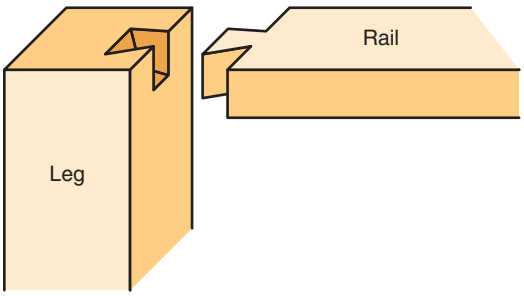


FACTS ABOUT WOOD

Beech, *Fagus grandiflora,* is a diffuse porous hardwood found in the eastern United States and Canada. Sometimes called *American beech* to differentiate it from European beech (*Fagus sylvatica*), it has excellent turning and bending characteristics. It is reddish to light brown in color, and is heavy, hard, and strong. It has prominent rays that make for a highly figured wood when quartersawn, and it is commonly used for bentwood furniture, handles, turning, and cabinetmaking. ■

DOVETAIL JOINT

The dovetail joint used in post-and-rail construction is seen in the joining of a top drawer rail to a table leg. A single large tail is cut into the rail, which then fits into a socket cut on the top of the leg (see **Figure 17-14**). This joint strongly resists all the forces that will be put upon it.

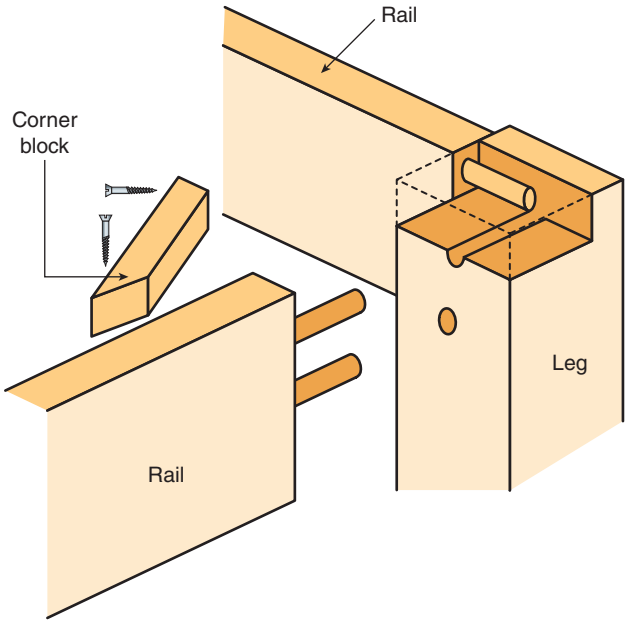


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FIGURE 17-14 Dovetail joint.

DOWEL JOINT

The dowel joint is not a particularly good rail joint and is suitable only for small, light-duty constructions, unless it is reinforced. One reinforcement solution is to cut and screw corner braces in place (see **Figure 17-15**).



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FIGURE 17-15 Dowel joint with corner brace.

WOODWORKING TIP:

Blades, bits, cutters, and knives all work better if they are clean and sharp. Each time you use a different blade or other cutting tool, inspect it for pitch and resin buildup and any nicks, gouges, or missing teeth. Clean them periodically. Nontoxic pitch and resin removers are available that work very well. An old toothbrush does a great job of scrubbing away built-up debris. Store all blades, bits, cutters, and knives separately to avoid damage. When they are dull, send them out to be sharpened or replace them.

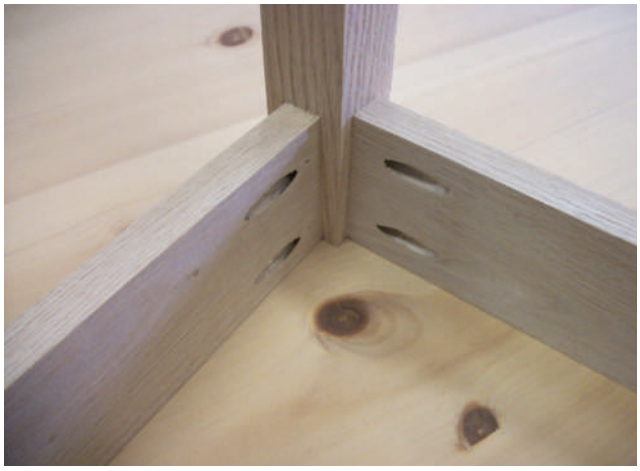

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FIGURE 17-16 Pocket hole joint.

POCKET-HOLE JOINT

Pocket-hole joinery can be employed to connect aprons to legs and rails to posts. Essentially, these are butt joints that are assembled with screws. A pocket-hole jig is used to create the angled holes on the inside faces of the aprons or rails, which are then attached to the legs or posts with screws designed to be used in this type of joinery. See **Figure 17-16**. This joint should be reinforced with a brace running from apron to apron (or rail to rail). It may also be attached using pocket-hole joinery, as shown in **Figure 17-17**. Like the dowel joint, it is appropriate for light construction.

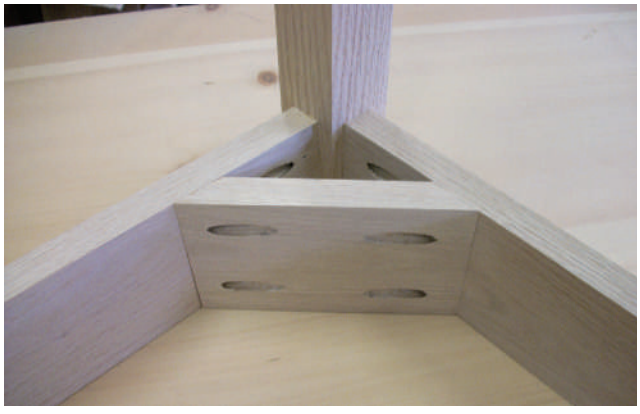

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FIGURE 17-17 A brace strengthens the pocket hole joint.

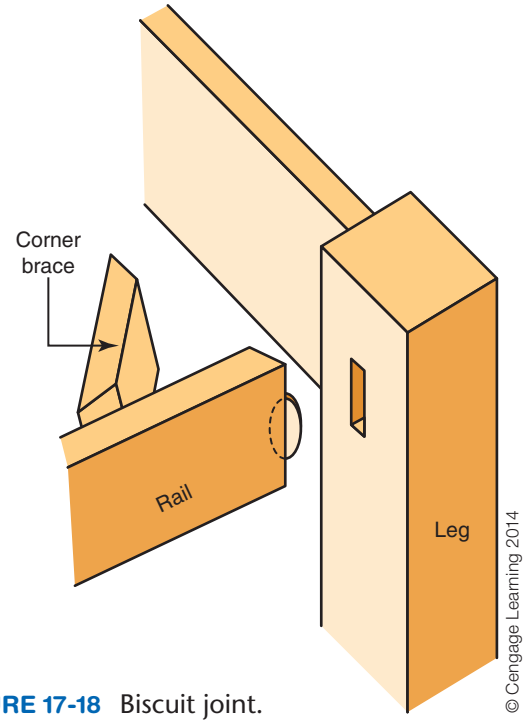
BISCUIT JOINT

Another joint suitable only for light duty is the biscuit joint, as seen in **Figure 17-18**. As with the dowel and pocket-hole joint, it should be reinforced with a corner brace. If the rail is wide enough to allow it, two biscuits should be used, and if the rail is thicker than 1″, biscuits can be stacked to further strengthen the joint.

BOLTED JOINTS

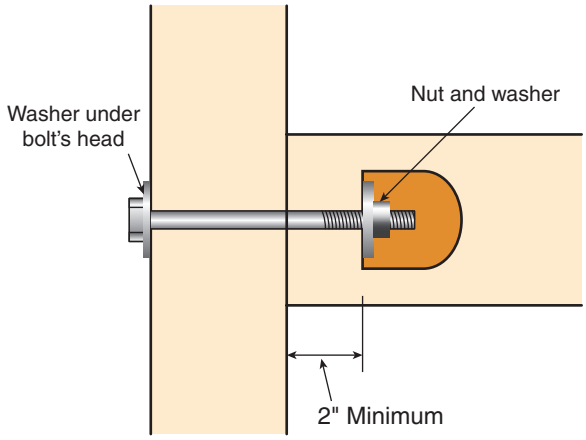
Specialized hardware can be also be used to produce rail joints. Beds are often bolted together using special bolts called *bed bolts*. A bolt fits through a hole drilled through the post and is captured by a nut that is recessed into the rail (see **Figure 17-19**). The bolt head may be recessed as well, and it is typically covered by a decorative plate that swings out of the way to allow access to the bolt. A much stronger version of this joint is formed when this hardware is used in conjunction with a mortise-and-tenon joint.

A metal corner plate allows aprons to be assembled to legs with butt joints. The plate has flanges that fit into kerfs milled in the aprons. A hanger bolt extending through a hole in the plate is then screwed into the leg and secured with a nut. As the nut is tightened, the assembly is pulled tightly together (see **Figure 17-20**). It is also possible to create a shop-made wooden version of the metal corner plate (see **Figure 17-21**).



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FIGURE 17-18 Biscuit joint.



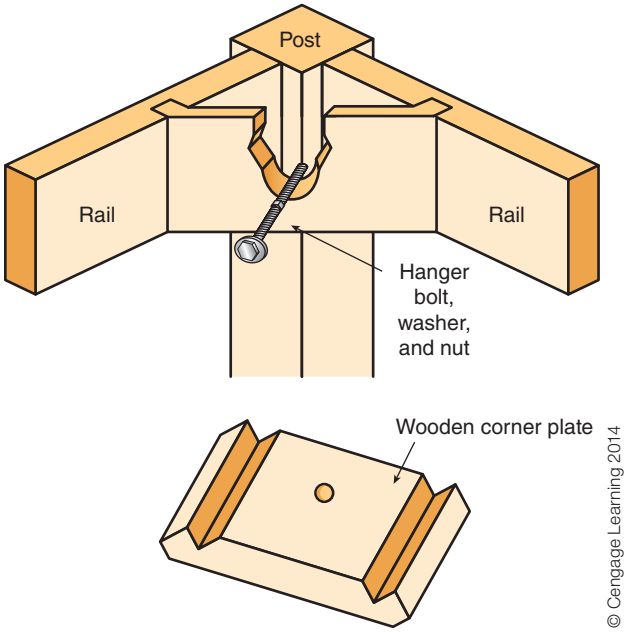
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FIGURE 17-19 Bed bolt.



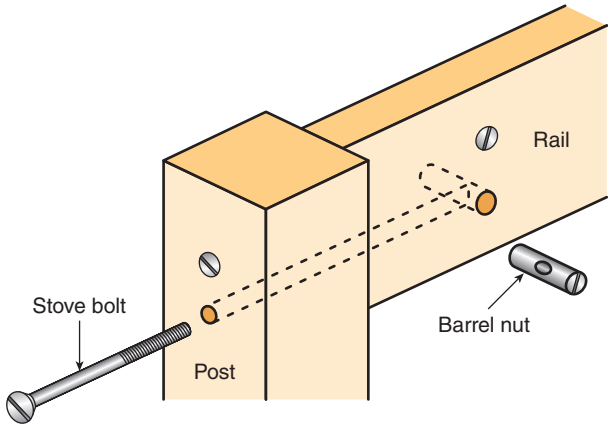
Image courtesy of Woodcraft Supply, LLC, www.woodcraft.com

FIGURE 17-20 Metal corner plate.



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FIGURE 17-21 Wooden corner plate.



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FIGURE 17-22 Bolt and barrel nut.

Another hardware joint utilizes a bolt and barrel nut. It is designed for relatively lightweight construction. The barrel nut is recessed into a hole in the apron or rail. It has a threaded hole in its side to accept a bolt, which is threaded into it. The bolt is inserted into a hole drilled through the leg or post and into the apron. This bolt hole intersects with the hole drilled for the barrel (see **Figure 17-22**).



Summary

Rail joints are used in joining aprons to legs or rails to posts. They are similar to frame joints, but differ in that the post or leg is generally thicker than the apron or rail. Joints commonly used in rail joinery include various mortise-and-tenon joints, including the tusk tenon for knockdown joinery and twin tenons for joining drawer rails to legs. Other rail joints are the bridle joint, the various lap joints, the dovetail joint for joining top drawer rails to legs, the dowel, pocket-hole, and biscuit joints, and several bolted joints.



Key Terms

edge-lap joint
full-lap joint
multiple-tenon joint
rail joints
tusk-tenon joint
twin-tenon joints



Check Your Knowledge

1. How are rail joints different from frame joints?
2. What joints are common to both frame joinery and rail joinery?
3. What joints are specific to rail joinery?
4. Which very sturdy rail joint is used for building heavy-duty furniture, such as workbenches?
5. What is the advantage of the tusk tenon version of the mortise-and-tenon joint?
6. What are two bolted joints a cabinetmaker might use, and what types of furniture might they be used on?

BUILD IT!

WORKBENCH



A

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Assembly list – workbench

Part	Dimensions (thickness × width × length)	Quantity
A. Lower side rails	$1\frac{1}{2}$" × 3" × 57"	2
B. Lower end rails	$1\frac{1}{2}$" × 3" × 19"	2
C. Lower shelf long cleats	$1\frac{1}{2}$" × $1\frac{1}{2}$" × 57"	2
D. Lower shelf short cleats	$1\frac{1}{2}$" × $1\frac{1}{2}$" × 13"	2
E. Lower shelf	$\frac{3}{4}$" × 16" × 57" sheet goods	1
F. Upper rails	$1\frac{1}{2}$" × 5" × 57"	2
G. Upper end rails	$1\frac{1}{2}$" × 5" × 19"	2
H. Cross cleats	$1\frac{1}{2}$" × 3" × 16"	2
I. Legs	$1\frac{1}{2}$" × 3 × $32\frac{1}{2}$"	4
J. Lower dividers	$1\frac{1}{2}$" × 3" × 6"	4
K. Upper dividers	$1\frac{1}{2}$" × 3" × $18\frac{1}{2}$"	4
L. Top	$\frac{3}{4}$" × 30" × 80" sheet goods or 30" × 80" door	2 pieces
Wood screws	#8 × $1\frac{5}{8}$"	
	#8 × $2\frac{1}{2}$"	
	#8 × 3"	
Pan head screws	#12 × $2\frac{1}{2}$"	

B

A completed workbench is shown in **Figure A**.

TOOLS REQUIRED

- Measuring tool
- Squaring tool
- Circular saw or miter saw
- Jointer
- Table saw
- Drill

MATERIAL REQUIRED

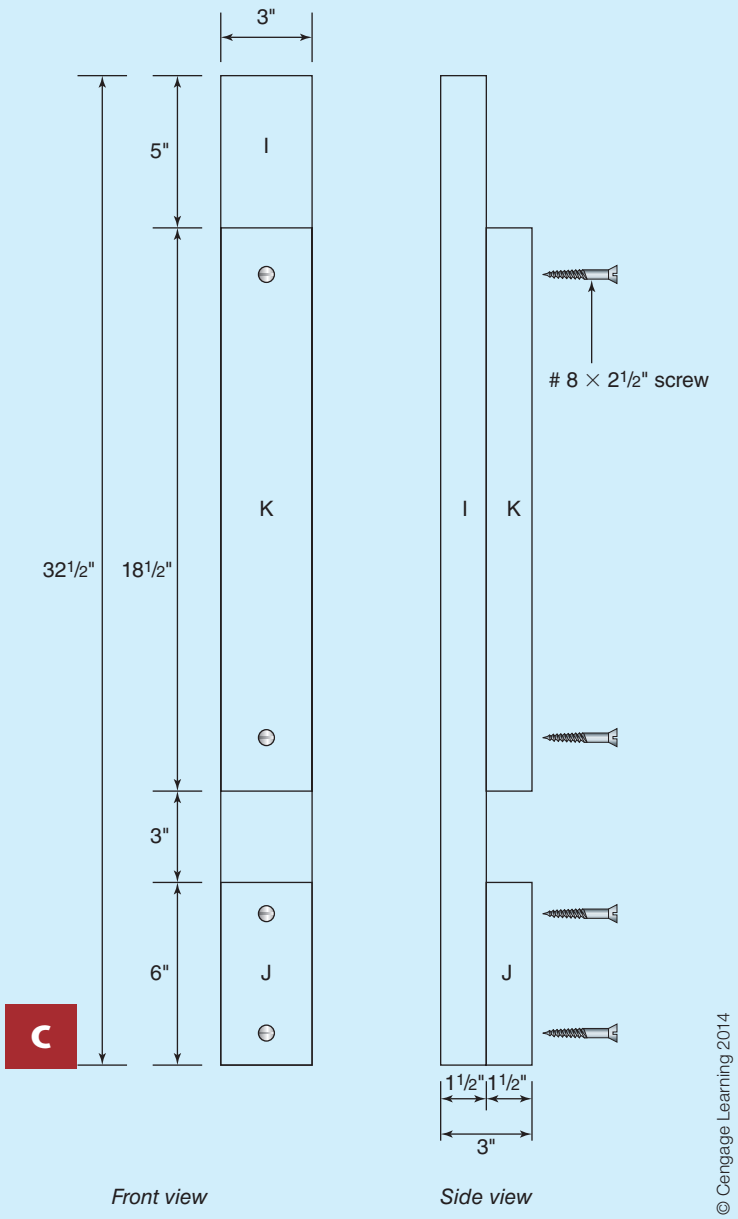
- 2-by framing lumber
- 3/4" MDF or plywood
- Solid-core wood door or material for a 30" × 80" top
- #8 wood screws: 1 5/8", 2 1/2", and 3"
- #12 × 2 1/2" pan-head screws

STEPS

1. Consulting the assembly list given in **Figure B**, cut the solid wood pieces to size and label them. Remember to joint, rip, and joint again.

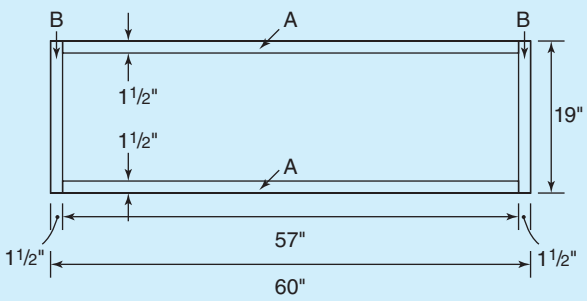
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2. Use 2 1/2" screws to glue and screw pieces J and K to piece I to form the four legs, as shown in **Figure C**.

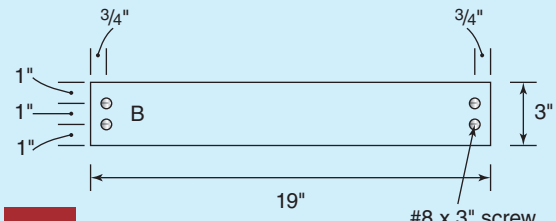


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Top view

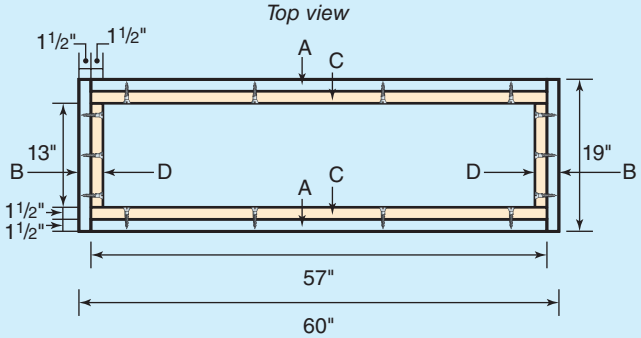


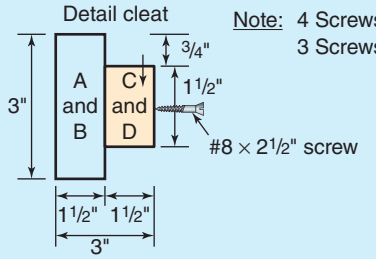
D

End view

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Top view





E

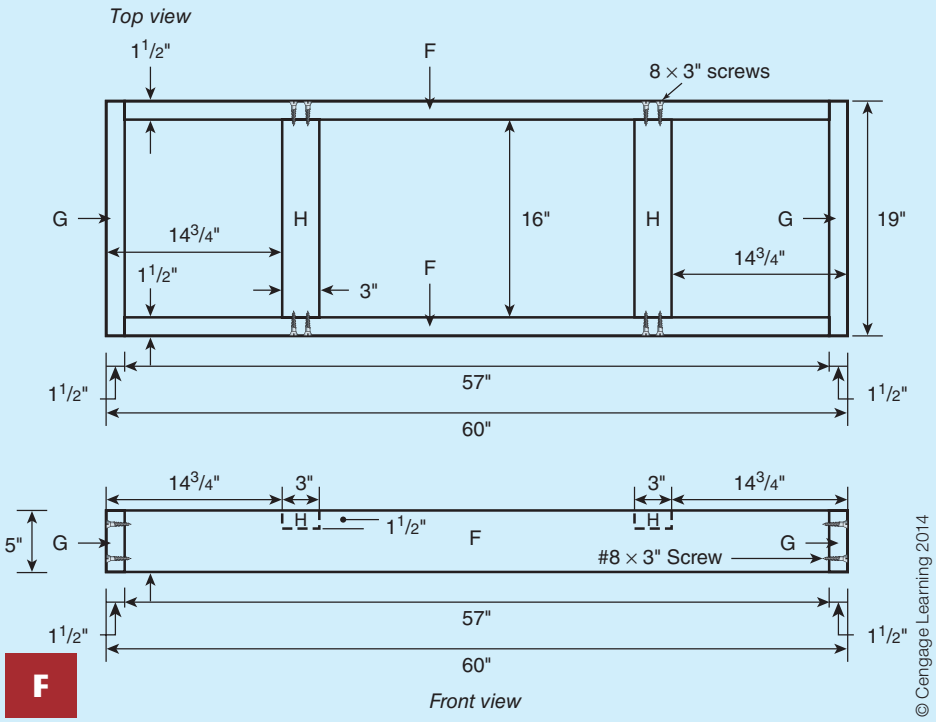
Side view

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3. Screw pieces A and B together to form the shelf support using 3" screws, as shown in **Figure D**.
4. Glue and screw shelf support cleats to the inside of the rectangle formed in the previous step. Use 2 1/2" screws and set the supports 3/4" down from the top edges of the A and B pieces, as shown in **Figure E**.

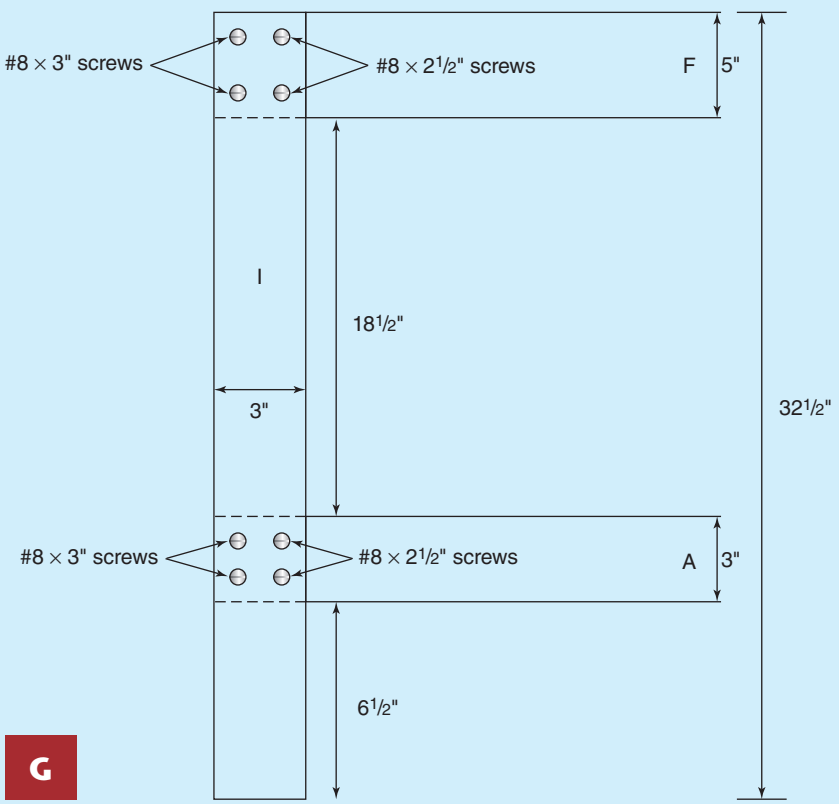
BUILD IT!

5. Use 3″ screws to assemble pieces F, G, and H to form the top support system, as shown in **Figure F**.
6. Assemble the legs and top and bottom supports with glue and screws. Use four screws at each of the eight intersections; use 3″ screws on the outside of each leg and 2 1/2″ screws on the inside, as shown in **Figure G**.



F

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G

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7. Cut the 3/4″ MDF or plywood piece to fit between pieces A and B as a bottom shelf; screw it down to the cleats with 1 5/8″ screws.
8. Drill two 3/16″ shank holes through the two pieces labeled H. Refer to **Figure H**.
9. Center a 30″ × 80″ solid-core door over the top; attach it to the frame by screwing through the two H pieces into the door with #12 × 2 1/2″ pan-head screws.
10. Other options for the top include gluing up a solid panel using 2-by stock or gluing and screwing together two pieces of MDF or plywood. Screw only from one side; this will become the bottom of the top. You can see this in **Figure H**. If you choose to use sheet goods for the top, it would be wise to protect the edges by attaching a trim strip around the perimeter, as shown in **Figure I**.
11. Attach a vise, referring to the instructions that came with your vise for correct placement.
12. If desired, finish your bench with several coats of linseed or tung oil.

BUILD IT!

PROJECT CHALLENGE

Kitchen Table

A completed kitchen table is shown in **Figure A**.

STEPS

1. Review the assembly list given in **Figure B**; assemble and lay out your stock. Hardwood is recommended.
2. Chances are you do not have easy access to stock that is 3" thick, which is what the legs call for, so we will glue up leg blanks. For the four legs, rip to 3 1/2" and crosscut to 32" eight pieces of 8/4 stock.



A(a)



A(b)

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Assembly list – kitchen table

Part	Dimensions (thickness × width × length)	Quantity
Top	1" × 34" × 62"	1
Leg	3" × 3" × $29\frac{1}{2}$"	4
Long apron	1" × 5" × $50\frac{7}{8}$"	2
Short apron	1" × 5" × $27\frac{7}{8}$"	2
Button blocks	$\frac{3}{4}$" × 1" × 2"	14
Wood screws	#8 × $1\frac{1}{4}$"	14

B

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C

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D

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E

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F

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3. Joint and mark one face of each piece, as shown in **Figure C**.
4. Glue and clamp up the leg blanks with the jointed faces together on each leg. Try to keep them aligned and space clamps about every 6", as shown in **Figure D**.
5. While the legs are setting up, make the top. Cut individual pieces a couple inches over finished length, joint and rip, and then lay them out on a bench. Allow a couple extra inches in width. If you are using flatsawn lumber, orient the growth rings on adjacent pieces so they alternate, as shown in **Figure E**. If you are using quartersawn lumber, you do not have to do this.
6. Arrange the pieces for best appearance, and mark the panel for easy reassembly, as shown in **Figure F**.

7. Joint each of the boards for the top, alternating between having the face into the jointer fence and having the face away. Reassemble the top and check for gaps. Glue and clamp the top, alternating clamps top and bottom, as shown in **Figure G**.
8. Clean the glue squeeze-out off the legs and bring them to finished size. This can be done by jointing an edge flat, then going to the planer and planing each leg until it is 3" square. Alternate planing adjacent sides of the leg. The jointed edge should be face down on the planer bed (see **Figure H** and **Figure I**).
9. Square an end on each leg, and then cut them all to final length.


G

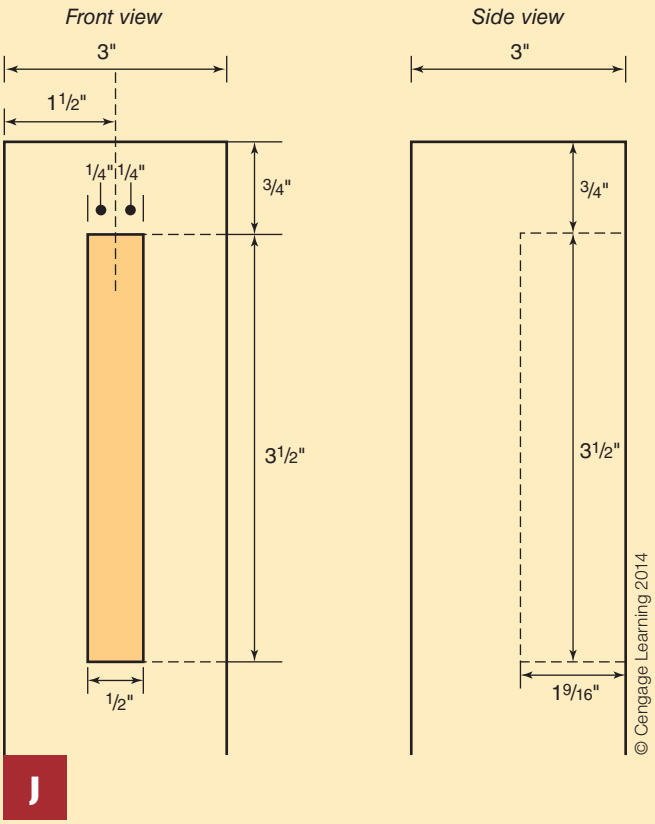
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H

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I

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J

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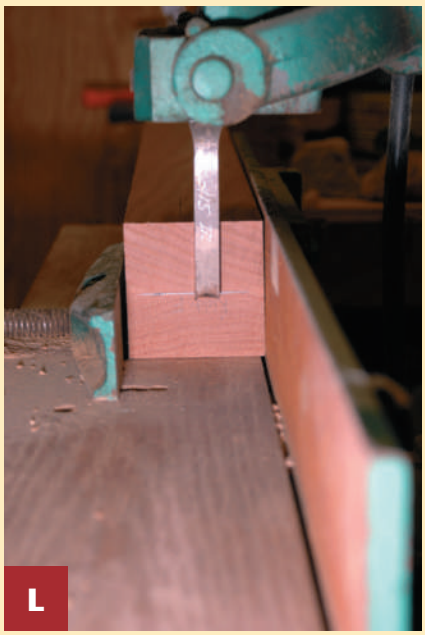


K

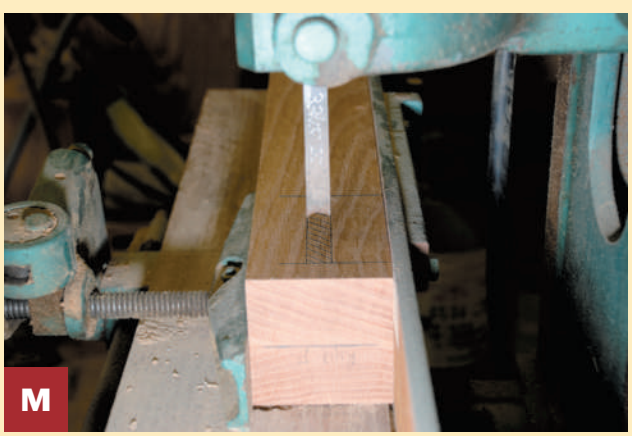
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10. Lay out the two inside faces on each leg for the mortises, as shown in **Figure J**. Only one mortise needs to be laid out completely; the others just need a start and stop line. Refer to **Figure K**.

11. Set up the mortising machine with a 1/2" mortising chisel, and adjust the table for the depth of cut, which is 1 9/16". Mark 1 9/16" on the end of a leg, and use it to set the depth of cut, as shown in **Figure L**.
12. Clamp the leg that has the mortise completely laid out on it in the mortising machine, and adjust the table in or out until the mortising chisel, when brought down, is aligned with the laid-out mortise. Refer to **Figure M**.
13. Turn on the machine and make the first cut at one end of the mortise. Make the second cut at the other end of the mortise by moving the table horizontally, as shown in **Figure N**.



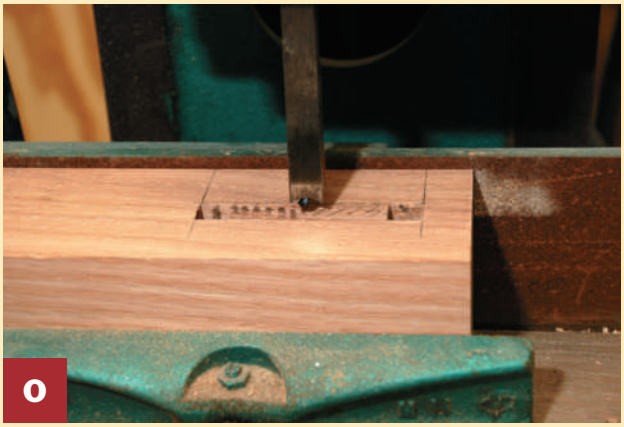
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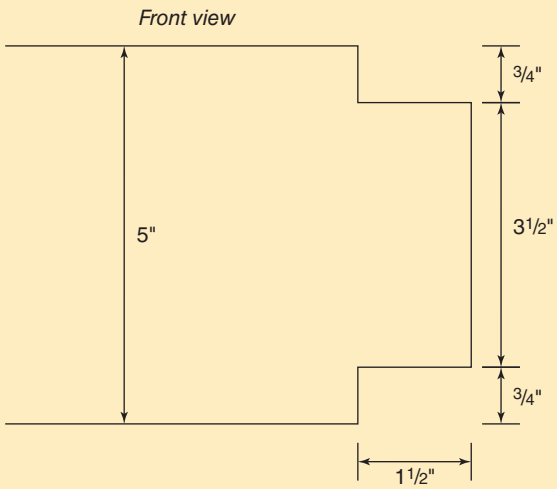


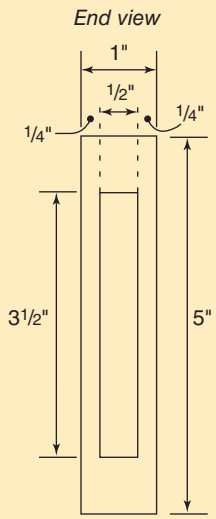
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O

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P

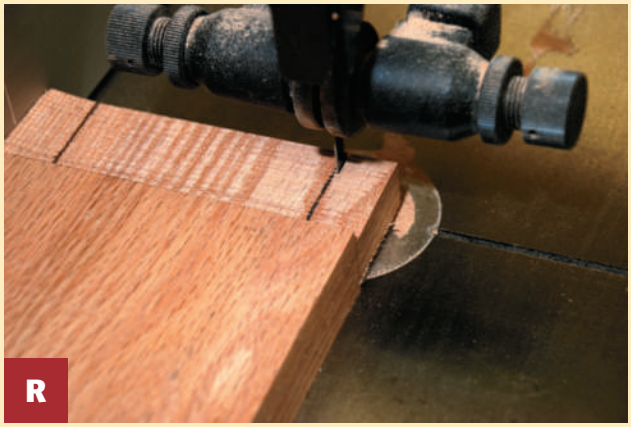
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14. Make a series of overlapping cuts to complete the mortise, as shown in **Figure O**.
15. Cut the remaining seven mortises in the same manner, making your first cuts to the inside of the start and stop marks you laid out.
16. Rout a 1/8" roundover on all four sides of each leg to soften the sharp edges.
17. Cut the four aprons to size and plane to a 1" thickness.
18. Lay out the tenons on either end of each apron piece as shown in **Figure P**.

19. Cut the tenons to thickness. This can be done on the table saw using the miter gauge and a dado blade; however, this may prove difficult, because the pieces are long. The task can also be done on the band saw using the fence as a guide; a third method is to use the miter saw by setting the depth stop and making multiple cuts, as shown in **Figure Q**. Another method is to install a dado blade on the radial arm saw.
20. Use a band saw, jigsaw, or handsaw to cut the tenons to width, as shown in **Figure R**.



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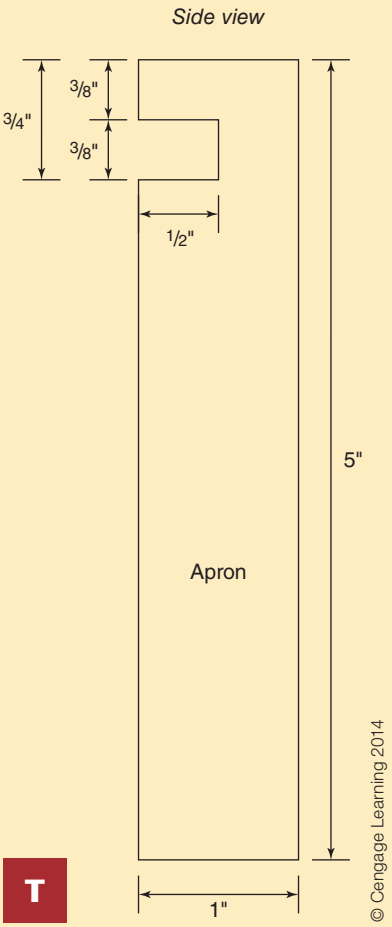


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S

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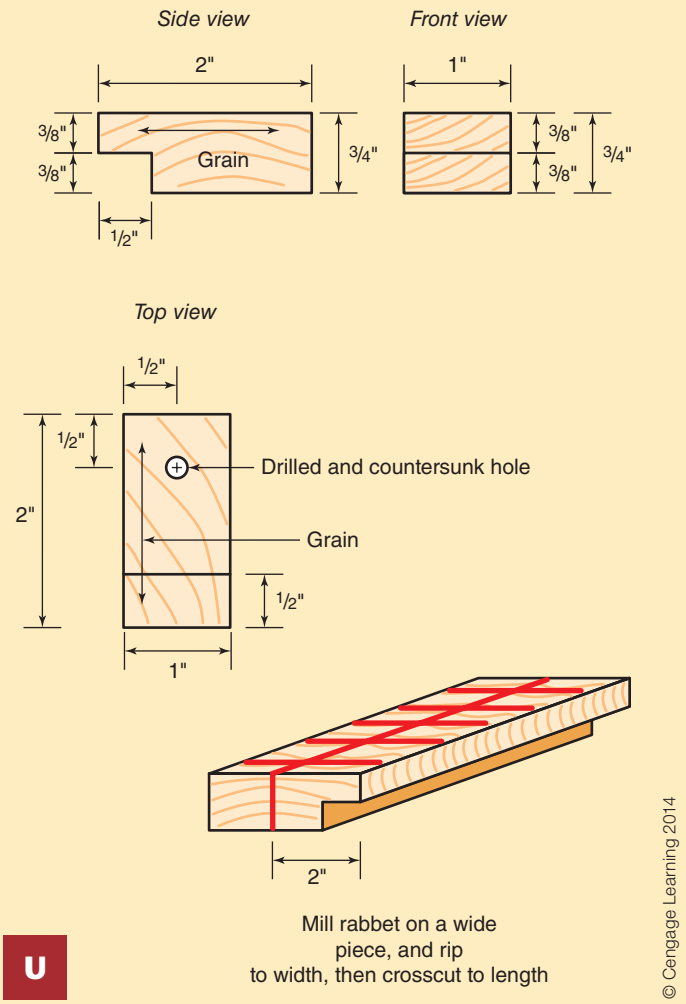


T

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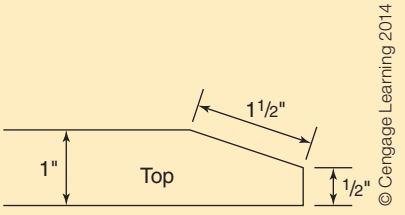
21. Smooth the rough surface of the tenons just sawn with a chisel or shoulder plane.
22. Miter the ends of the tenons on the miter saw, as shown in **Figure S**.
23. Set up a 3/8″-wide dado blade on the table saw, and machine a groove 3/8″ wide by 1/2″ deep 3/8″ down from the inside top edge of all four aprons. Refer to the diagram in **Figure T**.

24. Make the button blocks for attaching the top of the table to the base. You will need 16 — five for each long apron, and three for each short apron. Refer to **Figure U**. Make the rabbet on 3/4" stock prior to cutting off the buttons. Be sure to consider grain direction; it is important.
25. Drill and countersink holes in the button blocks for the screws. The screws should drop easily through the holes.
26. Dry assemble and clamp the legs and aprons. Check for fit and trim aprons if necessary.
27. Sand the legs and aprons and glue and clamp. Check the assembly for square by checking diagonal measurements.
28. Machine the top to final dimensions.
29. Plane or sand the top flat.
30. Lay out the bevel on the edges of the top, as shown in **Figure V**.



U

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V

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31. Plane the bevel, working to your layout lines (see **Figure W**).
32. Sand the top.
33. Apply finish to the base and the top. Be sure to finish both sides of the top.
34. When the finish has cured, place the top upside down on a bench, and center the base on it. Attach the base to the top with the button blocks and screws, as shown in **Figure X**. Keep the button blocks 1/8" away from the bottom of the groove in the long aprons to allow for expansion and contraction of the top.



18

Housed Joints

You'll Learn

After studying the chapter, the student should be able to:

- Define a housed joint
- List and identify various housed joints
- Explain the advantages and disadvantages of different housed joints

INTRODUCTION

When a case has dividers or shelves in it, a **housed joint** is required. The function of the housed joint, which is a type of case joint, is to hold dividers and shelves in place. This can be accomplished through the use of various kinds of housing joints, such as the butt, dado, dado-and-rabbet, tongue-and-dado, dado-and-spline, sliding dovetail, and multiple-tenon joints. In this chapter, we will cover each of these housing joints.

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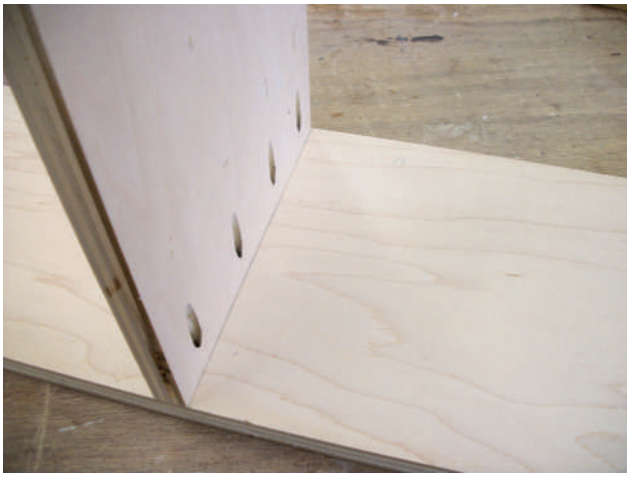
BUTT JOINT

A butt joint that is used as a housing joint must be reinforced. Nails or screws may be driven in from the outside of the case, but they leave visible marks that will need to be hidden on any furniture other than the strictly utilitarian. When finish nails are the fastener of choice, wood putty can be used. Screws can be recessed, in which case the resulting hole may be covered with plugs or buttons. Another option that uses screws is to employ pocket-hole joinery. The pockets and pilot holes are drilled through the shelf or divider, and then the screws pull the pieces to the case. See **Figure 18-1** and **Figure 18-2**. If used on shelves, they are driven from the bottom of the shelf, making them less visible. Plugs can be purchased to cover the holes if desired. Butt joints can also be reinforced with dowels or biscuits. The dowels may be blind, unseen when the case is assembled, or they can be driven in from the outside through holes drilled in the assembled joint, and may be considered a decorative detail (see **Figure 18-3** and **Figure 18-4**). A biscuited butt joint is a hidden joint (see **Figure 18-5**).



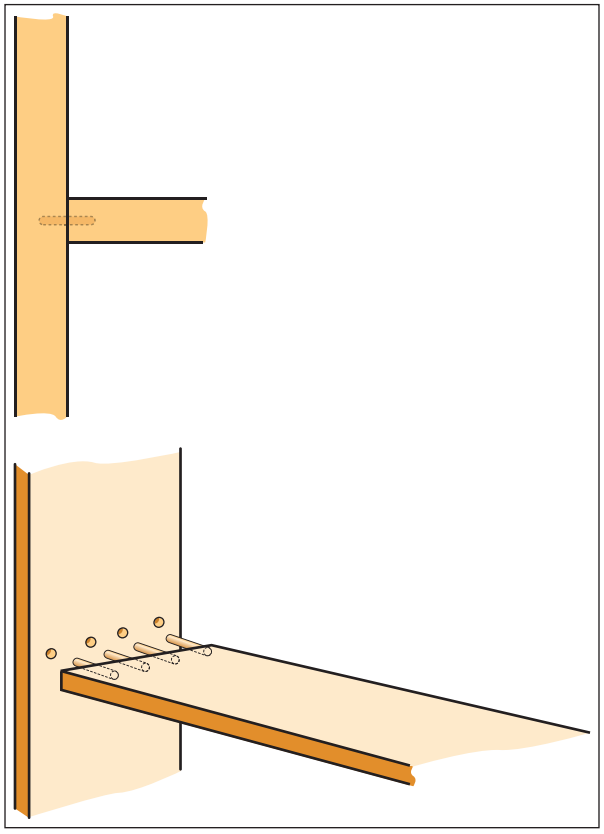
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FIGURE 18-1 Pocket hole for shelving.



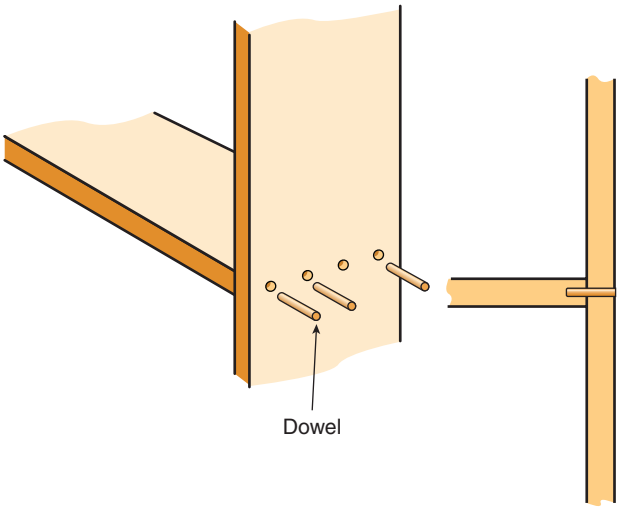
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FIGURE 18-2 Pocket hole joint for divider.



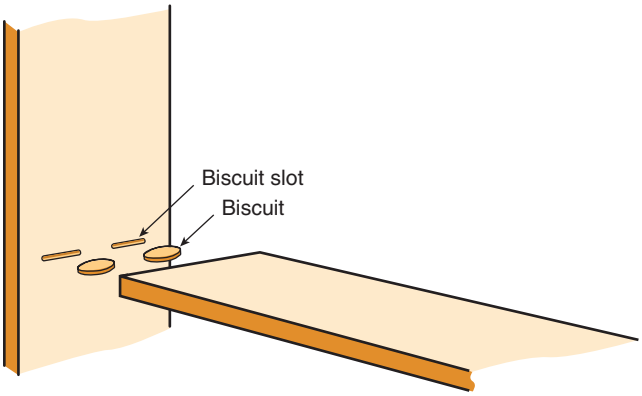
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FIGURE 18-3 Blind doweled butt housing.



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FIGURE 18-4 Through doweled butt housing.



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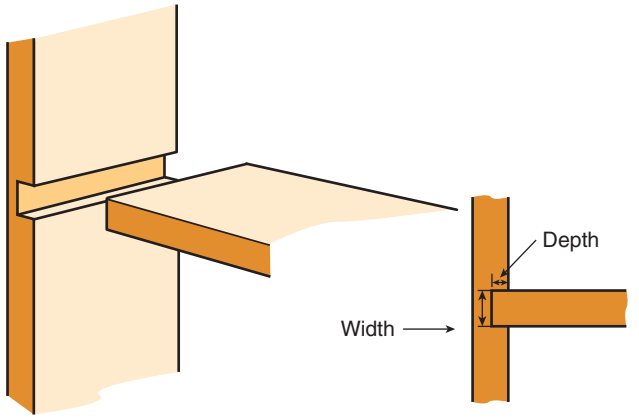
FIGURE 18-5 Butt housing reinforced with biscuits.

The butt joint is a low-end housing joint best suited for utilitarian rather than aesthetically pleasing construction.

DADO JOINT

The dado joint is the most commonly used housing joint in cabinet construction. A dado that is the same width as the thickness of the shelf or divider to be set into it is milled in the part that will accept the shelf or divider (see **Figure 18-6**).

The dado in a case side provides a ledge to support a shelf, and it also helps keep the shelf from cupping. However, it does not prevent the shelf from pulling out of the side. It is usually glued in place, but there is not a great deal of gluing surface, because there is so much end grain involved. Therefore, it may be wise to tack the shelf in place from the outside of the case.

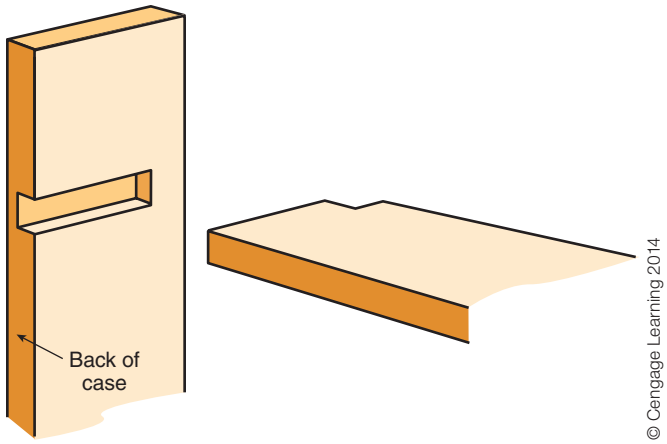


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FIGURE 18-6 Through dado housing.

The dado does not have to be particularly deep to adequately support the shelf. For solid wood, 1/8″ is deep enough, and 1/4″ deep is sufficient when using plywood, MDF, or particleboard.

Dadoes may run all the way through a case side, or they may be stopped or blind. A dado that runs all the way through the case is called a **through dado housing** (see **Figure 18-6**). **Figure 18-7** shows a *stopped-dado housing*, and **Figure 18-8** illustrates a *blind-dado housing*. The **stopped-dado housing** consists of a dado in the case that stops short of the front of the case; the **blind-dado housing** is stopped short of both the front and the back of the case. Note that both the stopped-dado and blind-dado housings require that the shelf be trimmed to fit the dado. Stopped-dado and blind-dado housings are used if the cabinetmaker does not



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FIGURE 18-7 Stopped dado housing.

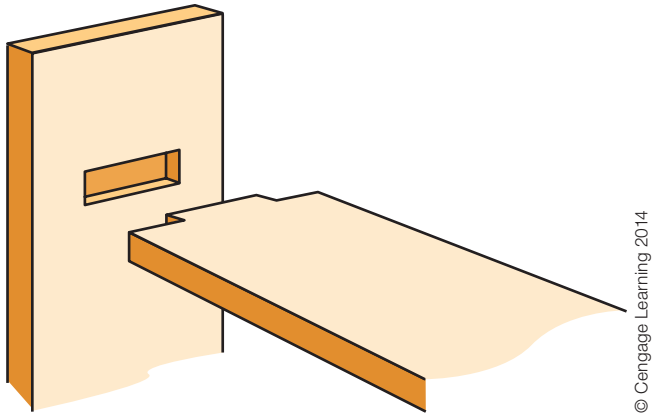

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FIGURE 18-8 Blind dado housing.

want the dado joint to show on the front or back of the cabinet.

The dado joint, particularly the through dado, is a simple and effective housing joint. Its disadvantage is seen when using sheet goods as shelves or dividers. Sheet goods are slightly undersized in thickness. Most often 3/4″ material is used for shelves and dividers in cabinet construction. Since sheet goods are slightly less than 3/4″ thick, shelves or dividers made from them will not fit snugly into dadoes that are milled 3/4″ wide, which results in a less than perfect fit — and an unsightly gap. This can be adjusted for by making a narrower dado, using a different arrangement of chippers if you are using a dado blade. When making dadoes using a router, a bit made specifically for this purpose may be purchased. It is important to store this bit separately from other straight bits: It is so close to a 3/4″ bit that the difference will not be noticeable. To get a properly fitting dado joint when using sheet goods, the cabinetmaker has the two choices outlined above or may choose to use a different type of joint to avoid this potential problem.

WOODWORKING TIP:

A simple, shop-built jig makes routing dados quick and easy, especially on large sheet goods that might be tricky to maneuver on the table saw (see **Figure 18-9***). A jig can be made to any length, but because it is specific for one size dado, it should be clearly marked. A piece of 1/4″ plywood or hardboard is glued and fastened to a 3/4″ scrap of sheet goods. The 1/4″ material should be the same length as the 3/4″, and its width should be the width of the 3/4″ material plus the distance from the edge of the router base plate to the center. Once these two pieces are fastened together, install the router bit to be used for the dadoing, and run the router along the 3/4″ piece to trim the 1/4″ to exact size (see* **Figure 18-10***). The finished jig can be clamped so that the 1/4″ piece is aligned with the dado line as shown in* **Figure 18-11***, and the router is then run along the fence created by the 3/4″ scrap. Label the jig so that it is clear what diameter bit is to be used with it.*

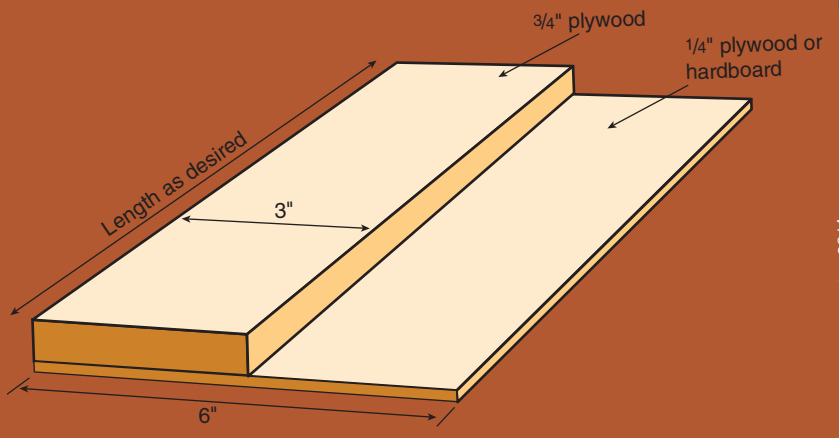


FIGURE 18-9 Router dado jig.

1. Glue 3/4" and 1/4" pieces together.
2. Trim jig to size by running router with the straight bit to be used along the 3/4" piece.
3. To use the jig, clamp it to the piece to be dadoed with the 1/4" edge along the layout line, and run router with base against 3/4" piece.

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FIGURE 18-10 Run the router with the bit to be used with the jig along the 3/4″ plywood piece to cut the 1/4″ piece to size.

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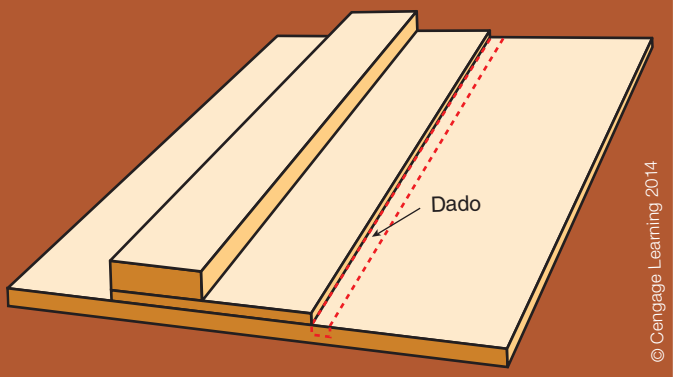


FIGURE 18-11 Clamp the jig to the work.

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DADO-AND-RABBET JOINT

The dado-and-rabbet housing joint has a dado milled into the case and a rabbet on the end of the shelf or divider. The rabbet creates a tongue that fits into the dado made in the case (see **Figure 18-12**). A shelf housed in a case can hold more weight if the rabbet is milled on its top surface.

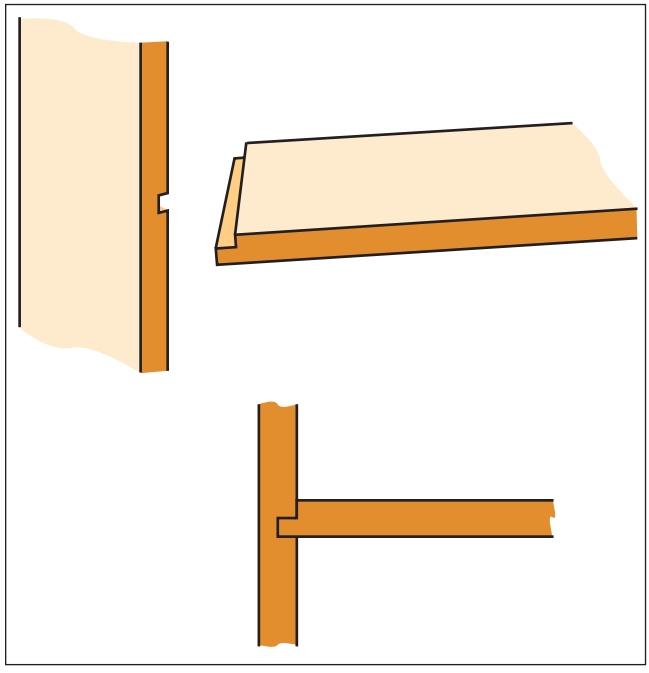


FIGURE 18-12 Dado and rabbet housing.

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This joint does not offer a lot of good gluing surface, but what it does have is sufficient provided the joint fits well. Like the dado joint, it may also be stopped or blind.

TONGUE-AND-DADO JOINT

The **tongue-and-dado housing** is similar to the dado and rabbet, but instead of a rabbet at the end of the shelf or divider, a tongue is milled with shoulders on both sides. The additional shoulder gives this joint more stability than the dado-and-rabbet configuration. The tongue and dado may either be through or blind, as shown in **Figure 18-13**. A stopped joint may also be cut.



FACTS ABOUT WOOD

Soft maple, *Acer rubrum,* is also known as *red maple*. It is not as strong or hard as hard maple, *Acer saccharum*. Like hard maple, soft maple is a diffuse porous hardwood. Soft maple grows in the United States and Canada. It is light creamy brown in color and has good steam-bending qualities. It stains well and polishes to a fine finish and is used for furniture, turning, musical instruments, flooring, plywood, and veneer. ■

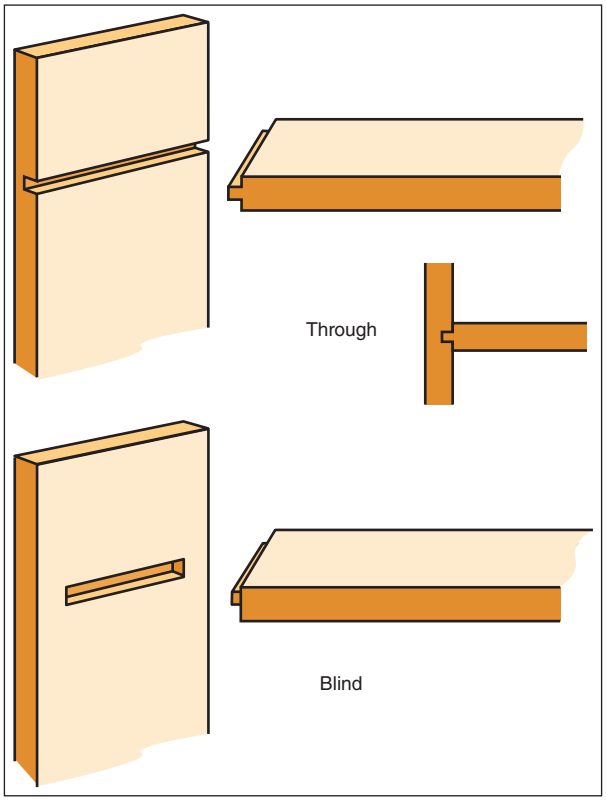


FIGURE 18-13 Tongue and dado housing.

DADO-AND-SPLINE JOINT

The **dado-and-spline housing** consists of dadoes milled in the two joining pieces. A spline is made which is fit and glued between them (see **Figure 18-14**).

The dado-and-spline joint is a good choice when working with MDF or particleboard. Neither of these sheet materials has any grain, so they have none of the strength that comes with grain. The spline should be set into the case about a third of the thickness of the case material. A deeper cut would weaken the case. The dado cut into the shelf for the spline needs to be about twice the depth of the dado that was made in the case. It needs to be longer so that the shelf has adequate support. Also, if the spline is located below the center of the shelf, the shelf will be able to carry more weight with less stress.

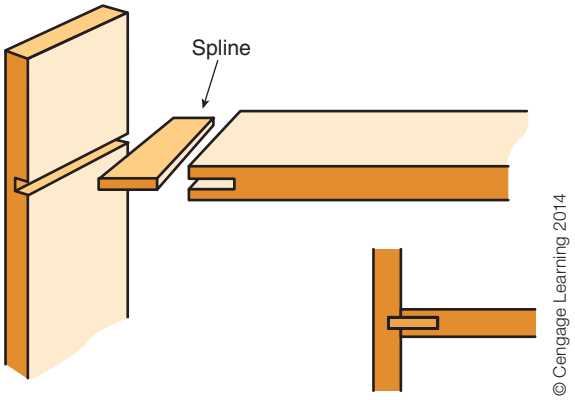


FIGURE 18-14 Dado and spline housing.

CAUTION

Keep blades and bits sharp and clean, and you will get cleaner cuts with less burning. Because less force is required to cut and shape material, it is also safer for the operator.

SLIDING DOVETAIL JOINT

The **sliding dovetail joint** is a more elaborate version of the dado joint; in fact, it is sometimes called a dado dovetail. The shelf or divider has a dovetail-shaped tongue milled on its end that fits into a correspondingly shaped dado on the case (see **Figure 18-15**).

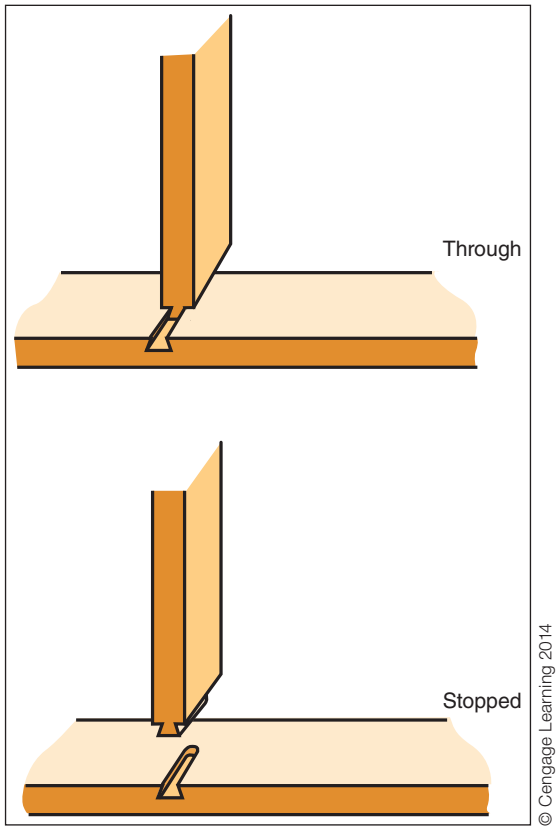


FIGURE 18-15 Sliding dovetail housing.

PROCEDURE 18-1

Making a Dado-and-Rabbet Housing

STEPS

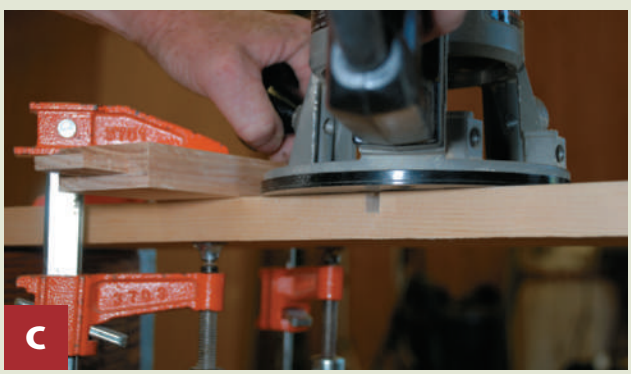
1. Mark out the position of the dado on the case sides, as shown in **Figure A**.
2. Fit the appropriate size straight bit in a router for the width of dado desired, and set it for the depth required.
3. If using a jig, like the one described earlier in this chapter, clamp it to the work with the 1/4″ edge lined up with your layout mark. If a straightedge is clamped to the work, you need to figure out the distance from the edge of the router base to the bit and offset the straightedge by this amount (see **Figure B**).
4. Turn on the router and machine the dado; keep the router base tight against the jig or straightedge, as shown in **Figure C**.
5. The rabbet can be made with the same straight bit you already have in the router. Lay out the rabbet, and adjust the depth of cut as needed.
6. Set the jig or straightedge so that the rabbet will be cut in the proper spot.
7. Mill the rabbet as shown in **Figure D**.



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Properly fit, this joint has much greater mechanical strength than the simple dado housing. It does not really even need glue, although using glue will add more strength. Due to its sloping sides, it needs to be slid into place, hence its name. The sliding dovetail may be a through or a stopped joint, just like the simple dado.

A variation on the sliding dovetail pictured in **Figure 18-15** is the **sliding half-dovetail**. This joint has just one sloping side (see **Figure 18-16**).

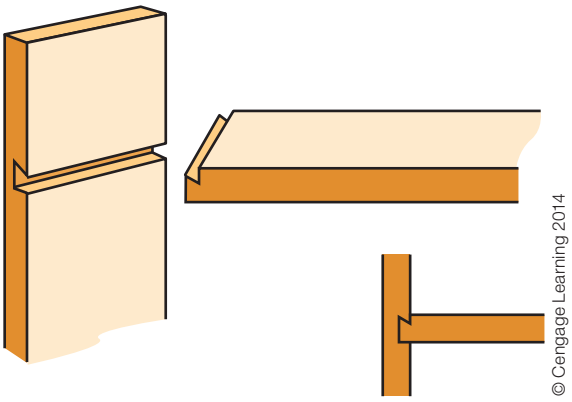


FIGURE 18-16 Sliding half-dovetail housing.

WOODWORKING TIP:

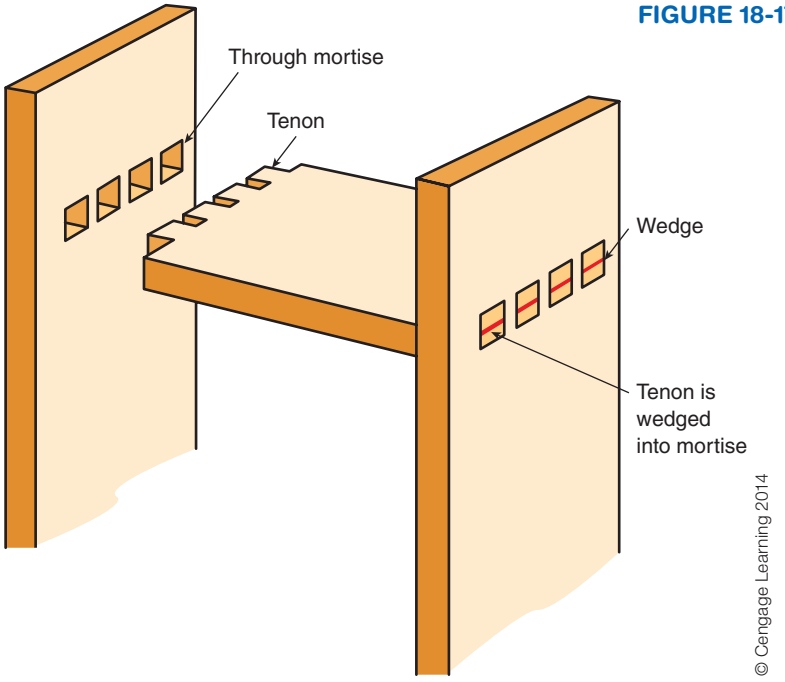
When routing the recess for a sliding dovetail, it is not possible to make the cut in a series of passes, as is usual for many other routed joints, due to the sloping nature of the dado. Rather than attempt to make this dovetail dado all at once and risk breaking the dovetail bit, first rout a dado with a straight bit that is about the same diameter as the narrowest part of the dovetail bit. This may be done in a series of passes. When the required depth is reached, put the dovetail bit in the router, adjust it to the final depth of cut, and make the pass. The bulk of the work has already been done by the straight bit, and the cut with the dovetail bit will be much easier.

MULTIPLE-TENON JOINT

The multiple-tenon housing is a mortise-and-tenon joint. It consists of multiple tenons on the shelf or case divider that fit into corresponding mortises in the case. It may be a blind joint but is more often a through joint (see **Figure 18-17**).

It is usual to cut kerfs across the end grain of each tenon and secure them in place with hardwood wedges. These provide a nice decorative touch, as well as locking the tenons into their mortises.

FIGURE 18-17 Multiple tenon housing.





Summary

Housing joints are case joints that allow shelves and dividers to be inserted into cases. There are a number of housing joints to choose from. The most commonly used housing joint is a simple dado, but there are other options as well. They include the butt joint, which must be reinforced somehow, the dado-and-rabbet, tongue-and-dado, dado-and-spline, sliding dovetail, and multiple-tenon joints. As with the other joints discussed, the final strength and attractiveness of the joint depends not only on the joint chosen, but also on the degree of precision with which it is executed.



Key Terms

blind-dado housing
dado-and-spline housing
housed joint
sliding dovetail joint
sliding half-dovetail
stopped-dado housing
through dado housing
tongue-and-dado housing



Check Your Knowledge

1. What is the purpose of a housing joint?
2. Which housing joint is most frequently used?
3. Is there any potential disadvantage to the joint you named in question 2 above, and if so, what is it?
4. How does a dado-and-rabbet joint differ from a tongue-and-dado joint? Does one have any advantage over the other? If so, what is it?
5. How is the dado-and-spline housing joint different from either the dado and rabbet or the tongue and dado? Is it particularly well suited for any particular material, and if so, what, and why?
6. How is a sliding dovetail housing like a dado housing? How does it differ? Is one better than the other, and if so, why?
7. What is a multiple-tenon housing?
8. How are the tenons in a multiple-tenon joint usually secured in place?
9. If a cabinetmaker wanted to make a housing that looked like a butt joint, but had the advantages of a dado or sliding dovetail housing, what might she do?
10. When making a dado-and-rabbet housing, should the rabbet be milled on the top or bottom of a shelf? Why is this?

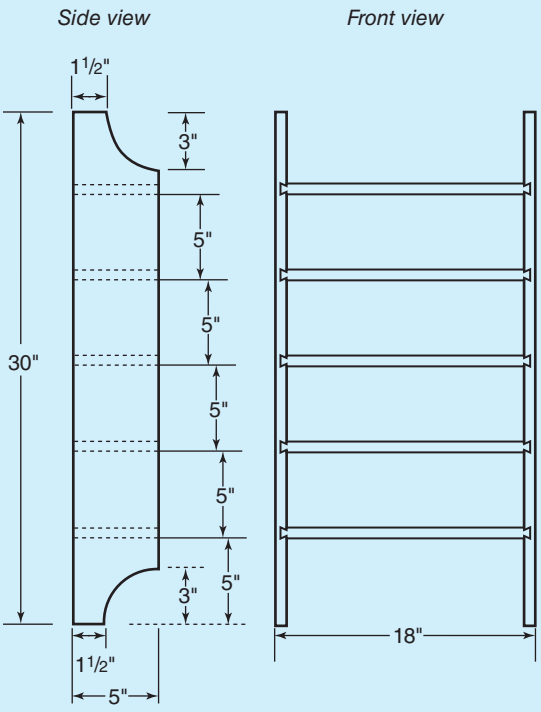
BUILD IT!

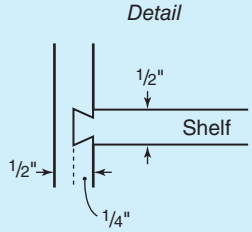
Hanging Shelf



A

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B

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A completed hanging shelf is shown in **Figure A**.

TOOLS REQUIRED

- Measuring tool
- Squaring tool
- Table saw
- Miter saw
- Band saw or jigsaw
- Router, router table, straight bit, dovetail bit
- Dado jig for router or straightedge

MATERIAL REQUIRED

- 1/2″ solid stock

STEPS

1. Review the plan shown in **Figure B** to determine the sizes of the component parts.
2. Mill pieces to size. Keep sides square at this point.

3. Lay out and cut dadoes in shelf sides. Sides can be placed side by side and dadoes routed through them at the same time, as shown in **Figure C**. Use a dado jig or a straightedge and straight bit whose diameter is the same as or a bit less than the smallest part of the dovetail bit you will use later. This will remove the majority of the material.
4. Remove the straight bit from the router, and install the dovetail bit and set it to the same depth. Rout the dadoes again, using the same positioning for the dado jig or straightedge as previously.
5. Using the dovetail bit in a table-mounted router, machine the dovetails on the ends of the shelves. Use a scrap of 1/2″ material for testing until the proper fit is achieved, and then mill the shelves. See **Figure D**.
6. Lay out and cut the curves in the sides with a band saw or jigsaw.
7. Sand the parts.
8. Assemble, glue, and clamp.
9. Do any final sanding and finish as desired.



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BUILD IT!

PROJECT CHALLENGE

Bookcase



A

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A completed bookcase is shown in **Figure A**.

STEPS

1. Review the materials list given in **Figure B**. Lay out and cut the sides and shelves to size.
2. Lay out and cut the dadoes and rabbets for the shelves in the sides, as shown in **Figure C**, with a dadoing jig or straightedge and straight bit in a router.
3. Machine a 3/8″-wide by 1/4″-deep rabbet on the back inside of the two sides to receive the back. Use a rabbeting bit in the router or a dado blade and sacrificial fence on the table saw.
4. Reinforce the front edge of the shelves by biscuiting and gluing on a 3/4″ × 3/4″ wide strip of matching hardwood.
5. Glue up a hardwood top slightly oversize, and when dry, plane and sand flush; cut to finished size.

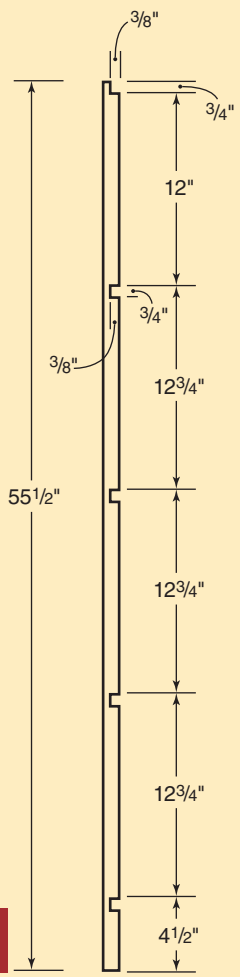
Assembly list – bookcase

Part	Dimensions (thickness × width × length)	Quantity
Side	3/4" × 11 1/4" × 55 1/2" plywood	2
Top	3/4" × 11" × 34 3/4" plywood	1
Shelf	3/4" × 10 1/4" × 34 3/4" plywood	4
Shelf strip	3/4" × 3/4" × 34 3/4"	4
Back	1/4" × 34 3/4" × 51 3/4" plywood	1
Overhanging top	3/4" × 13" × 37 1/2"	1
Stile	3/4" × 2 1/2" × 55 1/2"	2
Top rail	1/2" × 3" × 30 3/4"	1
Bottom rail	1/2" × 4 1/4" × 30 3/4"	1
#20 biscuits		4
#8 × 1 1/4" roundhead screw		6
#8 flat washers		6

B

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Side view - side



C

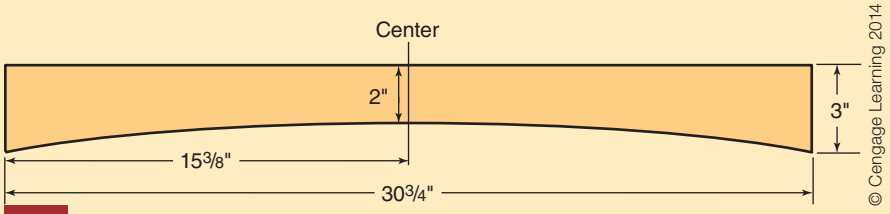
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6. Sand the shelves and the inside of the sides.
7. Assemble the sides and shelves with glue and clamp up.
8. Cut the back to size, sand lightly, and glue and staple into the sides and shelves, as shown in **Figure D**. Notice that the back ends at the bottom of the bottom shelf — it does not go all the way to the floor. You may wish to mill 1/4″ × 3/8″ × 3 3/4″ solid wood strips to fit into the rabbets that run all the way to the bottom of the sides.
9. Cut the stiles and rails for the face frame to the sizes specified in the assembly list. Note that the rails are 1/2″ thick, so if you are using 3/4″ stock, they will need to be planed to thickness.
10. Lay out and cut the arch on the top rail, as shown in **Figure E**, with a jigsaw or on the band saw. Sand smooth.
11. Using a 1/8″ router bit, round over the inside edge of the top and bottom rails, and the inside edge of the stiles.
12. Use #20 biscuits, one in each corner, to join the face frame components. Since the rails are 1/2″ thick and the stiles are 3/4″ thick, the plate jointer must be referenced from the back faces of the stiles and rails, as shown in **Figure F**.



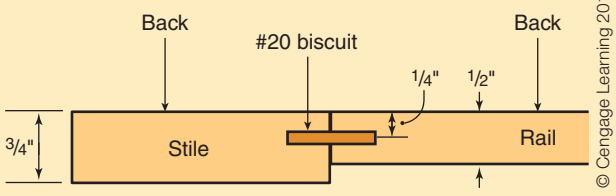
D

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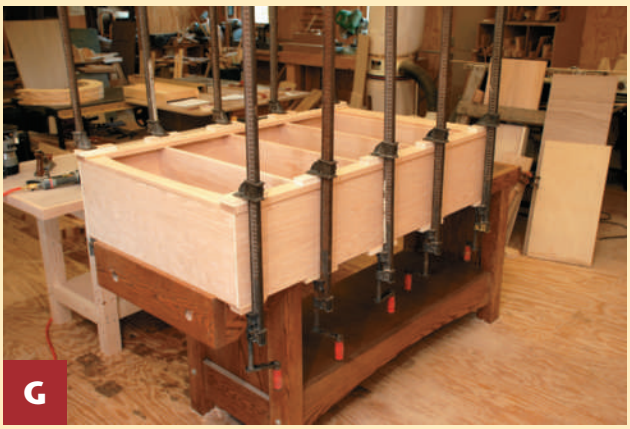
E

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F

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G

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H

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13. Glue and clamp the face frame together, checking it for square.
14. Once the face frame is dry, unclamp it, clean up the glued joints, and glue and clamp it to the case, as shown in **Figure G**. The face frame will overhang the sides slightly.
15. Trim the face frame flush with the sides. You can do this with a plane or a piloted, flush trim bit in a router, as shown in **Figure H**.
16. Rout a 1/8″ roundover on the outside edges of the stiles.
17. Rout a 1/8″ roundover on front and side edges of the top. Do both faces. Do not round over the back.
18. Fasten the top to the case through the top shelf, using six #8 × 1 1/4″ roundhead wood screws and washers. The back of the top is flush with the back of the cabinet, and the overhangs on each side should be equal. Drill 1/4″ shank holes through the top shelf. This will allow the solid top to expand and contract.
19. Do any final sanding and finish as desired.



19

Making Wide Panels, Thick Blanks, and Corner Joints

You'll Learn

After studying the chapter, the student should be able to:

- Identify the reasons for creating wide panels, thick blanks, and corner joints
- Articulate how wide panels, thick blanks, and corner joints differ from one another
- Discuss the methods of creating wide panels, thick blanks, and corner joints
- Articulate the advantages and disadvantages of the various methods of creating wide panels
- Discuss alternative methods to avoid cupping in wide panels
- Explain clamping for wide panels and thick blanks

INTRODUCTION

There are many occasions when the woodworker needs wider or thicker pieces than are available. One solution to needing wider pieces is to work with sheet goods. However, if you are working with solid wood, other solutions must be discovered. Wide pieces are needed for tabletops and often for panels. Thicker pieces may be needed for turning. Corners have to be built for columns and to form vertical corners for cabinets. The solution is a category of joinery called *edge joints*. Narrower boards are joined edge to edge to create wider panels, and thinner pieces are

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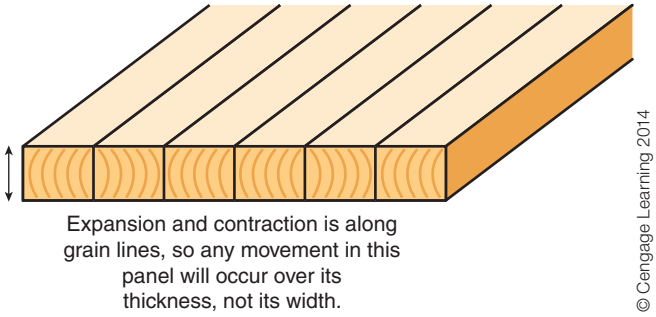
joined face to face to make thicker blanks. If the edge of one piece is joined to the face of another, a corner joint is created. There are various means for making each of the edge joints that will result in a stable, attractive product. This is what will be explored in this chapter.

WIDE PANELS

Wide panels are manufactured by joining two or more narrow boards together edge to edge. There are various methods of doing this. The joint between the edges may be a simple butt joint, or it may be either reinforced or positioned. Reinforced butt joints include the use of splines, biscuits, dowels, or butterfly keys. Positioned joints are joints such as the tongue-and-groove, shiplap, glue, lock miter, or finger joints.

Whichever type of joint is chosen for gluing boards edge to edge to make a wider panel, there is always a concern to keep the resulting wide panel from warping. There are several strategies available for combating this potential problem. One is to use quartersawn lumber: Because the expansion and contraction of quartersawn lumber is over its thickness rather than across its width, as with plainsawn material, a very stable wide panel can be created (see **Figure 19-1**). There are two possible disadvantages to this method. One is that quartersawn material does not show the distinct grain patterns that one may wish to showcase in a wide panel. The other is that quartersawn lumber is not nearly as readily available as plainsawn material.

A second option to reduce warping on wide panels is to use relatively narrow boards, no more than about 3 inches wide, to create the wider panel. This option may be combined with the third choice, which is to alternate the growth rings of successive boards in the panel (see **Figure 19-2**).



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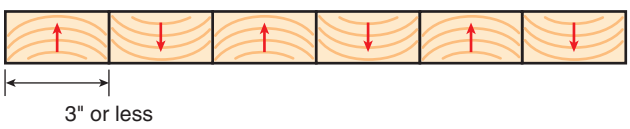
FIGURE 19-1 Using quartersawn lumber for wide panels minimizes warping.

The idea with option numbers two and three is that cupping will be limited over the width of each piece, and if the growth rings are alternated, the cupping will alternate from board to board and will therefore be less obvious than if each board cupped in the same direction (see **Figure 19-3**).

While these are good strategies for minimizing warping, if the cabinetmaker has very attractive boards, she may not wish to rip them up into narrow strips. Of course, even when choosing to use wider boards, the growth rings can be alternated.

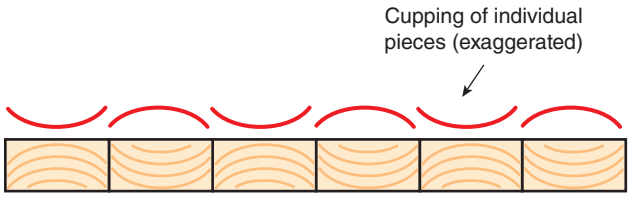
Time and care should be taken in laying out boards for a wide panel. Chances are good that the panel being made will be a highly visible part of the final project. Its appearance is very important. It is good to know the rules for minimizing warping, but the final call should be one based on appearance. One thing that should be avoided, for both aesthetic and practical reasons, is mixing quartersawn and plainsawn lumber. Since they do not expand and contract in the same way, a step in the final panel may result. Expansion and contraction of lumber occurs primarily across the grain, so the movement in a quartersawn board will affect its thickness, but movement in a plainsawn board affects its width (see **Figure 19-4**).

It is also important that all the lumber used for a panel be dried to a uniform moisture content, between 6 percent and 8 percent. It is also a good idea to have all the boards that will be used in a panel in the shop for a few days to acclimate to shop conditions before working with them.



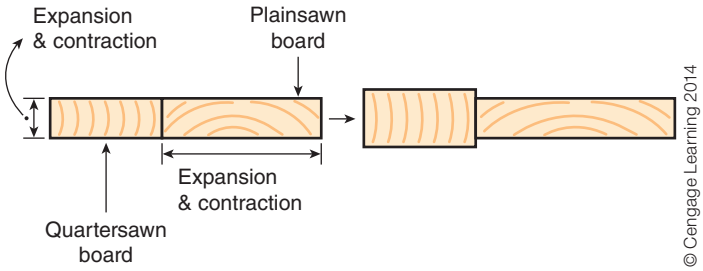
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FIGURE 19-2 Use narrow boards and alternate growth rings.



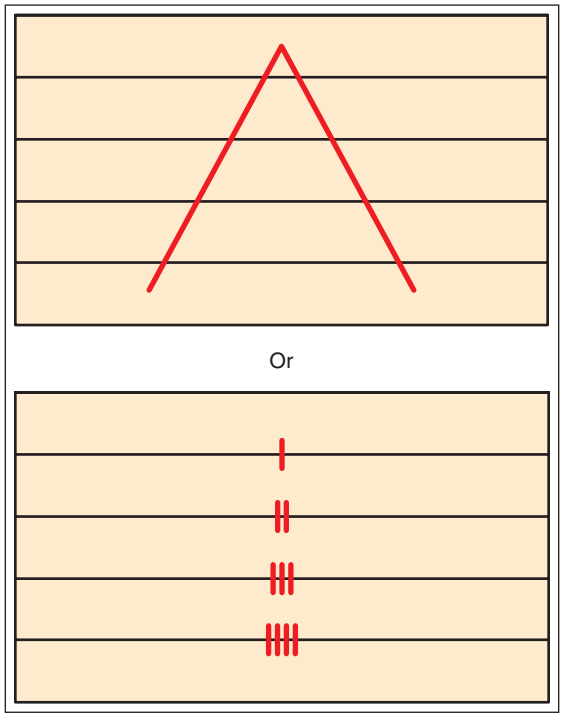
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FIGURE 19-3 Cupping will be limited to the width of the board and will alternate to be less obvious than if all boards cupped in the same direction.



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FIGURE 19-4 Plainsawn and quartersawn boards should not be mixed in a wide panel or a step may result.

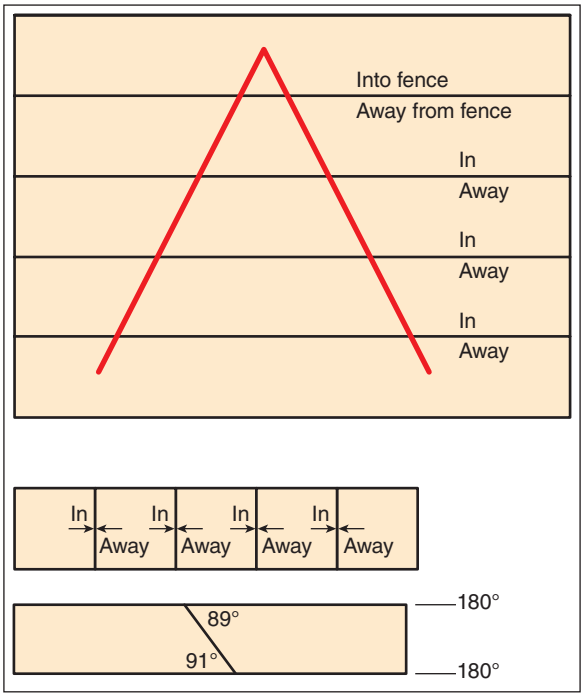


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FIGURE 19-5 Panels are marked for easy reassembly.

When the boards that will make up the panel have been studied and moved around to their final desired location, they are marked for easy reassembly (see **Figure 19-5**). Panels should always be made up slightly longer and wider than the final panel needs to be, and trimmed to final size afterward.

Once the panel is marked, each board is edged on the jointer to create an edge that meets its mating edge perfectly. There is a technique for doing this that will result in a good panel with no gaps between the boards, even if the jointer fence is slightly out of square with the jointer table. Even the slightest deviation from square will result in a gap, but this method will resolve that potential issue. The technique is to run mating boards through the jointer alternating



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FIGURE 19-6 Alternate the faces against the jointer fence.

the faces (see **Figure 19-6**). That is, if one edge is run with its marked face into the jointer fence, the edge of the next board that will butt against it is run with its marked face away from the jointer fence. The net result is that even if the jointer fence is a bit out of square, say one degree, the first board will get an 89° angle, but its mate will get a 91° angle; when they are set edge to edge, the sum is 180°, so the boards will butt together perfectly, and the final panel will be flat.

As mentioned previously, several choices exist for joining boards to form wide panels. Next we will look at some of these options.



FACTS ABOUT WOOD

Catalpa, *Catalpa speciosa,* is also known as *Catawba, cigartree,* and *Indian-bean*. It is a relatively soft hardwood with an uneven wavy grain. It is light tan in color with a prominent darker growth ring pattern. Since it is soft, it is unsuitable for furniture that will see heavy use, but it is decay resistant and ideal for outdoor carvings. ■

Simple Butt Joint

Simply butting boards edge to edge and gluing them yields a perfectly adequate joint. Like grain is being joined to like grain, and the glue gives all the strength

needed to create a strong bond. The only potential difficulty comes in keeping the boards aligned as they are glued up.

Reinforced Butt Joints

Reinforcing butt joints is helpful in avoiding the alignment problem that can occur when using a simple butt joint. There are several methods for reinforcing a butt joint, including splines, biscuits, dowels, and butterfly keys.

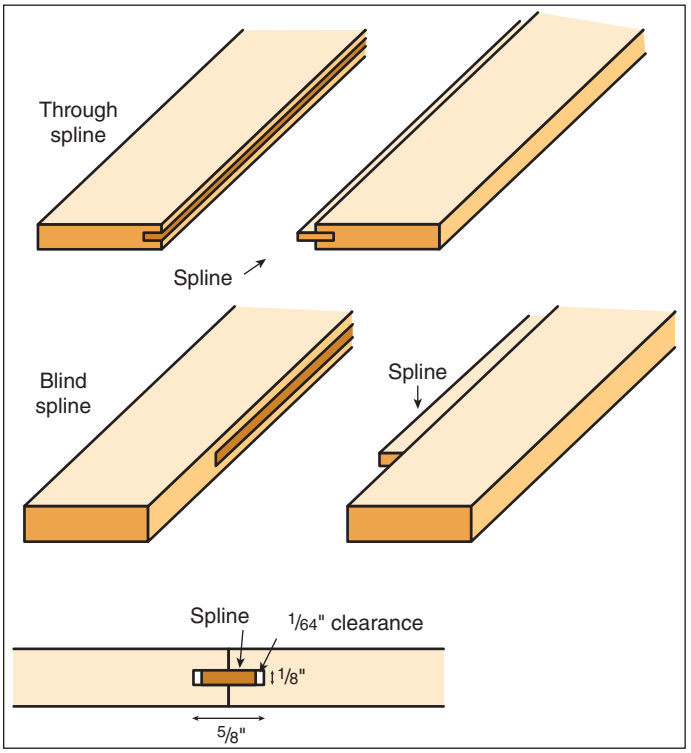
The use of splines in joining boards edge to edge offers an excellent alignment advantage. A groove is milled into the edges of the adjoining pieces. A strip of plywood or hardboard is inserted into the groove as the joint is glued up. The spline should be slightly narrower than the sum of the depth of the two grooves (see **Figure 19-7**). A splined joint may be through or blind.

Another option for creating a reinforced butt joint is to use biscuits. Biscuits come in three sizes, and the largest size that will fit should be used. Biscuits are spaced 8 to 12 inches apart (see **Figure 19-8**). The slot milled for the biscuit is enough larger than the biscuit itself that adjustment of the boards is possible during glue-up, which is an advantage. The glue swells the biscuit to fill the slot made for it.

A third choice for reinforcing a butt joint is the use of dowels (see **Figure 19-9**). Unlike biscuits, dowels offer no adjustment possibilities. Also, it is difficult to drill precisely matching holes in adjoining boards. For these reasons, dowels are not a particularly good way to reinforce a butt joint.

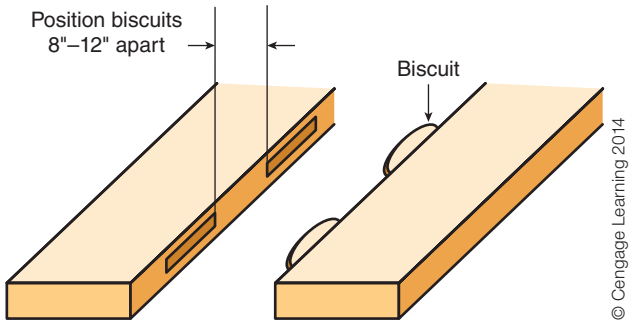
The use of **butterfly keys** is a traditional element of Japanese joinery. It consists of a double-dovetail–shaped piece, called a *key,* which is inset into the main pieces to help lock them together. The grain of the key runs across the joint. A recess for the key is let into each adjoining board in the shape of the butterfly, and the key joining the two is fit in place. The butterfly itself may be a decorative inlay, or it may extend all the way through the workpiece. Because this is a visible method of joining boards, unlike the other reinforcement devices covered, it has a strong decorative flavor, and may be made out of contrasting wood to further accentuate it (see **Figure 19-10**).

While the butterfly keys are meant to show, splines, biscuits, and dowels are not. They aid in aligning boards, which is an advantage if some of the boards to be joined are not absolutely flat, but they present a



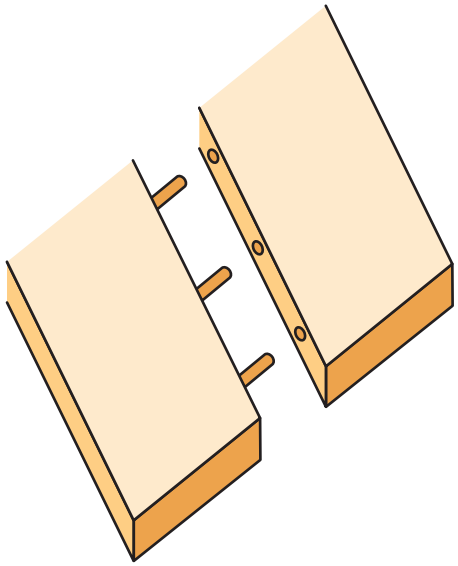
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FIGURE 19-7 Splined joint.



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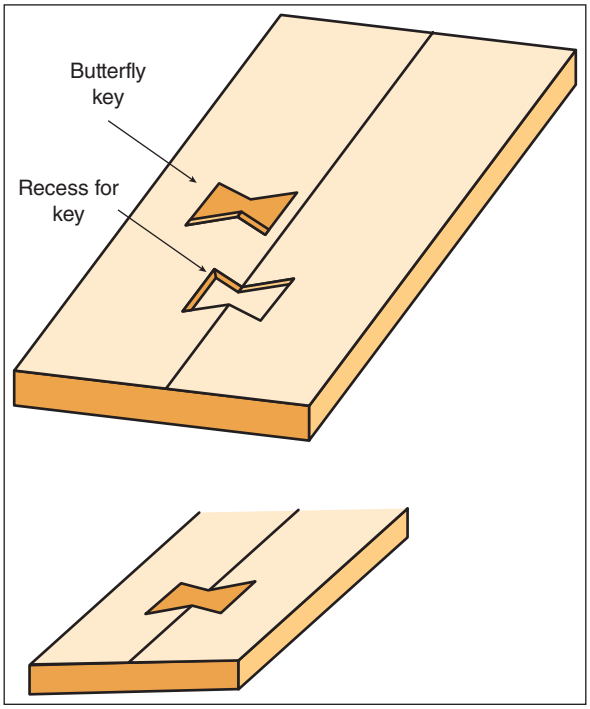
FIGURE 19-8 Butt joint reinforced with biscuits.



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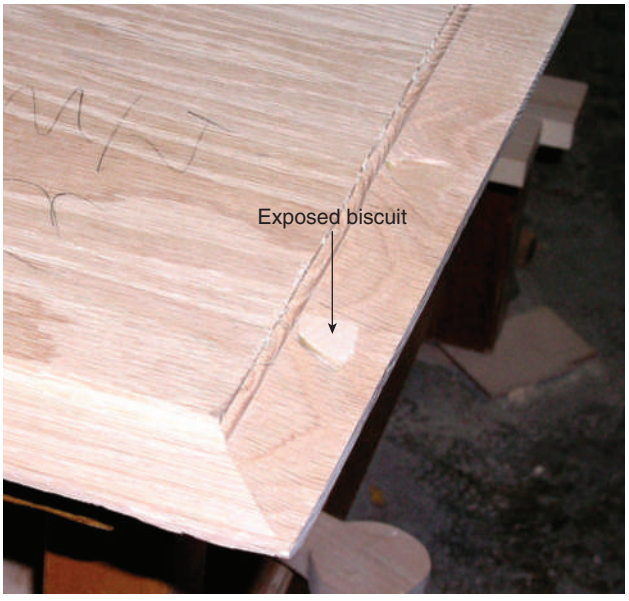
FIGURE 19-9 Butt joint reinforced with dowels.

significant disadvantage as well, if the panel is to be milled later. If this is the case, it is extremely important to keep track of where the alignment devices have been placed. This may be difficult to do, as often the glued-up panel will be planed and sanded smooth before it is machined. Later machining, especially in the case of panels that will be raised, may expose the alignment device, ruining the panel (see **Figure 19-11**).



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FIGURE 19-10 Butterfly keys used to reinforce a butt joint.

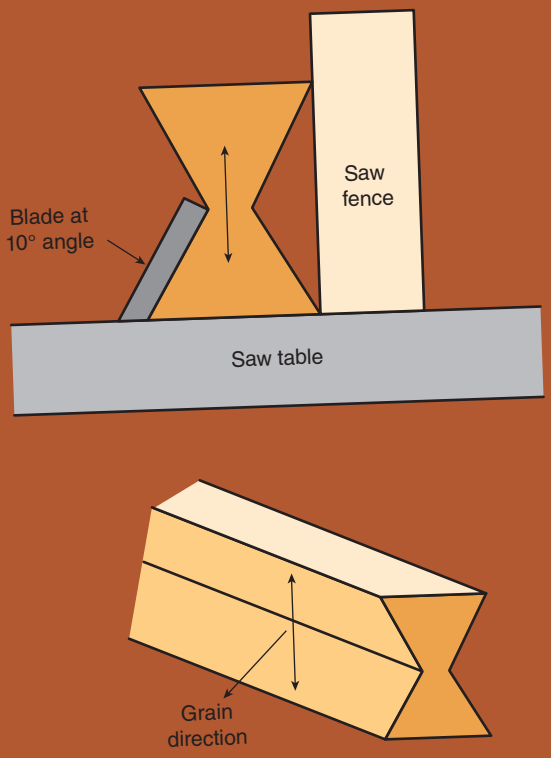


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FIGURE 19-11 Later milling of the panel may expose the alignment devices.

WOODWORKING TIP:

Butterflies can be made on the table saw. The saw blade height is set to half the thickness of the butterfly stock and tilted to 10°. Four bevel cuts are made, two on each side of the stock (see **Figure 19-12***). Then the material is crosscut to make individual butterflies.*



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FIGURE 19-12 Making butterflies on the table saw.

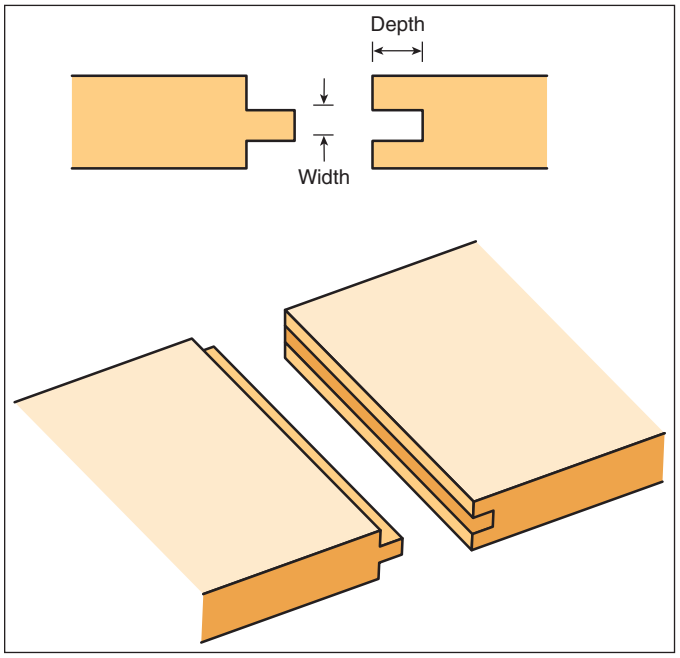
Positioned Joints

Positioned joints used for joining boards edge to edge for wider panels include tongue-and-groove, shiplap, glue, finger, and lock miter joints. A positioned joint has a profile milled on each of the adjoining boards so that they fit together flush. This is very helpful in aligning the boards for a resulting flat panel, and also offers extra gluing surface. An important thing to note with these joints is that all of them require more material than a butt joint, so the boards forming the original blank prior to machining will need to be wide enough to allow for this.

Tongue-and-groove joints have a tongue machined on the edge of one piece and a matching groove on the piece adjacent to it (see **Figure 19-13**). The tongue thickness is typically one-third the thickness of the stock being used. The length of the tongue is between

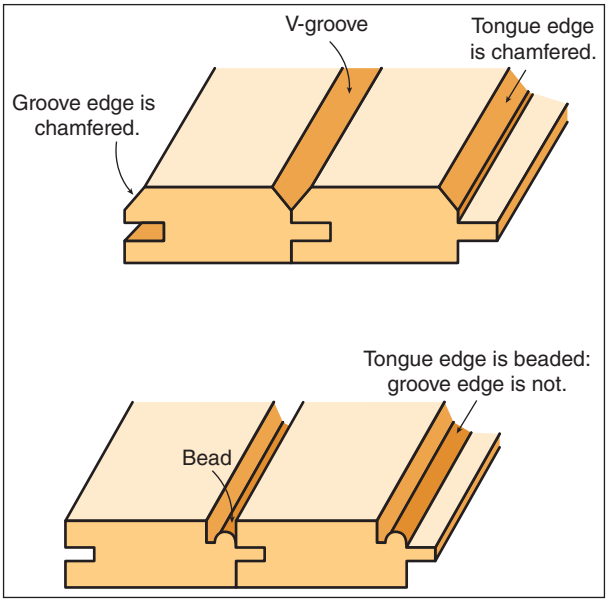
one-third and one-half the stock thickness. It is one-third if the boards are narrow (3 inches or less) and half if the boards are wider.

Tongue-and-groove joints may be glued or not. Sometimes they are decorated with a V-groove or bead. These decorative touches have a practical purpose as well, as they serve to disguise an opening that varies in width as unglued boards expand and contract due to seasonal changes (see **Figure 19-14**).



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FIGURE 19-13 Tongue-and-groove joint.

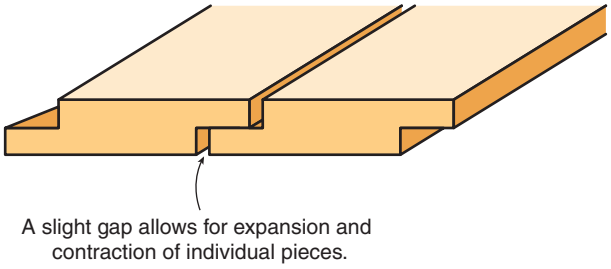


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FIGURE 19-14 Tongue-and-groove joints may be decorated with beads or V-grooves.

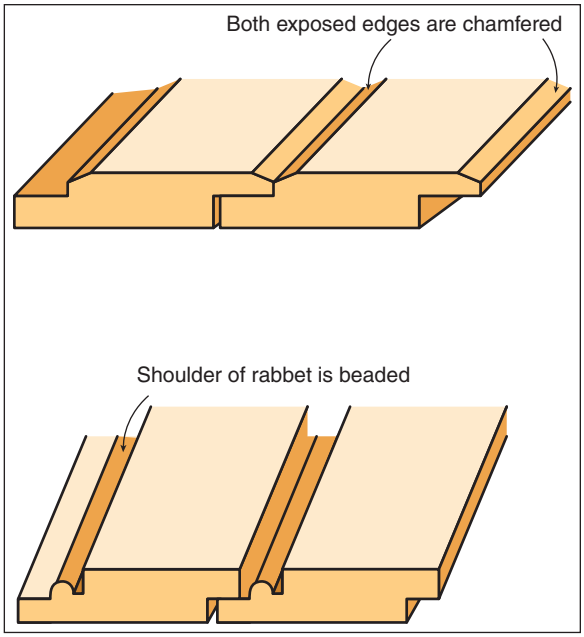
The **shiplap joint** has rabbets cut into the opposite faces of adjoining boards (see **Figure 19-15**). Unlike the tongue-and-groove joint, the shiplap joint cannot keep the surfaces of the boards flush, so it is not as good a joint. However, it can be cut more quickly since it only requires one setup, and if the wood is stable and the pieces can be fastened at frequent intervals, it is fine. The shiplap joint can be used to form the backs of cabinets. It is not a glued joint. Like the tongue-and-groove joint, it may be decorated (see **Figure 19-16**).

The glue joint, lock miter joint, and finger joint all require special bits or cutters that are used either with a table-mounted router or a shaper. In each case, an interlocking joint is created, as well as more glue surface than a simple butt joint. These are all excellent joints, offering alignment advantages as well as strength. The hardest part of using any of these joints is the time spent in setting up the machines. Some time will have to be spent running test pieces until



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FIGURE 19-15 Shiplap joint.



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FIGURE 19-16 Decorated shiplap joint.

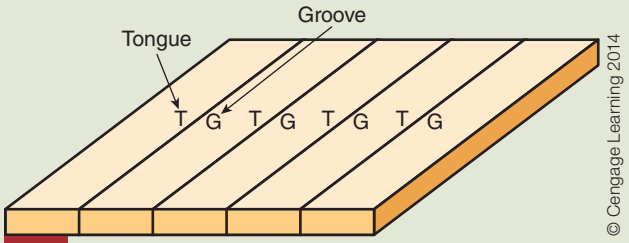
PROCEDURE 19-1

Milling a Tongue-and-Groove Joint for a Wide Panel

NOTE: This procedure assumes the use of 3/4" stock.

STEPS

1. Select the material that will be used for the panel, and cut it into pieces that are about an inch longer than the final panel will be. Wide boards should be ripped.
2. Arrange the boards, alternating the growth rings into a pleasing pattern, and mark it for easy reassembly later.
3. Follow the method described earlier to joint the edges of each board, alternating faces against the jointer fence.
4. Reassemble the panel and check for flush joints. Mark each board to indicate where the tongue or groove will be milled, as shown in **Figure A**.
5. Using a scrap that is the same thickness as the panel material, make a mark in the center of its thickness. At the table saw, set the fence so it will cut just to the outside of your mark, and raise the blade to just slightly over 1/4", as shown in **Figure B**.
6. Run your test piece with one face against the fence, and then flip it around and run the other face against the fence, as shown in **Figure C**. Check the resulting groove. It should be 1/4" wide and just over 1/4" deep. Make adjustments if necessary, and then run all the pieces that you have marked to get a groove.



A

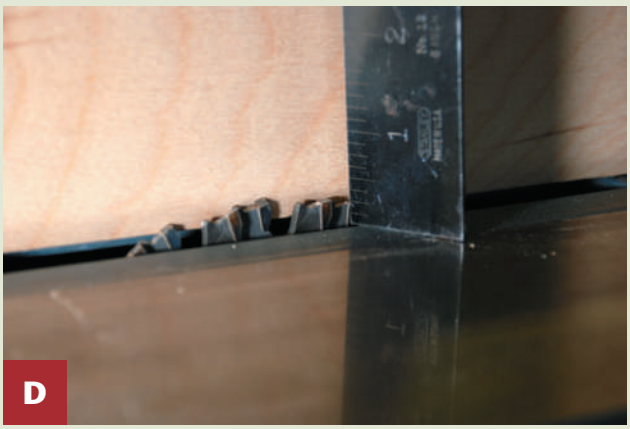
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B

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C

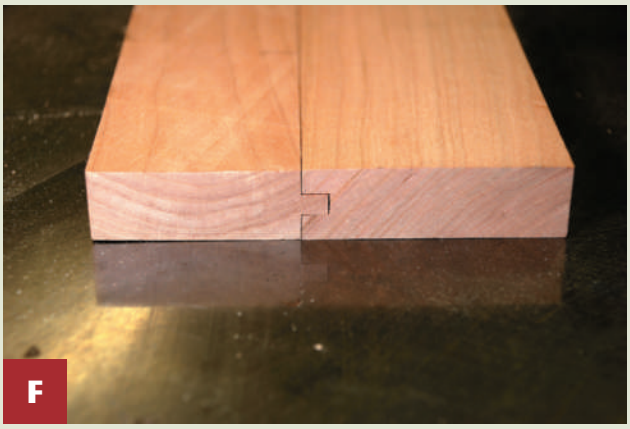
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7. Install a dado blade set for 1/4" wide in the table saw. Clamp a sacrificial fence to the fence, and bring it right over next to the blade. Set the blade height at 1/4" above the table, as shown in **Figure D**.
8. Take another test piece the same thickness as the panel material, and run it face down against the fence. Flip it over and run the opposite face; this process creates a tongue, as shown in **Figure E**.
9. Check the fit of the test tongue you just made in one of the grooves you made previously. It should fit snugly with a little bit of room in the bottom of the groove, as shown in **Figure F**. Make any adjustments needed, and then run all the pieces that are marked to get a tongue.
10. You are ready to glue up your panel.

the proper fence position and bit height are achieved. See **Figure 19-17**, **Figure 19-18**, and **Figure 19-19** for illustrations of glue joints, lock miter joints, and finger joints.

Clamping Up Wide Panels

Once the individual boards for a wide panel have been machined, it is time to glue them up. Clamps should be spaced 8 to 12 inches apart, alternating on the bottom and top of the panel (see **Figure 19-20**). The more joints there are in the panel, the closer the clamps should be spaced.

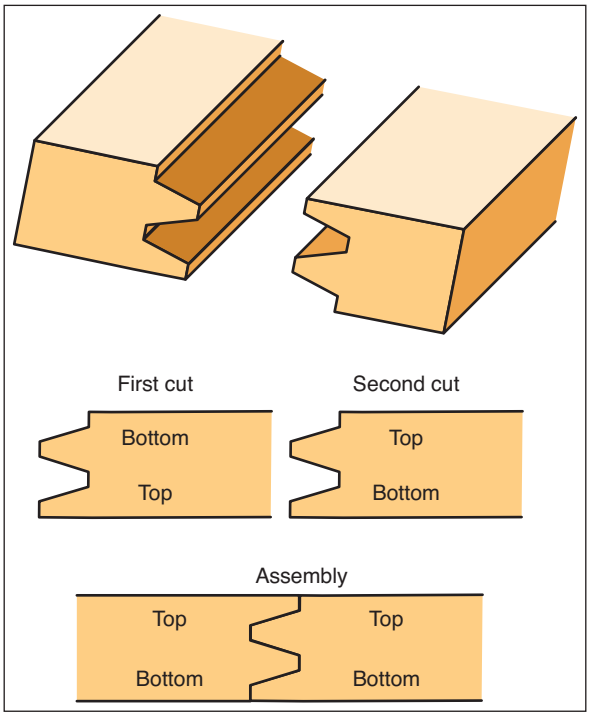


FIGURE 19-17 Glue joint.

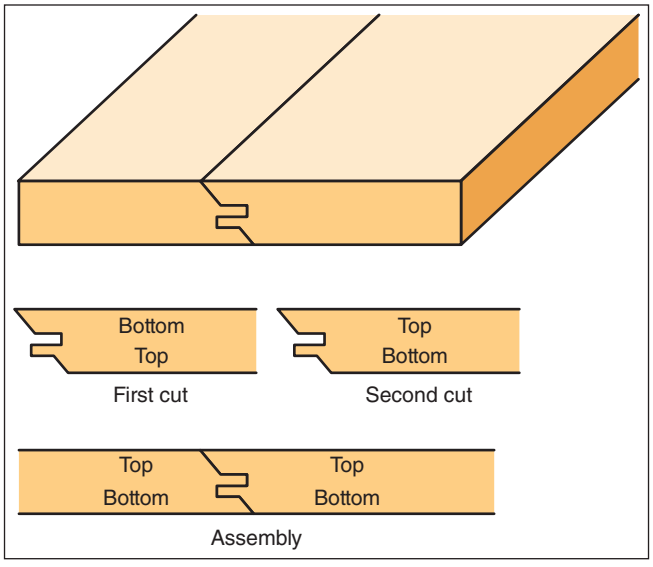


FIGURE 19-18 Lock miter joint.

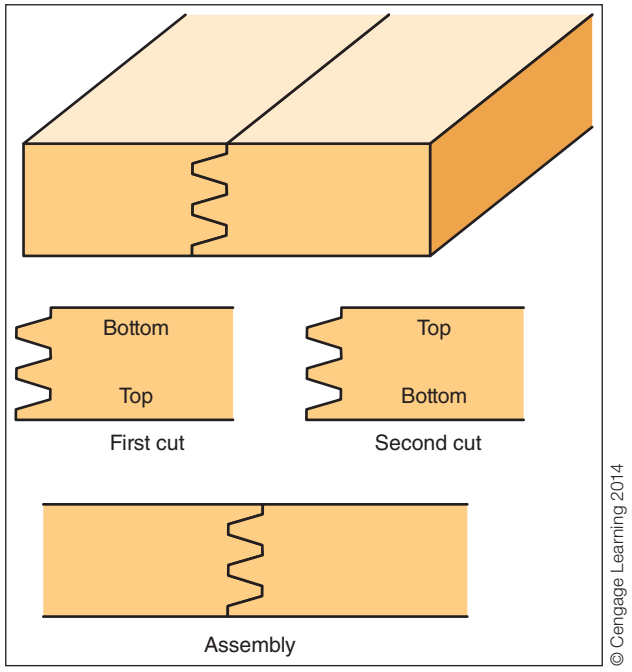


FIGURE 19-19 Finger joint.



FIGURE 19-20 Clamps should be alternated at the top and bottom of the panel.

WOODWORKING TIP:

When gluing up any kind of assembly, it is a wise practice to get out the necessary clamps and preset them ahead of time. Taking the time to do a dry clamp-up without glue can reveal potential problems that can be remedied before gluing. It will also ensure that you have enough clamps for the job and that the clamping will go quickly, which is a concern with glues that begin to set rapidly, such as the often-used yellow woodworker's glue.

Thick Blanks

Thick blanks are created when pieces are glued up face to face. Thicker blanks are needed when thicker pieces than are available are called for, perhaps for table legs, for turning purposes, or for a benchtop or butcher block (see **Figure 19-21**). When gluing up thick blanks, individual pieces of material are put together face to face; again, as with wide panels, like grain is being connected to like grain. Assuming the pieces to be glued are flat, glue provides all the fastening power that is needed. Because these thick blanks being created are often for pieces that will later be shaped somehow, and because glue provides all the necessary strength for joining face grain to face grain, reinforcement is rarely used.

There are two keys to getting a good joint: One is that the individual pieces that make up the blank are each flat and have parallel faces; in other words, they are uniform throughout their thickness. The second key is proper and adequate clamping. As when gluing up panels, clamps should be alternated top and bottom. Clamping for a thick blank will be closely spaced (see **Figure 19-22**).

Just as wide panels should be made up somewhat oversized and then machined to their final dimensions, thick blanks should also be made up oversize.

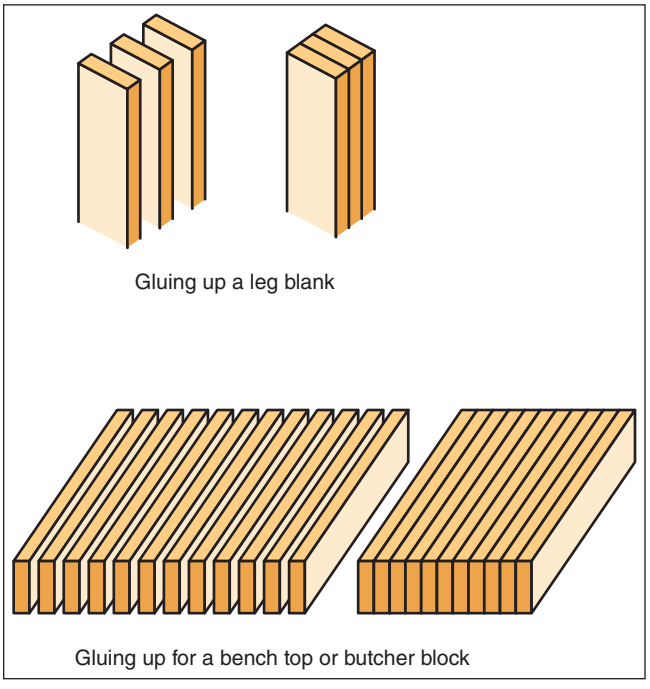


FIGURE 19-21 Face to face joints.

CORNER JOINTS

Wide panels are created by joining boards edge to edge. Thick blanks are made by joining boards face to face. **Corner joints** are constructed by joining the edge of one board to the face of another (see **Figure 19-23**). These are used to form the vertical corners of cabinets and columns. There are various methods for making corner joints. They include many of the same joinery techniques already discussed, such as the butt joint, both simple and reinforced, and the rabbet joint. Edge miter joints form a third important category of corner joints.

Butt Joints

As mentioned above, a corner joint is formed by attaching the edge of one piece to the face of another. While this glue joint is not quite as strong as joining edge grain to edge grain, as in a panel, or face grain to face grain, as with a thick blank, it is still a very strong glue joint and is perfectly adequate on its own without any reinforcement or positioning. So a simple butt joint glued together is fine, and it is the simplest and fastest way of creating a corner joint. However, the appearance of edge grain next to face grain may be unattractive. The seam between the two pieces may

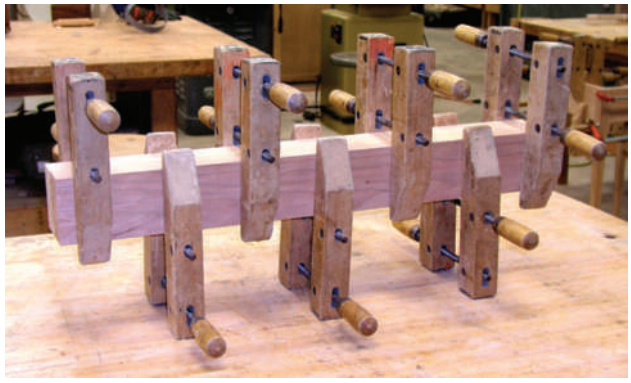


FIGURE 19-22 Clamping up a leg blank.

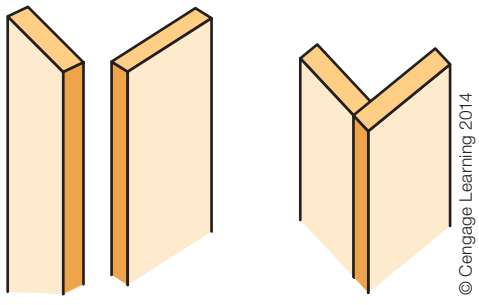


FIGURE 19-23 Corner joint.

be visible because of the difference in grain patterns. One way to conceal this is to cut a V-groove on the seam (see **Figure 19-24**).

Corner butt joints may also be reinforced with fasteners, such as nails or screws, which may be used instead of or in addition to glue. They do not add strength if glue is used, but they may take the place of clamping. Finish nail holes can be filled with wood putty. If screws are used and you wish to hide them, they can be recessed and the hole filled with a plug (see **Figure 19-25**). Alternatively, pocket-hole joinery can be used with the holes drilled from the inside face of one of the two pieces being joined, making them invisible from the outside.

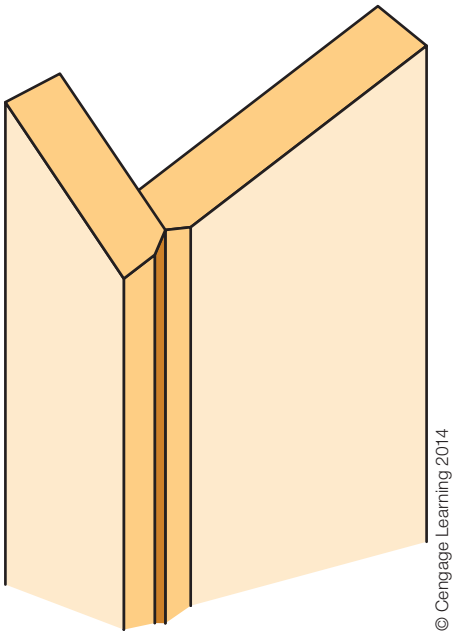

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FIGURE 19-24 Corner joint with V-groove.

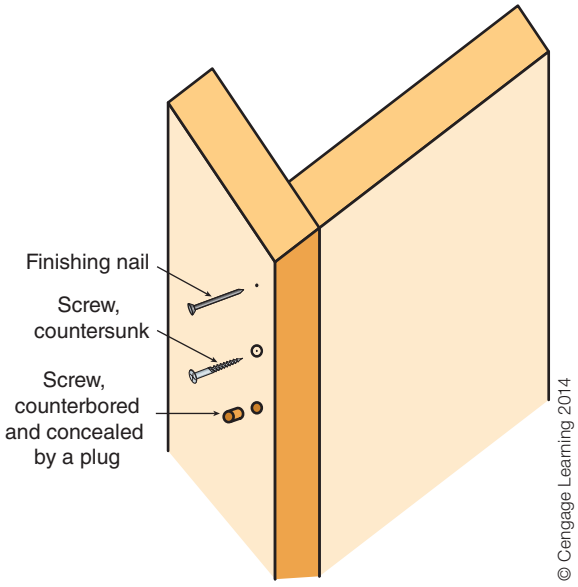


FIGURE 19-25 Fastened corner joint.

GREEN REMINDERS

Environmentally conscious woodworking shops give or sell the waste collected by their dust collection systems to local farmers to use for animal bedding. Note that black walnut is toxic to many animals and should not be used for this purpose.

A corner butt joint may also be reinforced in a less visible manner than using fasteners. Either biscuits or splines can be used. Their primary advantage is in keeping the joint properly aligned during clamping (see **Figure 19-26** and **Figure 19-27**).

Rabbet Joints

Several types of rabbet joints may also be employed in forming corner joints. They are the single-rabbet, double-rabbet, and rabbet-and-groove joints. Like the

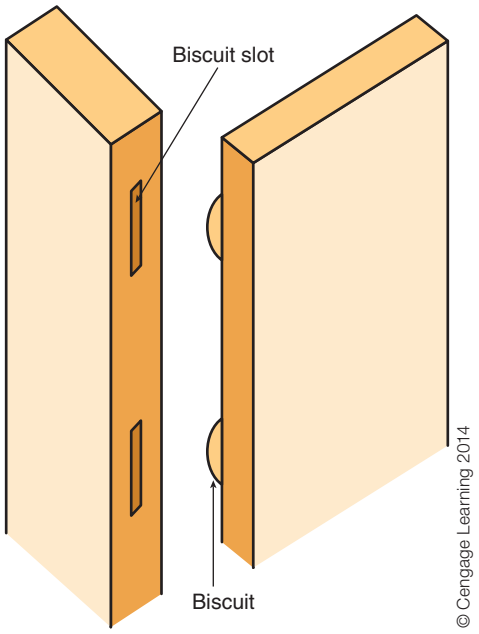


FIGURE 19-26 Biscuited corner joint.

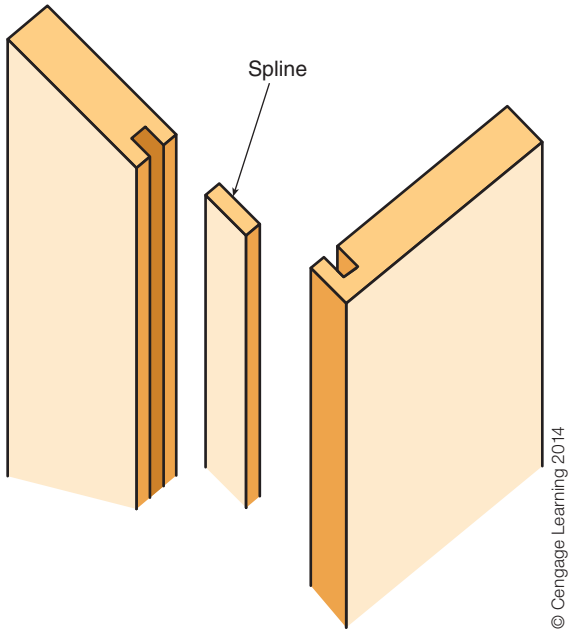


FIGURE 19-27 Splined corner joint.

biscuited or splined butt joints, they aid in aligning the joint. They also have the effect of less edge grain being revealed in the final product. The single-rabbet joint has a rabbet milled on one joining member into which the other fits. Typically, the rabbet is proportioned so that its width matches the thickness of the mating board. This yields a flush fit (see **Figure 19-28**). This joint may be chamfered for an attractive look that separates the face grain of one piece from the edge grain of the other (see **Figure 19-29**).

A third option with the single-rabbet joint is to cut the rabbet slightly less wide than the thickness of the mating piece, creating a **reveal**. A reveal allows part of the piece being covered to show. This gives a reverse corner appearance, which may be left as is or decorated later with a molding (see **Figure 19-30**).

The double-rabbet joint has a rabbet machined on each of the mating pieces (see **Figure 19-31**). The rabbet-and-groove joint combines a rabbet in one piece with a groove in its partner (see **Figure 19-32**). This joint has an advantage over the other rabbet joints in that each piece locks in place. The seam between the two pieces can be decorated to obscure the joint, as shown in **Figure 19-33**.

Edge Miter Joints

The edge miter joint looks similar to the case miter joint, but differs in its grain orientation. In the case joint, the end of one piece is joined to the end of another. With the edge miter, the edge of one piece is

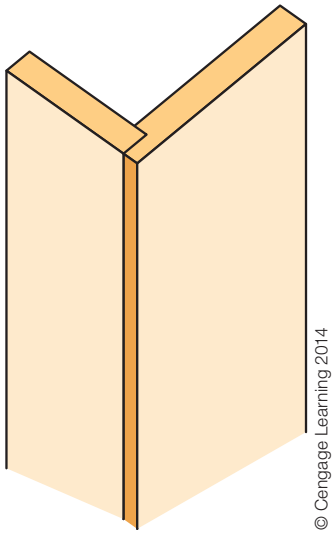


FIGURE 19-28 Single-rabbet joint, flush.

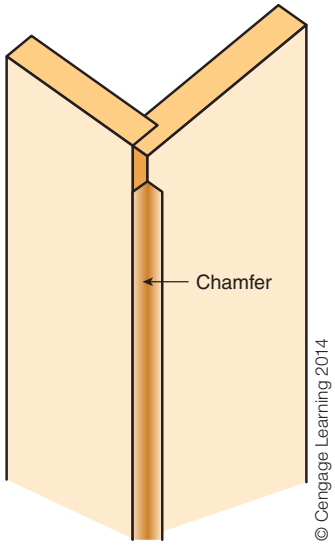


FIGURE 19-29 Single-rabbet joint, flush and chamfered.

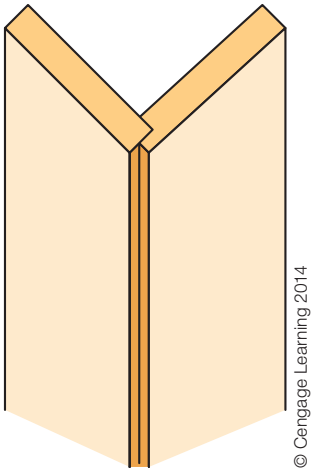


FIGURE 19-30 Single-rabbet joint with reveal.

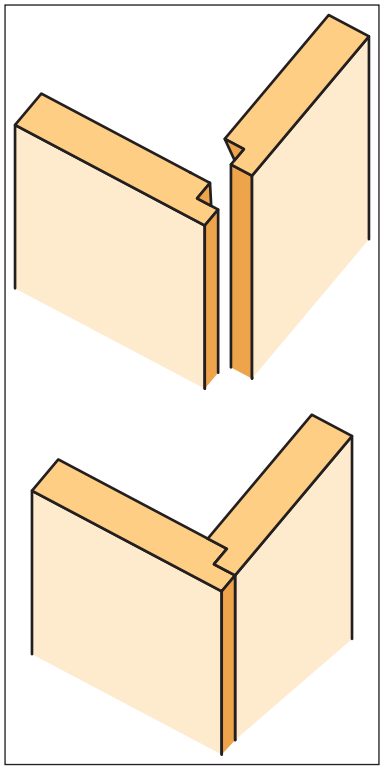


FIGURE 19-31 Double-rabbet corner joint.

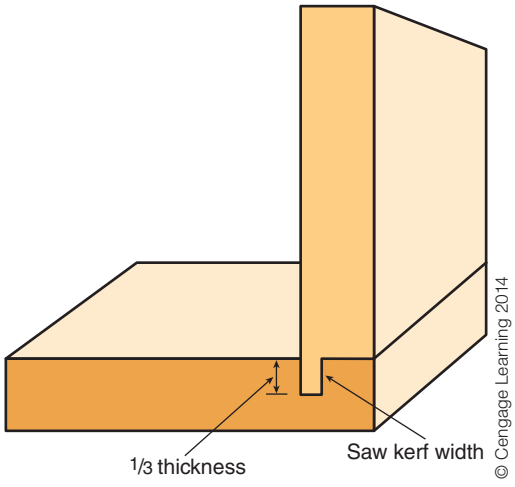


FIGURE 19-32 Rabbet-and-groove corner joint.

joined to the edge of its mate (see **Figure 19-34**). Since the glue joint is edge to edge, glue is all that is required to create a strong joint. As with all miter joints, it offers the significant advantage of concealing the change in grain. A well-crafted miter joint is almost imperceptible, since the change happens right at the corner. However, also like other miter joints discussed previously, it can be difficult to assemble successfully.

Corner miter joints may be reinforced to help in alignment. One method of reinforcing a mitered corner joint is to fasten it. Another is to use biscuits. A

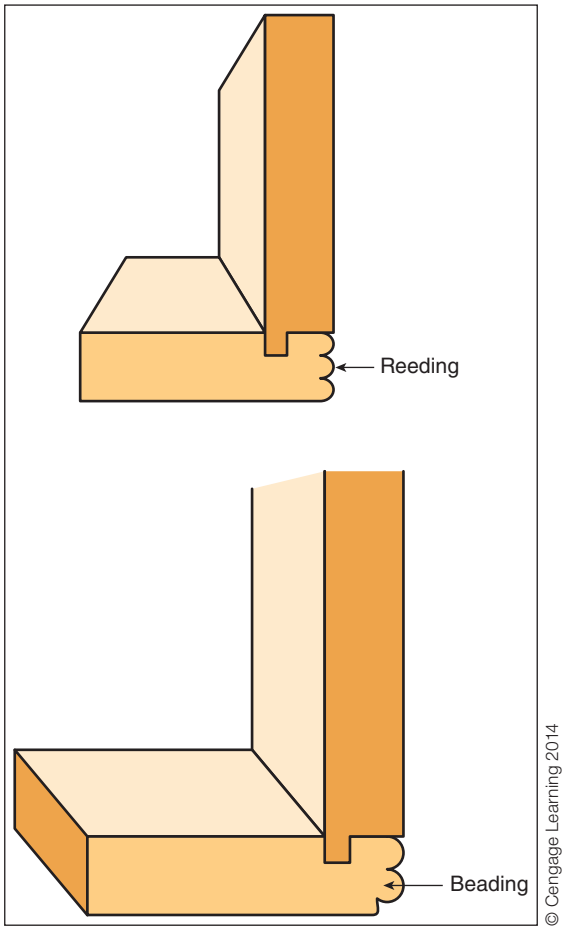


FIGURE 19-33 Decorated rabbet-and-grove joint.

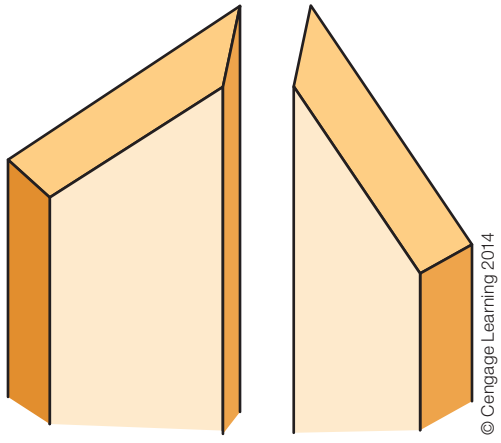


FIGURE 19-34 Edge miter joint.

third is to use splines, which may be through or blind. A fourth reinforcement option is to use glue blocks, which may be either continuous or intermittent (see **Figure 19-35** through **Figure 19-38**).

Another miter joint is the **lock miter joint**, which was discussed previously as one of the methods for making a panel. It is more frequently used to create an edge miter joint. It is a positioned joint that creates

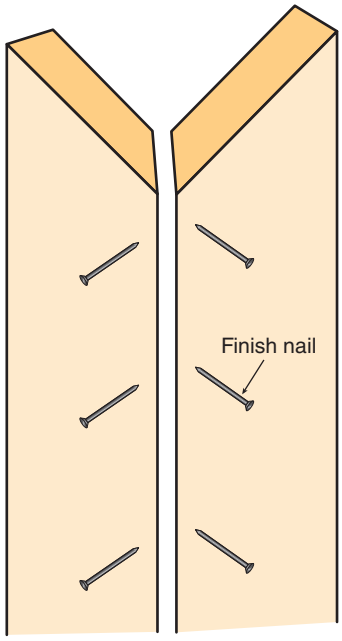


FIGURE 19-35 Fastened edge miter.

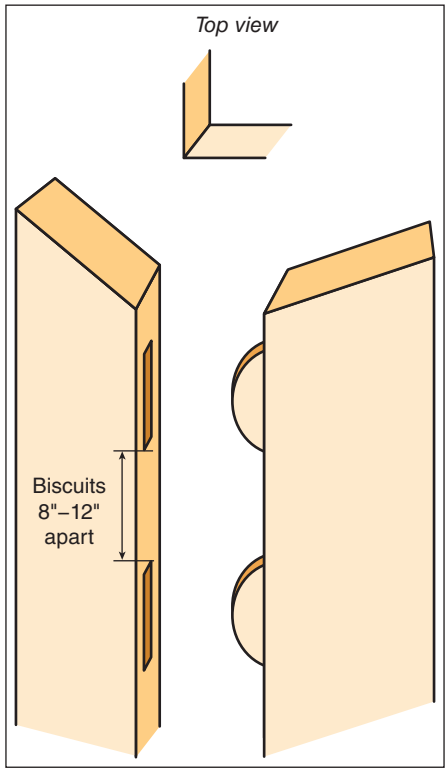


FIGURE 19-36 Biscuited edge miter.

a lock, which aids greatly in assembling the joint. It is cut with a bit on a router table or with a cutter in the shaper. One setup suffices for both parts of the joint. One piece is run with its face on the table, and the other is run with its face against the fence (see **Figure 19-39**).

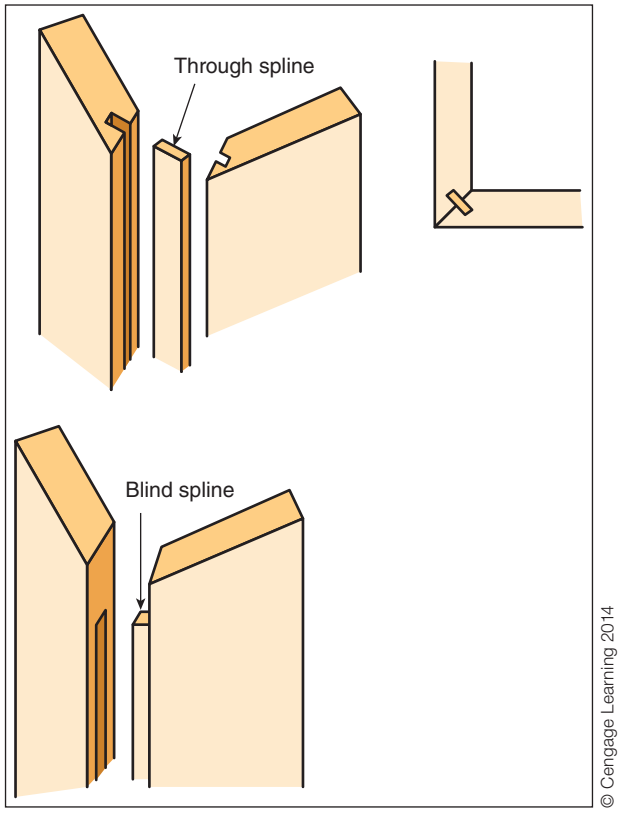


FIGURE 19-37 Splined edge miter.

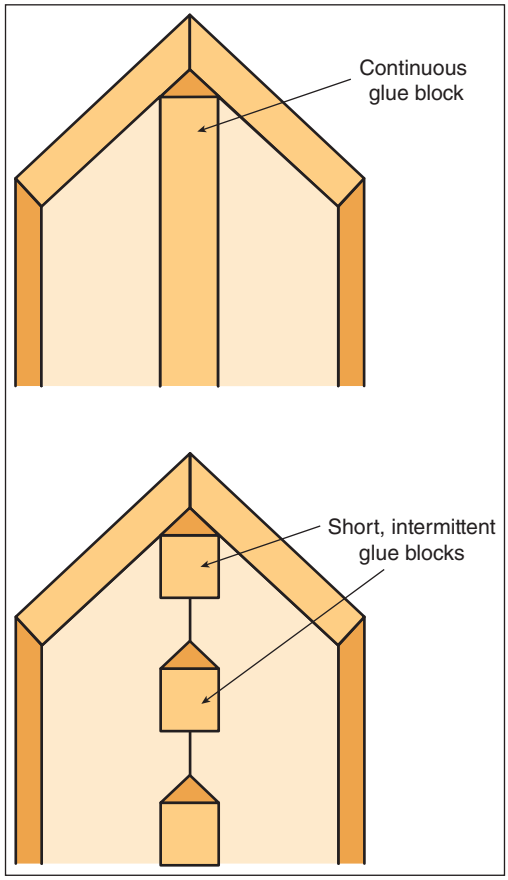
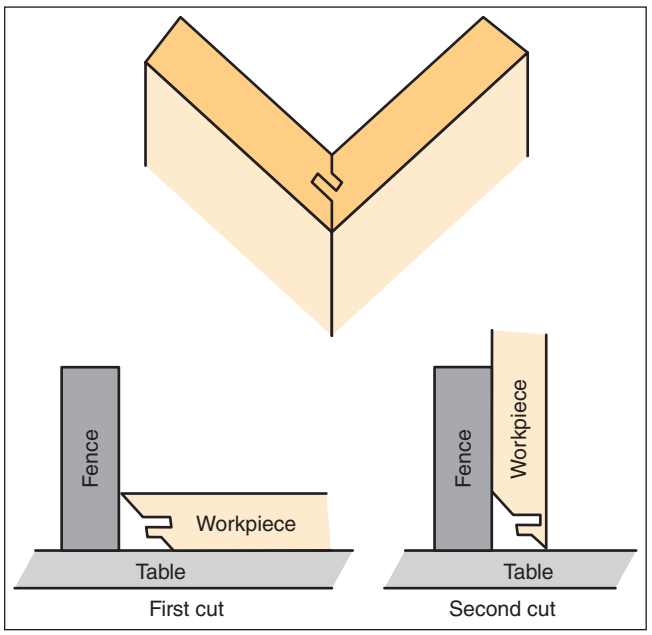


FIGURE 19-38 Edge miter with glue blocks.

CAUTION

When using the shaper, the cabinetmaker needs to be very careful. As with all other machines, adjustments should be made with the tool disconnected from the power source. Again, as with other tools, the cutting device should be securely tightened in place, and the fence should be checked to make sure it is locked. Additionally, with the shaper, the direction of the spindle's rotation must be checked. Unlike other tools, the shaper can spin its cutters in either direction. Since it is vitally important to run stock against the rotation of the cutter, spindle rotation must be checked prior to using the tool. It is a simple matter of turning the shaper on and off again to see which way the spindle is turning. If material is accidentally run with the rotation of the cutter instead of against it, the operator's hands may be pulled into the cutter, or the work piece may be grabbed and hurled across the shop.



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FIGURE 19-39 Lock miter corner joint.



Summary

There are three types of edge joints. Joining boards edge to edge creates wider panels, which may be needed for tabletops or panels. Joining boards face to face makes thick blanks, used for legs, butcher blocks, and for turning. Joining boards edge to face creates corners used for the vertical corners of cabinets and columns. While thicker blanks are usually made by simply gluing and clamping up thinner boards to reach the desired thickness, various joints may be used in the construction of wide panels and corners. It is not necessary to use joinery for these joints; the glue joint alone is sufficiently strong, but using joinery can be helpful in aligning the joints and also in creating different appearances.



Key Terms

butterfly keys
corner joints
lock miter joint
positioned joints
reveal
shiplap joint
tongue-and-groove joints



Check Your Knowledge

1. How are boards joined to create wide panels? Face to face, face to edge, or edge to edge?
2. How are boards joined to create thick blanks? Face to face, face to edge, or edge to edge?
3. How are boards joined to create corners? Face to face, face to edge, or edge to edge?
4. What are two ways to minimize warping in wide panels?
5. Why is it not a good idea to mix plainsawn and quartersawn lumber in a wide panel?
6. Once a wide panel is laid out, how should it be milled to get tight seams?
7. How should a wide panel be clamped?
8. Is it necessary to reinforce a butt joint in either a wide panel or a corner joint? How could it be done, and why would you do it?
9. List two uses for thick blanks.
10. List two positioned joints you might use to create a wide panel.
11. What do you have to take into account when laying out a panel that will have positioned joints?
12. What is the advantage of a mitered corner joint?
13. What is the disadvantage of a mitered corner joint, and how can you overcome it?
14. Where are you likely to see a shiplap joint used?
15. What tools could you use to create a lock miter joint?

BUILD IT!

Plant Stand

Figure A shows a completed plant stand.

TOOLS REQUIRED

- Measuring tool
- Squaring tool
- Table saw and dado blade
- Miter saw
- Router, chamfer bit, and decorative bit

MATERIAL REQUIRED

- 3/4" solid stock
- 3/4" scrap of cabinet plywood

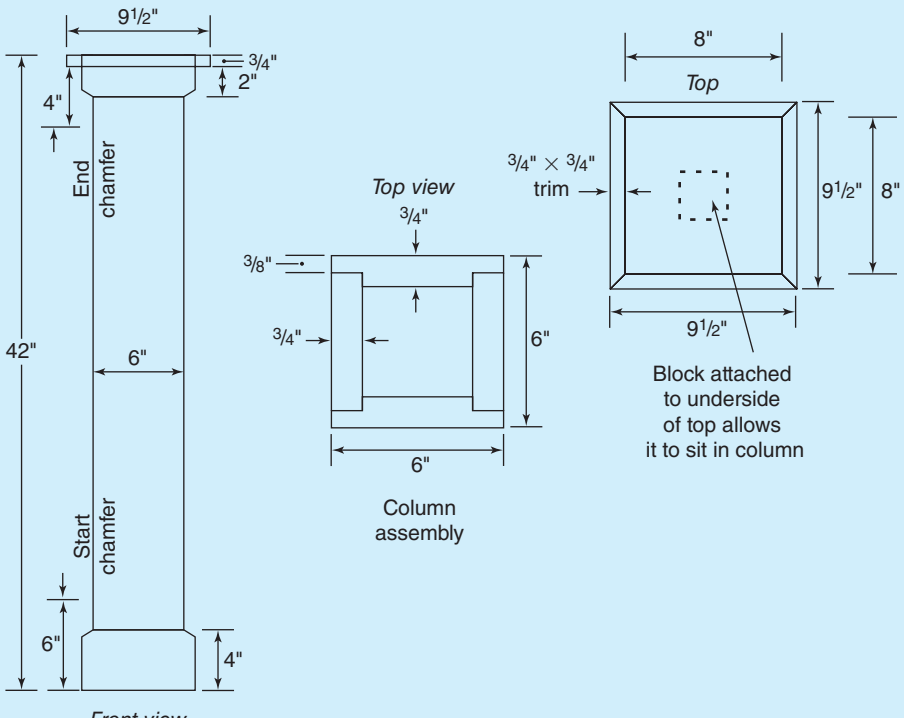
STEPS

1. Review the plan shown in **Figure B** to determine the size of the various parts.
2. Cut material for the column sides.



A

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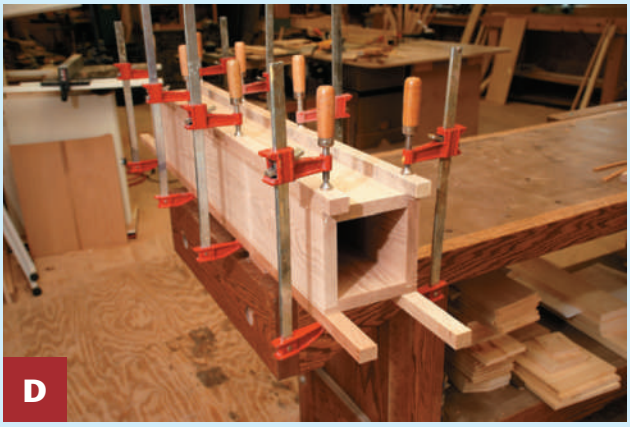
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3. Machine the 3/4"-wide by 3/8"-deep rabbet on each side of the two wider column pieces, as shown in **Figure C**.
4. Glue and clamp the column, as shown in **Figure D**. Notice that the material is protected from denting by the clamps with scrap material.
5. Mill the material for the trim, keeping it long to allow for the miter cuts later.
6. Rout a decorative edge on the trim for the base and top of the column and on the trim for the top.
7. Rout the stopped chamfers on the corners of the column. Do this in a series of passes, as shown in **Figure E**.
8. Miter and attach the top and bottom trim to the column with glue and clamp it in place, as shown in **Figure F**.


D

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9. Miter, glue, and brad nail the trim to the top, as shown in **Figure G**.
10. Place the top upside down on the bench, and center the column, also upside down, on top of it. **Figure H**
11. Scribe a line around the column onto the top, and remove the column, as shown in **Figure I**.


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12. Subtract for the thickness of the column and the trim, and draw another square inside the one you scribed, as shown in **Figure J**.
13. Glue and screw a scrap of 3/4" plywood slightly smaller than the inner scribed square to the top, as shown in **Figure K**. This will allow you to set the top on the column and have it stay in place.
14. Sand and finish as desired.

BUILD IT!

PROJECT CHALLENGE

Storage Table

Figure A shows a completed storage table.

STEPS

1. Review the assembly list given in **Figure B**. Mill the stiles and rails to size.
2. Cut a centered groove 1/4″ wide and 3/8″ deep on the inside edge of all the stiles and rails. Set the stiles to one side.



A

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Assembly list - storage table

Part	Dimensions (thickness × width × length)	Quantity
Stile	$^{3}/_{4}$" × $2^{1}/_{2}$" × $15^{1}/_{2}$"	8
Top rail	$^{3}/_{4}$" × $2^{1}/_{4}$" × $14^{1}/_{2}$"	4
Bottom rail	$^{3}/_{4}$" × 3" × $14^{1}/_{2}$"	4
Bottom	$^{3}/_{4}$" × 18" × 18" plywood	1
Panel	$^{1}/_{4}$" × $14^{7}/_{16}$" × $10^{15}/_{16}$" plywood	4
Bottom molding	$^{3}/_{4}$" × $2^{1}/_{4}$" × 21" rough	4
Top molding	$^{3}/_{4}$" × $1^{3}/_{4}$" × 21" rough	4
Lid	$^{3}/_{4}$" × $19^{1}/_{2}$" × $19^{1}/_{2}$" plywood	1
Lid trim	$^{3}/_{4}$" × 2" × 25" rough	4
Lid cleats	$^{3}/_{4}$" × 1" × 20" rough	4

B

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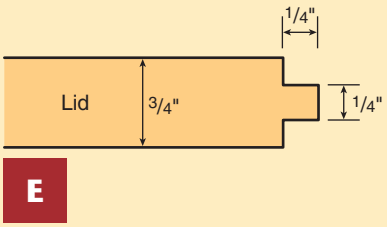
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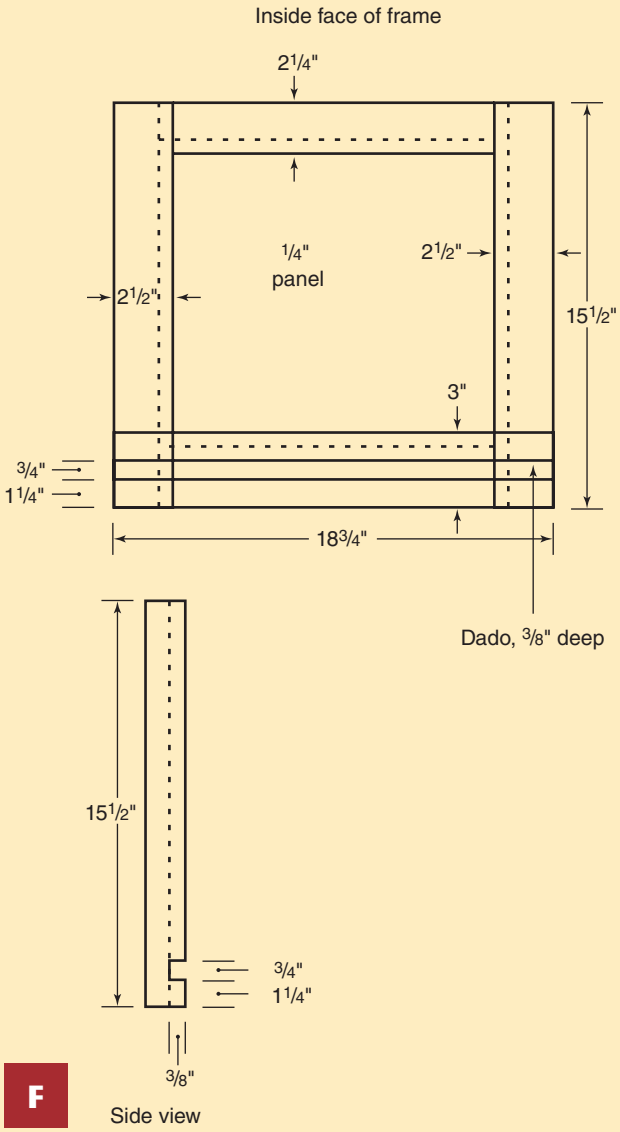


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3. Machine 1/4″-thick by 3/8″-long stub tenons on both ends of all the rail pieces. Do this on the table saw using the miter gauge, a dado blade set 1/4″ high, and a sacrificial fence, as shown in **Figure C**. Run a test piece first and check its fit in the groove on one of the stiles.
4. Cut the 1/4″ plywood panels to size and sand lightly.
5. Glue and clamp up the four panel assemblies. Protect the edges of the stiles with scrap, as shown in **Figure D**. Check to make sure they are square.
6. While the frame and panel assemblies are setting up, cut the 3/4″ plywood lid to size.
7. Make up the trim for the lid. Make enough to allow for mitering later.
8. Mill a centered 1/4″ × 1/4″ groove on the inside edge of the trim.
9. Mill a tongue on the lid to fit into the grooves on the trim, as shown in **Figure E**.

10. Miter the molding and glue and clamp it to the lid.
11. Go back to the frame and panel assemblies, and once the glue has cured, remove the clamps and clean up the glue residue.
12. Machine a 3/4"-wide by 3/8"-deep dado on the inside of each of the panel assemblies to accept the bottom, as shown in **Figure F**.
13. Set the blade on the table saw to a 45° angle, and make opposing bevel cuts on the stiles of each panel, as shown in **Figure G**. The panels should all be exactly the same size when you are done.
14. Cut the bottom to size.



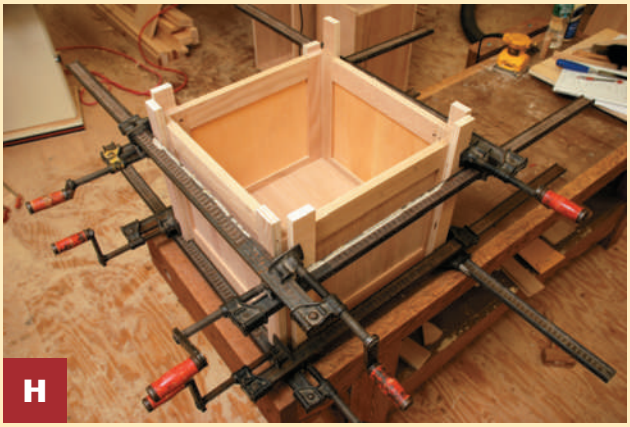
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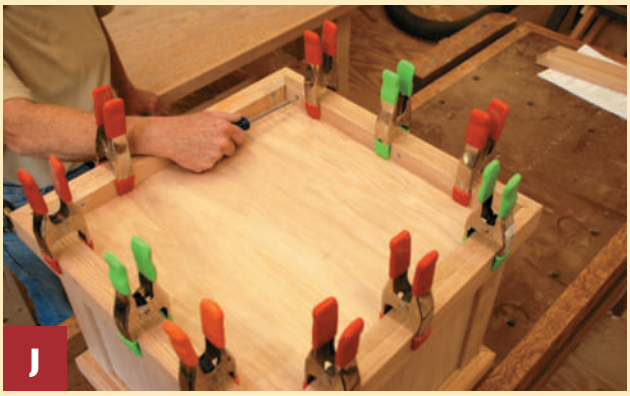
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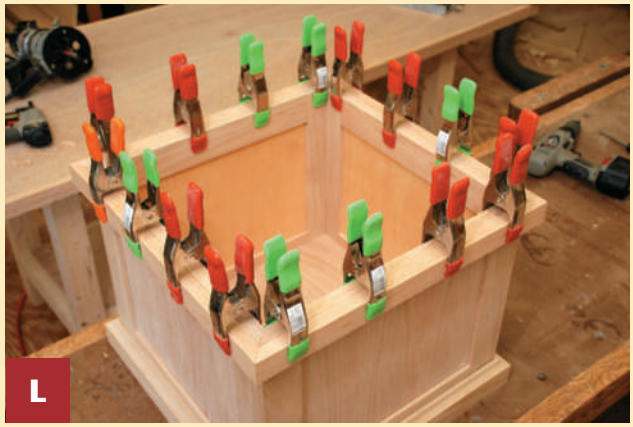
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15. Apply glue to the miters, and clamp them up with the bottom in place. It is not necessary to glue the bottom (see **Figure H**).
16. Make up the bottom trim; cut it to width and leave it long for mitering.
17. Rout a decorative profile of your choice on the top of the bottom molding, as shown in **Figure I**.
18. Miter, glue, and clamp the bottom trim in place. Place the box upside down on the bench to make this easier. Once clamped, pilot holes can be drilled and countersunk from inside the bottom rails, and then screws can be driven to hold the trim in place, as shown in **Figure J**.
19. Mill the molding for the top of the box to width and leave it a little long; rout a decorative profile on its bottom edge, as shown in **Figure K**.

20. Miter the top trim and glue and clamp it to the top of the box, as shown in **Figure L**.
21. Place the lid face down on the bench, center the box upside down on it, and trace around the perimeter with a sharp pencil.
22. Remove the box and draw parallel lines inside those you just made at a distance of 1 9/16". Mark an X to the inside of these lines, as shown in **Figure M**.
23. Cut 3/4" × 1" cleats that will be attached to the X side of the lines just drawn. These cleats will keep the lid in place.
24. Rout a 1/4" roundover around the bottom of the lid. You may wish to rout a roundover on the top side of the lid as well.
25. Miter, glue, and brad nail the cleat in place, as shown in **Figure N**.
26. Sand and finish as desired.


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SECTION VI


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Cabinet and Furniture Anatomy


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SUCCESS STORIES

Mike Dunbar

Title

Owner, The Windsor Institute — a school that teaches the art of making Windsor chairs — in Hampton, New Hampshire; author, *Restoring, Tuning, and Using Classic Woodworking Tools and Make a Windsor Chair.*

Education

Mike graduated from Worcester State College with a degree in French.

History

During college, Mike happened by a yard sale and picked up a pair of chairs for $15 without knowing what they were called. "I fell in love, and would just stare at these chairs," he says. He figured that if owning two was so nice, he wanted more, so he went to the library to study up. He quickly discovered that he'd bought antique Windsors, which went at the time for $200 to $1000 — not exactly a price that fits on a college student's budget. So he began trolling yard sales and flea markets for broken ones, thinking he could fix them.

After poring over books on the process, he eventually made his own chairs. He then began to devour books on the subject of furniture and taught himself hand woodworking. "I was trying to do things the way guys who made my chair

did them in the eighteenth century," he says. By the time he graduated, he'd developed his own business restoring and creating the chairs. (He didn't even attend graduation because he had a big order to finish.)

A few years later, Mike ended up on the cover of a woodcraft supply catalog and started getting letters from people wanting to know how to make chairs. So he wrote a book about it, and he began teaching. In 1992, he and his wife opened their own school.



Image courtesy of Mike Dunbar.

On the Job

The school offers weeklong programs, and Mike and his colleagues teach students how to make 11 different chairs. Now his daily life alternates between teaching classes and getting prepared for the next class with registration, accounting, and course planning. "I still get a lot of woodworking time in, and I get to spend it with people who are very excited to learn."

Best Aspects

"Even though I've made thousands of them, I still get a kick out of a chair being completed," says Mike. He also relishes the enthusiasm of his students and of being able to pass on this art.

Challenges

It was difficult at first, Mike says, to convey information to students. He found that different people had different ways of learning. "I do most things subconsciously, via muscle memory, but I had to figure out that I need to tell, to show, to provide written instructions."

Importance of Education

"There's a whole lot of engineering that goes into making a chair: Here you have something that weighs 15 pounds but must support 200 pounds. That takes some intelligence and understanding to figure out, and I think I'd be more successful teaching someone who had an education in math."

Future Opportunities

Mike feels very satisfied with the way things are going at present, and he may work toward publishing a few more books.

Words of Advice

"First get a good education," he says. "I learned *how* to learn getting my degree. And education is the cornerstone of every good career."

Story originally written by Margaret Magnarelli, 2008. Interview and photo provided by Mike Dunbar.



20

Cabinets and Casework

You'll Learn

After studying the chapter, the student should be able to:

- Define casework and list different types of casework
- Explain basic cabinet components and how they fit together
- Distinguish the differences between face frame and frameless cabinetry
- Identify the terminology associated with face frame construction
- Explain industry standards relating to base cabinets, wall cabinets, and vanities
- Explain kitchen cabinet installation procedures
- Demonstrate familiarity with more advanced forms of casework and their construction

INTRODUCTION

If asked to visualize a cabinet, the first thing most people think of is a kitchen cabinet. Kitchen cabinets fall into two categories: *base cabinets* and *wall cabinets.* Another common kind of cabinet is a bathroom vanity. Certainly these are all cabinets, but other common furniture items in a home are also cabinets. For example, bookcases are cabinets. So are entertainment centers, display cabinets, armoires, grandfather clocks, corner cabinets, and sideboards. What all these cabinets have in common is that they are all basically boxes

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that have been turned on their ends or edges. The bottom on the box is now the back of the cabinet, and the sides of the box are the top and bottom of the cabinet. When a box is oriented this way it is referred to as a cabinet or as casework. The term **casework** is a reference to the fact that the joints used in constructing these boxes are case joints. Any unit of furniture with two sides, a top, a bottom, and a back can be referred to as casework. Therefore, all the cabinets just listed are also examples of casework. A cabinet may be very simple, with just two sides, a top and bottom, and a back. It may be more complex, having doors, drawers, interior dividers, and shelves. Or it may have some of these elements and not others. It may have a **face frame**, a solid wood border attached to the front of a cabinet assembly, or it may not. In this chapter we will be investigating the construction of kitchen cabinets and their installation, as well as more advanced types of interior casework.

SIMPLE CASEWORK

The construction of kitchen cabinets and bathroom vanities is fairly straightforward and often utilizes very simple joinery techniques. In this section, we will explore various methods for building this type of casework. We will also cover the standards associated with kitchen cabinets and vanities.

There are two main types of cabinets: those with face frames and those without. Those without face frames are called *frameless* or **European cabinets**, because they were originally introduced in Europe. In either situation, the basic unit is a box, which is very often constructed of sheet goods such as plywood, rather than solid lumber. The method of building the box is different for face-frame cabinetry and frameless cabinetry.



FACTS ABOUT WOOD

There are many varieties of oak. The most common oak variety in North America is red oak, *Quercus rubra*. Found predominately in the eastern United States and Canada, it is fast growing, very hard, heavy, and strong. For these reasons, oak is a very popular hardwood. ■

Face-Frame Cabinetry

The essential parts of a cabinet are the sides, the bottom, and the back. Some cabinets have tops, but others, such as kitchen base cabinets and bathroom vanities, do not. Tops for these cabinets are manufactured separately and added later. The bottom is generally recessed into a groove, called a *dado*, which is machined into the sides (see **Figure 20-1**). Sometimes a top is fit into the sides by the same method. The back of the cabinet is usually set into a recess, called a *rabbet*, made on the back edge of the sides (see **Figure 20-2**). Often the material used for the back of the cabinet is much thinner than that used for the other parts.

If there are shelves in the cabinet, they will be either fixed or adjustable. Fixed shelves are housed in dadoes in the same way that the bottom was. Dividers in the cabinet will also be held in dadoes (see **Figure 20-3**).

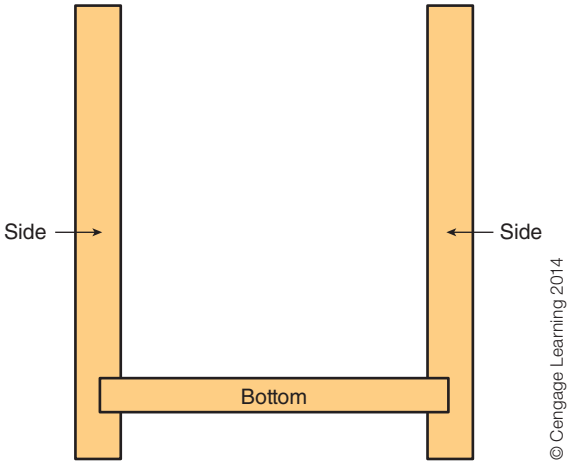


FIGURE 20-1 Cabinet bottom to sides connection.

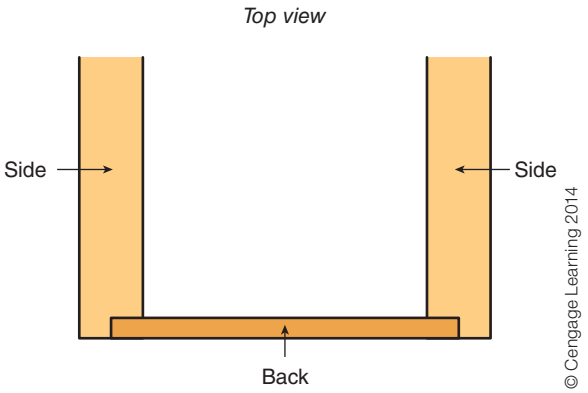


FIGURE 20-2 Cabinet back to sides connection.

Cabinets with face frames have a frame attached to the front, consisting of *stiles* and *rails*. The **stiles** are the vertical members, and **rails** fit between the stiles. A face frame may be divided by another vertical member, called a **mullion**, which fits between the rails (see **Figure 20-4**).

Face frames can be built using a number of different joinery methods. Some examples are half laps, dowels, biscuits, and pocket screws (see **Figure 20-5**). These are all frame joints.

Face frames are attached to cabinets in a variety of ways. They may be attached using finish nails or brads, biscuit joints, or a groove may be milled into the back of the face frame to fit into a tongue milled on the sides of the cabinet (see **Figure 20-6**). Face frames can also be attached to cabinets with rabbets milled in the face frame components.

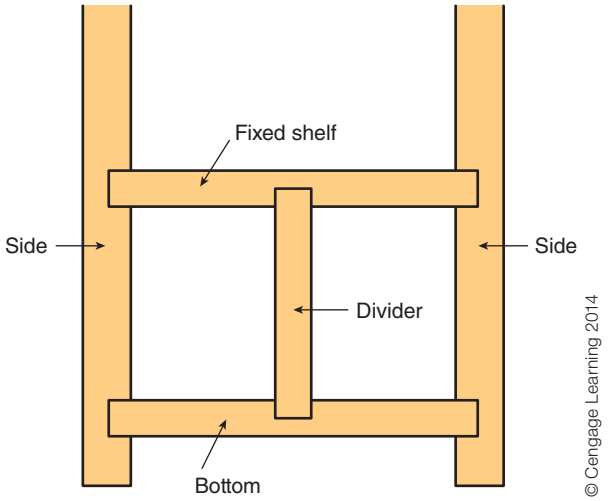


FIGURE 20-3 Fixed shelves and dividers are housed in dadoes.

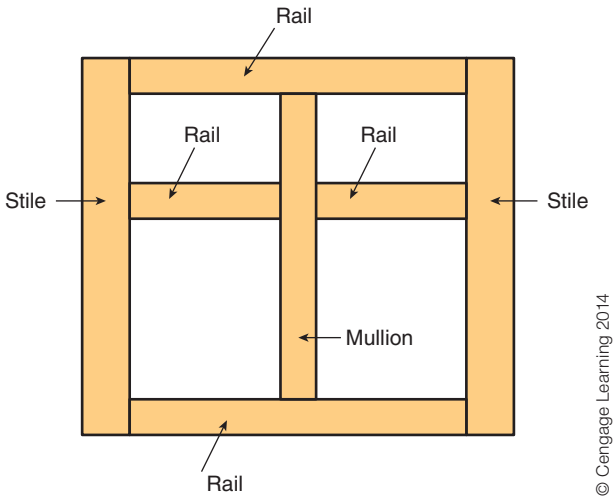


FIGURE 20-4 Face frame components.

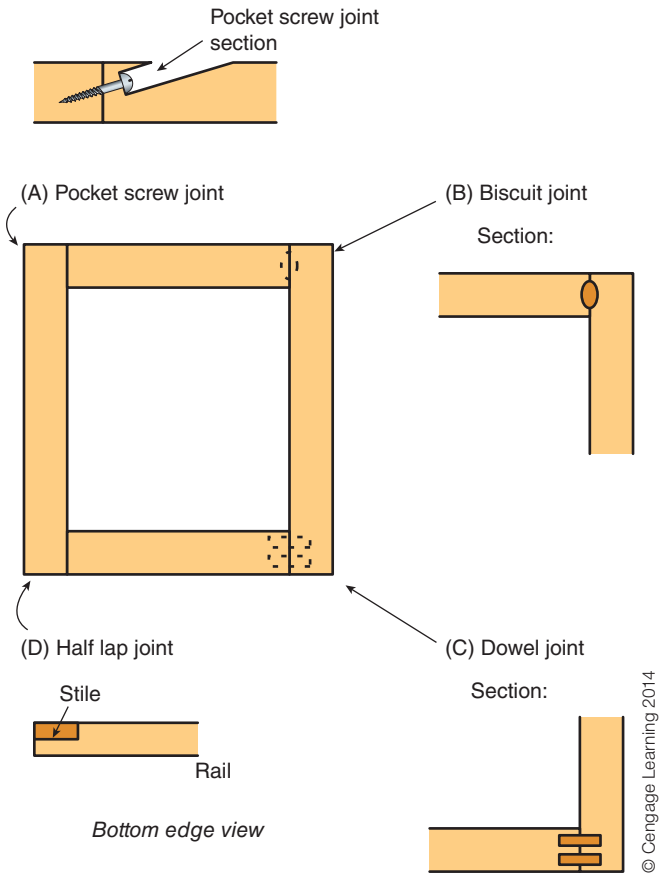


FIGURE 20-5 Face frame construction: half-laps, dowels, biscuits, and pocket screws.

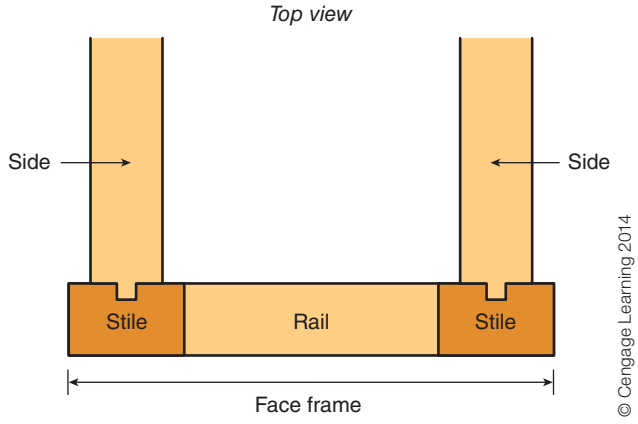


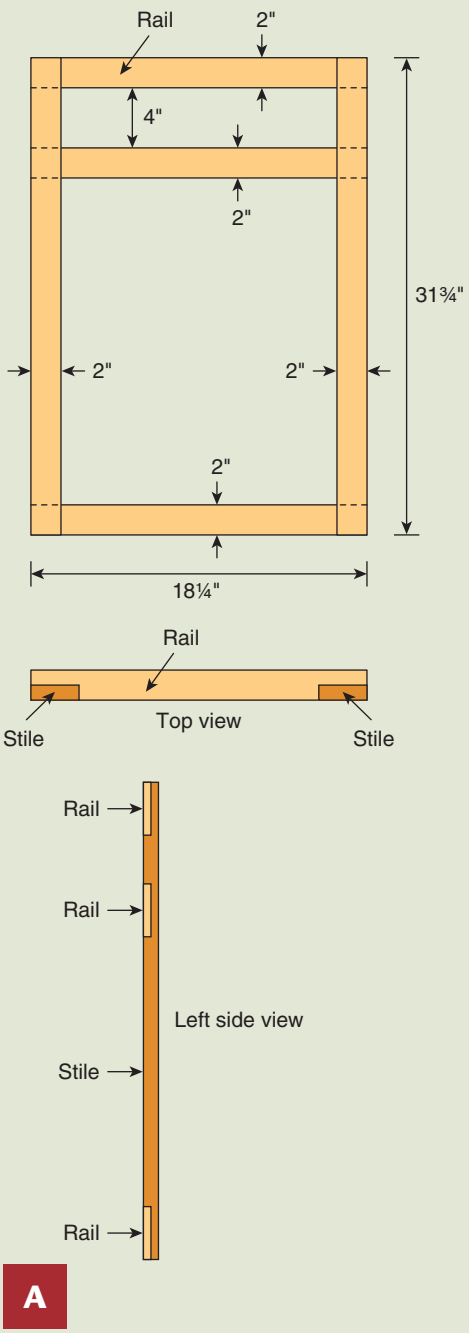
FIGURE 20-6 Face frame to cabinet attachment: tongue-and-groove joinery.

CAUTION

When using any tool, take a moment and think your way through the operation first, anticipating any potential problems. When using the table saw, make sure to have a push stick close at hand and adequate room on the outfeed side of the saw for the piece you are working on.

PROCEDURE 20-1

Building a Face Frame Using Half-Lap Joints

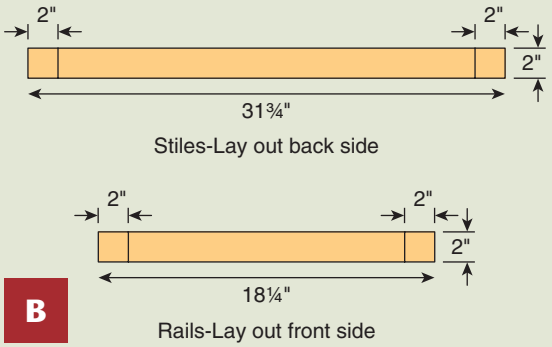


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STEPS

1. Determine the length of the stiles, rails, and any mullions or rails. The stiles are as long as the face frame is tall, and the rails are equal to the width of the face frame. A rail that fits between the two stiles will be as long as the top and bottom rails. **Figure A** shows an example.
2. Cut the stiles and rails to the width specified in the plans and the lengths determined in Step 1. Remember to joint, rip a bit oversize, and then joint to the finish width to remove any saw blade marks.

3. Lay out for the half-lap joints, paying careful attention to get the marks on the correct side of each board, as shown in **Figure B**.
4. Half-lap joints can be cut in a number of different ways. We will do them on the table saw with a dado blade. Install a dado blade set for its widest setting on the table saw, and raise it so that its height is equal to half the thickness of the wood you are using.
5. Adjust the fence so that your layout mark is on the far side of the blade, as shown in **Figure C**.
6. Using two test pieces that are the same thickness as the face-frame material, support one piece with the miter gauge and make a cut. Slide the piece to your left and make successive cuts until you have made a half-lap, as shown in **Figure D**. Repeat for the second test piece.



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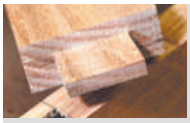


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7. Trim any ridges left from the saw with a chisel.
8. Put the two test pieces together to form a corner and check the fit, as shown in **Figure E**.
9. Adjust the height of the blade and the fence as needed. If the fit is not flush, the blade height needs to be adjusted. If the corner is not flush, the fence needs to be adjusted. Continue making test cuts until you are satisfied, and then run the pieces of the face frame.
10. Chisel the face of each joint flush if needed.
11. Apply glue to the joints and clamp up the face frame, positioning clamps at each joint and across the frame, as shown in **Figure F**. Check the frame for square, and adjust as needed.

European Cabinetry

The **32 millimeter cabinet** was developed in Europe, which is why these cabinets are sometimes called *European cabinets*. They do not have a face frame, and the construction of the box is simpler, making them easier and faster to build. Each side has a series of 5-millimeter (mm) holes drilled 32 mm apart at the front and back of the cabinet (see **Figure 20-7**). All doors and drawer faces are some multiple of 32 mm, allowing these holes to serve as mounting points for drawer slides and hinges. In terms of English measurement, 32 mm is equal to 1 1/4″, and 5 mm is equal to 3/16″.



HISTORY FACT

The reason European cabinets are called 32 mm cabinets is because when these cabinets were developed, 32 mm apart was as close as the bits could be placed in the manufacturing of the sides. ■

Instead of the tops and bottoms of these cabinets being set into dadoes, as they typically are in face-frame construction, they are usually doweled or screwed into place through the sides (see **Figure 20-8**). Face-frame cabinets use the sides extending beyond the bottom to act as the foundation of the cabinet; European-style cabinets are usually set on separate feet.

European cabinets are frameless, and so the labor and time of building a face frame is saved. The exposed edges of the material used to build the box need to be covered, and a veneer tape of the same material as the cabinet surface is generally used (see **Figure 20-9**).

European cabinetry has become enormously popular, largely due to the fact that it can be produced rapidly and is therefore less expensive than traditional face-frame cabinetry. By employing materials such

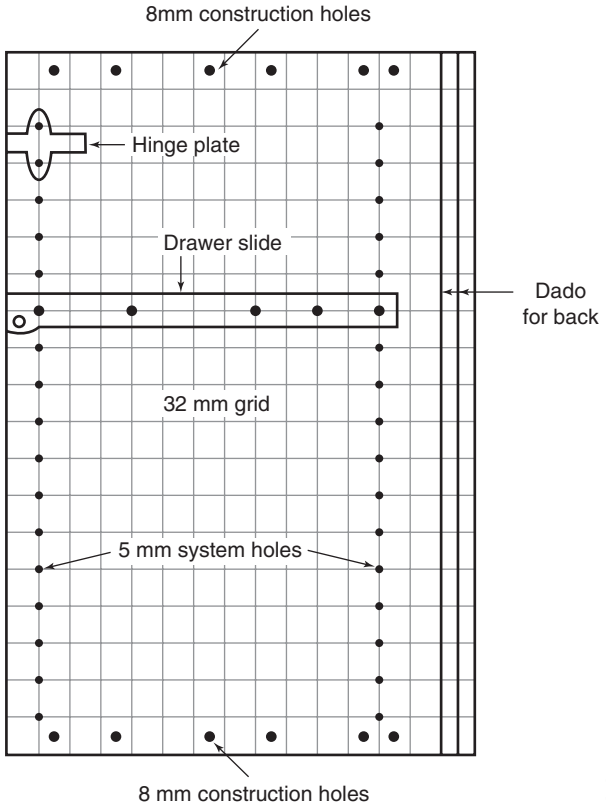


FIGURE 20-7 Side of a 32 mm cabinet.

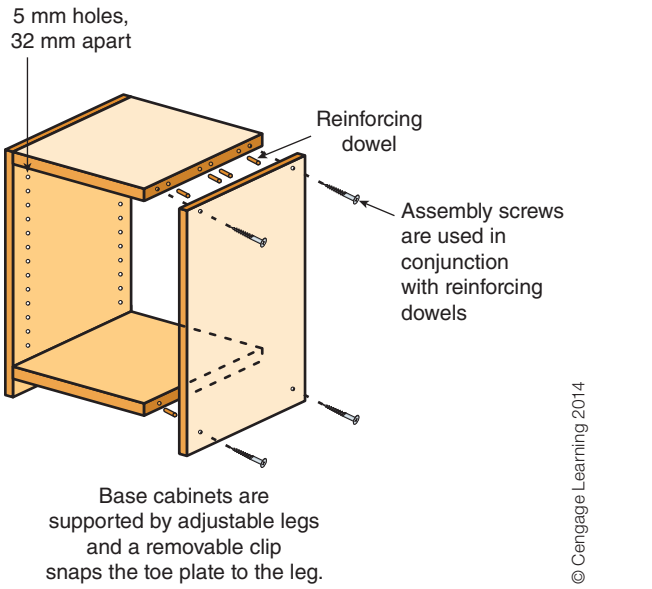


FIGURE 20-8 Construction of a 32 mm cabinet.

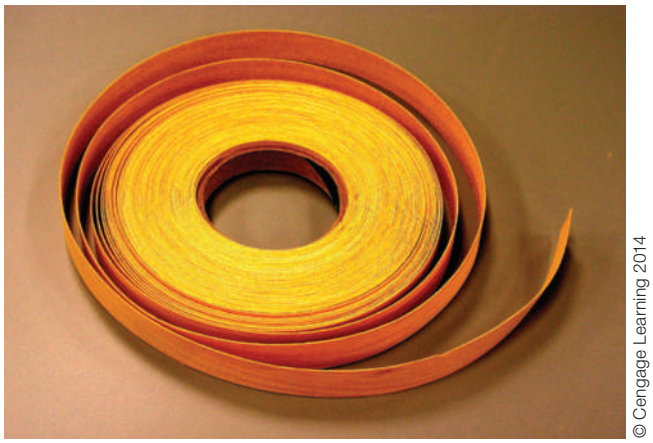


FIGURE 20-9 Veneer tape covers the exposed edges of European cabinets.

as melamine and other prefinished sheet goods, the need for finishing the cabinets is also eliminated, saving even more time and expense. In fact, many companies that produce traditional wood cabinets have eliminated the face frame as well. Cabinets without face frames tend to have a more contemporary appearance, while face-frame cabinets are representative of a more traditional look.

Standards

Kitchen cabinets and bathroom vanities are built to certain standards. Kitchen **base cabinets** are 34 1/2″ high. A base cabinet sits on the floor. When the countertop is added, the standard height of kitchen base cabinets is 36″. The depth of these cabinets is 24″, and with the addition of the countertop, it is 25″ from the wall to the outside of the counter (see **Figure 20-10**).

Most kitchen **wall cabinets** are 12″ deep and are usually 30″ high, although it is possible to purchase wall cabinets that are taller; they may go all the way to the ceiling. Wall cabinets are attached to the wall. Typically the top of kitchen wall cabinets is set at 84″, and often a soffit is built that reaches from the top of the cabinets to the ceiling.

While the majority of kitchen wall cabinets are 30″ high, in most kitchens you will find wall units that are not as tall, such as those over a refrigerator or stove. Another common wall cabinet that is deeper than the standard 12″ is a cabinet built to house a microwave, which requires more depth. The width of kitchen cabinets varies in 3″ increments, starting with a 12″ width, which allows cabinets to be purchased to suit the size of any kitchen. Cabinets may also be custom made.

Bathroom vanities, which are cabinets that contain a sink, are the same depth as kitchen base cabinets but are a total height of 34″ with the countertop, so the cabinets themselves are generally built 32 1/2″ in height.

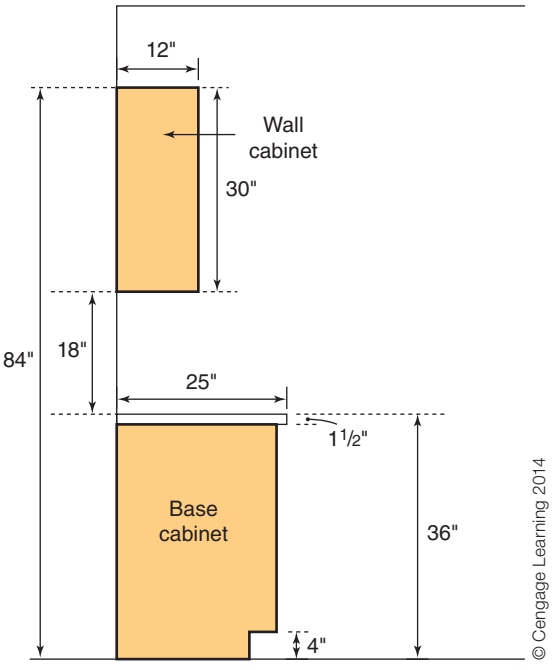


FIGURE 20-10 Kitchen base and wall cabinet dimensions.

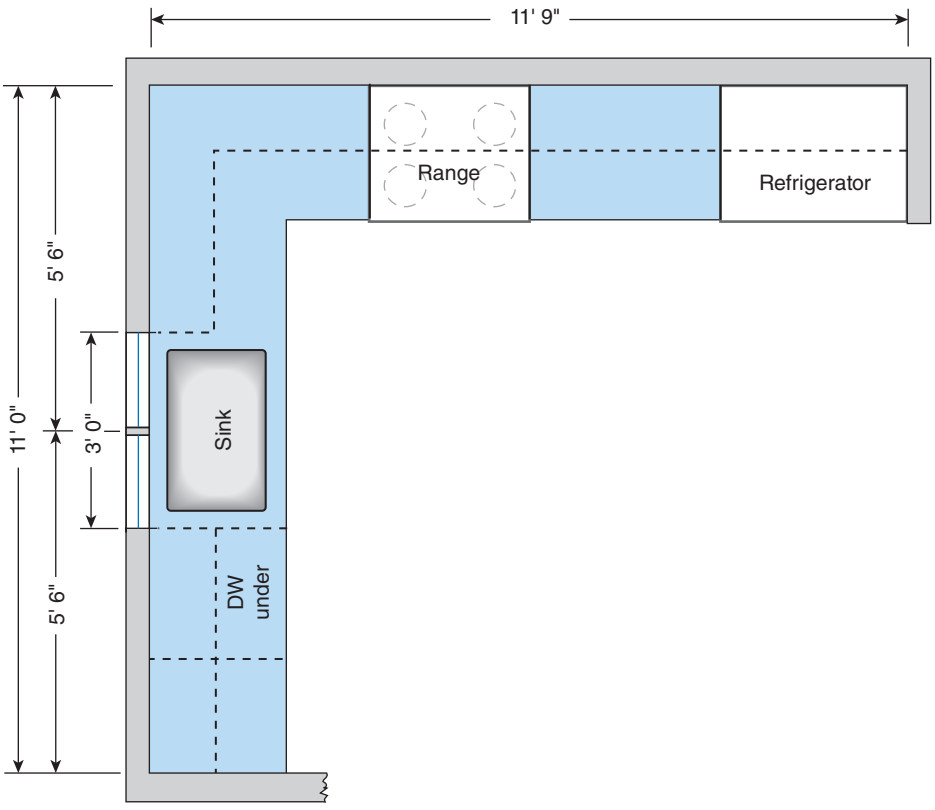
WOODWORKING TIP:

When using a dado blade in the table saw to machine rabbets, attach a piece of material to your fence, such as a straight board or plywood scrap. This will allow you to bring the fence right up to the blade without damaging your fence. The piece you have attached is called an auxiliary fence *or* sacrificial fence.

INSTALLING KITCHEN CABINETS

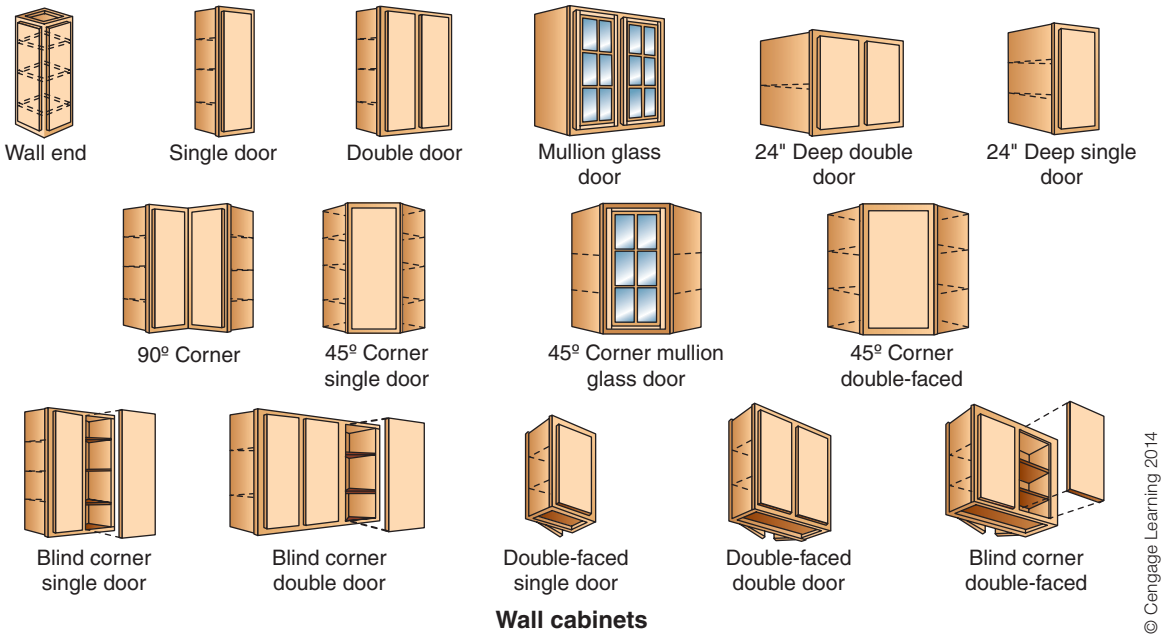
Whether you build or purchase the kitchen cabinets you are going to install, you need to approach the job with a plan. If this is a newly constructed or remodeled kitchen, you may or may not have blueprints that show the layout of the cabinets, giving the size and location of each of the cabinets. If you do not, prior to building or buying the new cabinets, you need to accurately measure the length of the walls on which the cabinets will be mounted. The next step is to draw a plan to scale, including windows and appliances, and the placement of the sink (see **Figure 20-11**).

If you are purchasing your cabinets, most retailers have the capability to do computer layouts, which enables you to quickly see various layout possibilities. There are many choices for both wall and base cabinets. **Figures 20-12** and **20-13** illustrate some of them. The size and type of cabinets is decided upon. Typically, the layout will show these choices. **Figure 20-14** shows a typical elevation drawing layout for purchased cabinets. Cabinets are identified



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FIGURE 20-11 Kitchen layout showing dimensions, windows, sink, and appliances.



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FIGURE 20-12 Wall cabinets.

as either W (wall cabinet) or B (base cabinet). The number on the base cabinet is its width, in inches. The first two numbers of the four-number sequence on the wall cabinets give its width, and the third and fourth numbers give its height, in inches. SB stands for sink base, and BC is a designation indicating blind corner. Once a layout has been decided upon, cabinets may be bought or built.

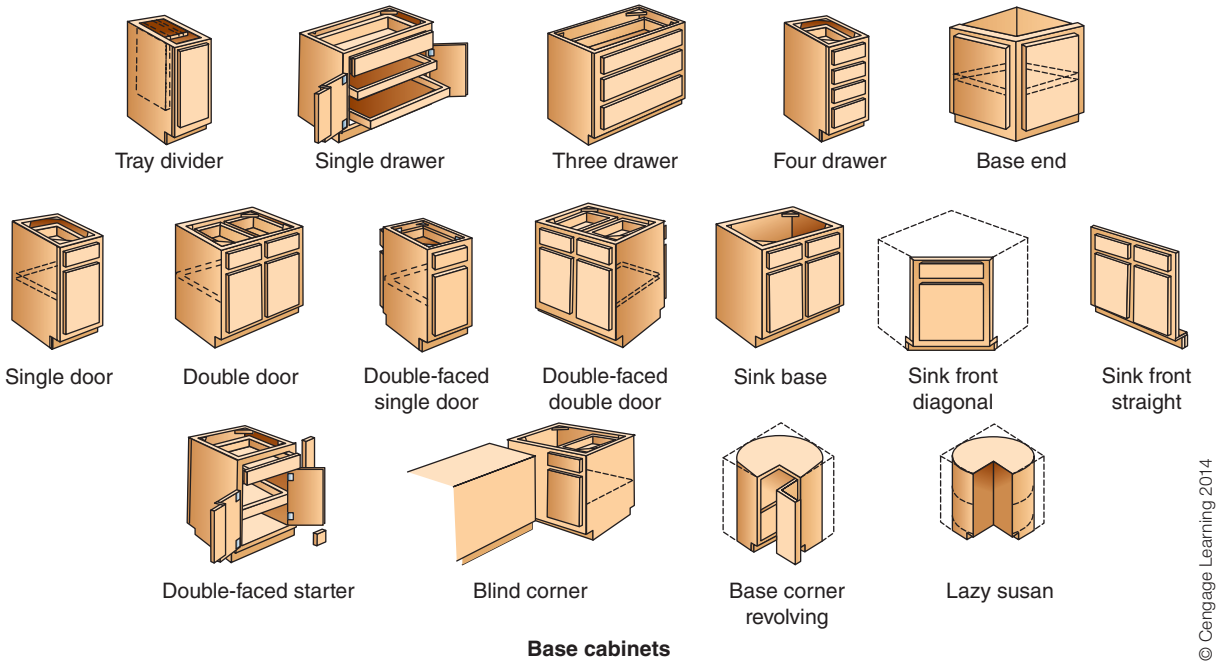


FIGURE 20-13 Base cabinets.

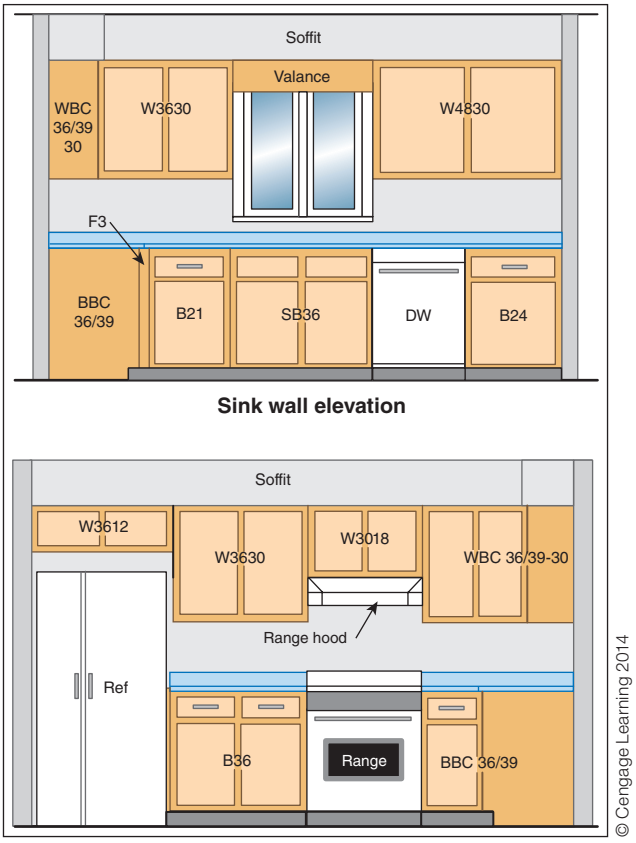


FIGURE 20-14 Kitchen layout showing cabinets.

The area in which the cabinets are to be installed should be clear and clean. Old cabinets need to be removed, and appliances moved out of the way. Any molding should be removed. Water and power should be shut off. Make sure you have plenty of room to work. Remove the doors, drawers, and any adjustable shelves from the new cabinets, and set them aside. Assemble the tools you will need. These include a chalk line, a 2″ level, a 4″ or 6″ level, two 4″ C-clamps, a drill with bits and drivers, a hole saw, a hammer and finish nails, and a step ladder. You may wish to have a stud finder and a cabinet jack as well. The cabinet jack helps hold wall cabinets in place as they are installed; if you are working without a helper, you will need some type of jack (see **Figure 20-15**). Ideally you should have someone else working with you.

Kitchen cabinets must be installed so that they are level and plumb, for both aesthetic and functional reasons. The walls and floors of the kitchens may not be level and plumb, so one of our initial steps is to lay out level and plumb lines that will guide the work. The first step is to find out if the floor is level or not, which is done by laying a long straightedge down on the floor where the cabinets will go and placing the level on it. If the floor is not level, find and mark the high point. Measure up 34 1/2″ from this point and then mark a level line all along where the cabinets will be installed. This line marks the top of the base cabinets.

Next measure up 19 1/2″ from the level line you drew and snap chalk lines. This line tells us where the bottom of the wall cabinets will sit. When the

1 1/2″-thick countertop is installed, there will be 18″ between the countertop and the bottom of the wall cabinets. One more horizontal line is needed to mark the tops of the wall cabinets. Measure up 30″ from the line you just made and snap lines. This is necessary since not all the wall cabinets are 30″ high. If they were, we could simply use the line we first snapped to install them.



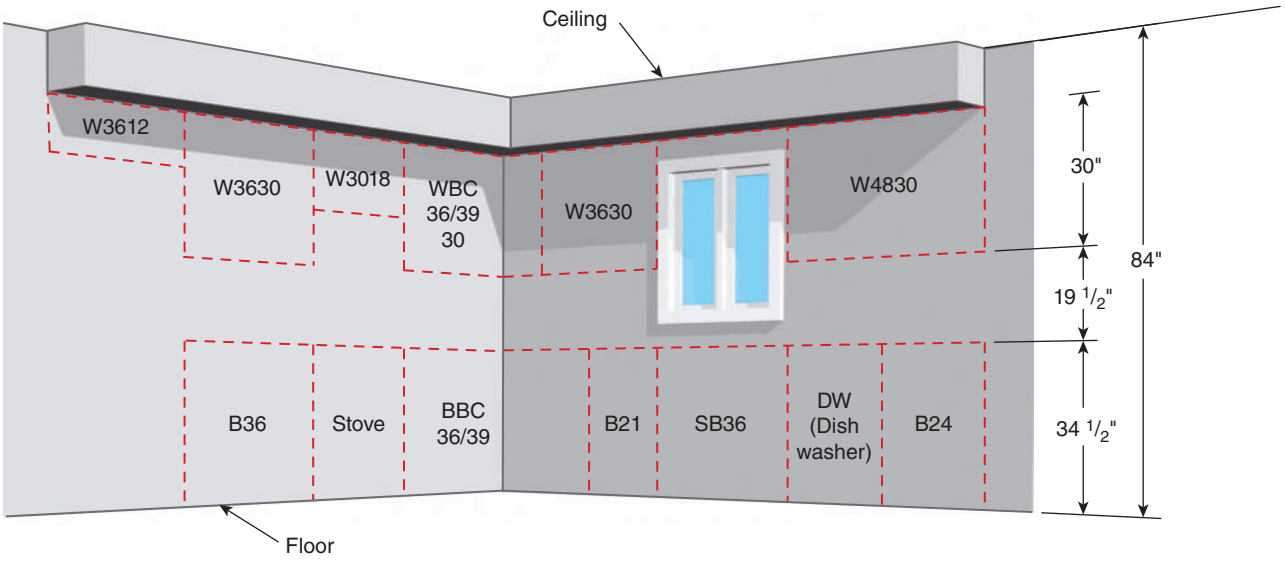
Image courtesy of rockler.com

FIGURE 20-15 A cabinet jack holds wall cabinets in place as they are secured to the wall.

Cabinets have to be securely attached to the wall, which means fastening them to studs, the vertical wooden members that make up the wall frame. Therefore, we must locate and mark the stud locations. Use the stud finder to locate the studs, or tap along the wall with a hammer until it doesn't sound hollow. Drive a small nail to see if you have hit a stud. Do this in a location that will be later covered by a cabinet. Once you have located one stud, it should be easy to find the others. Typically they are spaced 16″ apart, although in some homes they may be 24″ apart. Use the nail to check at each point, and then use your long level to mark plumb lines on the wall showing each stud location. Next mark out on the wall the specific cabinets you will install, as shown in **Figure 20-16**.

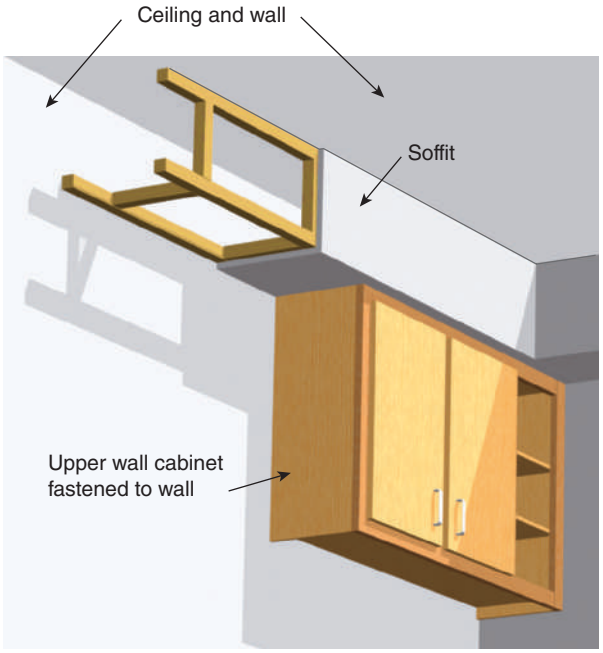
If you are going to put in a soffit, this may be done next. The soffit extends from the ceiling to the top of the wall cabinets. It is typically 14″ wide, allowing molding to be run under it and against the wall cabinets. The soffit is generally a 2 × 2 frame covered with 1/2″ sheetrock (see **Figure 20-17**).

You can install either the base cabinets or the wall cabinets first. Many people choose to put the wall cabinets in first so they don't have to lean over the base cabinets to install them. Installation is started in a corner. Before lifting the cabinet, predrill shank holes for the attachment screws through the attachment rails at



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FIGURE 20-16 Cabinet locations are marked out on the walls.



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Soffit built prior to cabinet installation

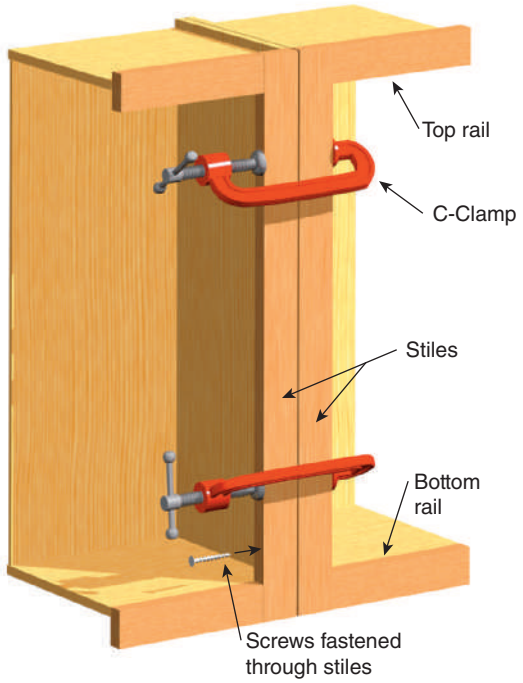
FIGURE 20-17 Soffit.

the back of the cabinet. Do a careful layout so that the screws will hit the studs. Cabinets are heavy and bulky, so it is helpful to have someone working with you. If there is a soffit, the wall cabinet is butted up against it and held in place by a helper or a cabinet jack. If there is no soffit, you may wish to temporarily screw a 1 × 3 beneath your second horizontal line to support the wall cabinets during installation. This is a viable option if the wall will be tiled or otherwise covered later. Alternatively, you can screw a 1 × 3 above the top horizontal line you made on the wall, which will give you something to butt the wall cabinets against and not leave marks in a visible area. Use a level to ensure that this cabinet is hung plumb, checking the front and side. Use shims as necessary; all the other wall cabinets depend on the first one being correctly aligned. Attach the cabinet to the wall using # 8 × 2 1/2″ round-head screws and washers, or similar-length screws with integral washer heads. Leave the screws just shy of snug.

WOODWORKING TIP:

You can make a simple jack for holding wall cabinets in place during installation by fastening together two pieces of 2 × 4 material to form a T. It should be as tall as the distance to the bottom of the wall cabinet or just a bit longer. Staple an old piece of carpet to the horizontal piece to protect the cabinets. The jack is wedged in place to hold the cabinet while it's being attached to the wall. This works well if the wall cabinets are being installed under a soffit or a ledger strip attached to the wall above the top of the cabinets. A jack is not needed if you are setting them on a ledger attached to the wall at the bottom of the wall cabinets, especially if you have a helper.

Next install one of the cabinets beside the corner cabinet, having predrilled shank holes in the appropriate locations, shimming as needed. Again, do not completely tighten the screws. Use two 4″ C-clamps to clamp the two cabinets together at the top and bottom, then predrill and countersink holes and fasten the two cabinets together with two 2 1/2″ × #6 wood screws (see **Figure 20-18**). If the cabinet does not have a face frame, use 1 1/4″ screws. Install the third wall cabinet in the same manner, fastening it somewhat loosely to the wall and attaching it to the second cabinet. Continue this process until all the wall cabinets are hung, and then go back and tighten all the mounting screws.



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FIGURE 20-18 Cabinets are screwed together so their fronts are flush.

As mentioned earlier, kitchen cabinets are available in 3″ increments. It may turn out that the length of the wall to be covered is not a multiple of 3″. This is an issue if the cabinets are meant to run to an intersecting wall. Cabinet manufacturers make filler strips to match the cabinet. The filler strip is cut to fit the open space and screwed in place through the adjoining cabinet.

Base cabinets are also installed beginning in a corner. Shim them as necessary so that they are even with your level line and level from front to back. This is where you'll use your 2 foot level. Again, lay out and drill shank holes through the mounting rail so the screws will hit studs. Fasten the cabinet somewhat loosely to the wall and install the one next to it in the same manner. Then fasten the two cabinets to one another, again making sure the fronts are flush at the top and bottom. Proceed to the third cabinet, and follow the same steps. Before the sink base is installed, you will need to lay out and drill openings for the water supply lines and the drain, using the hole saw. Filler strips may need to be installed on one or both side of the sink base unit. As you install the base cabinets, double-check your measurements for the appliance spaces and make sure they are correct. When all the cabinets have been installed, tighten the screws holding the cabinets to the wall, and trim off any protruding pieces of shim. Once the base cabinets are in place, the countertop can be installed, and the doors and drawers mounted.

ADVANCED CASEWORK

The kitchen cabinets and vanities discussed are simple types of casework, utilizing simple joinery techniques and few pieces. Other types of casework may be equally simple. More advanced casework has more parts and uses more complicated joinery.

These cabinets may be primarily made of sheet goods, like the cabinets already discussed. They may have face frames or not. They may be made of solid wood or use frame-and-panel construction.

While kitchen base cabinets and vanities very often have the sides coming down to the floor, other casework may have separate feet, sit on a base, or have trim attached around the bottom. Legs may extend below the cabinet to support it, or the sides may have decorative cutouts. Like some base cabinet and vanities, they may have drawers. Some have doors, some do not. There may be fixed or adjustable shelving. They may have decorative trim added.

Sophisticated casework may be made up of two or more separate structural units which are then fastened together. Individual units might include a base, a lower case, an upper case, and a cornice (see **Figure 20-19**). In casework that has both a lower and an upper case, often the lower case is an enclosed piece, fitted with doors and perhaps drawers and interior shelves as well. Often the upper unit has shelving and is either open or has doors with glass panels that allow you to see the contents of the cabinet. The cornice is the top part of the cabinet, and it is decorative. It may be simple or complex.

Figures 20-20 through **20-25** show some examples of more sophisticated casework.

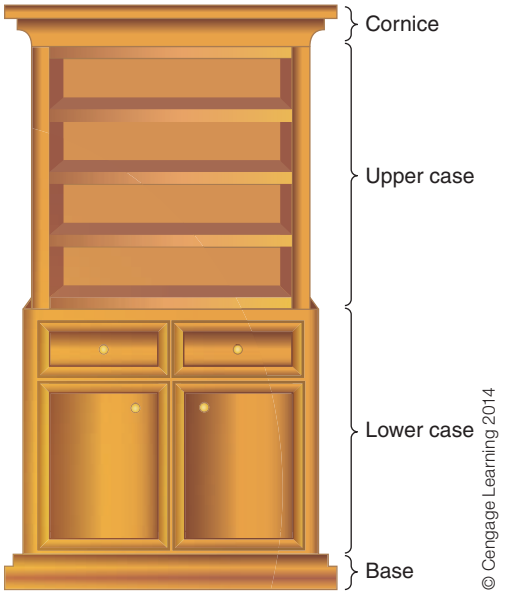


FIGURE 20-19 Advanced casework may consist of separate units.



FIGURE 20-20 Bookcase.



Image courtesy of John Lomas Custom Furniture

FIGURE 20-21 Credenza.



Image courtesy of John Lomas Custom Furniture

FIGURE 20-22 Sideboard.



Courtesy of Country View Woodworking, Ltd. and www.countrysideamishfurniture.com

FIGURE 20-23 Corner cabinet.



Image courtesy of Thomasville Furniture

FIGURE 20-24 Display cabinet.

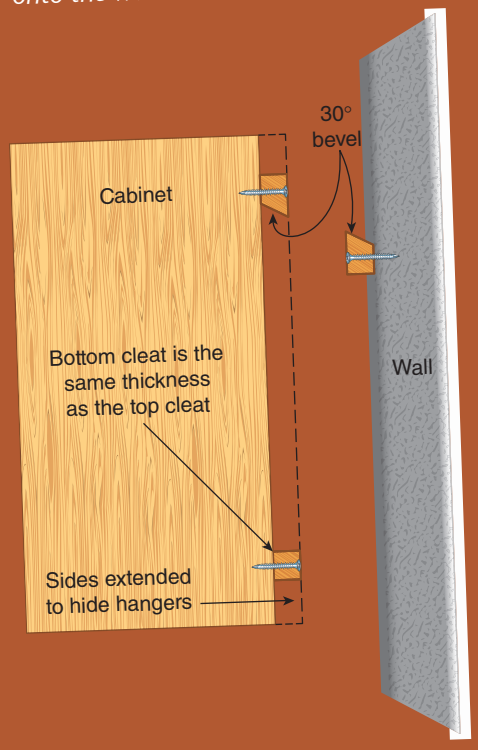


Image courtesy of Thomasville Furniture

FIGURE 20-25 Armoire.

WOODWORKING TIP:

If you want to hang a wall cabinet in such a way that it is easily removable, one way to do it is to install a cleat system like the one diagrammed in **Figure 20-26**. *The beveled piece of wood is attached level to the wall with the bevel up. A mating piece of wood, also beveled at 30°, is attached to the back of the cabinet with the bevel down. Another piece of wood that is the same thickness is fastened to the bottom of the cabinet so that the cabinet will hang plumb on the wall. To conceal the hanging mechanism, the sides of the cabinet are extended. To install, just lower the case onto the wall cleat.*



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FIGURE 20-26 Cleat system for removable wall cabinet.

SHELVES

Shelves may be fixed or adjustable. Fixed shelves are held in place with a housing joint, as covered in Chapter 19. There are various options for securing adjustable shelves in a cabinet. Some depend on purchased hardware, while others are fabricated in the shop. **Figures 20-27** through **20-30** illustrate some hardware options, and **Figure 20-31** details some of the shop-built choices.

The human eye easily picks up even small deflections in a shelf, as little as 1/32″ over 12″. Therefore it is important to build shelves that are sturdy enough to avoid sagging under load. **Figure 20-32** shows a span chart for various shelving materials. Ways of reinforcing shelves is illustrated in **Figure 20-33**. These methods are effective with solid wood as well as sheet goods.



Image courtesy of rockler.com

FIGURE 20-27 Shelf pins fit 1/4″ or 5 mm holes drilled in the cabinet sides. They come in different configuraitons and different materials.



Image courtesy of rockler.com

FIGURE 20-28 Shelf standards and clips.

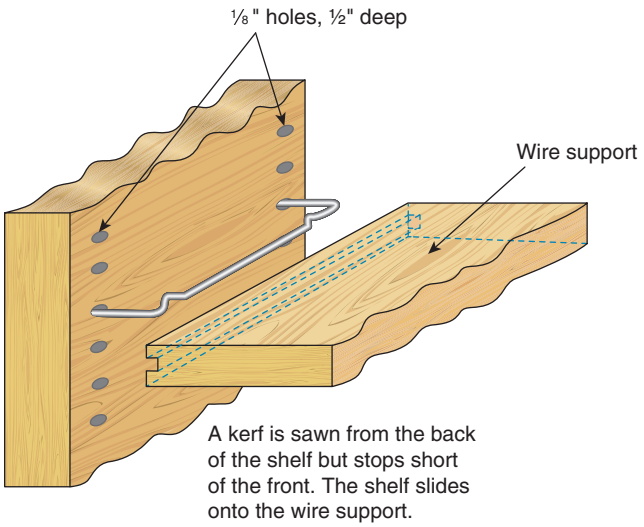


Image courtesy of rockler.com

FIGURE 20-29 Shelf standards and brackets.

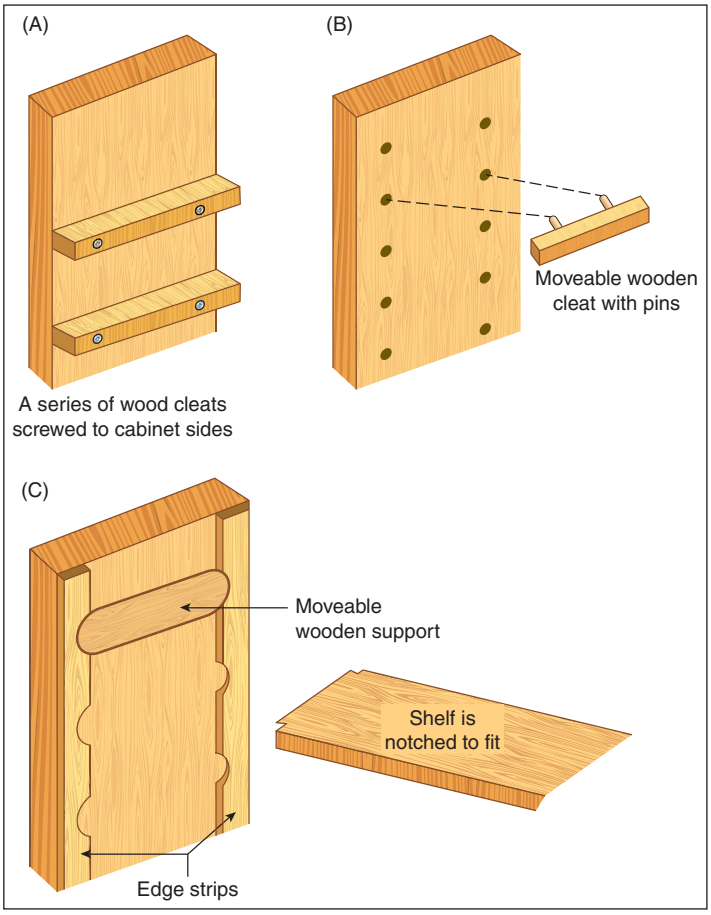
DECORATIVE TRIM AND MOLDINGS

Adding moldings and trim to a plain cabinet can turn it into a much more intricate and visually interesting one. Compare the two armoires shown in **Figure 20-34**. They are the same size, yet the addition of the moldings makes them look very different.



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FIGURE 20-30 Wire shelf supports are concealed.



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FIGURE 20-31 Shop-built choices for adjustable shelves.

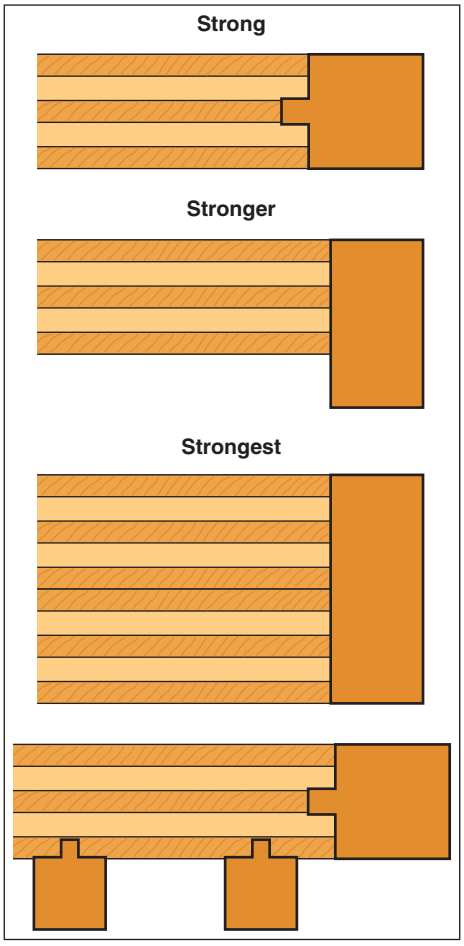
Moldings may be purchased or made in the shop. There are really only a maximum of three shapes in any given molding profile. They are a bead, a cove,

Material	Maximum Span
Plywood, ¾″	32″
MDF, ¾″	28″
Particleboard, ¾″	24″
Softwood, ¾″	36″
Softwood, 1″	48″
Softwood, 1½″	63″
Hardwood, ¾″	42″
Hardwood, 1″	48″
Hardwood, 1½″	66″

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FIGURE 20-32 Shelf span chart.

and a flat. Beads are convex curves, coves are concave curves, and flats are straight lines. See **Figure 20-35** for examples of common molding profiles, and **Figure 20-36** for common profiles that are a combination of shapes. By combining different profiles and sizes, an infinite combination of moldings can be made. Routers and shapers are commonly used to make moldings.



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FIGURE 20-33 Methods of strengthening shelves.



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FIGURE 20-34 Plain armoire and armoire with trim.

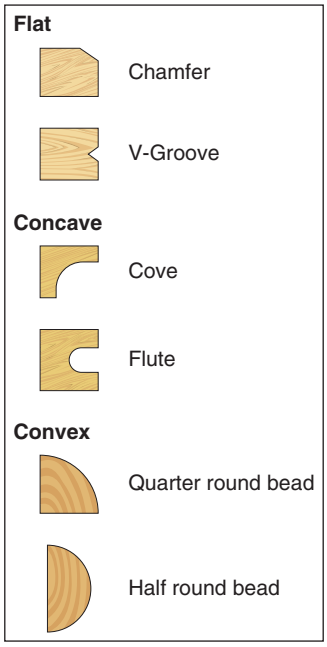


FIGURE 20-35 Simple shape molding profiles.

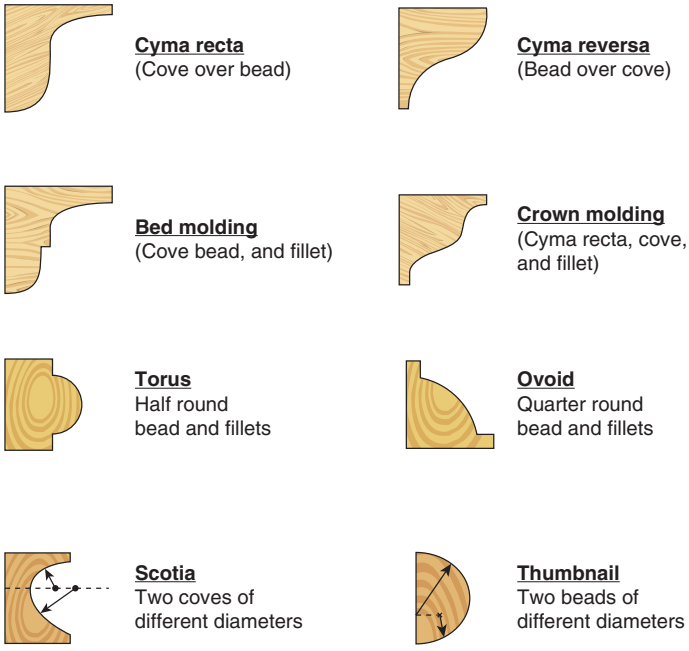


FIGURE 20-36 Combined shape molding profiles.

More complex and elaborate shapes can be created by combining separate moldings. These are called built-up moldings. The detailed cornices seen on some casework is often made this way. See **Figure 20-37** for examples of built-up moldings.

Cutting and Installing Molding

Moldings are mitered to wrap around a case. These are outside corner cuts that are usually made at 45°, since most corners are 90°. Miter cuts may be made on the miter saw, the table saw, or the radial arm saw. Opposing cuts are made in each of the two pieces that come together to form the corner (see **Figure 20-38**).

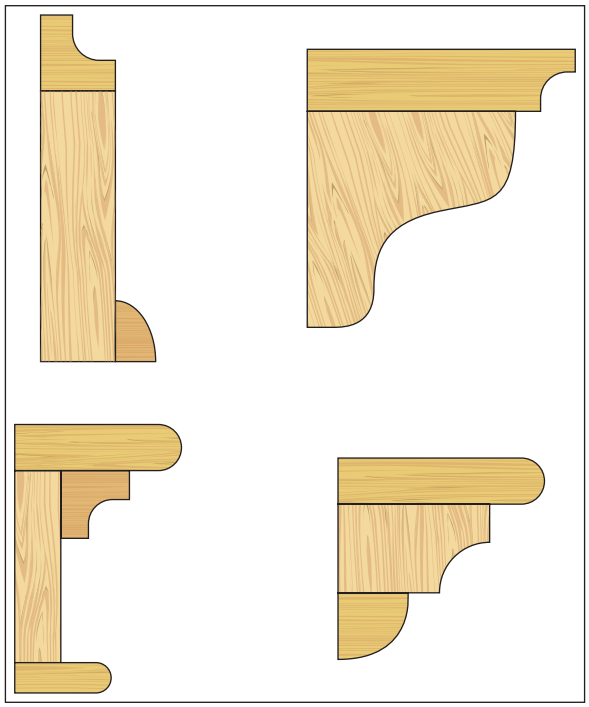


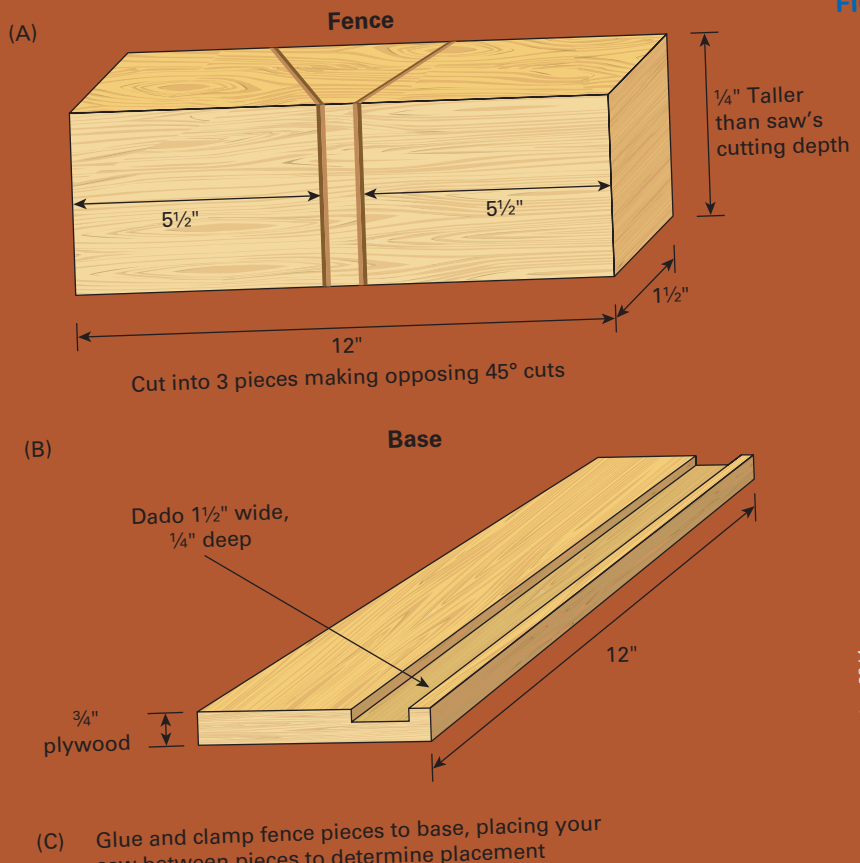
FIGURE 20-37 Built-up moldings.



FIGURE 20-38 Outside miter.

WOODWORKING TIP:

Small, decorative moldings are often better cut by hand to avoid splintering. Make the simple miter box shown in **Figure 20-39** *to fit your saw. If you run a 3/4" wide × 1/4" dado in the bottom of the base, you can glue in a 3/4" × 1 1/4" wide wood strip that will allow you to clamp the miter box in a bench vise while you use it.*



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FIGURE 20-39 Miter box.

More complicated casework may have inside as well as outside corners that require trim. Inside corners can also be mitered, as shown in **Figure 20-40**, but a more satisfactory approach is to cope an inside corner joint. Inside mitered corners may open up, leaving an unsightly gap. A coped joint is a fitted joint in which part of one piece is cut to fit over the molded surface of the other piece. A coped joint is made by butting one piece of molding into the corner, as shown in **Figure 20-41**. The mating piece of trim is then mitered with an inside miter cut (see **Figure 20-42**). The third step is to cut along the miter profile with a scroll saw or a coping saw, following the contour created on the face by the beveled cut, as seen in **Figure 20-43**. **Figure 20-44** shows the completed coped joint. Notice that it looks like a miter joint, except at the very top and bottom.



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FIGURE 20-40 Inside miter.



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FIGURE 20-41 When making a coped joint, one piece is butted into the corner.



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FIGURE 20-42 The mating piece gets an inside miter cut.



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FIGURE 20-43 Cut along the miter profile with a coping saw.

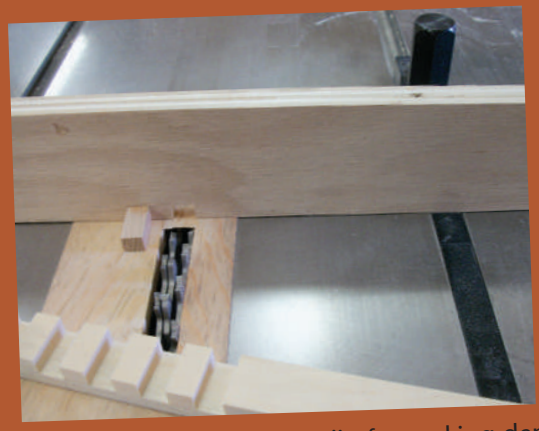


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FIGURE 20-44 Completed coped joint.

WOODWORKING TIP:

Dentil molding can be made on the table saw with a dado blade and a jig similar to a box joint jig (see **Figures 20-45** *and* **20-46***). The dado blade, the key glued in the jig, and the distance between the blade and the key are all the same measurement. To make a checkerboard molding, mill a wider piece using the same jig and then rip it into narrow strips, offset them, and glue them up (see* **Figure 20-47***).*



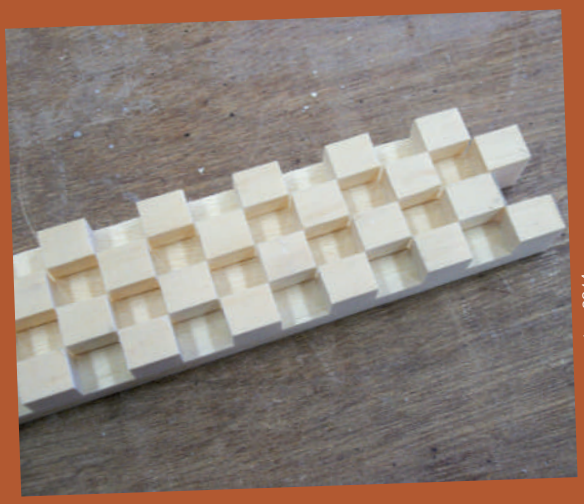
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FIGURE 20-45 Tablesaw jig for making dentil molding.



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FIGURE 20-46 Using the jig.

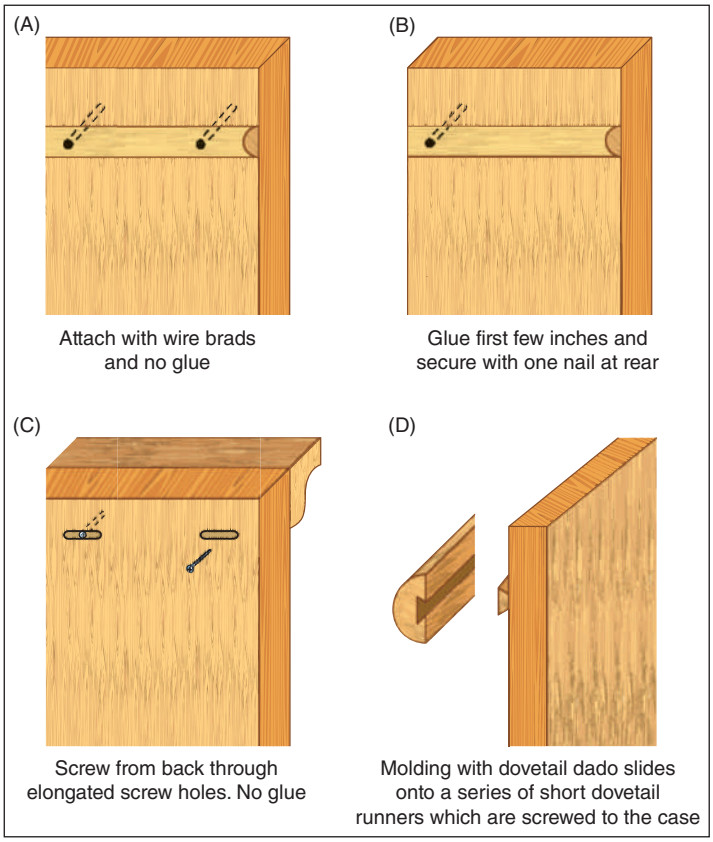


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FIGURE 20-47 Checkerboard molding.

Gluing and nailing molding in place is the easiest way to attach it to the case. With small moldings, or if clamping is not a problem, glue alone may be used. This strategy is fine if the molding is being attached to a panel product or, in the case of solid wood, if the grain of the molding runs parallel to the grain of the case. If, however, we are working with a solid wood case and the molding's grain runs perpendicular to that of the case, we have a different situation. If the molding is glued in place, the inevitable wood movement is restricted and eventually either the molding will come loose or the case will split. Therefore, we need to attach this molding in such a way that the wood can still move. There are several strategies for doing this.

One solution is not to use glue at all, but simply to attach the molding with wire brads whose gauge is small enough that they will flex and allow the wood to move. Another strategy is to use glue on the first 3″ of the molding and then use a finish nail or brad at the end of the piece. This will also allow movement and has the advantage of fewer nail holes. A third method is to screw the molding in place from inside the case, through slots that are cut perpendicular to the case's wood grain. Yet another option is to rout a dovetailed slot on the back of the molding and screw a dovetailed runner on to the case. This runner should not be installed as one piece or the same wood movement problem arises. Mill the runner and then cut it into several short lengths (see **Figure 20-48**).



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FIGURE 20-48 Strategies for dealing with wood movement in attaching molding to solid wood.



Summary

Cabinets are essentially boxes turned on a side or end. They are sometimes referred to as casework. Casework may be simple or complex.

Kitchen cabinets and vanities are a simple form of casework, consisting of two sides, a bottom, a back, and a top, which may be a countertop added later. There are two basic styles of cabinet: those with face frames and those without, which are called *European* or *32 millimeter* cabinets. Generally, very simple joinery — such as dadoes and rabbets or dowels and pins — is used to construct these types of cabinets. Kitchen cabinets may be base or wall cabinets. Standard height for base cabinets is 36″ with the countertop included. Bathroom vanities are shorter, with 34″ as the industry standard. When face frames are used, as in traditional cabinetry, they are attached to the cabinet after it is constructed. Most cabinets utilize sheet goods in their construction, making them relatively quick to build. European cabinets are even faster to construct, since they do not have face frames, although the exposed edges of the sheet goods must be covered to present a finished appearance.

More complex forms of casework may also be constructed of sheet goods, or may be solid wood, frame-and-panel construction, or a combination. They often are made up of two or more structural elements that are then fastened together. They can be enhanced by the addition of different types of trim and molding. When attaching trim to solid wood, it is important to take wood movement into consideration.



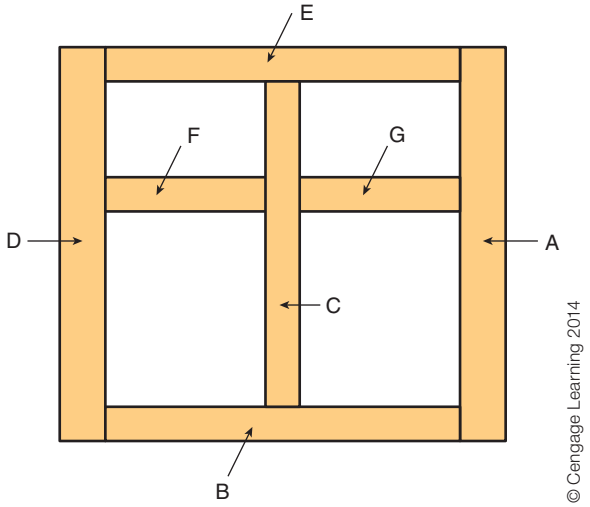
Key Terms

base cabinets
bathroom vanities
casework
European cabinets
face frame
mullion
rails
stile
32 millimeter cabinet
wall cabinets



Check Your Knowledge

1. Define and give examples of casework.
2. What is the main difference between traditional-style cabinets and European cabinets?
3. Why are European-style cabinets sometimes called 32 millimeter cabinets?
4. What is the standard height of a kitchen base cabinet?
5. What is the standard height of a bathroom vanity?
6. What are the depth and height of the standard kitchen wall cabinet?
7. What are two common exceptions to the standard kitchen wall cabinet, and how do they differ from the usual wall cabinet?
8. Label the parts of the face frame in **Figure 20-49**.



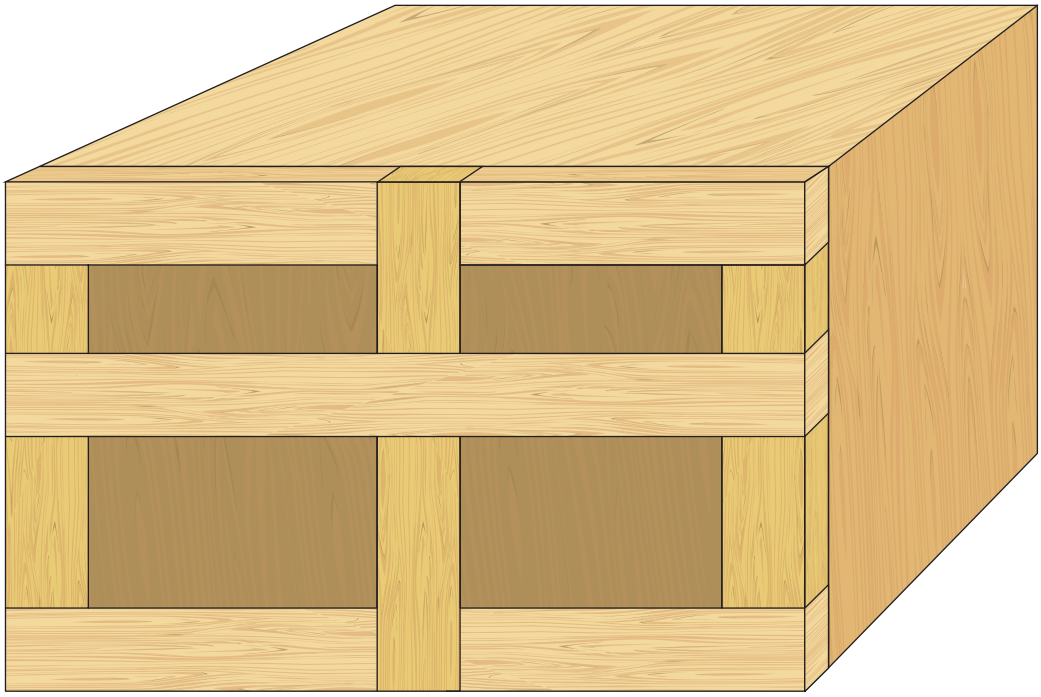
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FIGURE 20-49 Face frame components.

9. When installing kitchen cabinets, how much space should be left between the bottom of the wall cabinets and the countertop?
10. List the steps you would take once the kitchen area is clear and before you begin installing the new cabinets.
11. Where might a coped joint be used, and why?



What's Wrong with This Picture?



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BUILD IT!

18″ Wall Cabinet



A

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A completed 18″ wall cabinet is shown in **Figure A**.

NOTE: Door shown will be built in Chapter 21.

TOOLS REQUIRED

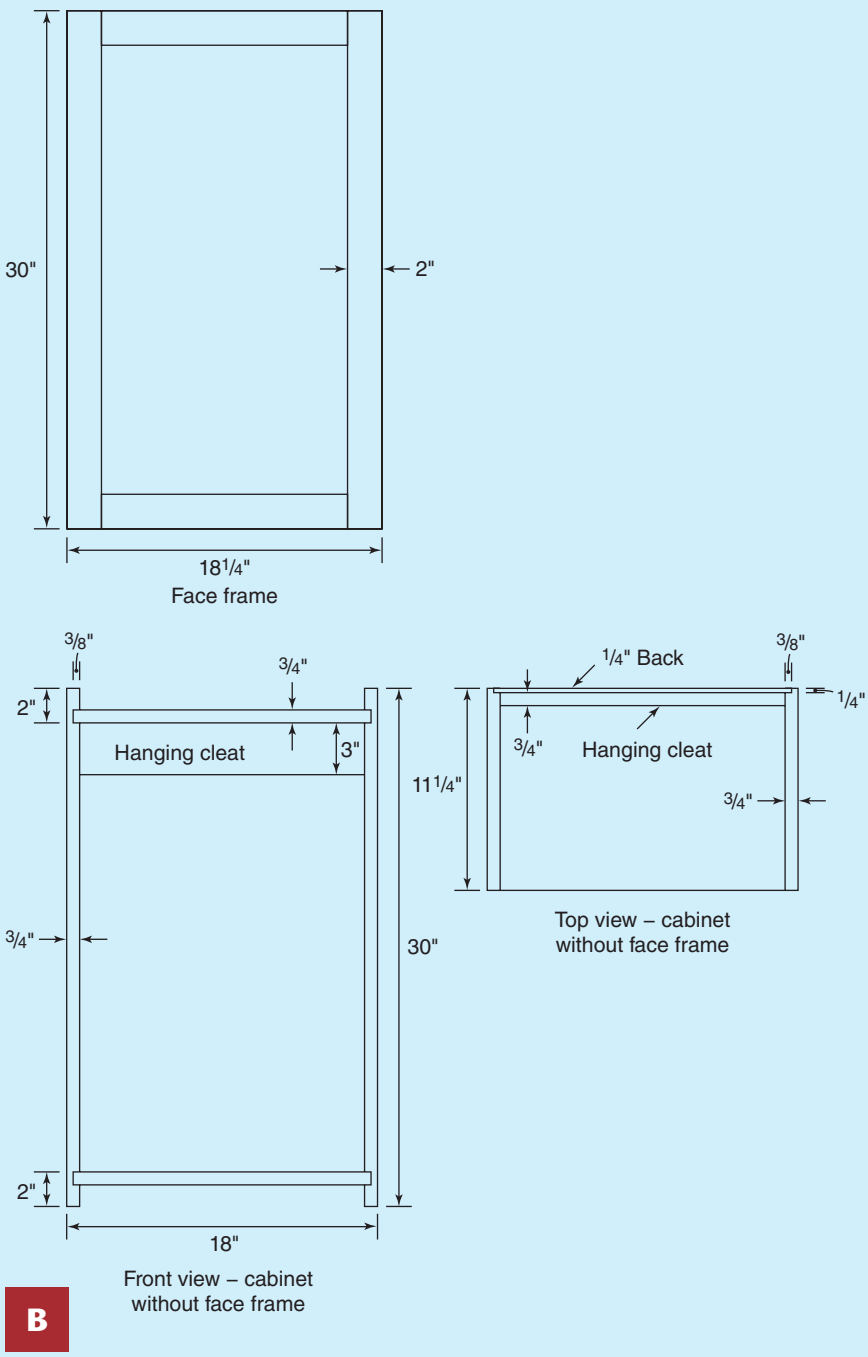
- Measuring tool
- Table saw
- Miter saw
- Router, 3/4″ straight bit, and 1/4″ rabbeting bit or dado blade for table saw
- Finish nailer
- Stapler
- Doweling jig or biscuit jointer

MATERIALS REQUIRED

- 3/4″ sheet goods for sides, top, bottom, and shelves
- 1/4″ sheet goods for back
- 3/4″ solid stock for the face frame, cleat, and shelf trim
- Dowels or biscuits

STEPS

1. Using the plan given in **Figure B** and the materials list shown in **Figure C**, determine the size of your sides, top, and bottom; cut them to size.



B

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BUILD IT!

Assembly list – wall cabinet

Part	Dimensions (thickness × width × length)	Quantity
1. Side	$^3/_4$" × 11$^1/_4$" × 30" plywood	2
2. Top	$^3/_4$" × 11" × 17$^1/_4$" plywood	1
3. Bottom	$^3/_4$" × 11" × 17$^1/_4$" plywood	1
4. Shelf	$^3/_4$" × 10$^1/_4$" × 16$^1/_4$" plywood	2
5. Shelf trim strip	$^1/_4$" × $^3/_4$" × 16$^1/_4$"	2
6. Hanging cleat	$^3/_4$" × 3" × 16$^1/_2$"	1
7. Back	$^1/_4$" × 17$^1/_4$" × 27$^1/_2$" plywood	1
8. Stile	$^3/_4$" × 2" × 30"	2
9. Rail	$^3/_4$" × 2" × 14$^1/_4$"	2
10. Shelf supports		8

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C



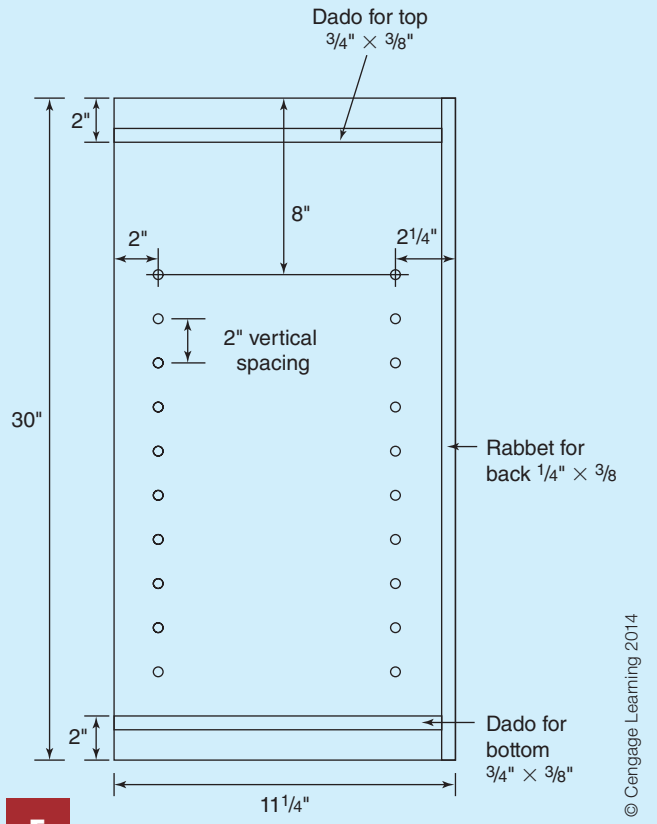
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D

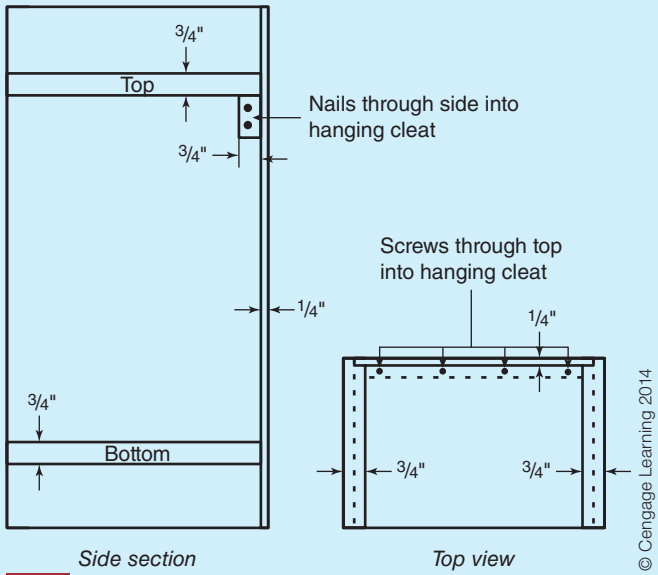
2. Cut rabbets on the inside of the back edge of each side.
3. Machine the dadoes in the sides for the top and bottom piece on the table saw using the dado blade or with a straight bit in the router and a guide (see **Figure D**).

BUILD IT!

4. Drill a series of 1/4" holes 5/16" deep in the sides on the drill press for adjustable shelves, as shown in the layout given in **Figure E**.
5. Assemble, glue, and clamp the sides, top, and bottom. Keep the front edges flush with each other.
6. Cut the back to size; glue and staple it into the rabbets on the sides and into the top and bottom.
7. Cut the hanging cleat to fit between the two sides, and glue it in place. Drive finish nails into it through the sides of the cabinet and 1 5/8" screws through the top, as shown in **Figure F**.
8. Cut the shelves to size and glue on hardwood strips to hide their front edge. Alternatively, you can use veneer tape.
9. Cut the stiles and rails for the face frame and assemble them with biscuits or dowels. Make sure the face-frame assembly is glued up flat and square.
10. Attach the face frame to the cabinet with glue and finish nails or brads. The top of the bottom rail should be flush with the bottom of the cabinet. The frame will overhang the cabinet slightly on each side.
11. If desired, trim the face frame flush with the cabinet using a piloted straight bit in a router.
12. Sand and finish as desired.



E



F

BUILD IT!

PROJECT CHALLENGE

18″ Base Cabinet



A

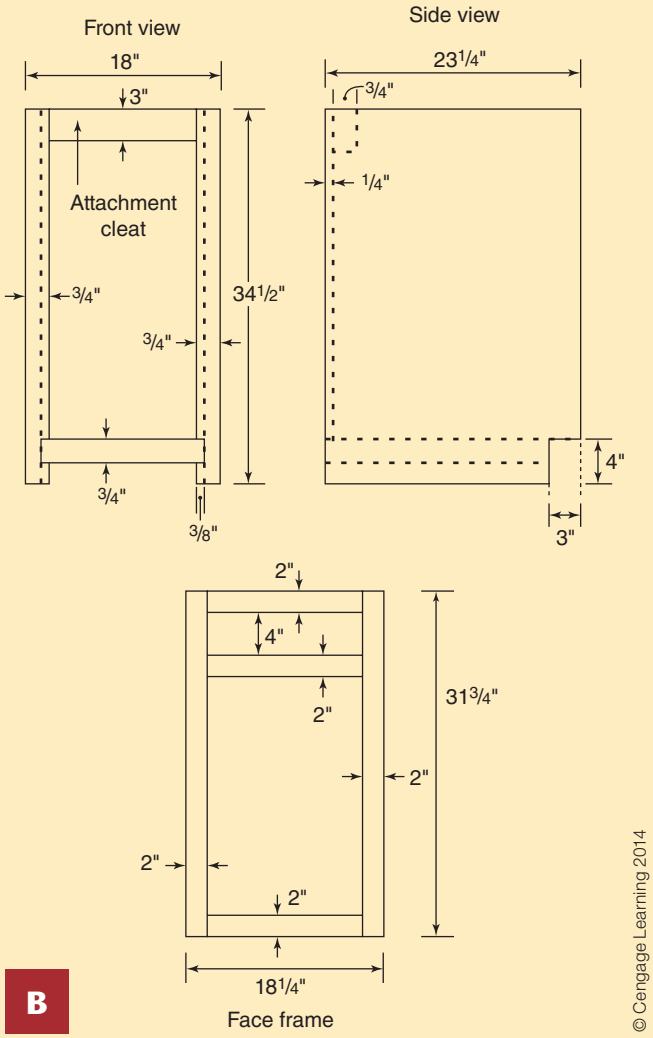
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A completed 18″ base cabinet is shown in **Figure A**.

STEPS

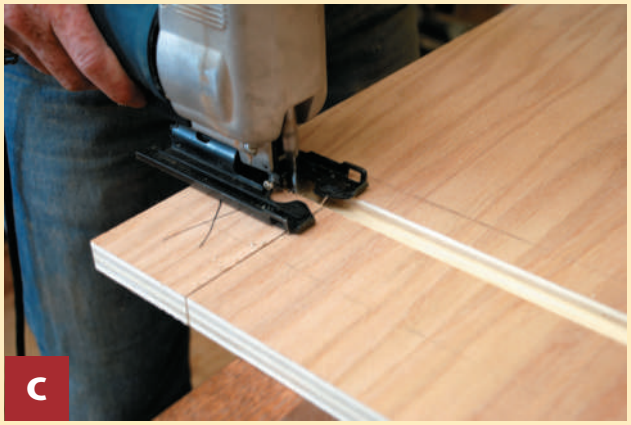
1. Using the plan given in **Figure B**, determine the size of your sides and bottom and cut them to size.
2. Machine the dado for the bottom in the sides of the cabinet using a dado blade on the table saw or a 3/4″ straight bit in a router with a straightedge or dadoing jig as a guide.
3. Machine a rabbet on the back of each side for the back, again using a dado blade in the table saw or a rabbeting bit in the router.
4. With the jigsaw, cut out the space on each side that will accept the kick plate, as shown in **Figure C**.

5. Assemble the sides and bottom of the cabinet with glue and either finish nails or brads.
6. Attach the back of the cabinet with glue and staples, driving them into the rabbets on each side and into the bottom.
7. Cut the attachment cleat to fit between the two sides. Glue and clamp it to the back, and drive finish nails through the sides to secure it in place.
8. Cut the kick plate to size from solid stock and attach to the cabinets with glue and finish nails.
9. Cut the face frame components to size and assemble them using biscuits or dowels.
10. Attach the face frame to the cabinet with glue and brads. It will slightly overhang each side and can be trimmed flush later if desired.
11. Make a temporary top from leftover 3/4" sheet goods, or wait until we get to the laminates chapter and build a proper countertop.
12. Sand as needed and finish as desired.



B

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C

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21

Cabinet Doors and Drawers

You'll Learn

After studying the chapter, the student should be able to:

- Demonstrate familiarity with different styles of doors
- Explain various methods of door construction
- Describe where door handles or knobs should be placed
- Understand and explain the different methods for mounting doors and drawers
- Describe different ways of building drawers

INTRODUCTION

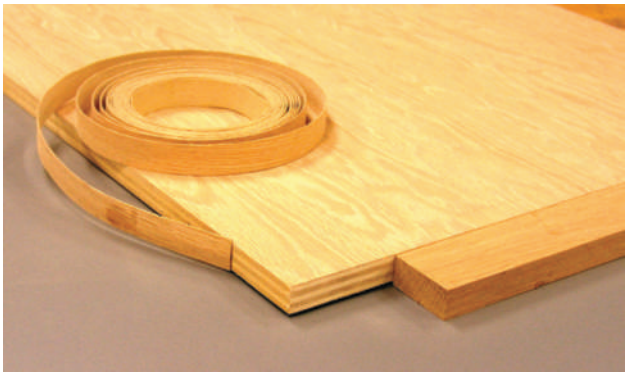
Doors and drawers form an important part of a closed cabinet. They allow the user to conceal items that would otherwise be visible, and prevent dust from accumulating on objects in the cabinet. Drawers allow a person to organize things, and doors or drawers may well be the focal point of a cabinet. Depending upon the style chosen and the materials used, we can create very different looks. In this chapter we will explore different styles of doors and drawers and discuss various methods for building them.

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DOOR STYLES

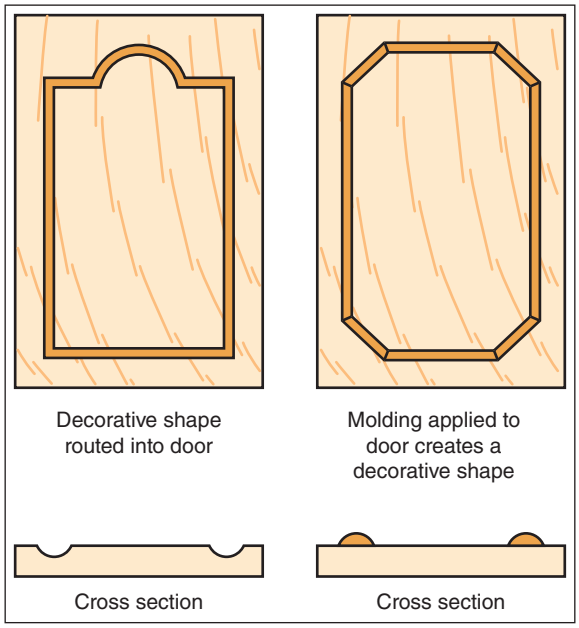
There are various styles of doors, including doors with frames, which may have flat or raised panels, and doors without frames. The most basic type of door is simply a flat door with no frame. It may be melamine, veneered plywood, or a plastic laminate applied over a substrate. The primary issue in building this style of door is covering the exposed edges of the sheet goods that are used. This can be accomplished with a veneer tape that matches the panel, by applying solid wood edges, or by laminating the edges (see **Figure 21-1**).

For added interest, V-grooves may be routed in the panel, or a shape may be routed into the panel. Moldings applied to the panel can also increase the visual interest and lend depth (see **Figure 21-2**).



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FIGURE 21-1 Exposed edges of flat doors must be covered.

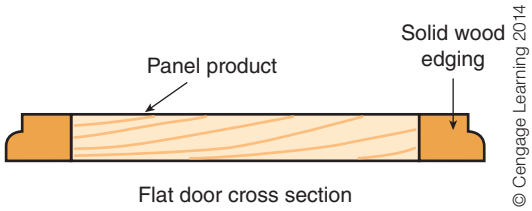


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FIGURE 21-2 Flat doors can be dressed up by routing or with applied moldings.

Applying a relatively wide, solid wood edge to the panel allows the builder to rout a decorative edge on what would otherwise be a square edge (see **Figure 21-3**). A second, more complicated style of door is the **flat-panel door**. This door has a frame, consisting of stiles and rails, that holds a flat panel. The panel is typically 1/4″ veneered plywood (see **Figure 21-4**).

Variations on the flat-panel door include using metal grills or glass, rather than sheet good panels. The essential difference in building a door that will have a glass panel is that the door must be designed in such a way that the glass may be easily replaced should it be broken. Usually glass will sit in a rabbet machined on the back of the stiles and rails, whereas a wood panel is captured in grooves milled in the stiles and rails. Glass panels may be held in place with glass clips, a removable wooden stop, or a high-quality silicone caulk (see **Figure 21-5**).



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FIGURE 21-3 A wide, solid-wood edge allows routing a shape on the edge of the door.



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FIGURE 21-4 Flat-panel doors.

The third style of door, and the most complicated and time consuming to build, is the **raised-panel door**. Like the flat-panel door, it has a frame consisting of stiles and rails, but its panel is solid wood, usually 3/4″ thick, with a profile milled on its edge (see **Figure 21-6**). Various profiles are possible, and the panel may simply be raised, or it may be raised and fielded. Examples of this are shown in **Figure 21-7** and **Figure 21-8**. Sometimes fitting the panel into the frame can be problematic, if the thickness of the panel and the stiles and rails are the same. Some cabinetmakers



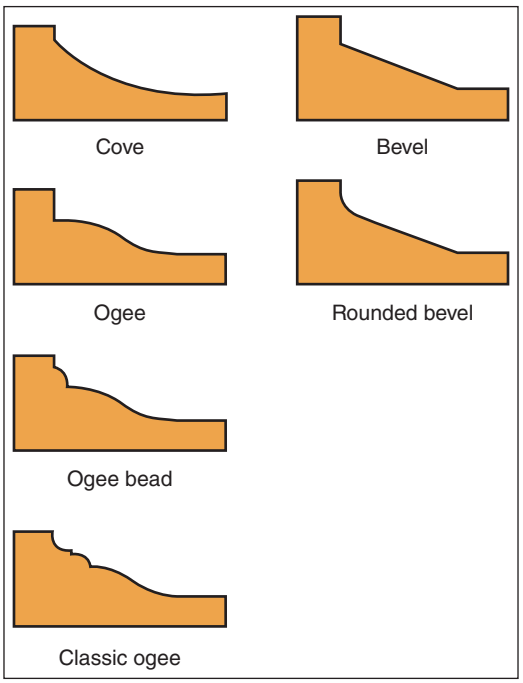
Image courtesy of rockler.com

FIGURE 21-5 Glass panels are held in rabbets by glass clips, removable wooden stops, or caulk.



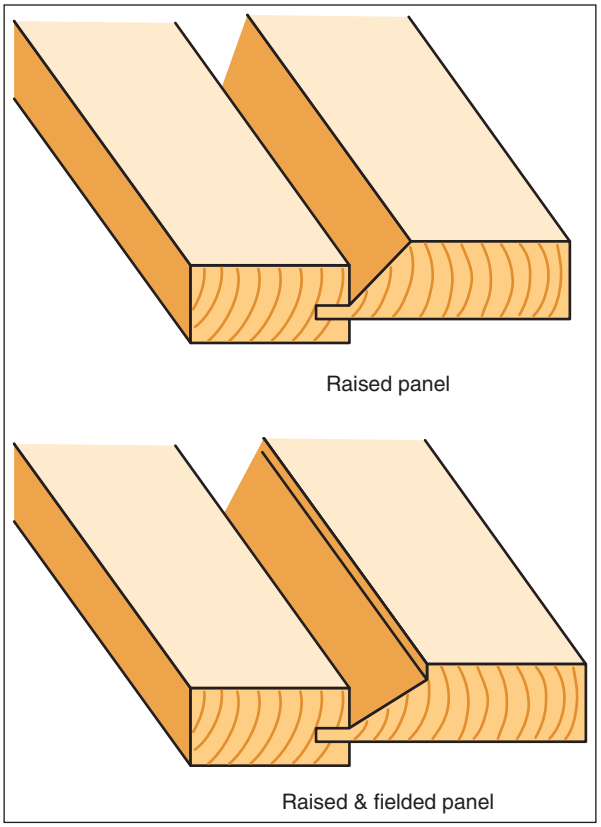
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FIGURE 21-6 Raised-panel doors.



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FIGURE 21-7 Various profiles are possible.



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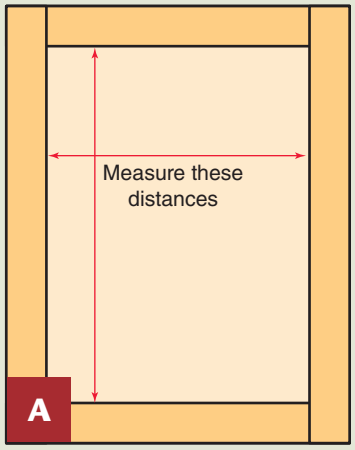
FIGURE 21-8 The panel may be simply raised, or it may be raised and fielded.

PROCEDURE 21-1

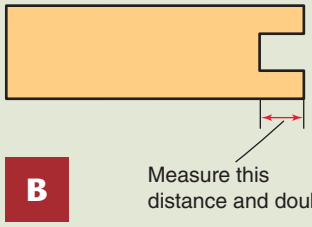
Making a Raised Panel on the Router Table

STEPS

1. Determine the size of the panel by first measuring the inside distance between the two stiles and the two rails (see **Figure A**).
2. Measure the depth of the groove in the stiles and rails, double that measurement, and add it to the length and width determined in Step 1 (see **Figure B**).
3. Subtract 1/16″ from the overall length and 1/4″ from the width. The panel will not change in length, but it will expand and contract across its width, which is why we subtract more from this dimension. Taking 1/16″ off the length simply makes it easier to fit.
4. Cut your panel to the dimensions determined.
5. Install a raised-panel cutter in the router table. Raise it just above the table. We will make a series of cuts, raising the bit a little each time. Align the fence with the router bit bearing.
6. Keeping the panel firmly against the fence, rout the end of the panel first, as shown in **Figure C**. We rout the end grain first so that any chip-out will be cleaned up when we make the pass with the grain.



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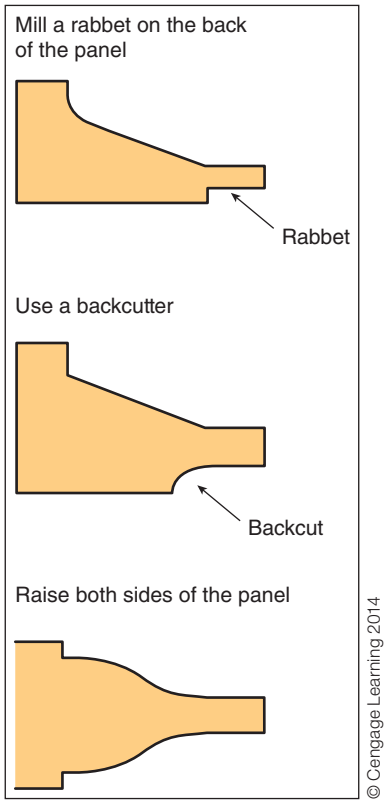


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7. Now rout a long side, the other end, and complete the first router pass with a long-grain pass.
8. Raise the bit 1/8″ and repeat, again always following an end-grain pass with a long-grain pass.
9. Continue until you have the profile you desire (see **Figure D**).

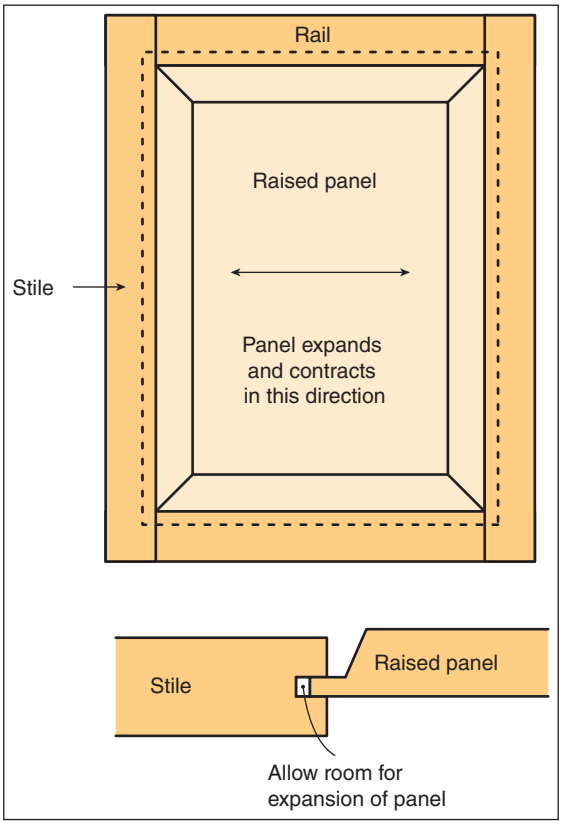
use 5/4 stiles and rails to avoid this problem, and others rabbet the back of the panel so that it will fit into the frame, or use a special cutter to make a backcut. Another option is to raise both the front and back of the panel (see **Figure 21-9**).

There is one essential requirement pertaining to raised-panel doors that is not a concern with flat-panel doors using sheet goods for the panel. That is that the panel must have room in the grooves to allow for seasonal movement of the wood. Solid wood, unlike sheet goods, expands and contracts, primarily across its width, so the width of the panel must be less than the distance from the bottom of the groove in one stile to the bottom of the groove in the other stile to allow for this movement. Using flexible synthetic rubber space balls allows for this movement and keeps the panel tight in the frame without rattling (see **Figure 21-10** and **Figure 21-11**).



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FIGURE 21-9 Fitting the raised panel to the frame.



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FIGURE 21-10 Room must be allowed in raised-panel doors for seasonal wood movement.



Image courtesy of rockler.com

FIGURE 21-11 Space balls keep the panel in place and allow for wood movement.

Under no circumstances should a solid wood panel ever be glued into its frame. This would make it impossible for the door panel to expand or contract without damaging the door or the panel. It will move, and if it is glued in place, the result will likely be a cracked panel.

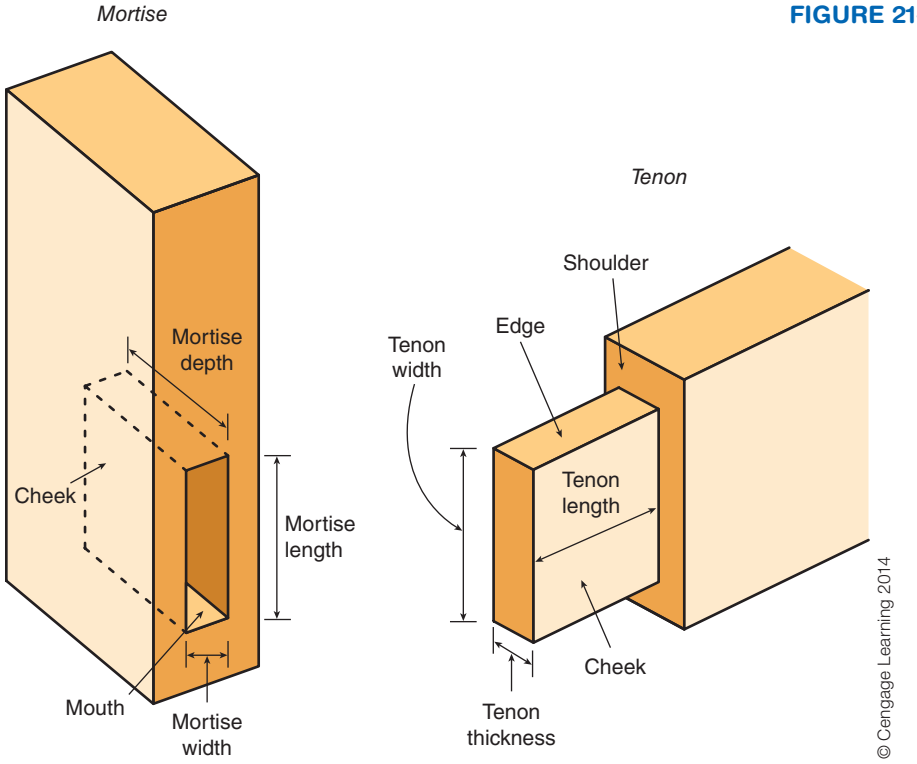
DOOR CONSTRUCTION

Here we will consider frame-and-panel door construction. The question is how the stiles and rails may be joined together to form the frame that holds the panel. These will be frame joints, which were covered in Chapter 16. Several options are available, including mortise-and-tenon joinery, cope-and-stick joinery, groove-and-stub tenons, lap joints, dowels, biscuits, and pocket screws. Each has advantages and disadvantages.

The strongest way to connect the door stiles and rails is with mortise-and-tenon joints. It is also the most time-consuming method. There are many types of mortise-and-tenon joints, as we discussed in detail in Chapter 16, where frame joints were first covered. For our purposes here, we will look at the basic components of a blind mortise and tenon. Essentially, the tenon is a projecting tab formed on the rail, which fits into a corresponding cavity milled into the stile (see **Figure 21-12**).

A second method for joining door stiles and rails is the cope-and-stick joint. This joint is milled using a shaper or the router in a table with cutters or bits specific for this task. The stiles receive a groove and profile, as do the rails, using one cutter. Then, using a corresponding cutter, the rails are machined to fit into

FIGURE 21-12 Mortise and tenon.



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the groove made on the stile. The effect is a coped corner, where the inside profiles come together. **Figure 21-13** shows two views of a cope-and-stick joint.

Assuming the cabinetmaker has a shaper or router table and the appropriate cutters or bits, this is a fast and attractive way of creating frames. The machine setup can be somewhat time consuming initially, but once set up, the process goes quickly. Since the mating surfaces of the stile and rail are not as extensive as with the mortise-and-tenon joint, this joint is not as strong.

The groove-and-stub tenon method of joining stiles and rails is closely related to the cope-and-stick joint, but it can be machined using just the table saw or a table-mounted router and simple straight bits. A groove is milled in both the stiles and rails, and then the ends of the rails are reduced in thickness to fit snugly into the stile's groove (see **Figure 21-14**).

Lap joints are another way of connecting the stiles and rails. In this case, half the material thickness is removed from the back of the stile and the front of the rail (see **Figure 21-15**).

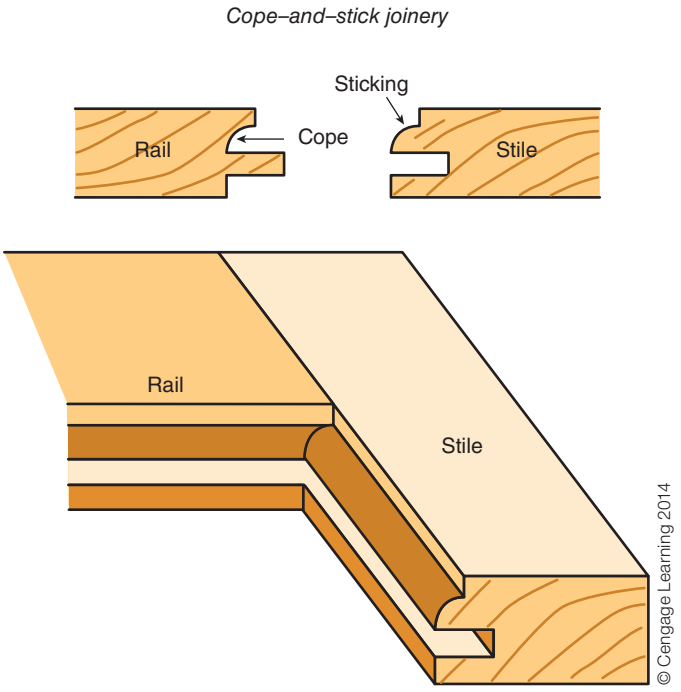


FIGURE 21-13 Cope-and-stick joinery.

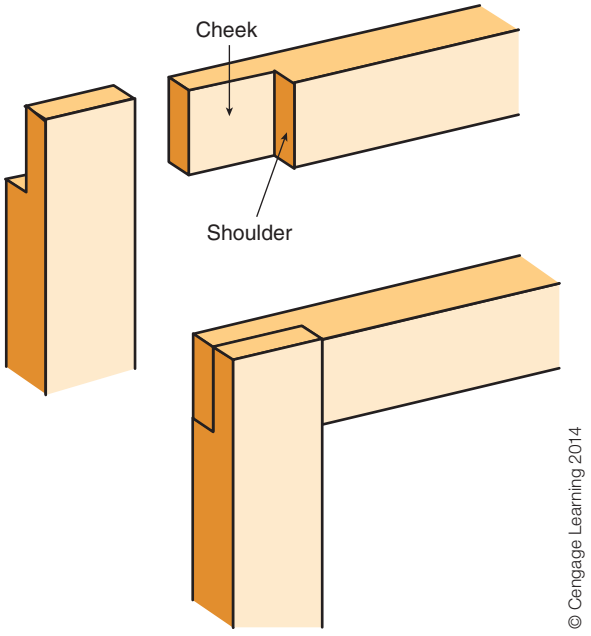


FIGURE 21-15 Lap joint.

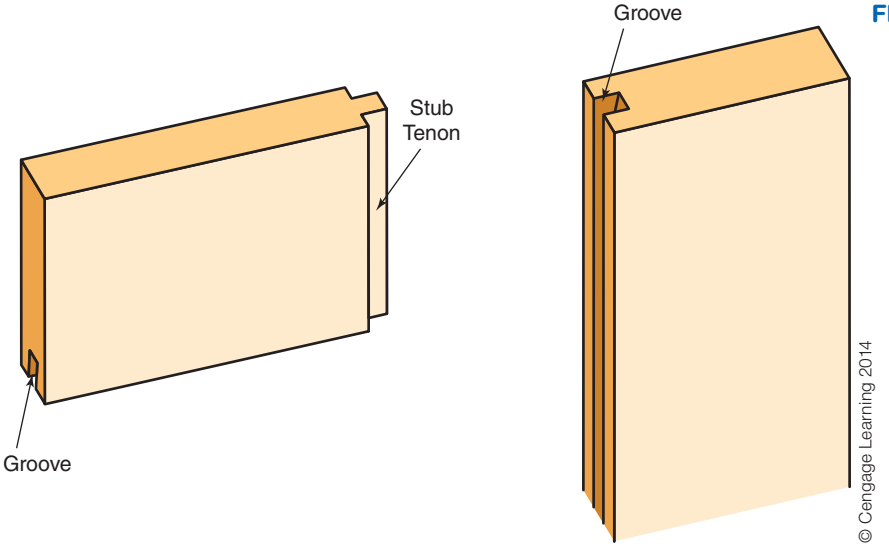


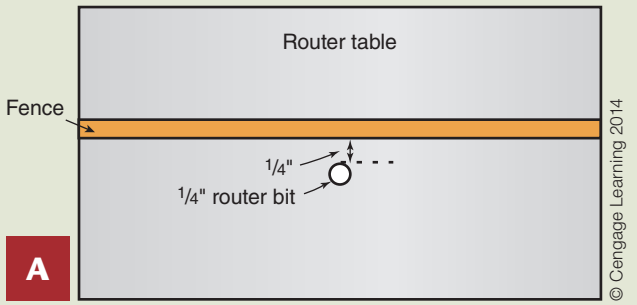
FIGURE 21-14 Groove-and-stub tenon.

PROCEDURE 21-2

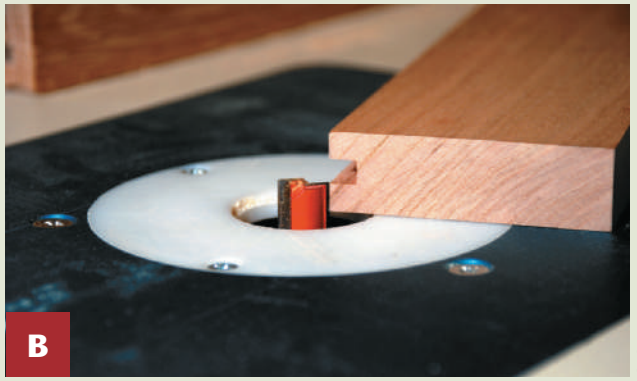
Milling a Groove-and-Stub Tenon Joint on the Router Table

STEPS

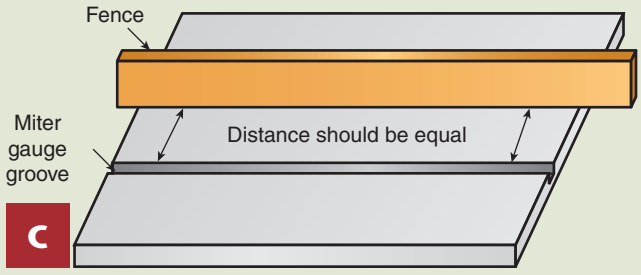
1. Insert a straight bit in the router table and set the fence so that the groove will be milled in the center of the stock. If using 3/4″ stock, the router bit will be 1/4″, and the fence will be set 1/4″ away from the bit (see **Figure A**).
2. Raise the bit 1/4″ above the table, and rout a groove on a test piece. Check to see if it is centered on the piece, and adjust the fence if necessary.
3. Run the grooves. If they need to be deeper than 1/4″, raise the bit gradually between passes until the desired depth of cut is achieved.
4. Replace the router bit with a 1/2″ or larger straight bit.
5. Using one of the grooved pieces as a guide, set the depth of cut so that it will take away material up to the groove (see **Figure B**).
6. Adjust the fence so that the amount of bit exposed is equal to the depth of the groove.
7. Check to ensure that the router table fence is parallel to the miter groove by measuring from the fence to the miter gauge groove at several points (see **Figure C**).
8. Supporting a test piece with a miter gauge, run first one end and then the other over the bit (see **Figure D**).



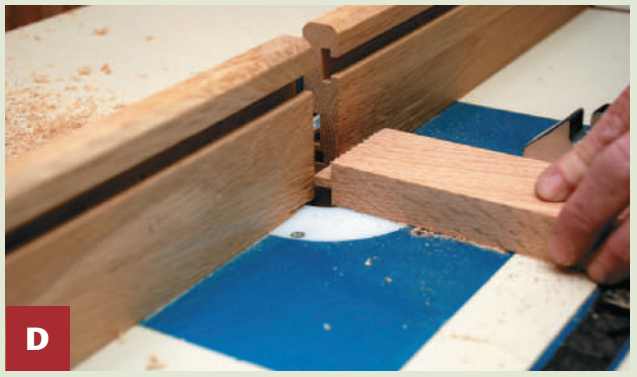
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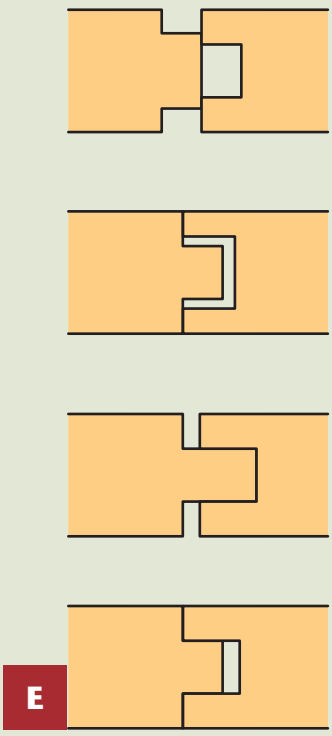
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E

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F

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9. Test the fit of the test piece. If it is too thick, raise the bit slightly, remembering that the amount you raise it is doubled when you make the cut. If the tongue is too thin, lower the bit. If it is too long, move the fence in to cover more of the bit. If it is too short, move the fence back. Continue testing until you have a good fit (see **Figure E**).
10. Mill the tongues. **Figure F** shows a completed groove-and-stub tenon joint.

The lap joint gives a lot of gluing surface, which makes it a strong joint. However, it is important that exactly half the material be removed from each surface, so when assembled, the stiles and rails will be flush with each other in order to avoid a tedious sanding job. This joint may be created on the table saw or radial arm saw using a dado blade, or on the router table. Multiple passes are required to achieve the full width of the cut. Another option is to use a regular table saw blade to make a defining shoulder cut, and then make a second cut with the piece held upright in a tenoning jig (see **Figure 21-16**).

The dowel joint, biscuit joint, and pocket-screw method of joining the stiles and rails are all simple butt joints between the stiles and rails, which are reinforced in different ways. The dowel joint connects the stile and rail components with dowels. Mating holes are drilled into each piece, dowels are inserted with glue, and the pieces are clamped together. A minimum of two dowels, which is typical, is required for each connection (see **Figure 21-17**).

The biscuit joint, like the dowel joint, depends on an independent piece glued into openings in the stile and rail to hold them together. A football-shaped, compressed beech-wood wafer, called a *plate* or a *biscuit,* is fit into mating slots milled into the stile and rail with a biscuit joiner (see **Figure 21-18**).

The biscuit joint has overtaken the dowel joint as a fast and simple way of joining frames together. It requires a more expensive tool to create, but offers a greater gluing surface, which makes it stronger; it is also more forgiving to fit together than the dowel joint. The slots milled by the biscuit jointer are somewhat larger than the actual biscuit, which allows some positioning as the joint is glued up, whereas the dowels must be dead on. As the biscuit absorbs the glue, it swells and locks the joint tightly in place. The negative aspect of using a biscuit joint is that even the smallest size biscuit slot that can be cut may show on the finished frame.

Pocket-screw joinery is another butt joint, this time with the stiles and rails joined together with screws. Angled and recessed holes are cut into the


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FIGURE 21-16 Second cut on lap joint using tenoning jig.

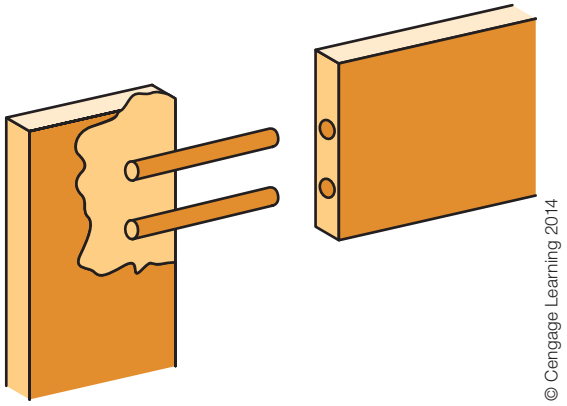
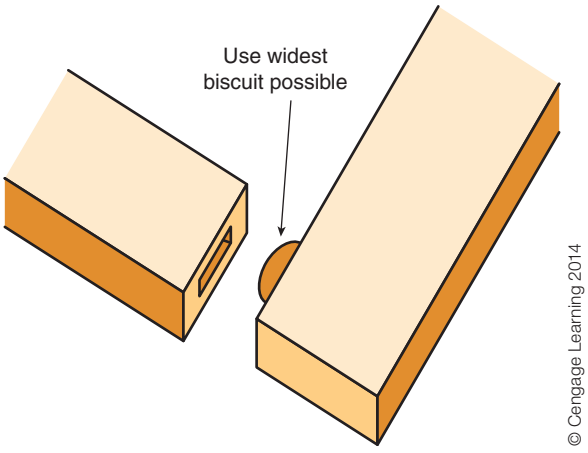

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FIGURE 21-17 Dowel joint.



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FIGURE 21-18 Biscuit joint.

back of the rails, and then the rails are screwed to the stiles (see **Figure 21-19**).

A variety of jigs are available for creating pocket holes, from the simple to the more elaborate. A special bit is used in a drill to create the hole. **Figure 21-20** shows a pocket-hole jig.

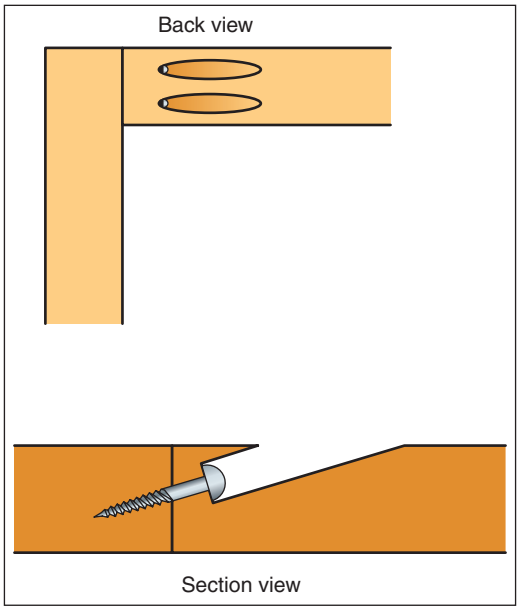


FIGURE 21-19 Pocket-screw joinery.

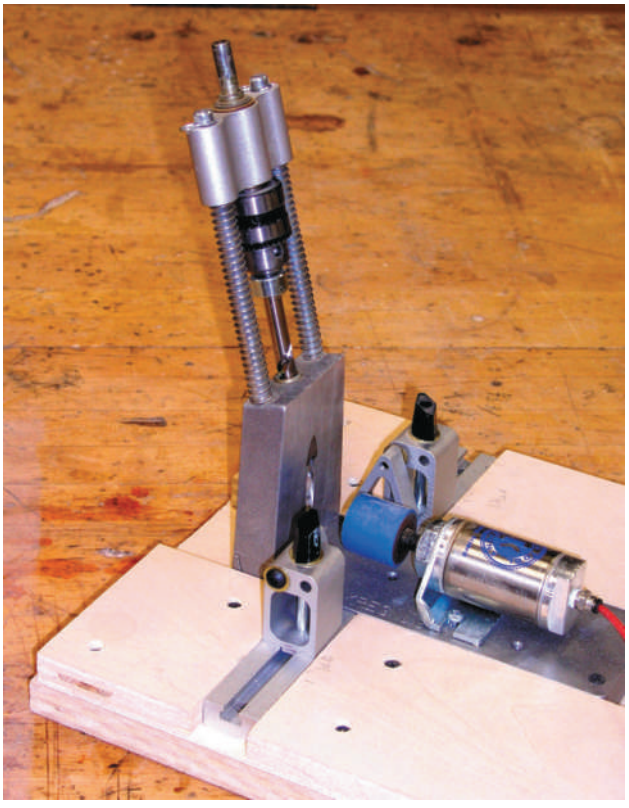


FIGURE 21-20 Pocket-hole jig.

Pocket-screw joinery is fast and effective, but it requires a jig and special screws. It also creates a frame that is unsightly from the back, although specially made plugs can be purchased to glue into the hole created for the recessed screw.

CAUTION

Clean as you go. Less clutter means more room and less chance of hazards accumulating. Before you walk away from a saw, pick up your cut-offs and dispose of them. This will also mean less work for you at the end of the workday.

Placement of Handles and Knobs

A flat door should have its handle or knob set 2 inches in from the edge of the door and 4 inches from the corner. The handle or knob of a door with a frame should be centered on the stile and set 3 to 4 inches from the corner (see **Figure 21-21**). Measure from the bottom corner if it is an upper door, but from the top corner if it is a lower door.

Door Mounts

Doors are placed in three ways relative to the cabinet: *inlay, overlay,* and *flush.* Each method creates a different look. The calculations for sizing the door are different for each, and each type uses a different kind of hinge.

Inlay doors sit partly into the face frame or cabinet, if it is without a face frame. Inlay doors typically have a 3/8″-wide by 3/8″-deep rabbeted edge all the

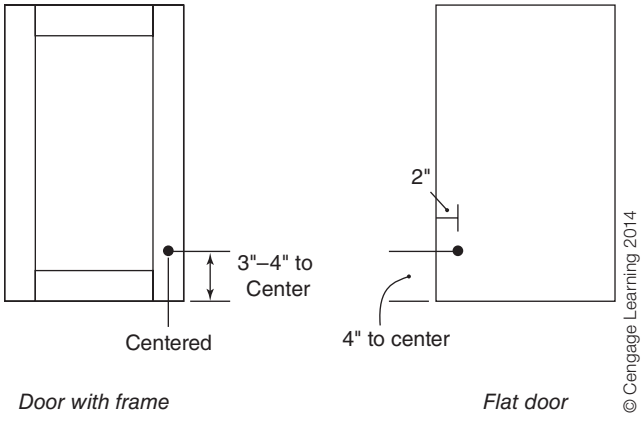


FIGURE 21-21 Placement of handles or knobs.

way around the back (see **Figure 21-22**). An inlay door is built 1/2″ wider and taller than the opening it will fit into. That 1/2″ allows space for the hinge and for alignment. Overlay doors sit totally in front of the face frame or cabinet (see **Figure 21-23**).

Overlay doors are built to be 3/4″ wider and taller than the door opening, yielding a 3/8″ overlap all the way around. The edge of the door may be square or shaped, and a 30° back bevel may be milled on the back of the door so that it can be opened without need for a handle. Flush doors fit inside the door opening and are flush with the face frame or cabinet (see **Figure 21-24**).

Flush doors are made 1/4″ smaller in width and height than their opening. This creates a 1/8″ gap all the way around. Flush doors are the most difficult of the three types to fit. The biggest problem is producing a nice, even gap all the way around. Any deviation is very noticeable.

Cabinet doors should not be wider than 24″, so any cabinet opening over 24″ should be fit with two doors. There are four options for double doors. One is to add a **mullion** in the center of the frame between the two rails. A mullion is a vertical member, like a stile, which fits between the top rail and the bottom rail. A drawback to using a mullion is that it makes the opening smaller, which might be a problem, depending on the size of the opening and what is meant to be stored in the cabinet. A second option is to build two doors and add an **astragal**. An astragal is a strip of wood attached to either the front or the back of one door to eliminate the gap between the two. The problem with this option is that one door must always be opened before the other. A third option is to build two doors and mill a rabbet on the front of one and the back of the other so that one overlaps the other. This has the same drawback as the astragal option. The fourth choice is to have the doors meet in the center with a very thin space between them. A 10° bevel is milled on the back of each door so that the gap can be made as narrow as possible. **Figure 21-25** illustrates these options.

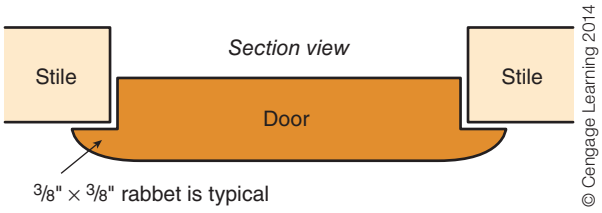


FIGURE 21-22 Inlay door.

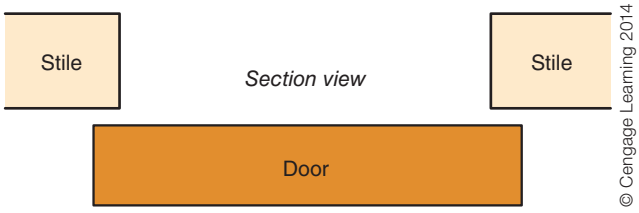


FIGURE 21-23 Overlay door.

WOODWORKING TIP:

Whenever a particular operation requires a machine setup, it is a very good idea to run test pieces once you have done the initial setup, so that any necessary adjustments can be made before running your actual piece. This simple technique can save a lot of aggravation.

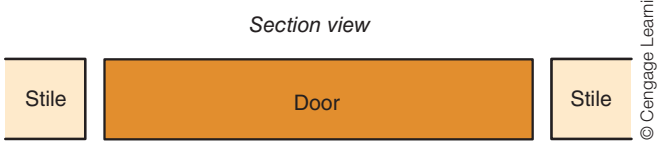


FIGURE 21-24 Flush door.

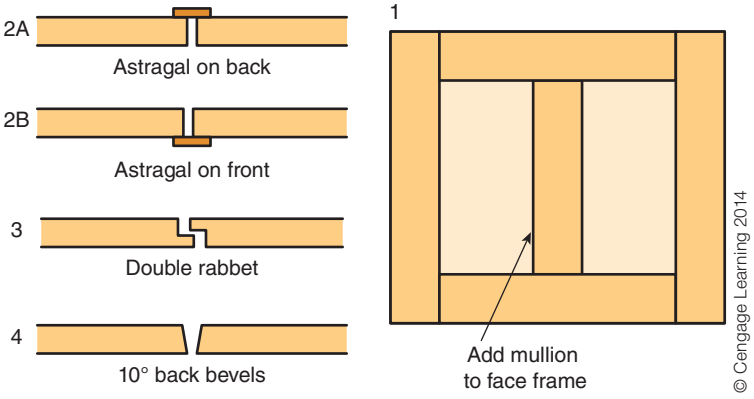


FIGURE 21-25 Options for door openings over 24″.

DRAWERS

Like doors, drawers may be inlay, overlay, or flush. Inlay drawers sit partially into the frame, overlay drawers completely overlay the frame, and flush drawers are even with the frame. The type of drawer mount should match the door mount.

Drawer Construction

A drawer is essentially a box. A face may be attached to the box, or the front of the box may serve as the drawer front (see **Figure 21-26**). The face attached to the box uses extra material, but it makes alignment of the drawer front easy. The drawer box is installed in the opening, and the face is aligned and attached to the box.

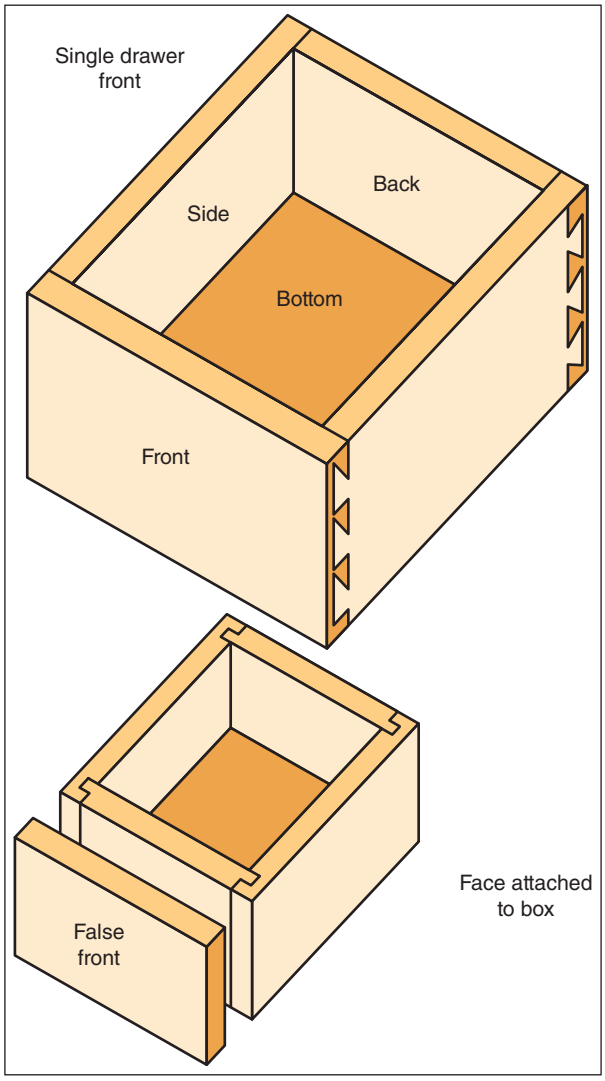


FIGURE 21-26 Single drawer front and face attached to box.

There are many ways to build a drawer. As mentioned, it is basically a box, so the joints that are used are case joints, which were covered in Chapter 15. The goal is to build a drawer that will withstand abuse without failing. Most joinery is strong in one direction and weak in the other, so it is important to be aware of this and have the strength of the joint oriented properly.

In building a drawer, the front-to-sides and sides-to-back connections may or may not be the same. It is fairly typical for the back of the drawer to be set into dados machined into the drawer sides a bit back from the end of the side. This is a strong connection, a simple joint to create, and since most drawers are not pulled all of the way out, this somewhat unattractive joint is rarely seen (see **Figure 21-27**).

The front-to-side connection is visible, and often a more elaborate joint is seen here. Options for front-to-side connections, which may also be used in the back, are the simple butt joint, rabbet joint, a dado and rabbet, drawer lock, box, and dovetails. A butt joint has the sides attached to the drawer front. It must be reinforced in some way, either with nails, screws, biscuits, or dowels.

A rabbet joint also needs reinforcement. A rabbet can be milled on the front the width of the side thickness, and the front will fit in between (see **Figure 21-28**), or, alternatively, a rabbet could be milled on the sides the width of the front thickness. A third choice is a double rabbet joint, where mating rabbets are milled both on the sides and the front of the drawer box.

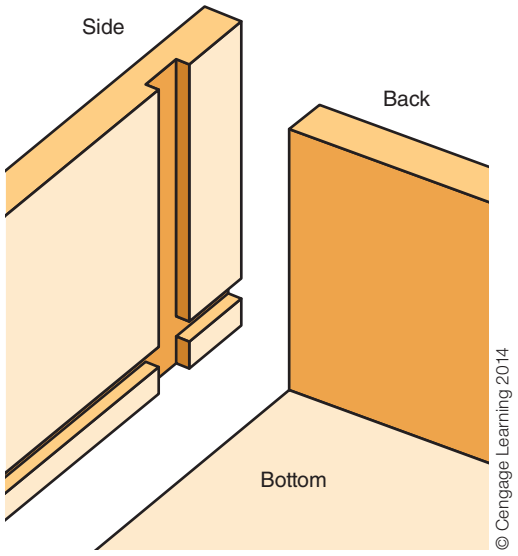
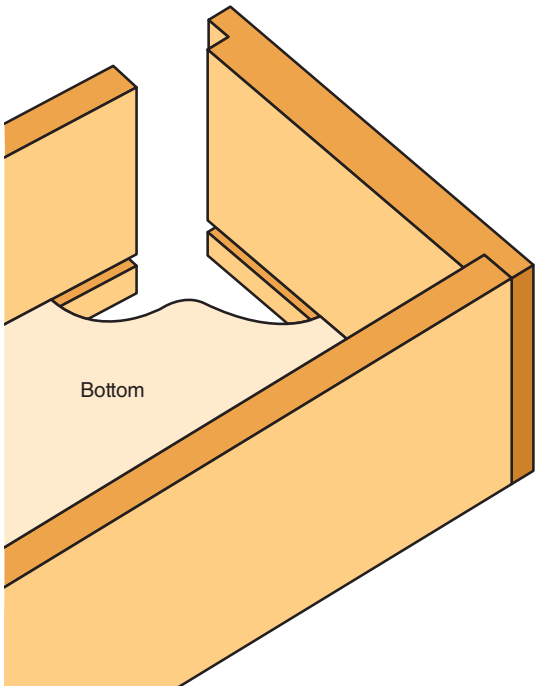


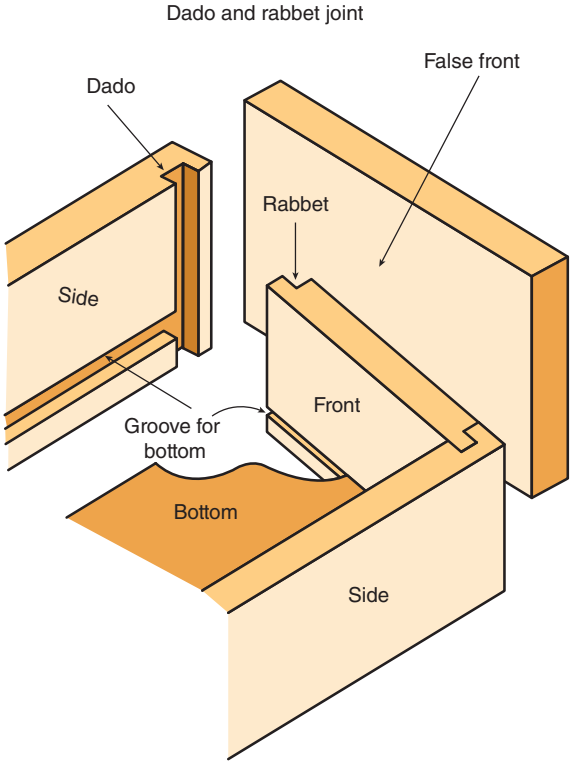
FIGURE 21-27 Drawer back in side dados.

A rabbet-and-dado joint does not require reinforcement, assuming a good fit is achieved. In this case, a rabbet is made on the drawer front, and a dado is made in the drawer sides (see **Figure 21-29**).



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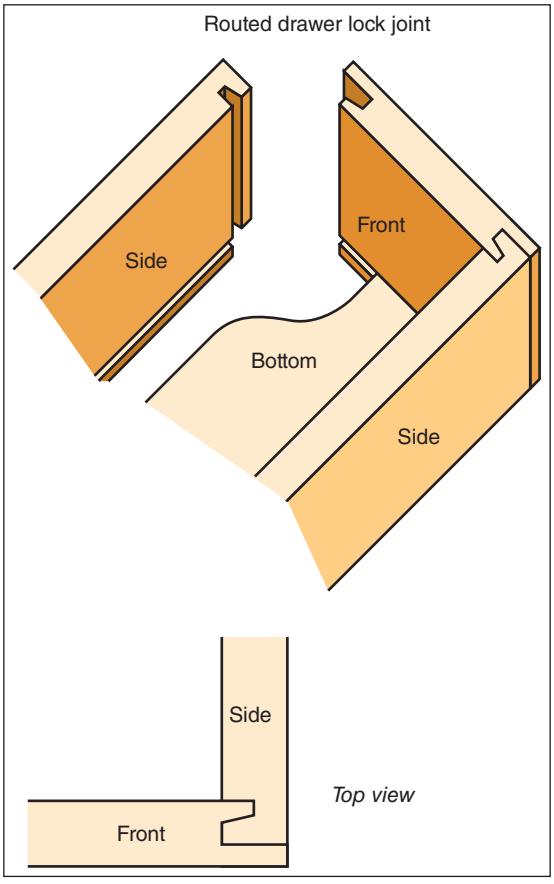
FIGURE 21-28 The drawer front has been rabbetted to accept the sides.



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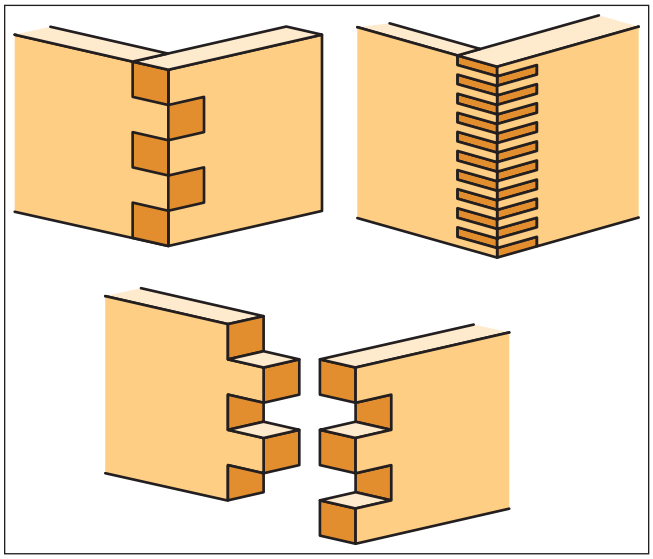
FIGURE 21-29 Rabbet and dado joint.

A drawer lock is similar to a rabbet-and-dado joint, but requires a special drawer-lock bit used with a table-mounted router (see **Figure 21-30**). A box joint is a very strong joint, primarily due to its large gluing surface. It is created using a box-joint jig, either on the table saw or on a router table (see **Figure 21-31**).



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FIGURE 21-30 Drawer lock joint.

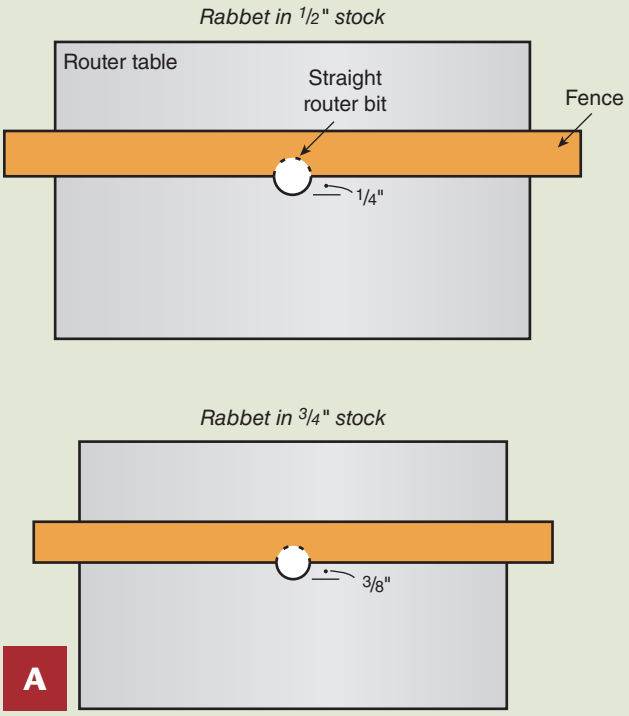


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FIGURE 21-31 Box joint.

PROCEDURE 21-3

Milling a Rabbet-and-Dado Joint on the Router Table



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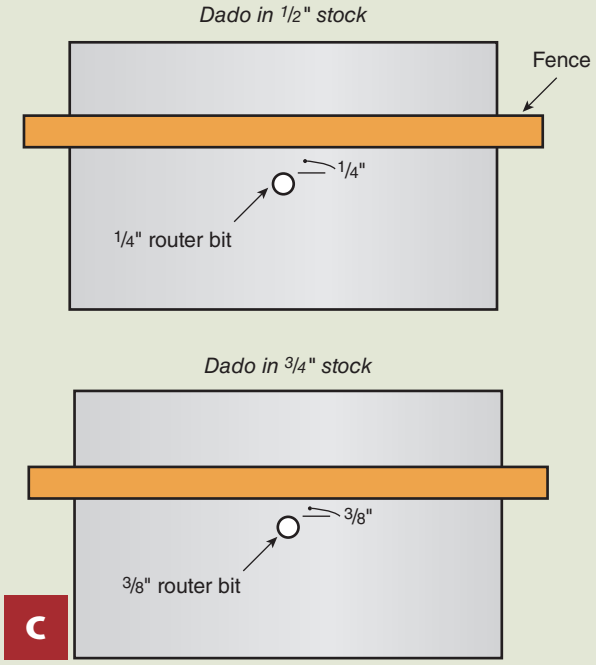


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STEPS

1. Install a straight bit in the router table; the bit diameter should be greater than half the thickness of the stock you are working with.
2. Raise the bit so that its height is half the thickness of the stock you are using.
3. Set the fence so that the amount of bit exposed is half the thickness of the stock. **Figure A** shows examples in 1/2″ and 3/4″ stock.
4. Make sure that the miter gauge groove and the fence are parallel to each other by measuring the distance between them at several points.
5. Using the miter gauge to support a test piece, mill a rabbet. Check the result to see if its length and thickness are half the total stock thickness, and adjust the bit height and fence as necessary. Continue to mill test pieces until the desired result is achieved, and then mill all the rabbets needed (see **Figure B**).

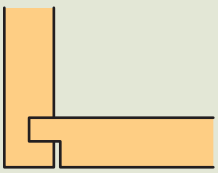
6. Replace the bit with another straight bit whose diameter is equal to half the thickness of the stock being used.
7. Raise the bit so that its height is half the thickness of the stock.
8. Set the fence so the distance between the fence and the bit is half the thickness of the stock. See **Figure C** for examples in 1/2″ and 3/4″ stock.
9. Supporting a test piece with the miter gauge, machine a dado (see **Figure D**).



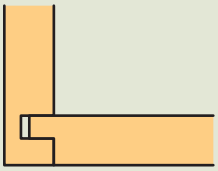
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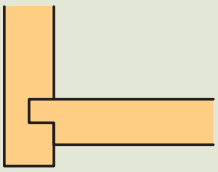
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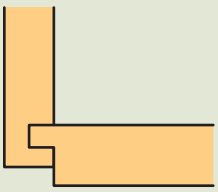
Dado too shallow – raise router bit



Dado too deep – lower router bit



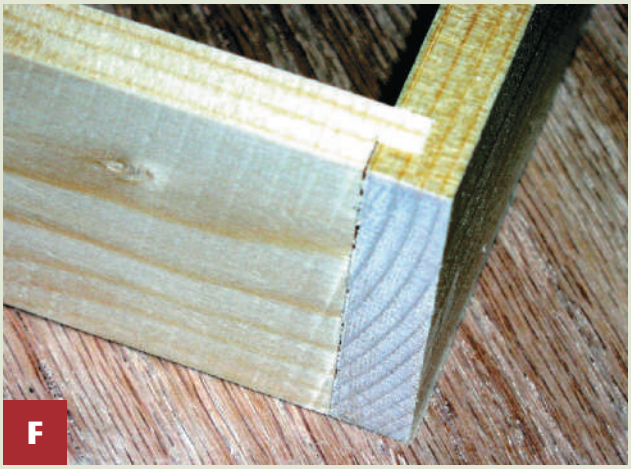
Joint not flush with side projecting – move fence in



Joint not flush with side back – move fence back

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E



F

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10. Check the fit of the test piece with one of the rabbets you made previously. Adjust the bit height and fence position until you get a good flush fit (see **Figure E**).
11. Mill the dados. **Figure F** shows a completed rabbet-and-dado joint.

The dovetail joint is the strongest of all the joints a cabinetmaker can choose from, and the most attractive. Three types of dovetail joint are possible: the *through dovetail, half-blind dovetail,* and *sliding dovetail.* The half-blind dovetail is the one most often seen in drawer construction.

The dovetail joint is an interlocking joint consisting of *pins and tails,* which fit into *sockets* (see **Figure 21-32**). Like the box joint, the dovetail joint offers a lot of gluing surface. In addition, it provides a mechanical lock. That is, it will only pull apart in one direction. Therefore, in the case of a drawer, the tails should always be on the side of the drawer, so it cannot be pulled apart from the front. The dovetails will either be through dovetails or half-blinds (see **Figure 21-33**).

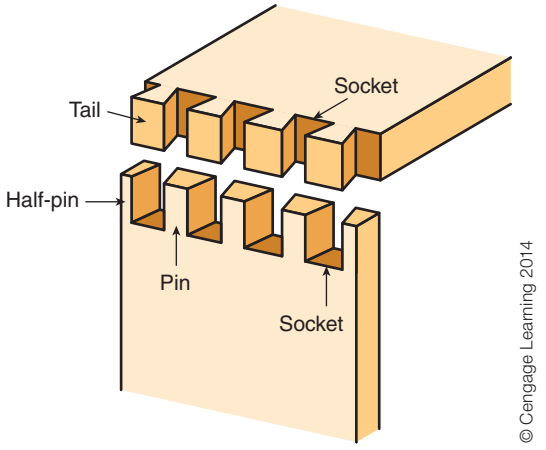


FIGURE 21-32 Pins, tails, and sockets.

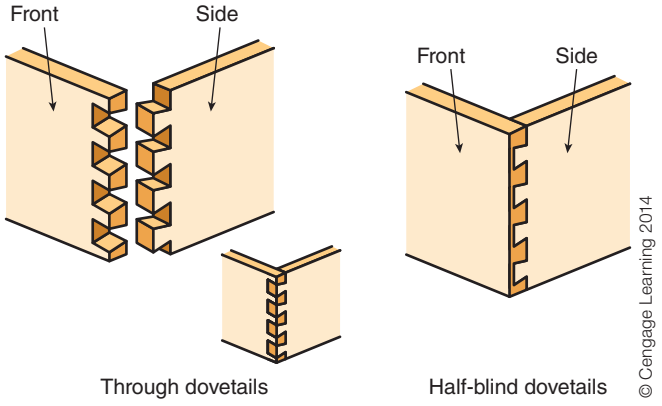


FIGURE 21-33 Through and half-blind dovetails.

A third type of dovetail joint sometimes seen on drawers is the *sliding dovetail,* which may be called a *dado dovetail* (see **Figure 21-34**).

The one component of drawer building that has not been addressed is drawer bottoms. Four basic options exist: One is to tack the bottom to the bottom edge of the other parts. This is simple, but unattractive and not strong. The second choice is to set the bottom into rabbets milled in the sides, front, and back (see **Figure 21-35**). This hides the bottom but is only suitable for small drawers that will not hold much weight.

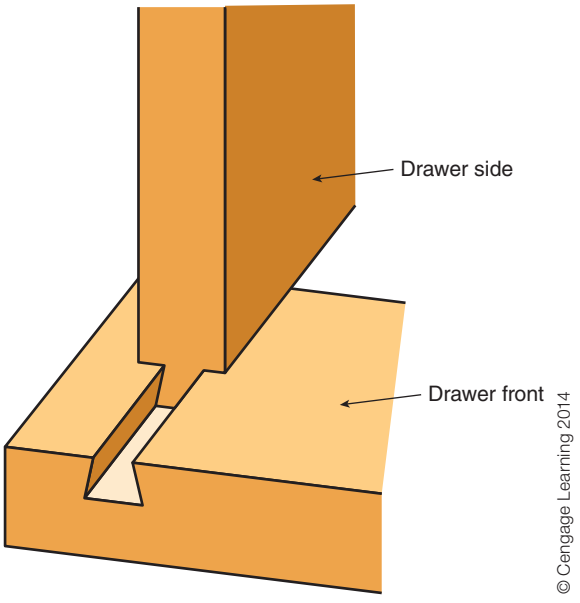


FIGURE 21-34 Sliding dovetail.

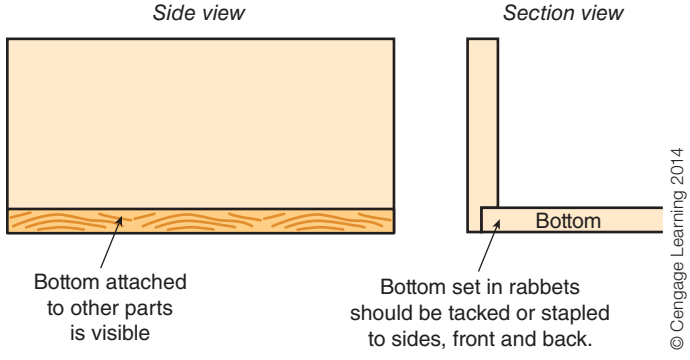
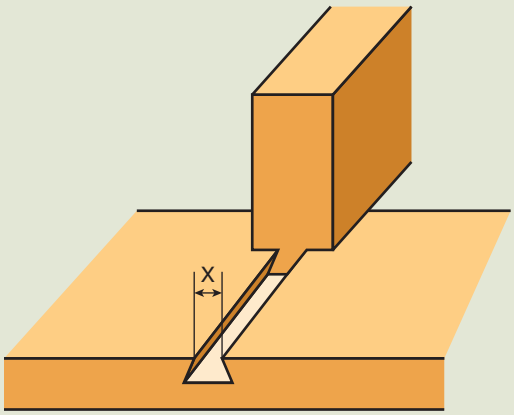


FIGURE 21-35 Drawer bottom attached to bottom edge of other pieces and drawer bottom fitted into rabbets.

PROCEDURE 21-4

Machining a Sliding Dovetail



A Mill dado the size of X or slightly smaller

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B

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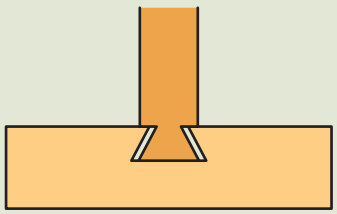
C

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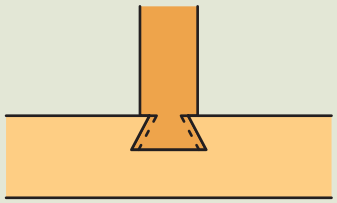
STEPS

1. Mill dados in the stock that will receive the dovetail, either on the table saw or on the router table. The depth of the dado should be half the stock thickness, and its width should be 1/8″ to 1/4″ less than the thickness of the piece that will get the dovetail, as **Figure A** illustrates.
2. Insert a dovetail bit into a table-mounted router, and set its height to be equal to the depth of the dado just machined.
3. Set the router table fence so that the cut will be made in the center of the dado.
4. Make sure that the fence is parallel to the miter gauge slot.
5. Supporting a dadoed piece with the miter gauge, run it over the dovetail bit, creating a dovetailed dado, as shown in **Figure B**.
6. Remove the miter gauge from the table and loosen the fence, but keep the bit at the same height.
7. Adjust the fence so that most of the bit is covered, and then run a test piece in the upright position. Flip it around and run the other side. You now have a dovetail, as shown in **Figure C**.

8. Check the test piece in the dado dovetail. If it is too thick and won't go in, move the fence to expose more of the bit. If it is too thin and loose, move the fence in, covering more of the bit (see **Figure D**). Run successive test cuts until you have a good fit.
9. Mill the dovetails. **Figure E** shows a completed sliding dovetail joint.



Dovetail loose – move fence back



Dovetail will not go in or too tight – move fence in

D

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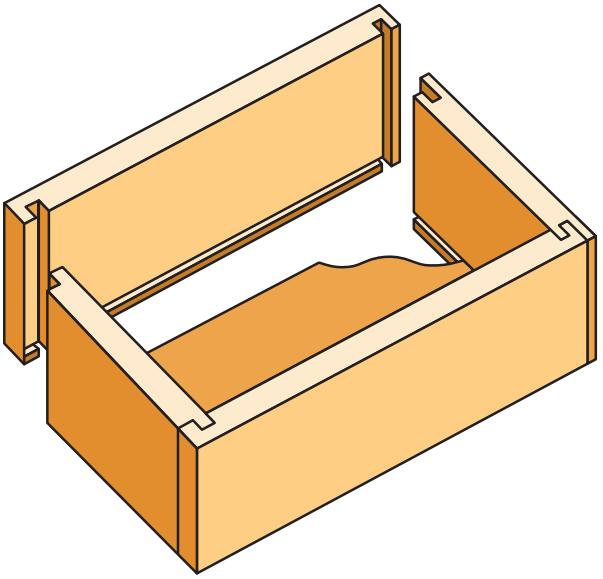


E

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The third option is to fit the bottom into grooves machined into all the other parts. This is strong, and the bottom will not show as the drawer is pulled out (see **Figure 21-36**).

The fourth choice is a combination of options one and three. The bottom fits into grooves machined into the front and sides of the drawer and is then tacked to the bottom of the back. This is called *open-back construction* (see **Figure 21-37**).



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FIGURE 21-36 Drawer bottom fitted into grooves on sides, front and back of box.

Open-back drawer construction is sufficiently strong and makes assembly of the drawer easier, because the bottom can be slid into place after the other drawer parts are assembled. It requires that the back be narrower in width than the sides and front.

The material used for drawer bottoms is generally 1/4″ plywood or a panel product. If the drawer is very wide, as in a chest of drawers, thicker material should be used, or a centered wooden strip, called a **muntin**, should be installed to prevent sagging (see **Figure 21-38**).



FACTS ABOUT WOOD

Cherry, *Prunus serotina,* is a member of the rose family. It is smooth-textured wood that is moderately strong and durable. It works well, but it burns fairly easily, so it is important to use sharp blades and bits and a steady feed rate. Cherry has a pronounced difference in color between its heartwood and sapwood. When first cut, the heartwood is a pinkish color, which turns a deep reddish color over time. The sapwood is yellowish to white. Cherry is used extensively for high-quality furniture, cabinetry, turning, carving, and architectural woodwork. ■

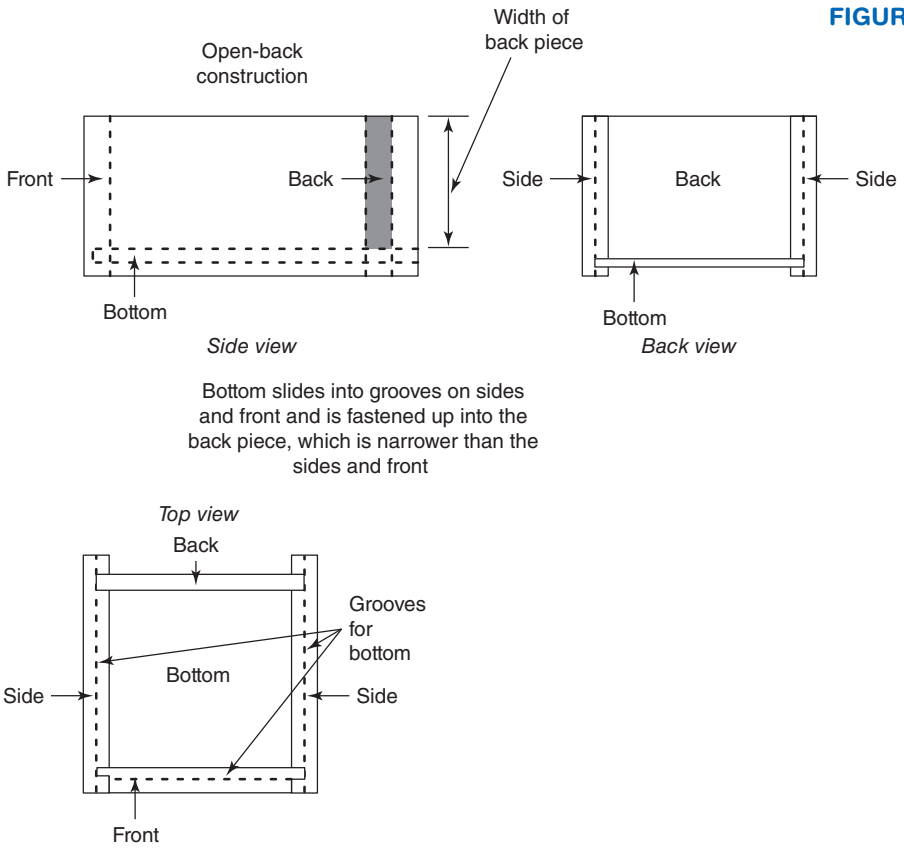
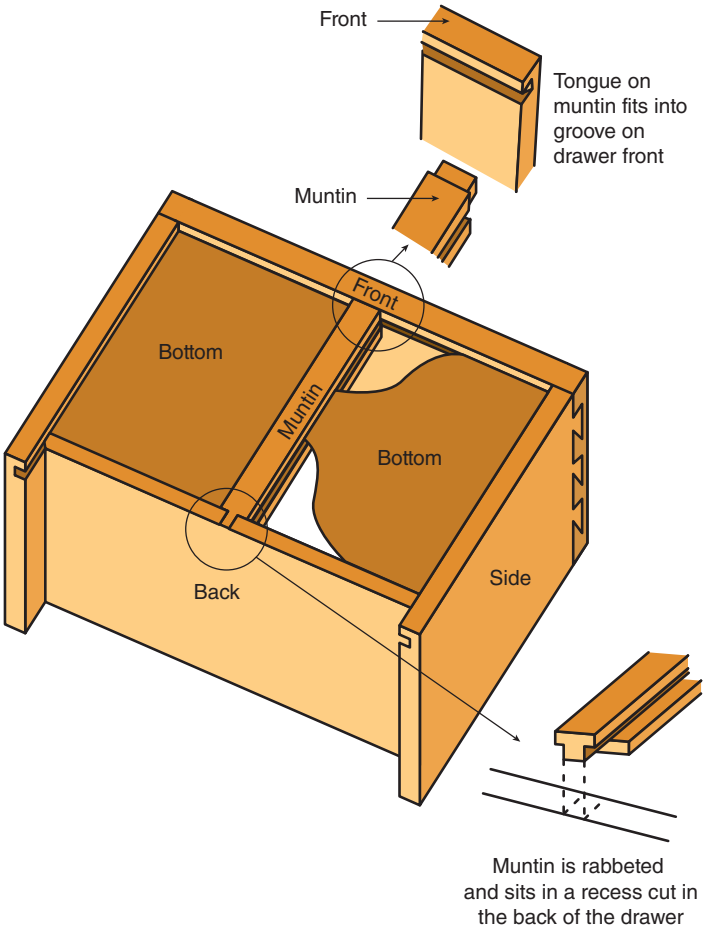


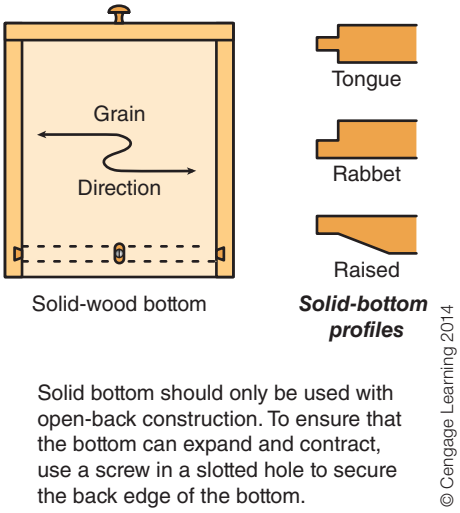
FIGURE 21-37 Open-back construction.

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FIGURE 21-38 A center muntin is necessary in wide drawers.



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FIGURE 21-39 Solid-wood bottom construction.

If solid wood is used for a drawer bottom, it should be thicker than 1/4″ unless the drawer is small; otherwise it is prone to cracking. Typically, the thickness of the bottom is reduced to 1/4″ at the grooves. When using a solid wood panel, open-back drawer construction should be used, and the grain direction of the bottom panel must run parallel to the back of the drawer. A screw in a slotted hole attaches the bottom to the back to allow the panel to expand and contract across its width (see **Figure 21-39**).



Summary

Doors and drawers may well be the focal point of a cabinet, not only serving an important function but serving the piece aesthetically as well. The style of door chosen and the method of mounting the doors largely determines the visual appeal of the cabinet. We could all take the same cabinet and build different types of doors and drawers to create very different-looking final projects. Doors may have frames or not. If framed, their panels may be flat or raised. Their mount relative to the cabinet can be inlay, overlay, or flush.

Drawers also may be inlay, overlay, or flush. Many different methods are available for building drawers, just as there are for constructing door frames. The choice the cabinetmaker makes will depend on tools she has to use, the time available for the job, the strength required for the joint, and the desired look of the finished product.



Key Terms

astragal
flat-panel door
mullion
muntin
raised-panel door

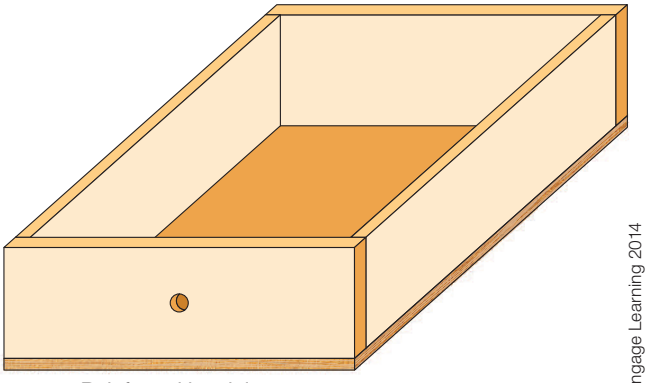


Check Your Knowledge

1. What are the two basic styles of door, and of these two styles, which is more complicated and why?
2. What is the difference between a flat-panel door and a raised-panel door?
3. What are four different joints that might be utilized to build door frames? Be prepared to discuss advantages and disadvantages of each.
4. What are the three ways a door can be mounted relative to the cabinet? Which of these demands the highest level of craftsmanship?
5. List three different methods for building drawers.
6. Are the techniques used to connect drawer sides to fronts always the same as those used to join the sides and back of the drawer? Why or why not?
7. True or false: Most joinery is strong in one direction and weak in the other.
8. What is the strongest type of drawer joint and what makes it so strong?
9. List the four methods for attaching drawer bottoms. Which would you choose and why?
10. What special consideration should the builder be aware of when solid wood is used for a drawer bottom?



What's Wrong with This Picture?



Reinforced butt joints
used in all corners

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BUILD IT!

Flat-Panel Overlay Door

Figure A shows a completed flat panel overlay door.

NOTE: The wall cabinet that this door is mounted to was built in Chapter 20.

TOOLS REQUIRED

- Measuring tool
- Square
- Table saw or circular saw
- Miter saw
- Router and decorative edge bit (optional)

MATERIALS REQUIRED

- 3/4″ × 2″ solid stock for frame
- 1/4″ sheet goods for panel
- Knob
- Pair of overlay hinges

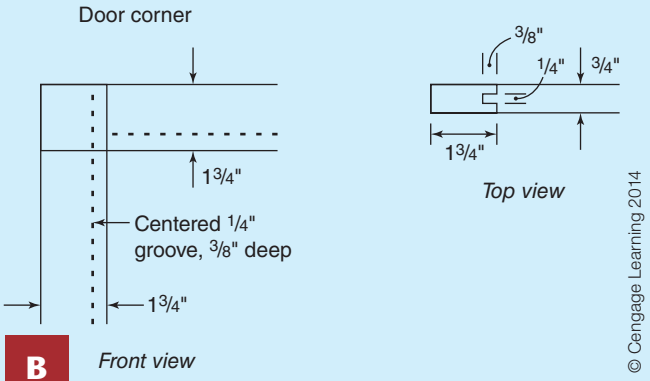
STEPS

1. Measure the opening in the wall cabinet you built in Chapter 20, and determine the size of the door. Remember that for an overlay door, you add 3/4″ to the length and width of the opening to get the door size. NOTE: If you also built the base cabinet, build this door at the same time.
2. Using the detail given in **Figure B**, determine the length of the rails.
3. Cut stiles and rails to size and mill a centered groove 1/4″ wide by 3/8″ deep on the inside of each stile and rail.



A

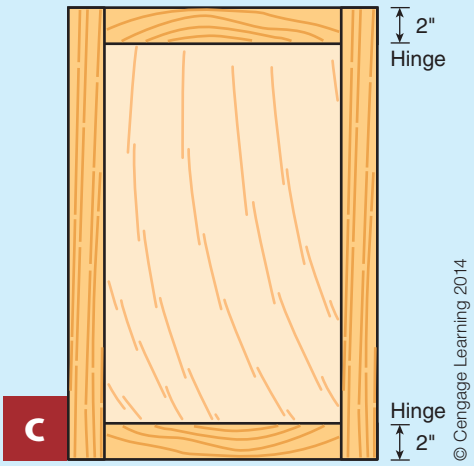
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B

Front view

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4. Machine a tongue on both ends of each rail to fit into the groove on the stiles.
5. Determine the size of the panel and cut it to size.
6. Assemble and glue up the door, checking to make sure it is square.
7. Using a router and a decorative bit of your choice, shape the outside edge of the door if desired.
8. Install the knob in the appropriate location.
9. Lay out the locations for the hinges on the door, as shown in **Figure C**.
10. Place hinges on the back of the door, and use a self-centering bit to drill the holes, as shown in **Figure D**, and then screw the hinges to the door.
11. Place the door on the cabinet so there is an equal overhang at the top and bottom. Using a self-centering bit, drill the holes to attach the hinges to the face frame, as shown in **Figure E**. Attach hinges and check the door fit.
12. Remove the hinges and knob, and then sand and finish the door to match the cabinet.
13. Reinstall the knob and remount the door to the cabinet.

BUILD IT!

PROJECT CHALLENGE

Overlay Drawer

Figure A shows a completed overlay drawer.

NOTE: The base cabinet that this drawer is mounted in was built in Chapter 20.

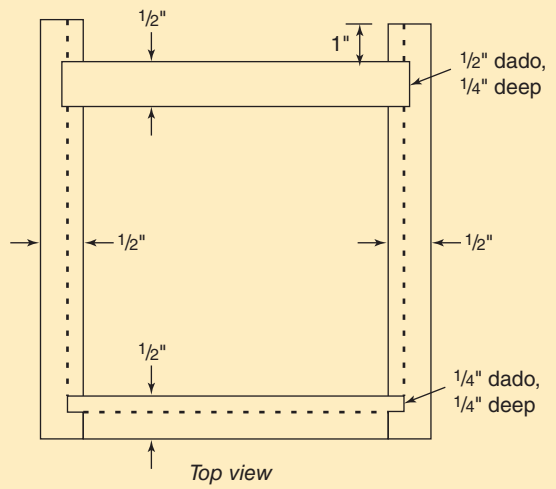
STEPS

1. Measure the opening in the base cabinet you built earlier, and subtract one inch in width to allow 1/2″ on each side for the drawer slides. Also subtract one inch from the height of the opening for the depth of the drawer. The drawer sides are 23″ long.
2. Referring to the diagram shown in **Figure B** and the measurements gathered in Step 1, cut the front, sides, and back of the drawer to size.
3. Using the diagram provided in **Figure B**, machine the joints on the sides and front and the grooves in the front and sides.
4. Cut the bottom to fit.
5. Dry assemble the drawer to check the fit of the component parts.

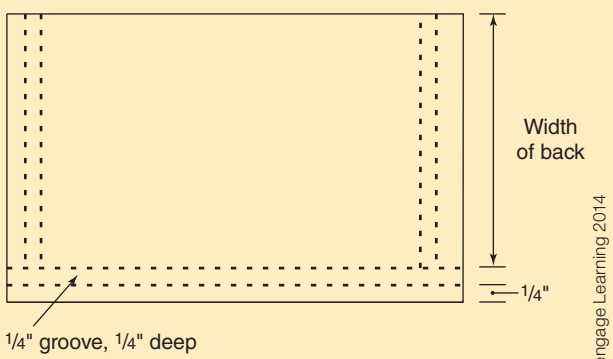


A

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Top view



Side view

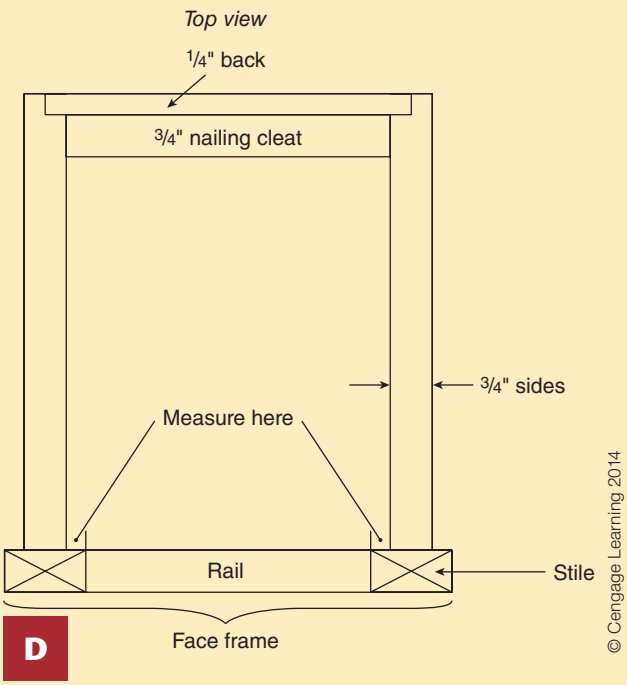
B

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C

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D

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6. Glue up and clamp, checking for square.
7. Slide the drawer bottom in the grooves in the front and sides, and staple into the back, as shown in **Figure C**.
8. Cut the material for the drawer face to size. It will be 3/4″ wider and longer than the opening in the cabinet.
9. If a decorative edge was milled on the edge of the door, create the same profile on the drawer face.
10. Find the center of the drawer face by drawing diagonal lines from corners. Drill a hole at this spot for attaching the knob.
11. Looking at the base cabinet, measure the distance from the inside of each side to the edge of the face frame, as shown in **Figure D**.

12. Plane solid stock to the thickness of the dimension just determined. The stock should be about 2″ wide.
13. Attach the pieces you just made to the sides of the cabinet. They should be located where the drawer slides will go and be level. Glue and screw them in place, as shown in **Figure E**.
14. Separate the drawer slides and attach them to both sides of the drawer and either side of the cabinet, as shown in **Figures F** and **G**.


E

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F

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G

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H

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I

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15. Check the fit of the drawer as shown in **Figure H**; it should close flush with the face frame of the cabinet.
16. Align and attach the drawer face, screwing it in from the back (see **Figure I**).
17. Drill through the hole you made in the face, through the front of the drawer, and attach the knob.
18. Remove the drawer slides and the knob and finish the drawer to match the cabinet.
19. Replace the slides and knob and install the drawer.



22

Tables and Desks

You'll Learn

After studying the chapter, the student should be able to:

- Identify the parts of a table and understand how they fit together
- Demonstrate knowledge of different types of tables
- Be familiar with the standards associated with various tables
- Recognize different types of desks and be able to discuss how desks differ from tables

INTRODUCTION

A **table** is a piece of furniture which is composed of a horizontal surface supported by a base. It is often used to hold objects or food at a comfortable height when sitting. Many tables are meant for combined use with chairs, so tables and desks are closely related. A desk is a table specifically designed for working and is also typically used in conjunction with a chair. Unlike many tables, only one side of a desk is usually suitable to sit on. In this chapter, we will look at the parts that make up tables and desks and the various forms tables and desks take.

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TABLE ANATOMY

Tables range from the very simple to the complex. The basic parts of a simple table are the *legs*, the *aprons*, and the *top*. **Aprons** are horizontal pieces that run between the legs and support the top (see **Figure 22-1**).

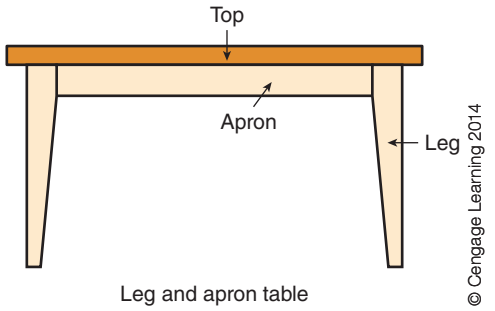


FIGURE 22-1 Table parts.

An infinite array of tables can be produced by varying these three elements. The legs may be square, tapered, or turned. The aprons can have different shapes. The top might be square, rectangular, round, or elliptical. **Figure 22-2** shows a few examples, and the possibilities are only limited by the builder's imagination.

TYPES OF TABLES

If you look around the average home, you will see a variety of different kinds of tables. The first one a person usually thinks of is the kitchen or dining room table, but you will also notice coffee tables, end tables, bedside tables, occasional tables, and perhaps a hall or sofa table. Each of these has certain standards associated with it.

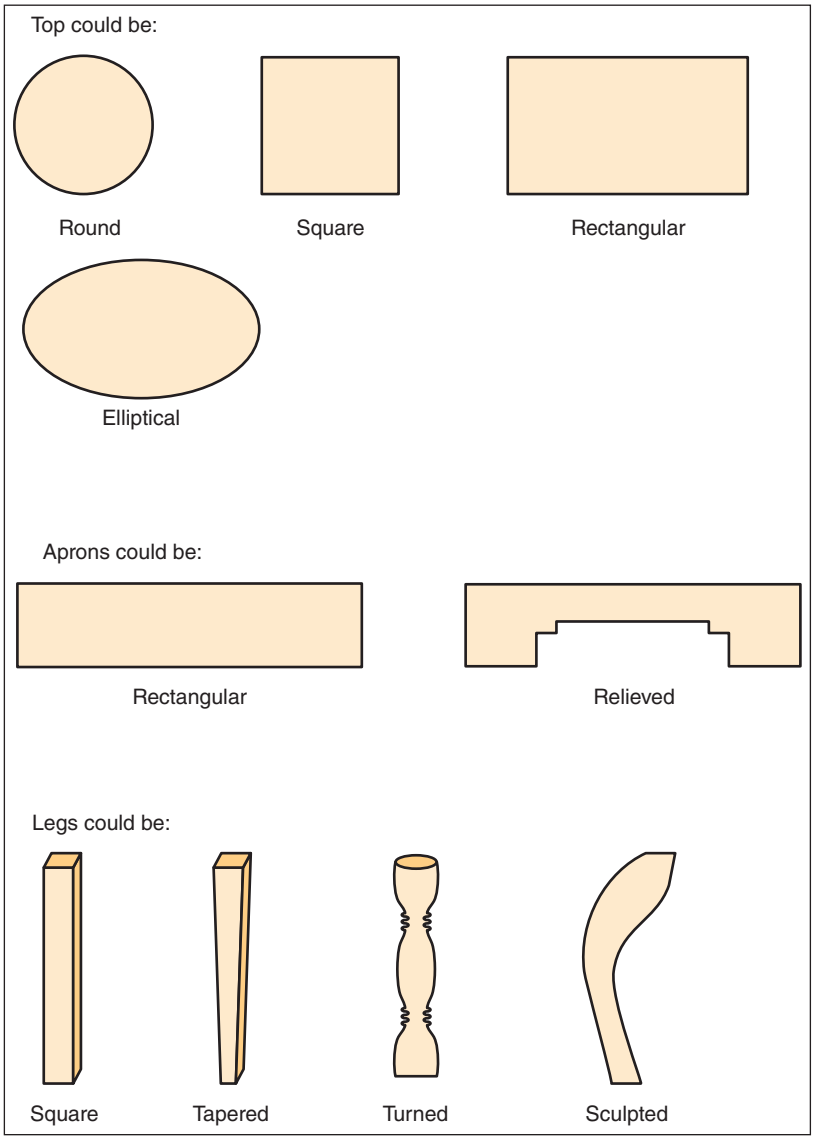


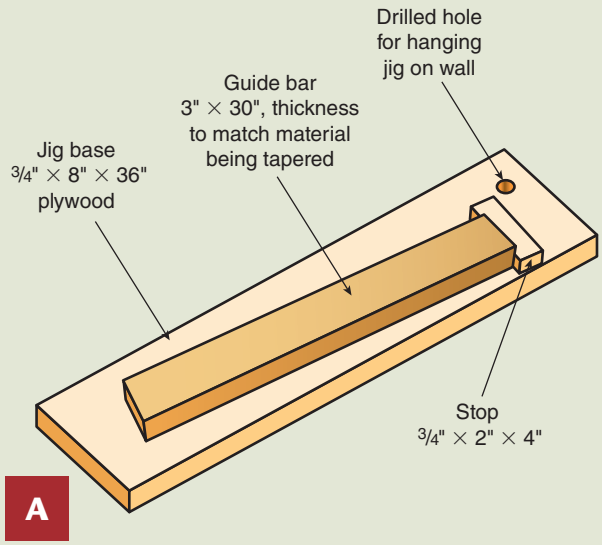
FIGURE 22-2 Various looks can be achieved by varying the basic elements of the top, apron, and legs.

PROCEDURE 22-1

Making and Using a Fixed Tapering Jig for a Two-Sided Taper

STEPS

1. Review the diagram given in **Figure A**.
2. Cut the base, guide bar, and stop to size.
3. Lay out the desired taper on one of the pieces you will be tapering. Refer to **Figure B**.



A

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B

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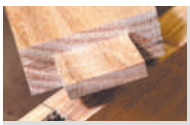


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4. Place the piece just laid out on the base so that the part to be tapered overhangs the side; draw a line along the side that rests on the base and across the end, as shown in **Figure C**.
5. Fasten the guide bar to the base along the long line you just drew, and fasten the stop to the short line.
6. Screw toggle clamps to the guide bar, taking care that when they are in the down position, they will not be in the cut line.
7. Set the fence at 8 inches.
8. Clamp the piece to be tapered in the jig, and raise the blade high enough to clear both the jig and the piece being tapered.
9. Turn on the saw and guide the jig along the fence to make the first cut, as shown in **Figure D**.
10. Unclamp the work piece and turn it 90°. Re-clamp it in the jig, using the cutoff from the first cut as a shim to keep the clamps tight, as shown in **Figure E**.



HISTORY FACT

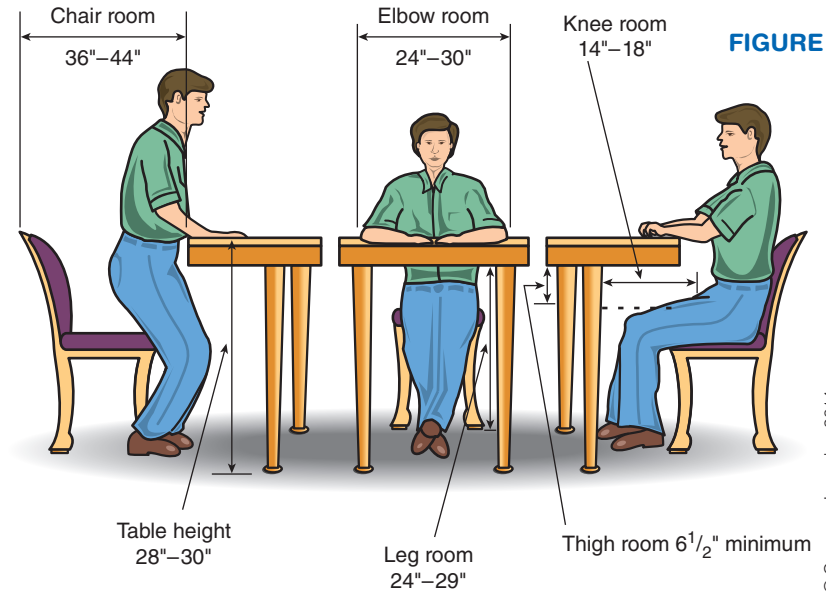
The word *table* is derived from the Latin word *tabula,* which means a board or plank. ■

Dining Tables

It has been said that the dining table that is most remembered is the one that is uncomfortable. To ensure comfort and ease of use, certain standards are followed when building a table. The top of the table should be 28 to 30 inches from the floor. There should be adequate room for a person's thighs beneath the apron and enough leg room for each diner. There should be elbow room for each occupant of the table, as illustrated in **Figure 22-3**. An example of a dining table is shown in **Figure 22-4**.

Other Tables

Coffee tables generally sit in front of a couch and are sometimes called *cocktail tables*. They should be 15 to 18 inches high and are usually 3 to 5 feet long and 22 to 30 inches wide (see **Figure 22-5**).



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FIGURE 22-3 Dining table standards.



Image courtesy of Thomasville Furniture

FIGURE 22-4 Dining table.



Image courtesy of Thomasville Furniture

FIGURE 22-5 Coffee table.

End tables sit to the side of chairs or couches; they are typically 2 feet high, 14 to 16 inches wide, and 20 to 24 inches deep (see **Figure 22-6**).

Side tables are sometimes called *sideboards;* these are oblong tables originally designed to be set at a wall close to the kitchen, where they would serve as a staging area for servants when they served meals. Today's sideboard provides storage, as well as a place to set serving dishes (see **Figure 22-7**).

Bedside tables, often called *night stands,* should be the height of the mattress or a bit lower (see **Figure 22-8**).

Sofa tables and hall tables tend to be relatively long, narrow tables. A sofa table is often placed behind the sofa and should be about the height of the back of the sofa. Hall tables are the same height, and the essential difference between them and sofa tables is their placement. Hall tables may be found in various locations throughout the house. **Figure 22-9** shows a sofa table and **Figure 22-10** shows a hall table.



Image courtesy of Thomasville Furniture

FIGURE 22-7 Side table.



Image courtesy of Thomasville Furniture

FIGURE 22-6 End table.



Image courtesy of Thomasville Furniture

FIGURE 22-8 Bed-side table.



Image courtesy of Thomasville Furniture

FIGURE 22-9 Sofa table.



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FIGURE 22-10 Hall table.



FACTS ABOUT WOOD

Hard maple, *Acer saccharum*, is the state tree of Wisconsin, Vermont, New York, and West Virginia. It is also called *rock maple* or *sugar maple,* which is the literal translation from the Latin. Maple is a dense, cream-colored wood. Hard and heavy, it is a straight-grained wood with a fine texture that occasionally displays a very attractive curly or birdseye figure. Maple is a fine furniture and cabinetmaking wood. Due to its high shock resistance and strength, in the past it was used for airplane propellers and shoe heels. ■

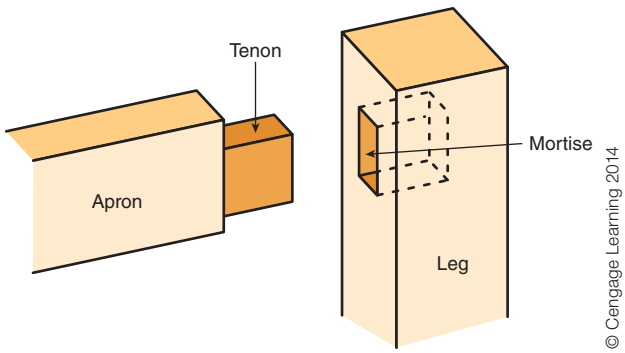
TABLE CONSTRUCTION

The basic type of table described earlier is sometimes called a *leg-and-apron table.* There are other styles of table that will be explored later, but first we will look at the leg-and-apron table. There are two important aspects to explore. One is how the aprons attach to the legs, and the other is how the top is attached to the frame of the table, which consists of the legs and the aprons. Legs and aprons are attached by rail joints, which were discussed in Chapter 17. The traditional rail joint, and the strongest, for connecting the legs and aprons is the mortise-and-tenon joint. A mortise is machined into the leg, and a tenon is created on the end of the apron (see **Figure 22-11**).

There are several variations on this basic joint. The mortise may be open at the top of the leg. The tenons may be mitered so that two aprons coming into the same leg meet in the center of the leg. The joint may be pinned for additional strength or for the appearance it provides (see **Figure 22-12** through **Figure 22-14**).

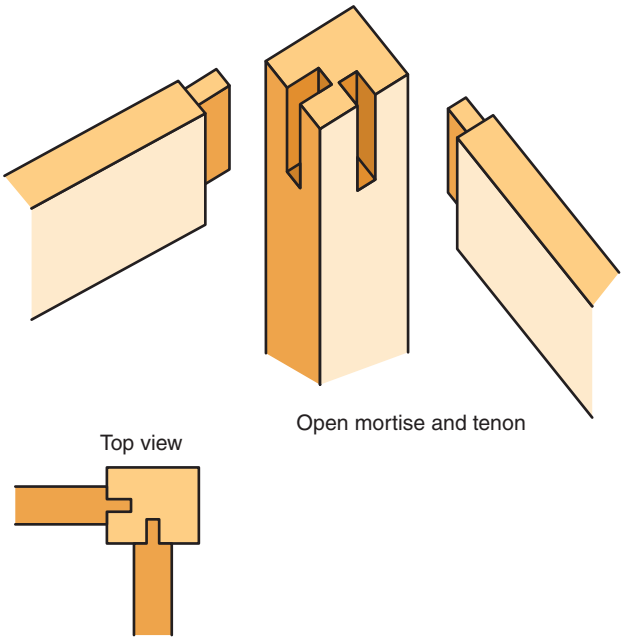
Larger tables often gain additional reinforcement from mitered braces that run from apron to apron (see **Figure 22-15**). Metal braces are also available, and the leg-to-apron connection can be made with butt joints. A kerf is cut into each apron into which the metal brace fits, and a hanger bolt is inserted from the center of the brace back into the leg. This method allows the table to be readily knocked down. Wooden braces can be made that work the same way as the metal ones (see **Figure 22-16**). Small tables that will not bear much weight may utilize dowel, biscuit, or pocket-hole construction for the leg-to-apron connection.

The top of the table can be attached to the frame in several ways. The primary consideration here is



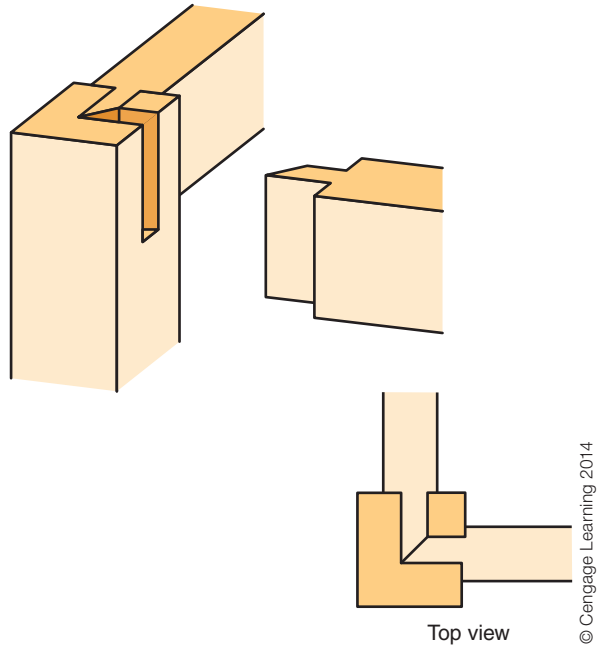
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FIGURE 22-11 Mortise-and-tenon leg-to-apron connection.



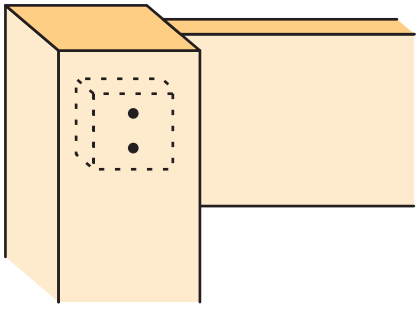
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FIGURE 22-12 Open mortise.



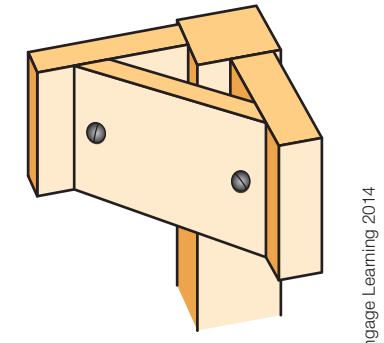
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FIGURE 22-13 Mitered tenons.



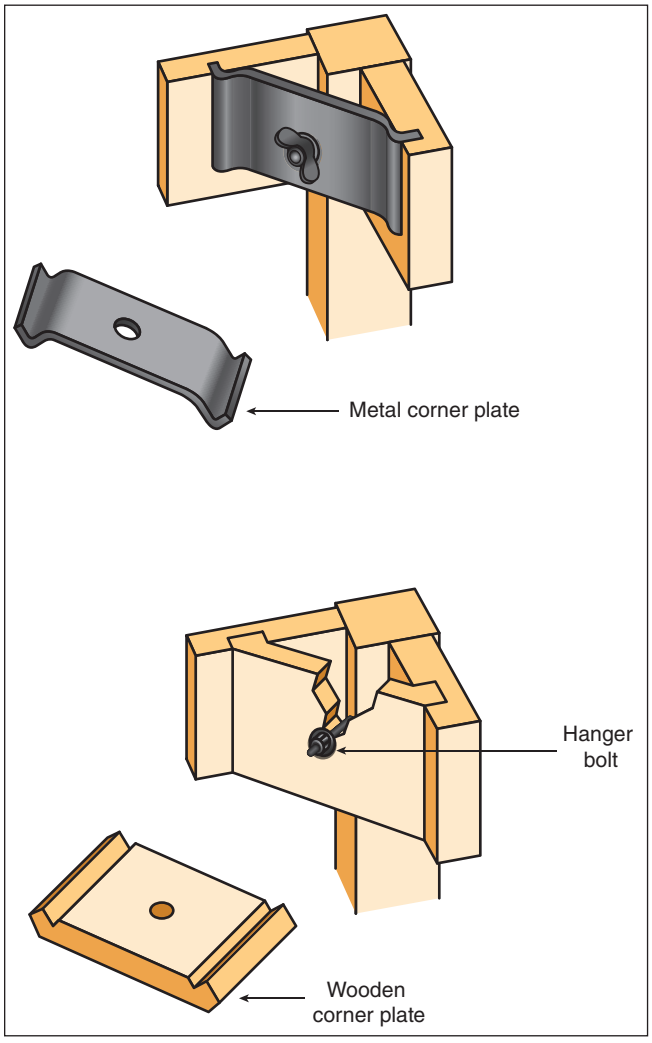
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FIGURE 22-14 Pinned tenons.



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FIGURE 22-15 Braces running from apron to apron provides additional strength.



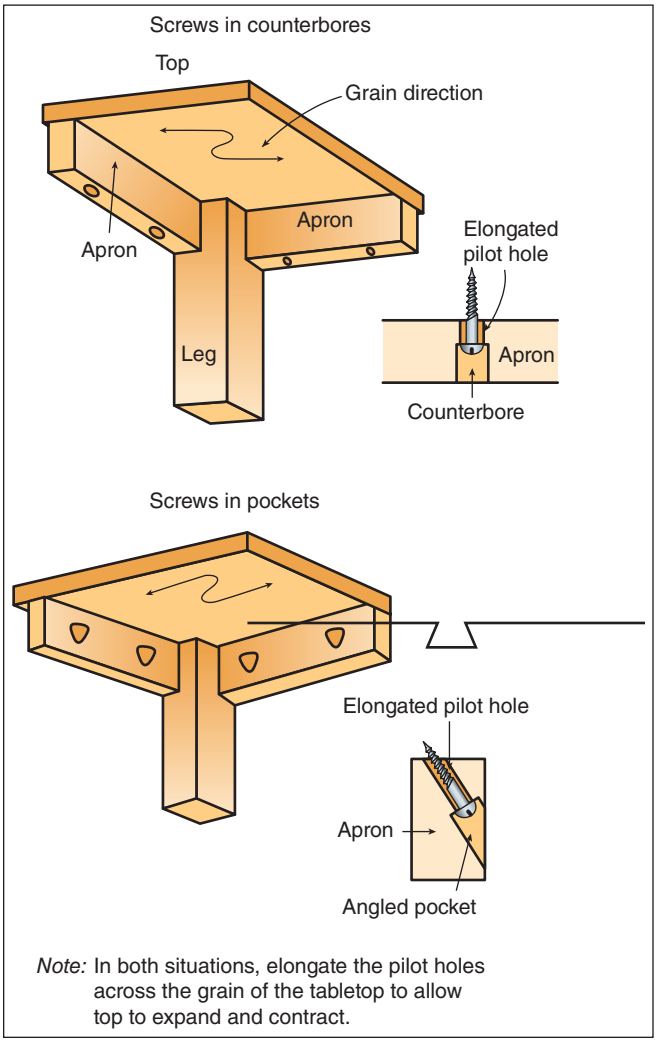
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FIGURE 22-16 Metal and wooden shopmade table braces.

allowing a solid wood tabletop to expand and contract with seasonal changes. If it cannot do that because it is fastened in such a way that it cannot move, the table will warp; in extreme cases, the top may crack.

One option is to drill oversize holes in the apron, through which screws are inserted up into the top. These holes may come all the way through from the bottom of the apron, or they may be angled in from the sides (see **Figure 22-17**).

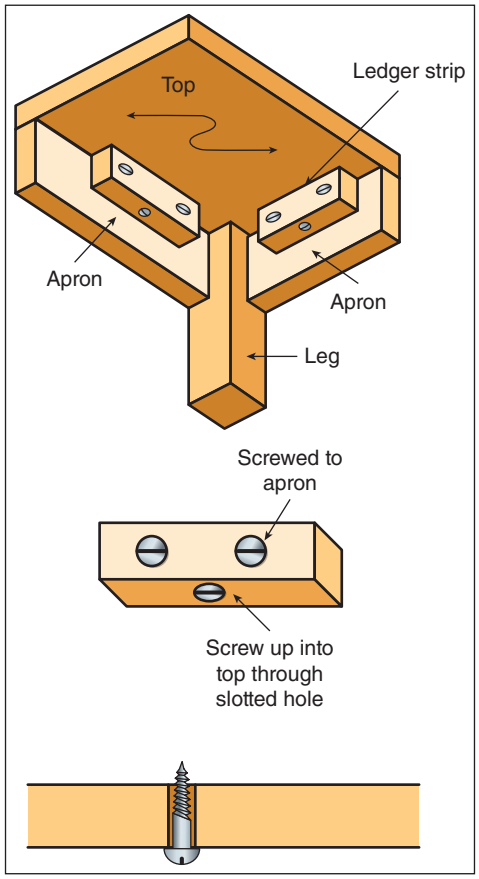
A second method is to attach a narrow strip of wood to the top of the apron and to drill oversize holes through it for attaching the tabletop. This strip may be continuous, or intermittent blocks may be used (see **Figure 22-18**).



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FIGURE 22-17 Attaching tabletop through the apron.

A third choice is to use commercially made tabletop fasteners. There are two commonly used types, both of which are metal. One kind is sometimes called a **Z-clip**. One end of the Z-clip fits into a kerf milled in the apron, and the other end is screwed into the top (see **Figure 22-19**). The other type of metal



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FIGURE 22-18 Attaching tabletop using a screwing strip.



Image courtesy of rockler.com

FIGURE 22-19 Tabletop attachment using Z-clips.

tabletop fastener is shaped like a figure eight. One end of the eight is set and screwed into a shallow hole drilled in the top of the apron. A screw is driven through the other end of the eight into the tabletop (see **Figure 22-20**).

A fourth choice is to make tabletop blocks, which work in the same way the Z-clips do (see **Figure 22-21**). These are sometimes called **button blocks**. The important thing with button blocks is to make sure that their grain runs the length of the block. All these methods allow a solid wood top to expand and contract without warping the table.



Image courtesy of rockler.com

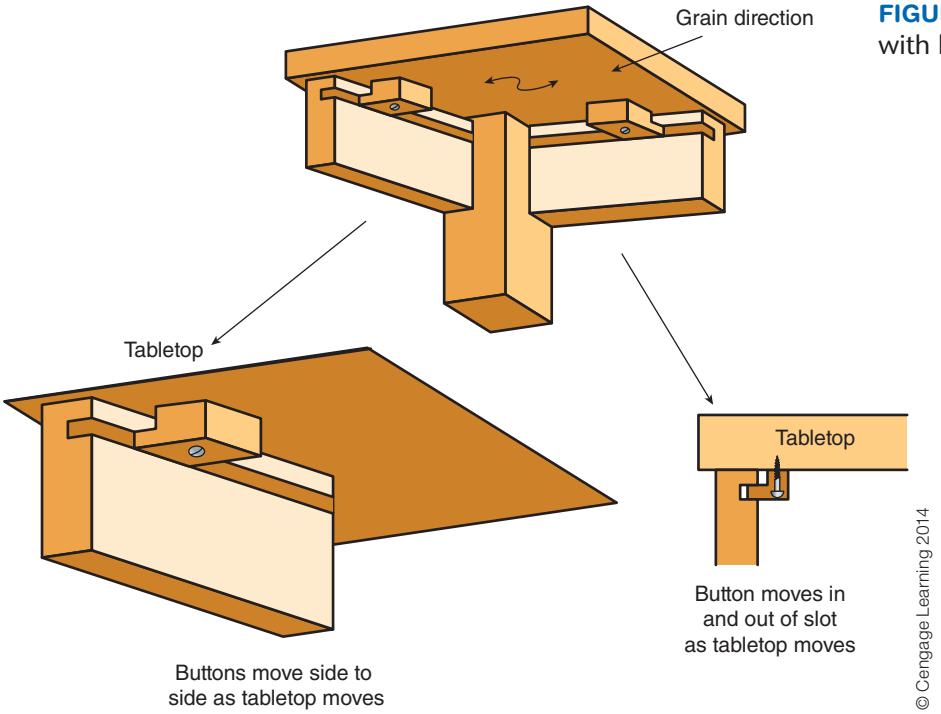
FIGURE 22-20 Metal figure-eight tabletop attachments.

GREEN REMINDERS

Electronic ballast fluorescent fixtures with reflectors use 40–70 percent less energy than standard magnetic ballast fluorescents, and operate without the hum typically associated with standard fluorescent fixtures.

Leg-and-Apron Tables with Drawers

Sometimes leg-and-apron tables have drawers, which can be constructed in two ways. An apron may have an opening cut in it, and a support structure built for the drawer (see **Figure 22-22**). This may compromise the strength of the apron, and it limits the size of the drawers. Another option requires a somewhat different construction than we have already considered. On the side of the table where the drawer will go, instead of an apron, two rails are installed (see **Figure 22-23**).



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FIGURE 22-21 Tabletop attachment with button blocks.

PROCEDURE 22-2

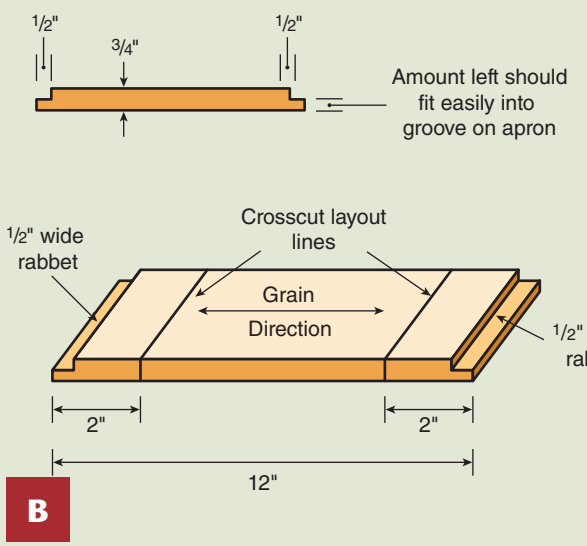
Making Button Blocks

STEPS

1. Measure the distance from the top of the apron to the bottom of the groove that was milled to accept the button blocks. This distance is typically 3/4".
2. Mill a board about a foot long to the same thickness as the distance just measured. A wider board will yield more button blocks, so use one that is at least 4" wide.
3. Joint one edge and square cut both ends of the board.
4. Using the table saw and a dado blade, mill a rabbet that is 1/2" wide on both ends of your stock, as shown in **Figure A**. The depth of the cut should be such that the portion of material remaining will slide into the groove milled in the apron.
5. Measure over 2" from each end of the board and make layout lines for crosscutting later, as shown in **Figure B**.
6. Set the band saw fence for 1", and rip off individual blocks. Use a push stick, as shown in **Figure C**.



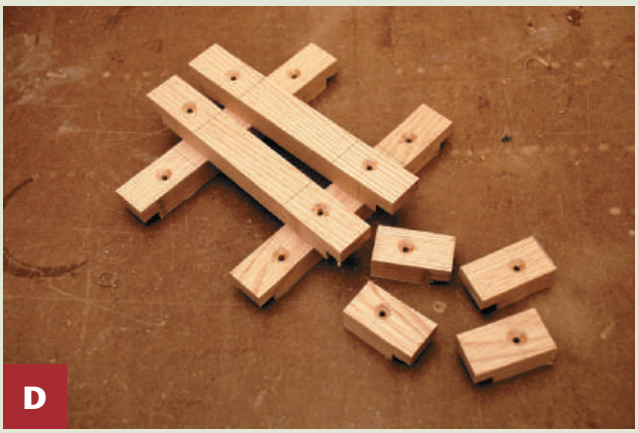
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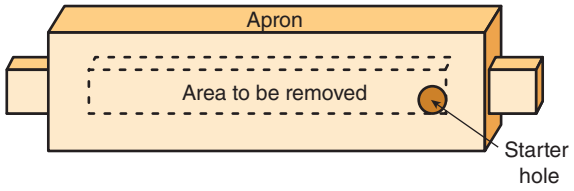


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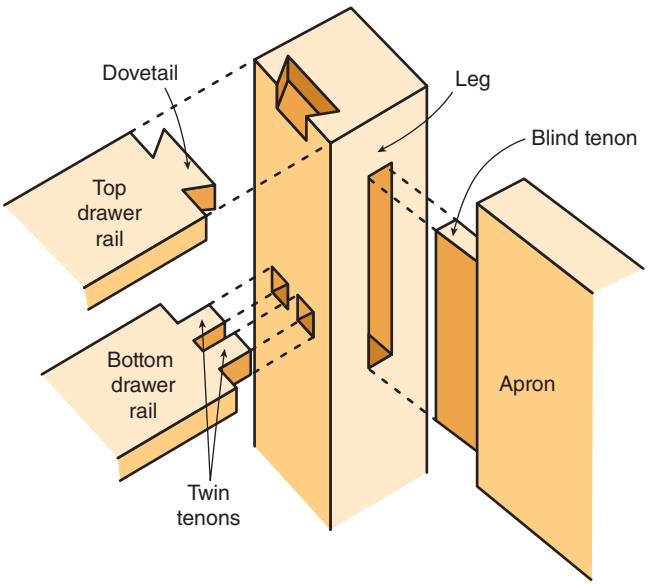
7. Drill and countersink a hole through the center of the solid part of each block. The hole should be large enough that the screw being used to attach the top will drop through it easily (see **Figure D**).
8. Cut blocks to length along the crosscut lines you marked out in Step 5. **Figure D** shows several button blocks cut to their final length.



1. Lay out area to be cut out.
2. Drill a starter hole large enough to fit a saw blade into.
3. Remove the waste with a jigsaw.

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FIGURE 22-22 An opening may be cut in an apron for a drawer.



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FIGURE 22-23 Drawer rails.

Tables Other Than Leg-and-Apron

Not all tables are leg-and-apron tables. There are also *trestle tables* and *pedestal tables*. **Trestle tables** may be the earliest table form. In the most rudimentary case, it is as simple as a board or sheet of plywood laid on top of sawhorses or trestles. A more advanced design consists of two trestles, made up of feet, posts, and tops, that are connected to one another with a stretcher. The tabletop is then attached to the trestles (see **Figure 22-24**). Many trestle tables are designed to be knocked down quickly and easily.

Pedestal tables consist of a central pillar that supports the top. This pillar rises out of a base or an arrangement of low but spreading feet (see **Figure 22-25**). Aprons are structurally unnecessary in pedestal tables but may be used for aesthetic reasons. A pedestal table offers unrestricted leg room, but the base may be in the way of a diner's feet. An important requirement in designing a pedestal table is stability. To achieve stability, the footprint of the base should be within 6 inches of the top's shadow in each direction (see **Figure 22-26**).

WOODWORKING TIP:

To determine the bevel angle for a column consisting of any number of sides, divide 360° by the number of sides, and then halve that number for the bevel angle. For example, if you wanted to create a 12-sided pedestal, divide 360° by 12. This yields 30. Half of 30 is 15, yielding a bevel angle of 15°.

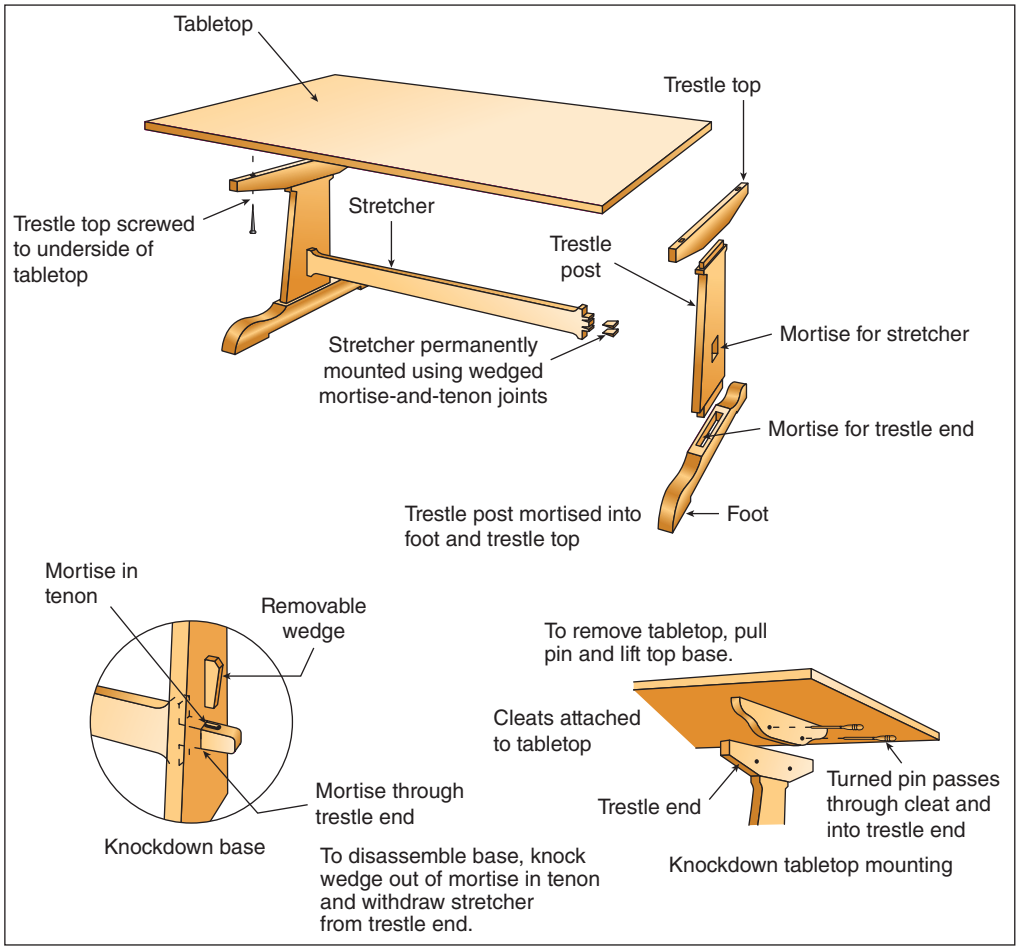


FIGURE 22-24 Diagram of a fixed trestle table and details for creating a knockdown trestle table.



Image courtesy of Thomasville Furniture

FIGURE 22-25 Pedestal table.

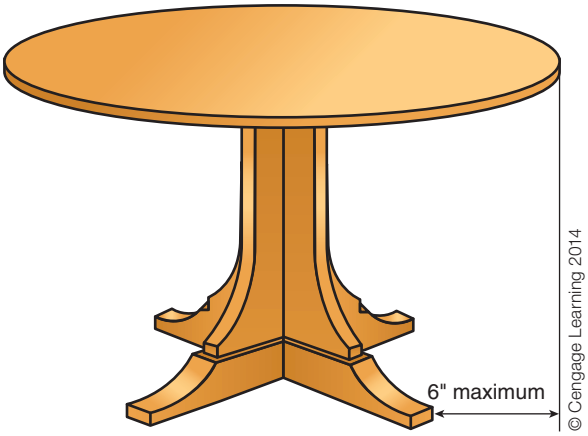


FIGURE 22-26 Top of pedestal should be within 6" of the top's shadow for stability.

Expanding Tables

Expanding tables include drop-leaf tables and extension tables. A **drop-leaf table** is any table that has leaves hinged to the tabletop that hang vertically when not in use. Sliding or pivoting supports hold the leaves up when desired (see **Figure 22-27** and **Figure 22-28**).

Extension tables are either leg-and-apron or pedestal tables that are cut in half and joined with special slides. When the table is opened up, leaves are set in place that make the table longer (see **Figure 22-29** and **Figure 22-30**).

More Tables

There are a host of occasional tables not yet mentioned. These include card tables, tea tables, demilune tables, handkerchief tables, basin stands, tripod tables, butler's tables, and tilt-top tables. Working with the simple components of legs and aprons or a pedestal, an incredible variety of tables can be created. **Figure 22-31** through **Figure 22-34** show several examples of occasional tables.

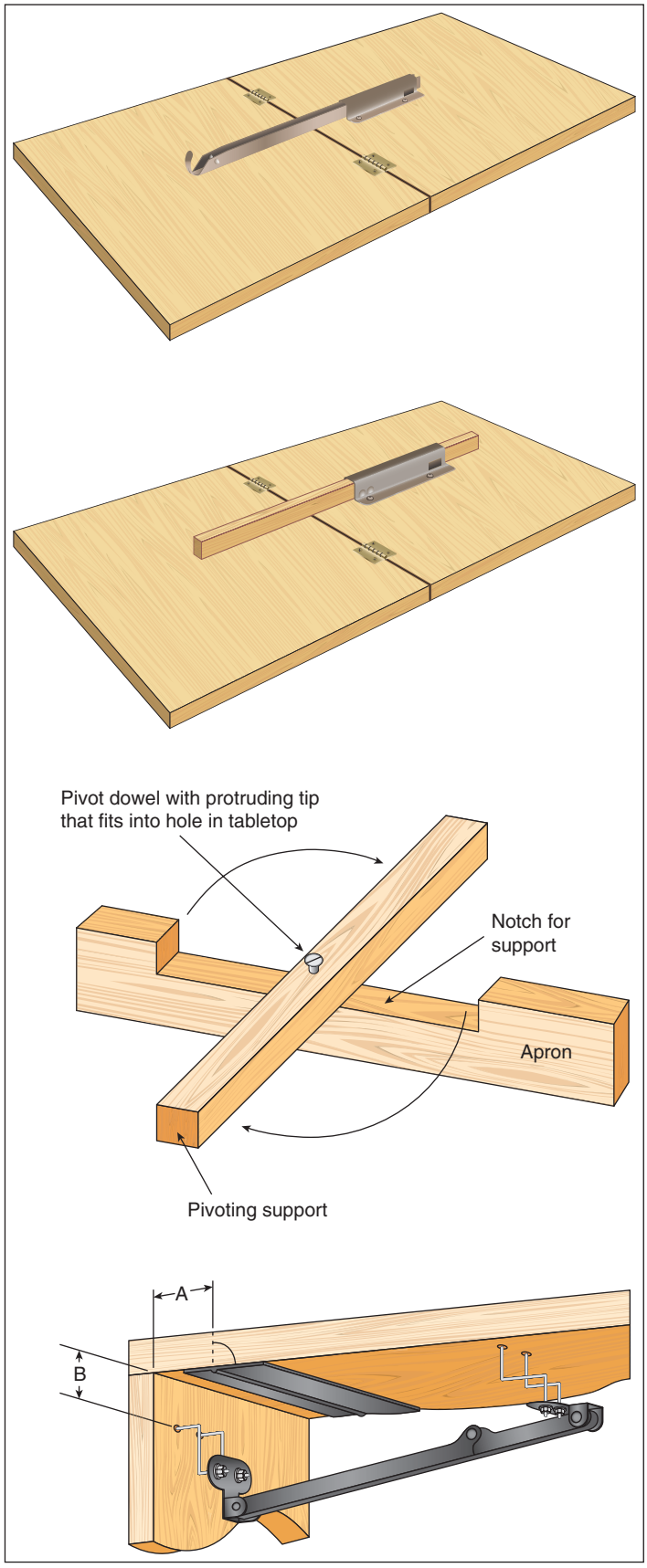
CAUTION

Be aware of your surroundings. If you work in a multiperson shop, as most of us do, it is not enough to pay attention to what you are doing. Others may not be as safety-conscious as you are, so it is equally important to be aware of what they may be doing.



Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 22-27 Drop-leaf table with leaves opened.



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FIGURE 22-28 Methods of supporting a drop leaf.



Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 22-29 Extension table with extra leaves in place.



Image courtesy of rockler.com

FIGURE 22-30 Extension table slides.



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FIGURE 22-31 Bow-front end table with two drawers.



Image courtesy of the Ball & Claw, Jeffrey Greene Furnituremaker, www.JeffreyGreeneNewport.com

FIGURE 22-32 John Townsend Tea table.



Image courtesy of John Lomas Custom Furniture

FIGURE 22-33 Demilune side table.

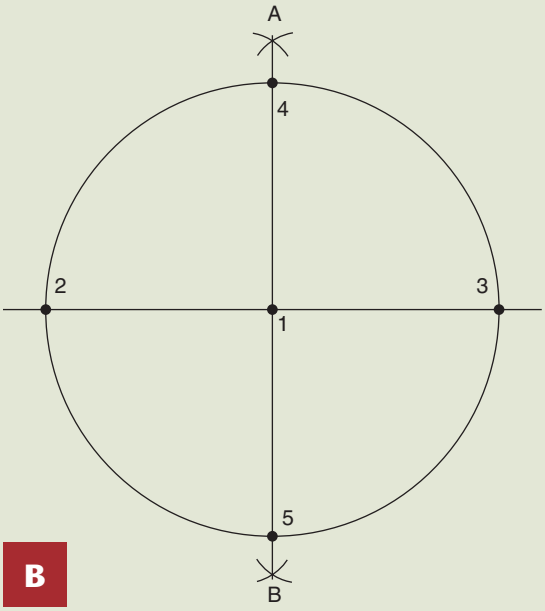


Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 22-34 Tripod table.

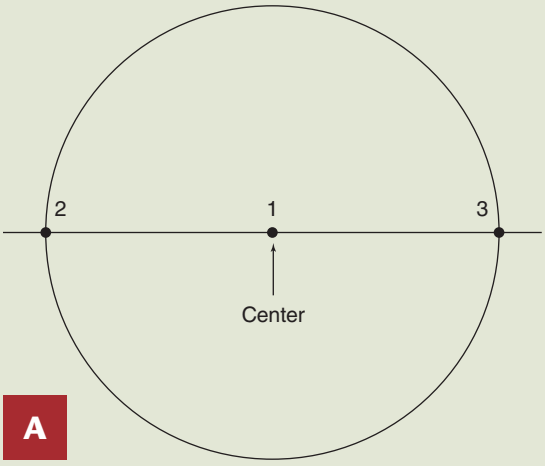
PROCEDURE 22-3

Making an Eight-Sided Column



B

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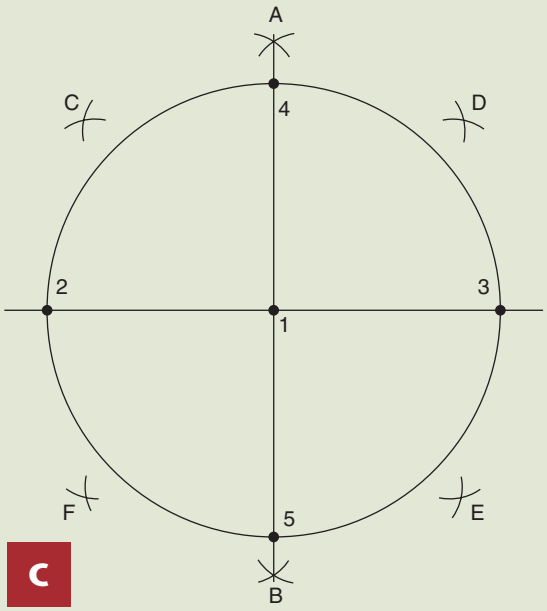
A

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STEPS

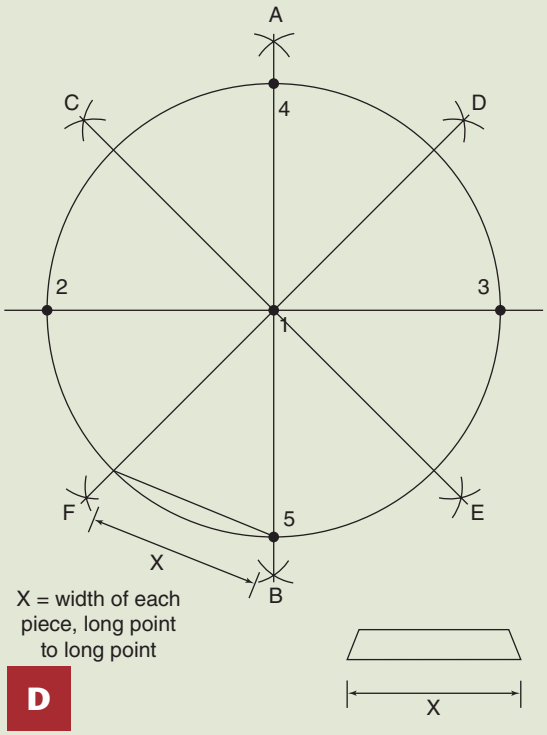
1. Decide how big you want the column's diameter to be. On a large enough sheet of paper or a scrap piece of plywood, draw a straight line, set a compass or trammel points in the center of the line, and draw a circle that is the diameter of the column you want to make. Mark the points as indicated in **Figure A**.
2. Refer to **Figure B**. Open the compass a bit wider than the radius used to draw the circle; place its point at point 2 and then at point 3 and scribe short arcs that intersect above and below the circle. Label these intersections points A and B, and then connect points A and B with a straight line. Label the points where this line touches the circle points 4 and 5.

3. Set the compass opening for the radius of the circle again and place its point at point 2 and scribe short arcs outside the circle; do the same at points 3, 4, and 5. The intersections of these lines create points C, D, E, and F, as shown in **Figure C**.
4. Connect points C and E and points D and F, as shown in **Figure D**.
5. Drawing lines between the points along the perimeter of the circle establishes the octagon. Measuring one of these lines tells you the width (X) of each of the eight pieces that will make up the column. Again, refer to **Figure D**.



C

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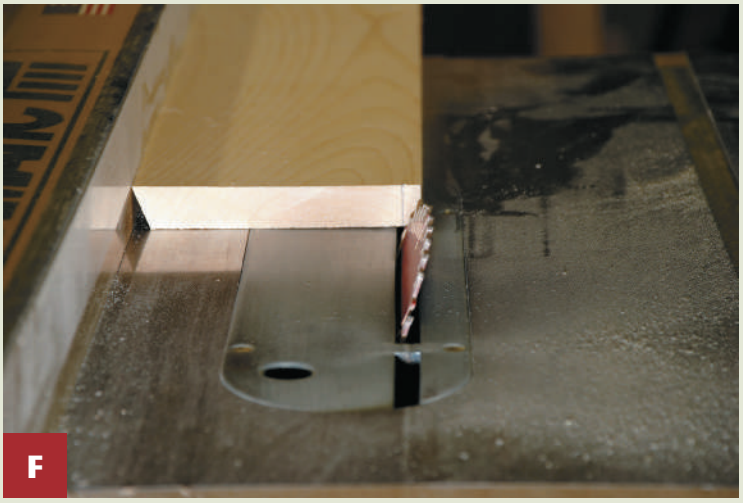
D

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E

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F

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G

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6. Cut pieces to the desired length, and rip them slightly wider than the measurement obtained in Step 5.
7. Tilt the table saw blade to 22.5°. Using the fence as a guide, rip this bevel on one side of each of your eight pieces, as shown in **Figure E**.
8. Set the fence so that the distance between the fence and the blade is the determined width. It will be easiest to do this if you mark one of your pieces, measuring from the bevel just cut, as shown in **Figure F**.
9. Rip the opposing bevel on each of your pieces, as shown in **Figure G**.

10. Glue and secure the column with wide painter's tape and band clamps, as shown in **Figures H** and **I**.
11. Remove the band clamps and clean up any glue residue, leaving the column as shown in **Figures J** and **K**.


H

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J

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I

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K

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DESKS

A desk should be comfortable to use and functional. To achieve this goal, certain standards are observed in designing a desk. The average height from the floor to the desktop ranges from 27 to 30 inches. *Legroom* is defined as the distance from the floor to the underside of the desktop, and it ranges from 24 to 29 inches. *Thigh room* is the distance from the chair seat to the underside of the desktop with a chair drawn up to the desk; the minimum dimension is 6 1/2". The horizontal distance from the desk's edge to an obstruction that will block the sitter's leg is called *knee room*, and it should be 14 to 18 inches. The vertical distance a person sitting at the desk can reach without standing up is called *reach,* and the standard is 19 to 20 inches (see **Figure 22-35**).

Just as there are many different kinds of tables, there are many types of desks. Among them are writing desks, slant-top desks, postmaster's desks, slant-front desks, secretaries, kneehole desks, rolltop desks, and computer desks.

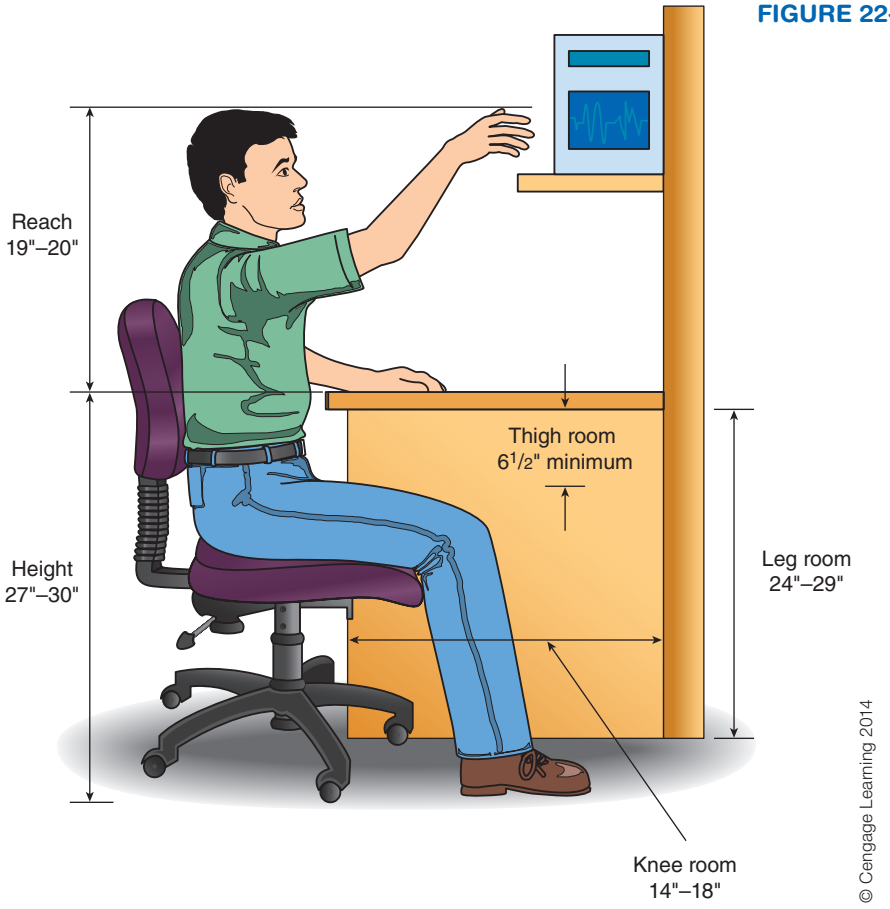
The **writing desk** is also called a *writing table,* because it is essentially a table with drawers. Its popularity developed along with literacy, when the alternative to face-to-face conversation was a letter. It traditionally had a leather-covered writing surface (see **Figure 22-36**).

The **slant-top desk** is also known as a school master's desk or a stand-up desk, because it was



Image courtesy of John Lomas Custom Furniture

FIGURE 22-36 Gloucester writing desk.



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FIGURE 22-35 Desk standards.

designed to be used by someone standing at it, rather than sitting. It is the working person's desk. The slope of the desk may vary, but 10° is a good standard (see **Figure 22-37**).

The **postmaster's desk** is also known as a *plantation desk.* It has many little cubbies sometimes hidden by doors, and is a combination of a table and cupboard (see **Figure 22-38**).

The **slant-front desk** is also called a drop-front desk. Its construction is like that of a chest of drawers. The front is hinged and opens to create a writing surface. It is an attractive piece of furniture but not a very good desk, primarily due to the lack of adequate knee room. It does have the advantage of having a lot of storage, and it can double as a chest of drawers (see **Figure 22-39**). Another desk related to the slant-front desk just described is the slant-front desk on a frame (see **Figure 22-40**).

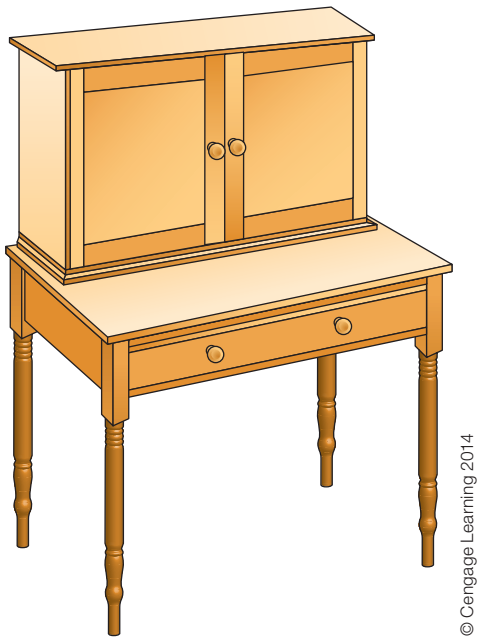
A **secretary** is a combination desk and bookcase. Like the slant front, it is a chest of drawers with a fold-down writing surface. It also supports a cupboard for books and storage (see **Figure 22-41**).

A **kneehole desk** has two chests of drawers that act as pedestals to support the desktop. For this reason, it is sometimes called a *pedestal desk.* The pedestals are typically joined by rails, which may house a



Image courtesy of Amish Country Furniture Sales, www.standupdesks.com

FIGURE 22-37 Slant-top desk.



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FIGURE 22-38 Postmaster's desk.



Image courtesy of the Ball & Claw, Jeffrey Greene Furnituremaker, www.JeffreyGreeneNewport.com

FIGURE 22-39 Newport slant-front desk.



Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 22-40 Slant-front desk on frame.



Image courtesy of the Ball & Claw, Jeffrey Greene Furnituremaker, www.JeffreyGreeneNewport.com

FIGURE 22-41 John Townsend Secretary.



Image courtesy of Thomasville Furniture

FIGURE 22-42 Kneehole desk.

small drawer over the kneehole. A modesty or **vanity panel** often closes the kneehole on the far side of the desk (see **Figure 22-42**).

A **rolltop desk**, also called a *tambour desk*, is characterized by a tambour curtain that pulls down to completely enclose the writing surface. The great advantage of the rolltop desk is that a cluttered desktop can be concealed (see **Figure 22-43**).



HISTORY FACT

The archetypal American desk is the rolltop kneehole desk, featuring a curved tambour top. It was first patented by Abner Cutler in 1850. Cutler was the owner of the Cutler Desk Company in Buffalo, New York. From 1886 until 1978, the desks were manufactured by the Standard Furniture Company, located in the village of Herkimer, New York, which, according to newspaper accounts, was considered the "desk capital of the world." ■

The computer desk is a latecomer to the desk scene. It has many different configurations, but certain standards are associated with it, again to make it comfortable for the user. The monitor and keyboard need to be positioned to prevent stiff necks, sore wrists, and tired eyes. The keyboard height is the distance from the floor to the top of the keyboard. It should



Image courtesy of Countryside Amish Furniture, LLC., www.countrysideamishfurniture.com

FIGURE 22-43 Rolltop desk.

be adjustable, ranging between 24 and 27 inches. It is often placed on a tray that slides out from under the desktop. *Sight angle* is defined as the angle between the sight line to the keyboard and the sight line to the monitor, and this angle should not exceed 60°. **Figure 22-44** shows an example of a computer desk.



Image courtesy of Bestar, www.bestar.ca

FIGURE 22-44 Computer desk.



Summary

Tables and desks are both extremely functional and potentially attractive pieces of furniture. There are many types of tables and desks. To make them as functional as possible, both tables and desks have certain standards associated with them. The primary components of the leg-and-apron table are the legs, aprons, and tops. Through varying these components, many different looks may be achieved. Desks are much like tables, except, of course, that they serve a different purpose. As with tables, many variations are possible, depending on the intended use of the desk.



Key Terms

apron
button block
drop-leaf table
kneehole desk
pedestal table
postmaster's desk
rolltop desk
secretary
slant-front desk
slant-top desk
table
trestle table
vanity panel
writing desk
Z-clip

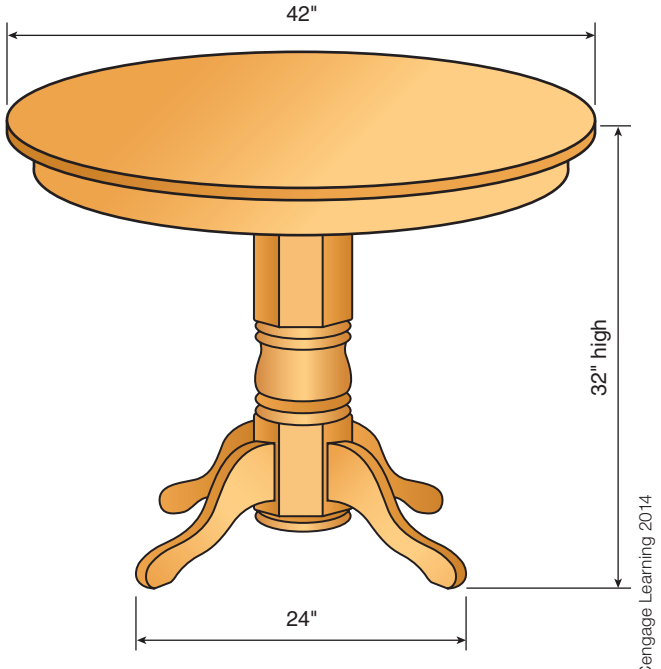


Check Your Knowledge

1. What are the primary components of a basic table, and how can they be altered to create tables of different appearances?
2. List the standards involved in creating a comfortable dining table.
3. Name five tables other than a dining or kitchen table and indicate what each is used for.
4. What is the strongest joint for attaching an apron to a leg?
5. If a drawer is to be installed into a table, what are two methods for doing this?
6. What are two methods for creating a table that can be enlarged to accommodate more diners?
7. List five different types of desks and explain how they differ from one another.
8. What are the standards associated with computer desks, and why are these standards so important?



What's Wrong with This Picture?



Pedestal dining table

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BUILD IT!

End Table

Figure A shows a completed end table.

TOOLS REQUIRED

- Measuring tool
- Square
- Table saw or band saw
- Mortising machine or plunge router with straight bit and mortising jig
- Miter saw
- Sander
- Router and decorative edge bit (optional)
- Drill and small twist bit

MATERIALS REQUIRED

- 3/4" × 4" solid stock for top and aprons
- 1 1/2" × 1 1/2" solid stock for legs
- Z-clips

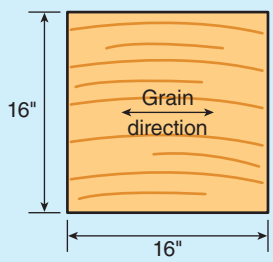
STEPS

1. Using the plans given in **Figure B**, determine the size of the legs, aprons, and tabletop.
2. Glue and clamp up an oversized blank for the tabletop and set aside.
3. Cut legs to length and carefully lay out mortises.
4. Machine mortises.

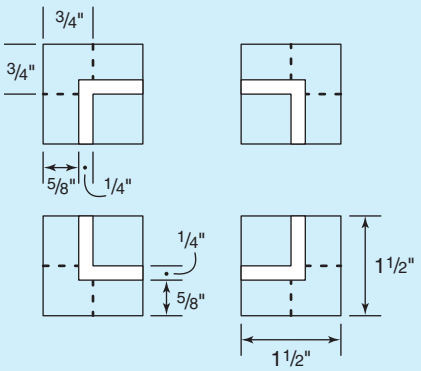


A

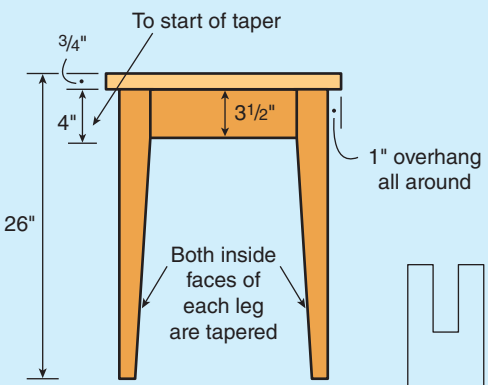
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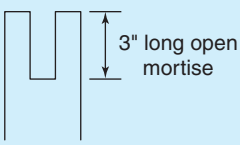
Top view

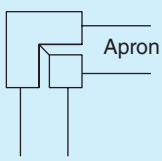


Legs – dotted lines represent size of leg at its bottom. This is the size they taper to.



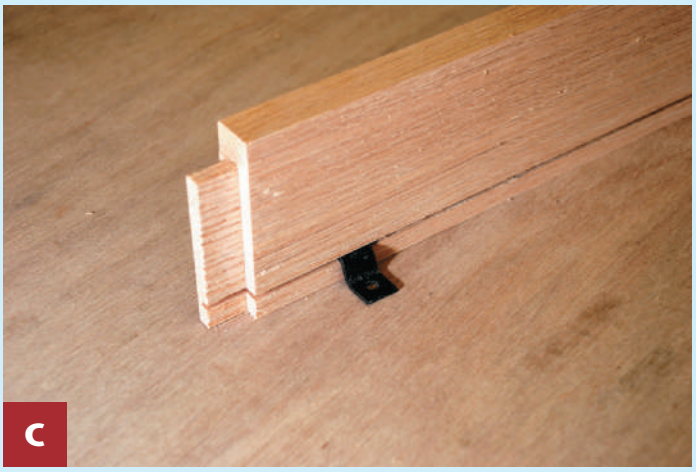
Side view





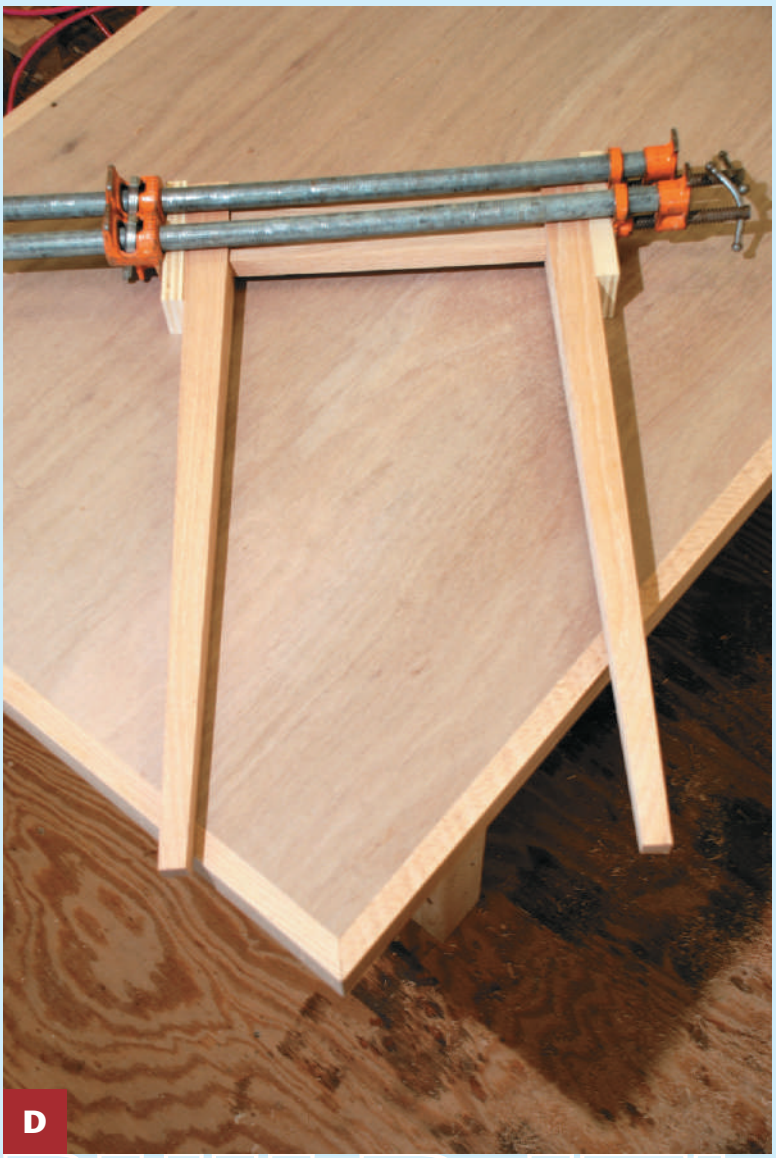
B

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C

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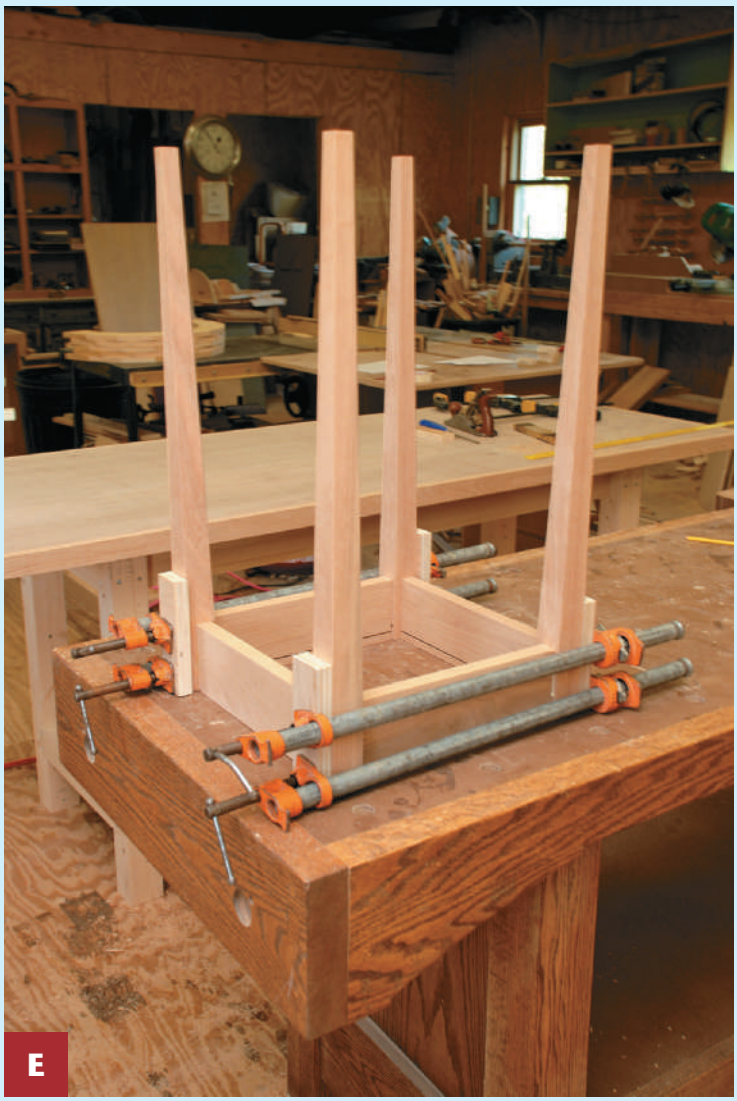
D

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5. Using a tapering jig, cut the tapers on the inside of each leg (this is the side with the mortise on it). This procedure may be done on the table saw, band saw, or with a hand plane.
6. Lay out and cut the tenons on each end of all four aprons. Check for a snug fit in the mortise, and miter ends at 45° so that they meet in the center of the mortise.
7. Mill a groove on the inside of each apron to accept the Z-clips, as shown in **Figure C**.
8. Sand legs and aprons.
9. Glue and clamp two separate leg-and-apron assemblies, each consisting of two legs and an apron, as shown in **Figure D**. Check to make sure the assemblies are square.
10. While these are drying, cut the tabletop blank to size and rout a decorative edge on it if desired, and then sand it.

BUILD IT!

11. Glue and clamp the two leg-and-apron assemblies together with the remaining two aprons, again checking for square. Refer to **Figure E**.
12. When the base of the table comes out of clamps, place it upside down on the bottom of the tabletop, and position it so that there is an equal overhang of the tabletop all around the frame.
13. Insert Z-clips in grooves, two per apron, and mark and drill the hole for the screw, as shown in **Figure F**.
14. Finish table base and top as desired.
15. Attach top.


E

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F

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PROJECT CHALLENGE

Trestle Table



A

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Assembly list - trestle table

Part	Dimensions (thickness x width x length)	Quantity
Leg	$1\frac{1}{2}$" x 6" x 25"	2
Upper support	$1\frac{1}{2}$" x $3\frac{1}{2}$" x 23"	2
Lower support	$1\frac{1}{2}$" x $3\frac{1}{2}$" x 23"	2
Foot	$\frac{3}{4}$" x $3\frac{1}{2}$" x $3\frac{1}{2}$"	4
Stretcher	$1\frac{3}{4}$" x 7" x 45"	1
Wedge	$\frac{1}{2}$" x $1\frac{1}{8}$" x $6\frac{1}{2}$"	2
Top	$\frac{3}{4}$" x $27\frac{1}{2}$" x 60"	1
Cleat	$\frac{3}{4}$" x $2\frac{1}{4}$" x 25"	5
Biscuit	#20	16
Dowel	$\frac{1}{2}$" x $1\frac{1}{2}$"	2
Screws	$1\frac{1}{4}$" #8 round head	50
Washers		50

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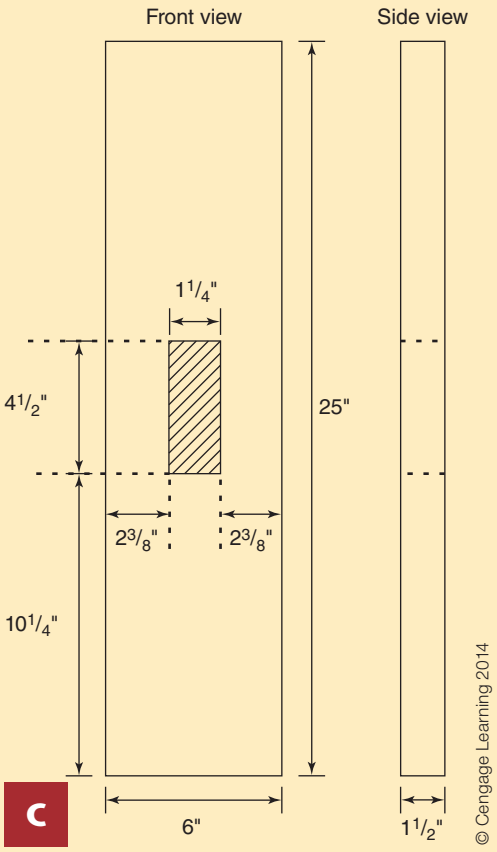
B

A completed trestle table is shown in **Figure A**.

STEPS

1. Consulting the assembly list given in Figure B, lay out and cut parts to rough size. Label each part.
2. Lay out and cut the pieces that will make up the tabletop. Orient the growth rings so that they alternate, and then mark the top for easy reassembly.
3. Alternating faces against the jointer fence, joint the boards for the top, then reassemble, glue, and clamp.

4. While the top is in clamps, cut the two legs to final size and lay out the through mortise as detailed in **Figure C**.
5. Using a 1 1/4" bit chucked into the drill press, remove most of the waste from the mortises (see **Figure D**).



C

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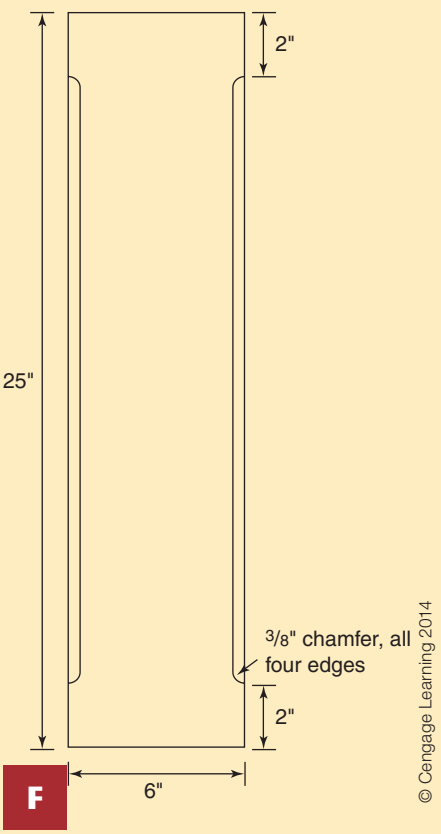
D

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E

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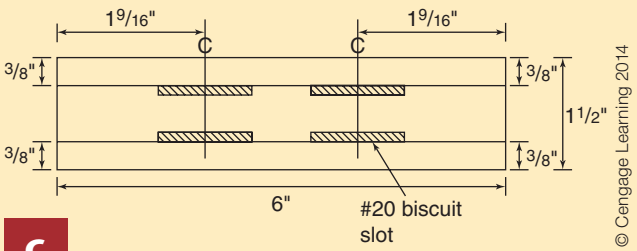


F

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6. Use a chisel and mallet to remove the rest of the waste from the mortises, as shown in **Figure E**.
7. With a chamfering bit in the router, rout stopped 3/8" chamfers on the four edges of the two legs, as shown in **Figure F**.

8. Cut the four supports to final size.
9. Referring to **Figure G**, lay out the top and bottom of each leg for biscuits, and then transfer these marks to the supports, centering the leg on the support along both its length and its width.
10. Cut slots for #20 biscuits in the locations marked.
11. Cut and glue the feet to the bottom supports, as shown in **Figure H**.



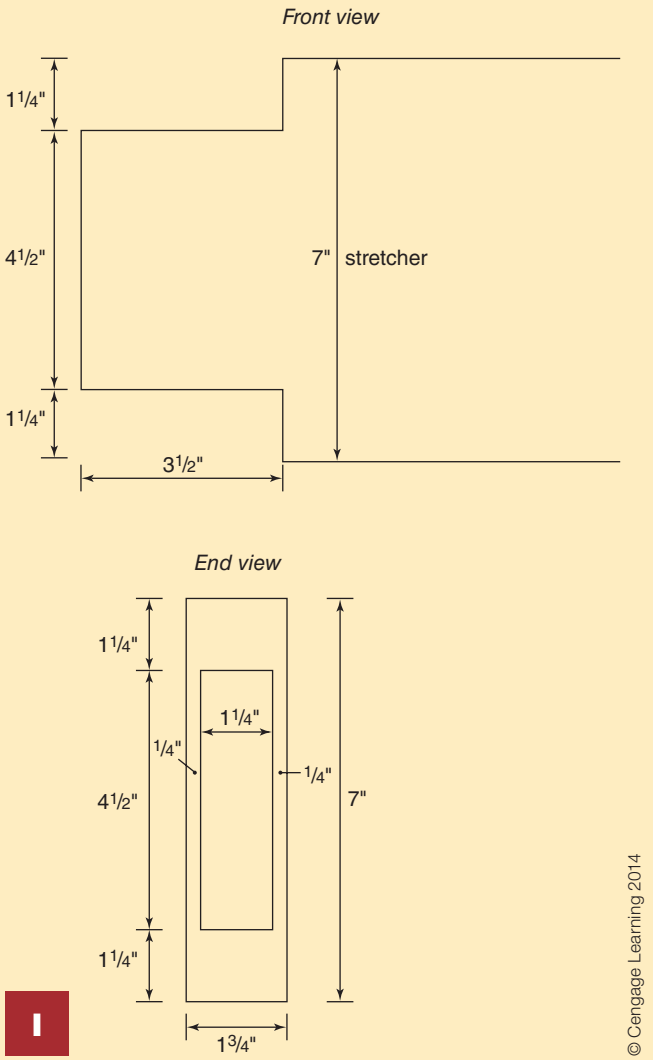
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H

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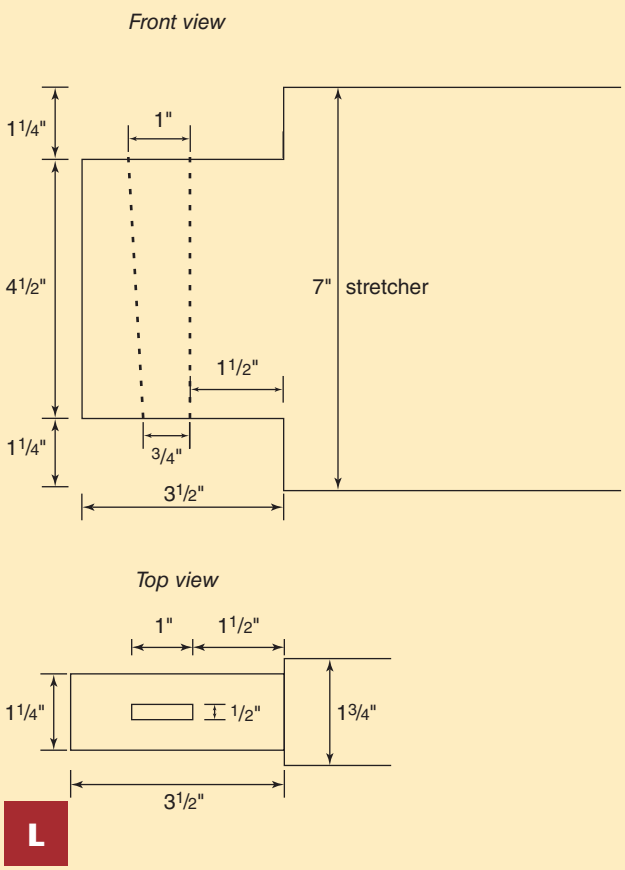
12. Cut the stretcher to final size and lay out the tenons, as shown in **Figure I**.
13. Cut the tenons on either end of the stretcher. This is a long piece that will be difficult to handle on the table saw, so you may wish to make the cheek cuts with a series of cuts on the miter saw after setting the depth stop. Finish the cuts carefully with a jigsaw, and then use a chisel to clean up the cuts and make sure that the tenons fit easily into the leg mortises.
14. Lay out for the arc on the bottom of the stretcher, as shown in **Figure J**.

15. Use a thin flexible stick to mark a smooth arc. Refer to **Figure K**.
16. Cut and sand the arc in the stretcher.
17. Turn the stretcher on edge; lay out for the tapered mortise that will take the wedge and hold the base of the table together (see **Figure L**).
18. Drill a 3/8" hole through the area just laid out for the wedge. Use the drill press and drill from both sides to meet in the center, being careful to align the bit with your layout marks.
19. Use a chisel to remove the remainder of the waste from the tapered mortises at either end of the stretcher.



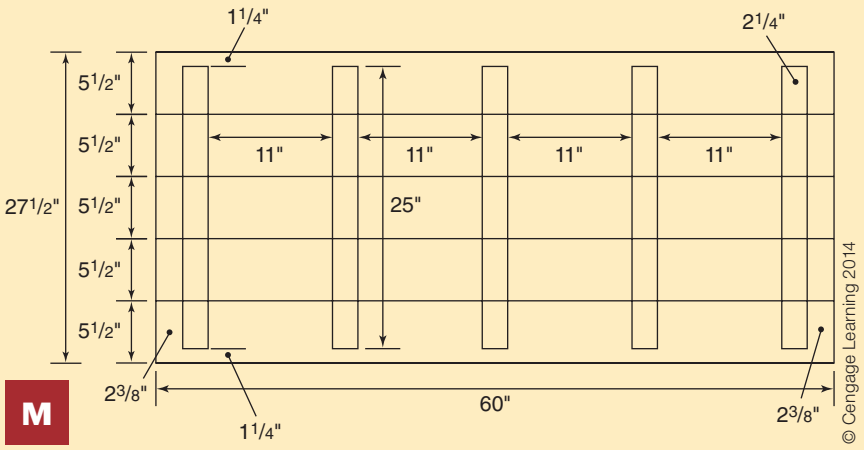
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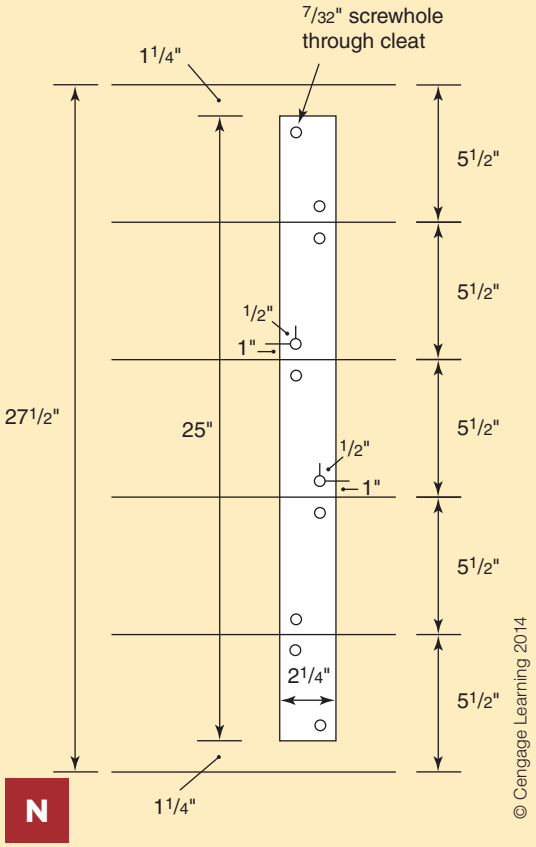


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M



N

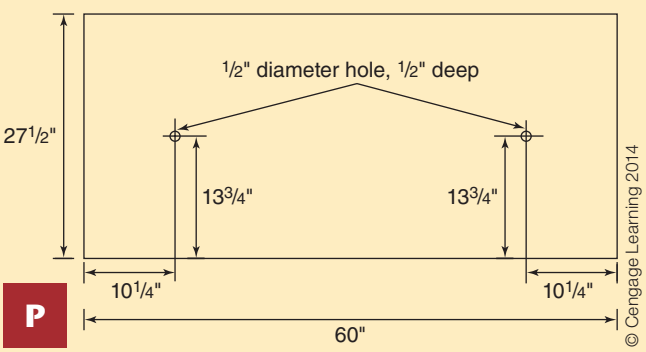
20. Clean up and cut the tabletop to final size. Turn it so that it is face down on the bench; referring to **Figure M**, lay out for the cleats.
21. Cut the cleats to final size. Place them on the top and mark for screws so that two screws will go into each board making up the top, as shown in **Figure N**.
22. Remove the cleats and drill 7/32" diameter holes in the places you just marked for screws.
23. Rout a 1/8" chamfer around the bottom ends and edges of each cleat.
24. With the tabletop upside down on the bench, place the cleats in position and drill 1/8" pilot holes into the top, taking care not to drill through the table.

25. Screw cleats to tabletop with #8, 1 1/4" roundhead screws and washers (see **Figure O**).
26. Drill a 1/2"-diameter hole 1/2" deep in the bottom of the top, as indicated in **Figure P**.
27. Turn the top over, sand it, and then rout a 1/8" chamfer around the ends and edges.
28. Using the band saw, cut the bevel on the four supports, as shown in **Figure Q**.



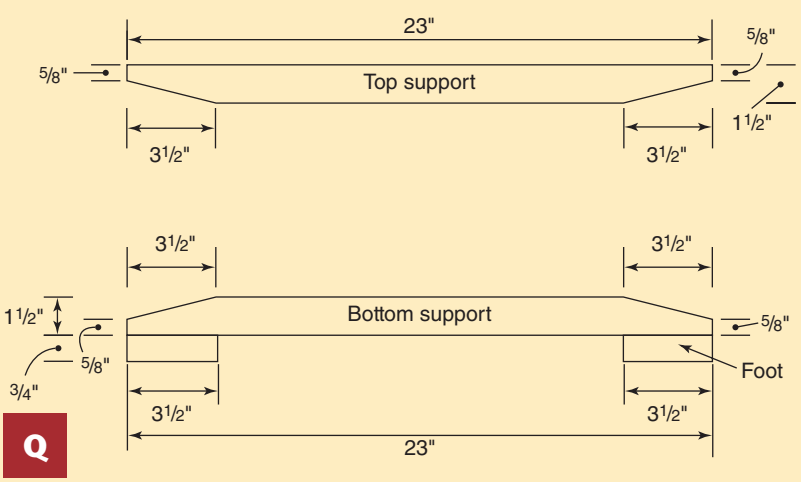
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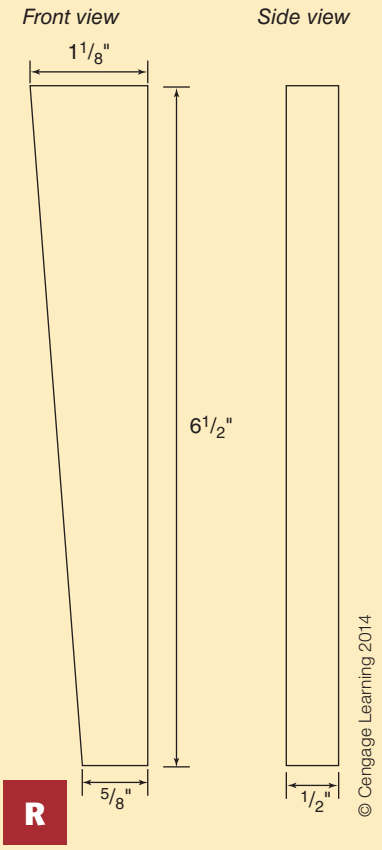
P

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Q

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R

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S

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29. Assemble the legs and supports with glue and biscuits and clamp.
30. Make two wedges for the tapered mortises in the stretcher, as diagrammed in **Figure R**.
31. Mark the location for the dowel pin that registers the top in place. Do this by placing dowel centers in the two 1/2" holes drilled in the bottom of the top. Then put together the stretcher and leg assemblies, place them in the proper location, and press down. The dowel centers will make indentations in the top supports (see **Figure S** and **Figure T**).

32. Drill a 1/2″ hole 1/2″ deep in each of the top supports that you just marked with the dowel pin.
33. Cut and glue a 1/2″-diameter dowel 7/8″ long in the holes just drilled in the top supports, as shown in **Figure U**.
34. Assemble the table, place the stretcher between the two leg assemblies, secure it with the wedges, and locate the top over the top supports so that it registers in place on the dowels. Check the fit of all the parts and adjust as necessary.
35. Disassemble the table and sand all the parts.
36. Finish as desired.


T(a)

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T(b)

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U

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23

Chests

You'll Learn

After studying the chapter, the student should be able to:

- Describe the function of chests
- Demonstrate knowledge of the standards of various types of chests
- Categorize different types of chests
- Recognize various examples of chests within a category

INTRODUCTION

This chapter is about chests of various types, from the simple to the more complex. We will first define what a chest is, and then we will take a look at the various types of chests and the different standards associated with them.

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DEFINITION OF A CHEST

The function of a chest is to store items safely. It should protect them from dust and debris. There are several kinds of chests, and many different examples within each category. The broad categories are blanket chests, chests of drawers, chest-on-chests, and dressers.

Blanket Chest

The **blanket chest** is the simplest form of chest. It offers the least possibility for organization. In its most primitive form, it consists of just six boards. They are the front and back, two sides, bottom, and top. Such chests are sometimes called *six-board chests.* They are the earliest form of chest. Of course, blanket chests are not just used for blankets; they can store any number of items. Another type of "blanket" chest that may come immediately to mind is a tool chest. For the sake of clarity, we will refer to all simple chests as blanket chests.

The dimensions of blanket chests vary greatly, but they typically run from 30 to 60 inches in length. The designer should be careful not to make the chest too wide from front to back or too tall, because either will make it harder to use. General guidelines are that the width should be between 12 and 24 inches, and the depth (height) should be between 15 and 24 inches (see **Figure 23-1**).

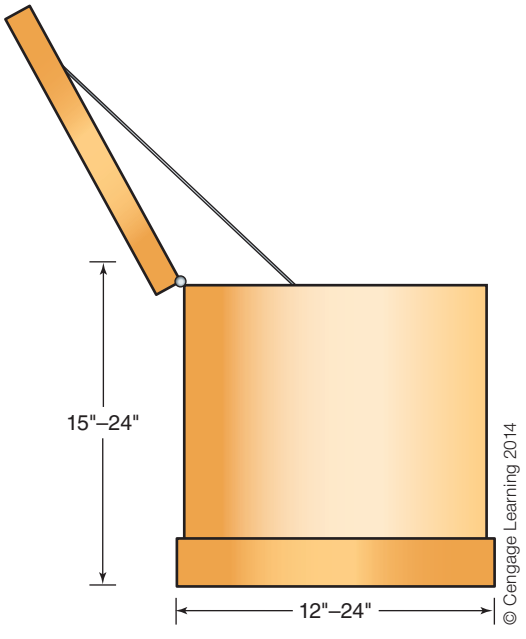


FIGURE 23-1 Blanket chest guidelines.

Simple blanket chests can be further developed by adding a base or feet of some sort. Greater possibilities for organization within the chest can be accommodated by adding trays or drawers. Much smaller chests can be built to hold smaller items.

WOODWORKING TIP:

An applied base can be made up of one or more pieces to create various looks. **Figure 23-2** *shows some examples.*

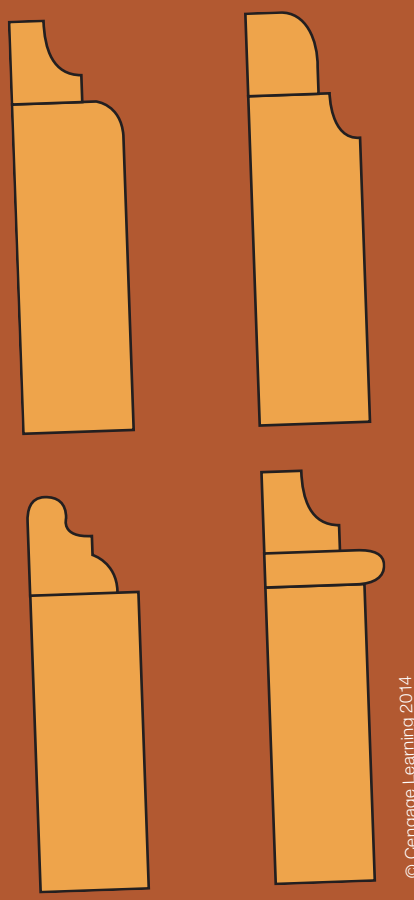
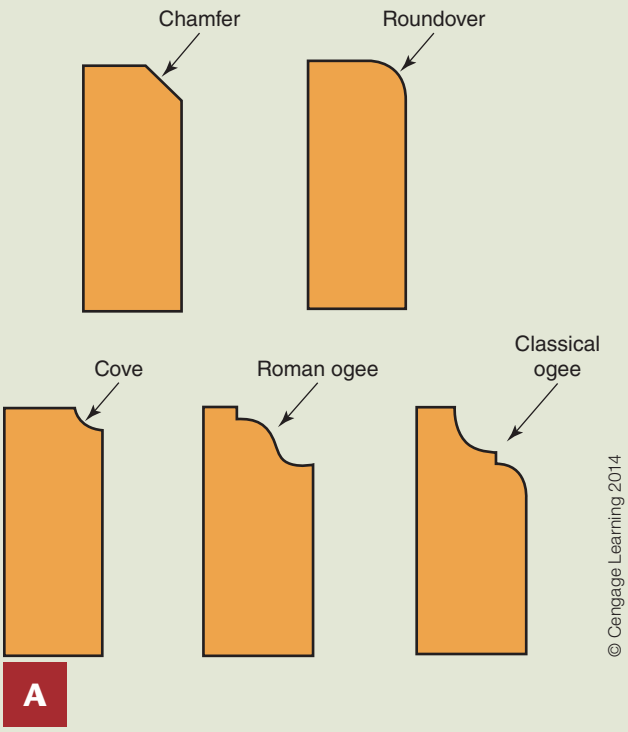


FIGURE 23-2 An applied base can be made up of one or more pieces to create various looks.

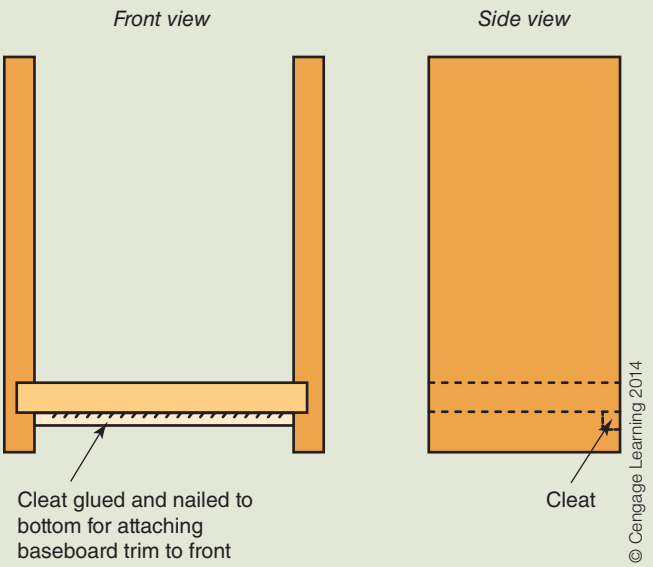
Blanket chests range from very crude to very complex, depending largely on the type of wood and joinery used to construct them. They may be just the six boards mentioned earlier, or they may use frame-and-panel joinery and incorporate either flat or raised panels. They may be plain or highly decorated; many possibilities exist. **Figure 23-3** compares two very different chests.

PROCEDURE 23-1

Applied Base



A



B

STEPS

1. Rout a profile on one edge of a board that will serve as a baseboard to a chest. The board or boards being used must be long enough to go around the perimeter of the chest. Allow some extra material. **Figure A** shows some examples of various profiles.
2. Miter the board just profiled to go around the bottom of the chest.
3. If the bottom is set into a groove in the sides, and the front is open, as shown in **Figure B**, glue and nail a cleat under the bottom for attaching the baseboard.
4. Glue and nail the mitered baseboard in place.



Image courtesy of Wood Creations, Inc., www.woodtoybox.com

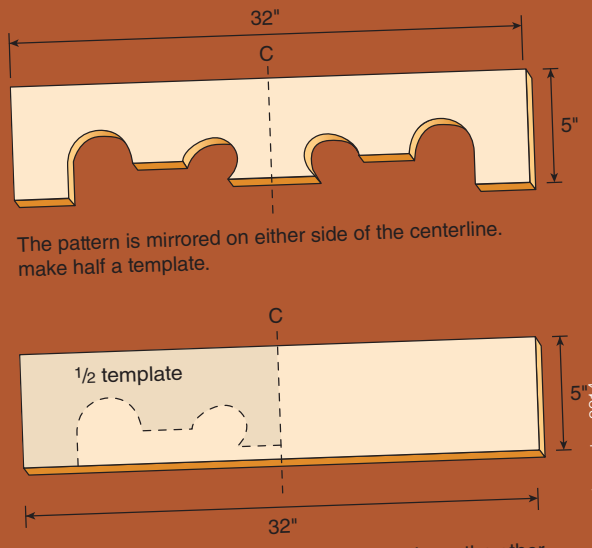


Image courtesy of Barkman Furniture

FIGURE 23-3 Two types of blanket chests: simple and more elaborate.

WOODWORKING TIP:

When making a symmetrical scrolled cut, you only need to make a pattern for half of it. Mark a centerline on the piece to be cut, lay the pattern on one side of the centerline and trace it, then flip it over to the other side and trace it (See **Figure 23-4**).



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FIGURE 23-4 Use a half pattern for symmetrical scrolled cut.

Chest of Drawers

The **chest of drawers** represents a much more evolved kind of chest; historically, it is a later form. As its name indicates, it is essentially a chest holding a number of drawers. It is a much more complex form of chest than the blanket chest and more difficult to build, but it offers many more organizational possibilities than does the blanket chest. Access is also easier. The challenge is to make it both functional and attractive.

To meet the goals of a functional and attractive chest of drawers, certain guidelines are observed. Big drawers are placed at the bottom, and small drawers are placed at the top. No drawer should be so big that it is hard to open and close. To make a chest of drawers manageable for the widest range of people, the largest drawer should not be more than 12 inches high, 24 inches deep, and 48 inches wide. No drawer should be too high to see into (see **Figure 23-5**). A chest of drawers is shown in **Figure 23-6**.



FACTS ABOUT WOOD

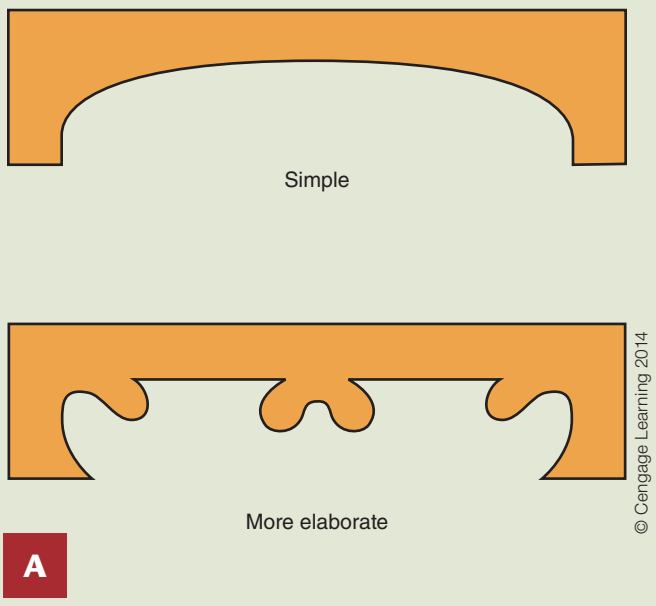
Basswood, *Tilia americana,* is also known as *American linden* or *American lime.* It is a light, cream-colored wood with a straight grain, very light in weight, and easy to work. It is considered one of the world's premier carving woods. It is odorless and for this reason has been used extensively for kitchen utensils and food containers. ■

Chest-on-Chest

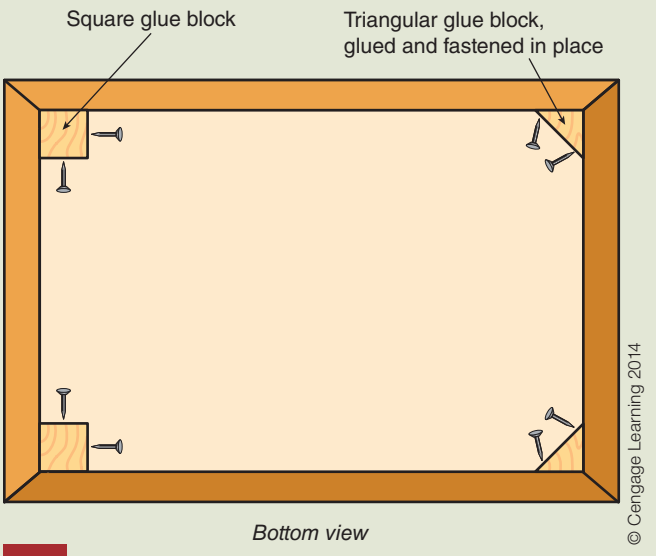
A **chest-on-chest** is just what it sounds like: One chest is placed on top of another (see **Figure 23-7**). It usually has drawers, and by placing one chest on top of another, space is saved. The chests are built

PROCEDURE 23-2

Making a Scrolled Base



A



B

STEPS

1. Select enough 3/4"-thick material to go around the perimeter of the case, allowing some extra.
2. Lay out a pattern on the base, and cut it on the band saw or with a jigsaw. It may be simple or complex. **Figure A** shows some examples.
3. Machine a 3/8" × 3/8" rabbet in the inside edge of each of the base pieces.
4. Turn the case upside down on your bench, and miter the base pieces to fit around the case, so that the rabbet supports the case.
5. Glue and brad nail the mitered pieces together.
6. Cut glue blocks to go in each corner of the base; glue and fasten in place. They may be triangular or square, as shown in **Figure B**.
7. Spread glue in the rabbet on the base and set the chest in the base.

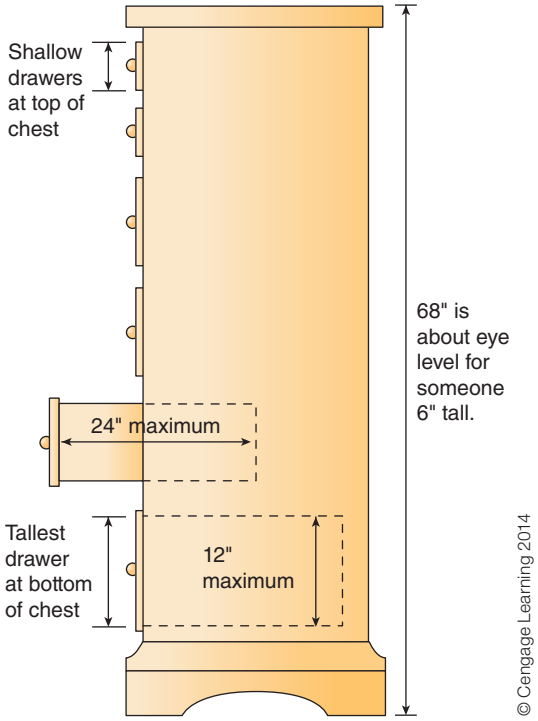


FIGURE 23-5 Chest of drawers guidelines.



Image courtesy of Thomasville Furniture

FIGURE 23-6 Chest of drawers.



Image courtesy of Thomasville Furniture

FIGURE 23-7 Chest-on-chest.

independently of one another, so they can be easily separated. General rules of thumb for the overall size of a chest-on-chest are as follows: Widths range from 36 to 48 inches, depths from 18 to 24 inches, and heights from 72 to 84 inches. You will notice that this height range severely stretches the rule about being able to see into the highest drawer, making the chest-on-chest somewhat less user friendly than the chest of drawers.

CAUTION

When crosscutting on the table saw, resist the impulse to reach over with your hand to remove the cut-off. Wait until the blade has stopped spinning.

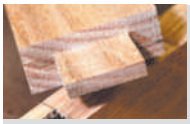
Dresser

A **dresser**, sometimes called a **bureau**, is essentially a low and wide chest of drawers. It is often part of a bedroom suite. The overall height of a dresser ranges from 29 to 34 inches. **Figure 23-8** shows an example of a dresser.



Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 23-8 Dresser.



HISTORY FACT

It is hard to imagine, but houses were once built without closets. People used a piece of furniture called an **armoire** to hold their hanging clothes. Another name for an armoire is a *wardrobe,* and it is a large, often ornate piece of furniture. Many armoires also had drawers for storing clothes that would be folded up. Today this furniture form is popular as an attractive entertainment center (see **Figure 23-9**). ■

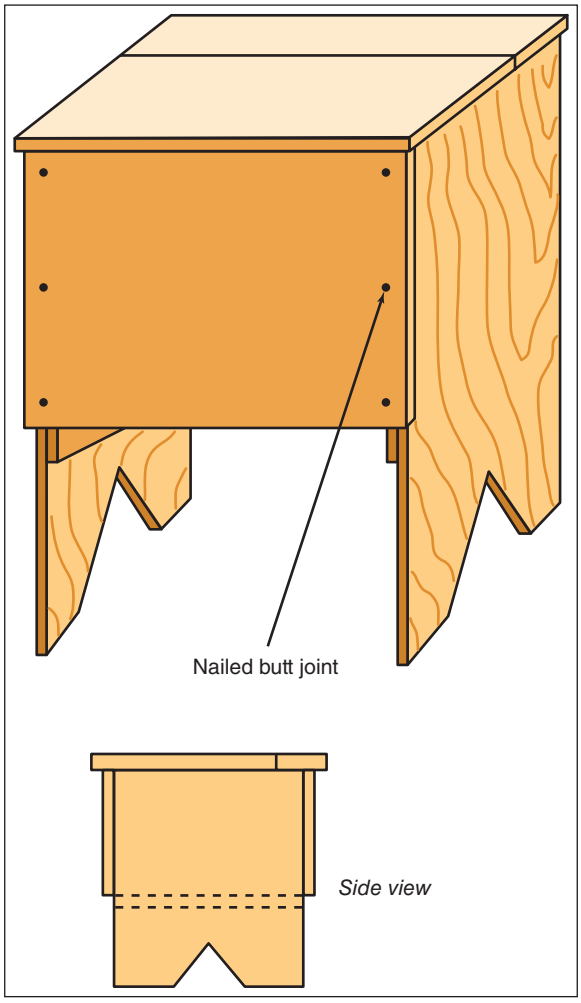


Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 23-9 Armoire.

Chests Through Time

It is interesting to look at how chests have changed through history. The accompanying illustrations and photographs (**Figure 23-10** through **Figure 23-17**) give you an idea of the vast array of possibilities available to the cabinetmaker wishing to build a chest.



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FIGURE 23-10 Primitive chest.



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FIGURE 23-11 Dovetailed chest with tray.



Image courtesy of www.amishhandcrafted.com

FIGURE 23-12 Frame-and-panel chest.



Image courtesy of the Ball & Claw, Jeffrey Greene Furnituremaker, www.JeffreyGreeneNewport.com

FIGURE 23-13 Boston bombe chest.



Image courtesy of the Ball & Claw, Jeffrey Greene Furnituremaker, www.JeffreyGreeneNewport.com

FIGURE 23-14 John Townsend block-front chest



Image courtesy of the Ball & Claw, Jeffrey Greene Furnituremaker, www.JeffreyGreeneNewport.com

FIGURE 23-15 John Townsend lowboy.

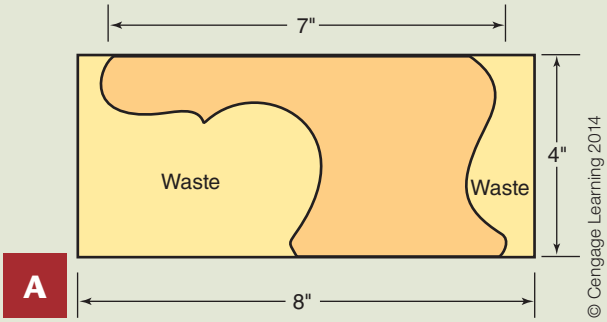


Image courtesy of the Ball & Claw, Jeffrey Greene Furnituremaker, www.JeffreyGreeneNewport.com

FIGURE 23-16 Connecticut highboy.

PROCEDURE 23-3

Making an Ogee Bracket Foot



A

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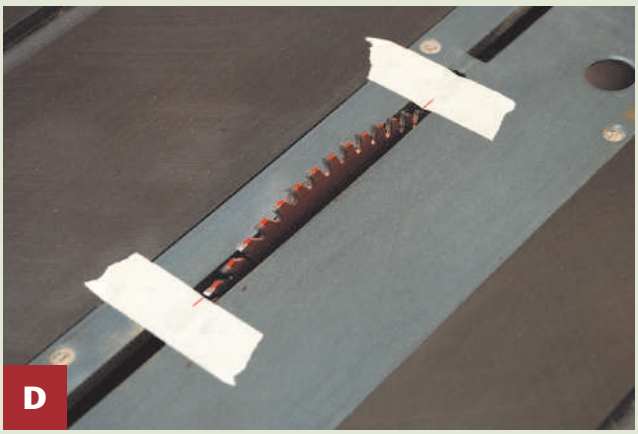
B

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C

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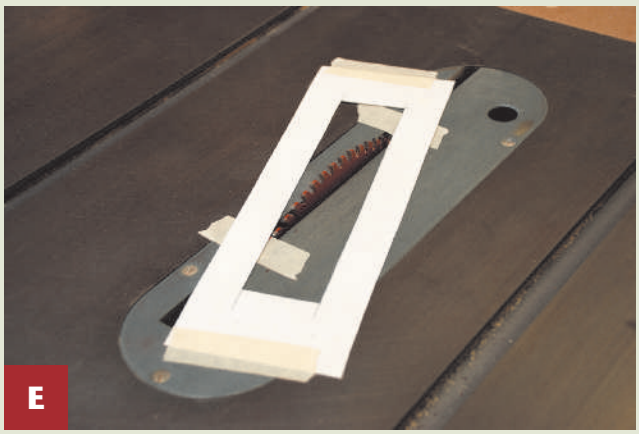
D

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STEPS

1. Make a template of the foot you want to make. **Figure A** shows a sample layout and **Figure B** is the template made from it using hardboard.
2. Mill a strip of lumber long, wide, and thick enough for both sides of the foot. This example uses a piece that is 1 1/2" thick, 4 1/2" wide, and 16" long.
3. Copy the shape of the ogee on both ends of the board, using the short part of the template as a guide. See **Figure C**.
4. Raise the table saw blade to the full height of the cove. In this case it is 5/8". Mark the points where the blade enters and exits the table (see **Figure D**).

5. Make a posterboard template with a window whose inside width is the same as the cove's final width, which in this example is 1 3/4". Place the template on the saw table and angle it so that the long edges touch the marks you made in Step 4 (see **Figure E**).
6. Mark one of the inside edges of the frame, remove the frame, and clamp a straight piece of stock to the table saw to serve as one fence. Then place the material to be machined against the fence to set the second fence (see **Figure F**).
7. Lower the blade so it is only about 1/16" above the table, and then cut the cove by making a series of light passes, raising the blade between passes until the desired depth of cove is reached, which in this example is 5/8" (see **Figure G**).
8. Elongate the cove you cut using a dado blade set to a width, height, and angle that will cut up near your layout line (see **Figure H**).



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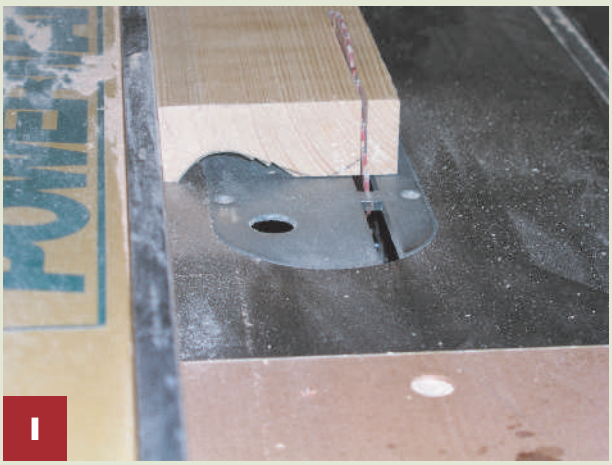
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9. Rip the blank to final width, using your layout mark as a guide (see **Figure I**).
10. Rough out the roundover located on the top outside corner with a regular blade on the table saw, tilted to 45°, as shown in **Figure J**. You might choose instead to use a round-over bit in the router table.
11. Plane and sand your foot blank to its final shape, using the ogee layout on each end as a guide.
12. Miter the blank into the two halves of the foot, and cut a groove for a spline, as shown in **Figure K**.
13. Use the long side of the template to draw the bracket outline on the flat side of each piece, setting the template on the piece so that it will end up 7" long. Cut out the shape on the band saw, as shown in **Figure L**.

14. Glue and clamp the two parts of the foot together with a spline in place. A glue block attached to the back of the miter will help keep the assembly square and add strength.
15. Remove the clamps, clean up any glue residue, and do your final sanding. **Figure M** shows the completed ogee bracket foot.



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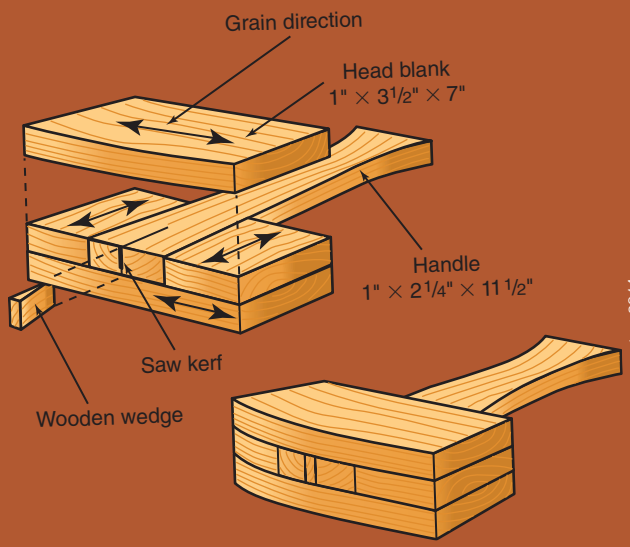


Image courtesy of the Ball & Claw, Jeffrey Greene Furnituremaker, www.JeffreyGreeneNewport.com

FIGURE 23-17 Boston serpentine-front chest.

WOODWORKING TIP:

Make a simple yet useful and attractive wooden mallet following the diagram in **Figure 23-18**. *Use hardwood scrap. The kerf into which the wedge is driven locks the mallet's handle firmly in the mallet head. For added interest, use two contrasting woods, such as maple and cherry.*



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FIGURE 23-18 Mallet diagram.



Summary

The function of chests is to provide safe, dust-free storage space. There are different types of chests, from the simple blanket chest to an elaborate chest of drawers. Whatever the type of chest, it should be easy to use, and certain guidelines are helpful when designing a chest. Introducing drawers into a chest permits a higher degree of organization, but it also means a more complicated building project.



Key Terms

armoire
blanket chest
bureau
chest of drawers
chest-on-chest
dresser



Check Your Knowledge

1. What is the simplest form of chest?
2. How can the simple chest be varied for easier use and different looks?
3. What is the rule of thumb for the top drawer in a chest of drawers?
4. What is the difference between a chest of drawers and a dresser?
5. What is another name for a dresser?
6. What are two rules governing the design and placement of drawers?
7. List four types of chests that have been developed through history.

BUILD IT!

Small Chest with Tray

Figure A shows a completed small chest with tray.

TOOLS REQUIRED

- Measuring tool
- Square
- Table saw and dado blade
- Miter saw
- Jigsaw
- Hammer and nail set
- Chisel and mallet
- Sander

MATERIALS REQUIRED

- 3/4" pine
- 1/2" pine
- 1/4" plywood for tray bottom
- Pair of surface mount stop hinges

STEPS

1. Consult the materials list given in **Figure B**, and machine and label the pieces required. If necessary, edge glue pieces to meet the required width.



A

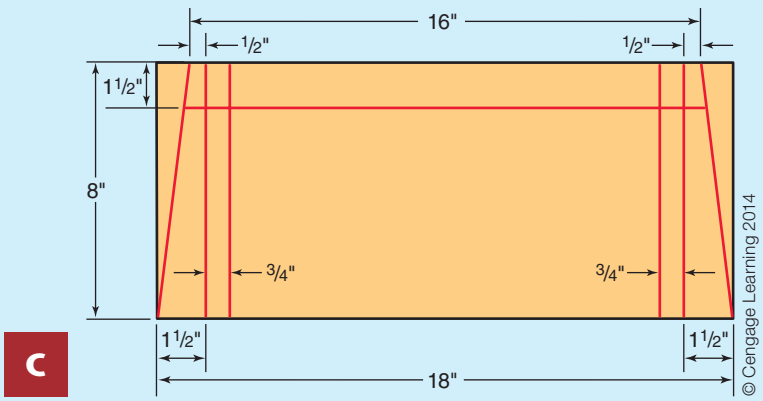
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Materials list – small chest with tray

Part	Dimensions (thickness × width × length)	Quantity
1. Side	$^3/_4$" × 8" × 18"	2
2. End	$^3/_4$" × 8" × 11"	2
3. Bottom	$^3/_4$" × $9^1/_2$" × 20"	1
4. Top	$^3/_4$" × $9^1/_2$" × 18"	1
5. Runner	$^1/_2$" × $^1/_2$" × $13^1/_2$"	2
6. Tray side	$^1/_2$" × 2" × $12^1/_2$"	2
7. Tray end	$^1/_2$" × 2" × $10^1/_8$"	2
8. Tray bottom	$^1/_4$" × $9^5/_8$" × $12^1/_2$" plywood	1
9. Surface mounted hinge 6d finish nails $1^1/_4$" screws 4d finish nails		2

B

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2. Lay out the sides for dadoes, slope, and the lid, as shown in **Figure C**.
3. Set up the dado blade on the table saw to cut 3/4" wide, and raise it so it will cut 3/8" deep. Adjust the fence for a distance of 1 1/2" to the blade.
4. Using the miter gauge, butting the end of the side against the fence, place the side face down on the table; make one dado, as shown in **Figure D**.
5. Turn the same piece around, and make the dado that will receive the other end.
6. Repeat for the other side.
7. Using a jigsaw or a band saw, cut along the slanted lines you laid out on each end of the two side pieces, as shown in **Figure E**; plane smooth.
8. Glue the ends and sides together, fitting the ends into the dados on the sides. Reinforce with 6d finish nails. Do *not* nail near the horizontal line you drew across the two sides. Set the nails using a nail set.
9. Lightly round the corners and edges of the top and bottom. You can do this with a sander.

BUILD IT!

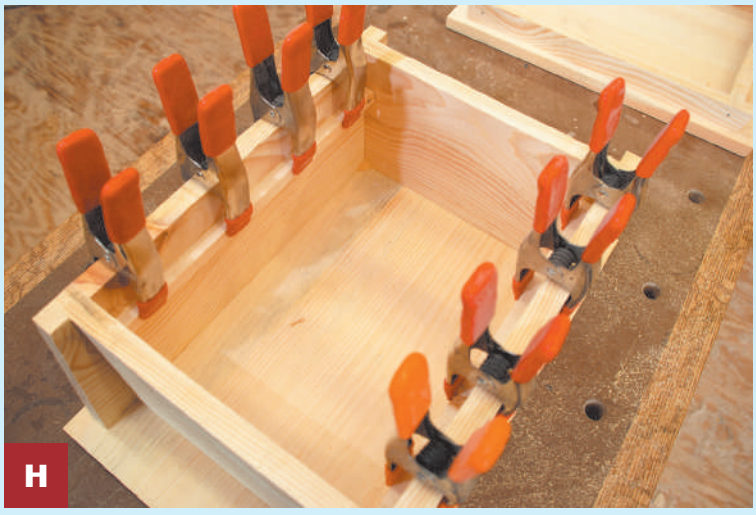
10. Glue and tack the bottom to the box to hold it in place. The box should be centered on the bottom.
11. So the box can hold significant weight, drill pilot holes and countersink 1 1/4" screws through the bottom into the box (see **Figure F**).
12. Turn the box over, and attach the top with glue and 4d finish nails. Set the nails using a nail set.
13. Measuring from the bottom of the chest, lay out lines around the chest at 7 1/4".
14. Use a jigsaw to cut along the line laid out in the previous step, separating the lid from the box as shown in **Figure G**.
15. Use a plane to clean up the sawn edges.
16. Glue and clamp the runners that will support the tray inside the box on either side; set them 1 3/4" down from the top edge of the box, as shown in **Figure H**.


F

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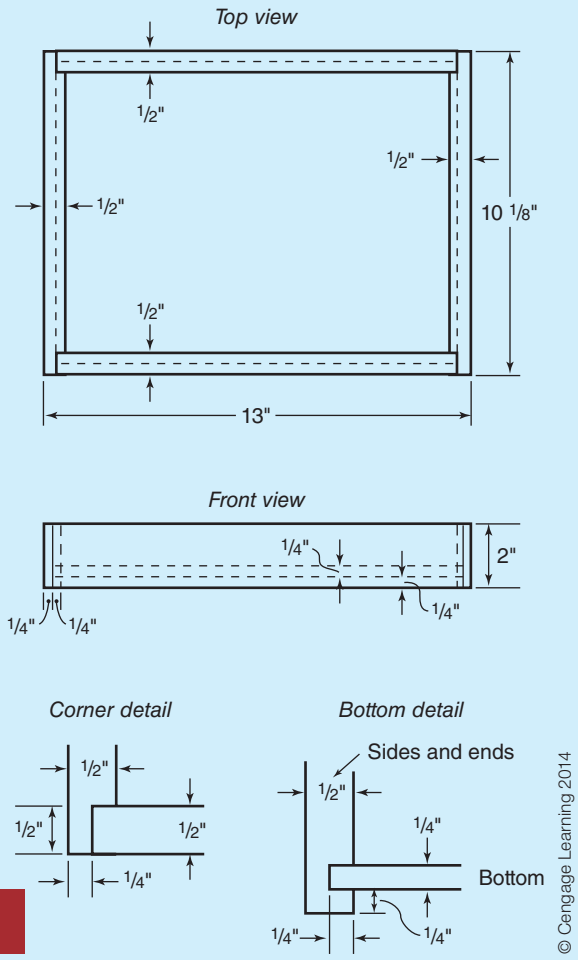

G

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H

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BUILD IT!



I

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17. Build the tray as diagrammed in **Figure I**, gluing and fastening the ends and sides with 4d finish nails.
18. Attach the lid to the box with two surface-mounted stop hinges, like those shown in **Figure J**.
19. To keep the top securely closed, you may wish to install a centered latch, like the one shown in **Figure K**.
20. Remove the hardware, sand as needed, and finish as desired. When the finish is dry, reattach the hardware.



J

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K

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BUILD IT!

PROJECT CHALLENGE

Dovetailed Blanket Chest

Figure A shows the completed dovetailed blanket chest.

STEPS

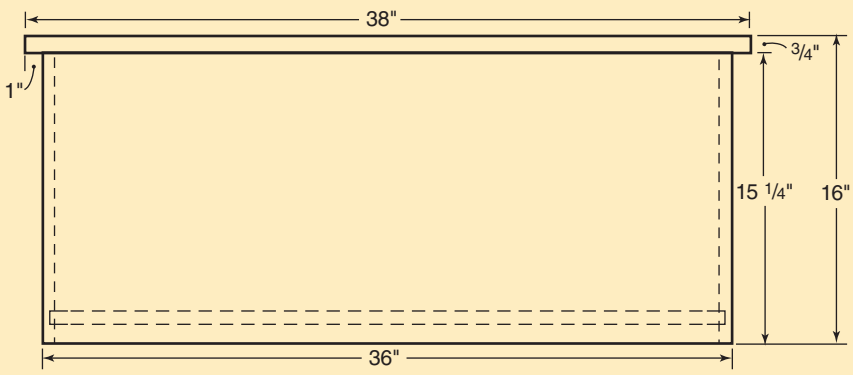
1. Using the plans given in **Figure B**, determine the parts needed and their sizes.
2. Glue up oversized blanks for the sides, ends, top, and bottom.
3. Mill the front, back, and sides to final size.

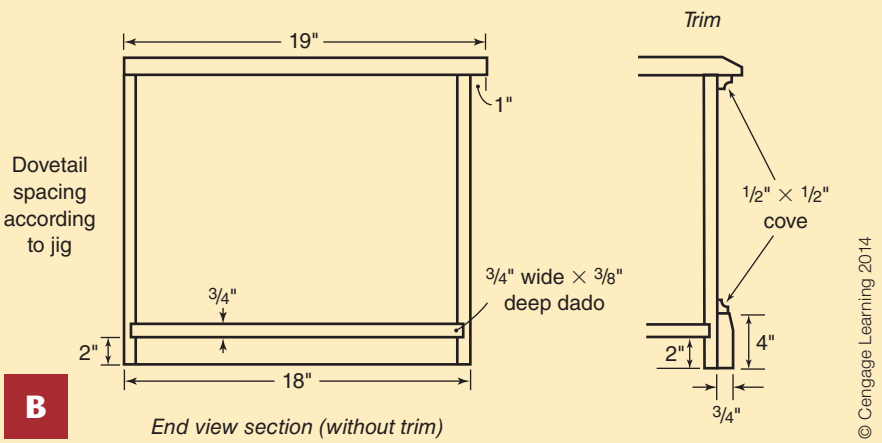


A

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Front view (without trim)





B

End view section (without trim)

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C

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D

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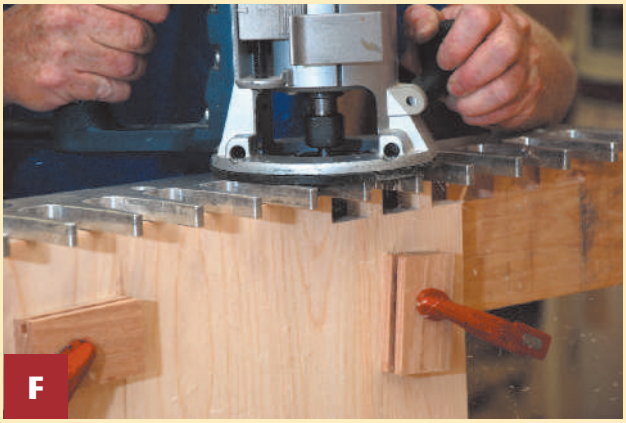


E

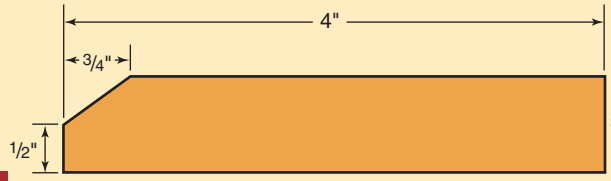
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4. Set up a through-dovetail jig, and rout the tails on both ends of the front and back with the dovetail bit, as shown in **Figure C**.
5. Lay out the sides and ends of the chest on the table, and identify each corner (see **Figure D**).
6. Mark the pin locations on the ends from the tails on the sides, putting the corners together so they correspond with the identifying marks you made in Step 5 (see **Figure E**).

7. Change the bit in the router to the straight bit, switch to the pin template, and rout the matching pins on the sides, as shown in **Figure F**.
8. Use a router or a table saw with a dado blade to machine the 3/4"-wide by 3/8"-deep dado in the front, back, and sides to accept the bottom.
9. Determine the size of the bottom, subtracting 1/4" in width to allow for expansion and contraction. Mill this piece.
10. Sand the insides of each piece, and assemble the box; glue the dovetail joints but *not* the bottom.
11. Cut the pieces for the larger piece of base trim over length, and plane the bevel, as illustrated in **Figure G**.
12. Miter the base trim to fit around the chest. Glue and attach, as shown in **Figure H**.
13. You can make up the trim for the top and the additional base trim at the same time. Rout a 1/4" cove on both sides of oversized pieces, as shown in **Figure I**.


F

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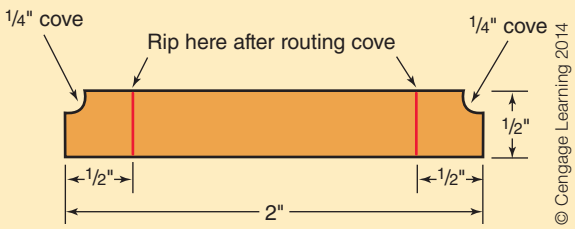


G

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H

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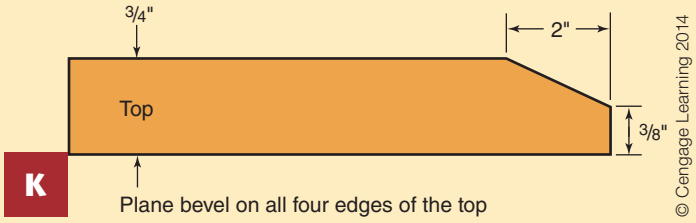
I

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J

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K

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L

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14. At the table saw, rip off the cove trim from both sides of each blank.
15. Miter, glue, and attach the cove trim. The top trim can be clamped in place. Use brads to secure the bottom trim, as shown in **Figure J**.
16. Cut the top to size and plane a bevel on the edges as shown in **Figure K**.
17. Attach the top to the chest with no-mortise hinges.
18. Install an eye hook in the lid and another in the box. Run a length of light chain from eye hook to eye hook to keep the lid from falling all the way back when opened (see **Figure L**).
19. Remove the hardware, sand the chest, and then finish as desired.
20. Reattach the hardware.



24

Beds

You'll Learn

After studying the chapter, the student should be able to:

- Describe different types of beds
- Explain the construction of a simple bed
- Understand the standards associated with bed construction
- Give examples of various kinds of beds

INTRODUCTION

We all know what a bed is. But are you aware of the wide range of beds available? Of course, beds vary in size, from twin beds to full beds, queen size, king size, and oversize king beds. Beyond size, though, there are different types of beds. Examples include the basic four-poster bed, sleigh beds, canopy beds, bunk beds, platform beds, futon beds, captain's beds, trundle beds, and Murphy beds.

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BASIC BED CONSTRUCTION

The framework of a bed is called a **bedstead** or a **bedframe**. The classic bed form has four posts, a headboard, a head rail, a foot rail, two side rails, and **slats** to support the box springs. It may or may not have a footboard (see **Figure 24-1**). Sometimes, instead of slats, a piece of plywood is used, which sometimes means no box springs will be used.

The **headboard** is attached at the head of the bedstead. Its basic function is to retain the pillows and other bed linens. However, a headboard frequently has aesthetic as well as utilitarian value, perhaps providing a decorative focus. It may also provide storage. The **footboard** is a board or panel forming the foot of the bedstead and also often has an aesthetic function.

There are four posts, one at each corner of the bedstead. The two posts at the head of the bed are connected by a **head rail** and the headboard. The posts at the bottom of the bed are connected by the **foot rail** and footboard, if there is one. The **side rails** run the length of the bed between the posts. The rails and either slats or plywood work together to support the box springs and mattress.

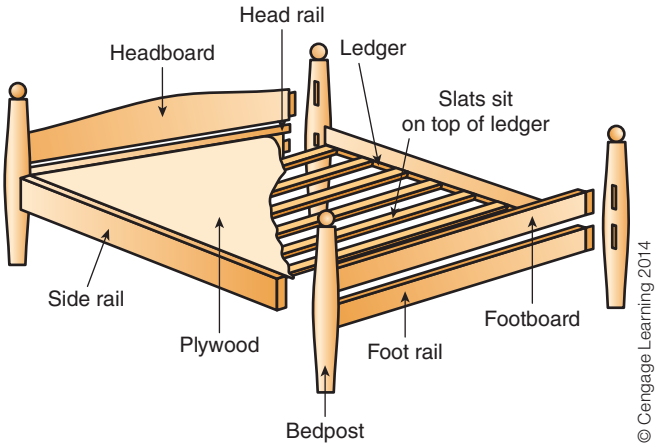
Within this basic framework, many variations are possible. The posts may be square, turned, or tapered. The headboard and footboard may take different shapes.

There are two general construction techniques for assembling the parts of a bed. The headboard and head rail and footboard and foot rail may be permanently attached to two posts each. The headboard and footboard assemblies are usually mortised together. In the second technique, the posts may not be permanently connected to any other parts. The side rails that connect the headboard and footboard assemblies are removable in either case, making transport of the bed possible. The removable slats run from side rail to side rail, sitting on the ledger which is securely attached to the rails. The posts are connected to the side rails and to the head rail and foot rail, if the posts are separate parts, using specific hardware designed for this purpose. **Figure 24-2** shows examples of bed assembly hardware.



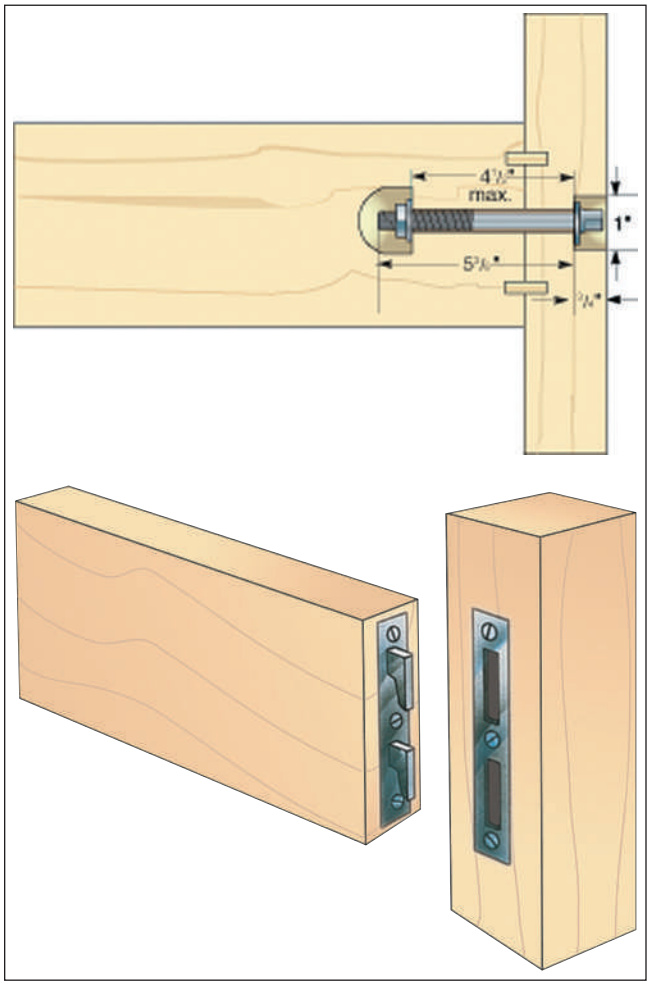
FACTS ABOUT WOOD

Butternut, *Juglans cinera,* is a member of the walnut family and is sometimes called *white walnut,* which is the literal translation from the Latin. Its heartwood is medium to dark brown in color, and it has a straight grain and coarse texture. It is a wood that is light in weight, and it is relatively soft and weak. It works easily with both hand tools and power tools, glues well, and polishes to a fine finish. It is a very good carving wood and is used for furniture, interior joinery, church altars, and boxes. ■



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FIGURE 24-1 Basic bed anatomy.



Images courtesy of rockler.com

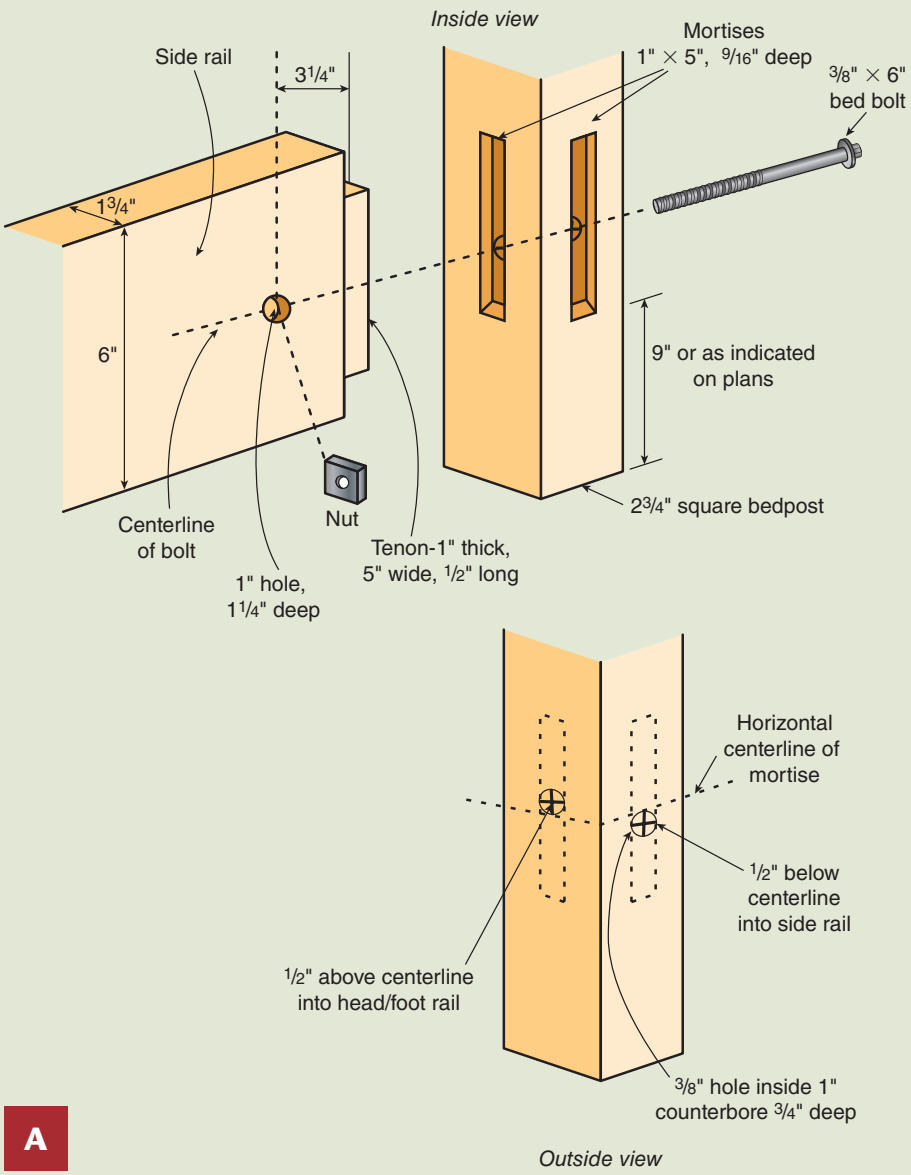
FIGURE 24-2 Two different types of bed hardware.

PROCEDURE 24-1

Installing Bed Bolts

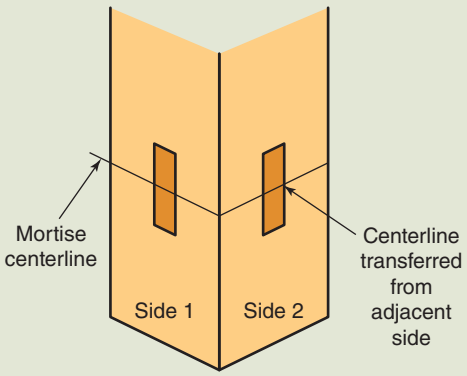
STEPS

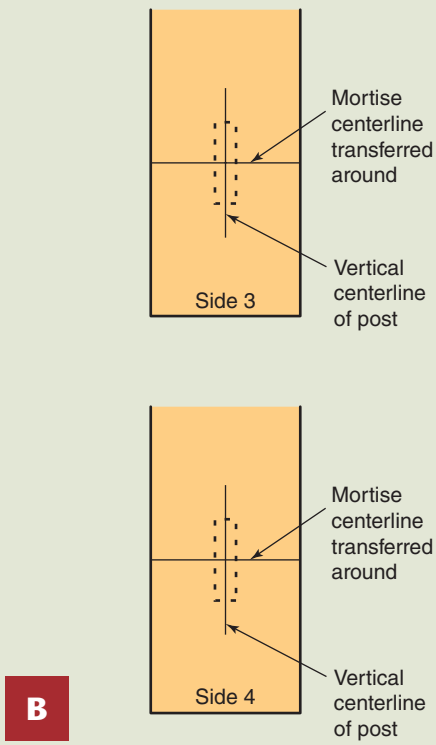
1. Mill centered mortises that are 1″ wide by 5″ long and 9/16″ deep in the post. If the posts are separate from the head rail and foot rail, you will need to make mortises for attaching the head rail and foot rail, as well as the side rails. If the foot rail and head rail are integral parts of the headboard and footboard assemblies, you will only need one mortise in each post. **Figure A** shows an illustration of a situation using two bed bolts per post.
2. Make tenons on the 1 3/4″-thick by 6″-wide rails to match the mortises. Make them 1/2″ long. This allows a bit of extra room in the end of the mortise, which will allow you to pull the rails tight to the posts.

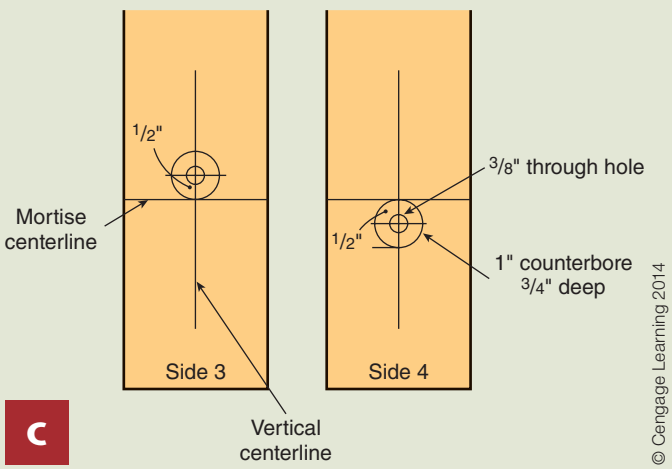


A

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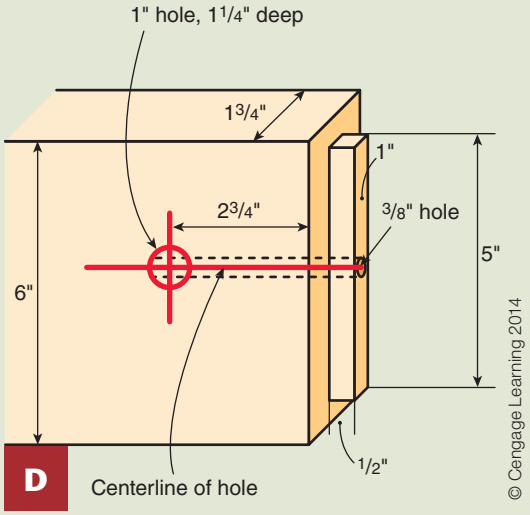






3. Mark the horizontal centerline of the mortise in each post and transfer it around to the opposite side of the post. Then mark the intersecting vertical centerline, as shown in **Figure B**.
4. If the posts will be connected to both the side rails and head and foot rails with bed bolts, measure and mark 1/2" above the horizontal centerline for one mortise and 1/2" below the centerline for the other mortise, as shown in **Figure C**. If only one bed bolt is used on each post, this step is not necessary. The hole will be drilled at the centerline.
5. Take the post to the drill press and drill 1" counterbores 3/4" deep at each marked location. Then drill 3/8" holes centered in the counterbore the rest of the way through the post.
6. Clamp the rails to the post and, using a long 3/8" bit, drill 3 3/4 " into the side rails.

7. Use a square and pencil to carry the centerline of the 3/8" hole just drilled around to the inside of the rail; measure over and mark 2 3/4" from the shoulder of the tenon, as shown in **Figure D**.
8. Use a 1" Forstner bit to drill a hole 1 1/4" deep at the centerline just marked.
9. Insert the bed bolt through the post and into the tenon. Its nut is held in the 1" hole drilled in the rail, and the bolt is tightened down, securely attaching the post to the rail.
10. Cover the holes in the posts with purchased bed bolt covers, as shown in **Figure E**, or make your own.





Standards for Beds

There is really only one standard for building beds, but it is very important. The bed must be able to accommodate the box springs and mattress, and mattresses are built to certain specific sizes. See **Figure 24-3** for more information. Of course, it is also critically important that the bed be built sturdily enough to support the load that will be placed on it.

The opening created for the box springs and mattress between the head rail, foot rail, and side rails should be slightly larger than the mattress to allow for tucking in the bed clothes. Adding an inch to the mattress size in both length and width is a good rule of thumb. Additionally, the bed should be built so that when it is assembled, it is at a comfortable height to get in and out of easily. The recommended height from the floor to the top of the mattress is 24 to 27 inches. The thickness of the bedding must be taken into account in these calculations, and 7 inches each for the mattress and box springs is standard.

The simplest form of bed is the **platform bed**. The platform is made of sheet goods, often plywood. This platform holds the box springs and mattress or, more frequently, simply a mattress. Platform beds may look like regular beds, as **Figure 24-4** illustrates, or they may consist of a base that supports the platform, as shown in **Figure 24-5**. The base is essentially a large box, smaller than the platform. One advantage to this type of bed is that there are no posts at the corners to stub a toe on. Platform beds can provide storage space by having drawers built into the sides of the base. Waterbeds generally use a platform-style bedstead.

Standard bed dimensions

Bed frames are designed to support mattresses, box springs, and futons with ample room for bedclothes.

Width and length

Bedding style	Interior frame width (mattress width)	Interior frame length (mattress length)
Crib	28" (27")	55" (54")
Single	37" (36")	77" (75")
Twin	40" (39")	77" or 82" (75" or 80")
Double	55" (54")	77" or 82" (75" or 80")
Queen	61" (60")	82" or 86" (80" or 84")
King	77" (76")	82" or 86" (80" or 84")

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FIGURE 24-3 Table of mattress sizes.



Image courtesy of PlatformBeds.com

FIGURE 24-4 Platform bed.



Image courtesy of PlatformBeds.com

FIGURE 24-5 Platform bed.

GREEN REMINDERS

Careful layout and machining means less waste.

Futon beds, which are a combination sofa and bed, are generally situated 12 to 15 inches off the floor; futon mattresses range in thickness from 3 to 6 inches, and they are more flexible than ordinary mattresses. **Figure 24-6** shows a futon bed in both its sofa and bed configurations.

CAUTION

Keep your cutting tools sharp. The harder you have to push, the less control you have, and the more likely you are to have an accident.

Types of Beds

The best way to illustrate the many types of beds is through a series of pictures. **Figures 24-7** through **Figure 24-20** show a variety of attractive styles.



Image courtesy of rockler.com



Image courtesy of rockler.com

FIGURE 24-6 Futon bed in its sofa configuration and as a bed.



Image courtesy of Countryside Amish Furniture, LLC., www.countrysideamishfurniture.com

FIGURE 24-7 Four-poster bed.



Image courtesy of Amish Traditions

FIGURE 24-8 Banister bed.



Image courtesy of Amish Traditions

FIGURE 24-9 Pencil-post bed.



Image courtesy of Thomasville Furniture

FIGURE 24-10 Sleigh bed.



Image courtesy of PlatformBeds.com

FIGURE 24-11 Canopy bed.



Image courtesy of Amish Traditions

FIGURE 24-12 Bunk beds.



Image courtesy of Amish Traditions

FIGURE 24-13 Captain's bed.



Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 24-14 Panel bed.



Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 24-15 Spindle bed.



Image courtesy of Amish Traditions

FIGURE 24-16 Bookcase bed.



Image courtesy of Thomasville Furniture

FIGURE 24-17 Day bed.



Image courtesy of rockler.com

FIGURE 24-18 Crib.



Courtesy of Hayneedle, www.hayneedle.com

FIGURE 24-20 Trundle bed.



Image courtesy of rockler.com



Image courtesy of rockler.com

FIGURE 24-19 Murphy bed closed and opened.

WOODWORKING TIP:

The throat plate that comes with a table saw usually leaves a gap around the blade that allows the blade to be tilted. However, it also means that your material is not well supported beneath the cut. You can easily make a zero-clearance throat plate that will minimize the chipping that can occur with a factory throat plate. Trace the factory throat plate onto a piece of cabinet plywood or melamine, or mill a piece of solid wood to the same thickness as the factory throat plate. Cut it out and sand it to fit. Lower the blade on your saw, fit the throat plate, and clamp it in place. The rip fence can be used to do this, if care is taken not to lock it in place over the blade. Turn on the saw and slowly raise the blade to the height you need. This will give you a throat plate that will fully support your work as you cut.

PROCEDURE 24-2

Installing Mortised Bed Rail Fasteners



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STEPS

1. Center the male bracket both horizontally and vertically on the end of the rail to which it will be fastened; mark around it, as shown in **Figure A**.
2. With a chisel and mallet, mortise out the marked area so that the plate of the bracket will sit flush with the end of the rail.
3. Place the bracket in position on the end of the rail, drill pilot holes, and screw the bracket in place.
4. Position the female bracket in the desired location on the post and mark around it.
5. Chisel out a recess for the plate of this bracket in the post.
6. Place the female bracket in the recess in the post, and mark out the location for the hook mortises (see **Figure B**).
7. Remove the bracket and use a 1/4" bit to drill overlapping holes 1/2" deep in the two marked locations; finish the mortises with a chisel.
8. Set the female bracket in position on the post, drill pilot holes, and screw the bracket in place.



Summary

There are many different sizes and kinds of beds. The basic bed consists of four posts, a headboard, a footboard, two rails, and bed slats. By varying these elements, many different looks can be achieved. The critical standard that must be observed in building beds is that the mattress and box springs must fit the bed.



Key Terms

bedframe
bedstead
footboard
foot rail
futon beds
headboard
head rail
platform bed
side rails
slats



Check Your Knowledge

1. What are the parts of a simple bed?
2. How are the posts usually connected to the headboard or footboard?
3. Why are most beds built so that the rails can be detached from the headboard and footboard assemblies?
4. How can the side rails be attached to the headboard and footboard assemblies?
5. What kind of bed utilizes the space under the bed for storage?
6. Which types of beds fold up?
7. Which bed has a curved headboard and footboard?
8. What are three ways the posts can be varied?
9. What is the most important consideration to keep in mind when building a bed?

BUILD IT!

Simple Low Platform Bed



A

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Figure A shows a completed low platform bed.

TOOLS REQUIRED

- Measuring tool
- Square
- Circular saw or power miter saw
- Table saw and dado blade or router table and 3/4″ straight bit
- Drill, 1/8″ bit, and 3/8″ flat-bottom bit
- Drill press and 3/8″ plug cutter
- Chisel or plane
- Sander

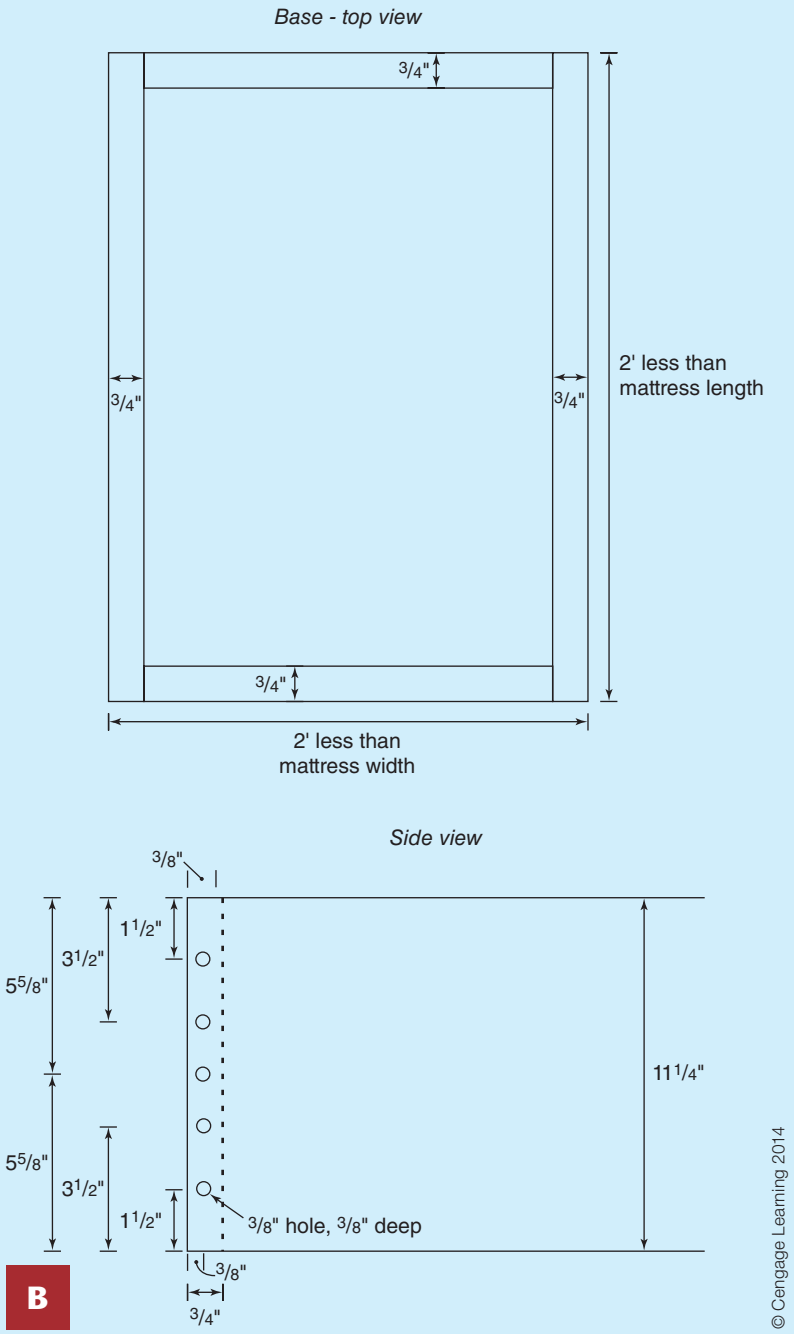
MATERIAL REQUIRED

- 1″ × 12″ pine
- 1″ × 6″ pine
- 3/4″ plywood
- 10 L-brackets and screws
- 2 1/2″ screws
- 6d finish nails

STEPS

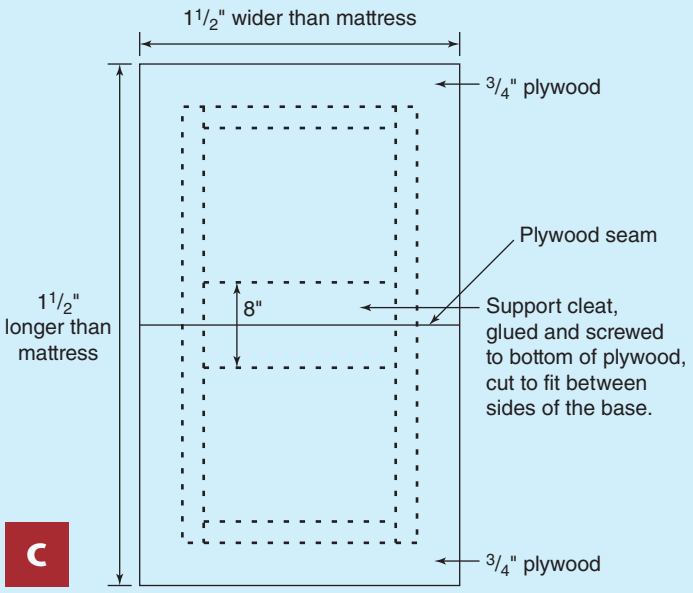
1. Measure the mattress you will be using on your bed, or consult the mattress sizing chart given earlier in the chapter.
2. Subtract two feet from the length and width of the mattress. This is the size of the box that will be built to support the platform.

3. Use the 1″ × 12″ pine to build the box. Use simple butt joints to attach the sides to the ends. Counterbore 3/8″ holes 3/8″ deep; drill 1/8″ pilot holes, and use 2 1/2″ screws. See **Figure B** for a diagram. Using 1″ × 12″s will result in a low bed. If you desire a higher bed, glue up material to reach the desired height.
4. Use the plug cutter on the drill press to make plugs to fill the counterbores you made in the base. Glue in place; when dry, plane or chisel flush with the surrounding surface.

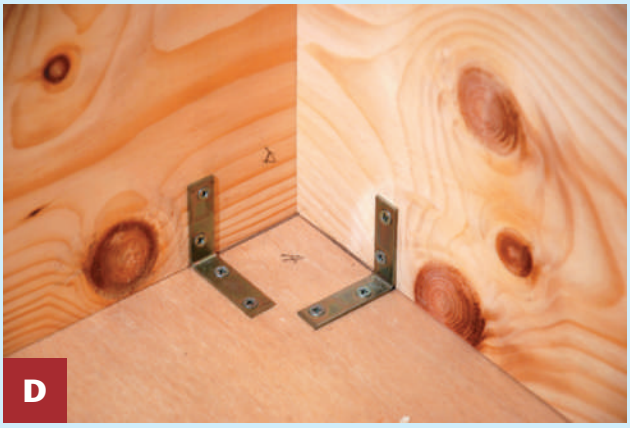


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BUILD IT!



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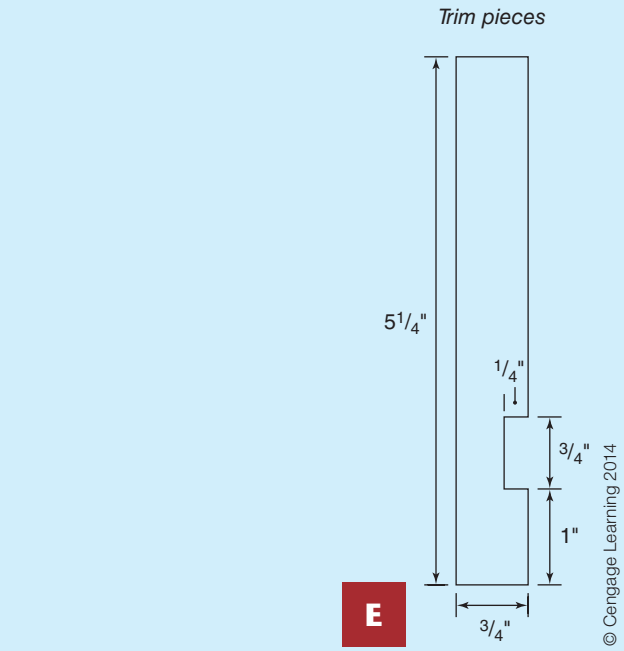


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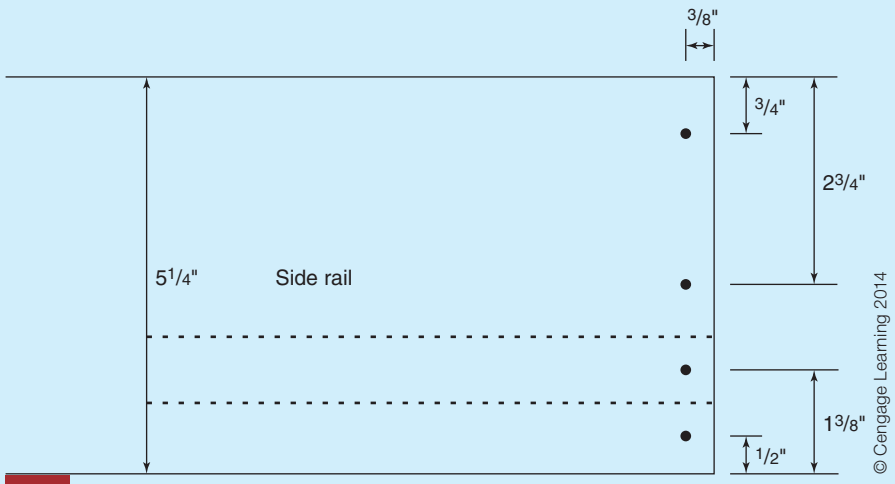
5. Add 1 1/2" to the length and width of the mattress and cut the 3/4" plywood to these dimensions. If you are building a twin bed, a single sheet of plywood will be enough. A bigger bed will require two sheets. If two sheets are needed, the joint between the two should run across the width of the bed. The two pieces should be reinforced from below using pine or plywood scrap glued and screwed in place, as shown in **Figure C**.
6. Center the base on the plywood platform and fasten them together with the L-brackets, as shown in **Figure D**.

BUILD IT!

7. Turn the bed right side up.
8. Joint, rip, and joint the 1″ × 6″ material to 5 1/4″ wide. Mill a 3/4″ dado 1/4″ deep in the 1″ × 6″ material as shown in **Figure E**.
9. Cut the 1″ × 6″ material to fit around the plywood. Pieces should run the length of the long sides, with the ends fit between them. Refer to **Figure F** for screw locations in the side rails and layout. Counterbore 3/8″ holes 3/8″ deep and predrill for the screws using a 1/8″ bit.
10. Spread glue in the dados on the rails, fit onto the plywood, and attach the side rails to the head and foot rails with 2 1/2″ screws. Drive 6d finish nails through the rails into the plywood, spacing them about 10 inches apart.
11. Make plugs and glue into the counterbored holes. When the glue is dry, plane or chisel flush.
12. Sand and finish as desired.



E



F

BUILD IT!

PROJECT CHALLENGE

Pencil-Post Bed



A

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Assembly list - pencil-post bed

Part	Dimensions (thickness × width × length)	Quantity
Post	$2\frac{1}{2}$" × $2\frac{1}{2}$" × 70"	4
Head rail	$1\frac{3}{4}$" × $3\frac{3}{4}$" × $55\frac{1}{2}$"	1
Foot rail	$1\frac{3}{4}$" × $3\frac{3}{4}$" × $55\frac{1}{2}$"	1
Side rail	$1\frac{3}{4}$" × $3\frac{3}{4}$" × 77"	2
Headboard	$\frac{3}{4}$" × $20\frac{1}{2}$" × $55\frac{1}{2}$"	1
Ledger	1" × 1" × $75\frac{1}{2}$"	2
Spreader	1" × 2" × $54\frac{1}{2}$"	1
Headboard cleat	$\frac{3}{4}$" × 2" × $17\frac{1}{2}$"	2
Dowel pins	$\frac{1}{4}$" × 2"	10
Bolt covers	$\frac{1}{4}$" × $1\frac{1}{2}$" × $2\frac{1}{2}$"	4
Screws - ledger to side rail	#8 × 2" wood screws	16
Screws - headboard cleats	#6 × $1\frac{1}{4}$" wood screws	8
Screws - spreader to ledger	#6 × $\frac{3}{4}$" wood screws	2
Screws - bolt covers	#6 × $\frac{3}{4}$" brass wood screws	4
Bed bolts + nuts	$\frac{3}{8}$" × 6"	4

B

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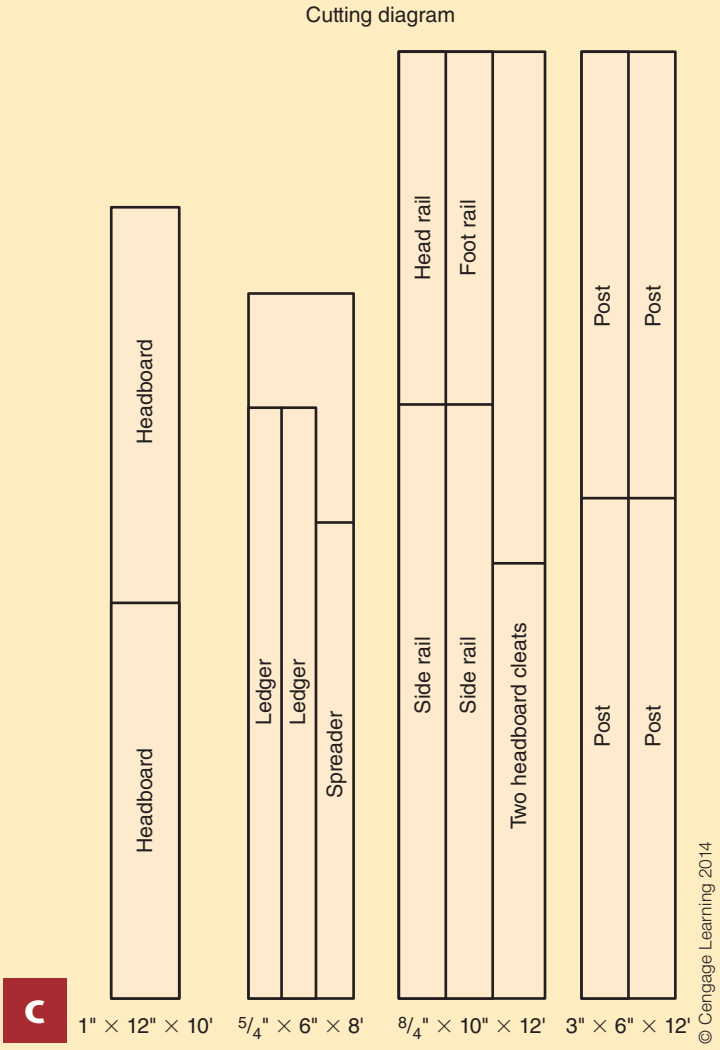
Figure A shows the completed pencil-post bed.

STEPS

1. Refer to the assembly list given in **Figure B**, and gather the material you will need.

Figure C shows a cutting diagram you can use if you can get pieces of the sizes indicated. You may find that you have to glue up pieces to get the thicknesses required.

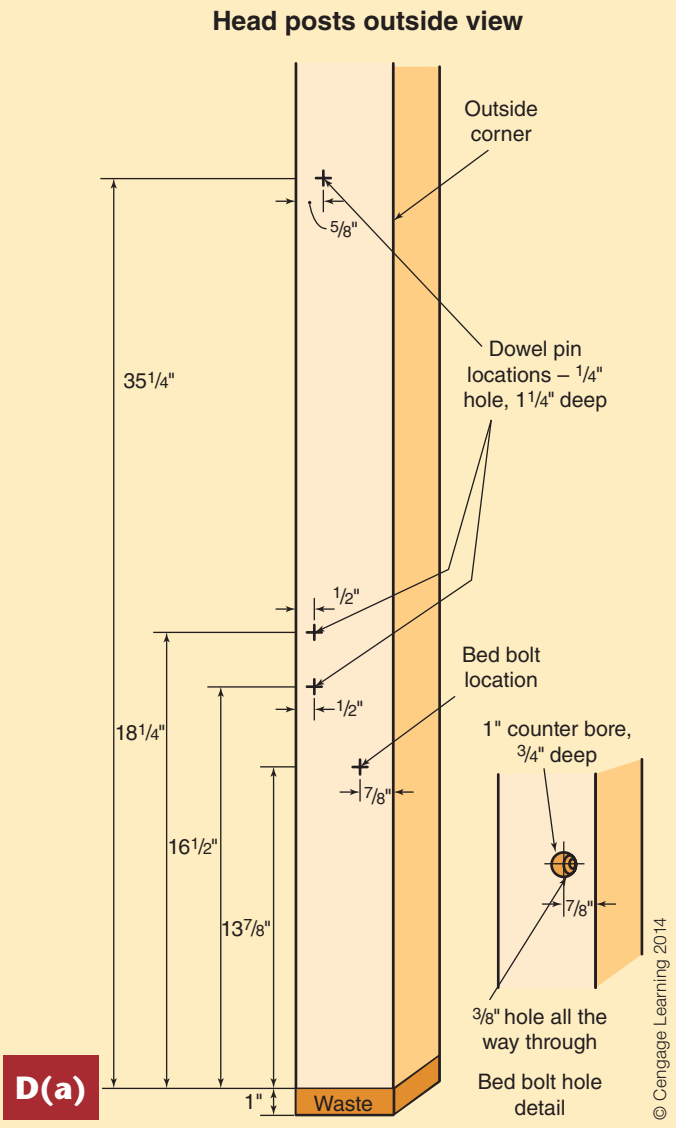
2. Cut the four posts, adding 2" in length to each one for waste. Joint, rip, and plane them square.
3. Label each post so you will not get confused about the layouts to come.

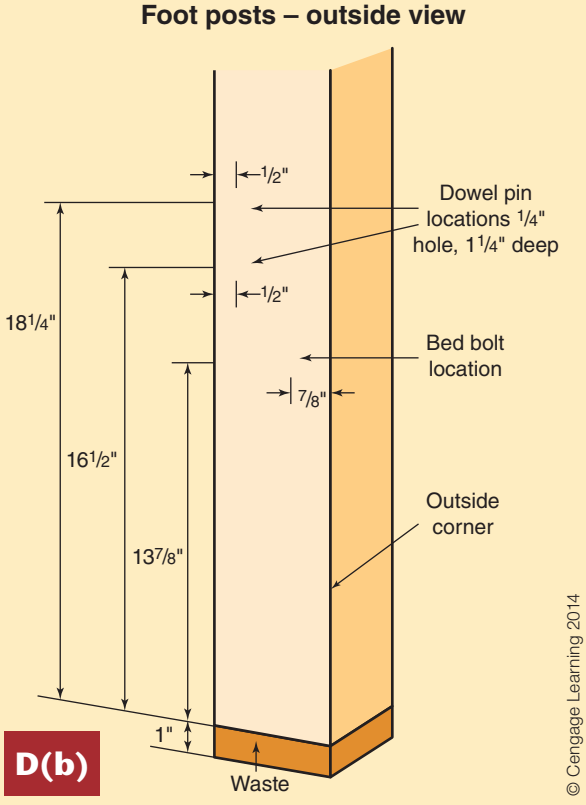


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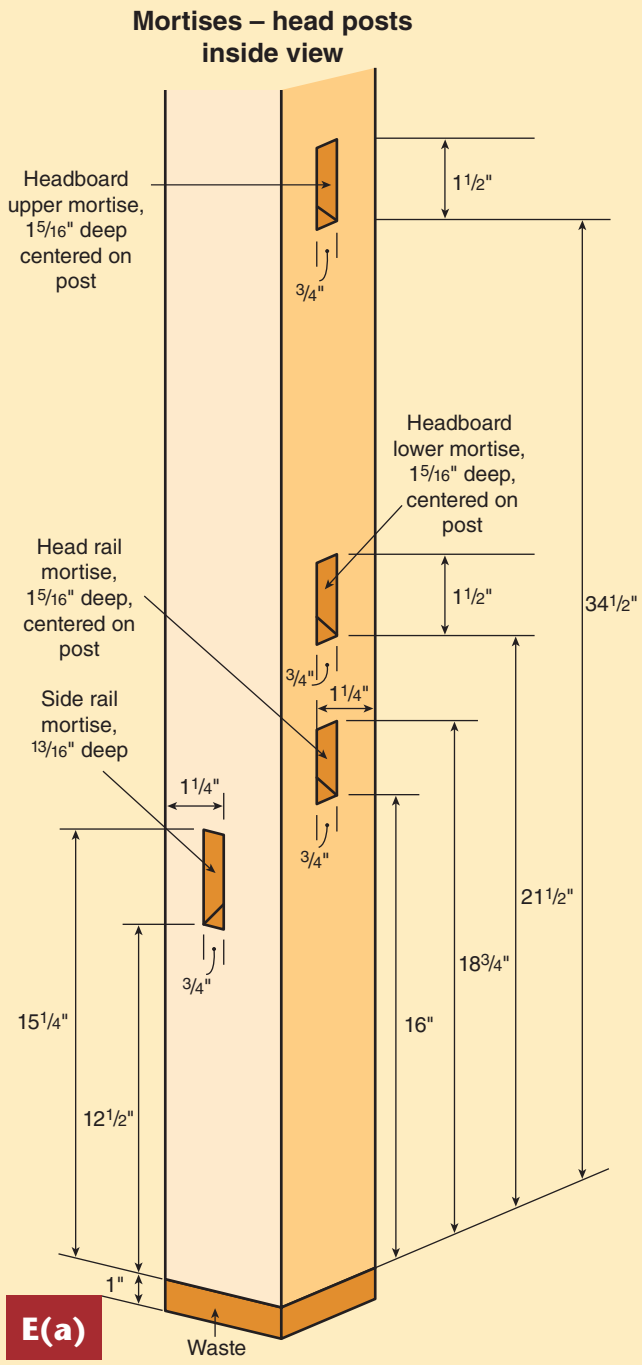
4. Referring to **Figure D**, lay out the locations for the bed bolts and for the dowel pins that will secure the tenons in their mortises.
5. On the drill press, drill the 1"-diameter counterbores for the bed bolts 3/4" deep. Change to a 3/8"-diameter bit, and drill the rest of the way through the post.

   Drill 1/4" holes 1 1/4" deep for the dowel pins in the places indicated.

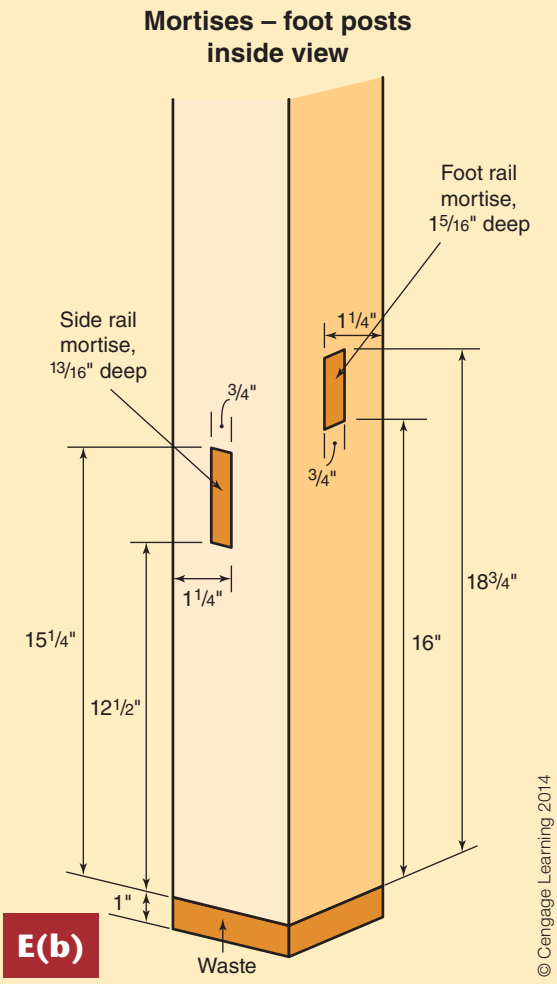




6. Consult the diagram given in **Figure E**, and lay out the mortises in each post.



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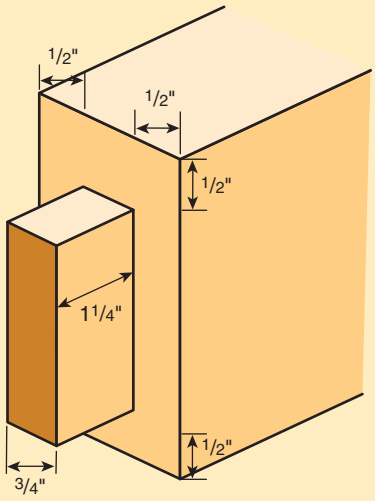


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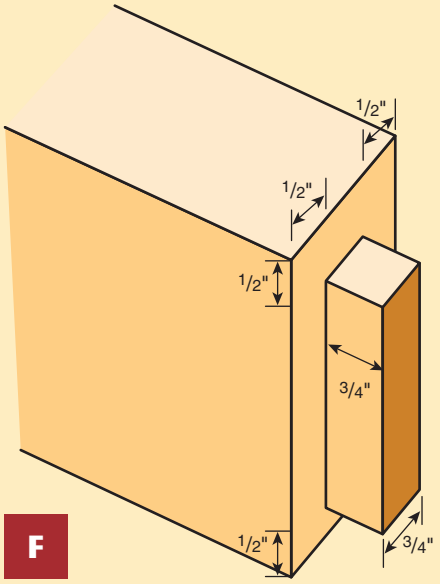
7. Install a 3/4" mortising bit in the mortising machine, and cut the mortises to the required depth.
8. Cut the head rail, foot rail, and two side rails to the sizes given in the assembly list.

9. Lay out the tenons on the rails as shown in **Figure F**.
10. Cut the tenons and pare them to fit their respective mortises. As they are trimmed to fit, label each tenon and its corresponding mortis with a letter for easy reassembly later. For example, tenon A fits into mortise A, tenon B fits into mortise B, and so on.
11. Assemble two posts with a side rail clamped between them; use a long 3/8" bit to extend the bed bolt hole in the post 4 3/4" into the side rail. Repeat at each bed bolt location.

Head rail and foot rail tenons

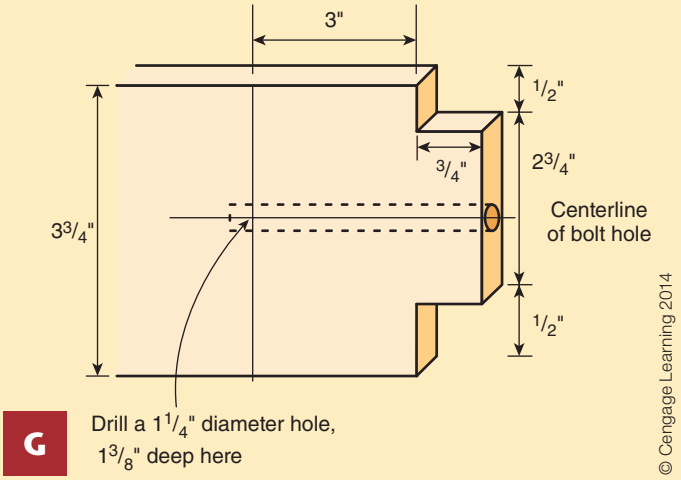


Side rail tenons

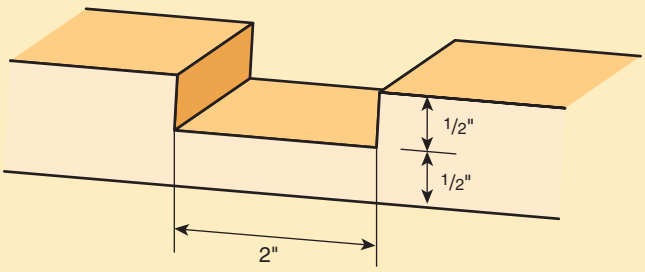


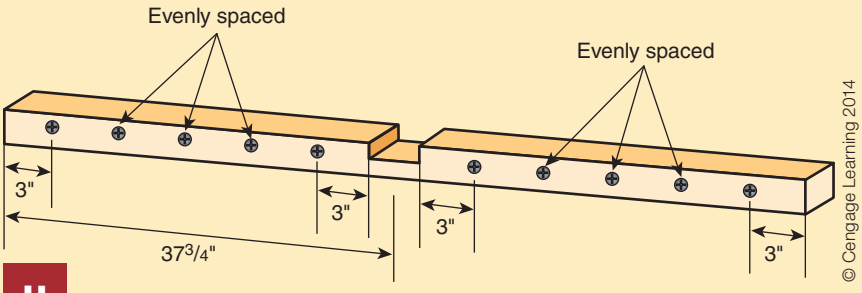
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G

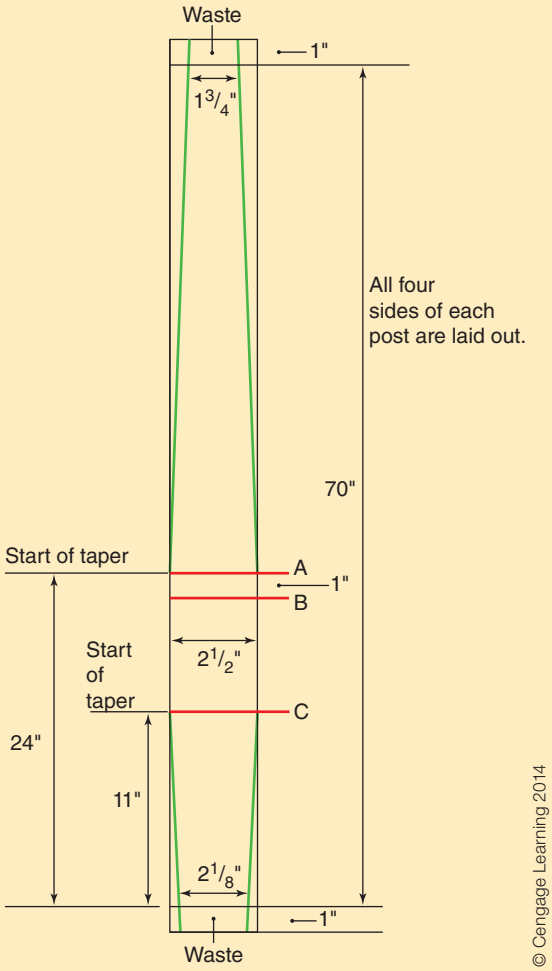




H

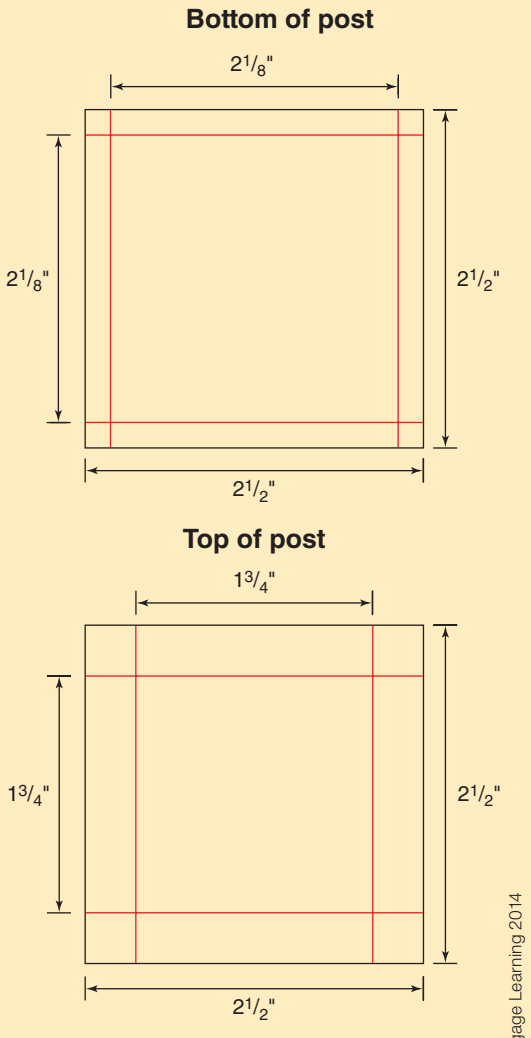
12. Lay the side rails on the bench with the inside face up, and extend the centerline of the hole. Measure over 3" from the tenon shoulder, and square a line down, as shown in **Figure G**. At the point where the two lines intersect, drill a 1 1/4" hole that is 1 3/8" deep.
13. Cut the ledgers to size. The ledgers attach to the side rails. Mark the center of each one, and cut a halved joint, as shown in **Figure H**.
14. Again referring to Figure H, lay out, drill, and countersink for the #8 × 2" screws that will attach the ledgers to the side rails.

15. Glue and screw the ledgers to the inside of side rails, flush with the bottom.
16. Consulting **Figure I**, lay out lines A, B, and C and then the lower and upper tapers on all four sides of each post. Square a line around the top and bottom of the posts 1″ in from the top and bottom of each post. This is a waste line; 1″ will be cut off the top and bottom of each post later.



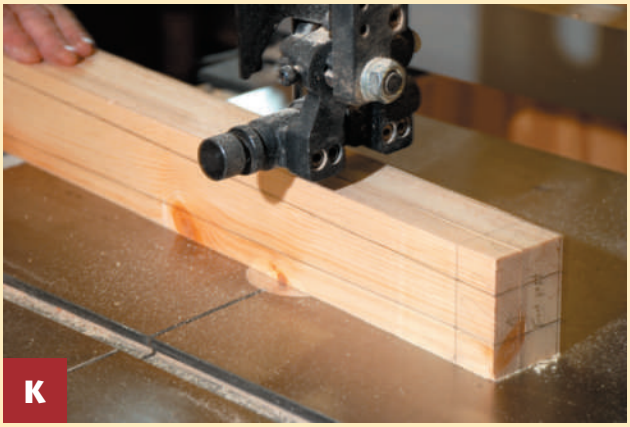
I

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J *Note:* Dimensions are slightly less than $2\frac{1}{8}$" and $1\frac{3}{4}$" square due to waste sections at either end of the post.



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K

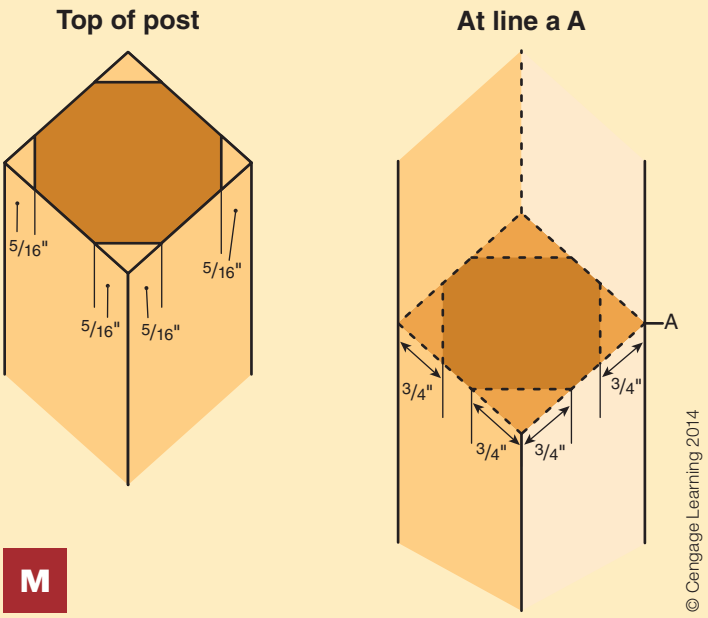
17. Connect the taper lines on the ends of each post, as shown in **Figure J**.
18. The long tapers on the posts can be rough-cut on the band saw, as shown in **Figure K**. Cut two opposite sides, making sure to leave the line.

19. Plane to the lines to establish the tapers, working from the top of the taper to the bottom (see **Figure L**). Plane one side at a time; redraw the waste line after the taper is complete, then go to the opposite and repeat the process. At this time, you should also plane the lower tapers on these sides.
20. Redraw the taper lines on the sides just planed and repeat Steps 18 and 19. Now the posts are tapered at the top and bottom on all four sides.
21. The top and bottom of each post can now be cut at the waste line.
22. Turn the top of each post into an octagonal shape by chamfering the four edges. Working at line A, measure over 3/4" from each corner and make a mark. At the top of the post, measure over 5/16" from each corner and make a mark. Refer to **Figure M**. Connect the marks on each side using a straightedge.



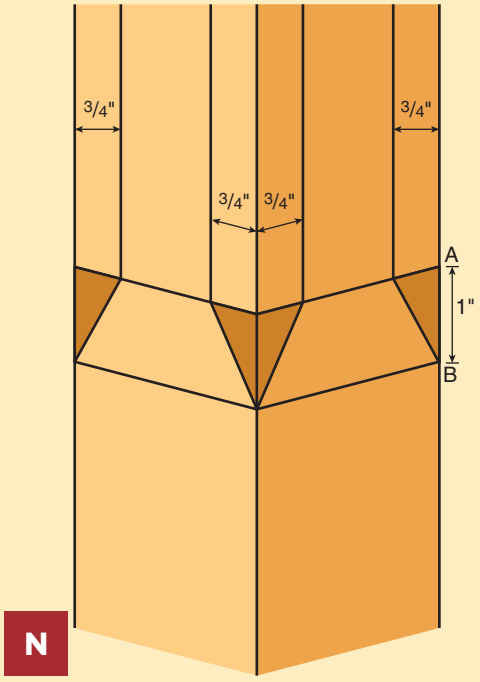
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O

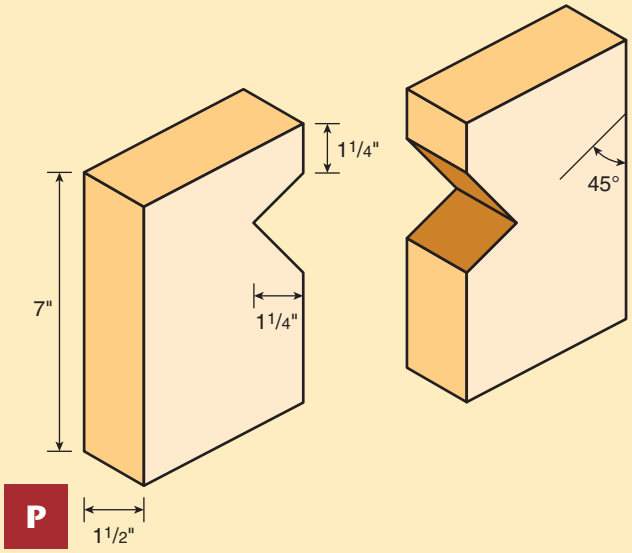
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23. Draw angled lines from the 3/4" marks on line A down to the corner at line B. This marks out the beveled stop, as shown in **Figure N**.

24. The post needs to be secured while the chamfering is done, as shown in **Figure O**.

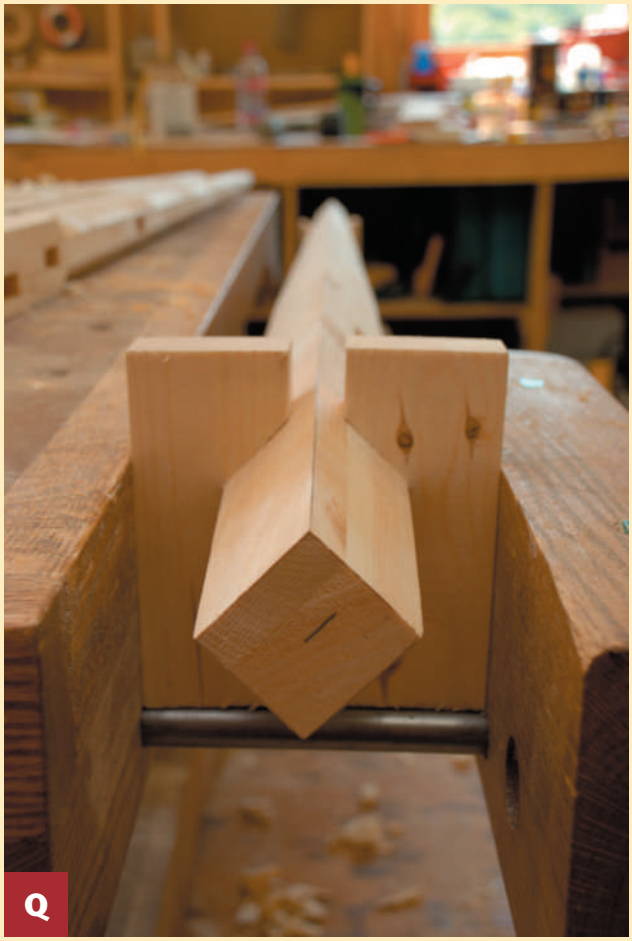
Make a pair of V-blocks, as shown in

Figures P and **Q**. The V-blocks are clamped in the bench vise with the lower end of the post between them, and the post is supported at the other end by a notched deadman



P

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S

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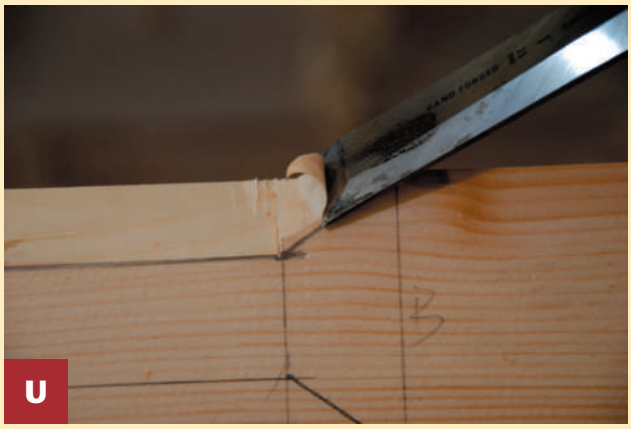
secured to the bench (see **Figure R**).

25. At line A, make a saw cut on the waste side of the line just shy of the chamfer lines. Use a 1″ chisel to pare out a box about 8″ long; take off a little material at a time, and do not go quite down to your layout lines (see **Figure S**). Once the box is cut, a plane can be used

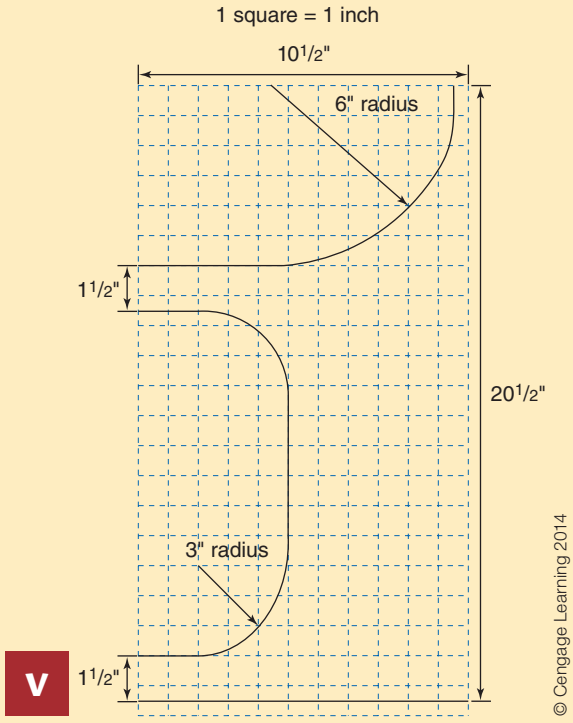
to cut the rest of the chamfer, as shown in **Figure T**. Next, cut the beveled stop with a 1″ chisel, removing a little material at a time (see **Figure U**). Repeat for all four sides of each post.


T

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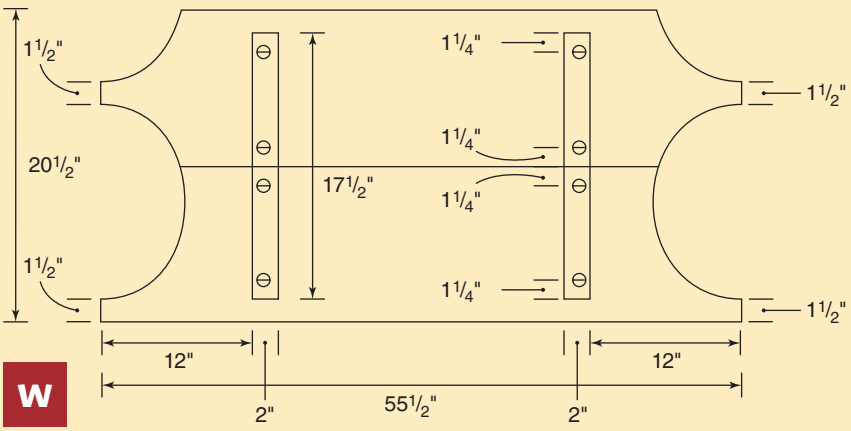

U

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V

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W

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26. Glue up the headboard blank. Using the pattern given in **Figure V**, lay out the headboard cuts. Check the location of the mortises in the posts to be sure the tenons you are creating on the headboard will be in the correct position.

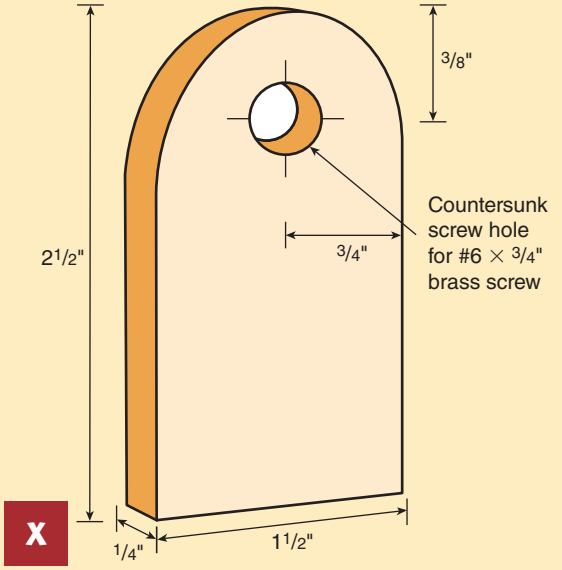
27. Use a jigsaw to cut out the scrolls on the headboard; sand smooth.

28. Cut the headboard cleats to size, and attach them to the back of the headboard with countersunk #6 × 1 1/4" screws (see **Figure W**).

29. Glue the foot rail between its two posts. Fit a drill with a 1/4" bit into the 1/4" holes drilled in the post; drill through the tenons of the foot rail. Cut and glue a length of 1/4" dowel into each of these holes. When dry, the dowels can be trimmed flush with the post.

30. Put together the headboard assembly next, fitting the headboard and the head rail between the two posts. Use a drill with a 1/4" bit, set it in the 1/4" holes drilled previously, and drill through the head rail tenons and the upper headboard tenon. Cut lengths of dowel, and glue and tap them into place.

31. Use the bed bolts to attach the side rails to the headboard and footboard assemblies.
32. Cover the bed-bolt holes in the post with purchased bed-bolt covers, or make your own following the diagram in **Figure X**.
33. Measure the inside width of the bed from the inside of one side rail to the inside of the other, and cut the spreader to length.
34. Cut halved joints on the ends of the spreader to fit into the halved joints on the ledgers. The spreader should sit flush with the ledgers when completed. Fasten in place with a countersunk #6 × 3/4" screw on each end.
35. Disassemble the bed, sand, and finish as desired.



X

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25

Chairs

You'll Learn

After studying the chapter, the student should be able to:

- Describe the parts of a chair
- Understand the standards associated with chairs
- Explain each component of a chair
- Demonstrate knowledge of chair construction
- List various types of chairs and other types of seating

INTRODUCTION

Chairs, stools, and benches provide us with a place to rest comfortably without lying down in bed. They allow us to dine, work at a desk in comfort, or relax with a magazine in hand and a beverage sitting near us on an end table or coffee table. There are many different kinds of chairs, some simple, some very elaborate. Some are simply functional, such as a rough bench, and others are complicated works of art. Whatever form a chair takes, it must be functional, durable, and reasonably attractive.

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TYPES OF CHAIRS

A **chair** is defined as a piece of furniture, consisting of a seat, legs, back, and sometimes arms, that was designed to accommodate one person. Chairs may be divided into four main categories: *side chairs, armchairs, easy chairs,* and *rocking chairs.* Some examples are shown in **Figure 25-1** through **Figure 25-4**.



Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 25-1 Side chair.



Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 25-2 Armchair.



Image courtesy of Thomasville Furniture

FIGURE 25-3 Easy chair.



Image courtesy of Shaker Style, www.shakerstyle.com

FIGURE 25-4 Rocking chair.

Chair Standards

For a chair to be functional, it should meet certain standards, and it should be comfortable. **Side chairs** differ from armchairs in that they do not have arms. A side chair should have a seat height of 14 to 19 inches, a seat width of 17 to 18 inches at the front, and a width of 15 to 15 1/2 inches at the back. The seat depth should range from 16 to 17 inches. The overall height of a side chair ranges from 28 to 35 inches, with 32 inches the average.



HISTORY FACT

Although chairs are plentiful today, this was not always the case. In fact, a chair for everyone is a relatively recent concept. We have surviving examples of chairs from the time of the ancient Egyptians, but it is clear that these chairs were for very high-ranking members of society. In the Middle Ages, the lord of the manor probably had a chair, but everyone else sat on a bench; so chairs came to symbolize social stratification. Even today, think of a set of eight dining room chairs: two of them have arms, the others do not. The two chairs with arms are usually occupied by the parents, the ranking members of the family. The word *chair* is used to denote the head of a committee. The person in an academic department who acts as the leader is designated as the chair. ■

An **armchair** is similar in structure to a side chair, except that it has arms. It also tends to have a somewhat larger seat than a side chair. The seat height is still between 14 and 19 inches, and the total chair height is 28 to 35 inches, with 32 inches the average. The seat width is 19 to 20 inches at the front and 16 1/2 to 18 1/2 inches at the back, with an overall depth of 16 to 17 inches. The arm is 8 inches above the seat, and the arm length is between 14 and 15 inches.

Side chairs and armchairs are typically used at tables and desks. In a set of eight chairs designed to be used at a dining room table, two are armchairs, typically placed at the head and foot of the table; the remaining six chairs are usually side chairs.

Easy chairs are lower, both in seat height and overall height, than either side chairs or armchairs. They also have a larger seat than either, and they are intended more for relaxing than either eating or performing a task at a desk. They are comfortable and generally upholstered. The seat height of easy chairs is between 13 and 18 inches, with 15 1/2 inches the average. The overall height is between 25 and 39 inches, and 30 inches is the average. The seat width in the front is 19 to 20 inches, and the width is 16 1/2 to 18 1/2 inches in the rear. The seat depth is 18 to 20 inches. Like armchairs, the arm height is 8 inches above the seat.

A **rocking chair**, sometimes just called a *rocker,* is a chair with two curved pieces of wood attached to the bottom of the legs. These two curved pieces of wood are known as *rockers*. A rocking chair contacts the floor at only two points, which enables the occupant to rock back and forth by shifting his weight or by pushing with his feet. Rocking chairs may or may not have arms. All measurements for rockers are taken from the floor with the rocking chair at rest. The seat height in the front is 15 1/2 to 16 inches. The seat height in the back is 12 to 12 1/2 inches. The seat width in the front is 19 to 22 inches, and in the back it is 16 1/2 to 19 1/2 inches. The seat depth ranges from 16 to 18 inches. If the rocker has arms, they are set at 8 inches above the seat and are 14 to 16 inches long. The overall average height of a rocking chair is 40 inches, and the rocker length is between 30 and 35 inches long.

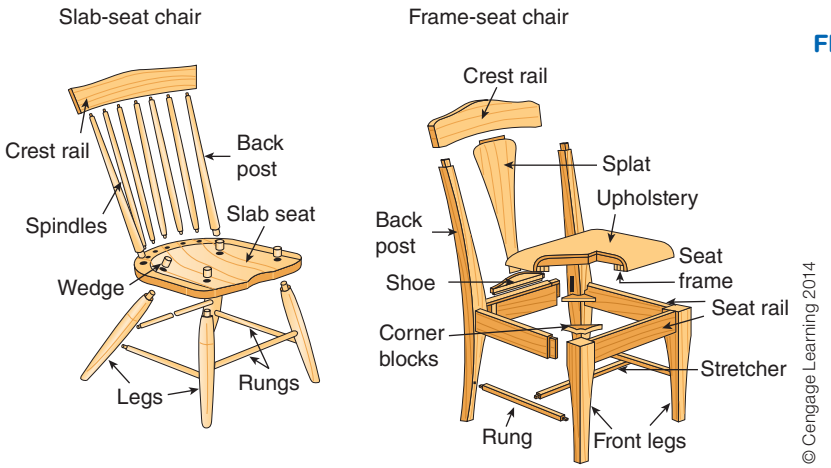
Whether a chair is comfortable depends to a large degree on the height of the person sitting in the chair. You will have noticed that a fairly wide range for seat height was given for most of the chairs previously described. When designing a chair specifically for a person of a certain height, you should follow the guidelines given below.

Occupant's Height	Seat Height
60”	14”
63”	15”
66”	16”
69”	17”
72”	18”

Chairs should be somewhat wider at the front than at the back, as you probably noticed when looking over the standards. Also, the chair should slant slightly back for optimum comfort. A slant of 5 to 15 degrees is typical for most chairs, because it prevents the back of the chair from pressing against the occupant's shoulder blades. The back slant on a rocker is greater, usually around 25 degrees.

Chair Components

Chairs have two major components: the *seat* and the *supporting frame*. The supporting frame includes the *legs, rungs, stretchers,* and *back*. **Rungs** run between the legs and connect them. **Stretchers** extend from one rung to another, providing another means of tying the chair frame together. Chairs may or may not have stretchers, and some chairs do not have rungs. The top of the back is called a **crest rail**, and it may be joined to the seat by one or more *splats* or by *spindles*. A **splat** is a



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FIGURE 25-5 Chair components.

piece of wood that runs between the seat and the crest rail; it serves to support the back and is often shaped but not turned. **Spindles** serve the same function, but they are turned (see **Figure 25-5**). Some chairs have cross rails running between the two back posts for lumbar support or a back cushion, rather than splats or spindles.

The seat may be an integral part of the chair, or it may be a separately attached piece that is set into a frame (see **Figure 25-6**). A seat to which the legs are attached is called a *slab seat,* and it is made of solid wood. Slab seats are often sculpted for comfort, as shown in the example. A frame seat incorporates four rails, and the seat itself is often upholstered. A third option for seats is an open frame, which may have a rush seat, a caned seat, or a cloth-tape seat (see **Figure 25-7**).

Chair Construction

Chairs are required to withstand more abuse than almost any other piece of furniture. They also must be sturdy enough to bear substantial weight, so very strong joinery must be used in chair construction. The strongest of the woodworking joints is the mortise-and-tenon joint, so this is the joint most often used in building quality chairs.

The chair frame can be built using primarily rectangular parts, in which case square mortise-and-tenon joints are used, or it can be built using round legs, tenons, and stretchers. If the parts of the chair frame are round, round mortise-and-tenon joints are used.

Chair Styles

There are many different and distinct chair styles, which follow furniture styles. Among them are



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Image courtesy of Thomasville Furniture

FIGURE 25-6 Slab seat and frame seat.


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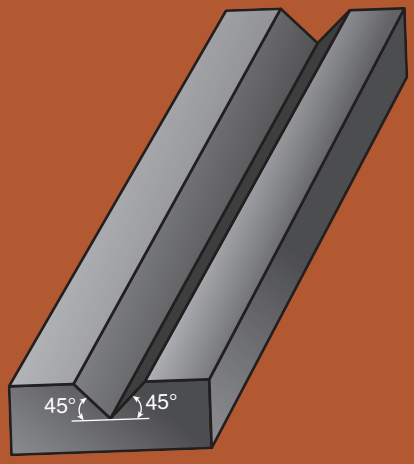

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FIGURE 25-7 Woven rush seat, caned seat, taped seat.

WOODWORKING TIP:

It is difficult to accurately drill holes in round stock. Making a simple jig, like the one illustrated in **Figure 25-8**, *makes it much easier to hold round pieces in position when drilling holes on the drill press. Use a piece of solid stock that is long enough to support the material you will be drilling. Draw a right angle V on the end of the stock, and then make two cuts on the table saw with the blade tilted to 45°. To use the jig, clamp it to the table so that the drill bit touches the center of the V when the quill is extended. Place the workpiece in the V, align the bit over your cutting mark, set the depth of cut, and drill the hole.*



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FIGURE 25-8 V-block jig for drilling holes in round stock on the drill press.



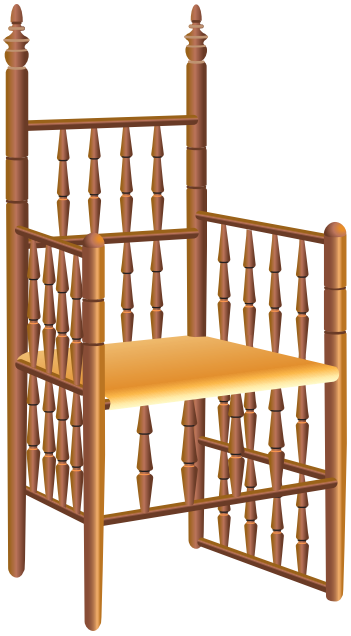
FACTS ABOUT WOOD

White ash, *Fraxinus americana,* is a coarse but generally straight-grained wood that is similar to oak in appearance but is lighter in color, with a pale brown heartwood. It is commonly used for baseball bats, tool handles, and cabinetry, and it is an excellent wood for bending. ■

Pilgrim, Queen Ann, Hepplewhite, Chippendale, Windsor, Mission, and Shaker. Each style has its own specific hallmarks. **Figure 25-9** through **Figure 25-15** show examples of each style mentioned.

Benches and Stools

Both **benches** and **stools** represent the earliest and simplest forms of seating that are still used today. As with chairs, parts may be rectangular, turned, or round. Benches and stools are generally backless, although not always. A bench provides seating for more than



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FIGURE 25-9 Pilgrim.



Courtesy of Cherry Brook Woodworks

FIGURE 25-11 Hepplewhite.



Image courtesy of Jean Bouteiller

FIGURE 25-10 Queen Anne.



Image courtesy of Jean Bouteiller

FIGURE 25-12 Chippendale.



Courtesy of Country Furniture Shop

FIGURE 25-13 Windsor.



Image courtesy of Amish Traditions

FIGURE 25-14 Mission.



Courtesy of McGuire Family Furnituremakers

FIGURE 25-15 Shaker rocking chair.



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FIGURE 25-16 Bench.

one person, and a stool, like a chair, is for a single occupant. **Figure 25-16** and **Figure 25-17** show examples of a bench and a stool.

Other Kinds of Seating

Other kinds of seating that have not yet been mentioned include sofas, folding chairs, pews, and outdoor furniture. **Sofas**, also called *couches,* are actually larger versions of easy chairs (see **Figure 25-18**). The same is true of **loveseats**, which are essentially small couches. They are designed to provide seating for more than one person.

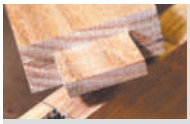
Folding chairs may be metal or wood and are useful for temporary seating, which can be easily set up and stored when not in use.

Pews are essentially benches with backs and, like benches, they are built to seat more than a single occupant. They are typically used in churches for seating the congregation.


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FIGURE 25-17 Stool.

Outdoor furniture comes in many different forms and materials. Two uniquely American pieces of outdoor furniture are the porch swing and the Adirondack chair. See **Figure 25-19** and **Figure 25-20** for examples of each.



HISTORY FACT

The first Adirondack chair was designed by Thomas Lee in 1903. He was vacationing with his family in Westport, New York, and wanted outdoor chairs for his family. ■


Image courtesy of Thomasville Furniture

FIGURE 25-18 Sofa.


Image courtesy of Amish Traditions

FIGURE 25-19 Porch swing.


Courtesy of Franklin Woodwright Shop

FIGURE 25-20 Adirondack chair.



Summary

Chairs give the occupant a place to rest or work. They should be sturdy, comfortable, and attractive. By following different standards, comfortable chairs can be built for various purposes, whether dining, working, or relaxing. The joint used most often in quality chair construction is the mortise-and-tenon joint, chosen for its superior strength. Although not chairs, benches and stools also provide seating. Many different types and styles of chairs have been developed and are in use today.



Key Terms

armchair
benches
chair
crest rail
easy chairs
loveseat
pew
rocking chair
rungs
side chairs
sofa
spindles
splat
stools
stretchers



Check Your Knowledge

1. What are the two basic components of chairs, and what is each made up of?
2. What is a crest rail?
3. How can the elements of a chair be changed to create different looks?
4. Why are the backs of chairs typically angled?
5. What kind of joinery is usually used for chairs and why?
6. What are the four chair types, and how do they differ from one another?
7. List three chair styles.
8. Name three kinds of seating that do not fall into the four categories of chair types.

BUILD IT!

Shaker-Style Bench

Figure A shows a Shaker-style bench.

TOOLS REQUIRED

- Measuring tool
- Square
- Compass
- Miter saw, circular saw, or handsaw
- Jigsaw
- Sander
- Router and 3/4" straight bit
- Drill and 3/8" flat-bottom bit
- 3/8" plug-cutting bit

MATERIALS REQUIRED

- 3/4" × 12" pine
- 1 1/4" screws

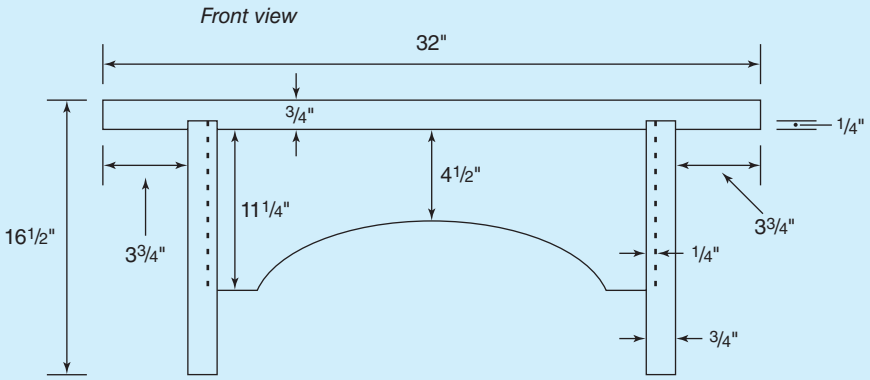
STEPS

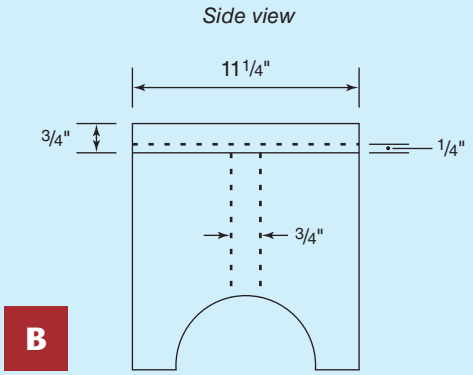
1. Using the plans given in **Figure B**, determine the sizes of the parts needed.
2. Cut parts to size.
3. Using a router and a 3/4" straight bit, rout a centered, 1/4"-deep plough in each end piece as shown in **Figure C**. This can be accomplished using a straightedge to guide the router or on a router table.



A

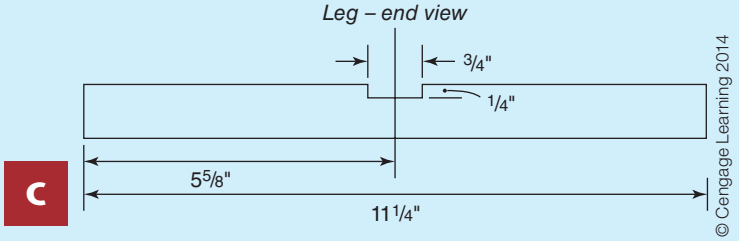
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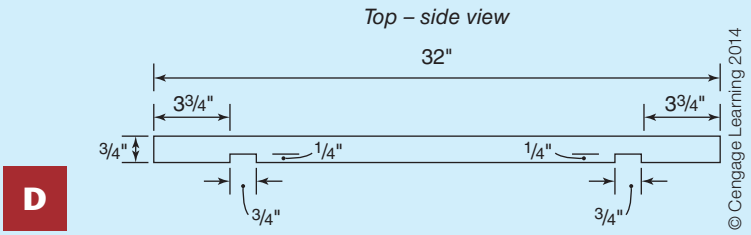
B

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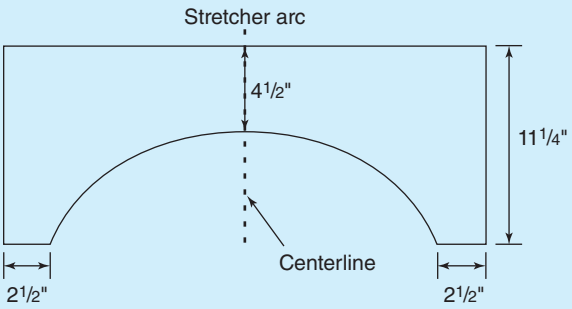


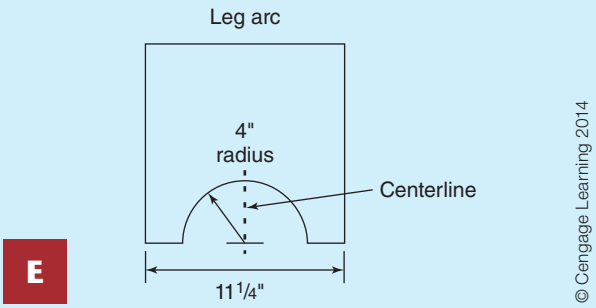
C

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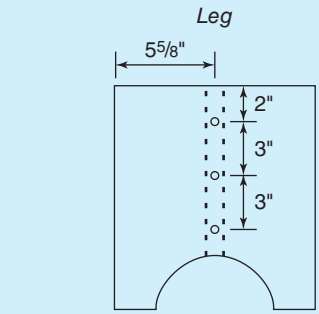


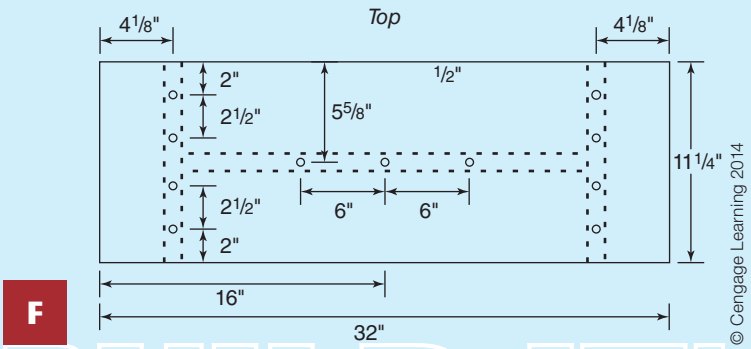
D





E





F

4. Using the same method, rout 1/4"-deep dadoes on the bottom of the benchtop in the appropriate locations, as detailed in **Figure D**.
5. Lay out the curves in the sides and the stretcher, as shown in **Figure E**; cut out the curves with a jigsaw.
6. Using a 3/8" flat-bottom bit, drill 1/4" deep holes in the ends and tops, where the screws will go. Refer to **Figure F** for screw locations.
7. Assemble the bench with glue, and screw it together.
8. Cut 3/8" plugs and glue over screws. When dry, plane plugs flush.
9. Sand and finish as desired.

BUILD IT!

PROJECT CHALLENGE

Adirondack Chair

Figure A shows the completed Adirondack chair.

STEPS

1. Review the assembly list given in **Figure B** and assemble the materials needed. A weather-resistant wood such as cedar, redwood, cypress, or white oak is recommended, but a less expensive wood like pine could be used if the chair will be thoroughly finished and will not be in a location where it will frequently get wet, such as on a porch. Alternatively, pressure-treated or weather-resistant wood could be used for the parts that will be in contact with the ground, with less expensive wood used for the remainder.



A

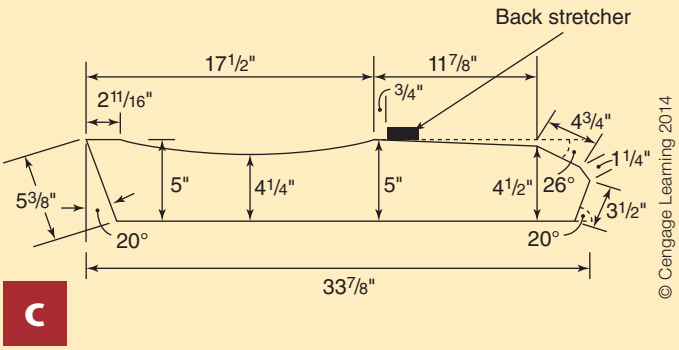
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Assembly list – adirondack chair

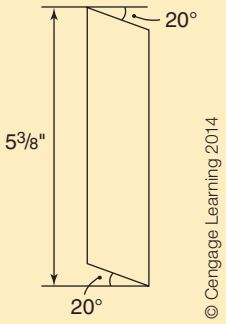
Part	Dimensions (thickness × width × length)	Quantity
Rear leg/side	$^3/_4$" × 5" × $33^7/_8$"	2
Front seat support rail	$^3/_4$" × $5^3/_8$" × $23^5/_8$"	1
Back stretcher	$^3/_4$" × $4^1/_4$" × $23^1/_{16}$"	1
Front leg	$^3/_4$" × $4^1/_4$" × $20^7/_{16}$"	2
Arm	$^3/_4$" × $5^1/_2$" × $28^1/_2$"	2
Arm bracket	$^3/_4$" × $2^1/_2$" × 6"	2
Arm stretcher	$^3/_4$" × $2^1/_2$" × 27"	1
Back slat	$^3/_4$" × 4" × $32^1/_2$"	5
Back support	$^3/_4$" × $1^1/_2$" × 18"	1
Seat slat	$^3/_4$" × $3^3/_8$" × $23^5/_8$"	5
Galvanized screws	#8 × 1" #8 × $1^1/_4$" #8 × $1^5/_8$" #8 × $1^3/_4$" #8 × 2" #8 × $2^1/_2$"	
Wood plugs	$^3/_8$" diameter	

B

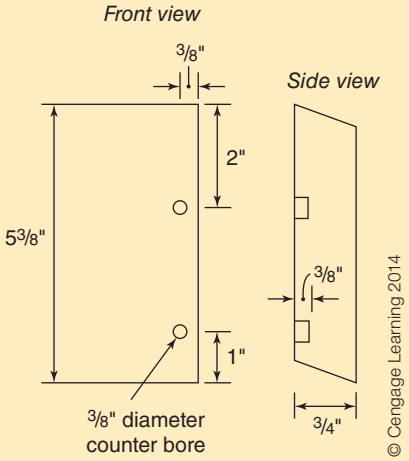
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C



D



E

2. Referring to the diagram given in **Figure C**, lay out and cut one leg using a jigsaw or band saw. Once cut, it can be copied onto the other leg blank, and that can be cut. If you plan to make more of these chairs in the future, it will be worth your while to make a template of the leg pattern from 1/4" plywood or hardboard.
3. Use the table saw to rip parallel, 20° bevels on the front seat support rail, and then cut the front rail to length. Refer to **Figure D**.
4. Counterbore two 3/8" flat-bottomed holes 3/8" deep on each end of the front seat support rail, as illustrated in **Figure E**.

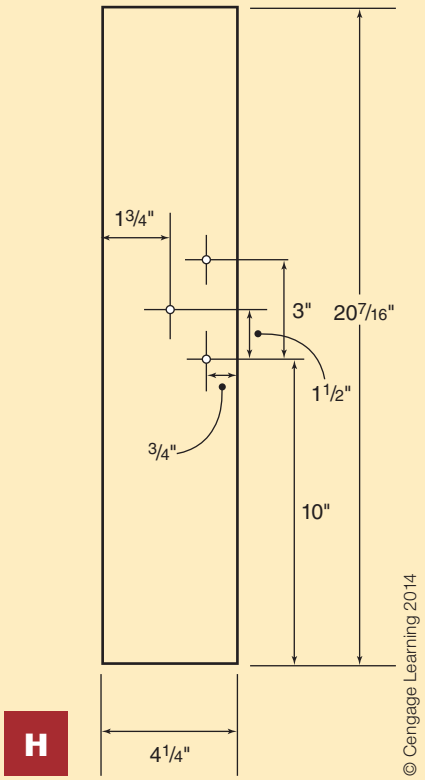
5. Clamp a leg vertically in a bench vise. Position the front seat support rail in the proper position and drill 1/8″ pilot holes through the rail into the leg. Repeat for the other leg, as shown in **Figure F**.
6. Screw the front seat support rail to the legs using #8 galvanized 2 1/2″ screws.
7. Cut the back stretcher to size. Counterbore the holes and screw the stretcher to the legs in the location shown in Figure C; use #8 screws, 2″ long (see **Figure G**).


F

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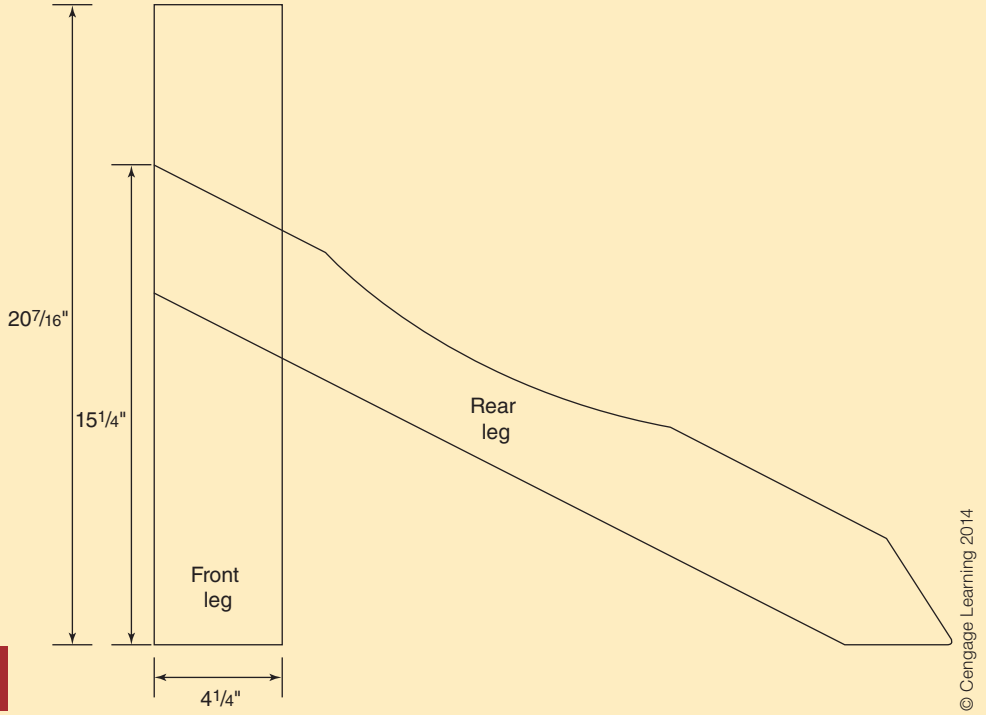

G

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H

8. Rip and crosscut the two front upright legs.
9. Lay out the screw location in the front legs as shown in **Figure H**; counterbore, drill pilot holes, and screw to the slanting legs in the location indicated in **Figure I** with #8 screws 1 1/4" long.



I

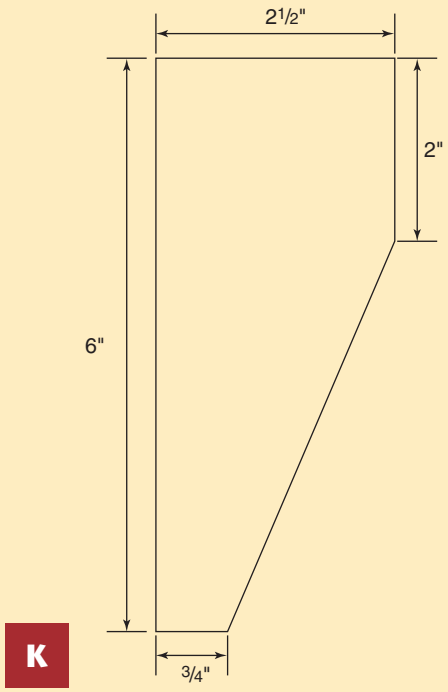
Figure J shows this step completed.

10. Mill the two arm brackets as detailed in **Figure K**.



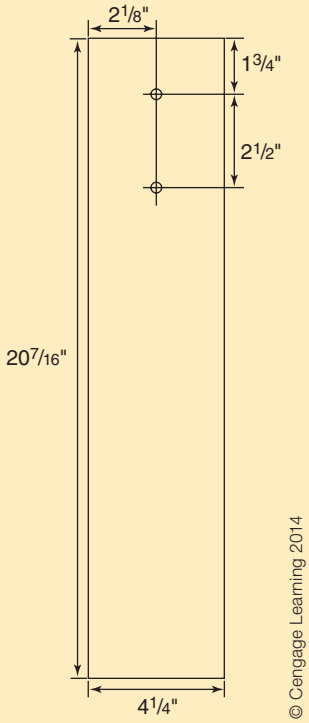
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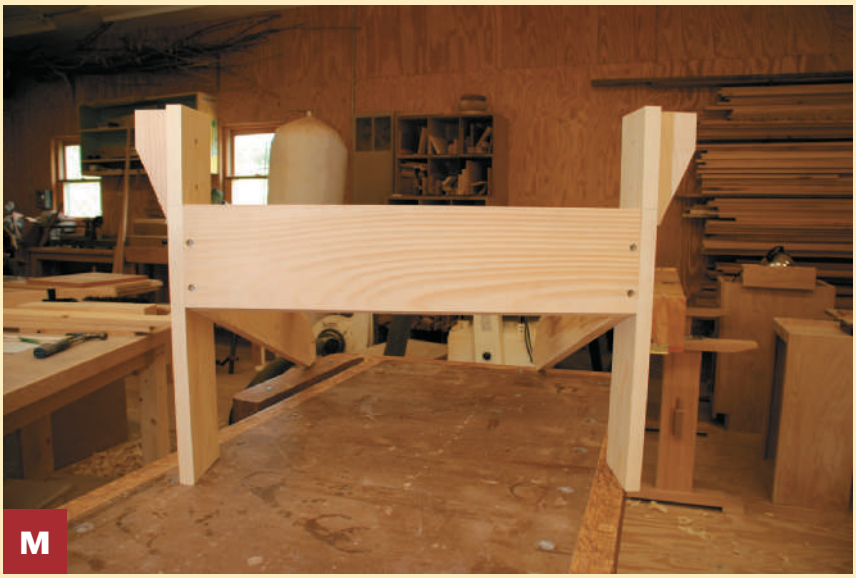
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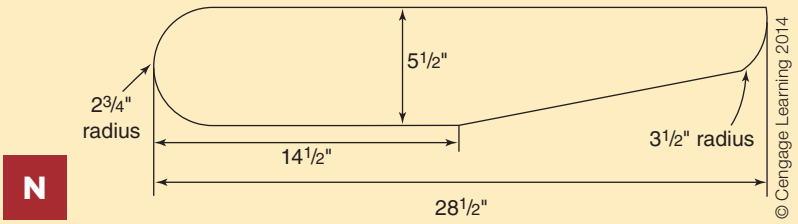


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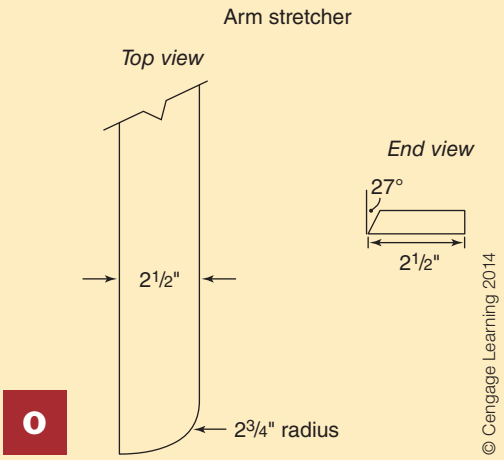
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11. Counterbore and drill pilot holes for the arm brackets in the upright legs. Be sure that the counterbores are drilled on the inside of each leg. **Figure L** shows screw locations.
12. Attach the arm brackets to the legs using #8 screws, 1 3/4" long. **Figure M** shows the arm brackets attached to the legs.

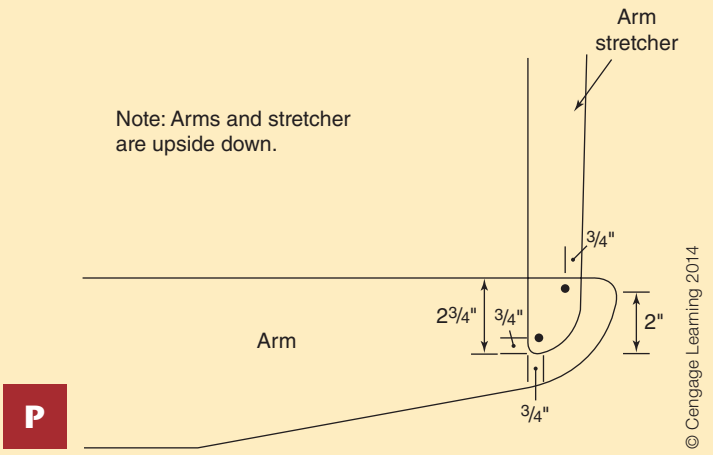
13. Lay out and cut the arms as shown in **Figure N**. As with the legs, if you are planning to make more than one chair, you may wish to make a template that can be used again.
14. Use a 1/4" round-over bit in a router to ease the edges of the arms.
15. Rip a 27° bevel on the front edge of the arm stretcher, and cut it to final size (see **Figure O**).
16. Round the ends of the arm stretcher, as shown in Figure O.
17. Turn the arms upside down on your bench and screw the stretcher to the arms. When the chair is assembled, the stretcher sits underneath the arms. Drill pilot holes and use 1 1/4" #8 screws. These screws should be countersunk; they do not need to be plugged (see **Figure P**).
18. Lay out the locations for the screws that will go through the arms into the upright legs and brackets, as shown in **Figure Q**; counterbore.



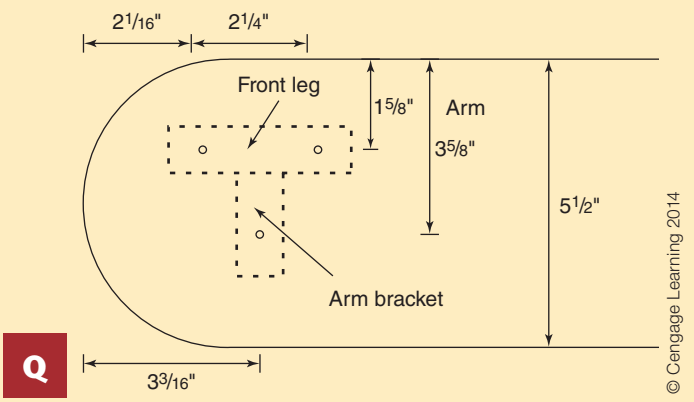
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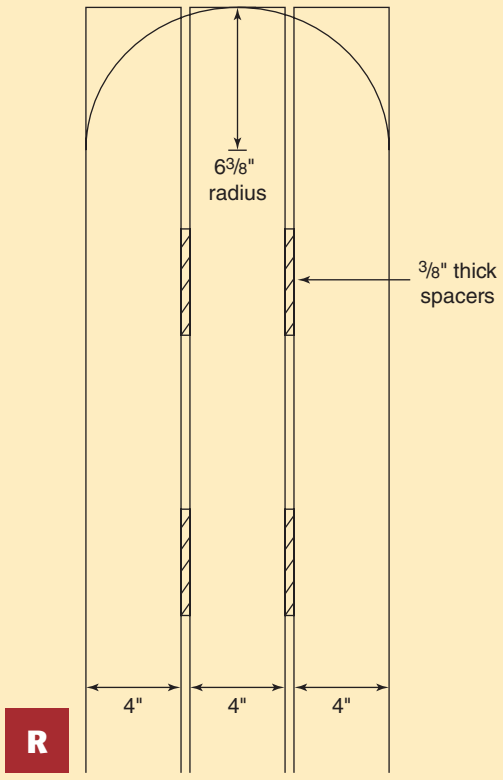
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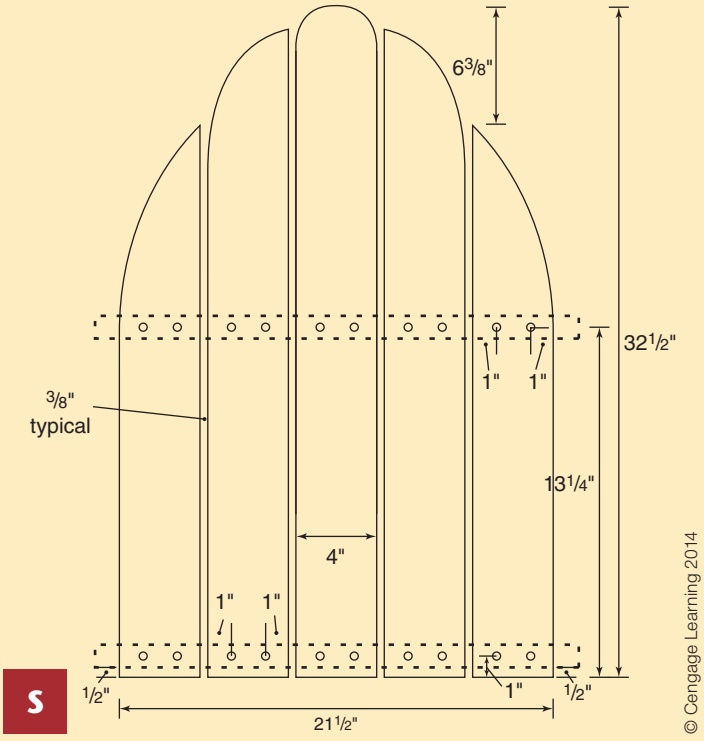


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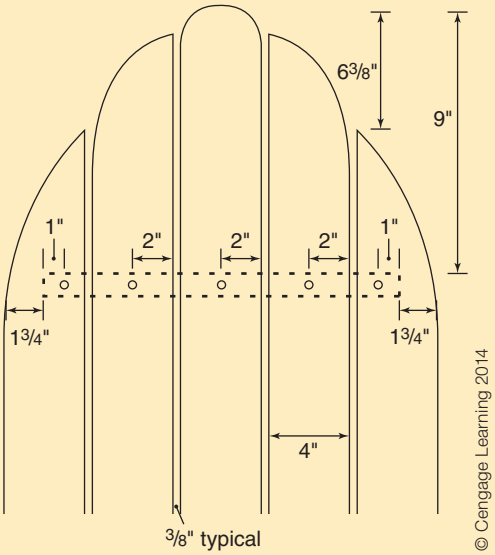
Q



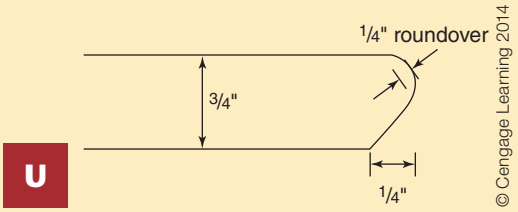


19. Set the arms and arm stretcher in place over the upright legs, supporting the back of the assembly with a scrap or with assistance from a helper. Bore pilot holes through the arms into the legs and brackets; screw them in place using #8 screws, 2" long.
20. Rip the back slats to width but leave them long.
21. Clamp three slats together with 3/8" spacers between them, and lay out the curve at the top, as shown in **Figure R**.
22. Unclamp the three slats, and cut the curve on each piece using a jigsaw or band saw.
23. Transfer the curve from the outside pieces to the remaining two slats and cut them.
24. Study the diagram shown in Figure S, and cut the five slats to final length.
25. Refer again to **Figure S**, and lay out for the screws that will attach the slats to the stretchers; counterbore holes in these locations.

26. Set the first slat in place, drill pilot holes, and attach the slat to the stretchers with #8 screws 1 5/8" long.
27. Place a 3/8" spacer between the slat you just installed and the next one; drill the pilot holes and then fasten it in place with #8 screws 1 5/8" long.
28. Go to the other side, and attach the short slat and the one next to it.
29. Center the remaining middle slat, drill pilot holes, and screw the slat in place.
30. Cut the upper back support and clamp it in place. See Figure T for placement.
31. Mark screw locations as noted in **Figure T**.
32. Remove the upper back support, and counterbore the holes in the locations just marked.
33. Clamp the upper back support back in place, drill pilot holes, and attach them with 1" #8 screws.
34. Use scrap and a 3/8" plug cutter to make plugs.
35. Glue plugs into all counterbores using an exterior glue. When dry, trim flush.



T



36. Cut the seat slats to size and counterbore for two screws at each end.
37. Round over the edges of the seat slats with 1/4" round-over bit in a router.
38. The slat that sits closest to the chair back should have a bevel planed on its underside to facilitate water drainage, as shown in **Figure U**.
39. Attach the seat slat just beveled to the slanting legs using 1" screws; keep the slat 1/2" away from the back.
40. Space and attach the remainder of the seat slats. The space between slats is approximately 3/8".
41. Plug the counterbored holes in the seat slats; when dry, trim flush.
42. Sand and finish as desired.



26

Hardware

You'll Learn

After studying the chapter, the student should be able to:

- Identify the different types of hinges and explain their installation
- Describe knobs, pulls, and handles, how they differ, and where they are used
- List types of catches and latches
- List different types of drawer slides and their installation
- Describe shelf hardware and its installation
- List other kinds of hardware the cabinetmaker may encounter
- Identify and explain different types of specialty hardware

INTRODUCTION

The hardware used on a cabinet or piece of furniture is a very important consideration when planning the piece to be built. Poorly selected or poorly installed hardware can detract from the overall appearance and function of the piece. Hardware should enhance the attractiveness of the project, and it should operate smoothly. Hardware that is properly chosen and installed is not particularly noticeable; but hardware poorly done is obvious, and it detracts from the quality of the piece. Hardware used in cabinet and

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furniture construction includes hinges of different types; knobs, pulls, and handles; latches and catches; drawer slides; and shelf hardware. There are various types of specialty hardware as well. In this chapter, we will cover the different kinds of hardware mentioned and discuss their installation.

GREEN REMINDERS

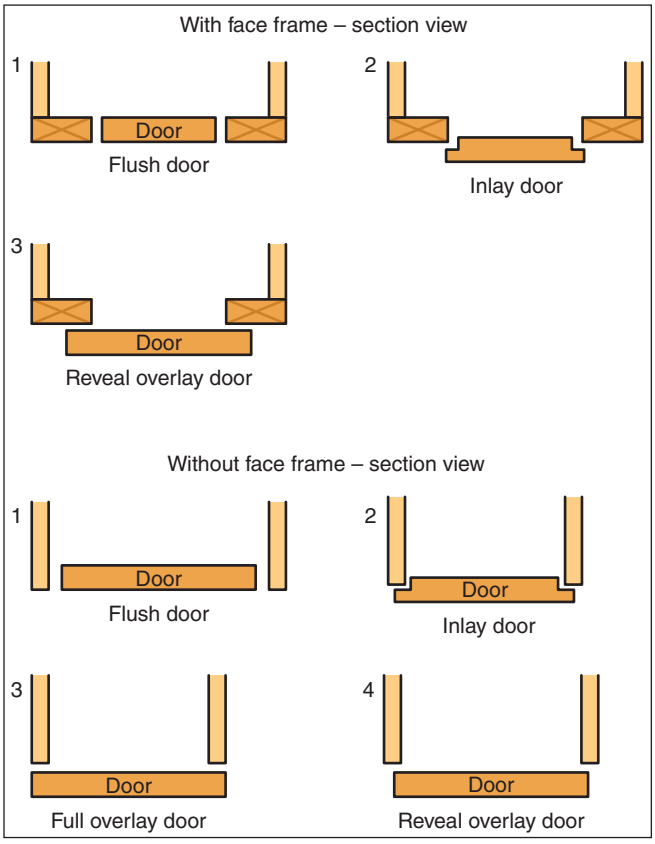
Use email rather than paper correspondence as much as possible.

HINGES

A **hinge** is a jointed or flexible device that allows the turning or pivoting of a part on a stationary frame. Hinges support doors and allow them to open. Hinges are also used so chest lids can be raised, slant-front desks opened, and drop leaves raised on tables. We will look first at door hinges.

The type of door hinge selected depends first on the type of door being hung. The door will be one of three types: *flush, overlay,* or *inlay,* which is also called *inset or lipped.* A flush door sits flush with the face frame, or it may be flush with the cabinet itself, as in the case of a cabinet without a face frame. An overlay door sits in front of the face frame or cabinet. If it exposes part of the cabinet in the frameless style, it is called an *overlay door* with a *reveal.* If it hides the edge of the cabinet completely, it is called a *flush overlay door.* An inlay door sits partly inside the cabinet or face frame. **Figure 26-1** shows illustrations of each of these situations. The types of hinges available are *butt, formed, pivot, invisible, European style,* and *surface.* **Figure 26-2** shows examples of each type and lists the door styles with which each type will work.

Butt hinges are used on flush doors; they have two leaves connected by a pin, which may or may not be removable. Some butt hinges have to be mortised into place, which requires a door with a solid wood edge; this type of hinge is very strong. Mortises, called **gains**, are cut into the door and the cabinet frame, each deep enough for one leaf of the hinge. Gains may be routed or chiseled out, and butt hinges of this kind have leaves that are either straight or **swaged** (see **Figure 26-3**). Swaged leaves are shaped for a closer fit. Only the knuckle of a butt hinge is visible when the door is closed.



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FIGURE 26-1 Flush, overlay, and inlay doors on cabinets with and without face frames.

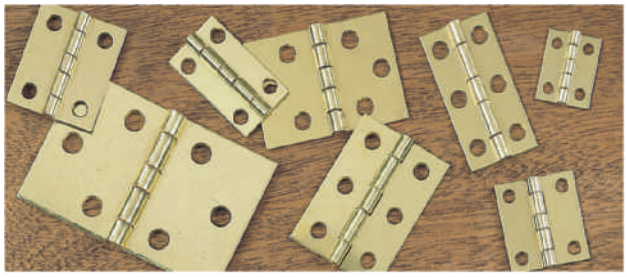


Image courtesy of rockler.com

Hinge type: Butt
Application: Flush doors (face frame)

FIGURE 26-2 Types of hinges and their applications.

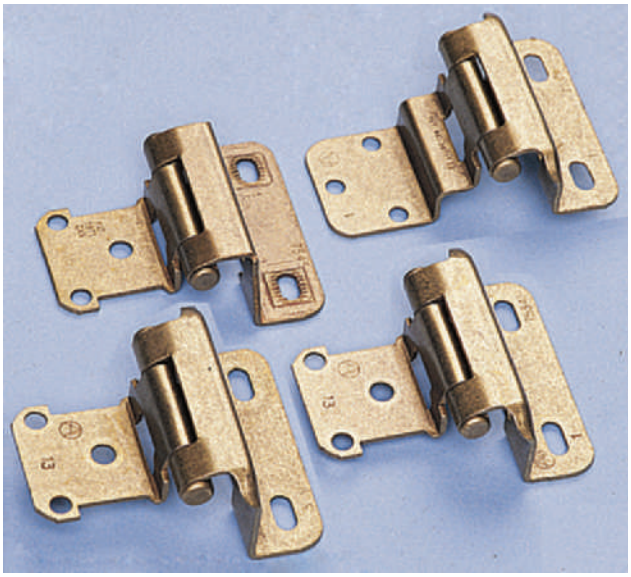


Image courtesy of rockler.com

Hinge type: Formed
Application: Flush doors, inlay doors, reveal overlay doors, and full overlay doors (both face frame and frameless)



Image courtesy of Woodcraft Supply, LLC, www.woodcraft.com

Hinge type: European style
Application: Flush doors, reveal overlay doors, and full overlay doors (both face frame and frameless)



Image courtesy of rockler.com

Hinge type: Invisible
Application: Flush doors (face frame)



Image courtesy of rockler.com

Hinge type: Pin
Application: Flush doors (both face frame and frameless)

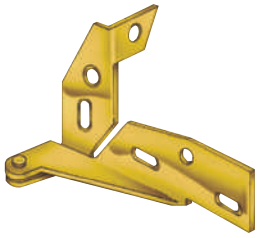


Image courtesy of rockler.com

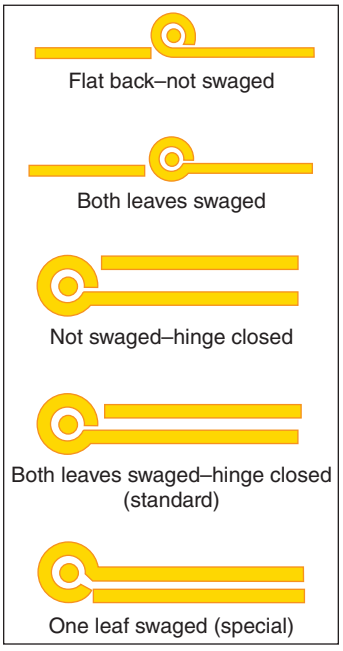
Hinge type: Pivot
Application: Reveal overlay doors and full overlay doors (both face frame and frameless)



Image courtesy of rockler.com

Hinge type: Surface
Application: Flush doors (face frame)

FIGURE 26-2 Types of hinges and their applications. (Continued)



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FIGURE 26-3 Flat-back and swaged butt hinges.

PROCEDURE 26-1

Installing a Butt Hinge



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STEPS

1. Lay one leaf of the hinge on the piece that will receive it, and trace around it with a sharp knife (see **Figure A**).
2. Use a knife to mark the depth of the hinge, as shown in **Figure B**.
3. With a chisel and mallet, deepen the knife marks made in Step 1. The bevel of the chisel should face inward toward the material that will be removed, as shown in **Figure C**.

4. Use a chisel and mallet to make a series of cuts 1/8" to 1/4" apart inside the area just outlined, as shown in **Figure D**.
5. Use a chisel to remove the material to the depth marked in Step 2 (see **Figure E**).
6. Check the fit of the leaf and adjust as needed.
7. Use a self-centering bit to drill pilot holes at the screw locations, using the hinge as a guide, as shown in **Figure F**.
8. Repeat Steps 1 through 7 for the other leaf of the hinge.
9. Attach each leaf of the hinge to the mating recesses with the screws provided.



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PROCEDURE 26-2

Installing Formed Hinges



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STEPS

1. Place the part of the hinge that attaches to the back of the door in the place indicated on the plans. If no indication is given, the rule of thumb is to space the hinges the length of the hinge away from each edge of the door, as shown in **Figure A**.
2. Holding the hinge in place, use a self-centering bit to drill the screw holes for the screws that will attach the plate to the back of the door (see **Figure B**).
3. Attach the hinges to the back of the door using the screw provided.

4. With the hinges attached to the door, open the hinges and place the door in the opening of the cabinet (see **Figure C**). Adjust it up and down so that you have an equal space at the bottom and top of the door.
5. Hold the door in position; use a self-centering drill bit to drill pilot holes for the top screw for each hinge, placing them in the center of the elongated hole (see **Figure D**).
6. Screw the hinges to the cabinet through the pilot holes just drilled, and close the door to check the top and bottom clearances.
7. If the hinges need to be adjusted, loosen the screw just inserted, shift the door to the right position, and then retighten the screws. Since the screw holes in the part of the hinge that attaches to the cabinet are elongated, some adjustment is possible.



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8. When you are satisfied with the position of the door relative to the cabinet, drill pilot holes for the lower screw in each hinge, positioning them at the top of the elongated hole (see **Figure E**).
9. Insert the remaining two screws.

Another type of butt hinge is the nonmortised butt. These are also used with flush doors. **Figure 26-4** shows an example of a nonmortised butt hinge; the center leaf is fastened to the back of the door, and the outer leaf is fastened to the frame. These hinges install much more quickly than mortised butts, but they are not as strong.

Continuous hinges, often called **piano hinges**, are a type of butt hinge (see **Figure 26-5**). They are long hinges that provide good support. Continuous hinges from 12 to 72 inches long are commonly available, and they can be cut with a hacksaw to the desired length.



Image courtesy of rockler.com

FIGURE 26-4 Nonmortised butt hinge.



Image courtesy of Woodcraft Supply, LLC, www.woodcraft.com

FIGURE 26-5 Piano hinge.

Formed hinges are also called *bent hinges* or *wrap-around hinges*. They can be used in all three of the door-to-frame situations mentioned: flush, inset, and overlay. Examples of formed hinges are shown in **Figure 26-6**. These hinges have one leaf bent to fit around the frame; the other leaf is either flat or bent and is screwed to the back of the door. Formed hinges are strong and do not require mortising. They are easy to install, and some offer a small degree of adjustment by means of elongated screw holes in the leaf that attaches to the cabinet. Formed hinges may be self-closing or not. Self-closing hinges have a spring that closes the door after it reaches a certain point, and a catch is not needed to keep the door securely closed.



Image courtesy of rockler.com

FIGURE 26-6 Formed hinges for overlay and inlay doors.

Formed hinges may have decorative finial tips of different designs and are available in several different finishes. A **finial** is an ornamental terminating point seen on a post, a piece of furniture, or, in this case, a hinge. Finial tips can also be found on butt hinges. **Figure 26-7** shows an example of a butt hinge with a decorative finial.

Pivot hinges consist of two plates that are riveted together. They can be used on overlay doors. They are attached to the top and bottom of the door and to the frame. When the door is closed, only the pivot part of the hinge is visible. A nylon washer between the two plates reduces friction and allows doors to open easily. These hinges do not have to be mortised, but if a closer fit is desired, the part of the hinge that fits over the door may be mortised in so that it is flush with the door (see **Figure 26-8**). A variation on the pivot hinge is used with glass doors, shown in **Figure 26-9**.



FIGURE 26-7 Finial-tipped hinge.

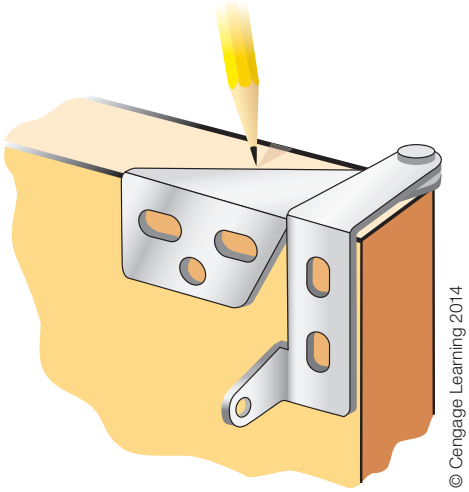


FIGURE 26-8 Pivot hinge.

Knife hinges are similar to pivot hinges but are smaller and not as strong as the latter (see **Figure 26-10**). Like pivot hinges, knife hinges are semi-concealed when the door is closed; only the pivot point is visible. Knife hinges do require mortising. Straight knife hinges are used on overlay doors, and L-shaped knife hinges are used on inset doors.

Pin hinges are used with flush doors and are sometimes called *pivot hinges*. Typically, mounting plates are fastened on the back of the top and bottom of the door. The mounting plates have a protruding pin that fits into corresponding holes drilled in the cabinet. A nylon bushing fits into the hole to prevent wear (see **Figure 26-11**).

Invisible hinges, also called **concealed hinges**, are completely hidden when the door is closed. They are used with flush doors. One type of invisible hinge is a **barrel hinge**, which has two metal barrels connected by a lever mechanism (see **Figure 26-12**). One barrel is set into a hole drilled into the side of the door, and the other is set into a corresponding hole drilled in the cabinet. Once set in place, they are tightened with screws that expand the barrels and lock them in



FIGURE 26-9 Pivot hinge for glass door.



FIGURE 26-10 Knife hinge.



Image courtesy of rockler.com

FIGURE 26-11 Pin hinge.



Image courtesy of Woodcraft Supply, LLC, www.woodcraft.com

FIGURE 26-12 Invisible barrel hinges.

place. These hinges are available in different sizes for different applications.

Another type of invisible hinge is the **Soss hinge** (see **Figure 26-13**). It is larger than the barrel hinge and has leaves that are mortised into the door edge and the cabinet. Routing jigs can be purchased or built. Soss hinges are also available in a range of sizes.

European hinges are concealed hinges that can be used with overlay and flush doors. They have an arm with a cup and a mounting plate and are sometimes referred to as **cup hinges** (see **Figure 26-14**). The cup is mortised into the door with a flat-bottom bit, typically a 35-millimeter Forstner bit. The mounting plate is screwed to the cabinet, and the arm connects the two. European hinges have more adjustability than other hinges. Once the door is installed, it can be moved up and down, side to side, and in and out by



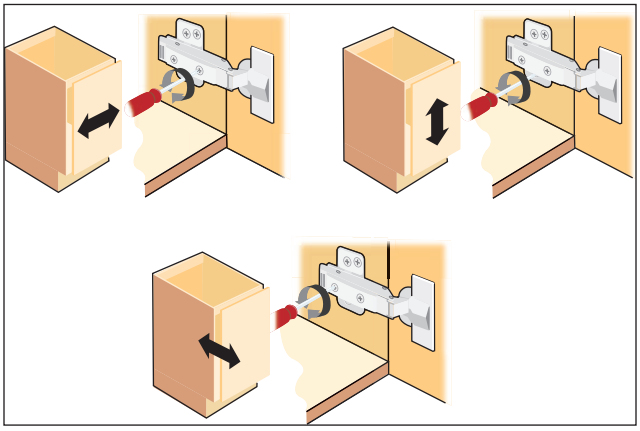
Image courtesy of rockler.com

FIGURE 26-13 Soss hinge.



Image courtesy of rockler.com

FIGURE 26-14 European-style hinge.



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FIGURE 26-15 Adjusting a European hinge.

means of set screws located in the arm (see **Figure 26-15**). European hinges are self-closing, eliminating the need for a catch.

Surface hinges are completely visible. They are mounted on the surface of the door and the surface

of the cabinet. They often have an H or HL shape (see **Figure 26-16**). These hinges form a decorative element on the cabinet and are often textured as well as finished. They are designed primarily for use with flush doors mounted in face-frame cabinets, but there are surface hinges available for use with overlay doors as well.

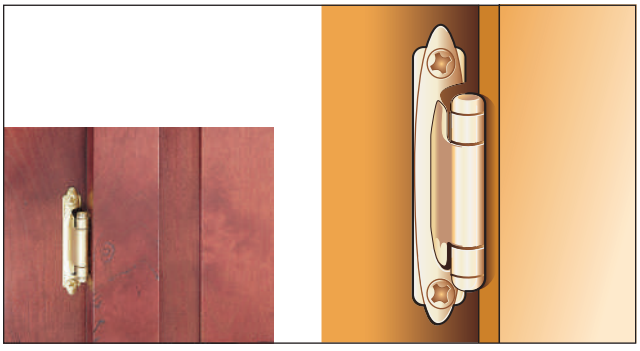
Another type of door hinge that is partially visible is a **semi-concealed hinge**. These hinges have a decorative part that mounts to the face of the cabinet frame, and the rest of the hinge is hidden behind the door (see **Figure 26-17**). These hinges are used with inlay and overlay doors.

Hinges are also used on chests. Butt hinges, continuous hinges, hidden barrel hinges, and Soss hinges may be used. Often in the case of a chest, a chain may be used to keep the top from going all the way over, or stop hinges can be purchased that will stop the opening action of the hinge at 95 degrees. Hinges may be hidden when the top of the chest is closed, partially visible, or surface mounted. An example of a surface-mounted hinge used with chests is the **strap hinge**. A strap hinge has two long straps or one strap and a butt-hinge leaf (see **Figure 26-18**). One part is attached to the part that will move, and the other is attached to the stationary frame. Strap hinges are also used with flush doors in face-frame construction.



Image courtesy of rockler.com

FIGURE 26-16 Surface hinges.



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FIGURE 26-17 Semi-concealed hinges.

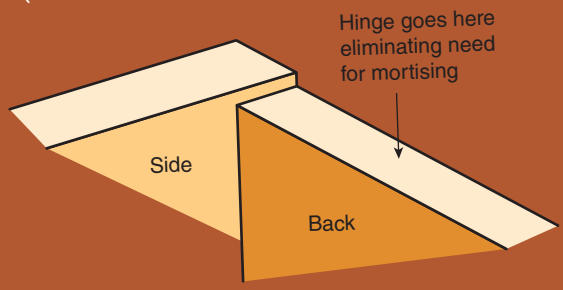


Image courtesy of rockler.com

FIGURE 26-18 Trunk strap hinges.

WOODWORKING TIP:

When installing a piano hinge on a box, installation is greatly simplified if the back of the box is made narrower in width than the other sides. To figure out how much narrower the back should be than the sides, measure the knuckle of the hinge when it is closed. This is most easily done with a caliper. Subtract 1/16" from this measurement, and then make the back that much narrower than the sides. The 1/16" you subtracted ensures that the lid will close completely in the front. Following this procedure eliminates the need for mortising (see Figure 26-19).



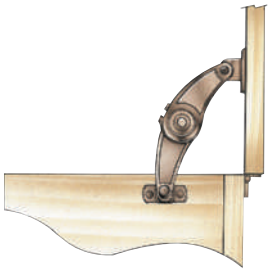
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FIGURE 26-19 Making the back of a box narrower than the sides simplifies the installation of a piano hinge.

Hardware is also used with chests and trunks to keep the lid from slamming shut; these are known as **lid supports**. **Figure 26-20** shows examples. Combination chest hinge and lid supports are also available, and these serve as both hinges and lid supports (see **Figure 26-21**).



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FIGURE 26-20 Examples of lid supports.



Image courtesy of rockler.com

FIGURE 26-21 Combination hinge and lid support.

Hinges are used to allow the fronts on drop-front desks to open. Often a continuous hinge or a flap hinge will be used in this application. The **flap hinge** is mortised into the desk body and into the drop front, and it is invisible when the desk is closed up. It permits the desk front to travel down and stops it at 90 degrees. Flap hinges have some adjustability through set screws (see **Figure 26-22**).

In the same way that lid supports keep a chest top from closing, **drop-front supports** also stop the desk surface from traveling farther down than desired. They are often used in conjunction with piano hinges; **Figure 26-23** shows examples. As with chests, combination hinge and drop-front supports can be purchased (see **Figure 26-24**).

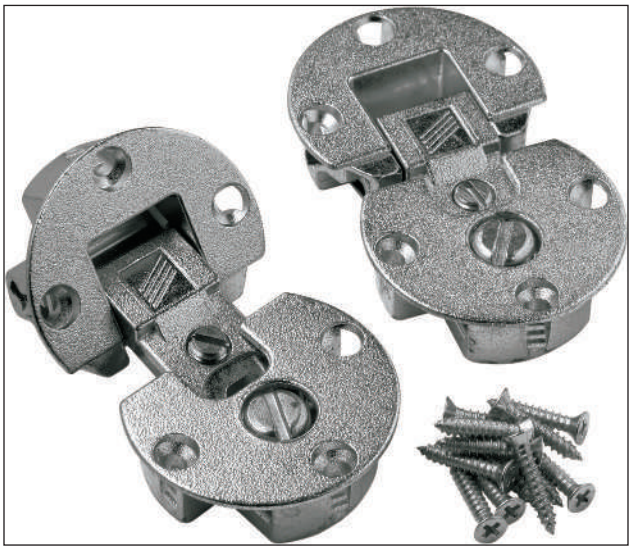


Image courtesy of rockler.com

FIGURE 26-22 Flap hinges.

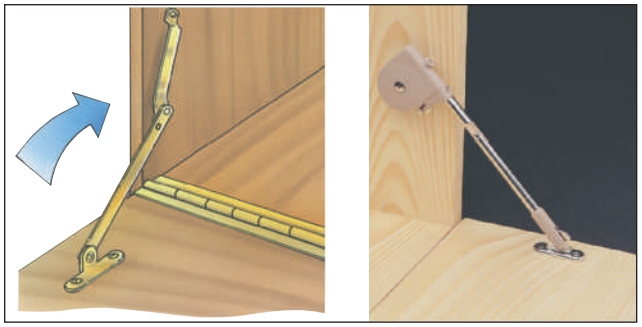


Image courtesy of rockler.com

FIGURE 26-23 Drop-front support.

Yet another situation where hinges are used is on drop-leaf tables, where they allow the leaves to be raised. **Drop-leaf hinges** are often used, in which half the hinge is attached to the table and the other half is attached to the table leaf (see **Figure 26-25**). **Drop-leaf supports** are required with this type of hinge. Drop-leaf supports hold a leaf in the upright position, level with the rest of the table. **Figure 26-26** shows examples of two different types. **Folding-leaf hinges** may be used with narrow leaves, which act both as hinges and supports (see **Figure 26-27**).

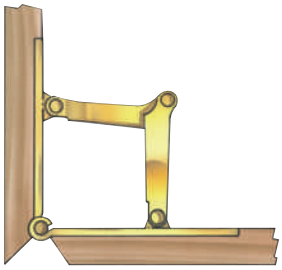


FIGURE 26-24 Combination hinge and drop-front support.

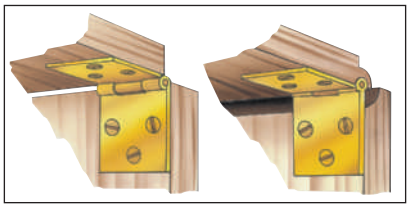


FIGURE 26-25 Drop-leaf hinges.

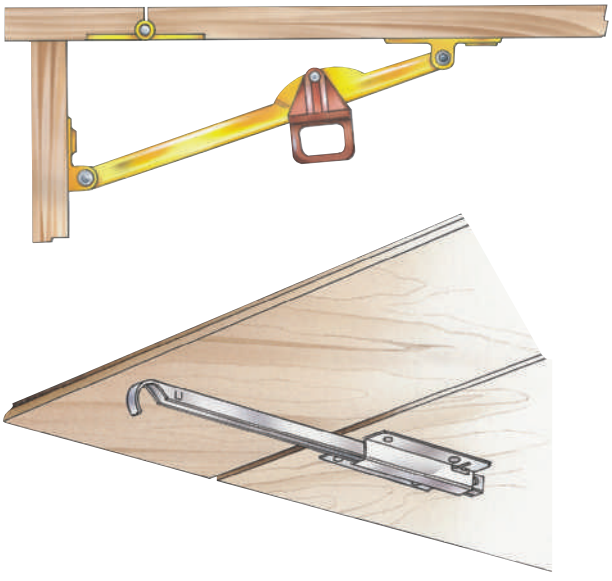


FIGURE 26-26 Examples of drop-leaf supports.

KNOBS, PULLS, AND HANDLES

Knobs and *pulls* are used for opening doors and drawers. The difference between a knob and a pull is that a **knob** is fastened in one place, and a **pull** is fastened in two places (see **Figure 26-28**).

Knobs and pulls may be wood, metal, ceramic, plastic, or a combination of these materials. They are available in a wide variety of styles, shapes, and sizes; **Figure 26-29** shows some examples. When used on drawers, they are usually centered. If the drawer is wide, it may have two knobs or pulls, which will make it easier to open. Knobs and pulls on doors are placed near a door edge. Refer to Chapter 21 on doors and drawers for proper placement.

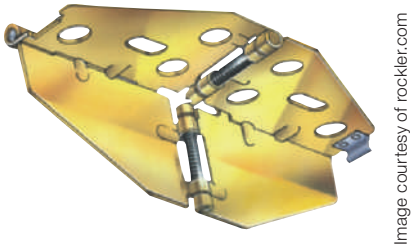


FIGURE 26-27 Folding-leaf hinge.



FIGURE 26-28 A knob is held in place by one fastener, a pull is held in place by two.

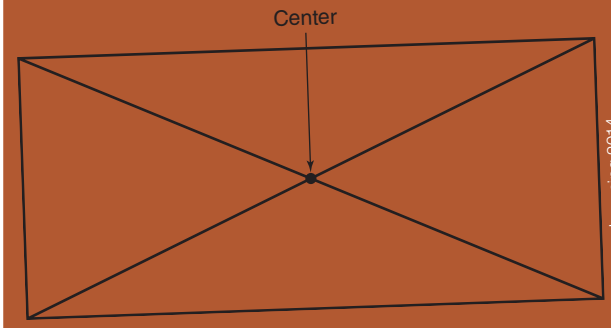


Image courtesy of rockler.com

FIGURE 26-29 Examples of knobs and pulls.

WOODWORKING TIP:

To find the center of a drawer, draw diagonal lines from each corner. Where they intersect is the center of the drawer (see **Figure 26-30**).



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FIGURE 26-30 Find the center of a drawer by drawing diagonal lines from each corner.

Knobs and pulls are usually held in place by a screw inserted through the back of the drawer or door. The hole should be large enough that the fastening screw drops through it. Then it is tightened with a screwdriver to pull the hardware tight.

Handles are used on chests and trunks, and they enable a person to lift the trunk easily. As with knobs and pulls, a great array of choices is available in different materials. Some protrude from the chest, and others fold flush to it. **Figure 26-31** shows some examples of handles.

When selecting hardware that will be a highly visible part of the final product, such as knobs, pulls, and handles, it is important to match the style of the hardware to the piece. A traditional piece should have the hardware appropriate to the period, for example, rather than modern hardware.



FIGURE 26-31 Examples of handles.

LATCHES AND CATCHES

Catches and latches are used for holding doors closed. **Catches** are located on the inside of the door and are not seen when the door is closed; **latches** hold doors shut from the outside and are visible. If self-closing hinges are used, neither a catch nor a latch is necessary.

WOODWORKING TIP:

Make your own protruding strip pull on the router table. Use a core box bit to rout a recess on the underside of the material in a series of passes, then use a round-over bit to ease the edges. Glue to the top edge of a drawer front. If the wood used is matched carefully to the wood of the drawer, it will look like the pull was carved into the drawer. Making the length of strip pull equal to the width of the drawer enhances this illusion. (see **Figure 26-32**).

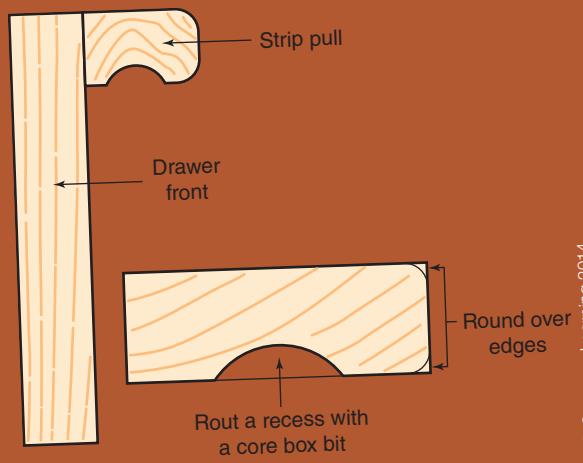


FIGURE 26-32 Shop-made strip pull.

The most commonly used catch is a magnetic catch. There are two parts: a *magnet assembly,* which is fastened to the cabinet, and a metal *strike plate* that attaches to the door. Magnetic catches may be rectangular or round. The round magnetic catches are less visible (see **Figure 26-33**).

Another type of magnetic catch is a touch catch (see **Figure 26-34**). When the door is pushed on, the

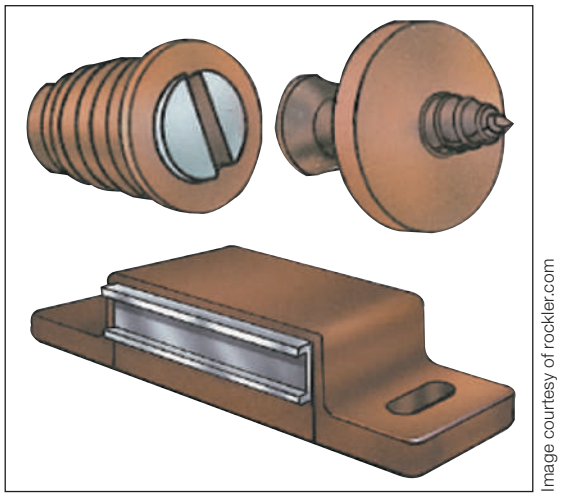


FIGURE 26-33 Round and rectangular magnetic catches.

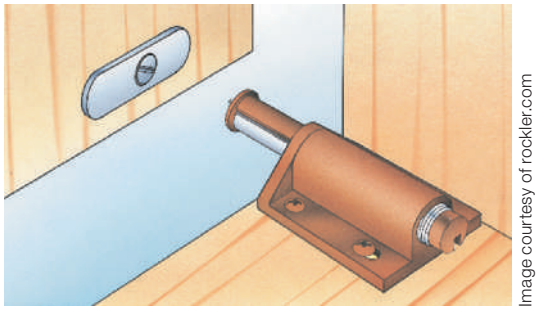
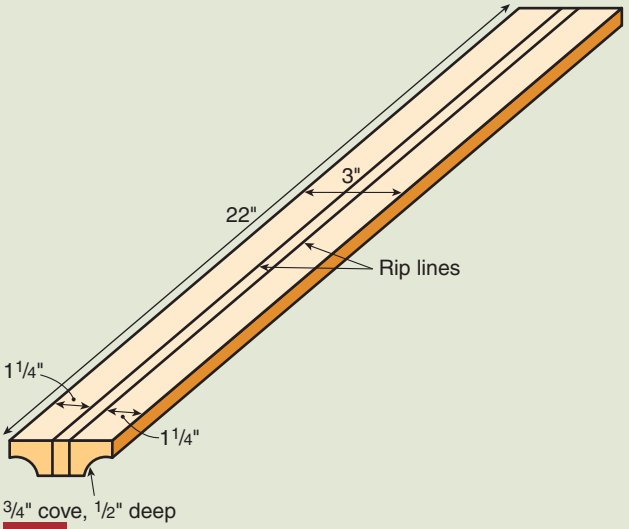


FIGURE 26-34 Magnetic touch catch.

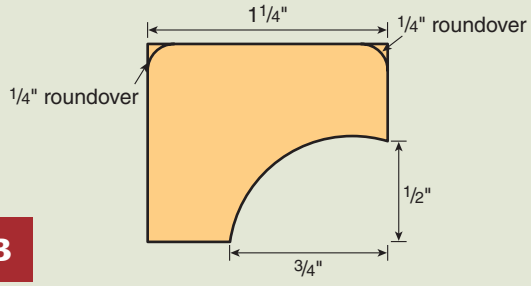
PROCEDURE 26-3

Making Multiple Simple Wooden Pulls



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A



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B

STEPS

1. Mill the material you wish to make into pulls 3/4" thick, at least 3" wide, and 22" long. Both edges should be jointed.
2. Install a 3/4" cove bit in the router table and in a series of passes, machine a 1/2"-deep cove on both edges of the material (see **Figure A**).
3. Rip two strips from the piece you just routed to 1 1/4" and then make a light jointer pass to clean up any saw marks.
4. Install a 1/4" round-over bit in the router table and round over the edges, as illustrated in **Figure B**.
5. Cut the strips into 4" lengths. You will have 10 pulls since you started with a 22" long blank.

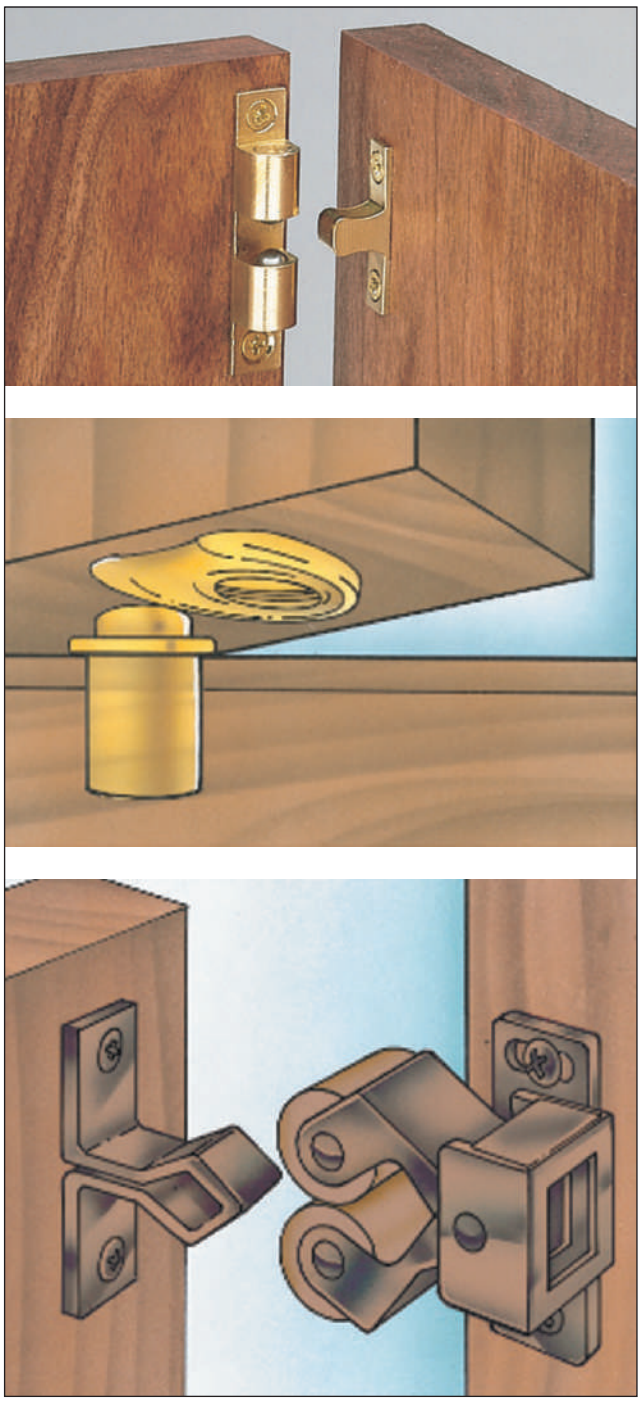


Image courtesy of rockler.com

FIGURE 26-35 Ball catch, bullet catch, and roller catch.

magnet releases, and the door springs open. Using this type of catch means that a knob or pull is not needed on the door. Other types of catches include two different types of ball catches, bullet catches, and roller catches (see **Figure 26-35**). Latches may be wood or metal (see **Figure 26-36**).

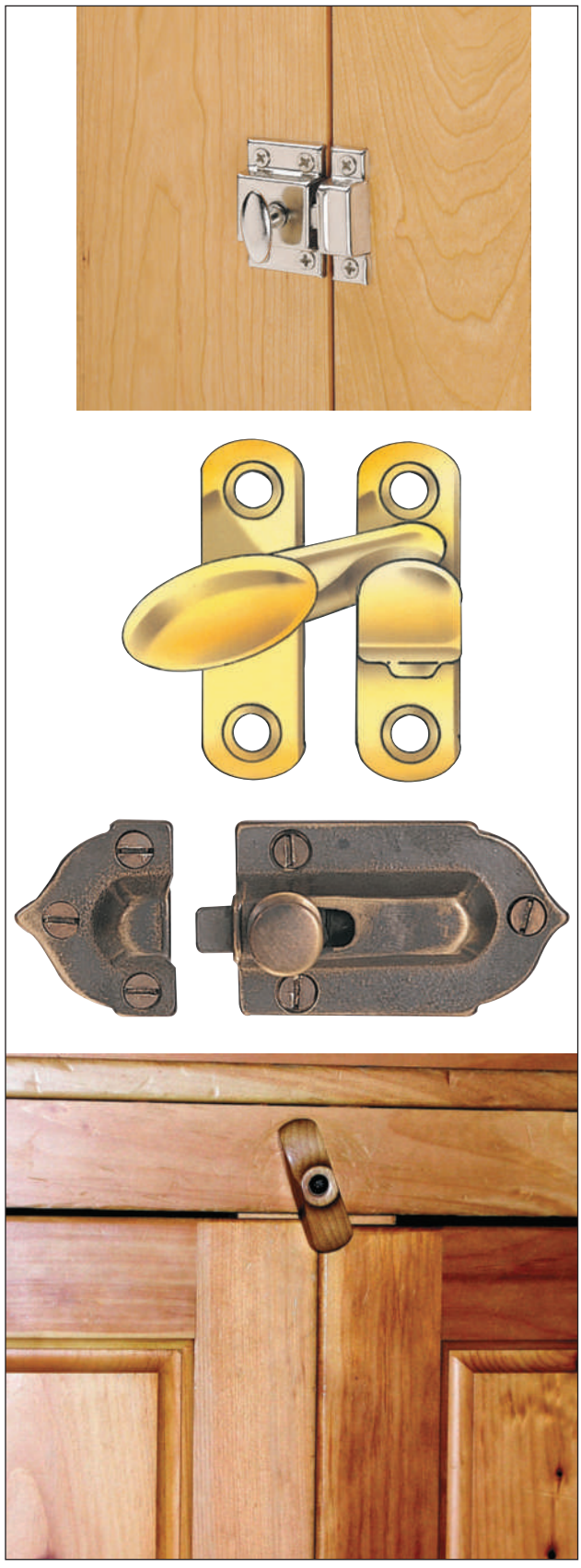


Image courtesy of rockler.com

FIGURE 26-36 Examples of latches.

DRAWER SLIDES

Drawer slides allow a drawer to open and close easily. They come in different lengths to fit different depth drawers and are rated for weight. They are available as three-quarter extension, full-extension, and over-travel slides. Three-quarter extension slides send the drawer out three-quarters of its length; full-extension slides extend the drawer its full depth, and over-travel slides come an inch or more beyond the cabinet. Full-extension and over-travel slides maximize accessibility to the drawer. Drawer slides may be center mounted, side mounted, or bottom mounted (see **Figure 26-37**).

Drawer slides may be wood, metal, or epoxy-coated metal. A drawer slide consists of two parts, which are usually separated from each other for installation. Typically, slides will have both slots and holes. When first installing the slides, it is a good idea to use the slots, because they allow some adjustability. Once the drawer fits properly, screws can be driven into the countersunk holes in the slide. Drawer slides require some room; for side- and bottom-mount slides, this is usually 1/2″ plus or minus 1/32″ on each side. When building the drawer, you must allow slide room. It is a good practice to have the slides in hand before manufacturing the drawers and to study the illustrations that come with the slides carefully. You will also have a much more satisfying experience installing the drawers if you have been careful to build your cabinet and drawers square. If either the cabinet or the drawers are out of square, it is difficult and time consuming to fit the drawers.

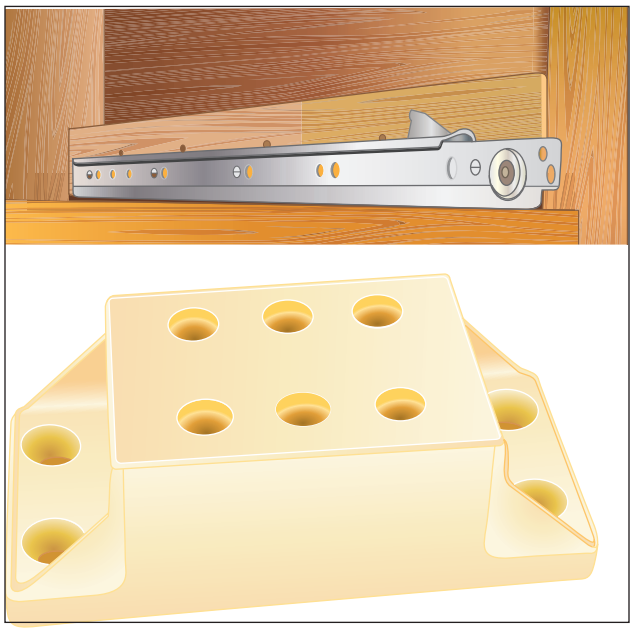
Drawer slides used with cabinets that have face frames require that the inside of the cabinet be blocked out to attach the slide, or rear-mounting sockets can be used (see **Figure 26-38** and **Figure 26-39**). You can block out the sides yourself or buy mounting blocks. Sockets are screwed to the back of the cabinet; they capture the rear of the slide. If sockets are used, either a thicker cabinet back than the typical 1/4″ back should be used, or a 3/4″ mounting strip should be attached to the inner back of the cabinet.

Commercial jigs are available to assist in installing drawer slides, and these can be very useful. You can also simply cut scraps of plywood that will support the slides in the cabinet and keep them even as you screw them in place (see **Figure 26-40** and **Figure 26-41**).



Image courtesy of rockler.com

FIGURE 26-37 Center-mounted, side-mounted, and bottom-mounted drawer slides.



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FIGURE 26-38 Face-frame cabinet blocked out for slide attachment, commercial moutning blocks.



Image courtesy of rockler.com

FIGURE 26-39 Rear-mounting socket.

Commercial slides offer the greatest ease in manipulating drawers in and out. However, small drawers often have shop-built slide mechanisms. Usually they are bottom mounted; **Figure 26-42** shows an example. Another option is to mill a groove in each side of the drawer and attach runners to the cabinet (see **Figure 26-43**). A third choice is to rout grooves in



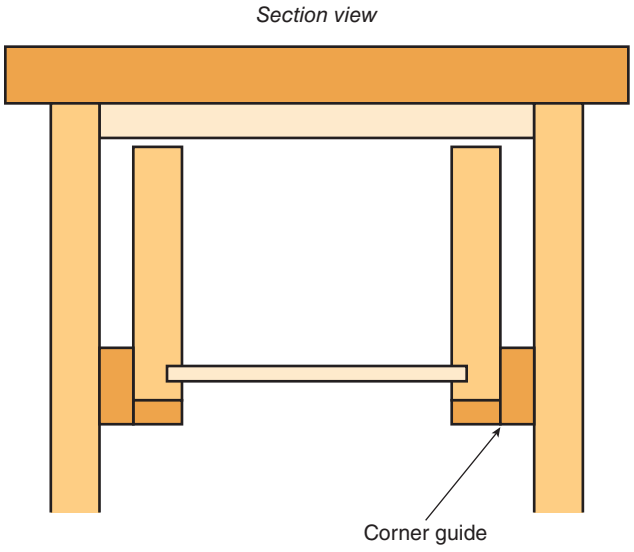
Image courtesy of rockler.com

FIGURE 26-40 Commercial jig for installing drawer slides.



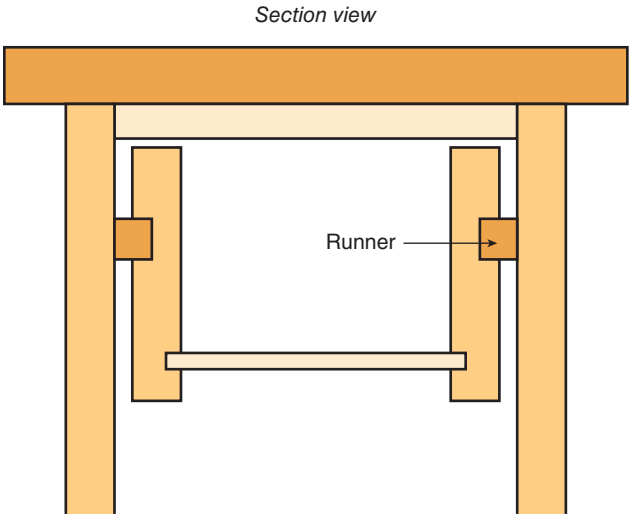
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FIGURE 26-41 Using a plywood spacer to set slides in a cabinet.



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FIGURE 26-42 Shop-built bottom slide.



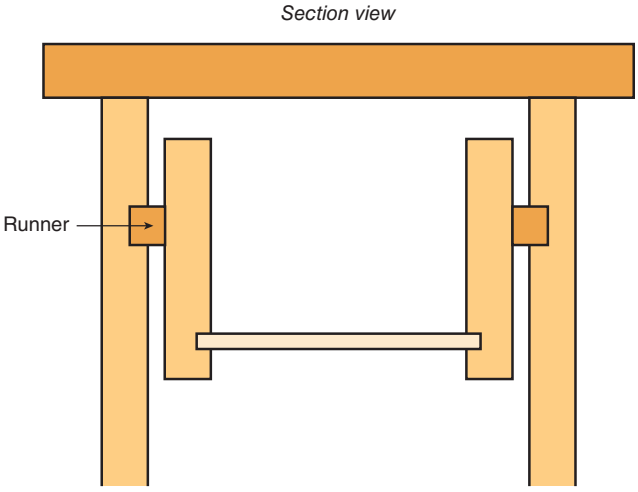
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FIGURE 26-43 Grooves machined in drawer sides run on runners installed in the cabinet.



Image courtesy of rockler.com

FIGURE 26-45 Nylon tape.



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FIGURE 26-44 Runners attached to drawer run in grooves machined in the sides of the cabinet.



Image courtesy of rockler.com

FIGURE 26-46 Pilasters and shelf supports.

the case and attach runners to the drawer (see **Figure 46-44**). In any case, the runners should be made of hardwood to better resist wear.

Larger drawers can also be used without commercial drawer slides. They often are supported by a web frame or a fixed shelf, but they can be difficult to open and shut easily when the wood swells. One way to alleviate this problem is to install a nylon glide strip on the web frame. It is self-sticking on one side (see **Figure 26-45**). This material can also be useful if you are renovating an existing set of drawers that is not working well.

SHELF HARDWARE

Shelf hardware consists of **pilasters** and **shelf supports** (see **Figure 26-46**). A pilaster is a vertically installed strip with slots to accept shelf supports, which in turn support the shelf.

Pilasters can be attached directly to the cabinet sides, but generally they are recessed into a 5/8″-wide groove 3/16″ deep, which gives a bit more shelf room and makes them less obtrusive. Pilasters are available in different colors and finishes, making them easier

PROCEDURE 26-4

Installing Recessed Pilasters

STEPS

1. Mill dadoes 5/8" wide and 3/16" deep at the locations where the pilasters will be inserted. This may be accomplished with a router and straight bit, using an edge guide, or with a dado blade on the table saw (see **Figure A**).
2. Press the pilasters into place; secure them to the cabinet sides with ring-shank nails or screws through the holes milled in the pilasters (these fasteners are sold along with the pilasters) (see **Figure B**).

NOTE: It is good practice to finish the pieces that will receive the pilasters prior to installing the pilasters to avoid getting finish on the pilasters.



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to match to the cabinet. The supports clip into the pilasters. Two pilasters per cabinet side are required. Pilasters are easily cut with a hacksaw; pay attention when cutting and again when installing them, and be sure they are all going the same way. The slots that take the shelf supports must line up.

If you do not want to see a pilaster in the cabinet, a series of 1/4″-diameter holes can be drilled in the cabinet that will accept a different kind of shelf support. These holes should be drilled before the cabinet is assembled for easy accessibility, and you must be careful that the holes line up. Jigs can be purchased for this purpose, but they can also be constructed easily. The shelf supports that fit in these 1/4″ holes are available in different colors and styles. Clear supports may be desirable for glass shelves. Cushioned shelf supports can also be bought. **Figure 26-47** shows examples of this type of shelf support.

Other Hardware

Other hardware not yet mentioned that a cabinet or furniture maker is likely to encounter includes locks, casters, levelers, table-extension slides, table pins, table locks, and bed hardware. Locks may be mounted to secure possessions inside doors, drawers, or chests. Locks may be surface mounted, half mortised, or fully mortised. They may fit through a hole drilled in the door or drawer (see **Figure 26-48**).



Image courtesy of rockler.com

FIGURE 26-47 Shelf supports that fit into drilled holes.

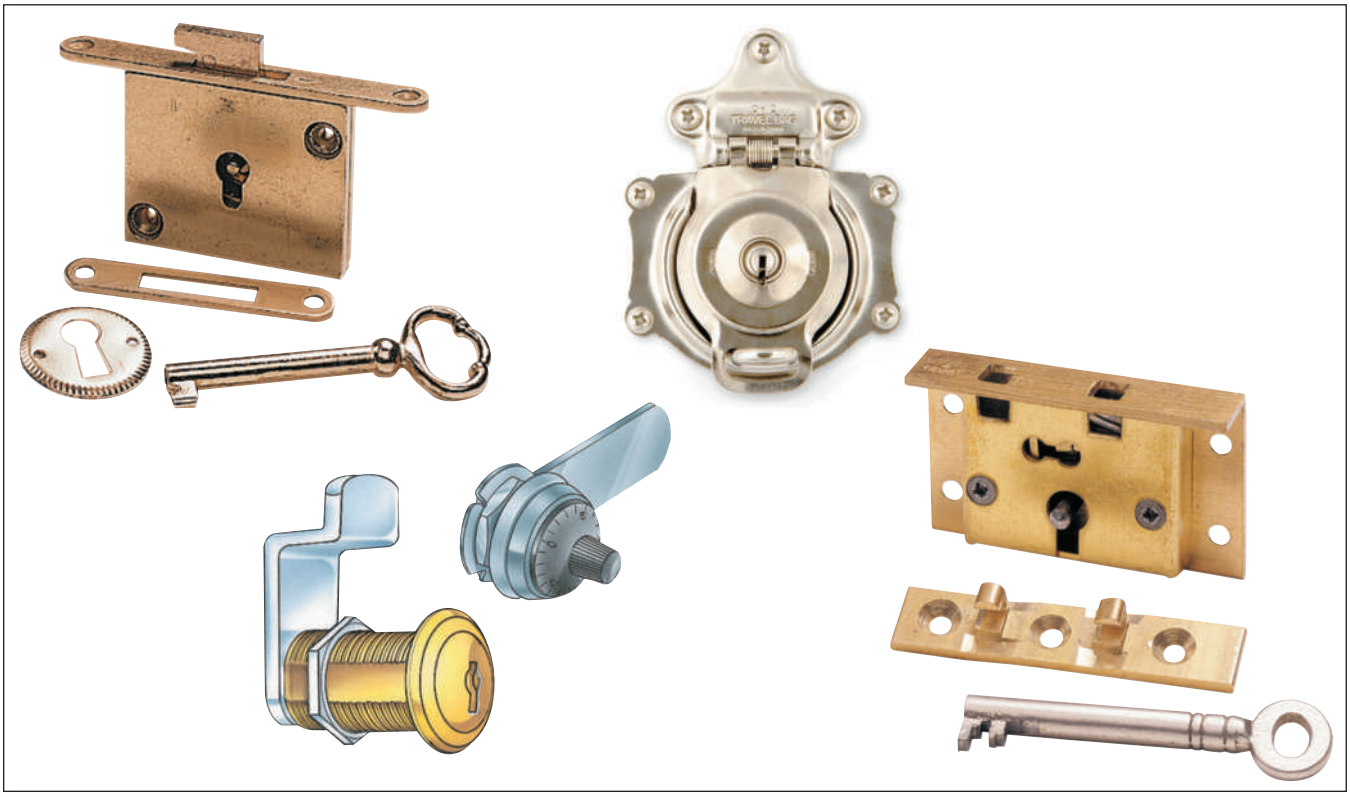


Image courtesy of rockler.com

FIGURE 26-48 Locks may be surface mounted, half mortised, fully mortised, or hole mounted.

The lock may have a mortised strike plate or a cam that turns to prevent the door or drawer from opening. Refer back to Figure 26-46 for examples of each. Sometimes the keyhole is covered by a decorative plate called an **escutcheon** (see **Figure 26-49**).

Casters allow cabinets or carts to be rolled from place to place. A caster is a type of wheel mounted with an offset steering pivot such that the wheel will automatically swivel to align itself to the direction from which it is pushed. Casters may be stem, plate, or socket mounted (see **Figure 26-50**).

Caster wheels may be plastic, rubber, porcelain, wood, or brass, and they are rated for weight. The rolling mechanism is usually wheels, but it may be balls. Some casters swivel; others just move in a straight line. Casters may be locking or nonlocking. In a four-caster system, typically the rear two casters are locking while the front two are not.

Levelers allow a cabinet or table to be adjusted until it is level. They are usually threaded, and by adjusting the amount of thread, leveling is achieved. Often the leveler is adjusted through a hole in the bottom of the cabinet. The leveler is adjusted up or down with a screwdriver or hex wrench (see **Figure 26-51**).

Other levelers are adjusted by twisting from the bottom of the leveler. Related to levelers are **glides**, which may nail or screw onto the bottom of furniture,



Image courtesy of rockler.com

FIGURE 26-49 Escutcheon plates.

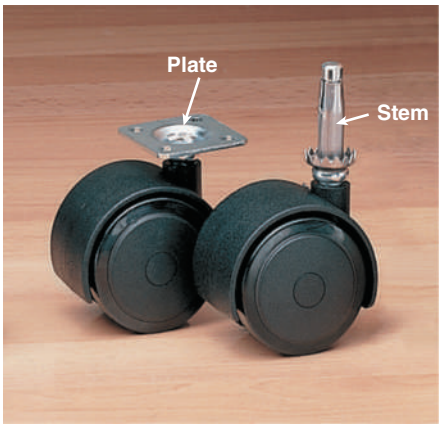
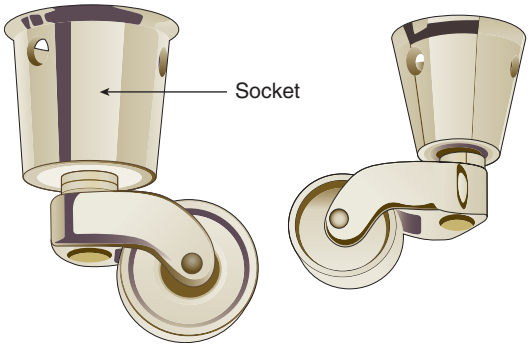


Image courtesy of rockler.com



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FIGURE 26-50 Casters may be plate, stem, or socket mounted.

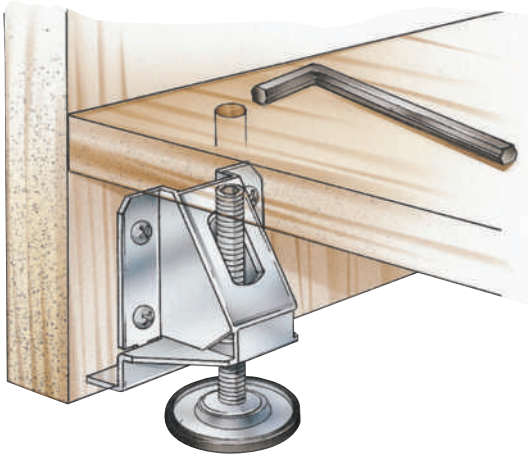


Image courtesy of rockler.com

FIGURE 26-51 The leveler may be adjusted through a hole in the base of the cabinet with a screwdriver or hex wrench.

often the legs, to make it easy to move the furniture around without damaging the floor. Screw-on glides are used with threaded inserts or T-nuts, and they also work as levelers. Glides usually have felt or plastic bottoms (see **Figure 26-52**).

Table-extension slides are used on extension tables (see **Figure 26-53**). They may be wood or metal. They are sold in sets of two and in different lengths to create various sized openings into which table leaves may be inserted. When table leaves are inserted into extension tables, they may be aligned with **table pins** or aligned and secured with **table locks** (see **Figure 26-54**). Table pins may be plastic, wood, or metal.

Bed hardware is used to attach rails to legs. There are two main types, as illustrated in **Figure 26-55**. Some bed bolts have square heads and require a special wrench.

WOODWORKING TIP:

When working with hardware, there are often multiple pieces and screws. Get in the habit of keeping the various parts in containers as you work so that they stay together and do not get lost.



Image courtesy of rockler.com

FIGURE 26-52 Glides may be nailed in or screwed on.



Image courtesy of rockler.com

FIGURE 26-53 Extension slides may be wood or metal.

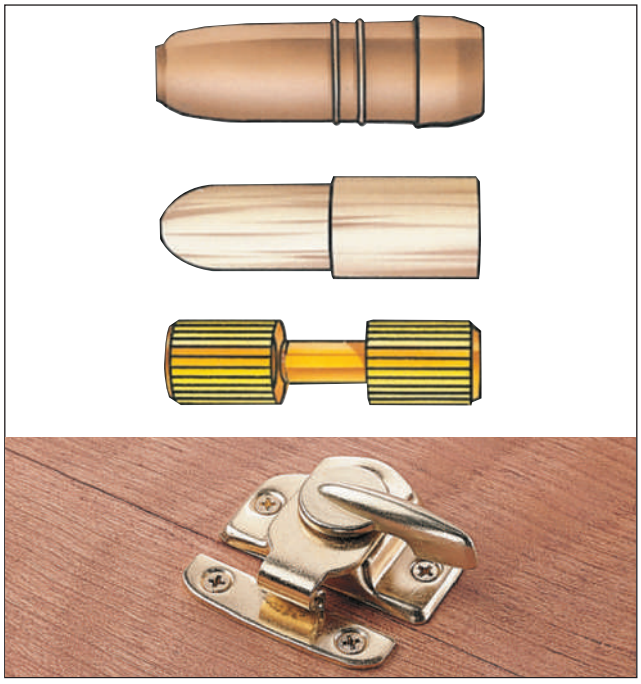


Image courtesy of rockler.com

FIGURE 26-54 Table pins and table lock.

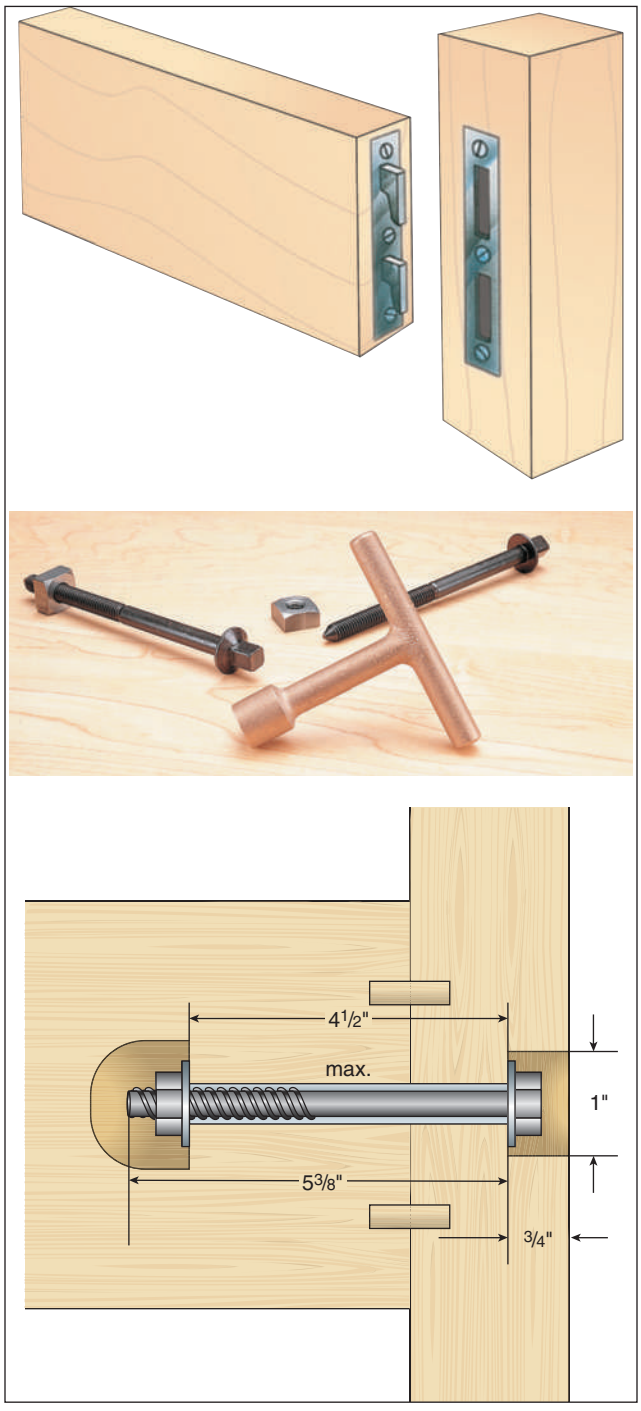


Image courtesy of rockler.com

FIGURE 26-55 Bed-rail fasteners, bed bolts, and special wrench.

SPECIALTY HARDWARE

The common types of hardware have been covered, but it is by no means an exhaustive survey of the hardware available to the cabinetmaker. In this section we will look at some specialized hardware, much of which was developed for use with computer and audiovisual equipment and for use in kitchens.

Kitchen hardware that the woodworker may use includes various types of lazy Susan hardware, pantry slides, sink-front trays, mixer lifts, and slide-out baskets of different configurations. All this hardware was developed to make working in the kitchen easier. **Figure 26-56** through **Figure 26-61** show illustrations of different types of kitchen hardware.



Image courtesy of rockler.com

FIGURE 26-56 Lazy Susan hardware.



Image courtesy of rockler.com

FIGURE 26-57 Pantry slides.



Image courtesy of rockler.com

FIGURE 26-58 Sink-front trays.



Image courtesy of rockler.com

FIGURE 26-59 Mixer lift.



Image courtesy of rockler.com

FIGURE 26-60 Slide-out baskets.



Image courtesy of rockler.com

FIGURE 26-61 Roll-out trash basket.



Image courtesy of rockler.com

FIGURE 26-62 Keyboard trays, grommet, heat vents.

Different kinds of hardware have been developed for use with computers and audiovisual equipment. They include various types of keyboard trays, grommets of different shapes and sizes for threading wires and cables through cabinet units, and heat vents (see **Figure 26-62**).

Also in this category are different compact disc holders, extension and swivel mounts for televisions, and wall mounts for televisions (see **Figure 26-63**). Extension and swivel mounts for televisions allow the TV to be hidden in a cabinet when not in use, then pulled out and swiveled for easy viewing. A special type of hardware was developed that is often used with the doors on these cabinets, which allows the user to open the doors and slide them back into the cabinet opening. This is a called a *flipper-door system,* illustrated in **Figure 26-64**.

There is also specialty hardware that allows ironing boards to be flipped up and hidden behind a cabinet door or slid out from a drawer (see **Figure 26-65**). Another type of specialty hardware is a sewing machine lift. There is hardware available to convert a coffee table into a dining table, and lifts are available that allow you to hide a large flat-screen television in a cabinet (see **Figure 26-66** and **Figure 26-67**).



Image courtesy of rockler.com

FIGURE 26-63 Compact disc holder, extension and swivel mount for televisions, and TV wall mount.



Image courtesy of rockler.com

FIGURE 26-64 Flipper door.



Image courtesy of rockler.com

FIGURE 26-65 Specialty hardware is made for hiding an ironing board in a drawer or behind a door.



Image courtesy of rockler.com

FIGURE 26-66 Hardware for converting a coffee table into a dining table.



Image courtesy of Wood Technology, Inc.

FIGURE 26-67 Large flat-screen TV lift.



Summary

Cabinetmakers and furniture builders have a lot of different types of hardware to choose from. This hardware includes hinges; knobs, pulls, and handles; catches and latches; drawer slides; and shelf hardware, along with different kinds of specialty hardware. Other kinds of hardware include locks, casters, levelers, and different kinds of table and bed hardware. Within each category, there are many choices. The goal in choosing hardware for a given project should be that it makes the furniture easier to use and either increases its attractiveness or at least does not detract from the overall functionality and beauty of the piece. Most hardware of any complexity comes with complete installation instructions, which should be studied carefully. It is also a very good idea to have the hardware you will use in hand before beginning the project, as it may determine the sizing of various component parts. Drawer slides are a good example of this. It is important to install hardware carefully and with precision; if poorly installed, it will not work well, nor will it look good. Sometimes it is a good practice with complicated hardware to install it in a mock-up prior to installation in the cabinet to be sure it will work as designed and that you understand it completely. Various jigs can be purchased or built to speed and ease hardware installation.



Key Terms

barrel hinge
butt hinges
casters
catches
concealed hinges
cup hinges
drawer slides
drop-front supports
drop-leaf hinge
drop-leaf supports
escutcheon
European hinges
finial
flap hinge
folding-leaf hinges
formed hinges
gains
glides
handles
hinges

invisible hinges
knife hinges
knob
latches
leveleres
lid supportes
piano hinges
pilasters
pin hinges
pivot hinges
pull
semi-concealed hinges
shelf supports
Soss hinge
strap hinge
surface hinges
swaged
table locks
table pins
table-extension slides



Check Your Knowledge

1. List five different kinds of hinges, and indicate what kinds of door mounts can be used with each.
2. When building a chest or trunk, what kind of hardware might you use in conjunction with the hinges?
3. What is the essential difference between a knob and a pull?
4. List three different types of catches.
5. Besides using a catch, what are two ways a door could be held closed?
6. How do three-quarter extension slides, full-extension slides, and over-travel slides differ? Which of the three gives you the best access to the drawer?
7. What are three different mounts for drawer slides?
8. If you did not want to use drawer slides, how else might you support your drawers? What could you use to make them operate easily?
9. Why do most drawer slides have slots milled in them, as well as holes?
10. Describe your options for shelf hardware.
11. What choices do you have for mounting locks?
12. If you wanted to be able to move a piece of furniture from place to place without damaging your floors, what kind of hardware would you install? What choices do you have?
13. You are building a table that can be expanded with leaves. What hardware do you need?
14. What kinds of hardware can you install in a kitchen to make it more user friendly?
15. List several types of hardware you might install in a home office or entertainment center.

SECTION VII


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Finishing


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SUCCESS STORIES

Teri Masaschi

Title

Owner, The Tijeras Collection, a restoration and finishing business in Tijeras, New Mexico; author of Foolproof Wood Finishing.

Education

Teri began her career at age 14 with an apprenticeship with a fine arts dealer who needed help restoring antiques.

History

That early work with the dealer set the stage for the rest of her career: "I'd be out in the backyard with a Queen Anne chair that had been in a fire, and once I washed it down with alcohol and saw the rosewood gleaming underneath, I was hooked." Within a few years, she started her own restoration business. In the late seventies and early eighties, she'd go to barn sales, flea markets, and estate sales and buy a truckload of broken and beaten up furniture for $100, refinish the stuff, and sell it at a profit. Soon people were coming to her for furniture repairs, and other woodworkers would bring her their finishing projects. Besides running her business, she teaches workshops at woodworking schools across the country.

On the Job

In order to manage her business efficiently, Teri organizes her days by task. "Scheduling is critical for your own mental health and for your customers' happiness," she says. Mondays she starts at her computer, answering emails from clients and students. After that's completed, she heads to her shop, where she works on repair assignments—perhaps regluing a set of chairs—and then she does sanding and prep work through Tuesday. Wednesday, she's making a push toward finishing: coloring, staining, and glazing. Thursdays, she applies top coats, and on Friday, she delivers pieces, picks up others, and buys supplies.



Image courtesy of Teri Masaschi

Best Aspects

Teri loves watching wood come alive in the refinishing process. But she also cherishes clients' reactions to their refreshed and renewed heirlooms. "I've had people hug me, and I've had people cry."

Challenges

One of the hardest—but most rewarding—parts of Teri's job is completing a finish on a large surface, such as a tabletop. These are least forgiving in terms of light exposure, so she has to make them appear flawless. "Even after all these years, it's hard for me," she admits. "But I get through it with patience, and also by communicating to the client that this is going to take time."

Importance of Education

The education, she says, shouldn't stop once you're in the career. "Anybody who wants to be a woodworker has to get out and take classes, if just to get re-energized," says Teri. "Otherwise you get stale in your shop."

Future Opportunities

Over the next few years, Teri would like to spend less time doing physical labor and more time teaching finishing.

Words of Advice

Those interested in finishing will find good jobs with furniture companies, she advises. "Good finishers are hard to find, so you'll be worth your weight in gold." She also suggests trying for work in Europe, where the art of finishing is thought of more highly than any other type of woodworking.

Story originally written by Margaret Magnarelli, 2008. Interview and photo provided by Teri Masaschi.



27

Surface Preparation

You'll Learn

After studying the chapter, the student should be able to:

- Describe what abrasives are and how they work
- List various types of abrasives, and explain the differences between them
- Explain the grit system
- Describe methods for removing dried glue
- Demonstrate knowledge of proper sanding techniques
- Describe planing and scraping as methods of surface preparation
- Explain methods of repairing dents and scratches
- Identify different types of wood putty, including their advantages and disadvantages

INTRODUCTION

Surface preparation is the sequence of steps taken prior to final finishing of a project. It includes sanding through a series of grits and involves repairing any scratches or dents that may exist. Final planing and scraping may be part of preparing the surface. Patches may need to be made, and wood putty may be required. In this chapter, we will explore sanding materials and methods, planing and scraping, and repairing and filling scratches and dents.

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ABRASIVES

The material that we call *sandpaper* is more accurately termed a **coated abrasive**. Coated abrasives are grains of a natural mineral or synthetic substance bonded to a backing. Each grain acts like a tiny cutting tool, abrading the surface of the wood.

Though our primary focus will be on coated abrasives, there are other items that fall into the category of abrasives. There are solid abrasives, such as sharpening stones and grinding wheels, and loose abrasives, which may be used for polishing in the final finishing step. Examples of these are *pumice* and *rottenstone:* **Pumice** is finely ground lava, and **rottenstone** is soft limestone ground into a powder. There are also abrasive tools, such as files and rasps. Steel wool may also be considered an abrasive tool.

Coated abrasives consist of three parts: the *abrasive grains* that do the cutting, the *backing* to which they are adhered, and the *adhesives* used in the bonding process. Abrasive grains are rated on the **Mohs scale**, which rates minerals for hardness. The Mohs scale ranges from a hardness of 1, which is the softest rating, to 15. Diamonds are a 15 on the Mohs scale, and talc is a 1.

The abrasive grains used for coated abrasives may be natural or synthetic. Two natural abrasive grains that are used are flint and garnet. Flint has a Mohs rating of 8. It is made from crushed quartz, and it is the softest and least expensive of the available papers for wood. Although the first mass-produced sandpaper used flint as its abrasive, it is no longer popular. It dulls quickly and clogs easily, making it a poor choice for fine cabinetmaking. Garnet has a Mohs rating of 10. It is slightly more expensive than flint, but since it lasts four to five times longer, it is actually a better buy. It is harder than flint, but still relatively soft. Garnet granules round over quite easily as it is used, and once the grains are dulled they won't cut as effectively; they tend to burnish, rather than cut. This is not necessarily a bad thing, because burnishing will seal end grain, making it absorb stains and finish more like the rest of a project. Garnet leaves a softer scratch pattern than other kinds of coated abrasives of the same grit, making it a good choice for final hand sanding.

Synthetic abrasive grains used for sandpaper include aluminum oxide, silicon carbide, and alumina zirconia. These synthetics are manufactured from natural minerals that are melted and crushed. Synthetic abrasives are more effective and durable than natural abrasives.

Aluminum oxide has a Mohs rating of 12. It is made from bauxite, coke, and iron. It lasts several times longer than garnet. It is the most commonly used coated abrasive in woodworking. In addition to being harder than garnet, it has another desirable attribute that garnet does not: its high friability. This means that when heat and pressure are applied, it fragments. When it fragments, its cutting edges are renewed. This self-renewing property means that aluminum oxide will last longer than a coated abrasive with low friability. Aluminum oxide is also relatively tough, meaning that its edges won't dull much before it fragments. Aluminum oxide's friability and toughness make it the longest lasting and most economical of the coated abrasives. It is excellent for machine sanding.

Silicon carbide is rated Mohs 13 and is made from silica sand and carbon; it is the hardest and most expensive of the synthetic abrasives. Like aluminum oxide, it is highly friable, but wood is not hard enough to fracture its surface, so it wears out more quickly than aluminum oxide. It is preferred for sanding between finishing coats or for rubbing out the final finish coat. It sometimes has a water-resistant backing and can be used with a lubricant like water or oil, which together make it a good choice for tool sharpening and wet-sanding finishes. It is available in very high grits. It can be purchased with a zinc stearate coating, which is a dry lubricant that helps keep the sandpaper from clogging. This type of paper is good for sanding finishes.

Alumina zirconia, also known as ceramic, has a Mohs rating of 11. It is an extremely tough and aggressive coated abrasive that holds its edge very well. It is often used on sanding belts and heavy-duty surfacing operations, such as thickness sanding. **Figure 27-1** presents a summary of the best uses for garnet, aluminum oxide, silicon carbide, and alumina zirconia coated abrasives.

Abrasive grains are bonded to a backing. The backing may be paper, cloth, fiber, or a combination of these. Various grades of paper are used, labeled A, B, C, D, E, and F. The lightest of the papers is the A grade; the heaviest is F. Cloth backings are also graded. The J grade is called *jeans cloth* and is light and flexible. The X grade, called *drill cloth,* is heavier, stronger, and more durable. The Y grade is the heaviest of the cloth backings. Fiber backing is very strong and stiff and is able to withstand the heat generated by prolonged sanding. It is made of chemically treated laminated paper and cotton rag. It is most

	Garnet	Aluminum Oxide	Silicon Carbide	Alumina Zirconia
Hand Sanding	*	*	*	
Power Sanding		*	*	*
Bare Wood	*	*		*
Painted Wood		*	*	
Wet Sanding			*	
Clear Finish			*	
Metal		*	*	*

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FIGURE 27-1 Sandpaper usage.

commonly used on sleeves for drill press or drum sanding. Combination backing is composed of two layers, paper and cloth. It is used for extra-heavy-duty disc sanding.

The adhesives that bond the abrasive grains to the backing are applied in two coats. The first coat is called the **bond coat** or make coat. It is applied to the backing, and the abrasive grains are placed on it. The second adhesive coat is called the **size coat**. It is applied on top of the abrasive grains and locks them in place. Five types of adhesives are used: One is animal hide glue, used for both the bond and the size coat; this is only used on flint paper. A second type is glue and filler, which is hide glue with a filler added that changes its characteristics so that it lasts longer. It is durable and strong and is used for both coats. A third type is resin over glue. The first coat is hide glue and the second is a synthetic resin; this type is very resistant to heat. A fourth type is resin over resin. A synthetic resin is used for both the bond and the size coats. It is both heat and moisture resistant. The fifth type is waterproof. It uses a synthetic resin for both coats, and it is applied to a waterproof backing; it is used for wet/dry sanding materials.

Abrasive particles are applied to their backings in two ways, called open coat and closed coat. Open coat sandpapers have space between the abrasive particles; the backing is only 50–70 percent covered with them. The spaces result in less clogging and loading of the sandpaper with swarf, the wood debris created by sanding. They act like the gullets on a circular saw blade, permitting clearance of waste. Closed coat papers are completely covered with abrasive grit. Open coat sandpaper is best for sanding wood, while closed coat is best for sanding metal and finishes.

After the abrasive grains are attached and locked into place on the backing with the bond and size adhesive coats, the resulting coated abrasive is quite stiff. To counteract this, the sandpaper is flexed. Three different patterns of flexing are done at the factory, depending on the desired final result. The three patterns of flexing are *single flex, double flex,* and *triple flex.* With single flexing, the coated abrasive is flexed in one direction. In double flexing, the material is flexed on the diagonal in two directions. Triple flex is a combination of single and double flexing, and it results in the most flexible final product (see **Figure 27-2**). Once flexed, coated abrasives are then shaped into sheets, discs, and belts of various sizes for use in sanding (see **Figure 27-3**).



HISTORY FACT

Coated abrasives were used as far back as the 1400s, when the Chinese used crushed shells and seeds attached to parchment with natural gum for abrasive work. Coated abrasive paper was being sold in Paris by 1769, and in 1835, a machine designed for producing coated abrasives was patented in the United States. ■

Grit System

The **grit system** is used to indicate the coarseness of the abrasive grains and consequently the coarseness of the sandpaper. Abrasive grains that will be adhered to a backing are sifted through a series of shaking screens to separate the different sizes. The grit size refers to the number of holes in the screen per lineal inch.

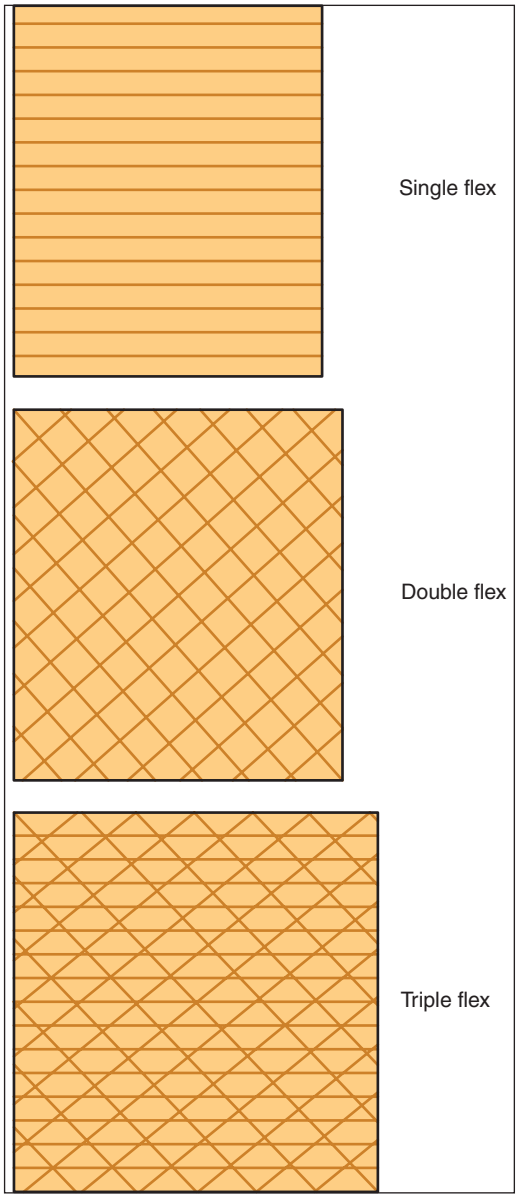


FIGURE 27-2 Flexing patterns.

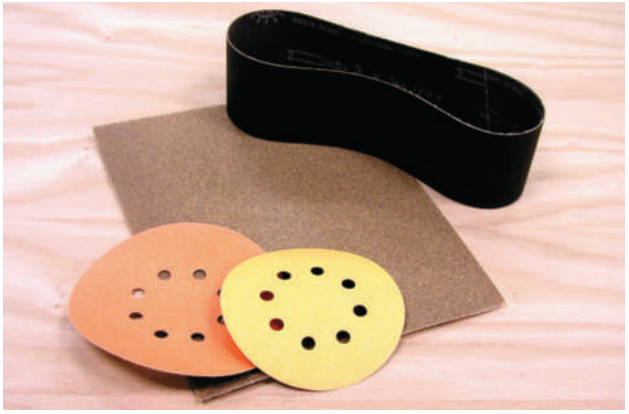


FIGURE 27-3 Coated abrasives are formed into sheets, discs, and belts.

So, for example, the grains used for a 100 grit coated abrasive are able to pass through a screen that has 100 openings per lineal inch, or 10,000 openings per square inch. The lower the grit number, the coarser the abrasive grains are. The sifting method is used for grit sizes from 16 through 220. Finer grains are referred to as *powders,* and they are graded through an air or water flotation process that separates particles by weight. Commonly used grit sizes in the shop are 60, 80, 100, 120, 150, 180, and 220. Finer grits may be used when doing final finishing to smooth the surface between coats of finish (see **Figure 27-4**).

There are actually three measurement systems for the size of abrasive grit: CAMI (Coated Abrasives Manufacturers Institute), FEPA (Federation of European Producers Association), and Micron grading. All three systems use the shaking and flotation methods of grit identification described above. The majority of coated abrasives manufactured today use the FEPA standards, which are known in the industry as "P" grading. Sandpaper is labeled on the back with the grit size. If there is a "P" in front of it, the grading system is FEPA. If there is no prefix, it is CAMI (see **Figure 27-5**). The CAMI system is used exclusively by U.S. manufacturers and tolerates a wider range of grain sizes within the definition of the grit than does FEPA, which uses tighter tolerances in grading abrasive particles, resulting in a more uniform scratch pattern. Still, there is very little difference between the coated abrasives graded by CAMI and FEPA up to 220 grit. Beyond that, they diverge considerably.

The Micron system is generally used for very fine grits, and refers to an abrasive particle's actual diameter in micrometers, rather than the total number of

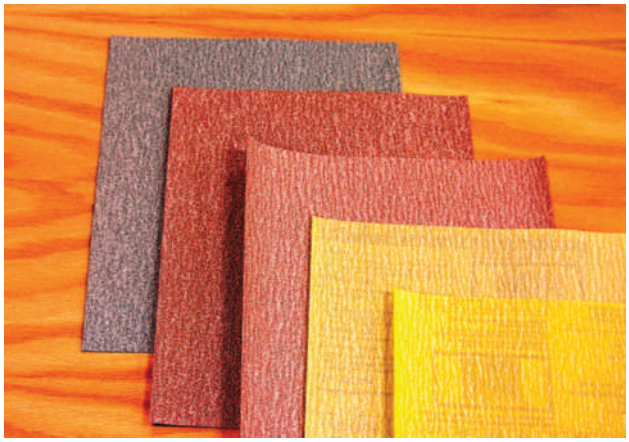
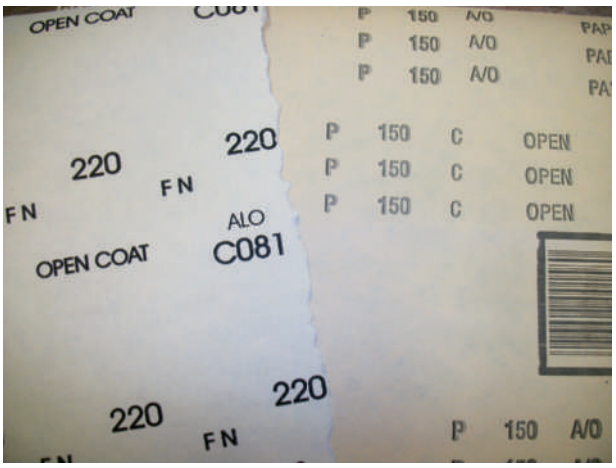


FIGURE 27-4 An assortment of coated abrasives of various grits.



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FIGURE 27-5 The 220 grit paper on the left was graded by the CAMI system and the 150 grit one right by FEPA standards. Both are open coats and a C weight paper is the backing on the 150 grit.

abrasive grains that can pass through a lineal inch of screen or mesh. The Greek letter mu (μ) indicates that the micron system was used. Micron-graded abrasives are most uniform in size, and because of this they are the best choice for sanding finishes. See **Figure 27-6** for a comparison of the different measurement systems.

Removing Dried Glue

Before we begin to sand, we have to remove any dried glue residue that may remain on the project. This is best done with a sharp chisel or scraper, taking care not to remove any wood fibers. Dried glue that is not removed will interfere with the wood's absorption of stain and finish, and some glues soften when exposed to the heat generated by the sanding process, which will clog the sandpaper.

GREEN REMINDERS

Keep a box for storing sandpaper that has been used but still has some life left in it; instead of always reaching for a new sheet or disc, first see if you have one that can still be used.

CAMI	FEPA	MICRON
60	60 80	
80	100	150 180
100	120	
120	150	100
150		80
180	180	
220	220	60
240	240 280 320	45 50
280	360	40
320	400 500	30
360	600	
400	800	20
500	1000	
600	1200	15
800		
1000		9
1200		5

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FIGURE 27-6 Comparison of the CAMI, FEPA, and Micron measuring systems

Sanding Techniques

We sand to level surfaces and to make them smooth. Using abrasives wears away, or abrades, the wood we are sanding. The abrasive grains act like tiny cutting tools, and as they wear away the surface, they also scratch it. An 80 grit coated abrasive is coarser and will cut faster than a 120 grit abrasive, but it will also leave deeper scratches. The higher the grit, the finer the scratches it leaves behind. For this reason, as we sand, we progress through a series of grits. Each higher grit used removes the scratches left by the previous grit. If grits are skipped, it is much more work to remove the previously left scratches. We may start with an 80 or 100 grit abrasive paper, disc, or belt. Next, 120 grit is used, then 150, then 180. You should never skip more than two grits; in other words, you could go from 120 to 180, but never from 120 to 220.

WOODWORKING TIP:

A simple jig for cutting sheets of sandpaper can be made by attaching a hacksaw blade to a piece of plywood. Often sheets are quartered for use with pad sanders. By laying out marks like those shown in **Figure 27-7**, *this can be done quickly and easily.*

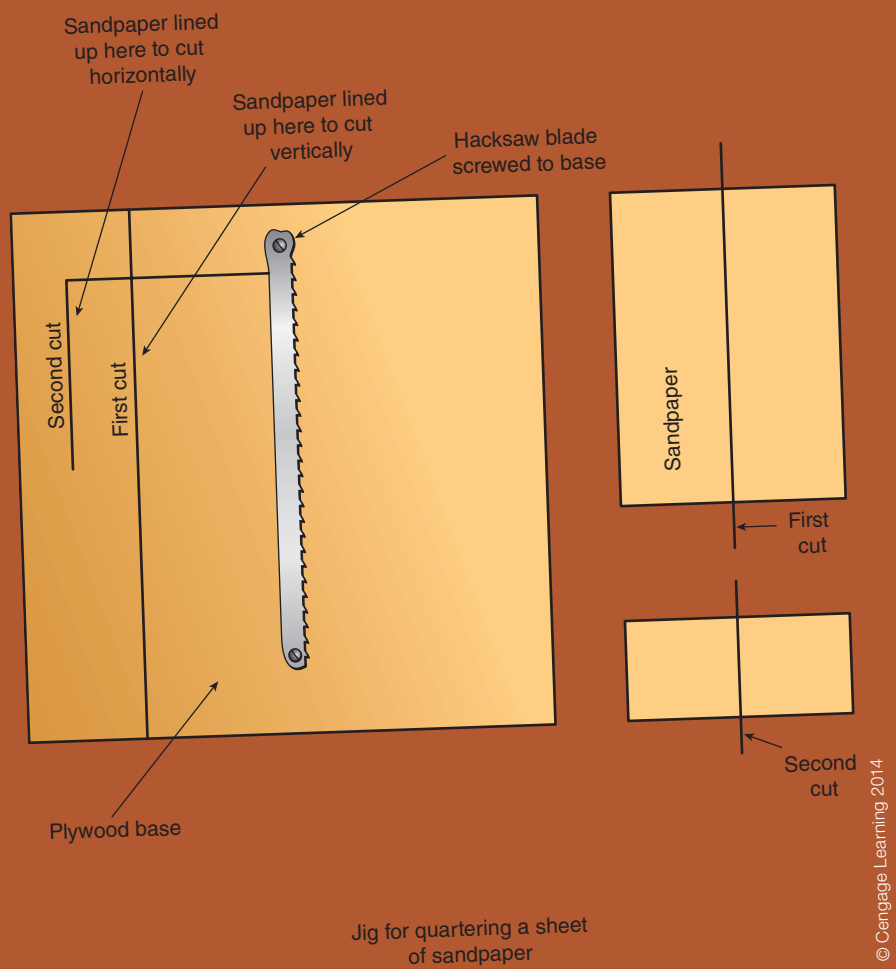


FIGURE 27-7 Sandpaper cutting jig.

When finished with one grit size and moving to the next finer one, it is very important to clean the surface you are sanding between grits. The reason for this is that you want to be sure that no abrasive grains from the previous sanding have been left behind. If they are, they will be trapped on the surface beneath the current sanding job and will cause deeper scratches. A tack cloth may be used to clean a surface between grits, or the surface may be blown clean with compressed air or wiped carefully with a clean cloth.

Coated 80 grit abrasives are used for rough work, such as leveling joints and leveling surfaces. For general sanding and easy leveling, 100 grit is a good choice. You are likely to start with 80 or 100 grit, and 150 grit may be the final paper used, depending on the type of finish to be applied and what surface is being sanded. Typically, inside surfaces are not sanded to as fine a surface as more visible surfaces, such as tabletops and door fronts.

It is good practice to think about accessibility of places that will need sanding. It is much easier to sand inside surfaces prior to assembly. For example, the inside parts of a drawer should be sanded before the drawer is glued up. This is equally true for other inside parts. Outside parts should be rough sanded before assembly, but final sanding is done when the piece is assembled.

CAUTION

Sanding creates fine particles of dust that should not be breathed in. Wearing a paper mask that fits well is highly recommended when doing any type of sanding, particularly machine sanding, which raises a great deal of dust very quickly. Paper masks are disposable and should be replaced periodically. To get more than one use out of a mask, store it in a self-sealing plastic bag.

Final sanding should always be done with the grain of the wood. Cross-grain scratches are particularly noticeable. If you have been using an orbital sander, your final sanding pass should be done with a hand block, and it must be done with the grain. Commercial sanding blocks are available, or you can simply wrap a piece of sandpaper around a properly sized, smooth piece of hardwood. Sanding without a block is discouraged, because fingertip pressure may cause unevenness in the final product, particularly when using softer woods.

Coated abrasives tend to load up with sanding dust as they are used. A rubber cleaning stick can be used on a running machine, such as a stationary disc sander or drum sander, to clean it off (see **Figure 27-8**). A palm sander or disc sander can be tapped to remove dust. Once a coated abrasive is worn, however, it needs to be replaced. At that point, little abrasive action is taking place, and all you are doing is exercising.

It is tempting when sanding with a portable sanding machine to put some downward pressure on the machine as you sand, especially when a lot of material needs to be removed. This is a mistake. If material needs to be removed more rapidly, start with a lower grit paper. The machine should be allowed to do the work. Leaning on it simply slows the machine down and shortens its life, as well as digging unnecessary scratches in the wood.

WOODWORKING TIP:

Good light is an important tool for detecting scratches caused by sanding. In addition to working in a well-lighted area, it is helpful to have a light that can be angled obliquely across a sanded surface to check for scratches. A good flashlight works well.



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FIGURE 27-8 Cleaning a sanding belt with a rubber stick.

Planing and Scraping

While sanding wears down wood by essentially grinding it away, planing and scraping remove wood in a very different manner. Planing shears off wood fibers and creates a very smooth surface, provided the plane iron is sharp and the plane is used correctly. When a lot of material must be removed, it is usually more efficient to plane prior to sanding. It is faster and considerably less hazardous to your respiratory and auditory health than sanding. In addition, planing does not create the scratches that sanding does. A well-tuned plane properly used will yield a silky smooth surface that is hard to duplicate by sanding. However, if the surface being planed is wider than the plane iron, it is almost inevitable that small ridges will be left on a planed surface. In a case like this, the best approach is to plane what you can and finish the surface by sanding. Depending on how good a surface you can get with your plane, you can start sanding with a relatively high-grit paper.

You may recall that there are two kinds of scrapers: *cabinet scrapers* and *card scrapers*. The scraper cuts by means of a small burr turned on its edge, and it allows you to take very fine shavings. Scrapers can be used to do a final cleaning after planing, which may permit sanding to be avoided altogether. Scrapers are

PROCEDURE 27-1

Sharpening a Card Scraper


A

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B

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STEPS

1. Remove the dull burrs on the scraper by using a mill file to file the edges square to the blade. This is most easily done with a jig that holds the file square to the scraper. The scraper is clamped in a vise (see **Figure A**).
2. Stand the scraper upright on a fine sharpening stone and move it back and forth, sharpening on its edges. Then place the scraper face down on the sharpening stone, and rub it in a circular motion to remove any roughness left by filing. Turn it over and repeat. Refer to **Figure B** and **Figure C**.
3. Place the scraper flat on the bench with its edge extending off the table. Lubricate the burnishing tool by rubbing it with a candle or a paraffin block. Draw the burnisher back and forth along the edge, exerting strong downward pressure. Flip the scraper over and do the same thing on the other side (see **Figure D**). Repeat for the other long edge.


C

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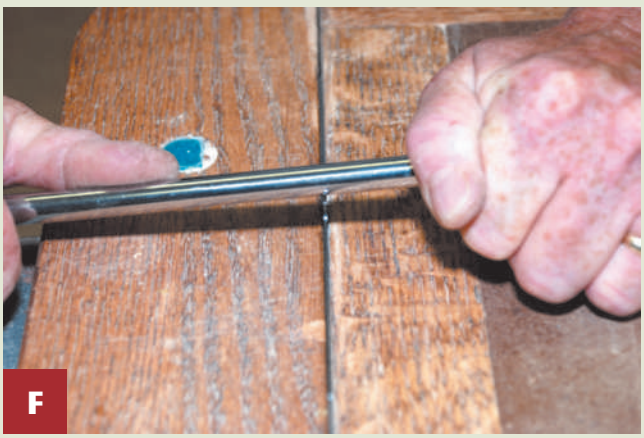

D

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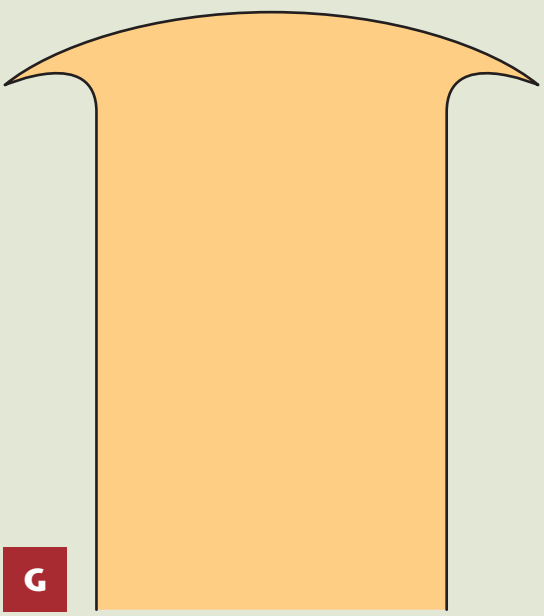
4. Clamp the scraper in the bench vise with the edge up. Hold the burnisher perpendicular to the scraper and make a few passes along the edge in one direction, as shown in **Figure E**.
5. Tilt the burnisher 10 to 15 degrees off vertical, and draw it along the edge with firm, even pressure until the burr is turned. Then tilt the burnisher in the other direction and repeat. You will have raised a cutting burr on both edges of that side (see **Figure F**). **Figure G** illustrates what the turned burrs look like, greatly magnified.
6. Flip the scraper over in the vise and repeat Steps 4 and 5 to create a burr on the other long edge.


E

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F

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G

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also useful for removing glue residue that may not be obvious until the wood is first colored. At this point, when it is clear that there is some glue residue left on the surface, because the stain or dye is not being absorbed in that area, that part can be carefully scraped and the coloring reapplied to that section.

Dents and Scratches

Dents and scratches mar your work, and they should be repaired, but they are two essentially different situations that call for different remedies. Scratches are places where wood has actually been removed. A scratch may be deep, medium, or light. Light scratches can be particularly difficult to see, but once color is added to the wood, they will show up dramatically, especially those which go across the grain. Discerning scratches requires good light and the willingness to go over a project very carefully. A helpful method for finding scratches is to wipe the project down with a thinner, such as mineral spirits or turpentine. This will allow the scratches to be seen more easily. Water can also be used, but thinner evaporates much more quickly, making it a more desirable choice.

Deep scratches up to 1/16 inch deep can be removed with a hand plane. This can only be done on solid lumber. A large area around the scratch should be planed away to make the planed area less noticeable. This must be done carefully with a sharp plane so that the situation is alleviated, not worsened. Medium scratches are best removed with a cabinet scraper, which will remove a fine layer of wood with each pass. Again, a larger area around the scratch should be scraped, allowing the scraped area to blend in. Light scratches can be removed with sandpaper and a block, and scratches deeper than 1/16 inch need to be patched or filled with putty.

In the case of scratches, wood is actually missing. Dents are areas where the wood fibers have been compressed, so no material is missing, but the wood cells have been crushed. Sometimes this process can be reversed. The simplest method, and the one to try first, is to put a few drops of water in the dent. If the damage is not too severe, the wood cells may absorb the water and regain their former shape, causing the dent to disappear. If this method does not work, a very hot knife or the tip of an iron can be placed in the water filling the dent. The heat will turn the water into steam, which will pass more readily into the wood cells, swelling them back to their original shape. Alternatively, a cloth dampened with water can be laid over the dent and a household iron placed over it. Be careful not to scorch the wood. A third method is to direct a jet of steam at the dent. For this you can use a small electric hot pot with an attached nozzle, which allows the steam to be concentrated on the area you wish to swell. If none of these methods works, the area will have be patched or, as a last resort, filled with wood putty.

Patches and Putties

Scratches and dents that cannot be removed by the methods described in the previous section have to be repaired in another way. One strategy is to patch the defects. The other is to fill them with wood putty.

Patching involves removing wood around the defect and replacing it with another piece of wood. There are numerous ways to do this, but the goal is the same in each: to remove the defect and replace the damaged section in such a way that the patch is less noticeable than the defect was. This means that the wood used in the patch must be of a color and grain configuration similar to the section removed. This is one reason to keep track of your scraps until a project is complete, because pieces may be needed for making patches.

One of the simplest ways to repair a small defect is to drill a hole with a flat-bottomed bit where the defect is and then to cut a plug using a plug cutter and glue it in place. Plug cutters come in standard sizes of 1/4, 3/8, 1/2, and 5/8 inches, so the hole you drill should be one of these sizes. The plug should be cut from similar material and glued in place. Be sure that the grain of the plug is running in the same direction as the grain of your workpiece. It should stand slightly proud of the surface; when the glue is dry, it can be planed and sanded flush (see **Figure 27-9**).

The method described above works adequately with small defects but not with larger ones. It also has the drawback that it tends to be somewhat visible due to the circular nature of the patch, even if a good job is done in matching color and grain. Another method is to create a patch with more irregular edges that will be less noticeable to the eye. In this case, an area is marked out around the defect. The edges marking the area to be removed are cut with a chisel, and the area within it is then carefully chiseled out. When relatively large areas need to be taken out, a router with a straight bit can be used to remove most of the waste, and the rest can be removed with a chisel. It is important to create a flat bottom within the recess so



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FIGURE 27-9 Patching with a plug.

that the patch will adhere to it well. The patch is then made to fit in the recess created. Again, match the patch to the surrounding wood with regard to color and grain pattern. The patch needs to fit well, so it is often wise to make the patch first, then trace around it to identify the area to be taken out. Like a plug, the patch should stand slightly above the surface and be planed and sanded down flush once the glue is dry (see **Figure 27-10**).

If the edge of a piece is problematic, such as if there was tear-out when routing a decorative edge, a narrow section of the panel can be ripped off and a new piece added and the profile milled again. Care should be taken to be sure that the color and grain pattern of the added section match the panel.



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FIGURE 27-10 Irregularly shaped patch.

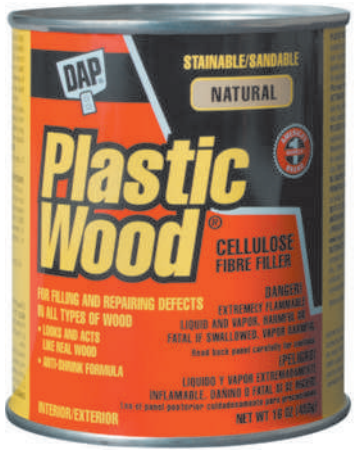
Another way of fixing defects is to use wood putty. There are many different kinds of putty available. Putty is a good option for filling small nail holes, but it is a last resort for fixing scratches and dents. This is because it tends to be difficult to match the putty to the wood, and because different putties either do not take stain at all, or they take it somewhat differently than the wood, which can result in the defect being highlighted rather than hidden.

There are many different types of commercially available putties, and these can be divided into two main categories. One category contains putties that harden and are applied before finishing. The second category includes nonhardening putties that are applied after the project has been finished.

Putties that harden may be either water or lacquer based. **Figure 27-11** shows some examples. They are applied with a putty knife. If the scratch or dent to be filled is not very deep, one application of putty is sufficient. Deeper defects should be filled with putty a bit at a time, allowing the putty to dry between



Image courtesy of Elmers Products, Inc., www.elmers.com



Courtesy of DAP Products, Inc.

FIGURE 27-11 Examples of hardening wood putties.

PROCEDURE 27-2

Patching a Defect



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STEPS

1. Identify the area you wish to remove.
2. Select a piece of material that closely matches the area that will be repaired; cut a patch large enough to cover it (see **Figure A**). Smooth the edges of the patch with a block plane.
3. Place the patch over the area it will replace, and trace around it with a sharp knife, as shown in **Figure B**.
4. Deepen the knife lines with a chisel and mallet, making sure the bevel of the chisel faces in (see **Figure C**).

5. Remove the area with a chisel. If much material needs to be removed, a laminate trimmer outfitted with a straight bit can remove most of the waste, and the remainder can be taken out with a chisel; this is shown in **Figure D** and **Figure E**.
6. Check the fit of the patch in the recess you just made. It should be snug. If it is too tight, plane a slight bevel on the edges of the patch and try it again.
7. Glue the patch in place. When it is dry, plane and sand it flush with the surrounding material.



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applications. The reason for this is that the putty can shrink or crack as it dries. By applying the filler in thin layers, this problem can be avoided. Whether the defect to be filled requires one application of putty or several thin layers, the final layer should sit slightly above the wood surface. Once it is dry, it can be sanded smooth. To determine how the putty you are using will react to stain, try it out on a test piece first. Several colors of putty are available, and you need to determine which one will give you the best match after staining.

Nonhardening putty is used to repair defects after the final finishing of the project is complete. Oil-based putty is the most widely used. It is available in a far wider range of colors than is hardening putty, and different colors can be mixed to achieve the desired color (see **Figure 27-12**). Another putty product that is non-hardening is wax sticks, which are also available in different colors (see **Figure 27-13**).



Image courtesy of Minwax, www.minwax.com

FIGURE 27-12 Nonhardening wood putty.



Image courtesy of Minwax, www.minwax.com

FIGURE 27-13 Putty stick.

A shopmade alternative to wood putties can be made by mixing sawdust and glue. Scrap stock from the project is sanded to create sanding dust. This fine dust is mixed with glue and pressed into the defect. Once dry it can be sanded smooth. This method works well for small gaps at joint lines, such as a miter frame joint. Epoxy is a better choice of glues for this procedure than aliphatic resin.



Summary

Preparing a surface involves getting the project ready for staining and finishing. It is the process of sanding, planing, and scraping to the final desired degree of smoothness. Coated abrasives are most frequently used for this process. Sanding is done by moving through a progressively higher series of grits, each of which removes the scratches made by the previous grit and replaces them with finer scratches. Defects such as dents and scratches are repaired by various methods, such as steaming, patching, and filling. Once these tasks have been completed, the project is ready for coloring and finishing.



Key Terms

bond coat
coated abrasive
grit system
Mohs scale
pumice
rottenstone
size coat



Check Your Knowledge

1. What are the steps taken in preparing a surface for coloring and finishing?
2. How does an abrasive work?
3. Give three examples of abrasives other than sandpaper.
4. What is the proper name for sandpaper?
5. What are the three parts of sandpaper? List three examples of each.
6. What does the term *grit* refer to?
7. Why is it important not to skip grits when sanding?
8. Why does it make sense to sand the insides of pieces prior to assembly?
9. How does planing or scraping differ from sanding?
10. How does a dent differ from a scratch?
11. How might you fix a dent? How might you repair a scratch?
12. Why is using putty to fix a defect a last resort?

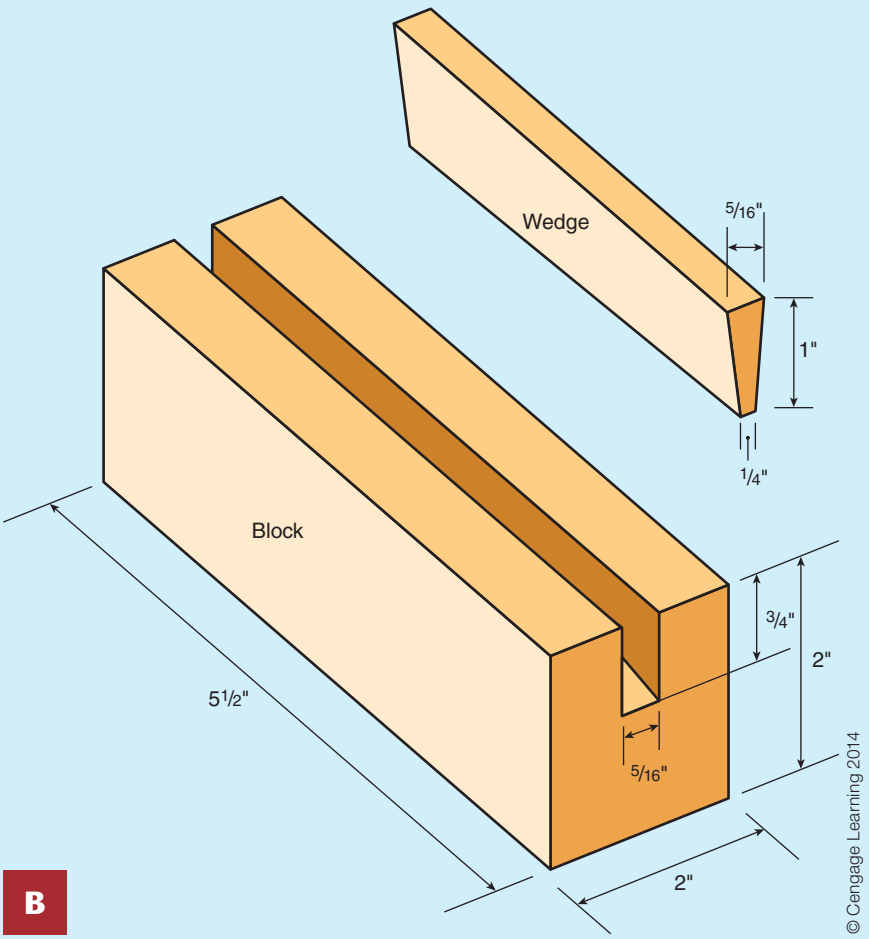
BUILD IT!

Simple Sanding Block



A

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B

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Figure A shows a simple sanding block.

TOOLS REQUIRED

- Measuring tool
- Square
- Miter saw or handsaw
- Table saw and dado blade
- Thickness planer
- Block plane

MATERIALS REQUIRED

- 2″ × 2″ × 10″ softwood block
- 1/2″ × 1″ × 10″ softwood

STEPS

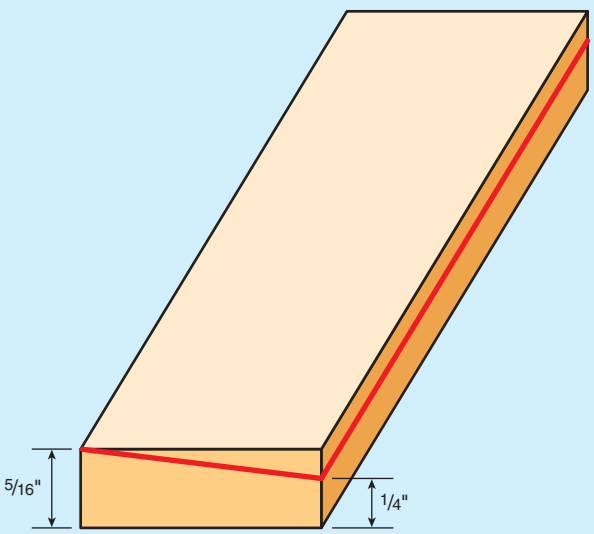
1. Review the diagram shown in **Figure B**. If necessary, glue two pieces of material together to get a block that is 2″ thick.

2. Set up the dado head in the table for a cut 5/16" wide, and plow a centered groove 3/4" deep (see **Figure C**).
3. Cut the block to its final length of 5 1/2" on the miter saw or with a handsaw.
4. Using the thickness planer, plane your 1/2" × 1" piece down to 5/16".
5. Cut this piece to its final length of 5 1/2".
6. Referring to **Figure D**, lay out the piece as shown.
7. Plane the bevel you just laid out with a block plane.
8. To use the sanding block, wrap a piece of sandpaper around the block and fold the edges into the groove. Insert the wedge into the groove narrow edge first to hold the sandpaper in place. All three full sides of the block can be used, and the narrow faces on either side of the wedge are useful for sanding narrow edges.



C

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D Plane to the red lines.

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BUILD IT!

PROJECT CHALLENGE

Custom Sanding Block



A

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Assembly list – custom sanding block

Part	Dimensions (thickness × width × length)	Quantity
Block top	2" × $2\frac{5}{8}$" × 7" pine	1
Block base	$\frac{1}{2}$" × $2\frac{5}{8}$" × 7" pine	1
Clamping pad	$\frac{1}{4}$" × $1\frac{3}{16}$" × $2\frac{5}{8}$" hardboard	1
Threaded insert	$\frac{1}{4}$"	1
Flat washer	$\frac{1}{4}$"	1
Studded round knob	$\frac{1}{4}$" × $\frac{3}{4}$"	1
Cork	$2\frac{5}{8}$" × 7"	1

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B

Figure A shows the custom sanding block.

STEPS

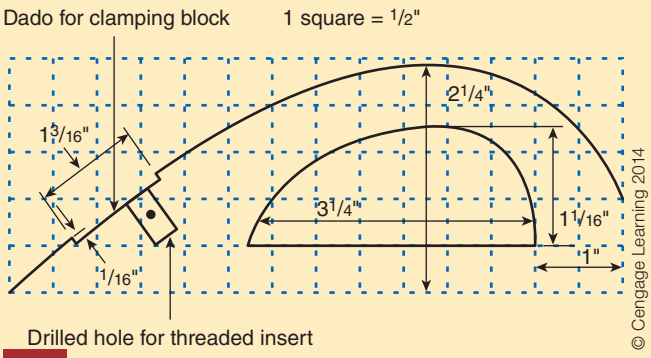
1. Study the assembly list given in **Figure B**, and gather the supplies you will need. If necessary, glue up pieces for the 2" block.

2. Clamp the 2" piece and the 1/2" piece together as shown in **Figure C**, and lay out the pattern given in **Figure D**.
3. Separate the two pieces, and cut out the inside curve in the thicker piece on the band saw. Sand smooth and then glue and clamp the two pieces together (see **Figure E**).
4. When the glue is dry, go back to the band saw, cut out the outside curve on the top of the block, and sand it smooth.
5. Refer to Figure D; make the dado in the block for the clamping pad with a chisel and mallet.



C

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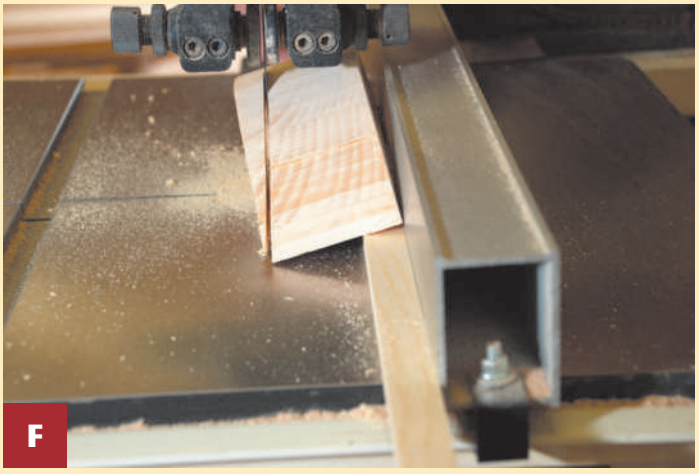
D

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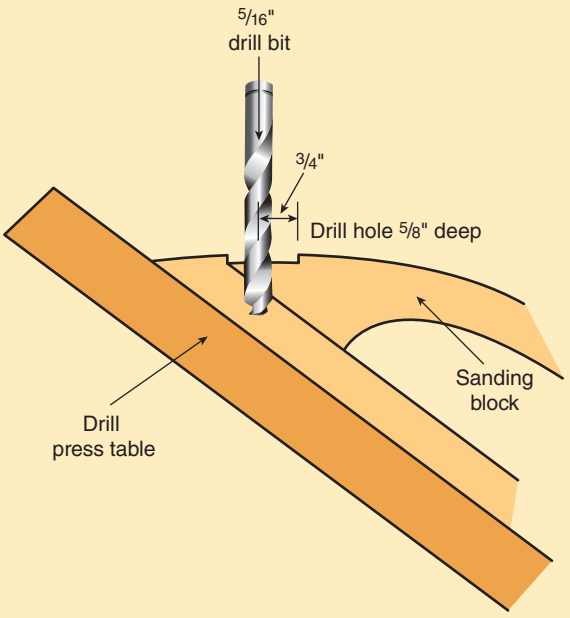
E

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F

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G

Table is tilted so that the bit is 90° to the dado bottom

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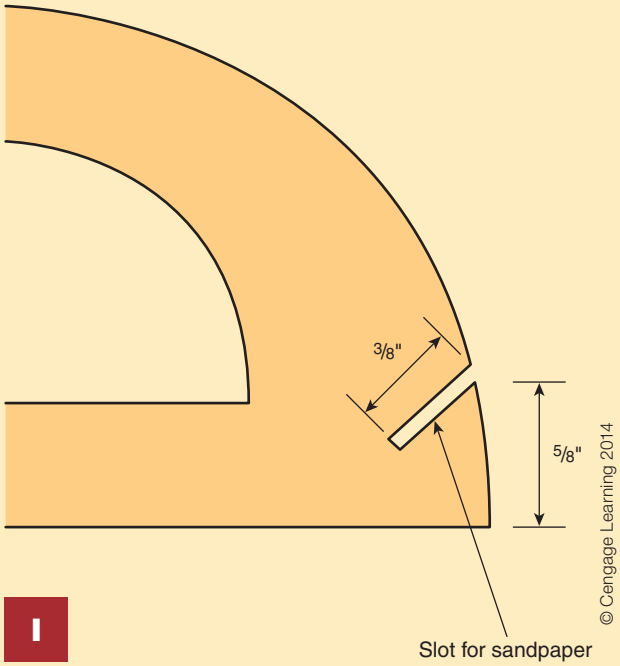


H

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6. Bevel the sides of the block by placing a 1/2" × 3/4" piece of scrap on the band saw next to the fence; cut each side, as shown in **Figure F**.
7. Drill a 5/16" hole for the threaded insert; make it 5/8" deep in the dado by tilting the table on the drill press so that the hole is at a right angle to the dado, as shown in **Figure G**. If your drill press table does not tilt, build a jig to hold the sanding block in the proper position.
8. Install the 1/4" threaded insert in the hole just drilled. The best way to do a good job of this is to use the drill press. Cut the head off a 1/4" bolt with a hacksaw, and thread on two nuts and the threaded insert. Chuck this into the drill press, and with the table at the same angle at which you drilled the hole, turn the chuck by hand to install the insert (see **Figure H**).
9. Make a clamping pad from 1/4" hardboard to fit the dado in the block. Chamfer the edges with a block plane, and drill a hole to match the hole in the block.

10. Make a 45° slot in the back of the block with a thin-kerf handsaw, as diagrammed in **Figure I**. Pass a piece of sandpaper through the kerf a few times until it slides in easily.
11. Soften the edges of the block to make it comfortable to grip.
12. Use a spray adhesive to attach a piece of cork or felt to the bottom of the block. Also attach a piece of sandpaper to the edge of the clamping pad to provide a better grip on the sandpaper being held in the block (see **Figure J**). Secure the clamping pad to the block with a 1/4" flat washer and threaded knob.
13. Cut a quarter sheet of sandpaper, slide the end into the back slot, secure the front under the clamping pad, and tighten the knob. You are ready to sand.



I

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28

Finishes and Application Methods

You'll Learn

After studying the chapter, the student should be able to:

- Describe the reasons for finishing
- Discuss various methods for coloring wood
- Identify the purpose of wood fillers and sealers
- Explain the difference between penetrating, built-up, and combination finishes
- Give examples of different types of finishes and discuss advantages and disadvantages of each
- Describe different methods of applying finish
- Explain the final finishing steps
- Discuss safety concerns that apply to the finishing process

INTRODUCTION

Once the surface has been prepared, the finishing work can begin. The finishing process consists of filling the wood if necessary, coloring the wood if desired, and applying the finish. There are many different ways of coloring the wood, and there is a wide array of finishes to choose from. All finishes fall into one of three categories: *penetrating finishes, built-up finishes,* and *combination finishes*. Each type has advantages and disadvantages. There are also different methods for applying finish, as well as specific safety concerns to be observed while finishing.

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REASONS FOR FINISHING

Finishing is done for several reasons. A primary reason is to enhance the beauty of the wood, but finishing also protects the piece. In addition, finishing makes the piece easier to clean.

Using stains and dyes allows color to be added to the wood, which can highlight the grain of the piece and make it more attractive. Woods with curly figures can be made more dramatic by coloring them. **Figure 28-1** shows an example of curly maple that has been stained. The stain accentuates the curl in the wood.

Finish protects the wood and enhances its natural beauty. Built-up finishes are more protective than either penetrating or combination finishes, but any type of finish will provide some protection against dirt and stains. They will also slow the transmission of moisture between the surrounding air and the wood project. Finishing cannot eliminate wood expansion and contraction, but it can slow it. Again, this is especially true of built-up finishes. When finishing, it is important to finish all parts of the project so that equal protection is afforded to each part. If, for example, the top of a table is finished and the bottom of the top is not, the bottom will absorb moisture more quickly than the top, which will cause the top to warp. Built-up finishes also provide some protection against scratching and denting.

Applying finish to a project also makes it easier to clean. Dust and dirt will land on the finish, rather than on the bare wood, and it can usually be wiped off. Once dirt and dust get worked into the pores of bare wood, they have to be sanded off. Built-up finishes are more protective against spills and stains than are other types of finishes. It is important to consider how the project will be used, however. Shellac, for example, is a built-up finish that dissolves if alcohol is spilled on it. Finishes marketed as exterior finishes are the only type that should be used for outdoor projects.



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FIGURE 28-1 Staining wood with a curly figure highlights the dramatic grain patterns.

CAUTION

When finishing, wear gloves. Not only will they keep your hands clean, they also keep toxic chemicals from being absorbed through your skin.

Coloring Wood

Wood may be colored for several reasons. It may make the wood more attractive, or it may be needed to match existing furniture or cabinetry. The wood may be colored to even up its natural color. Coloring wood is the process of adding or removing color from the wood. Color is added by staining or dyeing the wood, and color is removed by bleaching.

There are quite a few choices for adding color to wood. They include penetrating oil stains, pigmented oil stains, water stains, spirit stains, chemical stains, wax stains, varnish stains, lacquer stains, and gel stains. **Penetrating oil stains** are made of coal tar dyes dissolved in a thinner, which acts as a vehicle (see **Figure 28-2**). The thinner may be naptha, benzine, or



Image courtesy of Minwax, www.minwax.com

FIGURE 28-2 Penetrating oil stain.

turpentine. Penetrating oil stains are easy to apply and have excellent penetration into the wood fibers. They impart an excellent transparent color, and there is little streaking caused by overlap marks. They do not raise the grain and can be mixed with paste wood fillers, allowing the user to perform two finishing steps at once. But there are potential disadvantages to penetrating oil stains: Their final color will depend greatly on the type of wood to which they are applied, so it is wise to test the stain on a scrap piece to make sure it is what you want. Penetrating oil stains also may fade over time. They require at least 24 hours drying time, and paste fillers cannot be applied over this type of stain. It is also necessary to be careful what type of finish is applied over penetrating oil stains. They have a tendency to bleed through varnishes and lacquers due to the fact that the vehicles are either the same or very similar in chemical composition. There are also penetrating oil stains to which polyurethane has been added (see **Figure 28-3**). This has the advantage of combining two finishing steps.

Penetrating oil stains are brushed on with the grain. Brushing with the grain will prevent uneven absorption of the stain. Allow equal drying time for each section, and then wipe off the excess with a clean cloth.

Pigmented oil stains have pigments suspended in a vehicle. Pigments are unlike dyes, in that they do not totally dissolve. Pigmented oil stains are made up of four components: the color, the thinner or solvent, an oil, and a drier. The color is an oil color of the same type used to tint paint. A wide array of choices is available. The thinner is usually turpentine or benzine. Boiled linseed oil acts as a binder, and a drier is added to speed drying. Oil stains dry by oxidation, which is very slow. The mixing proportions of thinner, oil, and drier are the same and remain constant. The amount of color added depends on the shade desired. An advantage of pigmented oil stains is that they are very easy to apply. There is no need for concern over lap marks, and the ingredients for making a pigmented oil stain are easily obtained. This stain, like penetrating oil stain, does not raise the grain. There are several disadvantages to pigmented oil stains: First of all, pigmented oil stains are not penetrating stains; a film lies on the surface of the wood. They are not very transparent and must be wiped well. Paste fillers cannot be added over this type of stain either. They will fade over time, and 24 hours or more of drying time is required. Pigmented oil stains are applied the same way that penetrating oil stains are.

Water stains have a solvent of pure water, hence the name. The color may be synthetic or made from coal, tar, or vegetable dyes. The most commonly used water stains are **aniline dyes**. They come in a powder that is added to boiling water and allowed to cool (see **Figure 28-4**). Usually one or two ounces of powder are mixed with a quart of water. Using more or less water will affect the final color of the stain.

An advantage to water stains is that almost any color can be made. They are deep, penetrating stains



Image courtesy of Minwax, www.minwax.com

FIGURE 28-3 Penetrating oil stain with polyurethane.



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FIGURE 28-4 Aniline dyes are powders mixed with water.

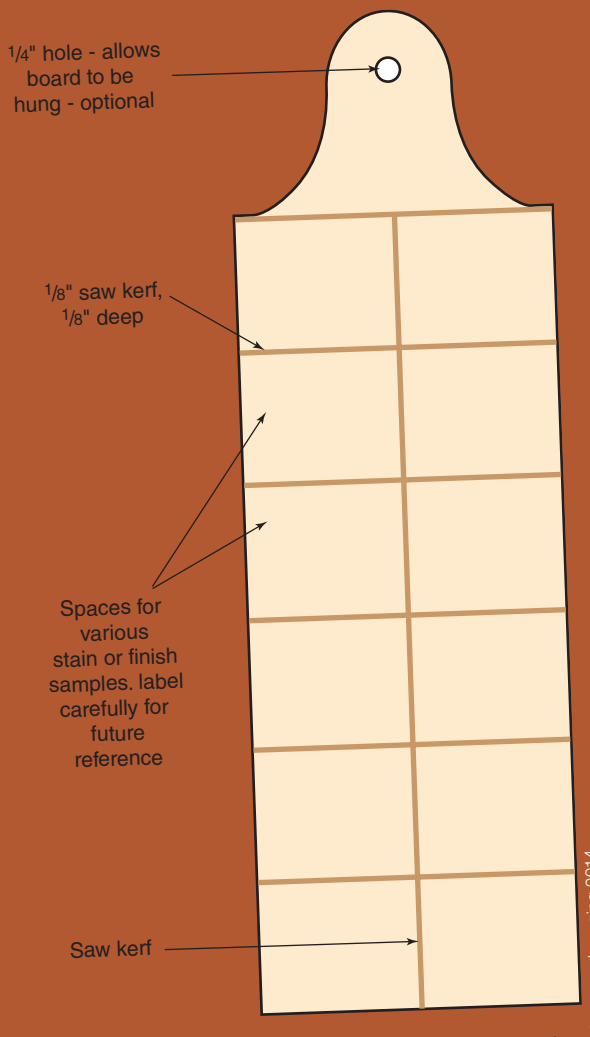
that will not fade over time, even in direct sunlight. Water stains leave an excellent transparent color. They dry quickly within a few hours. When dry, they appear dull, but when the finish is applied, the brilliant color that was seen when the dye was wet returns. It is possible to apply multiple coats to get the desired depth of color. Water stains are relatively inexpensive and keep well, since they come in powder form.

The primary disadvantage to water stains is in the preparation time required due to the fact that these stains are **grain raising**. This means that after the stain has been applied and has dried, the surface of the wood feels rough, as if it has little whiskers on it. If it is then sanded smooth, some of the stain will be removed. Therefore, the grain of the wood must be raised ahead of time. To do this, water is applied with a sponge and allowed to dry. The grain that is raised will feel like little whiskers. These are easily sanded off with a high-grit sandpaper, and then the stain can be applied. Water stains usually cannot be used on a surface from which a finish has been removed, so they are not good for refinishing work. Overlap marks tend to show with water stains, as do spatters, so when brushing on this kind of stain, you have to be careful about overlap marks. The key to avoiding lap marks is to keep the surface wet and wipe off any excess stain before it dries. Water stains may be applied with a rag or a brush, or sprayed on. The amount of time that elapses before wiping off any excess will not affect the final color.

Spirit stains are similar to water stains in that they are an aniline powder dye that is mixed with a vehicle. The difference is that the vehicle that the dye is dissolved in is denatured or ethyl alcohol or acetone rather than water. Typically a half ounce of powder dye is mixed with a quart of alcohol. Unlike water stains, a limited number of colors are available. An advantage spirit stains have over water stains is that they are non–grain raising. Spirit stains are able to penetrate some finish residue, so they are a good choice when refinishing. They have excellent transparency; however, they do not penetrate the wood very well, and the color will fade somewhat over time. Another attribute of spirit stains is both an advantage and a disadvantage: They dry very rapidly. The fact that they are so fast drying means that you can apply a finish the same day. Because they dry so quickly, spirit stains should be sprayed on.

WOODWORKING TIP:

Having a stain sample to show potential customers is a useful tool. You can keep a box of stained and labeled pieces to show people, or you can make up a sample board, like the one shown in **Figure 28-5**, *and use the spaces to show various stains. It is a good idea to have several of these made of different woods, since stains look different on different woods. You can also do this with finishes.*



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FIGURE 28-5 Stain-board diagram.



Image courtesy of rockler.com

FIGURE 28-6 TransTint dyes.

A dye has been developed that shares some of the characteristics of both water and spirit stains. It is called TransTint dye, and it comes as a concentrated liquid that can be mixed with water or alcohol. This product can also be added to shellac, lacquer, and water-based finishes to tint the finish (see **Figure 28-6**). Like water stains, it is available in a wide range of colors.

Chemical stains combine chemically with the wood to produce a permanent color. They enhance the natural grain patterns and color variations of the wood. Some chemicals used to make stains are tannic acid, potassium carbonate, potassium permanganate, potassium dichromate, ferrous sulfate, and copper sulfate. These chemicals come as dry powders or crystals and are dissolved in water. Chemical stains are grain raising, so the project must be wiped down with water, allowed to dry, and sanded prior to stain application. Some chemicals used to make chemical stains are common household products: Lye produces a light brown color, and acetic acid (vinegar) and iron filings give a gray color. A strong ammonia solution, 26 percent or higher, produces a soft brown. Chemical stains are applied with a sponge or synthetic bristle brush. Drips show, so work from the bottom to the top of the project. Chemical stains are usually very toxic, so gloves and goggles should be worn; a respirator may also be needed.

GREEN REMINDERS

Consider the environment when making choices about stains and finishes. Not only are some of the stains and finishes themselves potentially toxic to the environment; their solvents may be as well.

Wax stains are made of either a penetrating oil stain or a pigmented oil stain to which wax and a drier have been added. Their claim is that no topcoat is required over them. However, they provide very little protection against dents, scratches, and seasonal changes. They are easy to apply, with no worry about overlaps or streaking. Without a topcoat, they are not a good choice for a fine finish.

Varnish stains are a combination stain and varnish, so staining and varnishing are accomplished with one operation. These stains are more like paint, and they are not recommended.

Lacquer stains are purchased in a concentrated form and then thinned down with lacquer to the desired color. Using a lacquer stain is essentially coloring the finish. Lacquer is a finish, so by using a lacquer stain, both coloring and finishing are accomplished at the same time. Lacquer stains are most often sprayed on, because lacquer dries very quickly.

Gel stains are much thicker than any of the other stains discussed. They have the consistency of jelly (see **Figure 28-7**). Their great advantage is that due to

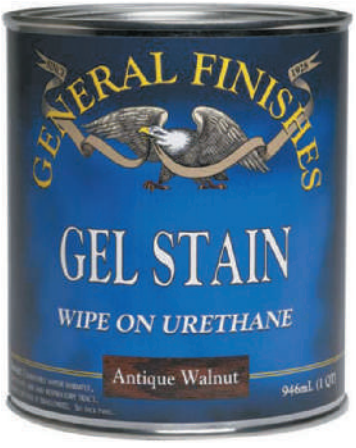


Image courtesy of rockler.com

FIGURE 28-7 Gel stain.

the viscosity of the stain, it will not run or drip. Gel stains are applied with a brush or a clean cloth. The excess is wiped off. Gel stains are available in a number of colors. They are very easy to apply, and they can be tinted.

Wood may be bleached to remove stains or to lighten its color. Bleaching affects different woods differently. Some woods, like oak, bleach easily, but others, such as cherry, do not bleach well. Commercial bleaching solutions can be acquired, or homemade solutions can be made.

Commercial bleaching solutions are usually two-step applications involving two different solutions. The first solution is applied, then the second, and then they must be allowed to dry completely. Then the wood is thoroughly rinsed with water, an acetic acid and water mixture, or a borax and water mixture. The reason for rinsing the wood prior to the next finishing step is to neutralize it after the bleaching process. If this step is omitted, or if it is not done thoroughly enough, blisters will appear in the finish.

Wood to be bleached must be clean and free of dust and marks. Prior to using a bleaching solution on a project, the solution should be tried on a scrap of the same material first. In most cases, if the piece being bleached is exposed to sunlight while the solution is drying, the bleaching effect will be intensified. After the surface has been rinsed, it must be sanded again prior to finishing to knock down the raised grain. The dust created by this sanding is very toxic, so it is imperative that protective measures be taken so that the dust is not breathed in by anyone. A respirator is strongly recommended. Bleaching solutions should be stored in a cool dry place, because exposure to sunlight will weaken them.

Homemade bleaching solutions can also be used. They are weaker than commercial solutions, but they may be adequate for your purpose. Three solutions can be made at home using one of the following: hydrogen peroxide, oxalic acid, or chlorine laundry bleach.

Hydrogen peroxide is the strongest acting of these three solutions. A 30 percent solution is typically used. The usual household solution is 15 percent. The stronger solution can be obtained from a chemical supply store or a store that sells refinishing supplies. The first step in using hydrogen peroxide to bleach wood is to flood the wood with a hot solution of lye and water, using four ounces of lye per quart of water. Allow this to dry for 30 minutes, and then wipe the surface with the hydrogen peroxide and allow it to dry. As it dries, the color will lighten or be removed. Once it is dry, the surface must be thoroughly rinsed with clean water to remove all chemical residues. It will then need to be sanded prior to final finishing. Gloves should be worn when applying the lye and water and also the hydrogen peroxide, and a mask or respirator should be worn while sanding.

Oxalic acid is mixed with hot water in a glass container, using three to four ounces of oxalic acid per quart of water. The area to be bleached must be evenly covered with the hot solution. It will work at room temperature, but is more effective when hot. This process can be repeated as necessary until the desired color is achieved. When the surface is dry, it must be thoroughly rinsed with clean water. Once dry, it must be sanded, and gloves and a mask or respirator are necessary.

Chlorine laundry bleach has the mildest bleaching action of the solutions discussed. Two to four ounces of bleach are mixed with a quart of warm water, and an even coat is liberally applied to the surface. Coats can be repeated at 5-minute intervals until the desired color is reached. As with the other solutions, the surface must be completely rinsed and then sanded. Again, wear gloves and use a mask or respirator.

Wood Fillers

Open-grained woods such as oak, mahogany, walnut, and ash require numerous coats of finish to achieve a smooth, built-up finish. Using a **paste wood filler**, also called a pore filler, on these woods fills the large open pores and levels the surface prior to applying a built-up topcoat, meaning that fewer coats of finish will be required (see **Figure 28-8** and **Figure 28-9**).

Using a wood filler is not a mandatory step, and is typically only done when a glass-smooth surface



Image courtesy of Woodcraft Supply, LLC, www.woodcraft.com

FIGURE 28-8 Paste wood filler.

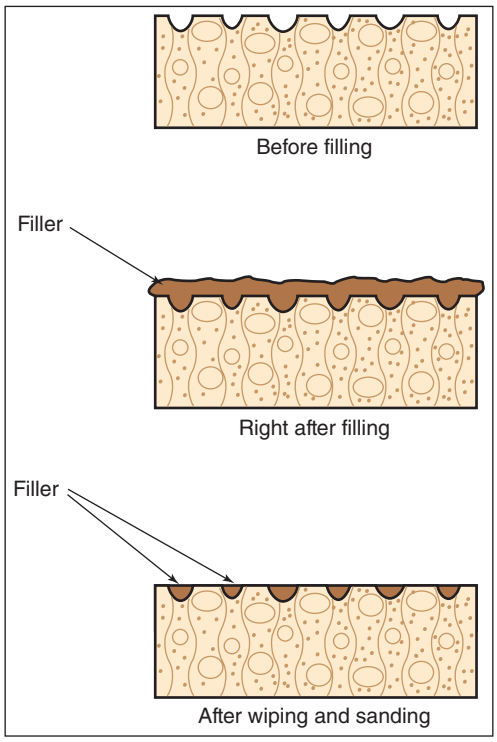


FIGURE 28-9 How paste filler works.

is desired, usually on flat surfaces such as tabletops. Paste wood filler is an inert material made from fine solids like quartz powder, silica, wood flour, and talc, which is mixed in a binder to hold it together and help it stay in the wood pores. Because it is inert, it won't shrink, and the finish will sit on a flat and smooth surface. Pore fillers may be oil-based or water-based, and are available in different wood tones or neutral, which can be tinted with artist's colors. Use oil colors for oil-based filler and acrylic colors for water-based. Using filler that is the same color as the wood hides the pores and creates a more uniform look, while using a filler that is lighter or darker than the work creates contrast.

Oil-based and water-based wood fillers behave differently. Oil-based fillers give you more time to work, while water-based pore fillers dry more quickly and sand more easily. They are applied a bit differently. In either case, start by stirring the filler well.

Oil putties are quite thick. They can be applied that way or thinned to the consistency of heavy cream with mineral spirits. Oil-based wood fillers can be applied with a brush, a putty knife or spackle knife, or a fine nylon abrasive pad. Work across the grain to pack the material into the pores. Allow it to sit until its glaze has dulled, and rub it in a circular motion with a piece of burlap to ensure that the pores are completely packed with filler. Then, with a clean piece of burlap wipe off the excess, working diagonally across the grain to avoid pulling the filler out of the pores. Let it dry for three days and then sand with a 220- or 320-grit sandpaper to remove any filler that may be left on the wood's surface. It is important that the filler be completely dry prior to finishing.

Water-based wood fillers are faster and easier to use. They are applied with a brush or fine abrasive pad. Because they dry quickly, it is best to do a small area at a time. Cover the area and then use a stiff piece of plastic like an old credit card to pull the material across the wood, working perpendicularly to the grain. This will both fill the pores of the wood and remove the excess filler. Let it dry overnight and then sand with a 220- or 320-grit paper.

Paste wood fillers may be applied before, after, or during staining by mixing the stain with the filler, but is it important to check the compatibility of the stain with the filler to determine the sequence, and to do some experimenting to get the look you want. As a general rule, dye stains are put on before filling, but pigment stains are used afterwards. Sealing can also be done before or after filling, but if done before it is easier to clean off the excess filler.

Wood *fillers* should not be confused with wood *putty,* although they are similar. Putty is used to repair defects; fillers are thinner, and their purpose is to pack the pores of open-grained woods to shorten the final finishing process when striving for a glass-smooth final finish.

Penetrating Finishes

Penetrating finishes are oils that are absorbed into the wood. They enhance the natural beauty of the wood, accentuating color and grain patterns. Penetrating finishes are natural finishes made from organic materials. Three main types are used: *linseed oil, tung oil,* and *nontoxic oils* (see **Figure 28-10**).

Linseed oil is extracted from the seeds of the flax plant. It is water repellent and resists heat and most stains. It is available as raw linseed oil or boiled linseed oil. Boiled linseed oil is preferred; it has been processed to reduce drying time, which is still considerable. In order to obtain adequate protection and luster, many coats must be applied. At least one and as many as three days of drying time must be allowed between coats, depending on drying conditions. If the weather is humid, more time must be allowed.



Image courtesy of rockler.com

Image courtesy of Minwax, www.minwax.com

Image courtesy of rockler.com

FIGURE 28-10 Boiled linseed oil, tung oil, and non-toxic oils are penetrating finishes.

Linseed oil is easily applied with a clean rag or brush. It may be thinned with one part turpentine or mineral spirits to two parts linseed oil to spread more easily. If the mixture is warmed, it also spreads more easily, but this is not necessary. A generous amount of oil is applied to the surface, working one section at a time. The section being worked on should be rubbed with a clean cloth until the oil is absorbed. The length of time this takes will vary depending on the wood, and it can take anywhere from 5 to 30 minutes. When finished, the surface is wiped with a tack cloth dampened with mineral spirits to remove excess oil. Allow to dry, and repeat until the desired effect is achieved.

Tung oil is made from the seeds in the fruit of the tung tree. It is available as pure tung oil or as polymerized tung oil. The polymerized tung oil dries more quickly, but it is more expensive. The most economical way to use pure tung oil to achieve the quicker drying time that polymerized tung oil will give you is to buy pure tung oil and cut it with mineral spirits. The first cut is 4:1 mineral spirits to pure tung oil. The proportion of tung oil is increased with each successive coat.

Tung oil is applied in the same manner as linseed oil: A small area is coated with the oil, and then it is rubbed in. Tung oil is easier to use than linseed oil; less rubbing is required to work it into the wood, and fewer coats are required to build a similar luster. Allow each coat to dry overnight before recoating. Two or more coats should be applied.

Nontoxic oils are chiefly used on cutting boards, kitchen utensils, bowls, and toys for small children. They also are generously applied and rubbed in. The classic nontoxic oil is mineral oil, but better choices



Image courtesy of rockler.com

FIGURE 28-11 Salad bowl oil and walnut oil.

are salad bowl oil and walnut oil (see **Figure 28-11**). Vegetable oils such as those found in the grocery store can also be used.

All penetrating finishes are easy to apply, and they have the additional advantage that when their luster dulls, additional coats can be applied without much trouble, other than cleaning the surfaces well. They do not offer the same degree of protection that built-up finishes do and so are not suitable for projects that will see heavy use.

Built-Up Finishes

Built-up finishes, as their name implies, lie on the surface of the wood rather than penetrating into it. As a class, built-up finishes offer more protection than do

penetrating finishes. Built-up finishes may be natural or synthetic. Examples of natural finishes include shellac, lacquer, and varnish. Synthetic finishes include synthetic varnish, synthetic lacquer, and water-based finishes.

Shellac is produced from a natural resin called *lac,* which is a byproduct of the lac bug, found in areas of the Far East such as India, Thailand, China, and Burma. It is an ancient finish that has been used for over 25 centuries. Shellac may be purchased premixed or in flake form (see **Figure 28-12** and **Figure 28-13**). Flakes are good indefinitely, but premixed shellac has a relatively short shelf life, although additives have been added recently that extend it. If buying premixed, however, it is probably wise not to buy more than will be used in a relatively short period of time. Flakes are mixed with denatured alcohol. If flakes are used, the amount of flakes per gallon of alcohol is referred to as the *cut.* A five-pound cut is average, and it means that five pounds of flakes are mixed per gallon of alcohol. A three-pound cut is a good mix when using shellac as a sealer coat.



Image courtesy of rockler.com

FIGURE 28-12 Premixed shellac.



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FIGURE 28-13 Different grades of shellac flakes.

Shellac is available in different grades, which yield different hues. From darkest to lightest, the grades are *seed lac, button lac, orange shellac, garnet lac, blonde shellac,* and *white shellac.* White shellac is clear.

Shellac can be used as a sealer or as a finish. It is an excellent sealer, creating a barrier coat between raw wood and final finish or between stained wood and final finish. It can be brushed on or sprayed. It is a thin finish, so three to five coats should be applied when it is used as a final finish, but no sanding is necessary between coats. The final coat may be rubbed out with steel wool and vegetable oil for a fine finish.

Shellac has several advantages. It has excellent durability and will not crack over time. It dries quickly, with only two hours of drying time needed between coats. It is an excellent sealer. Unlike many other finishes, it is nontoxic, so it is especially good for children's furniture and toys. It can be tinted with alcohol-soluble dyes.

Shellac also has disadvantages. It is not moisture resistant, and it will turn white when moisture comes into contact with it. It is not particularly heat resistant, and it is not at all alcohol proof. Alcohol will dissolve shellac.

WOODWORKING TIP:

One of the finest finishes is called **French polish**. *It is a combination of shellac and boiled linseed oil. Equal amounts of boiled linseed oil and a three-pound cut of shellac are mixed together to make the finish. A thin layer of finish is laid down with a lint-free cloth. It is applied with straight strokes and then rubbed into the wood with a circular motion. Multiple layers are applied until the desired effect is achieved. The resulting finish is very beautiful, but it is time consuming and strenuous to apply.*

Both natural and synthetic lacquers are available, although synthetic lacquers are much more widely used. Synthetic lacquer is made up of nitrocellulose or other cellulose derivatives mixed with plasticizers, pigments, and volatile solvents (see **Figure 28-14**). These may be brushed on, but they are typically sprayed, because they dry so fast. If you choose to brush on a lacquer finish, make sure you use a product that has



Image courtesy of rockler.com

FIGURE 28-14 Lacquer.

been formulated for this kind of application. It is often called brushing lacquer, and it has been treated to dry more slowly than spray lacquer. A high-quality natural bristle brush should be used. The fact that lacquer dries so quickly is an advantage: Several coats can be applied within a few hours. Lacquers are very durable and can be hand-rubbed to a fine finish. Lacquer is a clear finish, unlike varnishes, which add a yellow tint. It is also more heat resistant than shellac, and the synthetic type is moisture resistant. One disadvantage of lacquer is that spraying is the best way to apply it, so spraying equipment is needed. If applied over a penetrating oil stain, the surface should be sealed first. Like shellac, lacquer can be tinted with a compatible dye, and the coloring and finishing steps can be combined. Lacquer is available in different sheens: satin, semigloss, and gloss.



Image courtesy of rockler.com

FIGURE 28-15 Natural varnish.

GREEN REMINDERS

Historically, the wood strippers used in refinishing work have been highly toxic. Newer citrus- and soy-based products are not as hazardous to you or the environment.

As with lacquers, there are both natural and synthetic varnishes. The oldest type of varnish is oil varnish, which is natural. It is made of natural pine resins or fossilized gums mixed with tung or linseed oil and turpentine (see **Figure 28-15**). The main disadvantage of an oil varnish is that it has a long drying time, 24 hours minimum. Another type of varnish is spar varnish (see **Figure 28-16**). This is a waterproof finish that can be used on exterior projects. It is also highly resistant to other types of abuse.

Polyurethane is a synthetic varnish that is made up of plastics and solvents. It is a highly durable finish that dries more quickly than oil varnish; it takes four to six hours to dry. Quick-dry types are also available (see **Figure 28-17**). They have a higher proportion of solvent in them to make them dry more quickly. Polyurethane, unlike shellac and lacquer, cannot be hand-rubbed to a fine finish. Like lacquer, it is available in different



Image courtesy of rockler.com

FIGURE 28-16 Spar varnish.



Image courtesy of Minwax, www.minwax.com

FIGURE 28-17 Fast-drying polyurethane.

sheens: gloss, semigloss, and satin. The amount of sheen is controlled by the manufacturer by adding **silica** to the mixture. Silica is a type of sand that causes less light to be reflected, making the finish appear less shiny.

All varnishes are thicker finishes than either shellac or lacquer, so fewer coats are required. They may be brushed or sprayed on, and they are usually thinned with solvent for spraying. Wipe-on varnishes are also on the market (see **Figure 28-18**). They are easy to apply, but they require more coats. The fact that varnishes are so durable makes them an attractive choice for furniture that will see heavy use.

Varnishes add a yellow tint, called **ambering**. This can give the wood a warm feeling but may not always be desirable. As with other finishes, the product should be tested on a scrap prior to use.

Water-based finishes are relatively new in comparison to other finishes. Their development was prompted by regulations concerning **volatile organic compounds (VOCs)**, which are released into the atmosphere when



Image courtesy of Minwax, www.minwax.com

FIGURE 28-18 Wipe-on polyurethane.



Image courtesy of Minwax, www.minwax.com

FIGURE 28-19 Water-based finish.

spraying lacquers and varnishes. The solvent in water-based finishes is water, which of course makes cleaning up much easier. Water-based solvents are similar to synthetic varnishes and are often referred to as *water-based polyurethanes* (see **Figure 28-19**). They are also available in different sheens and may be brushed or sprayed on. When first applied, the finish is white, but it dries clear, unlike varnishes. Water-based finishes dry quickly, but because they are water based, they raise the grain; so after the first coat, the project will need to be lightly sanded.

Combination Finishes

Combination finishes enjoy some of the advantages of both penetrating finishes and built-up finishes. They are sometimes called *synthetic penetrating finishes*.



Image courtesy of Minwax, www.minwax.com

Image courtesy of rockler.com

FIGURE 28-20 Combination finishes.

A blend of oils and phenolic resins, they are easy to apply, durable, can be brushed or wiped on, and are applied like penetrating finishes: The surface is evenly coated, and the finish is worked into the wood, then any excess remaining on the wood is cleaned off with a dry, clean cloth. Two coats are sufficient, but additional coats build more gloss and protection. **Figure 28-20** shows examples of commercially available combination finishes.

WOODWORKING TIP:

It is easy to make up your own combination finish using a mixture of linseed oil, spar varnish, and turpentine. Equal parts of each ingredient are mixed together. The mixture is applied liberally to the surface, and the excess is rubbed off with a clean, soft cloth. This creates a very nice finish that will build to a high gloss.

GREEN REMINDERS

Stains and finishes that are no longer usable must be disposed of properly. Different areas have different regulations, so check with your local landfill for information on how to get rid of these materials safely.

Sealers

Sealers are used for two reasons. One is to act as a barrier coat between stain or wood filler and the topcoat, and the other is to prevent the topcoat from being absorbed into the wood. Sealers are not used under penetrating finishes, and a separate sealing step is not necessary under all topcoats, since some do a fine job of sealing by themselves. Included in this category are shellac, varnish (both natural and synthetic — polyurethane) and the combination finishes. Some finishes, however, such as lacquer and water-based finish, are improved by the use of a sealer coat. The sealers used are specific to the topcoat that will be applied, so a lacquer sealer is used with lacquer and a water-based sealer with water-based finishes. The sealer locks in any contaminants and reduces the number of topcoats needed by preventing excessive absorption of the finish. Sealer can be applied with a brush, pad, or air gun. If there are any concerns about the compatibility of a topcoat with an already applied stain or filler, it is a good practice to use a sealer. Shellac is often used as a sealer for this purpose.

Application Methods

Methods of applying finish are wiping, brushing, and spraying. Whatever method is used, the surface to be finished should be clean and dust-free. Ideally, finishes should be applied in a dust-free environment, although this is less of a concern with penetrating and combination finishes than it is with built-up finishes.

If a finish is wiped on, a cloth that is soft, clean, and dry should be used. If a finish is brushed on, a high-quality brush should be used that will not shed bristles into the finish. When finishing, coat the inside of the project first, then the bottom, sides, and top.

Take care not to apply built-up finishes too heavily, as they will sag and run. Good lighting is an essential tool to check for drips and runs. If the finish has dried and you notice drips, they can be shaved off with a sharp chisel or utility knife blade.

WOODWORKING TIP:

Never store a brush by resting it on its bristles. Hang it with the bristles down, and wrap the bristles in paper to help them hold their shape.

Finishes that will be sprayed on require spray equipment, such as a spray gun, to apply the finish. **Figure 28-21** shows the anatomy of a typical spray gun. A siphon goes down into the reservoir, which is opened when the trigger is pulled. High-pressure air draws finish from the reservoir, atomizing the finish and blowing it out through the nozzles. A fluid nozzle sits just inside the air nozzle at the end of the gun. Spray guns may be suction fed, like the one shown in Figure 28-21, or they may be gravity fed, like the one shown in **Figure 28-22**.

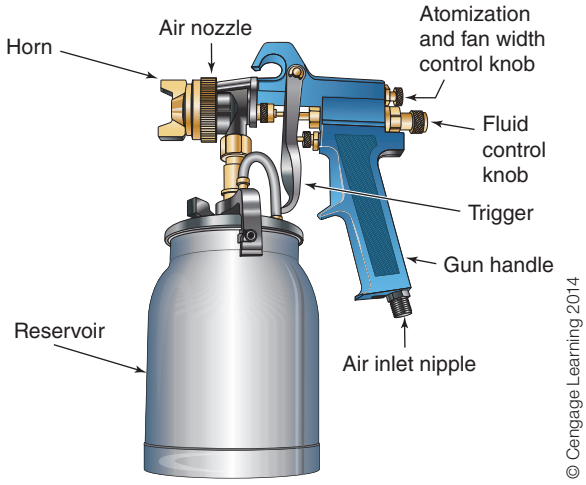


FIGURE 28-21 Diagram of a suction-fed spray gun.



FIGURE 28-22 Gravity-fed spray gun.

There are two types of spraying systems: One is a compressor system, and the other is an HVLP system. **Compressor systems** use a compressor, a regulator to adjust air pressure, water and dirt filters to keep any contaminants in the air line out of the finish, and a spray gun (see **Figure 28-23**). These systems may be referred to as *LVHP* systems. **LVHP** stands for low volume, high pressure.

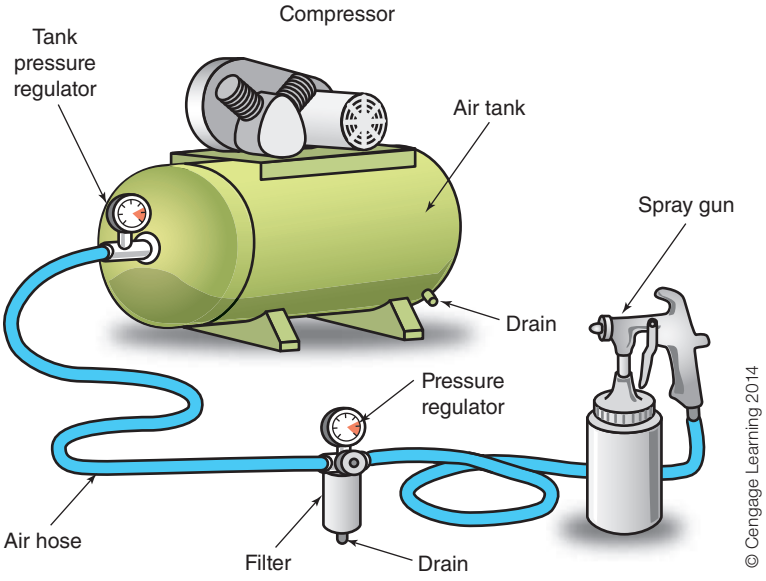


FIGURE 28-23 Compressor spraying system.

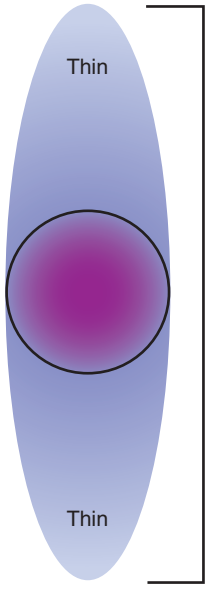
An *HVLP* system is much more efficient than a compressor system, in which a great deal of the finish ends up in the air rather than on the project. **HVLP** stands for high volume, low pressure. Whereas compressor systems are set to run on about 30 pounds of pressure, HVLP systems work at three to four pounds of pressure, and they use an electric blower rather than a compressor. A 1 1/2"-diameter hose is used. There is no water in the line, so there is no need for filters. **Figure 28-24** shows an example of an HVLP system. Both systems use a spray gun for applying the finish, although different guns are used with each system. Spraying is a much faster way of applying finish.

When using a spray gun, adjust the nozzle so that you get a wide, elliptical spray pattern called a *fan*, and then overlap each pass by about one-third the width of the fan (see **Figure 28-25** and **Figure 28-26**). The greatest amount of finish is deposited in the center of the fan, and by making overlapping passes, an even layer of finish is applied. The gun should be held between 6 and 12 inches from the surface being sprayed.



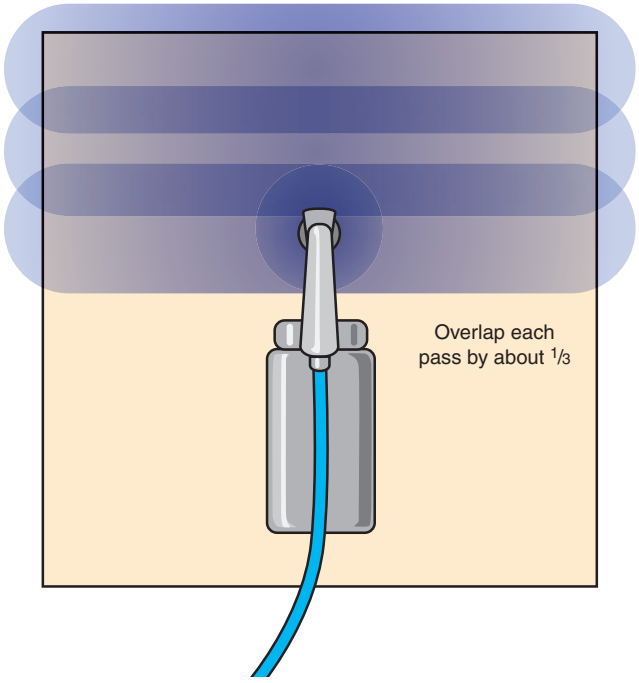
Image courtesy of Woodworker's Supply Inc., www.woodworker.com

FIGURE 28-24 HVLP spraying system.



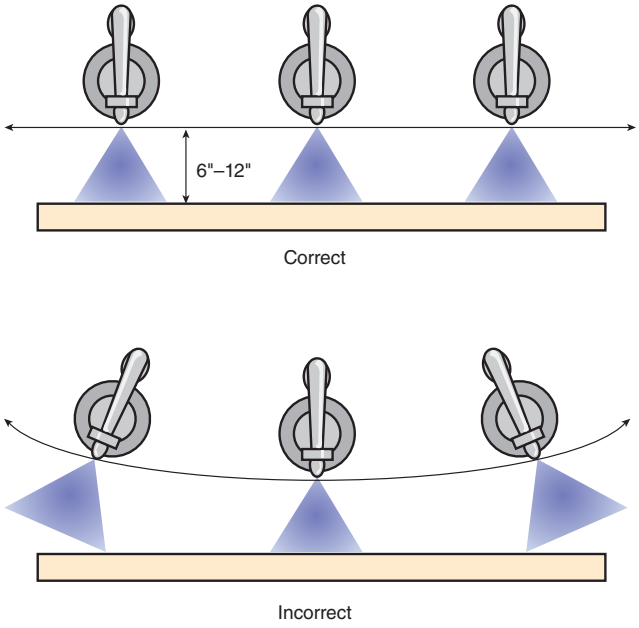
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FIGURE 28-25 Adjust spray gun for a fan pattern.



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FIGURE 28-26 Each pass should overlap its predecessor by approximately one-third of the fan.



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FIGURE 28-27 Move your arm in a straight line to deposit an even coating of finish.

In order to achieve an even layer of finish, it is also important to keep your arm moving in a straight line as you spray, rather than swinging it in and out, which will result in a deposit that is heavier in the center of your swing and lighter at its beginning and end (see **Figure 28-27**).

Finishing the Finish

When discussing several of the built-up finishes, the phrase "rubbed to a fine finish" was used. This is possible with shellac and lacquer, but not with varnishes or water-based finishes. Rubbing out a finish involves using very fine abrasives that polish the surface and bring it to the desired degree of sheen. For many years, two powdered abrasives, pumice and rottenstone, were used for this purpose (see **Figure 28-28**). They are sprinkled on the surface along with a fine mist of water or paraffin oil, which acts as a lubricant, and then the surface is rubbed with a felt block. Pumice is the coarser of the two abrasives, so it is used first. It is followed by rottenstone for a higher-gloss finish. Today, very fine coated abrasives developed by the automotive industry are available that will do the same thing. Fine steel wool can also be used. Automotive rubbing compounds designed for automotive paint can also be used with good results. When the final desired degree of gloss is reached, the project must be carefully wiped down with a clean cloth. For a bit more protection, some woodworkers apply a very fine coat of paste wax and rub it out until its glaze is completely gone (see **Figure 28-29**).



Image courtesy of rockler.com

FIGURE 28-28 Pumice, rottenstone, felt blocks, and rubbing oil.



Image courtesy of Minwax, www.minwax.com

FIGURE 28-29 Paste wax.

Safety Concerns for Finishing

Many of the materials used in finishing are toxic, so care must be taken when using them. Many of them are also highly flammable. The solvents used in finishing for thinning and cleaning up, such as turpentine and mineral spirits, are also potentially dangerous and must be handled intelligently. Wearing a thin pair of gloves, such as surgical gloves, is recommended: Chemicals can be absorbed through your skin; guard against this by keeping your hands covered. Work in a well-ventilated area or outside. When spraying, always wear a respirator. Having a dedicated spray booth is the best possible situation.

CAUTION

Fire can be a disaster in a woodshop. To avoid fire hazards, dispose of dust and shavings regularly. Never store oily rags in your shop, make sure your wiring is up to code, and be prepared: Install a smoke alarm and keep a high-quality fire extinguisher easily accessible.

All finishing materials should be kept in a secured, fireproof metal cabinet. Oily rags must be disposed of properly in a fireproof can. If this is not possible, they can be soaked in a bucket of water or spread out to dry. Once dry, they can be disposed of safely. Never throw an oily rag into a trash bin or container with sawdust in it. Spontaneous combustion is a possibility, so finishes and solvents that are not being used should be tightly capped.

One of the most important things to do when using coloring agents, finishes, and solvents is to read the instructions on the container. They will tell you how to use the material safely and effectively and will also give drying times and instructions on how to clean up.



Summary

The finishing process consists of coloring the wood if a color is desired, filling the wood if necessary, and applying the finish. There are numerous stains to choose from if the wood is to be colored. It may also be bleached, either to even up the color, to remove color, or to restore color in refinishing. Filling the wood is something that may be done with open-grained woods, such as oak or ash, to reduce the time spent finishing. Final finishes may be penetrating, built-up, or combination finishes. The finish used depends on the way the product will be used, the look desired, the skills possessed by the finisher, and the equipment available. The materials used in finishing are often hazardous, so appropriate precautions should be taken when using and disposing of finishing materials. All finishes are not compatible with all stains, so carefully read all directions associated with all supplies used. Follow the directions given by the manufacturer for use of individual products. Take the time to test stains and finishes on pieces of scrap to ensure that you are getting the color and finish you are aiming for.

Finishing is an extremely important part of the work involved in creating a cabinet or piece of furniture, and it should be given the time it demands. Experiment with different types of stains and finishes until you find one that is easy to use and gives good results.



Key Terms

ambering
aniline dyes
built-up finish
chemical stains
combination finishes
compressor systems
French polish
gel stains
grain raising
HVLP
lacquer stains
linseed oil
LVHP
paste wood filler
penetrating finishes
penetrating oil stains
pigmented oil stains
polyurethane
shellac
silica
spirit stains
tung oil
varnish stains
volatile organic compounds (VOCs)
water stains
wax stains



Check Your Knowledge

1. Why use a finish, including coloring, on projects?
2. What is the difference between a penetrating oil stain and a pigmented oil stain?
3. What great advantage do water stains have over other types of stains?
4. What is the primary disadvantage of water stains?
5. How do spirit stains differ from water stains?
6. List three other types of stains not mentioned in the previous questions and discuss each.
7. What kinds of wood benefit from the use of paste fillers? Why are paste fillers used?
8. Two types of penetrating finishes were discussed. What are they and how do they differ?
9. What are the advantages and disadvantages of shellac?
10. How are lacquers best applied? Can they be tinted?
11. Name a frequently used and popular type of synthetic varnish.
12. What is the primary advantage of varnishes?
13. What are combination finishes? Why are they used?
14. What do we mean by "rubbing out" the finish? Can all finishes be rubbed out?
15. What are the potential hazards of finishes, and how are they guarded against?



What's Wrong with This Picture?



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SECTION VIII


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Special Topics


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SUCCESS STORIES

Marc Spagnulo

Title

Owner of Marc's Wood Creations and founder of The Wood Whisperer (thewoodwhisperer.com), an online forum for amateur woodworkers that offers instructional videos and podcasts.

Education

Marc has a degree in molecular biology from Rider University; he also did an apprenticeship with David Marks, host of the DIY network show *Wood Works*.

History

After a few years working at biotech firms after college, Marc began to question his career choice. He had enjoyed doing woodworking projects with his stepdad and working on projects around the house, so he decided in 2003 to take an apprenticeship with David Marks, host of the DIY network show *Wood Works*, to see where it would lead him. Not long after, Marc and his wife moved to Arizona for her work, and Marc began to think about making a viable business out of custom furniture and woodworking. It was a rough go at first, with not enough work. So after six months, he went back to working in a lab. But, he says, "There's nothing more sobering than being in an office behind a computer pursuing someone else's dream."

So when he saw an ad placed by someone looking for help in a refinishing shop part time, he quit his job at the lab and seized the opportunity. It was a steady income and let him build his custom furniture business in the meantime. Finally, in 2004, it got to the point where he could quit the refinishing shop.

In 2005, he got the idea for The Wood Whisperer. His wife had bought him an iPod, and he discovered podcasts, including one about a weekend woodworker. Marc felt he could do something similar, and take it a step further by adding instructional video. And so he did. "Before I knew it, I was getting a lot of emails back," Marc says. As the business started to grow, he realized he could turn it into a revenue stream with advertising and sponsorship. Now he issues two videos a month. The site gets 50,000 unique visitors a day with 500,000 page views, and the site downloads are approaching the 1.5 million mark — and Marc rarely has time to do any custom woodworking any more.

On the Job

Every day is a little bit different for Marc. If he's not filming or writing a script, he's editing video, writing a story for the Web site, or doing an audio podcast. He and his wife, who wields the camera, run most aspects of the business themselves, but this year they've decided to hire out for someone to seek sponsorships.

Best Aspects

Marc enjoys being his own boss and combining his interests in technology, woodworking, and entrepreneurship.

Challenges

The hardest part for Marc is that he's a trailblazer, because no one else has harnessed the power of Web video in woodworking. "Since we don't have a model to follow, a lot of it comes down to trial and error," he says. It's also a risk, he discovered, to put yourself out there as an "expert."



Image courtesy of Marc Spagnulo.

"We've got a lot of armchair quarterbacks, who will be the first to step up and argue that something I've said is not completely right." So how does he deal with that? "I have never been hesitant to say I don't know the answer."

Importance of Education

"The techniques are what can make or break you in the long run," says Marc. So he's glad he learned good ones by watching David Marks on TV and later working with him.

Future Opportunities

Marc's goal is to continue being a recognized resource for woodworking education. He's toying with the idea of shooting a pilot, as well as the possibility of putting his Web videos onto DVDs.

Words of Advice

One of the points he took from his apprenticeship: If you want to become a self-employed woodworker, consider teaching workshops on the side. It's one way to guarantee a steady income to supplement your earnings while building your business.

Story originally written by Margaret Magnarelli, 2008. Interview and photo provided by Marc Spagnulo.



29

Bending Wood

You'll Learn

After studying the chapter, the student should be able to:

- Identify reasons for bending wood
- Explain the various methods for creating bends
- List advantages and disadvantages of each method
- Demonstrate familiarity with various bending forms and jigs
- Discuss safety considerations in bending wood
- List woods that have good bending qualities
- List and define other methods of creating curves in wood

INTRODUCTION

When building furniture, curves are sometimes required. This may be for aesthetic reasons, such as adding a curve to a drawer front, or it may be for reasons of comfort, such as adding a curve to the slats on a chair back. Sometimes the curve is essential to the function of a piece, such as the curve seen on a rocking chair's rocker. **Figure 29-1**, **Figure 29-2**, and **Figure 29-3** illustrate some curved forms seen in furniture.

There are several different methods for making curved pieces. One is to cut the curve out of a solid piece of wood (see **Figure 29-4**). However, this method tends to create a lot of waste, and depending on the

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FIGURE 29-1 Curved arms and back rail on chair.


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FIGURE 29-2 Curved desk legs.


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FIGURE 29-3 Curved chair back.

amount of curve required, grain run-out may weaken the piece. Wood is strong only along the grain. You can see in **Figure 29-5** that the grain at the top of the arc is all short grain and

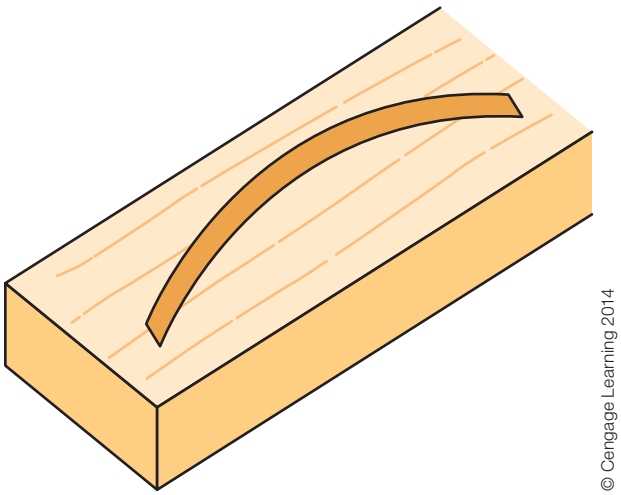

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FIGURE 29-4 Curved parts may be cut out of solid wood.

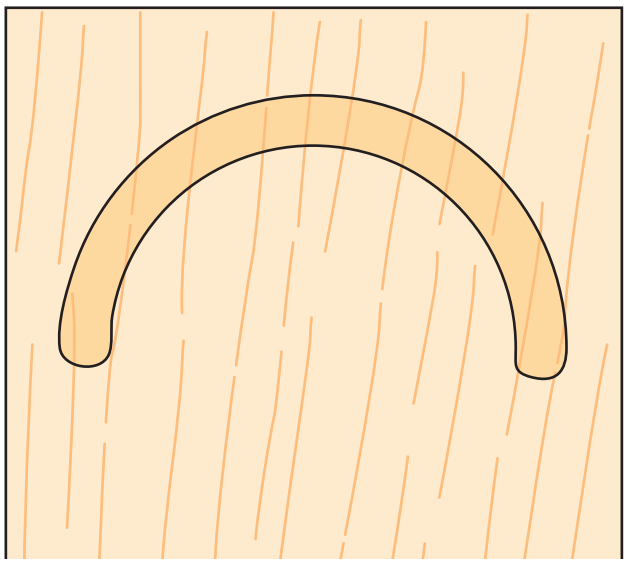

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FIGURE 29-5 The short grain at the top of this tight curve made of solid wood weakens the piece.

therefore very prone to breaking. For bends beyond a quarter of a circle, other methods are preferable, all of which involve bending the wood. Wood may be bent by dry bending, laminating, or plasticizing the wood. In this chapter, we will explore these three methods of bending wood to create curved parts. We will also look at cutting curved pieces from solid wood, creating curves by the method known as *coopering*, and segment lamination.

DRY BENDING

Dry wood may be bent in two ways. One way is to bend the piece by hand and hold it in place with fasteners, adhesives, trim, or a combination of these. This is called *plain bending*. The other method of dry bending is known as *kerfing*.

Plain bending is limited to fairly thin pieces of stock. The bends that can be achieved are quite small. Straight stock that is free of defects should be used, and the material should always be tested prior to use. To do this, bend a sample piece to the desired shape. If it cracks or splinters, plane it to a lesser thickness and try the bend again, experimenting until the required bend is achieved without fracturing. The final bend must be securely fastened in place in such a way that the bend will hold.

Kerfing is a second method of dry bending that allows greater bends to be achieved than those possible through plain bending, and thicker pieces of wood may be used. Kerfing involves sawing kerfs across the grain on one face. This permits easier bending and allows much sharper curves to be made. Depending on whether the curve is concave or convex, the kerfs will open or close as the wood is bent (see **Figure 29-6**). Kerfing may be used to create rounded aprons for a table, as illustrated in **Figure 29-7**.

The major disadvantage of kerfing is that is weakens the board. To combat this, the wood bent through kerfing should be attached to another component, or alternatively, the kerfs may be filled with epoxy or auto-body filler just before bending. When the filler dries, it will stabilize the bend, making the piece nearly as strong as it was prior to kerfing. It is important to work quickly, because both epoxy and auto-body filler set up fast.

Both solid wood and plywood can be kerfed for bending. Solid wood is more susceptible to fracturing across the grain. Another problem with kerf bending is that the bend only occurs where the kerf is; in between the kerfs are flat spots. The farther apart the kerfs are, the larger the flat spots. Sanding may help this problem somewhat, but it can also aggravate the situation. As the curve is sanded, material is worn away above the curve, making it more susceptible to fracturing. If veneered plywood is used, the danger is that you may sand through the surface veneer. A good solution that has been used for many years is to use the kerf-bending technique to create a substrate for veneer. A less expensive wood may be kerfed and bent for use as a solid substrate, or a lower grade of plywood may be used. The final step would be to apply a finish veneer to the curved surface.

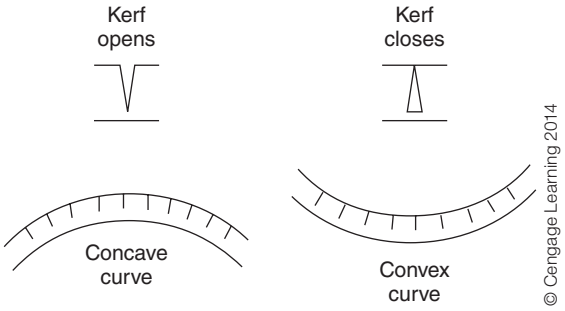


FIGURE 29-6 Kerfs open or close for concave and convex curves.

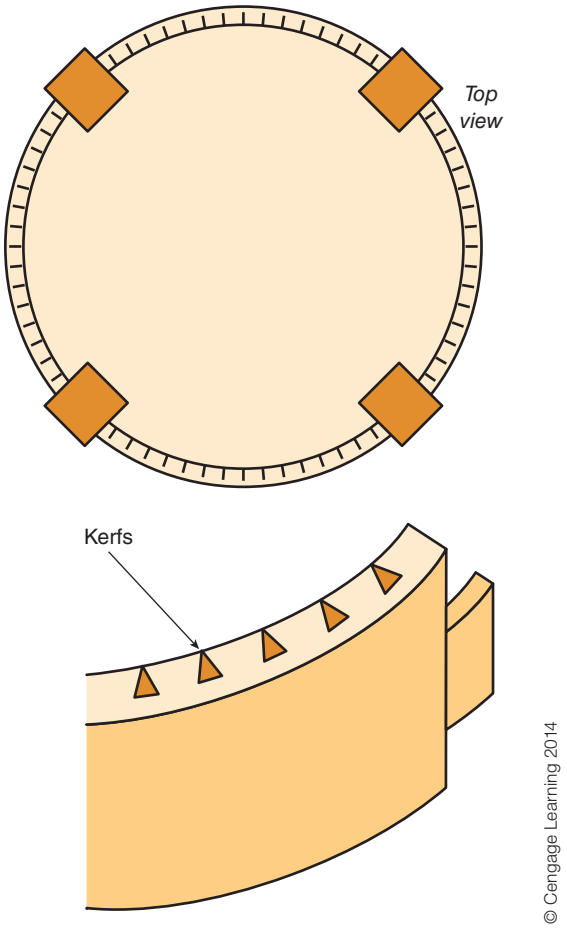
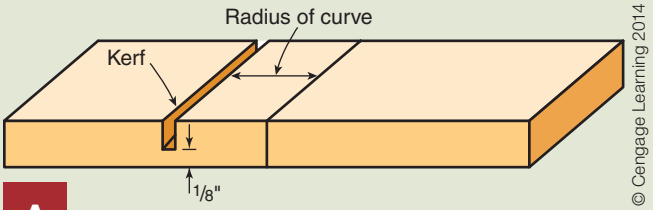


FIGURE 29-7 Kerfing used to create rounded aprons for a table.

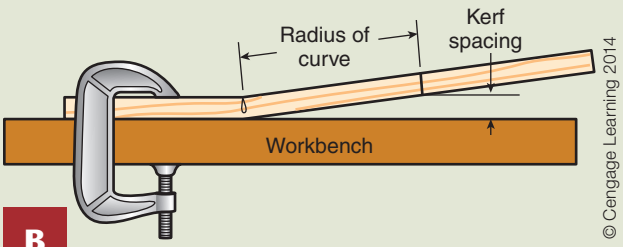
PROCEDURE 29-1

Determining Kerf Spacing for a Given Bend



A

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B

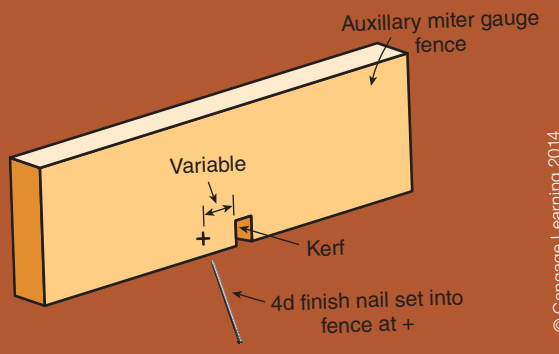
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STEPS

1. Cut a piece of wood as thick as the piece you want to bend.
2. Cut a kerf about 6" from the end of the board and deep enough so that 1/8" of material is left.
3. Measure and mark the length of the radius of the desired curve from the kerf, as shown in **Figure A**.
4. Clamp the end of the board to your bench, and lift up the other end until the kerf closes. The distance between the board and the bench at the radius mark is equal to the minimum kerf spacing (see **Figure B**).

WOODWORKING TIP:

A simple jig can be built to cut evenly spaced kerfs in a board without measuring each one. Attach an auxiliary fence to the table saw's miter gauge, and use it to support your stock while making the first kerf. Measure the kerf-spacing distance over on the auxiliary fence, and drive a small finish nail near the bottom of the fence at this point. Refer to **Figure 29-8**. *To use the jig, place the first kerf you made in the board over the nail and make a second kerf. Then move that kerf over the nail and repeat.* **Figure 29-9** *shows a kerfing jig in use.*



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FIGURE 29-8 Kerfing jig diagram.



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FIGURE 29-9 Kerfing jig in use.

The amount of curve that can be achieved through kerf bending depends on the depth and spacing of the kerfs. The deeper and more closely spaced the kerfs are, the greater the bend that can be accomplished. However, it is equally true that the deeper and closer the kerfs are, the weaker the resulting bend. A remaining wood depth of less than 1/8″ should never be left at the bottom of the kerf. If working with plywood, the bottom layer of veneer should run the length of the piece to be curved.

LAMINATION BENDING

Laminated bends are made by bending thin layers of stock that have been coated with glue around a form. They are held in place with clamps or vacuum pressure until the glue has set. Bent laminations are very strong. They are used to form wooden tennis rackets, chair backs, curved stair stringers, and in the arched beams seen in churches and public buildings. The technique of bent lamination is also used to create trim that will fit around a curved surface. **Figure 29-10** shows an example of bent lamination.

The advantages of bent lamination are that it is very strong over any degree of arc, and the wood is extremely stable after it is bent. The disadvantages are several: One is that gluing is messy and will require cleaning up the curve afterward. More importantly, from a safety point of view, most of the glues appropriate for bent lamination are toxic, so proper safety precautions must be taken when working with them. This is especially true when sanding, so take particular care to protect your lungs. Another disadvantage is aesthetic: The layers, called **lamina**, are visible in the finished product.

One way to minimize the visibility of the lamina is to mill them from one piece of stock. Mark the stock on the ends and on the face, then resaw or rip pieces off and stack them sequentially (see **Figure 29-11**). Defect-free, straight-grained stock should be used.

The radius of the curve being bent will determine the thickness of the pieces you cut for the laminations. Thinner pieces have greater flexibility than thicker pieces and will bend around sharper curves. To determine how thick your laminations should be, rip a strip from your blank, or from a scrap piece of the same species, and try to bend it around the form you will be using. If it does not bend easily into place, rip a thinner piece and try that. Once you have determined the thickness that will work, cut all the pieces you will need for your bent lamination.

Rather than using solid stock that has been ripped or resawn into thinner pieces, veneer can be used. The only disadvantage to using veneer is that it is relatively expensive compared to solid wood, and it will take many more layers to build up much thickness in your final piece. However, it will save the time spent ripping and smoothing multiple lamina from a solid piece of stock, and it is less wasteful, because much of the material sawn ends up as sawdust.

The glues used to glue up bent laminations should be slow-set glues to give you sufficient time to clamp your project up in its form. Urea formaldehyde glue (plastic resin) gives you time to adjust the laminations as necessary, because it sets slowly. As mentioned earlier, however, care should be taken in working with this adhesive. Before applying the glue, dry clamp the lamina in the form; this gives you the opportunity to ascertain that the layers will bend without cracking. It also means that you can be sure that you have enough clamps to eliminate any gaps between the lamina.

Once the glue has cured, the bent lamination is cleaned up. A belt sander, electric hand planer, or hand plane can be used. When sanding, wear long sleeves and a dust mask or respirator that fits well, and use a


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FIGURE 29-10 Example of bent lamination. The curve is made of many thin pieces glued together.

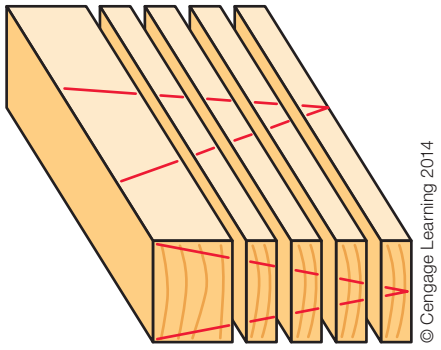

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FIGURE 29-11 Using a single piece of stock for bent laminations minimizes the visibility of the multiple layers.

dust-collection system. Since the hazardous dust can be absorbed through the skin as well as through the lungs, long sleeves are recommended. Wearing gloves when removing the lamination from the form is a good idea, because the dried glue beads can be very sharp.

Plasticized Bending

Plasticizing wood makes it possible to bend it. The lignin is made soft and pliable through plasticizing, which allows the cellulose fibers bound together by the lignin to slide past one another. Wood can be plasticized by heating it, soaking it in very hot water, or steaming it. The plasticized wood is held in the bent position until it cools. As it cools, the lignin hardens again, and the wood assumes its new, bent shape.

Dry-heat bending is sometimes called *hot-pipe bending* and is most frequently associated with the construction of musical instruments. This method works well for pieces that are 1/4″ or less thick and up to 6″ wide. Heat is directed into an iron plumbing pipe, usually by means of a propane torch (see **Figure 29-12**). Thin strips of wood that have been soaked in water are rolled back and forth over the pipe. With pressure applied downward, the wood will gradually bend. A full-scale drawing of the desired shape is useful for checking bends as they are made. Forms are not used.

CAUTION

When hot-pipe bending, wear short sleeves and gloves. Getting a long sleeve too close to the flame of a torch can result in a bad burn. Welding gloves will protect the wearer's forearms and hands.

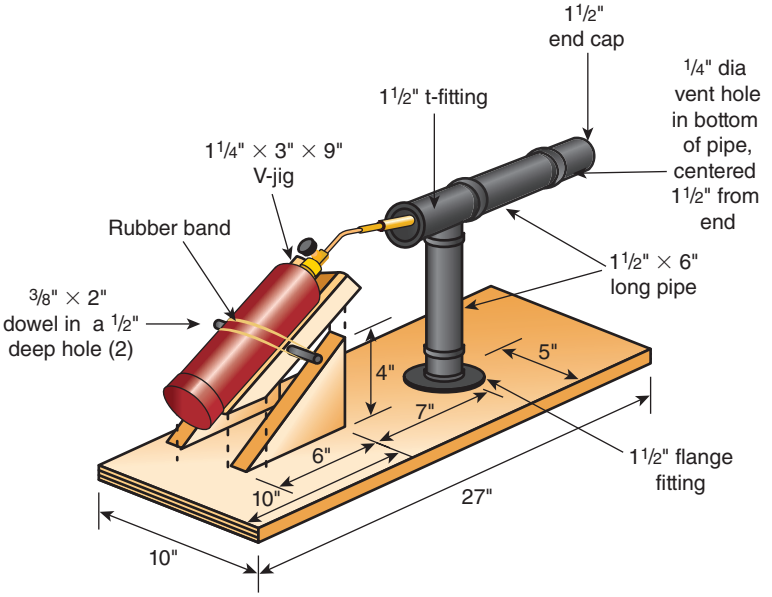


FIGURE 29-12 Dry-heat bending jig.

WOODWORKING TIP:

Dry-heat bending can also be accomplished through the use of a hot air gun of the sort used for softening paint and varnish for stripping. It is aimed at the area to be bent in much the same way as a flashlight beam would be directed. This method is appropriate for thin strips and might be used for fashioning basket handles, for example. A jig like the one shown in **Figure 29-13** *allows the user to anchor the piece under one peg and bend it around another. A wide variety of curves are possible by varying the positioning of the pegs.*

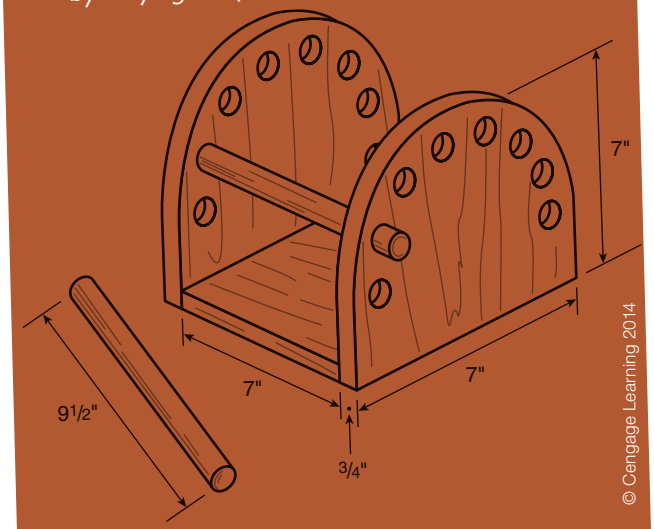


FIGURE 29-13 Double-peg jig.

It is also possible to plasticize wood and then bend it with very hot or boiling water. This method works for various thicknesses of wood, but it is really only practical for partial bends, such as the crook in the top of a cane, or relatively short pieces (see **Figure 29-14** and **Figure 29-15**). The issue is having a large enough container to put the piece into. The thicker the piece to be bent, the longer it needs to be immersed in the hot water.

Heavy plastic window boxes can be used as receptacles for hot water if longer pieces need to be bent. This works for heating the strips to make Shaker oval boxes (see **Figure 29-16**). A metal container filled with water can also be placed on a woodstove or propane camp stove, which will heat the water. Placing a piece of plywood over the container will help the water to heat more quickly.

CAUTION

Whenever a source of heat is used, for whatever reason, be sure that the area is free of combustible debris. A fire extinguisher should be close at hand. Do not use extension cords if working with electric heating elements, as you are more likely to overload the circuit and cause a fire.

The third method of plasticizing wood for bending is through the use of steam. Steaming is typically used when bending material thicker than 1/4″ that is longer than what could be accommodated in a pail or water container. Steaming has the advantage of being less wasteful of material than lamination bending, and because there are no lamina, there is no problem with layers being visible. Steam bending requires forms. It also requires a steam container and a source of steam. See **Figure 29-17** and **Figure 29-18** for illustrations of a steam box.

Steam for the steam box is generated by boiling water. The steam is directed into the steam box by



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FIGURE 29-15 Pouring boiling water into a bucket.



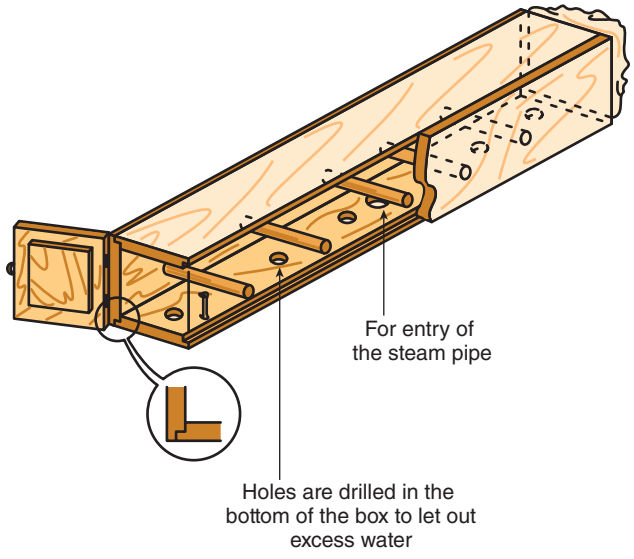
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FIGURE 29-14 Using a saucepan on a stove.



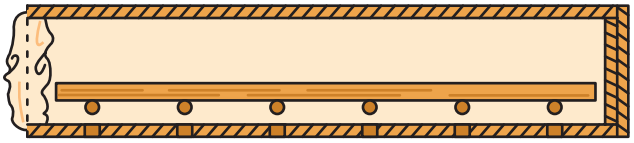
Image courtesy of Brent Rourke, shakerboxesnb.com

FIGURE 29-16 Shaker oval boxes.



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FIGURE 29-17 Steam box diagram.



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FIGURE 29-18 Steam box section view.

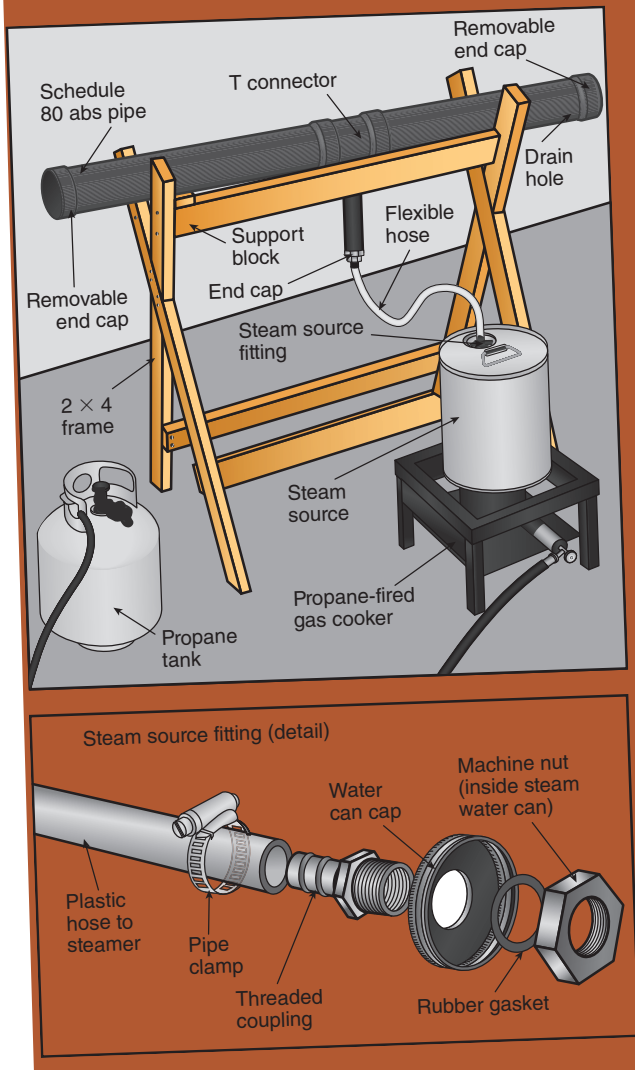
means of a rubber hose. Radiator hoses work well. An electric kettle can be used for boiling water, or a closed container may be used, such as a five-gallon drum fitted with a removable cap or plug. The hose running into the box from a pipe soldered to the drum transmits the steam. The water container can be heated with a portable gas burner or an electric hot plate. Wood that is steam bent should be straight grained and free of defects. The rule of thumb for steaming time is one hour per inch of wood thickness.

CAUTION

Steam is invisible and highly dangerous. The steam generated for steam bending is at 212°. When removing material from a steam box, stand back when you open the door, and handle the wood with thick gloves when loading and unloading the box. Never let the boiler run out of water. To maintain the temperature of the boiler, it is better to add smaller amounts water more frequently than to add large amounts at once. If the boiler does run out of water, let it cool before adding more. Adding water to a dry, hot boiler can cause an explosion.

WOODWORKING TIP:

A steam box can be built using PVC pipe (see Figure 29-19). One end is capped, the pipe should be slightly tilted, and drain holes for condensation must be drilled. Pieces to be steamed are placed in the pipe, and the open end is closed off. The pipe must be supported, because it has a tendency to become somewhat flexible and sag when heated by the steam.



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FIGURE 29-19 PVC steam box.

Bending Forms and Jigs

Lamination bending, hot-water bending, and steam bending all require forms. Forms may be one sided or two sided. **Figure 29-20** and **Figure 29-21** show examples of each.

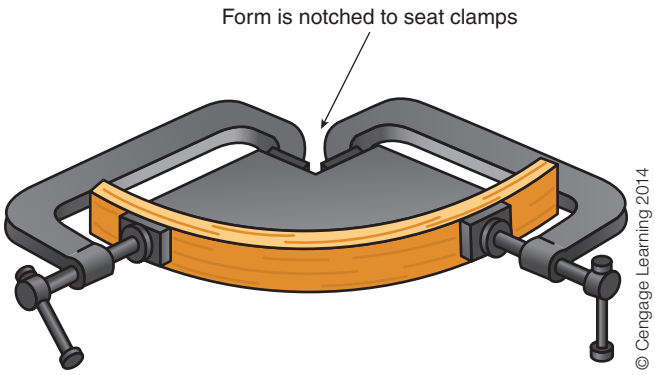


FIGURE 29-20 One-sided form.

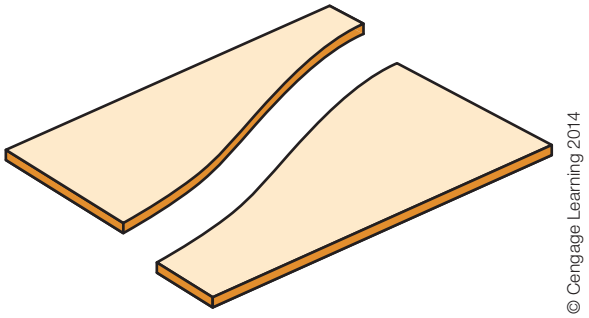


FIGURE 29-21 Two-sided form.

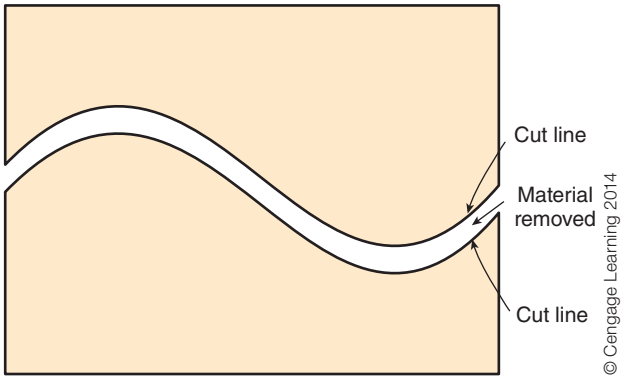


FIGURE 29-22 Two-sided forms require the cutting of two parallel lines. The distance between the lines is equal to the thickness of the material being bent.

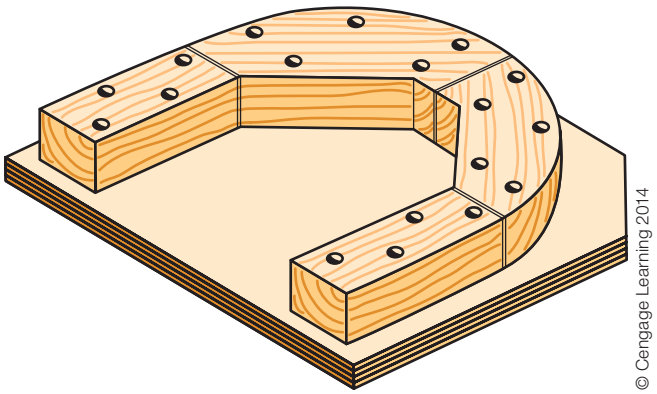


FIGURE 29-23 Solid wood form.

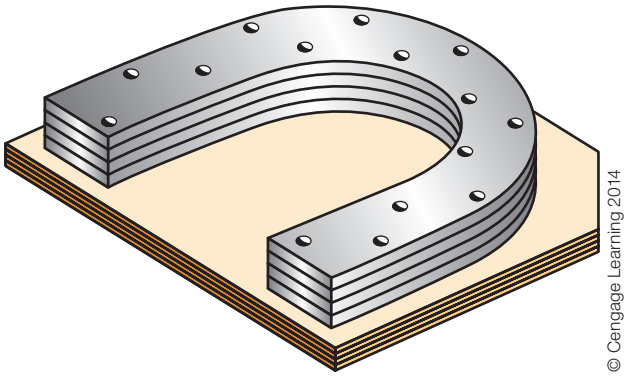


FIGURE 29-24 Laminated form.

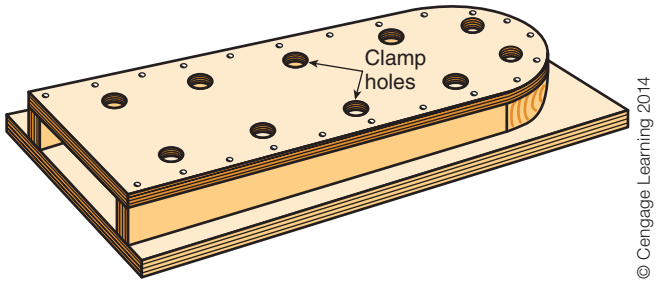


FIGURE 29-25 Box-construction form.

Two-sided forms cannot be made by simply cutting the form material in two. Two parallel lines are required to allow for the thickness of the wood being bent. Two cuts are made, and the center section is removed (see **Figure 29-22**).

Forms can be built using solid wood, by laminating, or through box construction (see **Figure 29-23**, **Figure 29-24**, and **Figure 29-25**). Forms should be as tall as the material being bent is wide. They must be ruggedly constructed and capable of withstanding great force. MDF and plywood make good forms, but particleboard does not, as it tends to chip away after a few uses.

If tight curves are to be made using steam-bent lumber, a bending strap should be used. The bending strap not only gives the person bending the wood much greater leverage, it also acts as a safety device

PROCEDURE 29-2

Build a Steam Box

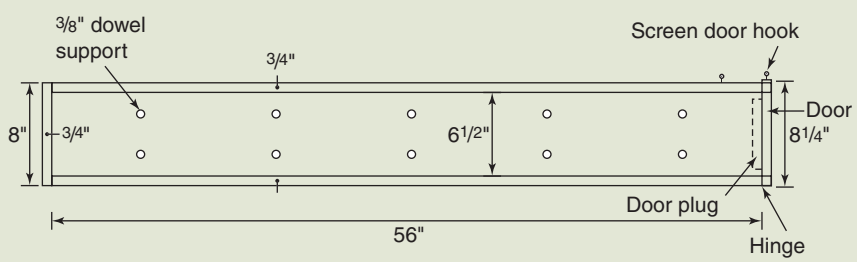
Assembly list for steam box

Part	Dimensions (thickness × width × length)	Quantity
Side	$^3/_4$" × $6^1/_2$" × 56" exterior plywood	2
Top	$^3/_4$" × 7" × 56" exterior plywood	1
Bottom	$^3/_4$" × 7" × 56" exterior plywood	1
End	$^3/_4$" × 7" × 8" exterior plywood	1
Door	$^3/_4$" × 7" × $8^1/_4$" exterior plywood	1
Door plug	$^3/_4$" × $5^3/_8$" × $6^3/_8$" exterior plywood	1
Dowel	$^3/_8$" × $7^1/_4$"	10
Hinge	$1^1/_2$" × 3"	1
Screen door hook	–	1
Meat thermometer	Optional	
Screws	#8 × $1^3/_4$" galvanized	
Legs	$1^1/_2$" × $3^1/_2$" × 15"	4

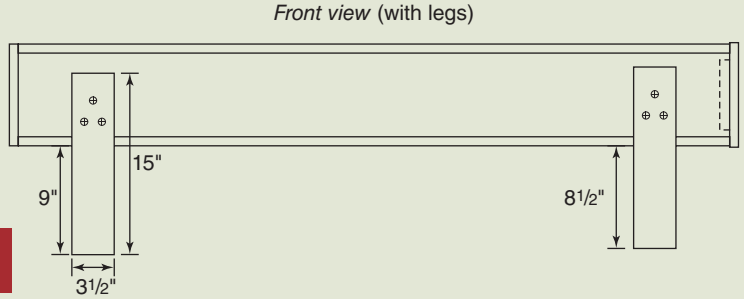
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A

Front view (without legs)



Front view (with legs)



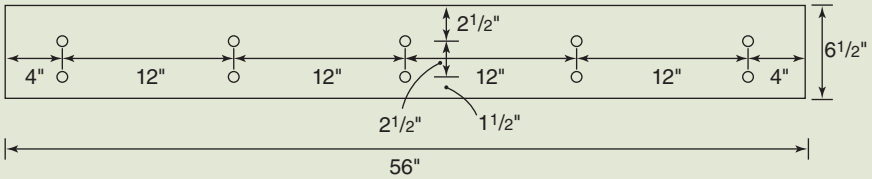
B

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STEPS

1. Refer to **Figure A** for a list of materials and to **Figure B** for a diagram of the box. This box is 56" long, but you can adjust the length to suit your needs.
2. Cut the pieces needed to size.

3. Line up the sides of the box and drill 3/8″ holes through both pieces, as indicated in **Figure C**.
4. Assemble the sides, the bottom, and one end of the box with galvanized screws.
5. Tap the 3/8″ dowels through the sides of the box as shown in **Figure D**. These will support your bending stock when it is in the box.
6. Glue and screw the top on the box. Use a water-resistant or waterproof adhesive.
7. On the bottom of the box in the center, drill or cut a hole to accommodate the pipe that will bring the steam into the box. Refer to **Figure E**. Different steam systems will require different size holes.



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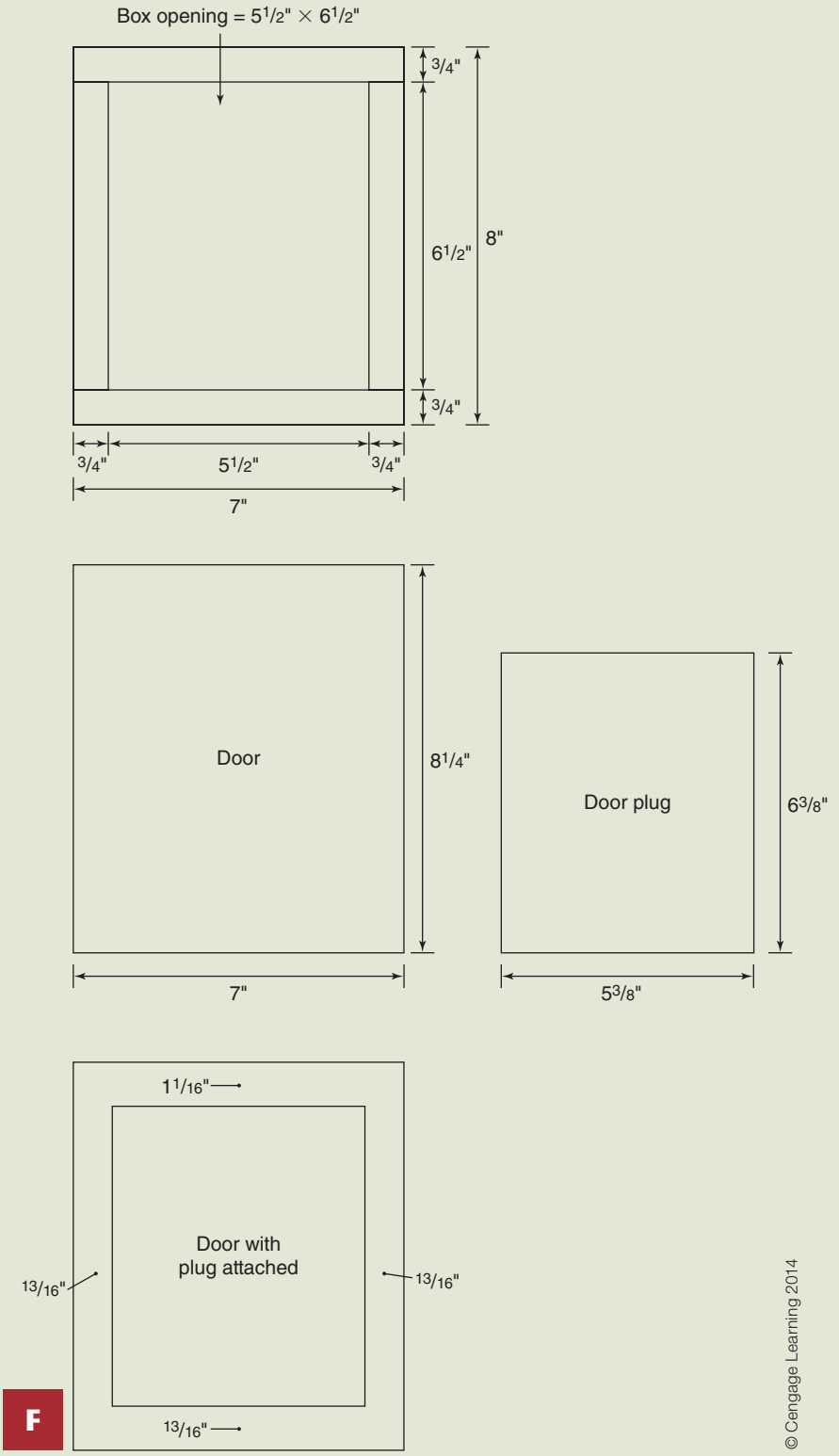
C


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D


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E

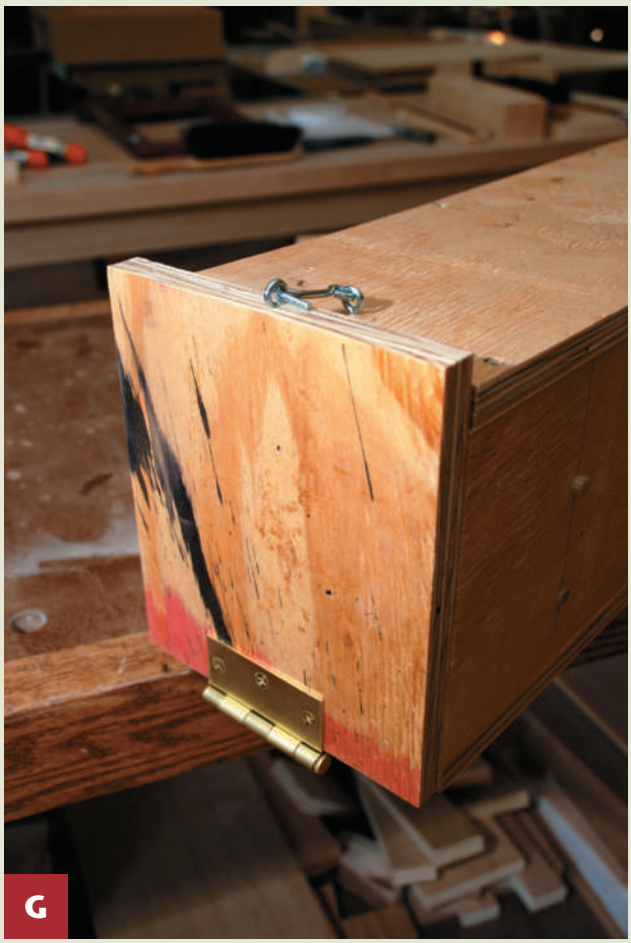


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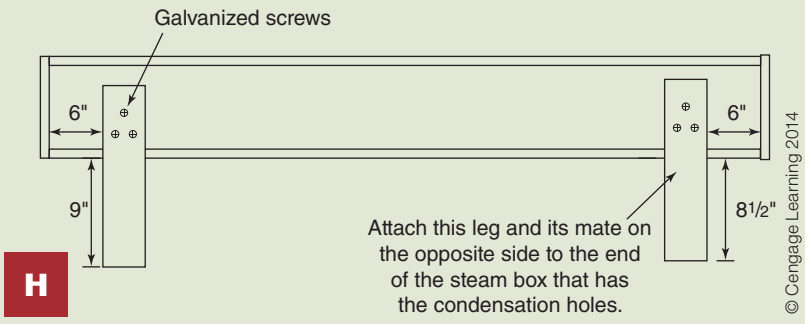
8. Glue the plug to the door. Check your box opening; the plug should be 1/8″ shorter in length and width than the opening to allow for swelling (see **Figure F**).

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9. Attach the door to the box with a large butt hinge. A screen-door hook is used to keep the end closed (see **Figure G**).
10. Turn the box over and drill two 1/4" holes toward one end of the box to allow condensation to drain.
11. Drill a tight-fitting hole to accept a meat thermometer on the top of the box near one end. This is an optional step, but using the thermometer allows you to monitor the box's temperature, which should remain above 200° throughout the steaming cycle.
12. Attach the legs to the box with galvanized screws in accordance with **Figure H**. This tilts the box so that condensation will run out the condensation hole. **Figure I** shows the completed steam box. You may notice that this particular steam box has doors at both ends. You can make one like this by omitting the end and making two doors, which allows access to the box from both ends. **Figure J** shows the steam box in use.


G

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H

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I

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J

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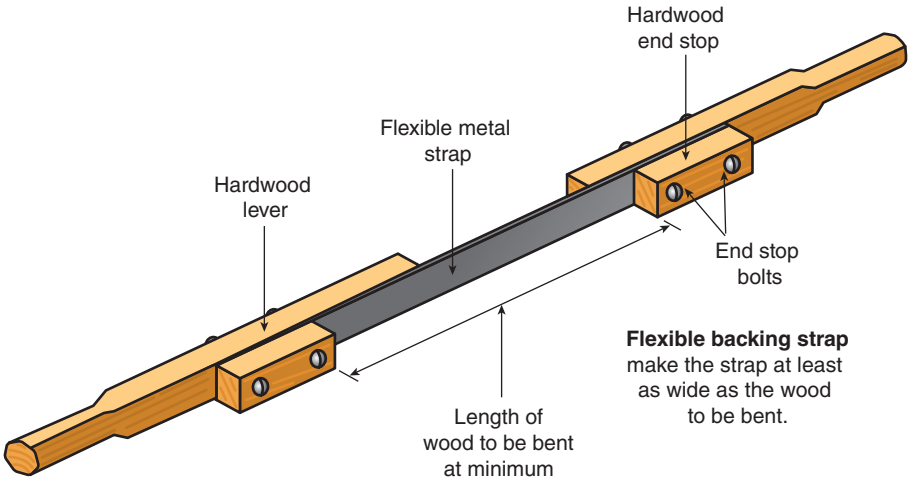


FIGURE 29-26 Bending strap.

should the piece break. **Figure 29-26** shows how to build a bending strap, and **Figure 29-27** illustrates one in use.

When working with hot water or steam, it is important to have the forms close to the heating source. It is imperative that you be able to move quickly, because the wood begins to cool as soon as it is removed from the steam box or hot water. Any clamps that will be used should be close at hand. You must work just as quickly when working with bent laminations, which is one of the reasons you perform a dry run before applying the glue. The bend you have created should stay in the form until it is thoroughly dry. This may take quite some time, depending on how fast the glue cures and how thick the piece that has been boiled or steamed is. Sometimes leaving the bend in the form is not practical, especially if you have a number of pieces that need to be bent using the same form. One way to overcome this difficulty is shown in **Figure 29-28** through **Figure 29-30**. The piece is placed in the form, clamped in the center and bent, and then tied together and removed from the form to dry.

When bending stock into round or elliptical shapes, solid forms are often used; **Figure 29-31**

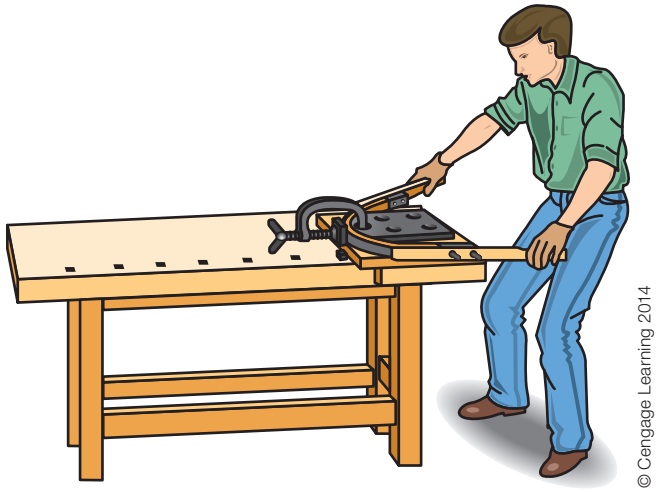


FIGURE 29-27 Bending strap in use.

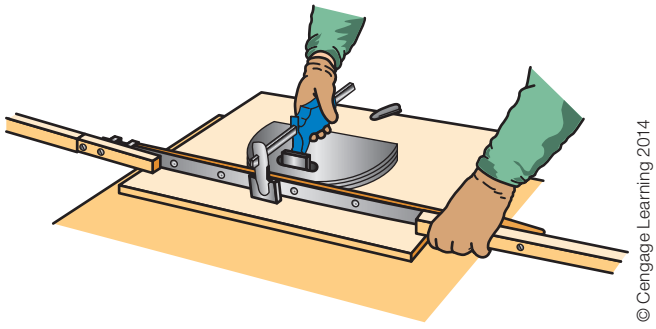


FIGURE 29-28 A hot blank is removed from the steam box and clamped to the form with the bending strap behind it.

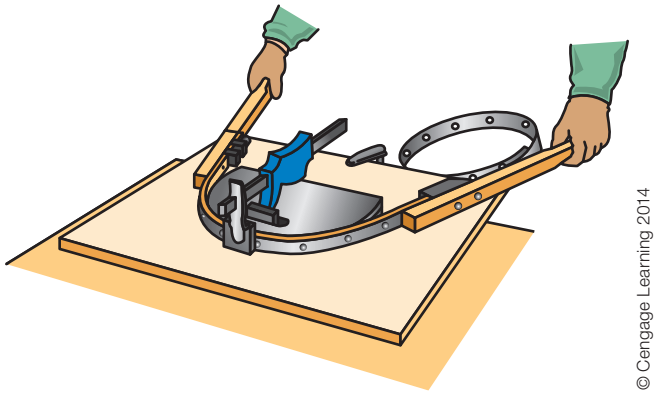


FIGURE 29-29 The wood is immediately bent around the form using the strap.

shows some examples. Usually very thin wood is used in these situations. This method is used for making oval boxes and trays. The wood is plasticized, bent around the form, then taken off and tacked together. Drying forms, called *keepers,* are placed in the bent wood so that it keeps its shape as it dries. Two keepers are generally used per box; one is placed at the bottom and the other at the top. **Figure 29-32** shows examples of keepers. The holes drilled in them are to make it easy to insert and extract them.

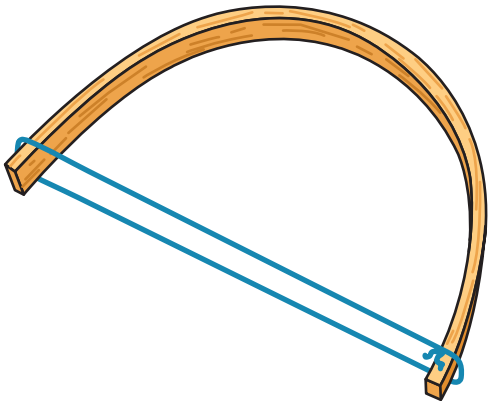

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FIGURE 29-30 After the bend is complete, a string is tied around the ends to keep the shape until the piece is dry.

Bending wood tends to require a great many clamps. As mentioned earlier, clamps should be close at hand, and if possible, they should be preset so that the wood can be clamped into its form as quickly as possible. Another option is to use a vacuum press, which eliminates the need for clamps and uses atmospheric pressure instead. The wood to be bent is placed over a one-sided form and placed in a heavy plastic bag. The bag is sealed and all the air is sucked out of it with a vacuum pump. The pump turns on automatically as needed to maintain the vacuum. Atmospheric pressure provides clamping pressure evenly over the entire area (see **Figure 29-33**).

Wide laminations, such as for a curved door panel, require a different type of form than those looked at so far. **Figure 29-34** shows an illustration of a form for a wide lamination. These wide laminations are particularly well suited for vacuum press use. Only the bottom part of the form would be used. If it were to be clamped, this would be done as shown in **Figure 29-35**.


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FIGURE 29-31 Solid forms.


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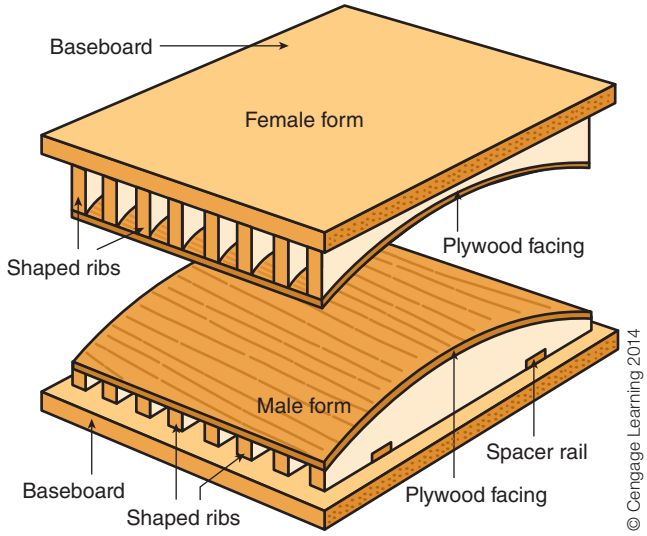
FIGURE 29-32 Keepers.


Image courtesy of rockler.com

FIGURE 29-33 Bending with a vacuum press.

Bending Qualities of Wood

Different species of wood have different bending qualities, making some much easier to bend successfully than others. The United States Forest Products Laboratory has conducted bending tests on hundreds of boards from many species. The list shown in **Figure 29-36** shows the rating generated as a percentage of the boards successfully bent. The higher the number, the more likely it is that the wood will bend well. Some woods are more suitable for certain bending projects than others. The table shown in **Figure 29-37** lists woods appropriate for various bending tasks.



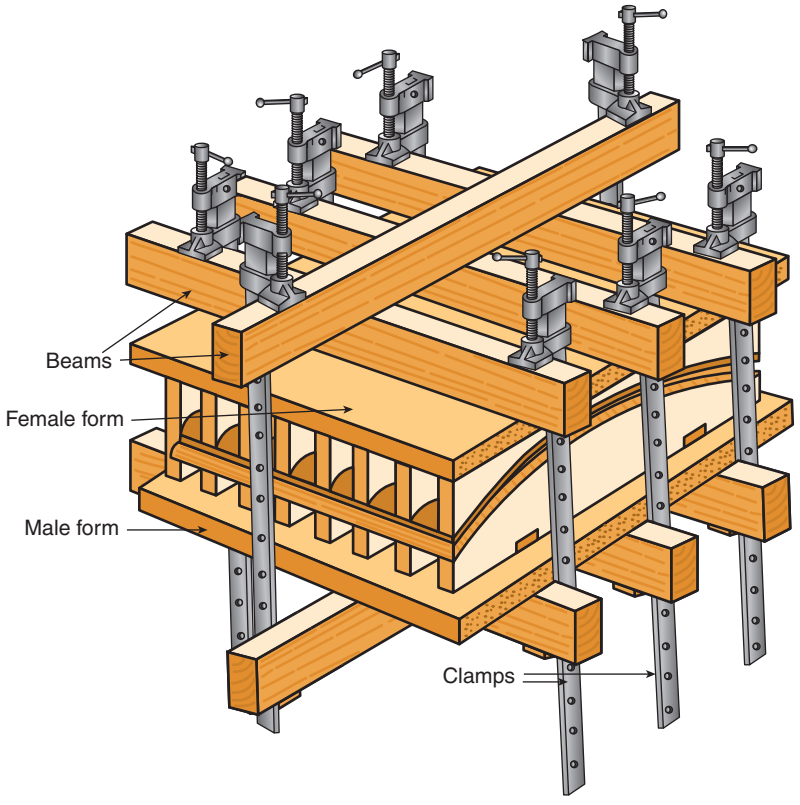
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FIGURE 29-34 Form for wide laminations.

Ash	67
Basswood	2
Beech	75
Birch	72
Chestnut	56
Elm	74
Gum, Red	67
Hackberry	94
Hickory	76
Magnolia	85
Maple, Hard	57
Maple, Soft	59
Oak, Red	86
Oak, White	91
Poplar, Yellow	58
Sycamore	29
Walnut	78
Willow	73

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FIGURE 29-36 Comparison of woods in bending tests.



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FIGURE 29-35 Clamping up a wide lamination.

Items	Beech	Oak	Ash	Chestnut	Cherry	Sycamore	Teak	Rose wood	Lime	Willow	Maple
Walking sticks			×	×							
Slats for gardening baskets	×		×	×	×	×				×	×
Boats planks		×	×				×				
Boat ribs		×	×	×							
Water skis	×		×	×		×					×
Chair backs	×	×	×	×	×	×					×
Sides for musical instruments					×	×		×			
Linings for musical instruments									×	×	×

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FIGURE 29-37 Bent items and recommended wood species.

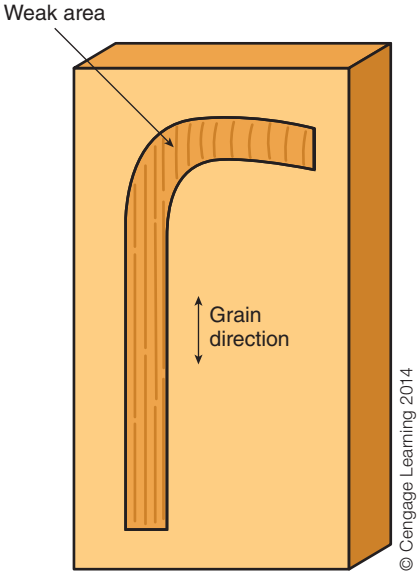


FIGURE 29-38 Grain run-out causes a curve cut from solid lumber to be weak beyond 90 degrees.

Woods with lesser bending qualities may be fine for gently bent laminations, provided they are sawed thin enough. Steam bending of thick wood into tight curves requires woods more highly rated for bending. Regardless of the wood chosen for bending, it is important that it be free of defects and that it have a straight grain.

Curved Pieces Without Bending

Curved pieces do not have to be bent. There are three choices for the woodworker wishing to create a curve without going through a bending process: milling solid lumber, segmented lamination, and coopering.

Milling solid lumber into a curved shape only requires a good band saw or a template, router, and flush trim bit. The resulting curve is strong, provided that the curve is less than 90 degrees. This is because wood is only strong with the grain. If a piece is milled beyond 90 degrees, there will be short grain at one point in the arc, which is very weak (see **Figure 29-38**).

Although milling curves from solid lumber creates a good deal of waste, a strong argument can be made that it is less time consuming than bending. This may make it the most cost-effective method of creating curves of less than 90 degrees if both material and labor costs are taken into consideration.

Segment lamination is a method for making curves using short pieces of solid stock stacked in staggered rows. It is also called *brick stacking*, because it resembles the way bricks are laid in a staggered pattern (see **Figure 29-39**). A full-sized pattern of the curve to be made is laid out. The width of each piece needs to be greater than the thickness of the curve, and the

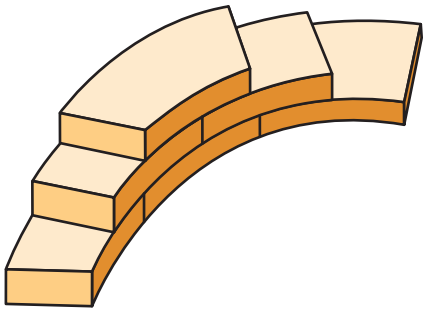
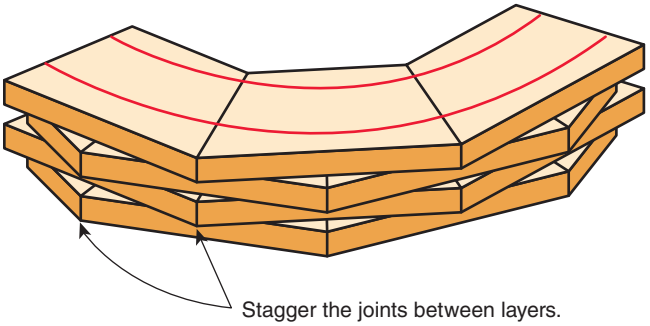
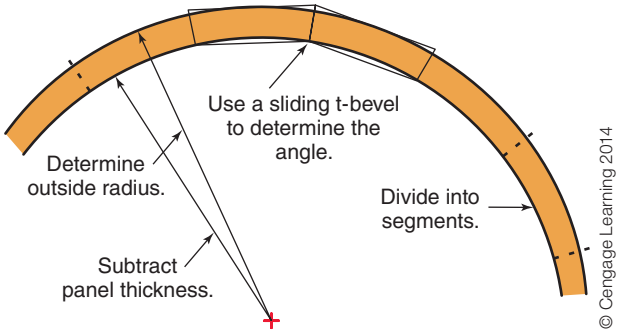

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FIGURE 29-39 Segment lamination.



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FIGURE 29-40 Segment length and width covers both the inside and outside of the curve.



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FIGURE 29-41 Layout for determining bevel in coopered curves.

length of each segment is determined by selecting a piece that covers both the inside and the outside of the curve (see **Figure 29-40**). Next, the angle for the segment ends is determined. A sliding T-bevel can be used to transfer this angle to the saw, or it can be determined using a protractor. The pieces are cut to the determined lengths and angles on a miter saw or with the miter gauge on the table saw. The pieces are assembled and glued together with pressure applied by hold-down clamps or by weight placed on top of the assembly until the glue has cured. Then the final curve is cut on the band saw, planed, scraped, and sanded smooth. It may be that only the outside face needs to be sawn, if the inside will not show.

The segments may also be individually curved prior to assembly, rather than cutting the entire curve after glue-up. A template is made for one segment and is used to duplicate all the other pieces. Segment laminations will, of course, show the joints. This may be used to achieve a nice effect by using contrasting species of wood, or the segmented lamination might be made of less desirable woods and veneered after smoothing.

GREEN REMINDERS

Wood scrap can be recycled to use for heating purposes by those who have woodstoves or wood-fired boilers.

Coopering is another method of creating curves without bending. It is a method of joining wood strips edge to edge to create a curve, unlike segment lamination, where pieces are joined end to end. In coopering, the edges of the wood strips are beveled. The process for figuring out the bevel to be ripped on each piece is the same as that used to compute the angles cut on the ends of segment-laminated pieces. The method for determining the width of each coopered piece is the same as that used for figuring out the length of each segment-laminated piece, namely that it must cover both the inside and outside of the desired curve (see **Figure 29-41**). Bevels are ripped on the table saw. Again, a sliding T-bevel or protractor can be used in determining the bevel.

The beveled pieces are called **staves**. Narrower staves mean more pieces will be required to complete the curve, but it will also result in a greater thickness and less time spent planing, scraping, and sanding the curve into its final shape (see **Figure 29-42**).

A form is needed for gluing up coopered panels. The form should be as long as the panel and as wide as the total of all the staves plus a little extra. Molded pieces should match the radius of the curve, and they should be attached to a base every 12 to 18 inches. Drill holes in the end pieces of the jig for clamps

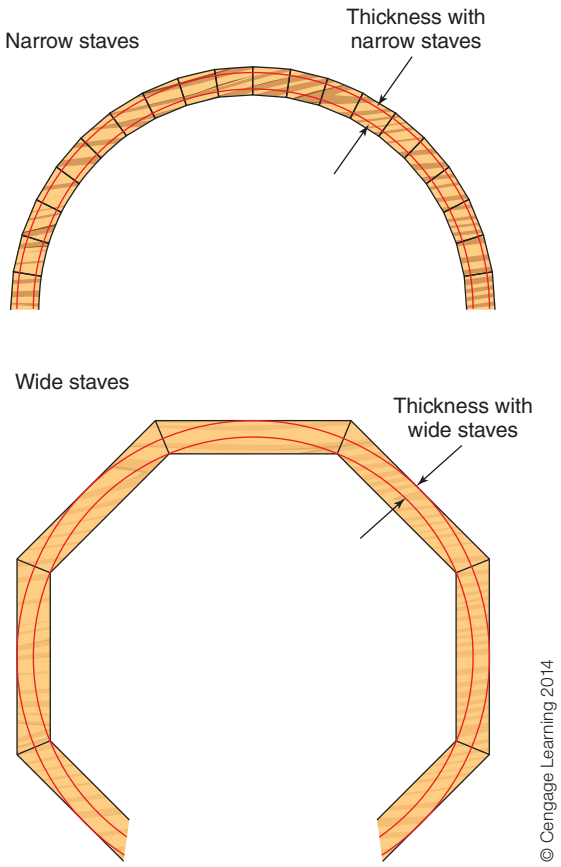


FIGURE 29-42 Narrow staves mean more pieces but less clean-up.

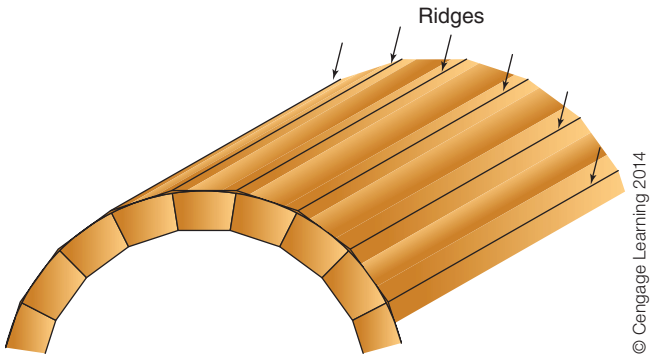


FIGURE 29-44 Ridges remain where beveled edges meet.

(see **Figure 29-43**). It is a good idea to cover the curved surface of the form with packing tape or seal it with several coats of varnish so that the glued-up panel will not stick to it. As with other glue-ups, a dry run with clamps is good practice before spreading glue.

When the coopered panel comes out of its form, there are ridges where each pair of beveled edges meet (see **Figure 29-44**). Working first with a hand plane, then a scraper, and finally sandpaper, smooth the panel into the desired curve.

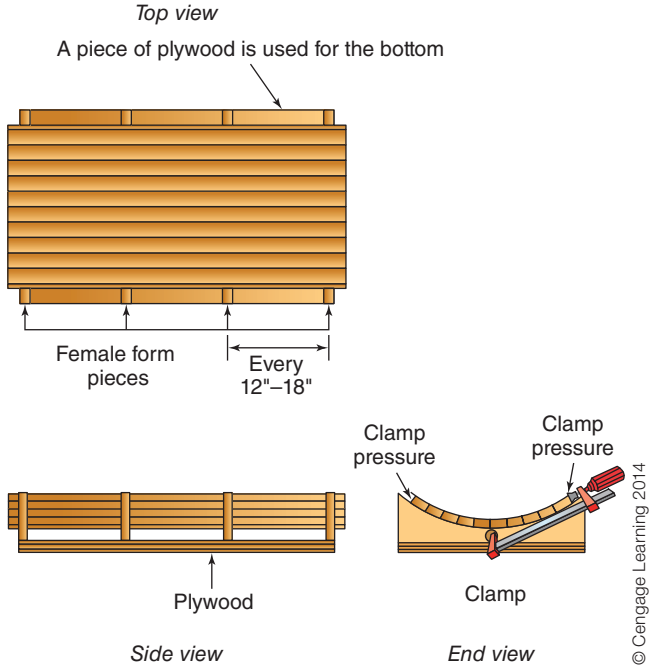
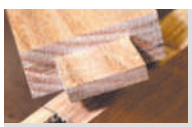


FIGURE 29-43 Gluing form for coopered panels.



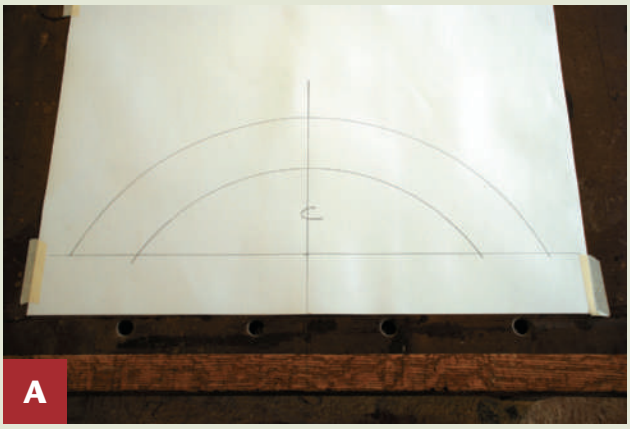
HISTORY FACT

Coopering is an ancient trade. Coopers were responsible for making casks, which were as important in earlier times as cardboard boxes are today. Casks were an indispensable part of colonial life and commerce. Today, we tend to refer to casks as *barrels,* but barrels were only one item made by coopers. Barrels are a type of cask. A barrel of gunpowder held 100 pounds. A barrel of beer held 36 gallons. A large wine cask that held 130 gallons was known as a *butt,* or pipe. Wine also came in rundlets, which held 18 gallons; tierces, which held 42 gallons; and puncheons, which held 84 gallons.

Coopering had three broad divisions. One was called *tight work,* which produced containers for liquids. Dry tight work was the making of containers for powdery material. Slack work created containers for holding dry goods. ■

PROCEDURE 29-3

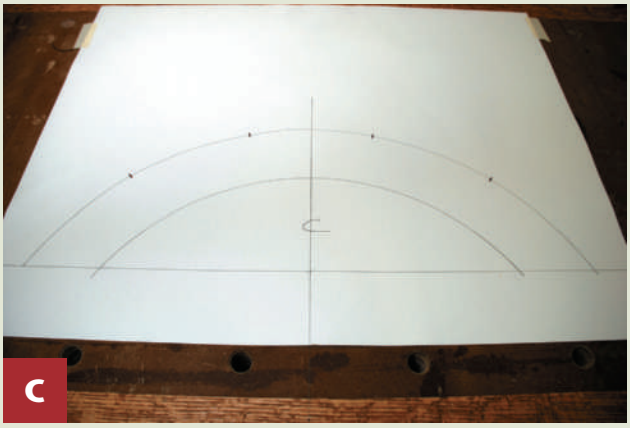
Creating a Curve Using Segment Lamination



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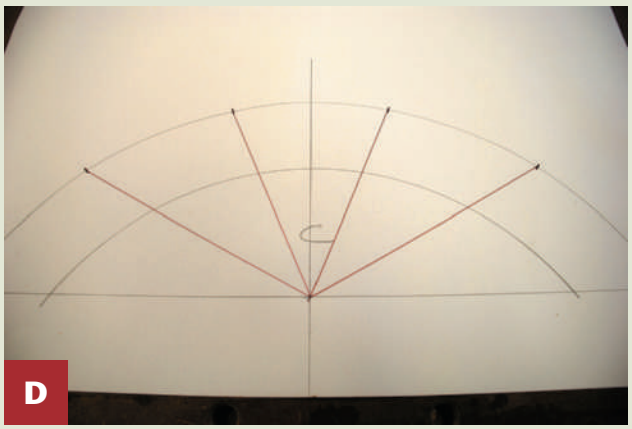


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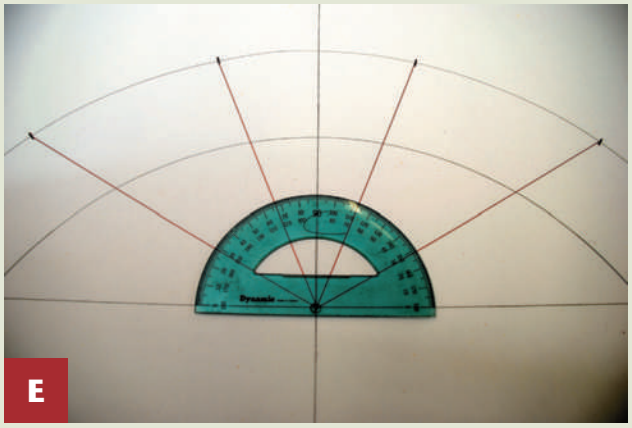
STEPS

1. Decide on the curve you wish to create, and make a full-size template of the inside and outside of the curve. Draw a straight line along the base of the curve, and mark its center point, as shown in **Figure A**.
2. Rip material to width, making it 1" wider than the thickness of your curve.
3. Determine the rough length of individual pieces by setting a piece on your template and noting how much is required to cover both the inside and outside of the curve (see **Figure B**).
4. Determine the angle that will be cut on the ends of each piece by first marking off the rough length along the template curve, as shown in **Figure C**.

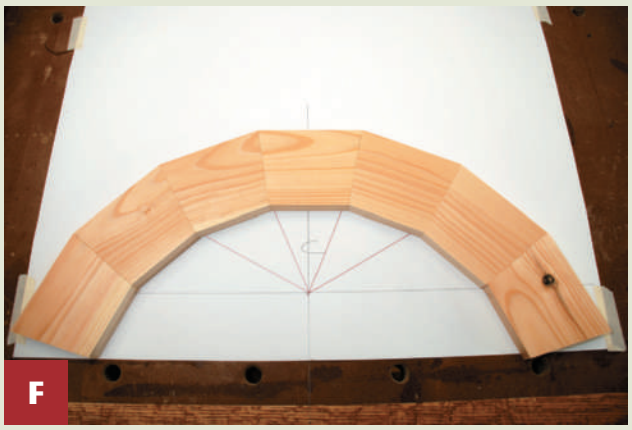
5. Draw lines from the length marks you made along the curve back to the center point marked on the horizontal line (see **Figure D**).
6. Use a protractor or sliding T-bevel placed on the horizontal line to determine the angle, as shown in **Figure E**. The angle is divided in half to determine the saw setting for the cut. For example, if the angle is 30°, the mating pieces will each be cut at 15° and then, when they are put together, you have the 30° angle.
7. Cut the individual pieces.
8. Assemble the first row of pieces, as shown in **Figure F**.


D

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G

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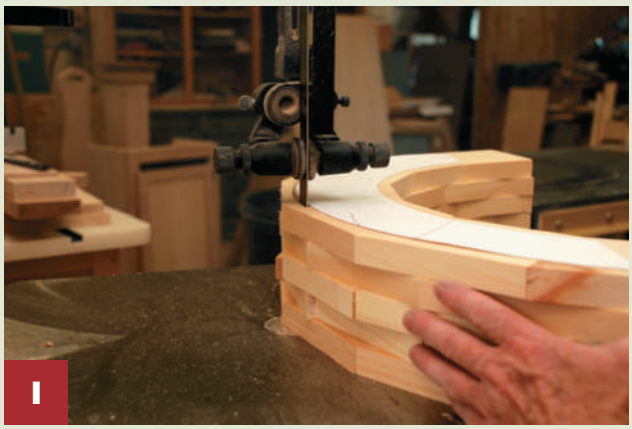


H

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9. Spread glue on the first row and lay the second row in place, staggering them by half, as shown in **Figure G**.
10. Repeat for as many rows as are needed to achieve the desired height.
11. Place weight on top of the assembly and wait for it to dry.
12. Transfer the curve from the template onto the glued-up assembly, as shown in **Figure H**.

13. Cut the curve on the band saw, as shown in **Figure I**. **Figure J** shows the completed curved piece.
14. Scrape and sand smooth.
15. If you wish, you can veneer the outside of the curve (see **Figure K**).


I

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J

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K

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Summary

Creating curves in wood moves the cabinetmaker into a whole new and exciting realm, one in which she is no longer constrained by rectilinear forms. There are many applications for curved work, including table aprons, chair slats, and rockers. Curves can be milled from solid wood or created by segment lamination or coopering. Wood can also be bent into curves, and some woods are more suitable for bending than others. Various methods for bending wood include dry bending, lamination bending, and bending through plasticizing the wood. Plasticizing can be achieved with hot water or steam. Forms are often used to hold pieces in the desired shape until they are dry. Wood may be clamped into forms, or vacuum pressing can be used. Wood to be bent should be straight grained and free of defects. Whatever method of creating curves in wood is used, attention to detail and trial runs are essential to success.



Key Terms

coopering
dry-heat bending
kerfing
lamina
laminated bends
plasticizing
segment lamination
staves



Check Your Knowledge

1. Name three situations where curving the wood results in a more pleasing, comfortable, or functional piece of furniture.
2. What is kerfing, and how is kerf spacing determined?
3. What is one disadvantage to kerfing?
4. How can kerfed curves be strengthened?
5. What is lamination bending?
6. What are two disadvantages to lamination bending?
7. What safety precautions should be taken during lamination bending?
8. What are three ways of plasticizing wood for bending?
9. What type of bending is most often used for forming the curved sides of musical instruments?
10. Why can a two-part form not be made with one cut?
11. What are two ways of holding wood to a form?
12. List three woods that bend well.
13. Why is it important to move quickly when creating bends in woods? How can you do this?
14. What dangers are there in bending, and how can they be avoided?
15. Other than bending the wood, what are three ways of creating curves? List and discuss the differences between them.

BUILD IT!

Walking Stick

Figure A shows a completed walking stick.

TOOLS REQUIRED

- Measuring tool
- Band saw
- Plane
- Sander
- Router table and a piloted 3/8" round-over bit

MATERIAL REQUIRED

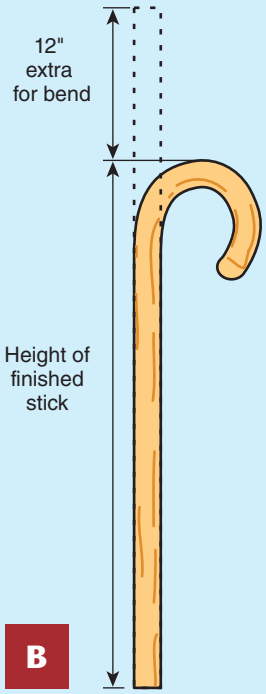
- Length of straight-grained oak a minimum of 1 1/8" thick, 3" wide, and 42" long
- 3/4" plywood for bending jig
- 3/4" pine for bending jig
- 1 1/4" screws for bending jig
- Rubber ferrule (optional)

STEPS

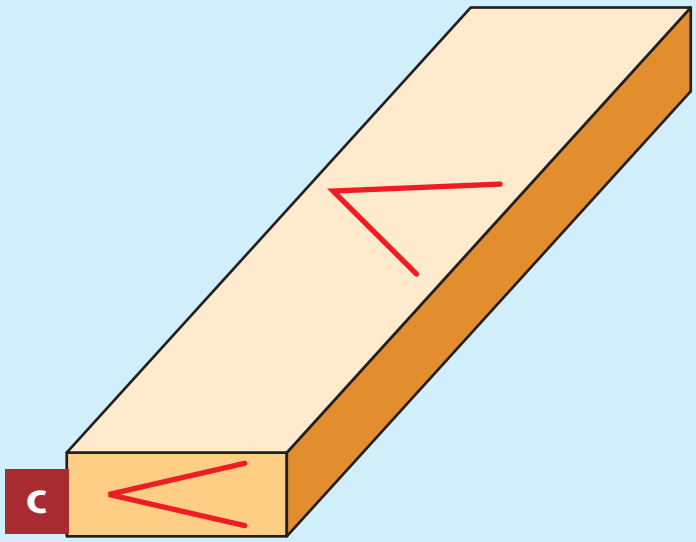
1. Study **Figure B**. Determine a comfortable height for your walking stick and add 12" for the curve. Cut your piece about 4 extra inches longer than this; the tip and top of it will be trimmed later.
2. Joint and mark one edge of the board.
3. On the top and on one end of your board, make marks as shown in **Figure C**. This will make reassembling the strips later possible.



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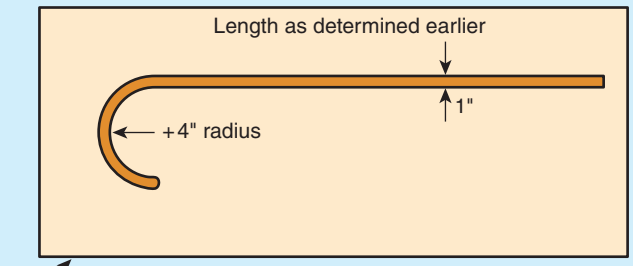


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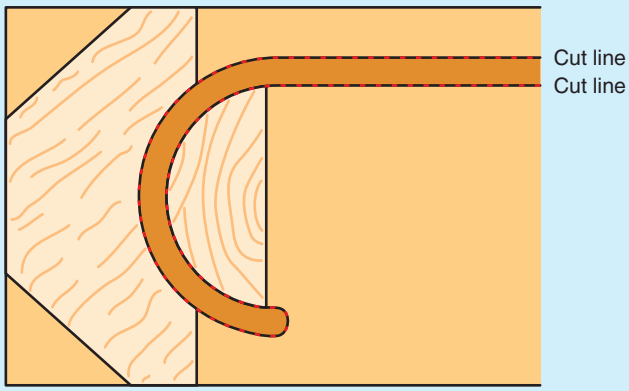
E

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4. Set the fence on the band saw to resaw a thin strip. Make the cut, butting the jointed edge of the board against the fence.
5. Bend the strip to see if it can make a tight curve at the top for the handle. If it is not possible to do this, or if the piece breaks, set the band-saw fence for a narrower cut and try it again until you have a piece that will bend.
6. Continue to cut strips on the band saw, as shown in **Figure D**, always butting the same side of the board against the fence. Keep the pieces stacked sequentially as they come off the saw.
7. Resaw enough strips so that when you squeeze them together you have an inch of material. Then make a few extra in case some break during glue-up.
8. On a piece of 3/4" plywood, lay out the walking stick as shown in **Figure E**. This is the base of your bending jig.

BUILD IT!

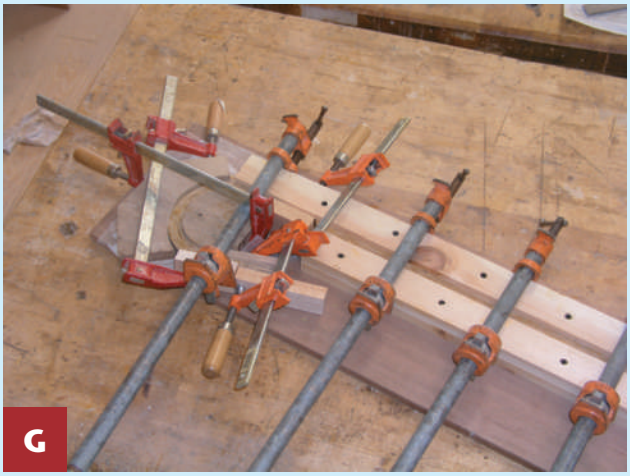
9. On another, smaller piece of 3/4" plywood, lay out just the top part of the walking stick and then use a jigsaw or band saw to cut it out (see **Figure F**). The two pieces outside the handle will be part of your bending jig.
10. Glue and screw the inside curved piece to the base of the jig. Set the outside curved piece aside for now.
11. Glue and screw a piece of 3/4" pine 1 1/2"–2" wide to the inside of the straight part of the walking stick jig, and then glue and screw another piece on top of it, keeping the inside edges flush with one another. Attach them 3" down from the first curved piece you attached to the jig.
12. Glue and screw together two more pieces of pine that are 1 1/2"–2" wide, keeping the edges flush.
13. If you plan to use the jig more than once, finish it with varnish and let it dry. This will keep the walking stick from sticking to it during glue-up. Alternatively, you can use waxed paper.



F
1. Cut at curve
2. Cut at black lines
3. Shaded areas are used in the jig

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BUILD IT!



G

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14. Lay out the thin oak strips in order and coat them with glue.
15. Put the strips against the fixed parts of the jig and then bring in and clamp the outer curved piece at the top and the pine piece along the side. Try to keep the pieces down on the jig, and clamp. Use enough clamps to draw the strips tightly together (see **Figure G**).
16. Allow the glue to cure thoroughly and then remove the walking stick from the jig. Plane and sand it smooth and then cut the top and bottom to the length desired.
17. In a series of passes on the router table using a 3/8" piloted bit, rout a 3/8" roundover on all four edges and then sand smooth.
18. Finish with several coats of a penetrating or combination finish.
19. Fit with a rubber ferrule if desired.

BUILD IT!

PROJECT CHALLENGE

Oval Box

Figure A shows a completed oval box.

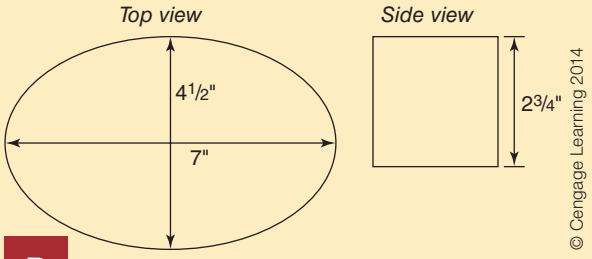
STEPS

1. Make a solid form as shown in **Figure B**. Glue up stock to the necessary thickness, and then cut and sand it to the shape shown in **Figure C**. Glue or screw a block to the top of the form so it can be held in a bench vise.



A

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B

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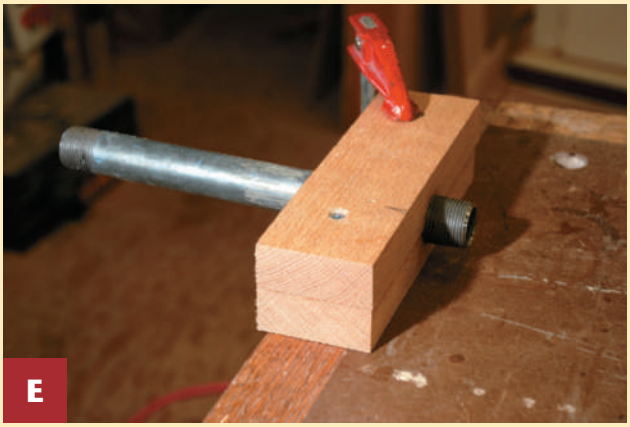


C

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D

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E

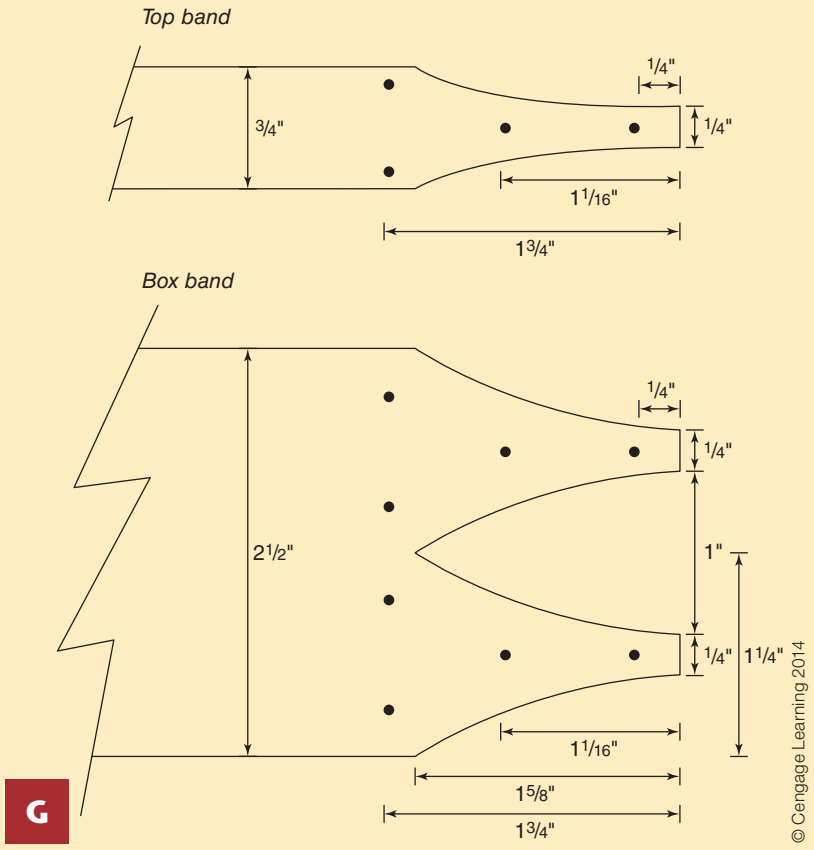
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F

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2. Using the same pattern used to make the form, make two keepers from 1/2" material. Drill 5/8" finger holes in each keeper to make them easy to use. After cutting out the keepers on the band saw, tilt the stationary sander for a 10° bevel and sand to your layout line, as shown in **Figure D**. This makes the keepers easier to get into the box.
3. Make an anvil as shown in **Figure E**. This is used when driving the tacks that hold the box together. Drill a hole to accommodate the steel pipe in a piece of stock, then cut the piece in half, and reassemble it with the pipe held between the two pieces.
4. Prepare two maple blanks, one that is 3/4" wide and another that is 2 1/2" wide. Make the wider piece 22 9/16" long and the narrower piece 23 5/16" long. Go to the band saw and resaw pieces that are about 1/16" thick off each blank, as shown in **Figure F**. Sand smooth.

5. Use the templates given in **Figure G** to lay out the fingers and tack positions on the two bands.
6. Cut the fingers on the band saw, and then smooth and bevel the edges with a knife, as shown in **Figure H**.
7. Place the bands in a trough long enough to hold them, and pour boiling water over them until they are covered. Let them soak for 20 to 30 minutes.



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8. Remove the wider band from the water and bend it around the solid form. Mark where the piece laps itself (see **Figure I**).
9. Loosen the band slightly to remove it from the form, and bend it again so that your pencil marks line up. Put the box over the anvil, and drive small tacks at the places you marked for tacking earlier, as shown in **Figure J**. As the tacks hit the anvil, they will be peened over.
10. Place two keepers in the box, one positioned at the top and the other at the bottom. The keepers should stay in place for a day or two, until the box is dry.
11. Take the narrower strip from the water, bend it around the box with the keepers in it, and mark where the piece laps itself. Refer to **Figure K**.
12. Remove the band from the box, bend it so that your marks line up, and use the anvil to drive the tacks as you did earlier with the box. Place the band back around the box to dry.

13. After the box is dry, you can make its top and bottom. Remove the top band. Place the box on a piece of 1/4" pine, and trace around the inside. Do the same with the lid band.
14. Use the band saw to cut close to your layout lines, and then sand to the lines with the stationary sander tilted for a 4° bevel.
15. Gently insert the bottom into the box and the top into the lid band. When you have them inserted, drill a series of 5/32" holes 1/2" deep through the box into the bottom and top, spacing them about 1 1/2" apart.
16. Wooden toothpicks are used to secure the top and bottom inside the bands. They can be cut in half and then tapped into the holes just drilled, as shown in **Figure L**. Snip off the protruding toothpicks, sand, and finish the box as desired.


L

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30

Veneering

You'll Learn

After studying the chapter, the student should be able to:

- Define veneering
- List reasons for using veneers
- Identify the tools used in veneer work
- List various substrates for veneers
- Identify various veneer matching patterns
- Explain the process of creating a veneering surface
- Explain different methods for attaching veneer to a substrate

INTRODUCTION

Veneering is the process attaching a thin layer of wood, called *veneer,* to some type of solid substrate, sometimes called a **core material**. Veneer was covered in Chapter 11. Veneering is a way to create beautiful surfaces. You will remember that the best of the logs harvested are cut into veneer, and that it is cut by a variety of different methods. By matching the veneers in different ways, striking patterns can be created. Using veneers allows the woodworker to work with woods that would be prohibitively expensive if purchased as solid lumber, and it is a chance to work with beautifully figured wood cut from burls, butts, and crotches that are

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not usually available as solid lumber. It is also a means of using beautiful and rare wood efficiently and in an ecologically sound way.

In this chapter, we will look at veneering tools, core materials used in veneering, and the skills involved in doing veneering work. We will also cover different methods of matching veneers to form patterns and various means of attaching veneer to a substrate.



HISTORY FACT

The use of veneers has an ancient history. Examples of veneered furniture more than 3500 years old were discovered in the tombs of the Egyptian pharaohs. Veneered work was also produced in great quantity by the Romans during the time of the Roman Empire. After this, veneering went out of fashion for a long time, until it was revived in the eighteenth and nineteenth centuries. Extensive use of veneer characterizes both the Victorian and Federal periods, but its popularity waned until it again became popular in the late twentieth century. ■

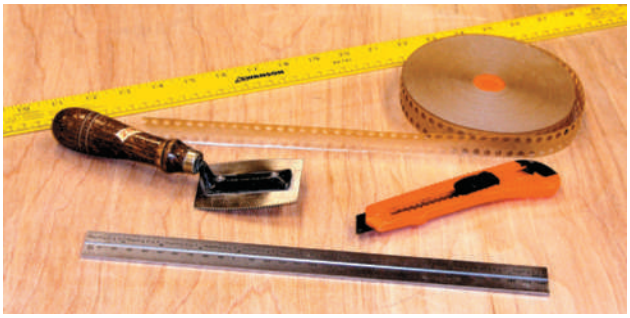
VENEERING TOOLS

The tools used in veneering are relatively few and simple. They include a very sharp knife with a fine blade, a veneer saw, a good straightedge, and veneer tape (see **Figure 30-1**). You may also use a veneer punch, a household iron, and a veneering hammer or a roller (see **Figure 30-2**).

The knife used for cutting veneer should have a very sharp point and be ground on both sides. The blade of a utility knife is too thick. Craft knives and surgical scalpels are good choices. Knives are used in conjunction with a straightedge to cut veneer.

Veneer is also cut with a **veneer saw**, which is designed to be used against a straightedge in the same way that a knife is (see **Figure 30-3**). The veneer saw has a very thin blade and its teeth have no set (i.e., the teeth are not angled out from the blade), so it makes a very narrow cut. In truth, it is really not a saw at all, but a knife with a serrated blade. The blade is curved to prevent it from snagging as it is drawn across the veneer. Saws do a better job than knives at cutting thicker veneers. They are also often better to use when cutting with the grain, because the point of a knife may tend to wander away from the straightedge.

The straightedge should be reliable. A lightweight metal straightedge is preferred, because it will remain true. The edge of a wooden or plastic straightedge will be worn away over time by the action of the knife or saw. A 12-inch metal rule is good for small work, and a framing square can be used for longer cuts.



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FIGURE 30-1 Veneer saw, craft knife, veneer tape, straightedges.



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FIGURE 30-2 From left to right: veneering hammer, roller, household iron, veneer punch.



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FIGURE 30-3 Using a veneer saw.

Veneer tape is used to hold the cut veneer pieces together until after they are glued. It is essentially a gummed paper that is moistened and attached to what will be the face side of the veneer. After the veneer has been glued to its substrate, the tape is dampened and scraped off. Some veneer tape is perforated. Masking tape is sometimes used on small projects, but it tends to be more difficult to remove later on. A better choice if tape is to be used is painter's tape.

Veneer punches are used to repair defects in veneer. They come in different sizes. Each punch has a cutter that cuts an irregularly shaped hole. The punch is placed over the defect and struck with a mallet to remove the defect. Then the same punch is used to cut an identical patch from a matching piece of veneer. The fact that the hole punched is irregularly shaped makes it a less obvious patch. The patch is taped into the recess created for it with veneer tape.

Depending on the method used for attaching the veneer to its substrate, a household iron may be used to activate the adhesive. The veneer must be dampened before the iron is used on it to keep it from being scorched.

A **veneer hammer** is not a hammer in the traditional sense. It is used to press the veneer down against the core material once the adhesive is in place. A veneer hammer may be wooden or metal. Wooden hammers have a brass strip in the head, which transmits pressure provided by the user. The hammer is pressed down firmly against the veneer and moved back and forth across the panel. This process squeezes out excess adhesive and trapped air so that the veneer is firmly anchored to the core at all points. A roller can be used for the same purpose.

WOODWORKING TIP:

You can make your own veneer hammer (see Figure 30-4).

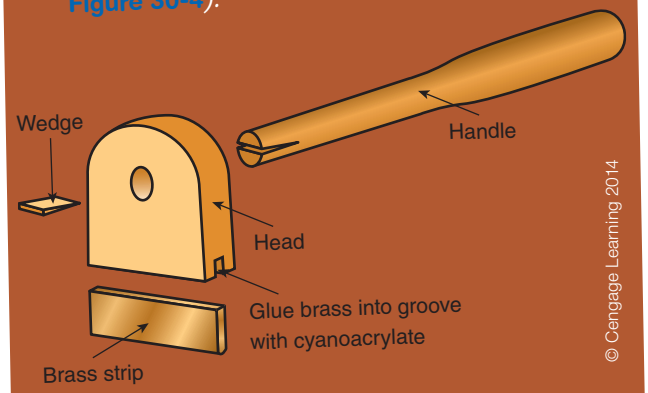


FIGURE 30-4 Veneer hammer.

Substrates for Veneer

The surface to which the veneer is attached is called the *substrate,* or *core material.* It is also referred to as the **groundwork**. Preparation of the groundwork is important to the final quality of the veneered piece. Any defects will telegraph through the veneer, because it is so thin. Improperly prepared groundwork will also prevent proper adhesion of the veneer to the substrate.

Manufactured panel products, such as plywood, particleboard, and MDF, make good core materials for veneer. Particleboard and MDF in particular are very flat and even. Solid lumber can also be used, but its tendency to expand and contract may cause problems with the veneer; for this reason, quartersawn boards work best to minimize such problems. You may also apply veneer over a curved surface that was brick laid, kerf bent, or coopered. Regardless of what the groundwork is, it should be uniformly smooth and flat. Any defects, such as tear-out caused by the planer or small holes, should be filled and sanded smooth. Knots should be cut out, and the area should be patched and smoothed. To encourage good adhesion, solid wood substrates are roughed with a **toothing plane**, which has grooves in the plane iron (see **Figure 30-5**). Board products can be lightly scuffed with 80-grit sandpaper.

Matching Veneer

Unless the area to be veneered is small, chances are that sections of veneer will have to be joined together to cover the entire surface. If the veneer leaves you are

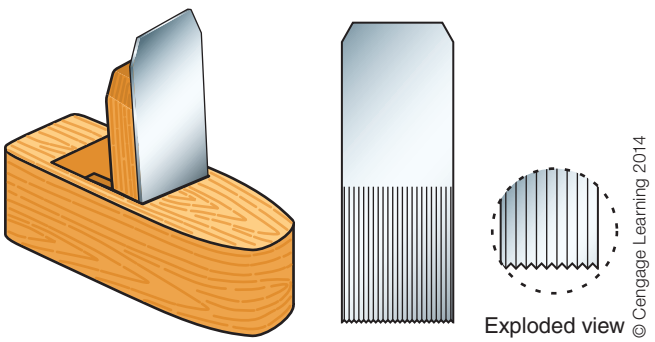
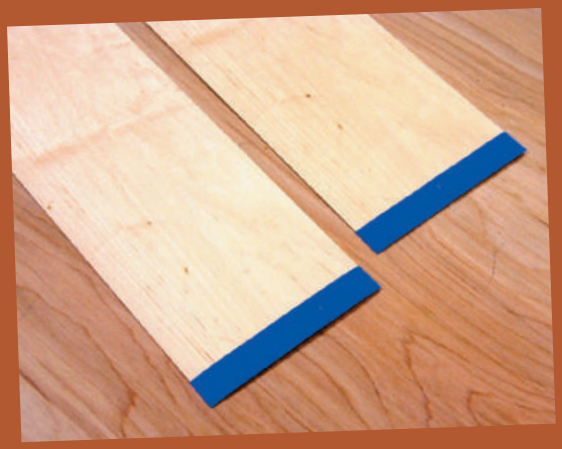


FIGURE 30-5 Toothing plane.

WOODWORKING TIP:

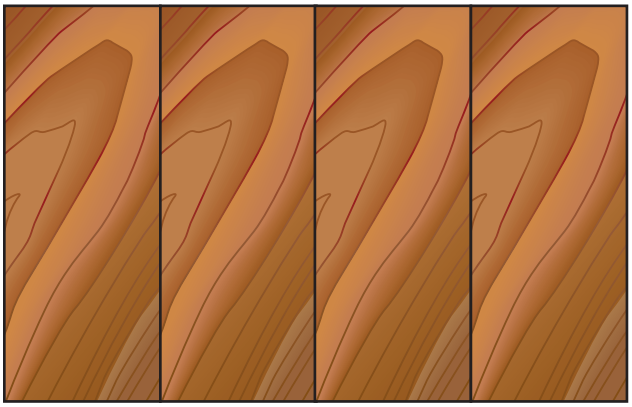
Veneer is a fragile material that must be handled carefully. It comes either stacked in sheets, or, if it is very long, it may be rolled for shipping. Veneer should be stored flat, so unroll it as soon as you get it to allow it to settle out. Veneer has a tendency to split from the ends; if the ends are taped with veneer tape or masking tape, this tendency is greatly reduced (see Figure 30-6).



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FIGURE 30-6 Taping the ends of veneer will greatly reduce splitting and chipping.

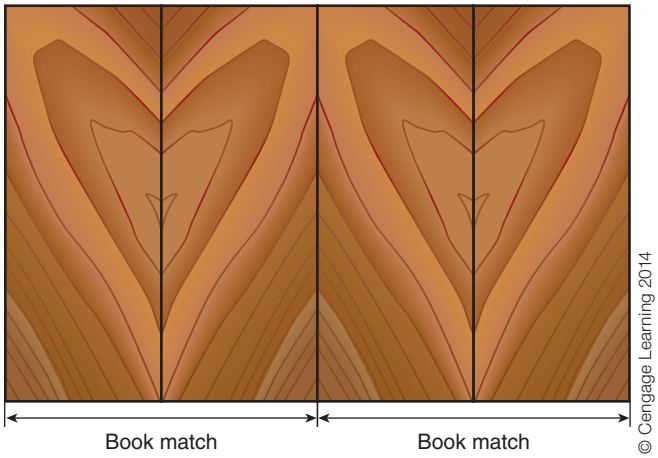
using came from the same **flitch**, many different interesting and visually striking patterns can be made. Arranging leaves that came from the same flitch side by side is called a **slip pattern** (see **Figure 30-7**). If leaves from the same flitch are positioned like they were opened from a book, the resulting pattern is called a **book match** (see **Figure 30-8**).



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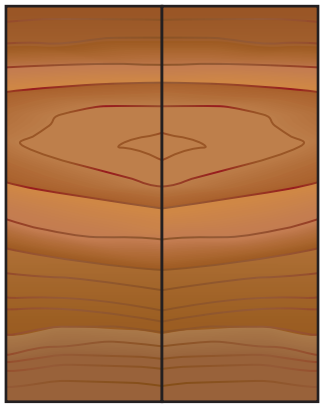
FIGURE 30-7 Slip match.

Slip matching and book matching are the two most common ways to match veneer, but many other possibilities exist, including the butt, diamond, reverse diamond, and the butt-and-book match (see **Figure 30-9** through **Figure 30-12**). Laying out and



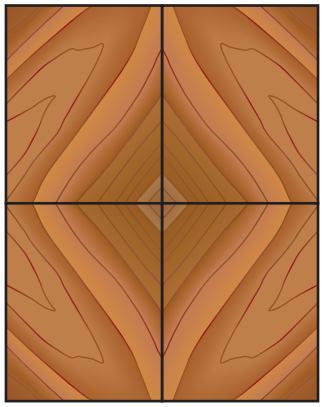
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FIGURE 30-8 Book match.



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FIGURE 30-9 Butt match.



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FIGURE 30-10 Diamond match.

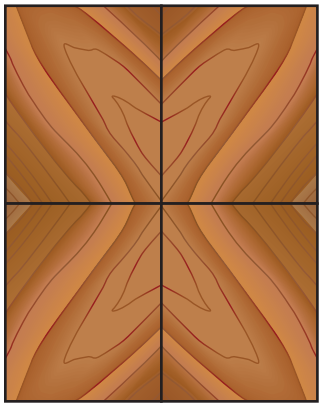

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FIGURE 30-11 Reverse-diamond match.

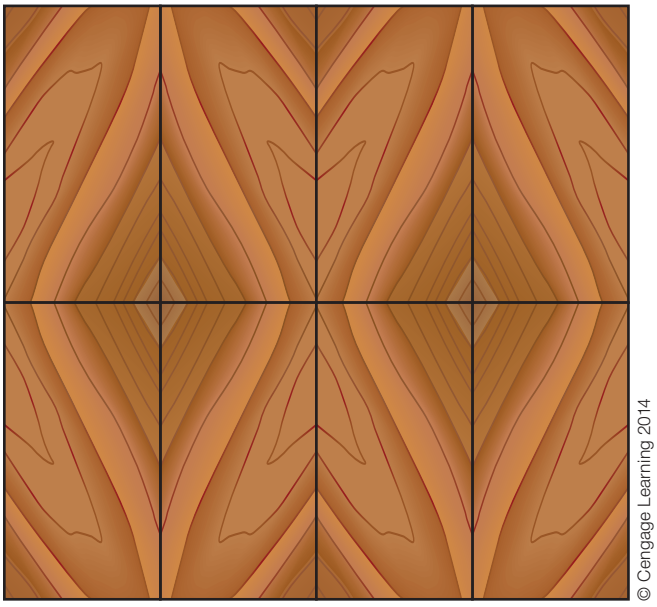

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FIGURE 30-12 Butt-and-book match.

cutting veneer in pie-shaped pieces is another possibility that is very dramatic. Another method is to use contrasting veneers.

Cross banding is a technique used to set off a center panel; it is essentially a border, and it has the effect of highlighting the center section. Cross banding generally has a grain that runs at a right angle to the edge of the central veneer panel, but it can also run parallel to the edge of the center panel. The cross bands may meet with a butt or miter joint (see **Figure 30-13**). The center panel does not necessarily have to be a rectangle. Two examples of other options are shown in **Figure 30-14** .

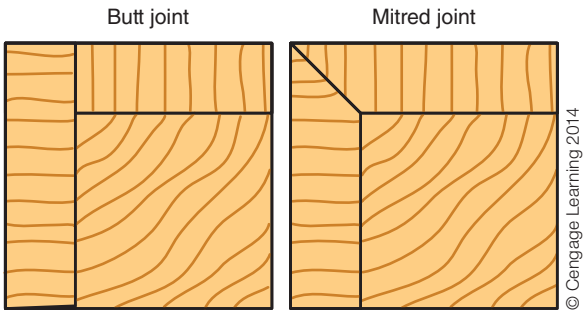


FIGURE 30-13 Cross banding.

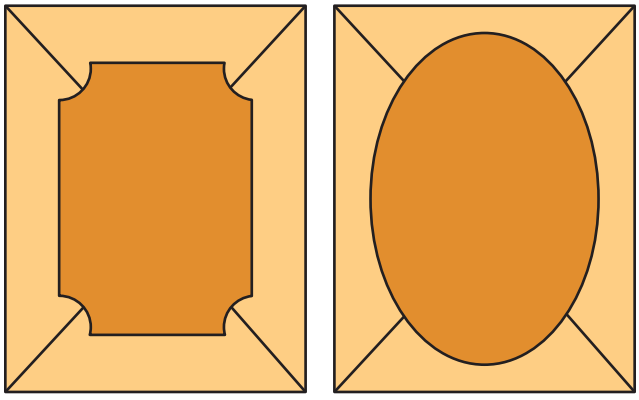

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FIGURE 30-14 Veneer designs based on a central panel and veneer border.

WOODWORKING TIP:

Some highly decorative veneers, such as burls and crotches, buckle very easily. Before they can be worked with, they must be flattened. If veneers are not completely flat, it is not possible to get a good joint between pieces or to get a good bond with the groundwork. There are several methods for flattening buckled veneer. The simplest is to moisten it well with warm water, which will make it more pliable, and then to sandwich it between sheets of plain white or blotting paper and apply pressure. A veneer press can be used, or the veneer can be placed on a flat surface with a piece of sheet stock and weight over it.

If the simple methods of wetting and pressing described above do not flatten the veneer, a solution made up of four parts water, two parts white glue, one part denatured alcohol, and one part glycerin can be used. The leaves are placed between layers of nylon window screen and weighted down for several days. The screen will prevent the layers from sticking together.

VENEERING PROCESS

Once a pattern is decided on, the veneer is cut and assembled prior to bonding to its core. Whatever the pattern chosen, the procedure for working with the veneer is the same.

Veneer has a front and a back, more properly referred to as a **tight face** and an **open face**. When the veneer is sliced from the log, tiny checks are created on one face; this is the open face. The other side, the tight face, has no little splits (see **Figure 30-15**). You cannot tell from looking at the veneer which is the open face. To determine this, roll the veneer parallel to the grain. If it rolls easily, the outside of the roll is the open face. If it resists rolling, the outside is the tight face. Mark the open face. Chalk makes a good marker with veneer. In most veneering work, the open face is the back, which will be glued to the substrate; the tight face is the front. The extent to which this is true depends on the pattern selected, as some patterns require using both the open and closed faces as the surface of the final product.

Veneer pieces are cut slightly oversize to allow for trimming later on. A straightedge is used to guide the knife or saw cut. Cutting is done in several passes, and light pressure is put on the knife, or a gentle pull or push stroke is used with the saw. Trying to cut through the veneer in a single pass may split or splinter the material.

If two pieces of veneer are to be laid side by side, cut both pieces at the same time by overlapping the two leaves. This approach will ensure that the adjacent pieces match. Tape the two pieces together on the front and the back so that they will not shift during cutting (see **Figure 30-16**). Taping or pinning the veneer to a surface will make it easier to cut accurately. Pins made for this purpose are called *veneer pins*. They look very similar to regular pushpins with large plastic heads, but they have a much finer point.

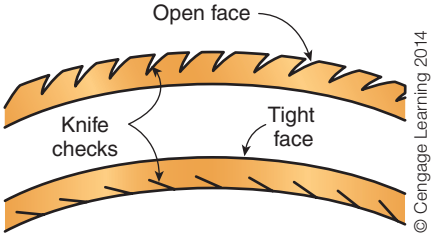


FIGURE 30-15 Open and tight faces.

After the pieces are cut, place them on a contrasting background or hold them together up to the light and check for any gaps between them. If there are any gaps, the edges must be jointed. This can be done with a hand plane, on the jointer, or with a piloted, flush-trim router bit (see **Figure 30-17**). Whatever method is used, the veneer should be held securely between two battens, as shown in **Figure 30-18** . This prevents the veneer from bending.

Once the veneer is trimmed, arrange the pieces with the good side up. Place veneer tape across the joint at 4- to 6-inch intervals, and then run a piece of veneer tape down the length of the joint (see **Figure 30-19**).

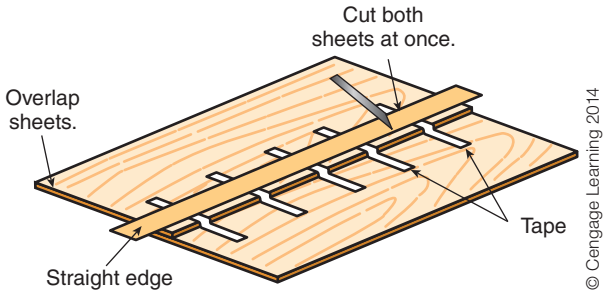


FIGURE 30-16 Overlap adjacent leaves and cut simultaneously.

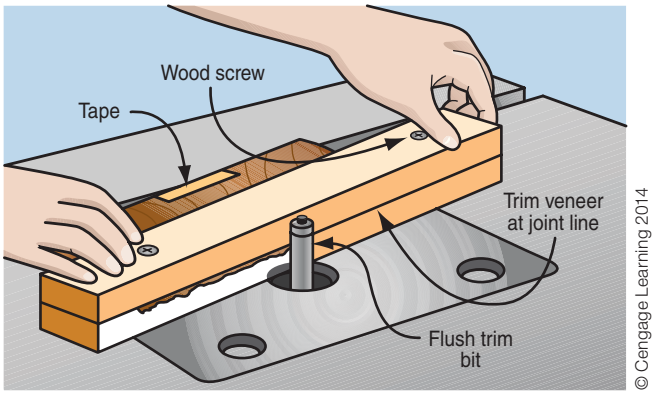


FIGURE 30-17 Overlap adjacent leaves and cut simultaneously.

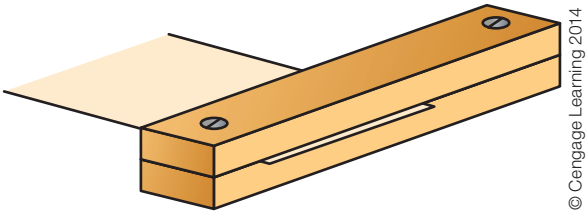


FIGURE 30-18 Clamping jig for trimming veneer.

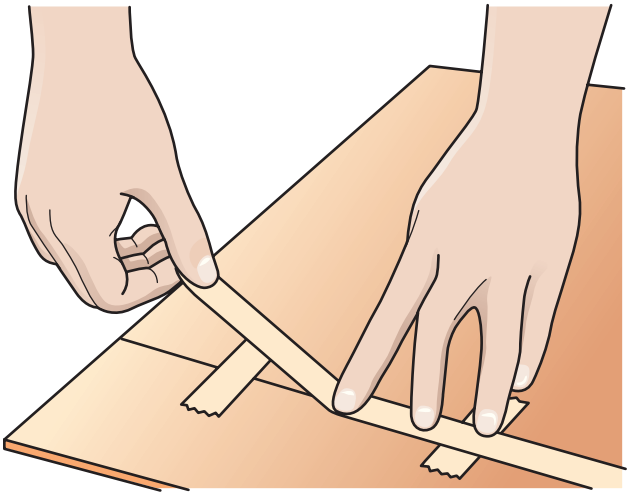
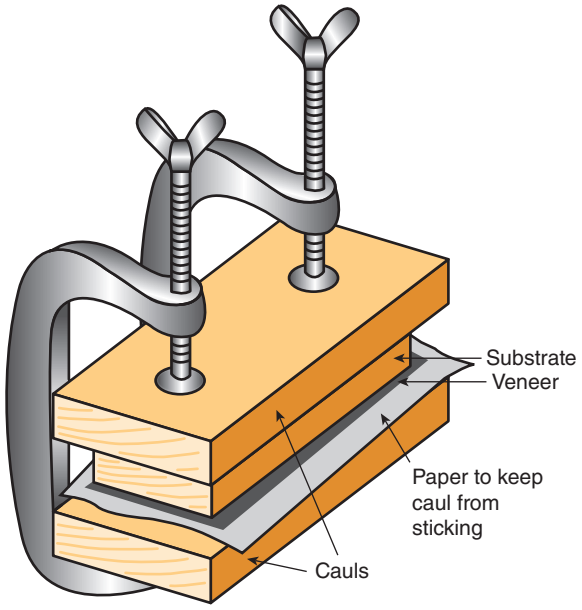

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FIGURE 30-19 Taping the veneer.



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FIGURE 30-20 Using cauls.

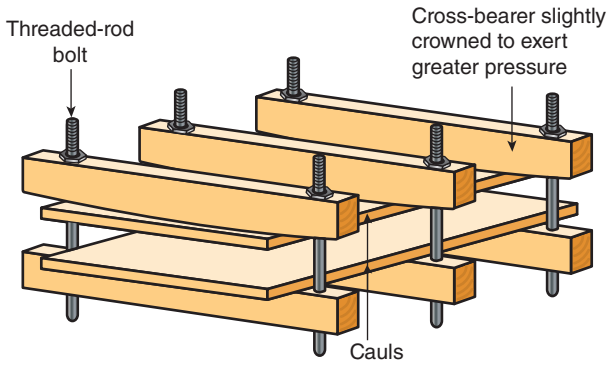
ATTACHING VENEER

Once the pieces of veneer have been cut and trimmed as needed and taped together, they are ready to be attached to the groundwork. This is done either by hand or with **cauls**, sturdy boards between which the glued veneer and substrate are clamped (see **Figure 30-20**).

Cauls may be flat or curved, depending on the whether the groundwork is flat or curved. Using cauls rather than hand veneering is more time and material consuming, because the cauls must be constructed; but it is a better choice for a veneered surface made up of many pieces taped together and for particularly delicate and brittle veneers, such as burls. It also allows the veneering of both sides of a substrate at the same time. When cauls are used, slow-setting adhesives are employed, because they allow more time for assembly.

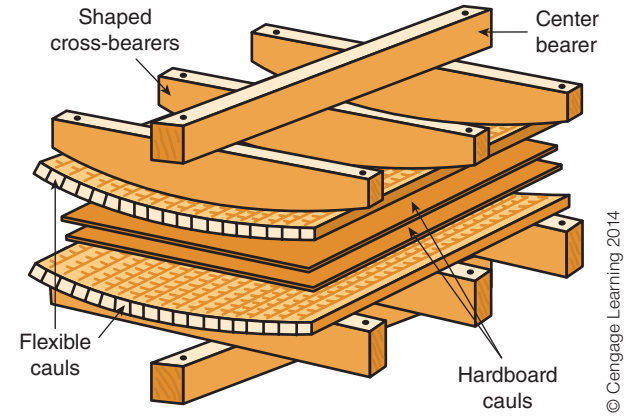
Glue is applied to the substrate and allowed to dry until tacky. The work is then placed in the caul assembly and padded on both sides with newspaper to take up any unevenness on the surface caused by the veneer tape. A layer of plastic is placed inside the newspaper layer to prevent the veneer from sticking to it.

The veneered material is clamped between the cauls and left to dry. **Figure 30-21** , **Figure 30-22** , and **Figure 3-23** show illustrations of a flat-caul press, a curved-caul press, and the procedure for veneering two sides of a panel simultaneously.



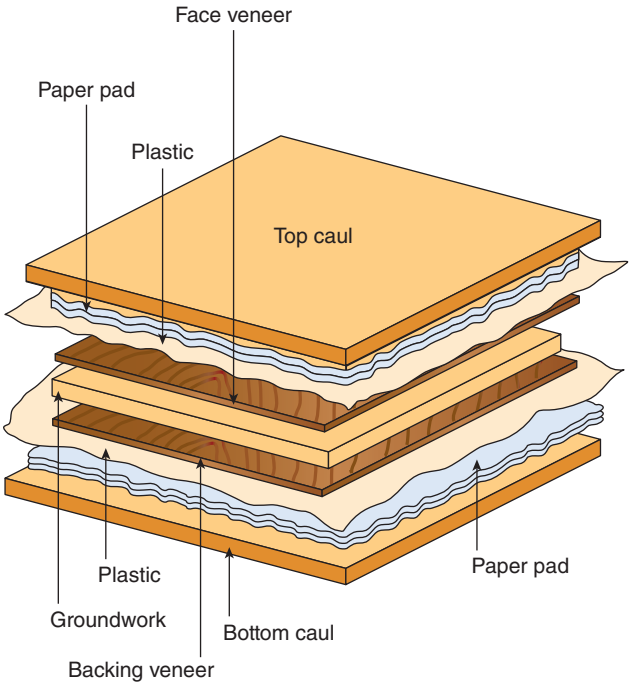
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FIGURE 30-21 Flat-caul assembly.



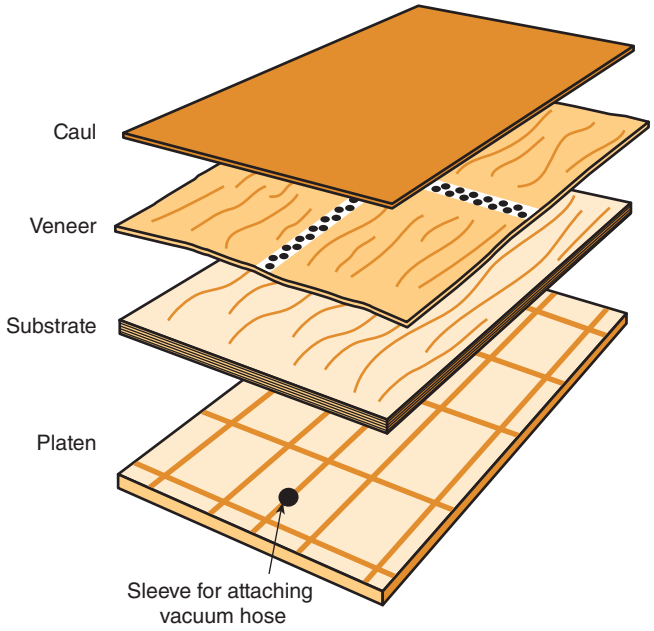
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FIGURE 30-22 Curved-caul assembly.



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FIGURE 30-23 Veneering face and back of groundwork simultaneously.



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FIGURE 30-24 Placement of platen, caul, veneer, and substrate within a vacuum bag.

If the woodworker has access to a vacuum press, the need for clamps is eliminated, and one of the cauls is eliminated. There is a *platen* inside the vacuum bag. A **platen** is a flat panel that has been kerfed to a depth of about 1/8 inch at 2-inch intervals along both its length and width, which helps create a better vacuum inside the bag. The substrate with the veneer is placed in the bag with the caul on top of it (see **Figure 30-24**). Plastic may be placed between the caul and the veneer to keep them from sticking together. The bag is closed, and the vacuum pump is turned on.

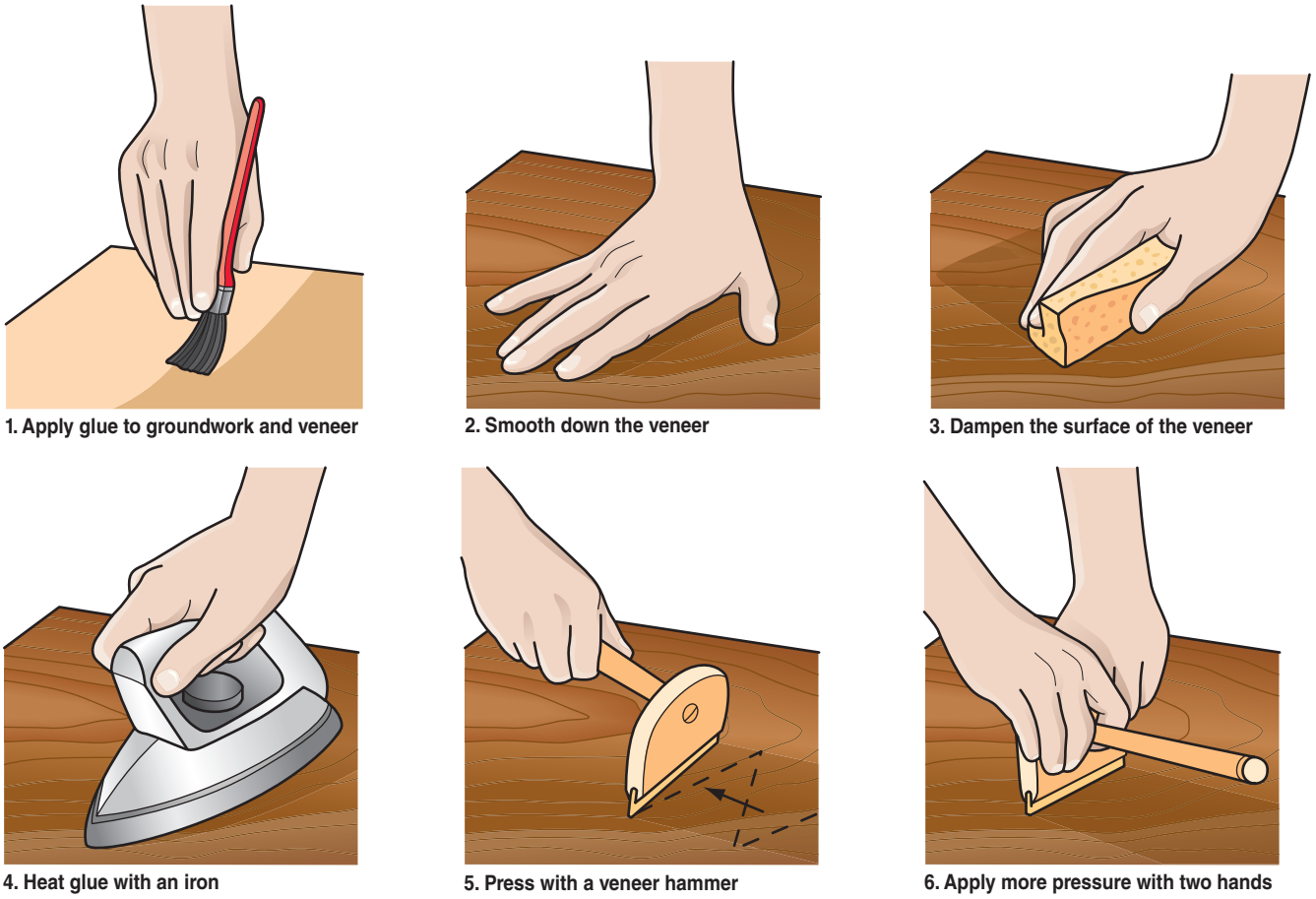
The woodworker has several choices of adhesives to attach the veneer to a substrate. They include hot hide glue, glue film, and resin glues, such as urea formaldehyde, white glue, and contact cement. The procedure for using each varies somewhat. As mentioned above, slower-setting glues work best when cauls are used.

The oldest method of laying veneer employs hot hide glue. The glue is heated in an electric glue pot specifically for that purpose or in a double boiler on the stove to about 120 degrees. The glue should be a smooth consistency; no lumps should be present. Glue is spread evenly over the core material and over the veneer. When the glue is nearly dry but still a bit tacky, the veneer is placed on the substrate and smoothed down by hand. Next, the veneer is dampened with a nearly dry sponge. This closes the wood pores and keeps the iron, which is run over the surface, from sticking to the veneer. The iron melts the glue and draws it into the veneer. Immediately upon removing the iron, the veneer hammer is used to press the veneer to the core. Start in the center and press to the outer edges to remove air bubbles and excess glue. As this is done, ever greater pressure is exerted upon the veneer hammer, working back and forth against the groundwork. This is known as *hammer veneering,* which is illustrated in **Figure 30-25** .

Glue film is an easy, less messy way of attaching veneer to the groundwork. Glue film comes as a paper-backed sheet cut slightly oversize and placed on the core material with the paper side up. A hot iron is passed slowly over it, heating and softening the glue. The paper backing is then peeled off, and the veneer is placed on top. Then a veneer hammer, block of wood, or roller is used to press the veneer firmly to the substrate.

It is also possible to purchase veneer that already has a glue film on it, although it is significantly more expensive than buying veneer alone. Such veneer is placed over a clean, smooth core material, then ironed and pressed in a manner similar to that just described for the use of glue film.

Another option for adhesive is contact cement, which is brushed or rolled onto the core material and

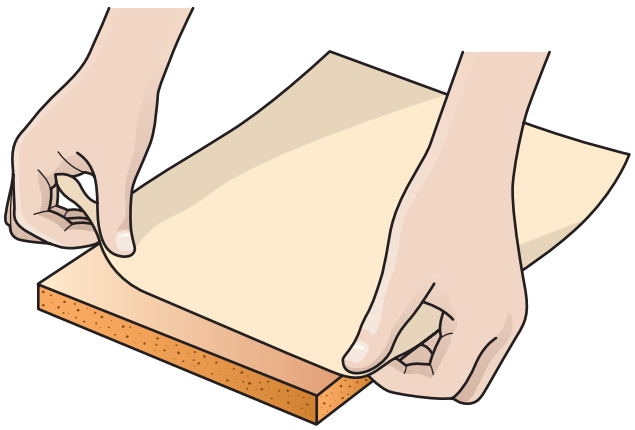


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FIGURE 30-25 Steps in hammer veneering.

onto the back of the veneer and allowed to dry. Some shops are equipped to spray contact cement. Next, a sheet of newsprint or brown paper is laid over the substrate, leaving a strip of the substrate exposed. The veneer is carefully aligned over the substrate and pressed against the strip not covered by paper. Contact cement bonds upon contact, hence the name. Therefore, the veneer must be positioned very carefully, because there is no room for error. Once it has adhered to the exposed edge of the substrate, the paper is gradually slid out, and the veneer is pressed down with a block of wood, a veneer hammer, or a roller. Once the paper has been slid out completely, the veneer is rubbed all over with the pressing tool. **Figure 30-26** and **Figure 30-27** illustrate this process. Contact cement allows you to apply veneer to curved and flat surfaces. It is not recommended, however, for brittle or highly figured veneers that are prone to splitting.

After veneer has been applied to the groundwork, and the glue is dry, the edges are trimmed; remember



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FIGURE 30-26 A sheet of paper is placed over the substrate after the contact cement has dried, leaving an exposed edge.

that it was applied slightly oversized. The panel is inspected for any defects that may need repair. Feel the surface carefully to check for any blisters or lumps. A blister will occur where the veneer has not

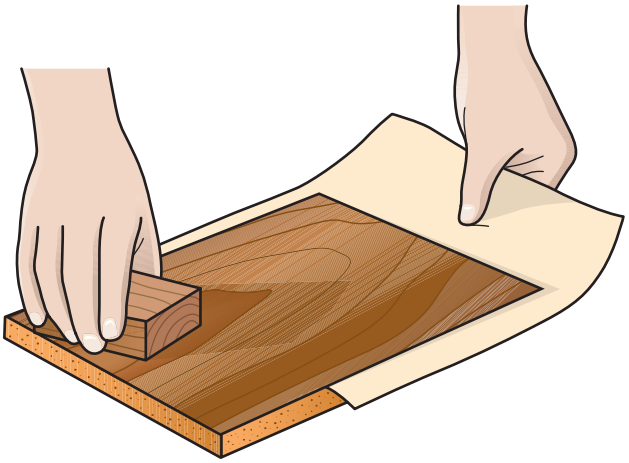

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FIGURE 30-27 The paper is gradually slid out as the veneer is pressed into place.

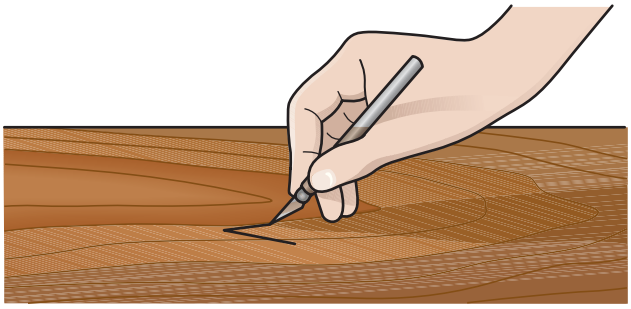

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FIGURE 30-28 Repairing a blister or lump.

properly adhered to the core, and a lump may occur if a speck of dirt or sawdust ends up between the veneer and the substrate. In either case, make a V-shaped flap with a sharp knife in the problematic area, and lift the flap gently (see **Figure 30-28**). Remove any debris that may be trapped beneath the veneer, and then glue the flap back down. The repair will be almost invisible.

Another area of veneering that we have not yet touched on is edge veneering, or edge banding. You may remember that edge-banding material was discussed in Chapter 11. It is used to cover the edges of veneered surfaces. This is especially necessary when using panel products for a core material.

Edging veneer is available in different widths. It may have a hot-melt adhesive already applied to it, or it may be a peel-and-stick veneer. Of course, you could cut your own veneer for edge banding, which you would need to glue on using one of the methods described previously

Veneer for edging is sold in widths that are slightly wider than the panel the edging will be attached to. Most commonly, 7/8-inch veneer is used for application to 3/4-inch panels. The peel-and-stick veneer has a sticky back covered with paper: The paper is peeled off, and the veneer is pressed to the substrate edge. It is then burnished with a block of wood, a roller, or a veneer hammer to ensure a good bond.

Veneer tape with hot-melt adhesive on its back must be activated by heat. It is set in place on the panel edge, and then a household iron or a veneer iron is run over it to soften the glue and make it stick. **Figure 30-29** shows a veneer iron. Application of the veneer tape (illustrated in **Figure 30-30**) is followed by the application of pressure using a roller, block, or veneer hammer.


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FIGURE 30-29 Veneering iron for edge veneers.

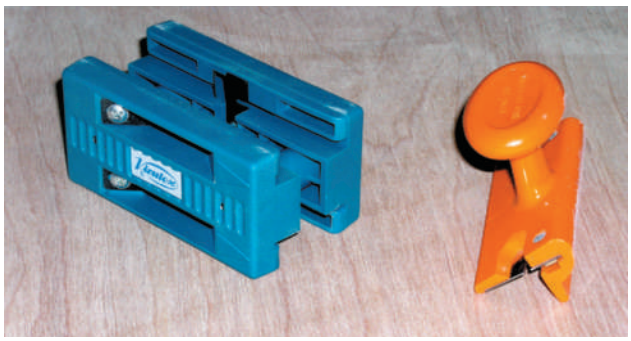

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FIGURE 30-30 Veneering iron for edge veneers.

If you are cutting your own veneer, cut it slightly wider than the desired width, and glue it on using one of the methods discussed earlier.

After proper adhesion of the edge banding has been achieved, the edge banding is trimmed with a veneer edge trimmer. These trimmers contain sharp blades that slice the veneer off flush with the surface of the substrate. They may be one or two sided. Two-sided trimmers trim both edges at the same time. **Figure 30-31** shows examples of veneer edge trimmers. After trimming, the edges are lightly sanded to create a smooth corner.

Edge banding is used on panel products that come already veneered to hide the edges. It is also used on panels you veneer yourself. If the latter is the case, veneer the edges after veneering the bottom of the panel but before veneering the top; this will ensure a clean look, and it will render the veneer edges as unnoticeable as possible.



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FIGURE 30-31 Double and single edge veneer edge trimmers.



Summary

Learning the art of veneering opens up a new world of possibilities to the woodworker. Veneering is the practice of covering a substrate with a thin layer of wood. It allows the use of expensive and rare woods in a cost-effective and environmentally conscious fashion. It also permits the use of highly decorative and distinctive materials — such as burls, butts, and crotches — that are not normally available as solid materials. By arranging veneer leaves in different ways, many dramatic and striking effects can be achieved. Veneer is cut using a straightedge and a knife or a veneer saw. Edges are carefully matched so that there are no gaps. The veneer is taped together with veneer tape on its face and then glued down to a smooth, clean substrate using one of several methods. Once dry, the tape is moistened and removed, and overlapping edges are trimmed. Once any necessary repairs are made, the surface is ready for careful sanding and finishing.



Key Terms

book match
cauls
core material
cross banding
flitch
groundwork
open face
platen
slip pattern
tight face
toothing plane
veneer hammer
veneering
veneer punches
veneer saw
veneer tape



Check Your Knowledge

1. What advantages are there to using veneer instead of solid lumber?
2. Why should veneer not be cut in a single pass?
3. What is a veneer punch? What is it used for?
4. What is the best way to cut adjacent pieces of veneer?
5. List several matching patterns for veneer and describe them.
6. How are veneer pieces attached to one another prior to adhesion to the core material?
7. Name several substrates that can be used for veneer work. Explain why some are better than others and when each might be used.
8. What adhesives can be used for attaching veneer to a core material?
9. How does caul veneering differ from hand veneering?
10. Describe the process for attaching veneer to the groundwork using contact cement.

BUILD IT!

Book-Matched Panel



A

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B

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C

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Figure A shows a book-matched panel.

TOOLS REQUIRED

- Craft knife or veneer saw
- Veneer hammer or roller
- Veneer edge trimmer
- Brush or roller
- Laminate trimmer and flush trim bit

MATERIAL REQUIRED

- 12″ square of 3/4″ cabinet-grade plywood.
- Veneer tape
- Two consecutive leaves of veneer that are about 7″ wide and 13″ long
- Contact cement

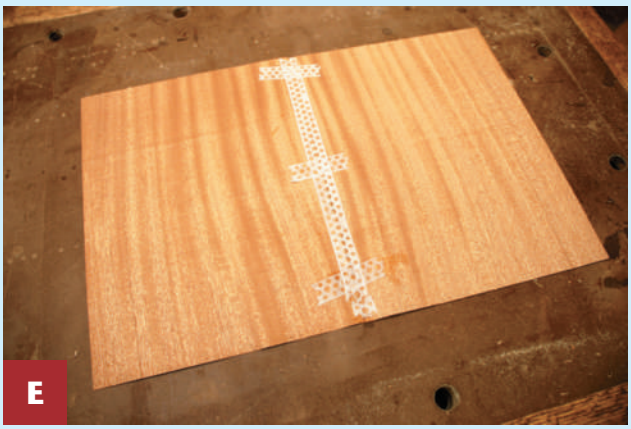
STEPS

1. Attach veneer tape to the edges of the substrate. Trim the edges with an edge trimmer, as shown in **Figure B**.
2. Take the two consecutive leaves of veneer and open them as you would the leaves of a book, as shown in **Figure C**.

3. Overlap the two pieces; cut them with a straightedge and knife or veneer saw, as shown in **Figure D**.
4. Check for fit and trim if necessary. Using veneer tape, tape the two pieces together. Remember that tape goes on the face of the panel (see **Figure E**).
5. Coat the back of the veneered panel and the substrate with contact cement and allow it to dry.
6. Place a sheet of paper that is larger than the panel over the substrate; then place the veneer, glued face down, on top of the paper (see **Figure F**).


D

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E

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F

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7. Slowly pull out the paper while pressing down on the veneer as the paper is removed.
8. Use a veneer roller to securely adhere the veneer to the substrate, as shown in **Figure G**.
9. Trim the overhanging edges with a laminate trimmer and a flush trim bit, as shown in **Figure H**.
10. Moisten veneer tape with a damp sponge and scrape it off.
11. Sand and finish as desired.

BUILD IT!

PROJECT CHALLENGE

Diamond-Matched Panel

Figure A shows a diamond-matched panel.

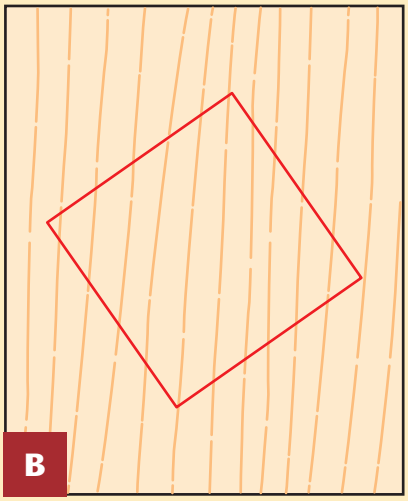
STEPS

1. Attach veneer tape to the edges of the substrate. Trim the edges with an edge trimmer.
2. Take four consecutively stacked leaves of veneer and use chalk to lay out a square that is diagonal to the grain pattern (see **Figure B**).



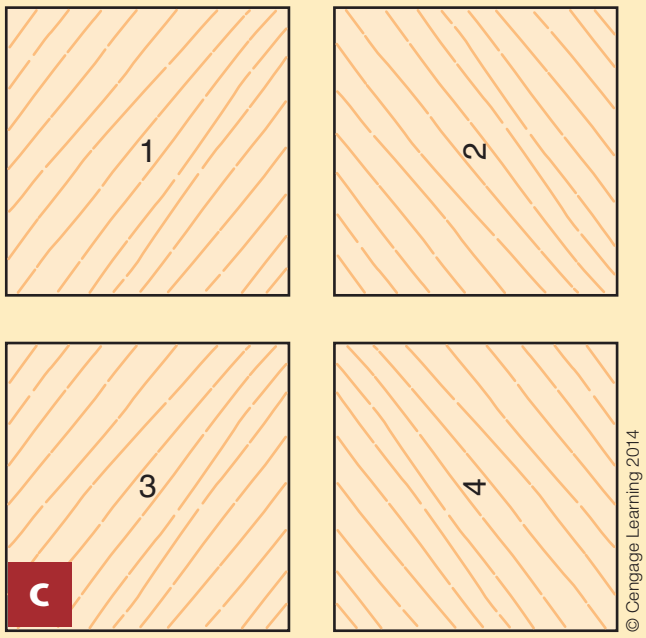
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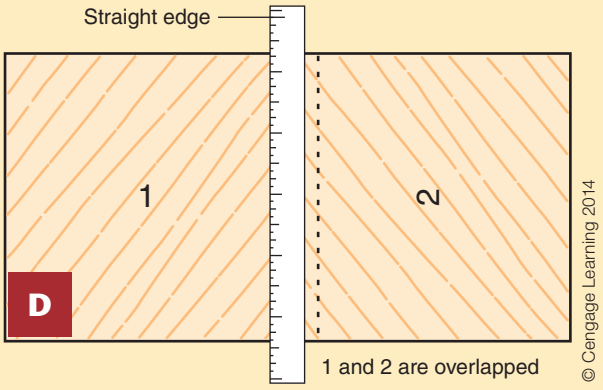
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B

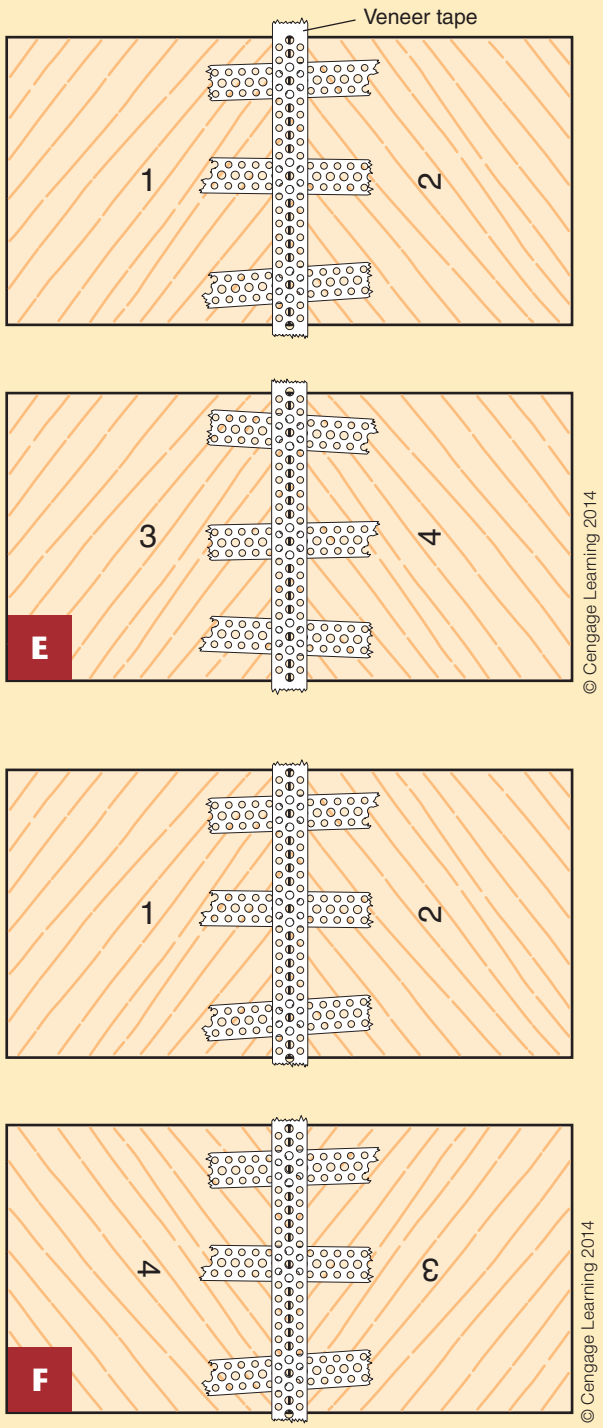
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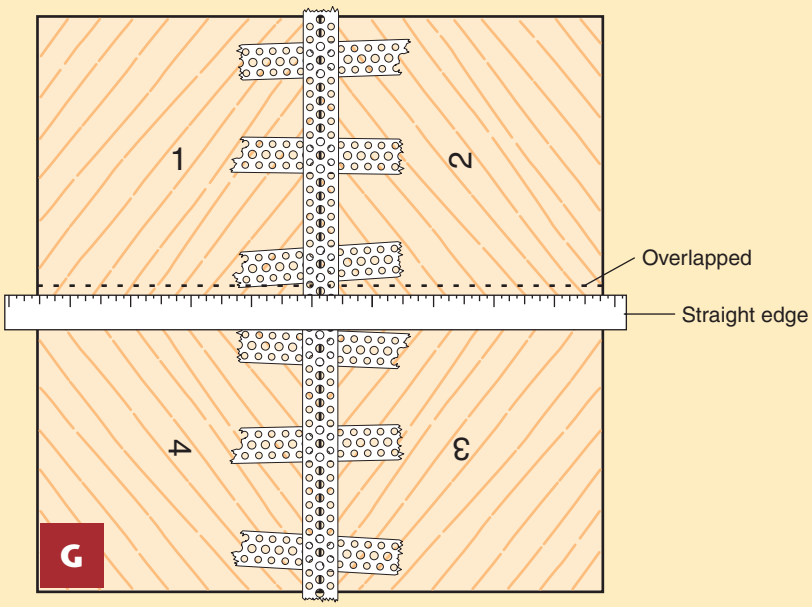


3. Temporarily tape the four pieces together and use a straightedge and veneer saw or knife to cut out the chalked square.
4. Separate the pieces and label them from the top down as 1 through 4.
5. Turn pieces 2 and 4 90° to the right (see **Figure C**).
6. Lap piece 2 over piece 1 and cut them with a straightedge and knife or veneer saw. Repeat with pieces 3 and 4 (see **Figure D**).

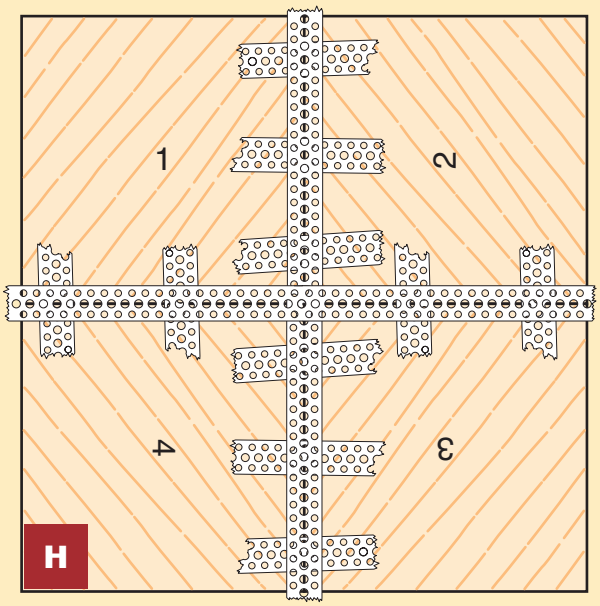
7. Check for fit and trim if necessary. Use veneer tape to tape piece 1 to piece 2 and piece 3 to piece 4, as shown in **Figure E**. Remember that the tape goes on the face of the panel.
8. Turn the 3 and 4 match 180° (see **Figure F**).



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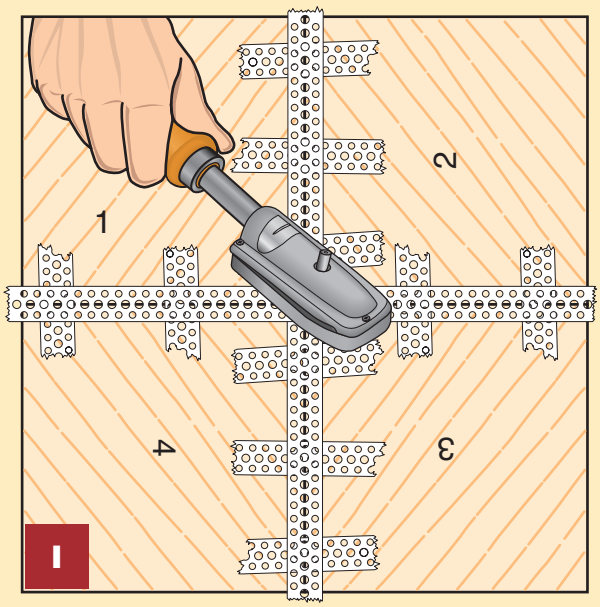
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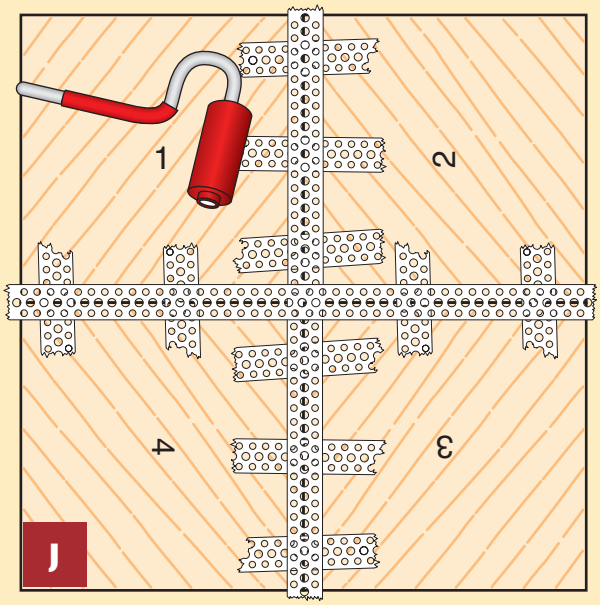
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9. Overlap the 1 and 2 match with the 3 and 4 match, and make another cut. Check the fit, and tape these two sections together. Refer to **Figure G** and **Figure H**.
10. Coat the back of the veneered panel and the substrate with white PVA glue. Allow it to dry until just slightly tacky.

11. Lay the veneer sheet over the substrate. Dampen it slightly with a squeezed-out sponge.
12. Iron the veneer to reactivate the glue. Go over the whole panel with a roller, block, or veneer hammer to press the veneer in place (see **Figure I** and **Figure J**).
13. Trim the overhanging edges with a laminate trimmer and a flush trim bit.
14. Moisten the veneer tape with a damp sponge and then scrape it off.
15. Sand and finish as desired.



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31

Decorative Techniques

You'll Learn

After studying the chapter, the student should be able to:

- Identify and define various decorative techniques
- Explain the inlay process
- Describe the creation of parquetry
- Explain methods for creating marquetry
- Describe special finishing concerns associated with inlay, parquetry, and marquetry
- Describe how carving can be used to accent a surface
- Describe the basic techniques of chip carving

INTRODUCTION

A woodworker can add interest and value to his work through the use of decorative techniques. These decorative techniques include inlay, intarsia, parquetry, marquetry, and carving. In this chapter, we will define and explore each of these techniques. The tools used for each will be covered, as will the basic processes involved in their creation.

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INLAY

Inlay involves decorating a surface without adding any thickness to the work. Wood or veneer is laid into a recess in the surface of the piece and sits flush with the surrounding wood. **Figure 31-1** shows examples of inlay.

The tools used for inlay work include the router and edge guide, plane, and chisels. Laminate trimmers are also used; because they are smaller than routers, they may be easier to handle. A scratch stock, which was traditionally used for inlay work in the days prior to routers, may also be used. A **scratch stock** is a tool that holds a sharp cutter. By moving it back and forth, a groove is scraped out; this scratching technique is what gave the tool its name. Another traditional tool that may be used is the **router plane,** which has a chisel-like cutter; it is used to level square-sided recesses and to cut dadoes (see **Figure 31-2**, **Figure 31-3**, and **Figure 31-4**).

Inlay material includes *strings* and *bandings*. **Strings** are thin, narrow strips of wood from one species.



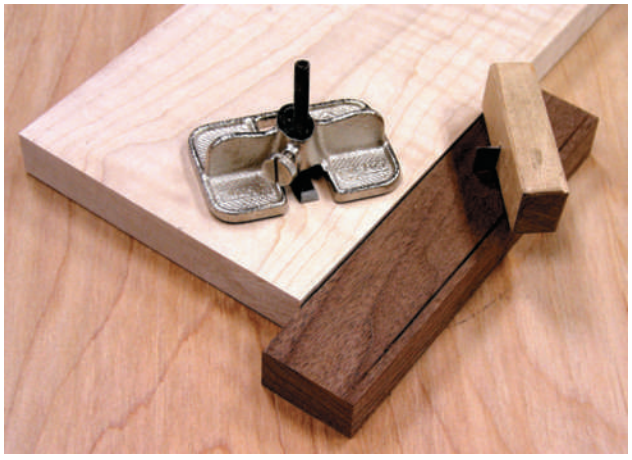
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FIGURE 31-1 Examples of inlay: table leg and drawer front.



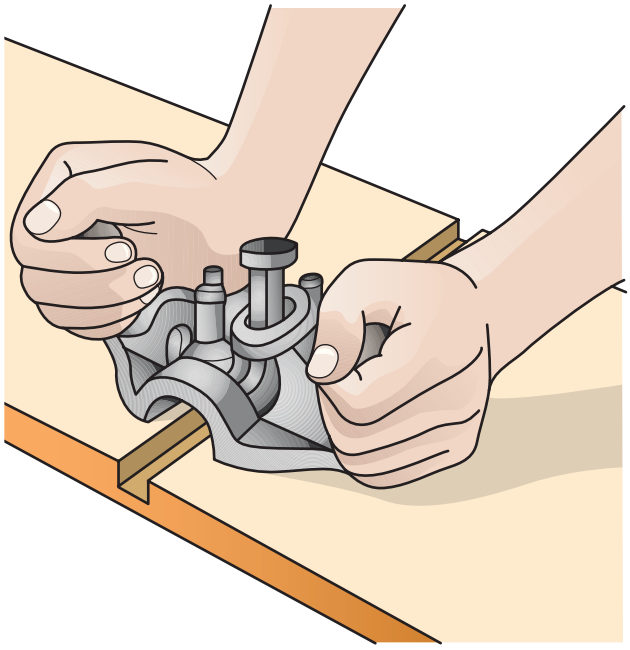
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FIGURE 31-2 From left to right: Block plane, chisel, laminate trimmer, and router fitted with an edge guide.



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FIGURE 31-3 Router plane and scratch stock. A recess has been cut in the walnut with the scratch stock.



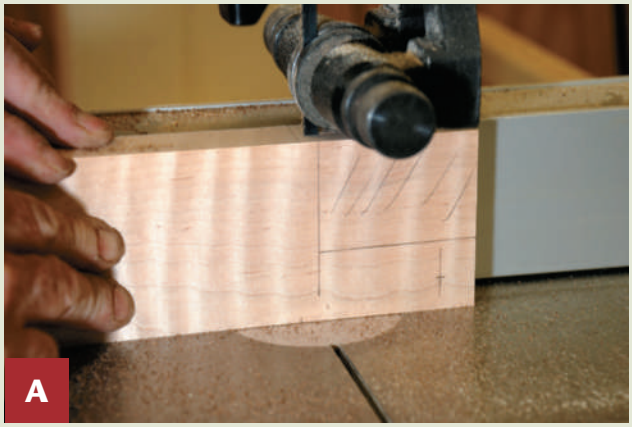
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FIGURE 31-4 Using a router plane to cut a dado.

Typically they are made of boxwood, either in its natural light color or stained black. Thin strips of metal, such as brass, may also be used for strings. **Bandings** are made up of two or more species of wood; they have a design, which may be very intricate. Bandings are made by gluing solid blocks and veneers together and then slicing them into thin strips. **Figure 31-5** shows examples of strings and bandings. Strings and bandings can be purchased or made. Wood from a contrasting species may also be cut into a shape and used as an inlay (see **Figure 31-6**).

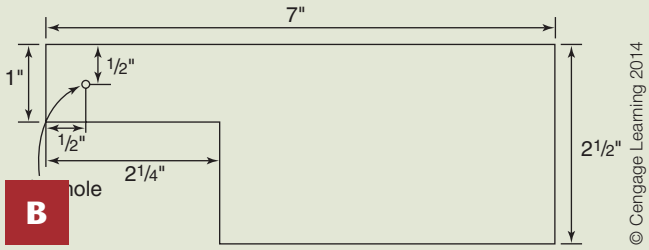
PROCEDURE 31-1

Making and Using a Scratch Stock



A

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B

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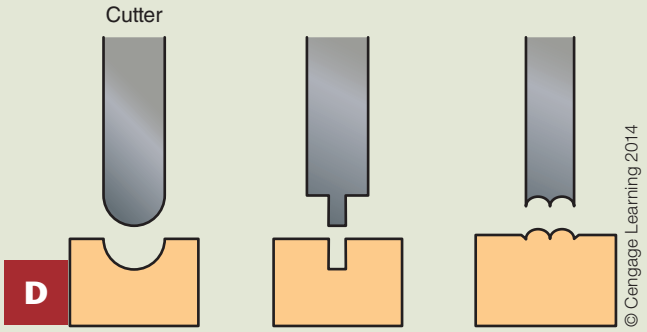
C

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STEPS

1. Cut a piece of 3/4"-thick hardwood 2 1/2" wide and 7" long.
2. Using the band saw, cut a stopped kerf 2 1/4" long, centered on the thickness of the wood, as shown in **Figure A**.
3. Cut the block to match the dimensions shown in **Figure B**.
4. Use a file to round the fence of the scratch stock, as shown in **Figure C**.
5. Drill a hole to take the bolt that will secure the cutter. Refer back to Figure B.

6. Use a piece of an old band saw blade, handsaw, hacksaw, or scraper to make the cutter. The negative of the shape you want to make is filed onto the cutter with a small file, as shown in **Figure D**.
7. Sharpen the cutter by honing both sides on a stone.
8. Secure the cutter in the scratch-stock body and tighten the bolt.
9. Draw the scratch stock back and forth in one spot to make a groove or shape, as shown in **Figure E**.



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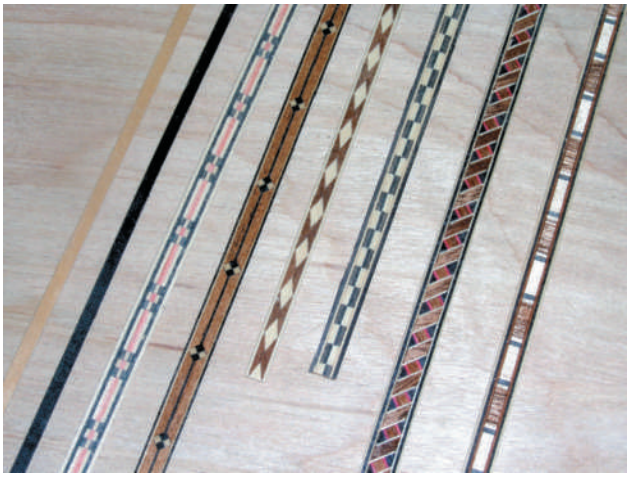

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FIGURE 31-5 Strings and bandings.


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FIGURE 31-6 Wood from a contrasting species used as an inlay.

When strings or bandings are used, a recess the width of the inlay is cut in the surface. This recess is made slightly shallower than the inlay is thick. A router, laminate trimmer, or scratch stock may be used. The router or laminate trimmer is used with an edge guide or is guided by a straightedge clamped to the work. Alternatively, the router may be used in a table with the router fence as a guide. The recess is cleaned so that it is free of sawdust, and the string or banding is glued and pressed into place. When the glue has dried, the string or band is planed flush with the surface.

If a shape made from a contrasting wood is to be set into the surface, the wood is first cut to the desired

shape. It is then placed on the surface and traced around with a sharp knife. The outline is deepened with a chisel, the bulk of the waste to be removed is taken out with a router bit, and the remainder up to the outline is taken out with a chisel. The contrasting wood is then glued into place.

INTARSIA

Intarsia differs from inlay work in that the material set into the recess created in the ground surface is not flush with the surface, but stands proud; that is, it stands higher than the surface, and the edges of the individual pieces are often rounded over. This gives it a more three-dimensional effect, and it is often used for pictorial representations. Intarsia uses various shapes, sizes, and species of wood fitted together like a mosaic. The same methods are used for intarsia as for inlay; the only difference is that the material set into the recess is thicker than the recess is deep when the project is completed. Today much intarsia work is glued to a plywood background, rather than set into a recess in the wood. **Figure 31-7** shows examples of intarsia.

PARQUETRY

Parquetry is the creation of geometric patterns or motifs through the use of symmetrically shaped pieces of veneer. An endless variety of patterns are possible. The pieces of veneer are taped together with veneer tape and bonded to a substrate.

One classic parquetry pattern is a checkerboard, in which contrasting strips of veneer of equal width are cut and taped together side by side; this assembly is turned 90 degrees and cut into strips of the same width as the original strips. The resulting strips are staggered by one square and taped together. The projecting squares are cut off and the checkerboard pattern is ready to be attached to its substrate (see **Figure 31-8**).

Striking parquetry patterns can be made by varying the grain direction of the pieces. For example, if the same procedure used to create the checkerboard pattern is followed, but the grain of every other strip is reversed, the end result is a basket-weave design (see **Figure 31-9**).



Image courtesy of fantasticwoodworking.com



Courtesy of Intarsia by Harvey Zeugin

FIGURE 31-7 Intarsia

Cutting an assembled checkerboard pattern diagonally allows you to reassemble the strips in other designs (see **Figure 31-10**). By alternating the width of the strips, other patterns are possible. See **Figure 31-11**.

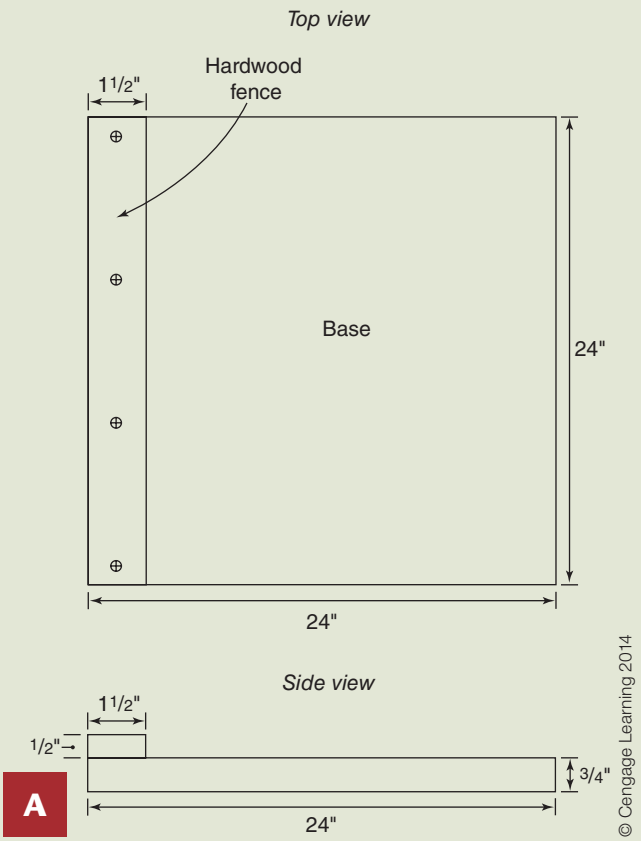
Diamond patterns can be created by cutting an alternating pattern at a 60-degree angle. Staggering and

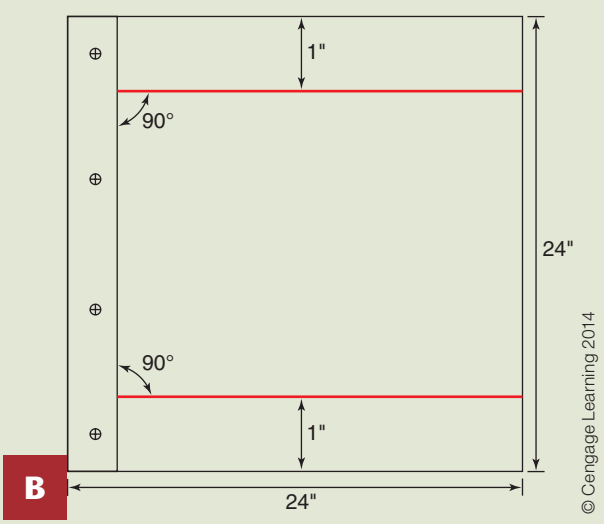
PROCEDURE 31-2

Making and Using a Parquetry Jig

STEPS

1. Cut a piece of 3/4″ particleboard, MDF, or plywood to 24″ × 24″. This will be the base of the jig.
2. Cut and screw a 1/2″ × 1 1/2″ × 24″ piece of hardwood flush with one edge of the base. This piece will serve as the fence, as diagrammed in **Figure A**.
3. Mark out two lines at a 90° angle to the fence. These are called *setting-out lines* (see **Figure B**).
4. Cut two 1/4″ thick spacer blocks. Their size is determined by the width of the pieces to be cut. For example, if the strips you will be cutting are 2″ wide, you will need two 2″ spacer blocks.





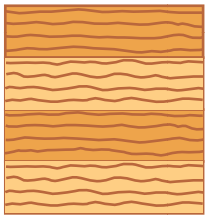


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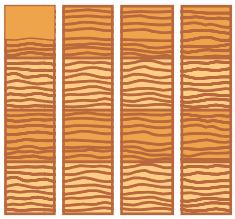


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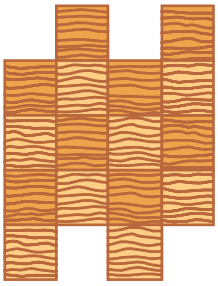
5. To use the jig, first square one edge of the veneer by lining it up on one of the setting-out lines. Put the two spacer blocks against the fence and butt a straightedge to them. Keeping the veneer on the setting-out line, slide it under the straightedge so that it shows, but not all the way to the fence, and then cut it with a veneer saw or a knife (see **Figure C**).
6. To make a series of strips of the same width, slide the squared-up edge all the way to the fence, keeping it aligned with the setting-out line. Cut and repeat as many times as needed (see **Figure D**).



(A) Cut strips of light and dark veneers, the width of each being equal to the sides of the checkerboard squares, then tape alternate strips together.



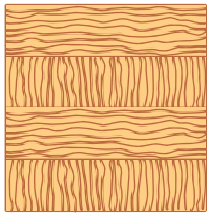
(B) Cut the assembled work into new strips, cutting at right angles to the original cuts. The resulting strips will be made up of individual squares.



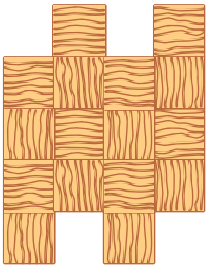
(C) Line the strips up and tape them together to form a checkerboard pattern. There will be one extra square at the end of each line.

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FIGURE 31-8 Making a checkerboard pattern.



(A) Cut strips of veneer of different grain direction (the two being at right angles to each other), but of equal width. Tape the alternate strips together.



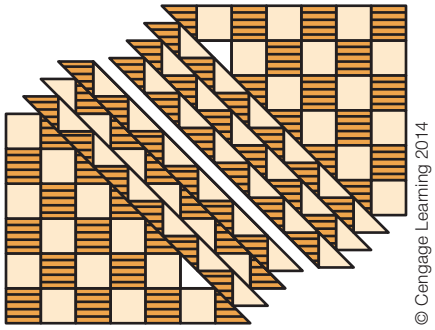
(B) Cut the assembled work into new strips, cutting at right angles to the original cuts. Line the new strips up and tape them to form a pattern of squares of alternating grain direction.

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FIGURE 31-9 Making a basket-weave pattern.

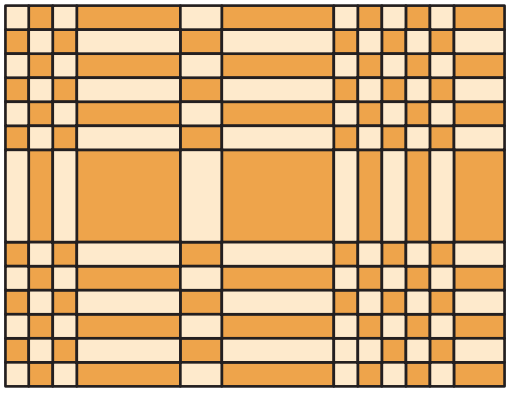
reversing the resulting cuts creates other designs (see **Figure 31-12**).

Using the same species of wood and alternating the grain direction is also very attractive. A classic pattern is the isometric cube, created by joining three



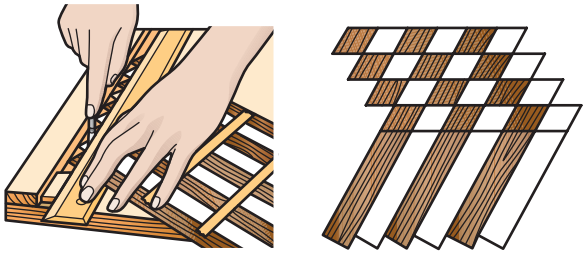
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FIGURE 31-10 Cut the checkerboard pattern diagonally and reassemble for different designs.



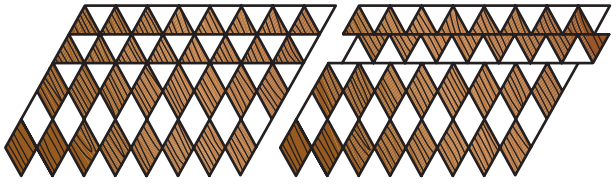
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FIGURE 31-11 Alternating the width of the strips creates different patterns.



Tape and cut strips to 60 degrees

Cut and stagger diamond strips



Cut and stagger or reverse diamonds to create other patterns

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FIGURE 31-12 Cut the checkerboard pattern at a 60-degree angle to create different designs with diamond shapes.

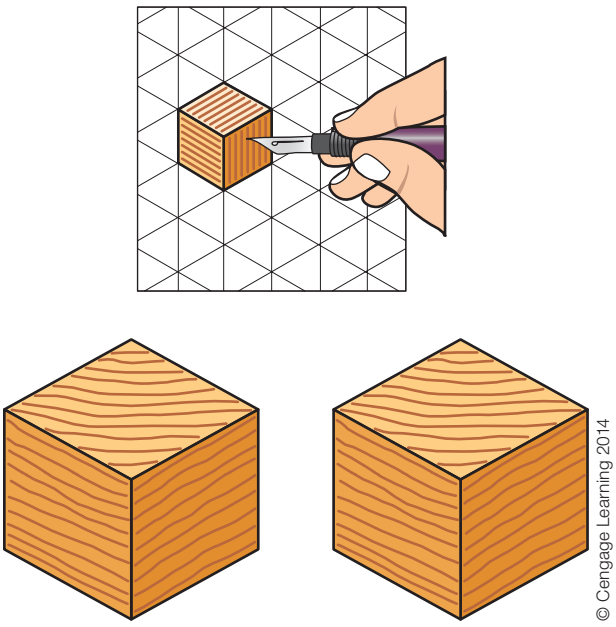

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FIGURE 31-13 Isometric cube pattern.

60-degree diamonds (see **Figure 31-13**). This is a spectacular pattern over a large surface.

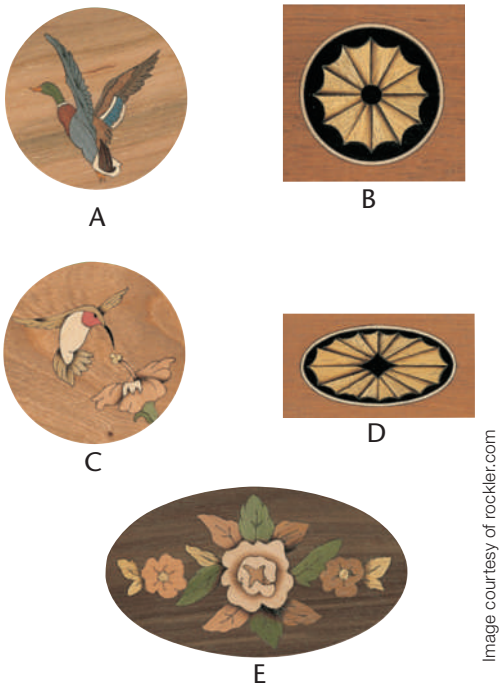


Image courtesy of rockler.com

FIGURE 31-14a-e Marquetry motifs can be purchased for inlays.

WOODWORKING TIP:

One way to experiment with the many possibilities of parquetry is with graph or isometric grid paper and colored pencils.

GREEN REMINDERS

Be conscientious about turning off the lights when you leave your shop.


Courtesy of Inlay-Arts.

FIGURE 31-15 Buffet embellished with marquetry

MARQUETRY

Marquetry, like parquetry, uses veneers that are taped together and glued to a core. Where parquetry uses geometric patterns, **marquetry** is the creation of decorative patterns and pictures. In this respect it is similar to intarsia. Marquetry motifs can be purchased and inlaid into a surface using the techniques discussed in the inlay section. **Figure 31-14** shows examples of marquetry motifs, and **Figure 31-15** shows a cabinet which has been embellished with marquetry work.

The process of making marquetry patterns begins with the design. Once a design has been selected or drawn, different veneers are selected for the various parts of the design. By changing the grain directions of the different pieces, various effects can be achieved. Veneers for

marquetry pictures can be cut with a knife or they can be sawn. The work must be very precise, so sawing is often preferred. The sawing may be done on a scroll saw or by hand with a **fret saw**. A fret saw is like a coping saw but has a much deeper throat (see **Figure 31-16**). Whether a scroll saw or a fret saw is used, a very thin, fine-toothed blade is required. This results in a very smooth cut, and it enables the operator to make tight turns.

There are two basic ways to cut marquetry designs: One is to cut each piece of the design individually. The other method is calling the *overlapping method,* or **stack method**. In the stack method, a stack of veneers are taped together, one layer for each veneer used in the design. Each veneer should be an inch or so oversize in each direction. A sheet of scrap veneer or thin cardboard is placed on the top and the bottom of the stack to prevent tear-out of the good veneers. The pattern is then attached to the top of the stack. A spray mount adhesive can be used for this. A small starter hole is bored for the saw blade. Then all the cutting is done at once. This works best using a saw rather than a knife (see **Figure 31-17** and **Figure 31-18**).

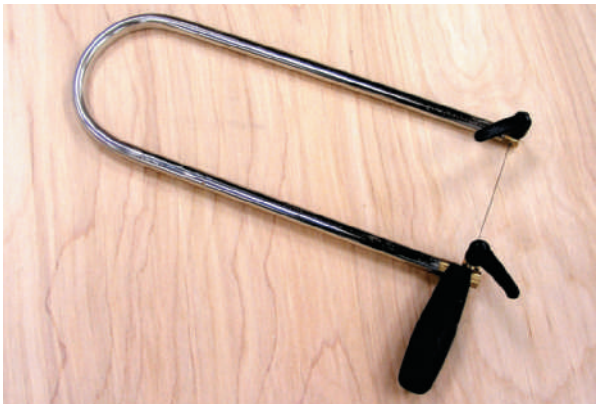
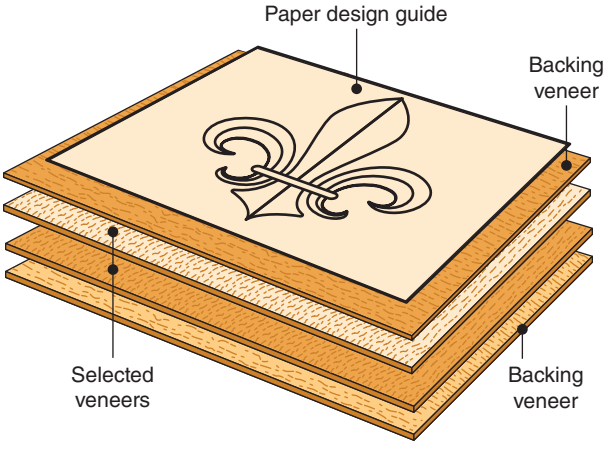

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FIGURE 31-16 Fret saw.



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FIGURE 31-17 Stacking veneer for simultaneous cutting.

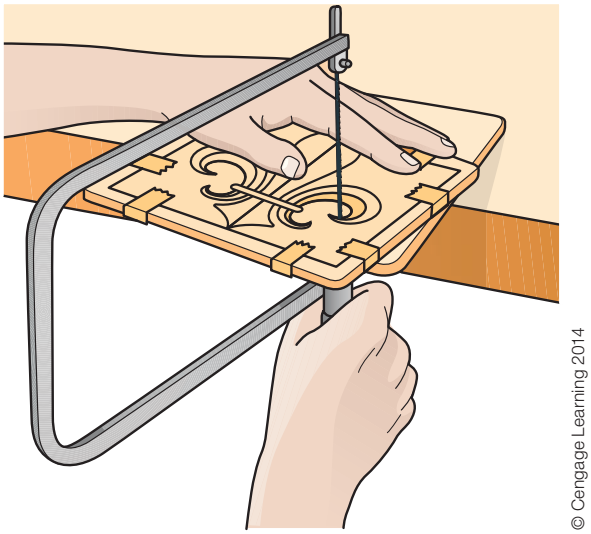

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FIGURE 31-18 Cutting the stack.

A benefit of using the stack method is that you end up with multiple components — as many as the number of veneer sheets used — in whatever colors you need for your design.

WOODWORKING TIP:

Patterns can be enlarged or reduced using a photocopier. Also, a reversed image created by the photocopier can be placed face down on the veneer, and if a hot iron is pressed over it, the image is transferred to the veneer (see **Figure 31-19**).

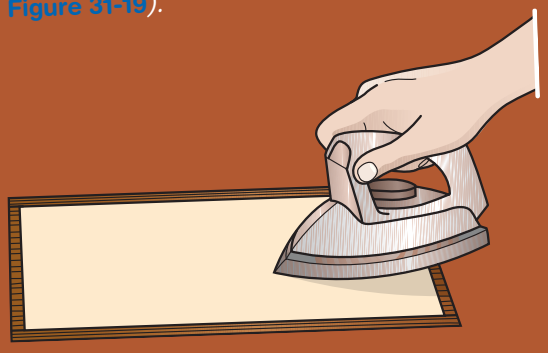

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FIGURE 31-19 Iron the back of a photocopy to transfer the image.

Cutting pieces of veneer individually for a picture can be done with a sharp knife, using a technique called the **window method**. The pattern is first taped to a piece of cardboard along the top edge so that it is hinged and can be lifted up. A sheet of carbon paper is placed between the pattern and the cardboard, and the background is traced. The pattern is then flipped up

out of the way, and the marked area of the cardboard is cut out. The background veneer is then slid under the cardboard and temporarily taped in place. Using the "window" cut in the cardboard as a template, the veneer is scored. Then the cardboard is moved out of the way, and the veneer is cut the rest of the way through on the scored line. Then the veneer piece just cut is pressed into the window cut in the cardboard and taped in place. For each section of the design, the pattern is brought down over the background veneer, and another section is traced and cut in a similar manner. Veneer is laid into veneer and taped with veneer tape, and in this manner the picture or design is gradually built up. One of the great advantages of this method is that it allows the veneer to be seen through the window prior to cutting. This allows you to check it for color and grain direction to make sure the desired effect is being achieved. When all the parts have been cut, the assembled design is removed from the cardboard and glued to a substrate. **Figure 31-20** through **Figure 31-24** illustrate these steps.

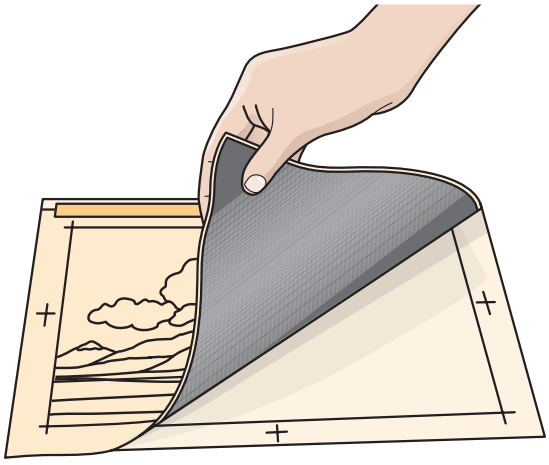

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FIGURE 31-20 Hinge the design to the cardboard and trace one of the main elements.

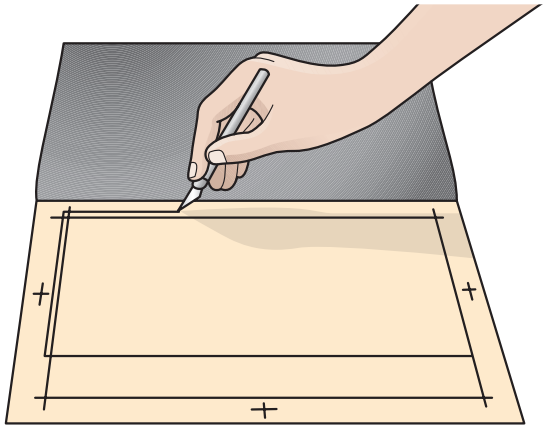

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FIGURE 31-21 Cut a window in the cardboard.

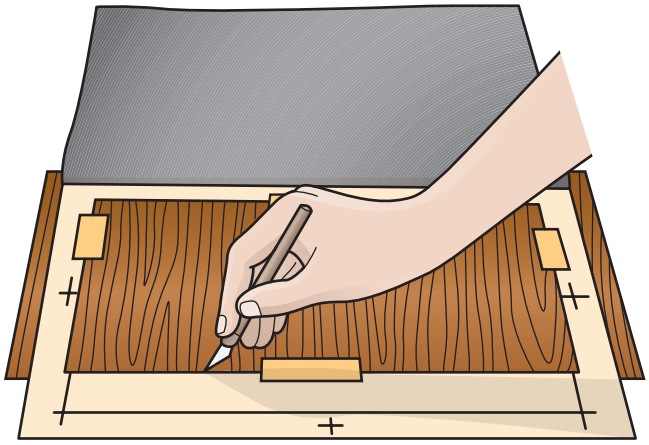

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FIGURE 31-22 Use the window as a template to cut the veneer.

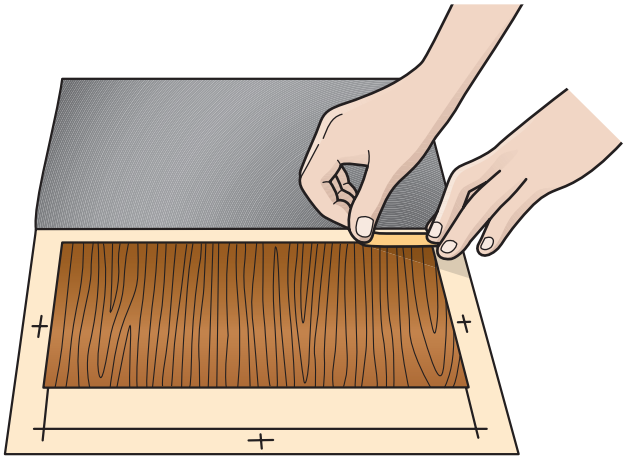

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FIGURE 31-23 Tape the veneer into the window.

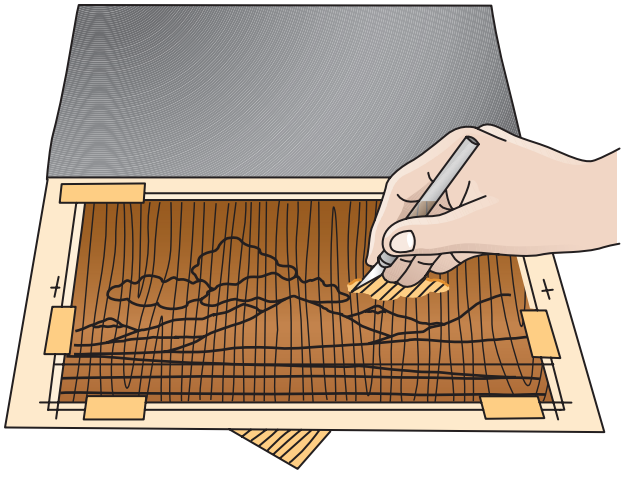

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FIGURE 31-24 Trace additional elements and cut each.

WOODWORKING TIP:

Shading veneer produces the three-dimensional effect often seen in veneered shell, oval, and fan motifs. Veneer is shaded by scorching it slightly, which is done by inserting it into hot sand. Clean, fine sand should be used in a baking tray under low heat. The veneer is grasped with tweezers and the edge is held in the sand for a few seconds; this will darken the edge, which will help give the design depth. In order to shade an internal section, hot sand is spooned onto the veneer. Some experimentation is required to see how long the hot sand and veneer should be in contact with each other (see **Figure 31-25** *and* **Figure 31-26***).*



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FIGURE 31-25 Shading an edge in hot sand.



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FIGURE 31-26 Shading an interior section.

Finishing Inlay, Parquetry, and Marquetry

Finishing a surface that has been decorated with inlay, parquetry, or marquetry presents a challenge, because grain may run in many different directions. There are usually color differences involved as well, which may present an issue if part of the surface is to be stained.

We have learned to sand with the grain, but how do we approach a surface that has grain running in various directions? The best solution is to use a very fine-grit abrasive, 220 or higher, and to use a random oscillating sander. The scratches created will be very small, randomly placed, and, consequently, nearly invisible to the naked eye.

If only part of the surface is to be stained in a particular color, there are several different methods that may be used. Maple stringing, for example, may need to be laid into a walnut surface that is to be filled and stained. One solution to this problem is to stain and fill the walnut prior to inlaying the stringing; this method is probably the best choice. Another option is to tape off the stringing or banding so that it does not get stained, but this may prove to be difficult if the stringing is extremely narrow. A third choice is to seal the inlay with shellac after taping off the walnut surrounding it, so the shellac is not absorbed into the walnut. The shellac will prevent the inlay from taking the stain.

CARVING

Carvings may be used as decorative overlays. They are attached to a surface and project from it. Carvings may be made from wood or molded wood fiber, and they may be purchased or you may make your own. Many choices of decorative carvings are available commercially; **Figure 31-27** shows some examples.

Carvings fall into one of three categories: **relief carving**, **carving in the round**, and **chip carving**. In relief carving, the background is cut away to leave a design. Carving in the round involves starting with a block of wood and taking away material to leave a figure; this is the most challenging type of carving. A mallet and an array of chisels and gouges are used for both relief carving and carving in the round (see **Figure 31-28**). **Figure 31-29** is an example of carving in the round and **Figure 31-30** is an example of relief carving.

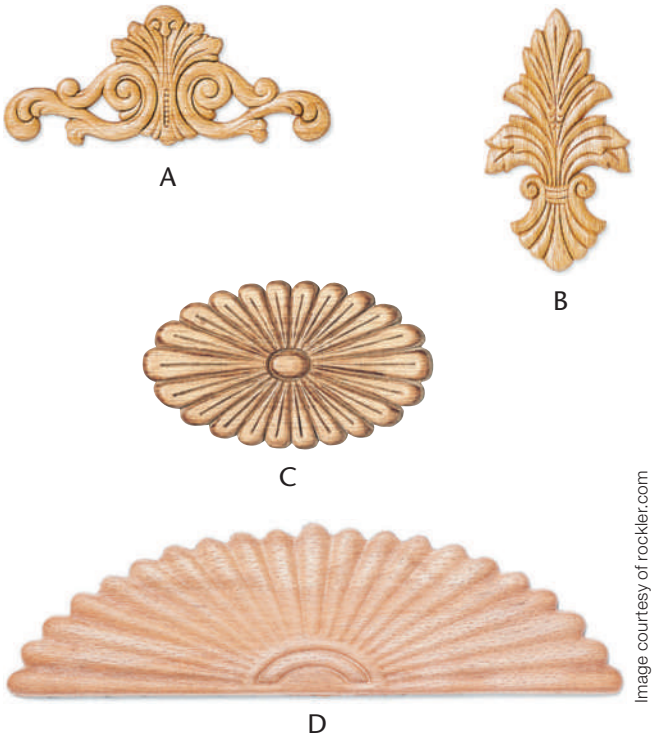


Image courtesy of rockler.com

FIGURE 31-27a-d Commercially available carvings.



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FIGURE 31-28 Carving tools and mallet.

Chip carving is an ancient type of carving in which knives are used to remove small chips of wood from the project in a single piece. It requires little in the way of tools and has been used for hundreds of years as a decorative technique. It is more easily mastered than the other two types of carving and is generally based on geometric shapes, although free-form chip carving is also done. Chip carving is a good technique for making borders and lettering.



Image courtesy of Stefanie Rocknak

FIGURE 31-29 Carving in the round.



Relief Carving courtesy of Nora Hall Carving Designs/Photograph by Tom Krent

FIGURE 31-30 Relief carving.

There are two basic knives used in chip carving: a cutting knife and a stab knife (see **Figure 31-31**). It is important that both of these knives be very sharp. Both a medium-grade and a very fine stone are needed, as

well a strop for final polishing of the blade. Ceramic stones work very well (see **Figure 31-32**). The sharpening angle for the cutting knife is 10 degrees; for the stab knife, it is 30 degrees (see **Figure 31-33**).



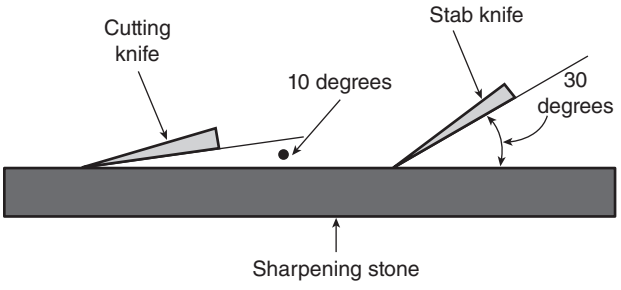
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FIGURE 31-31 Stab knife (top), and cutting knife.



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FIGURE 31-32 Leather strop, charging compound, fine and medium grit ceramic stones.



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FIGURE 31-33 Angle for sharpening knives.

WOODWORKING TIP:

While many different types of wood can be carved, those most suitable for chip carving are basswood (Tilia Americana), *butternut* (Juglans cinera), *and Eastern white pine* (Pinus strobus). *Basswood is the number one choice, especially for beginners. It is relatively soft, with a straight, tight grain. The fact that it is light in color creates a very good contrast between the light and shadow interplay that emphasizes this type of carving.*

Chip carving is the process of removing a series of wood chips to form an engraved design that is lower than the surface of the wood. It is the opposite of relief carving, in which material is removed so that the design projects from the wooden background.

The cutting knife is the primary carving tool; it is used to make all the cuts. The stab knife is not used for cutting at all; its function is to indent or impress a mark into the wood to enhance the design. If you had to choose only one carving knife, the cutting knife is the best one to have. Other tools that are important for chip carving work are a metric ruler, a square, a very fine pencil, a compass, an eraser, tracing paper, and carbon paper (see **Figure 31-34**).

Many attractive and diverse borders can be laid out with a series of 4-millimeter squares. By removing triangular chips in different ways, various patterns are created. The process for removing a triangular chip is illustrated in **Figure 31-35**; the third cut frees the chip. A sampling of possible patterns is shown in **Figure 31-36**.



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FIGURE 31-34 Metric ruler, fine pencil, eraser, compass, square, tracing paper, and carbon paper.

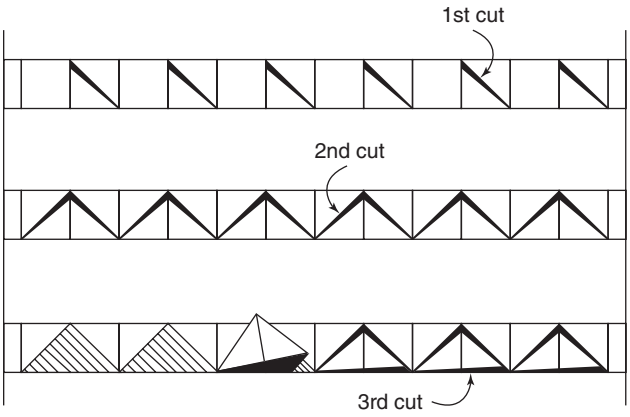


FIGURE 31-35 Sequence for removing triangular chips.



FIGURE 31-37 Holding the cutting knife.

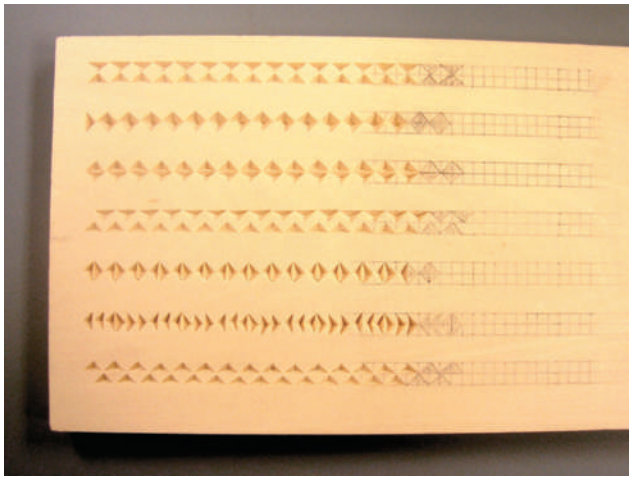


FIGURE 31-36 Some possible patterns.

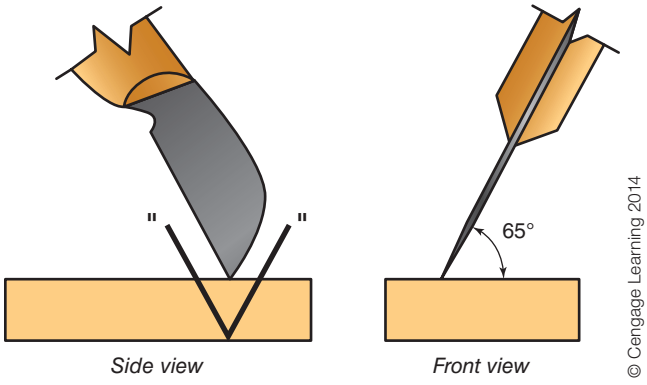


FIGURE 31-38 The cutting knife is held at a 65-degree angle.

The cutting knife is held as illustrated in **Figure 31-37**. Some part of your hand is always in contact with the work to serve as a guide and to provide better control of the cuts. Keeping your elbow close to your body gives you greater leverage. The angle at which the knife is held is about 65 degrees (see **Figure 31-38**). The three sides of a triangular cut should meet at the bottom of the cut. Holding the knife properly feels awkward at first, but with practice, it will feel more natural.

A curved chip is removed with two cuts that meet in the center, as is a straight-line chip. Mastering the curved chip allows the carver to create intricate borders, rosettes, lettering, and free-form carving. Rosettes are laid out using a compass. **Figure 31-39** and **Figure 31-40** show how to lay out two different rosettes. The areas you choose to carve out will determine the final look (see **Figure 31-41** and **Figure 31-42**).

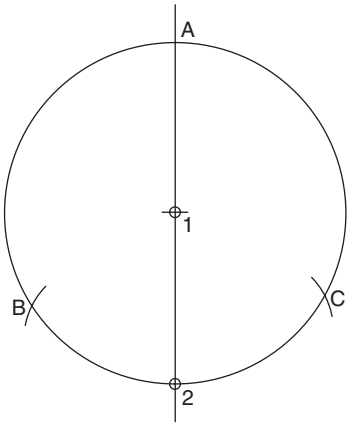
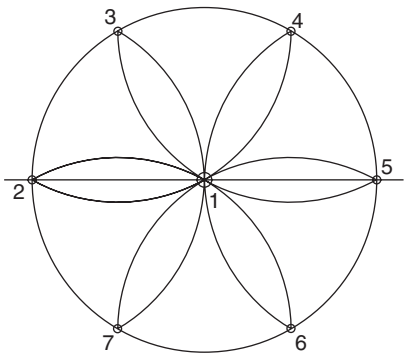


FIGURE 31-39 Laying out a three-sided rosette.

Lettering has always been a big part of chip carving. **Figure 31-43** shows an example; this is where tracing paper and carbon paper are helpful. The letters you wish to carve are laid out from a lettering guide onto the tracing paper and then transferred to the cutting surface using carbon paper (see **Figure 31-44**). Roman letters are very legible and are perhaps the easiest type of lettering to cut. **Figure 31-45** illustrates a Roman alphabet that you may enlarge or reduce as desired for lettering work.

Chip carving offers another opportunity for the woodworker to embellish or decorate a project. It requires very little in the way of tools and is an enjoyable task that can be practiced almost anywhere.



1. Draw a horizontal line.
2. Make a circle at point 1.
3. Using the same compass opening, set compass at point 2 and strike points 3 and 7.
4. Set compass at point 3 and repeat until you return to point 2.

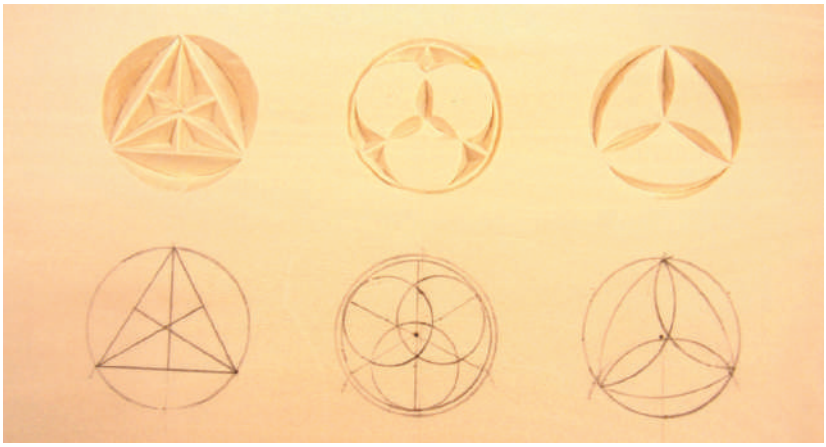
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FIGURE 31-40 Laying out a six-sided rosette.



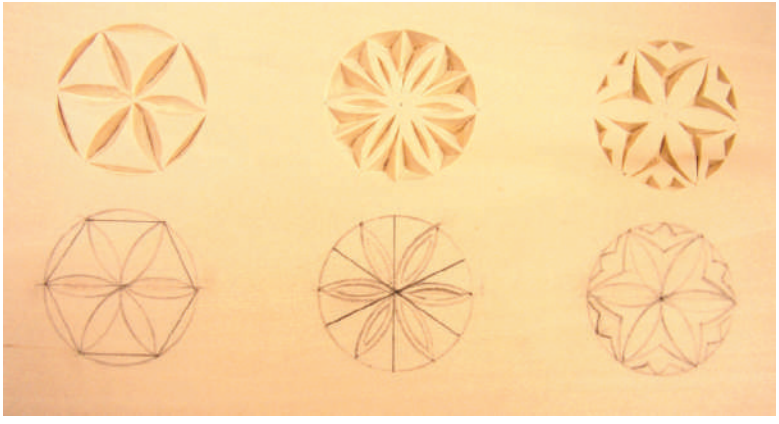
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FIGURE 31-43 Example of chip-carved lettering.



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FIGURE 31-41 Three-sided rosettes.



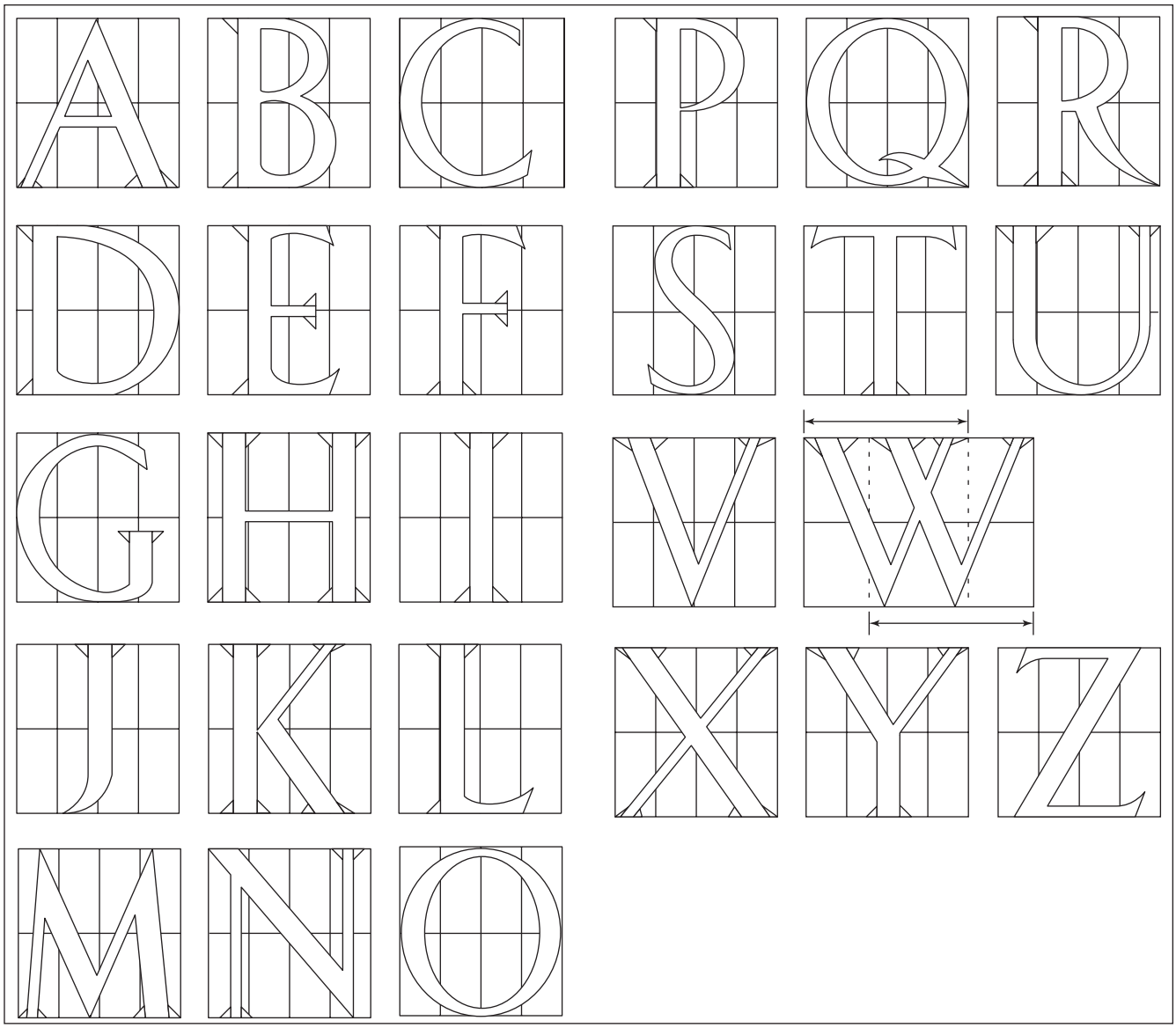
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FIGURE 31-42 Six-sided rosettes.



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FIGURE 31-44 Lettering is traced onto tracing paper and transferred with carbon paper to the carving surface.



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FIGURE 31-45 Roman alphabet.



Summary

By mastering different decorative techniques, the woodworker can enhance his work dramatically. Among these techniques are inlay, intarsia, parquetry, marquetry, and carving. Inlay is recessed and sits flush with the surface of the work. Intarsia stands proud of the surface of the work. Parquetry and marquetry both use veneers to create different effects: Parquetry uses various geometric shapes to create patterns to excite visual interest, whereas marquetry is more pictorial. In both cases, the color of the veneer and the orientation of its grain is an important part of the final appearance. A carving may be used as an overlay, and this type of carving may be purchased or made from a separate piece of wood and attached to the surface of the work. Other types of carving are relief carving, carving in the round, and chip carving. Chip carving requires the fewest tools and is the most accessible to the beginning carver.



Key Terms

bandings
carving in the round
chip carving
fret saw
inlay
intarsia
marquetry
parquetry
relief carving
router plane
scratch stock
stack method
strings
window method



Check Your Knowledge

1. List the various decorative techniques covered and define each.
2. What is the difference between stringing and banding?
3. What tools may be used to create the recess for an inlay?
4. What is the difference between inlay and intarsia?
5. What do parquetry and marquetry have in common? What is the difference between the two?
6. List and describe the two methods of creating marquetry designs.
7. Name one advantage of each of the two methods listed above.
8. How does relief carving differ from chip carving?
9. At what angle should a chip-carving knife be held when cutting?
10. What is the premier carving wood?



What's Wrong with This Picture?



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Chip-Carved Plaque

Figure A shows a chip-carved plaque.

TOOLS REQUIRED

- Metric ruler
- Sharp pencil
- Measuring device
- Tracing paper
- Masking tape
- Carbon paper
- Chip-carving knife
- Combination square
- Sander

MATERIALS REQUIRED

- 3/4" × 6" × 16" basswood

STEPS

1. Copy the Roman alphabet given in Figure 31-45; adjust the size until the letters are about an inch high.
2. Draw straight, horizontal lines on a piece of tracing paper to serve as baselines. Copy the letters from the Roman alphabet to make up the saying PRACTICE MAKES PERFECT, as shown in **Figure B**.
3. Lay out centerlines vertically and horizontally on the basswood, as shown in **Figure C**.



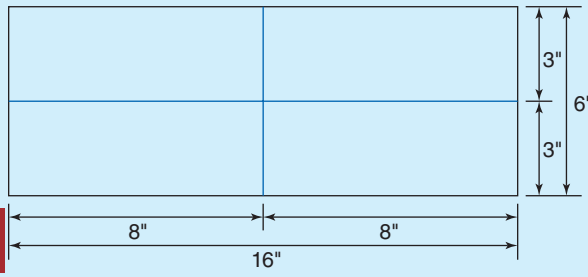
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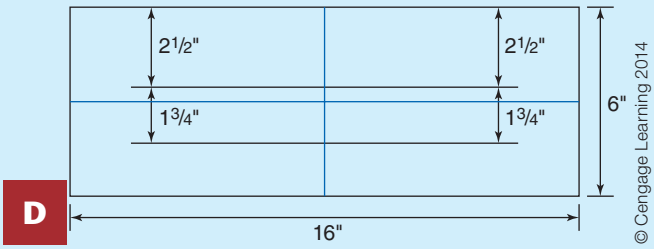
B

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C

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D

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4. Measure down 2 1/2" from the top of the board, and draw a horizontal line across the length of board. Measure 1 3/4" down from the line you just drew and draw a second horizontal line. see **Figure D**.
5. Measure the length of the word PRACTICE that you copied onto the tracing paper; divide that length in half. Measure this distance from the beginning of the word, and make a mark at that point. Now place the tracing paper on the basswood; line up the word PRACTICE on the first horizontal line on the board by shifting it back and forth until the halfway point you marked on the tracing paper lines up with the vertical centerline on the board. Use masking tape to tape the tracing paper to the board. Refer to **Figure E**.
6. Slide the carbon paper between the wood and the tracing paper. Carefully trace the word PRACTICE, and then remove the carbon and tracing paper.

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7. Measure the length of the words MAKES PERFECT, then divide that length in half, measure over from the beginning of the words this distance, and make a mark.
8. Align the words MAKES PERFECT on the third horizontal line down from the top of the board. Use the mark you made on the tracing paper to align the center mark on the tracing paper with the vertical center mark on the board. Tape the tracing paper to the board and use carbon paper to transfer the words onto the board. When you are done, it should look like **Figure F**.
9. Use your sharpened chip-carving knife to cut out the individual letters. When you are done, it should look like **Figure G**.
10. Working from your horizontal centerline, lay out an even number of tick marks spaced 4 millimeters apart on either side of the centerline, until you are well beyond the lettering you have carved. Allow a minimum of 1/4" to the edge of the board.
11. Following the same procedure, lay out tick marks at the other end of the board (see **Figure H**).



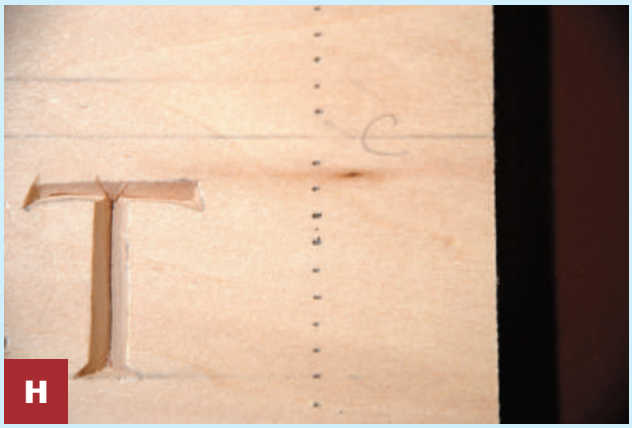
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H

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I

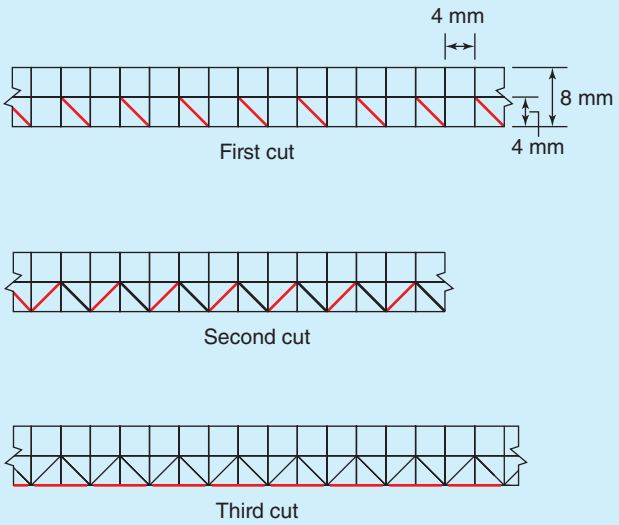
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12. Working from the vertical centerline, lay out an even number of tick marks spaced 4 millimeters apart on either side of the centerline, until you are well beyond the lettering you have carved.
13. Using the marks you just made, draw two outer lines on each of the four edges of the plaque, as shown in **Figure I**.
14. Again using the 4-mm tick marks, lay out the rest of the border grid. **Figure J** shows the completed grid.
15. Carve the inner border first, as shown in **Figure K** and **Figure L**.



K



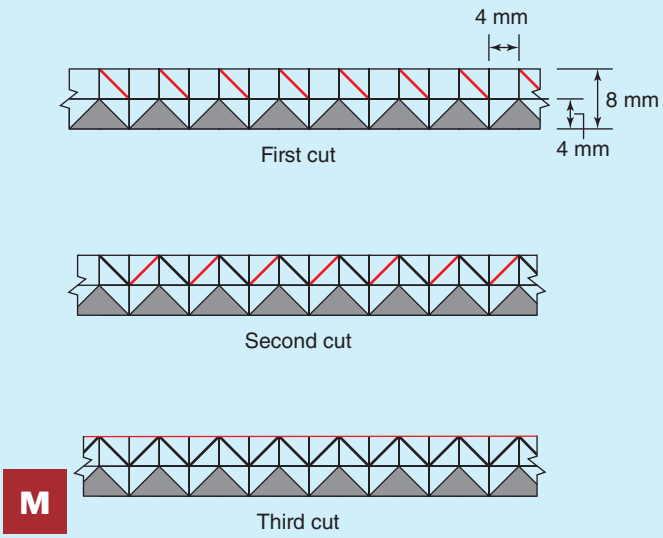
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16. Carve the outer part of the border as shown in **Figure M** and **Figure N**.
17. Carve out a triangular chip on each corner to complete the border, as shown in **Figure O**.
18. Sand and finish as desired.



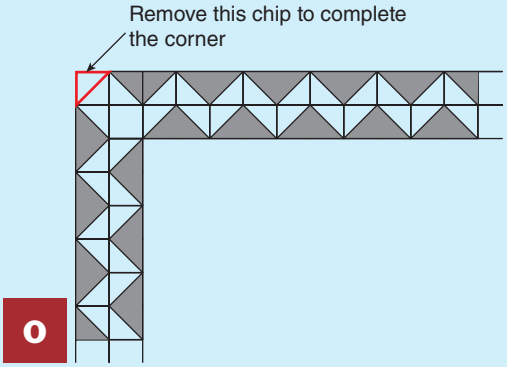
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O

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PROJECT CHALLENGE

Parquetry Checkerboard



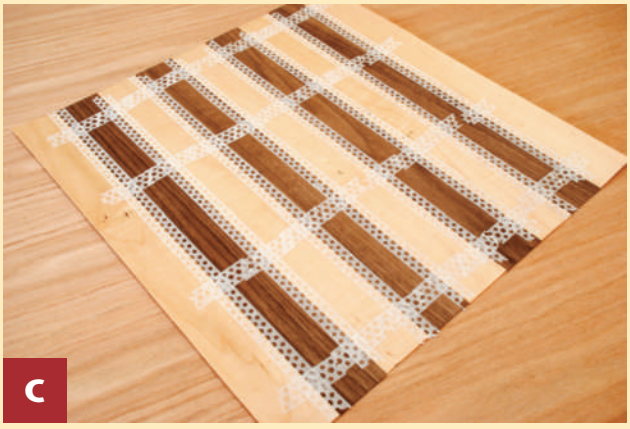
A

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B

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Figure A shows completed parquetry checkerboard.

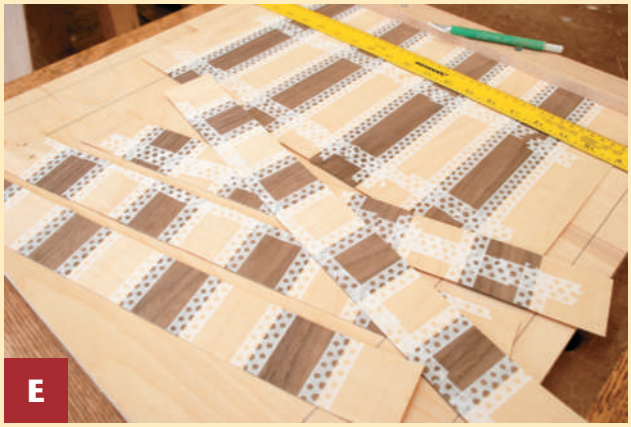
STEPS

1. You will need three different veneers: one light, one dark, and a third that contrasts well with both. Set the third piece aside for now.
2. Use a veneer saw or a craft knife to cut 2″ × 18″ strips from the light and dark veneer, four of one color and five of the other. It will be helpful to use the jig described in the parquetry section of this chapter (see **Figure B**).
3. Butt and tape the strips together, alternating the colors, as shown in **Figure C**.

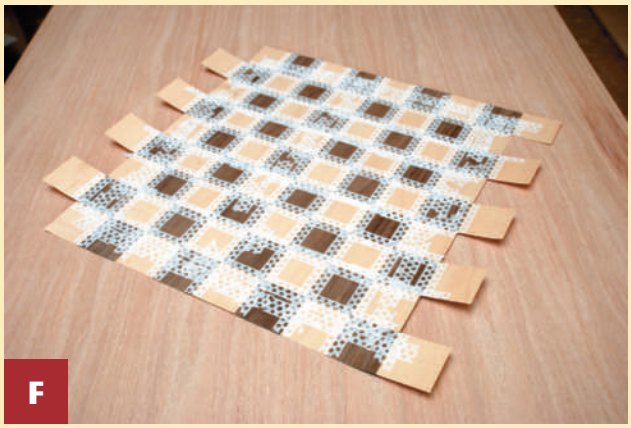
4. Turn the assembled panel 90° and trim the end square, as shown in **Figure D**.
5. Push the edge just cut against the fence, and cut the panel into 2" strips, as shown in **Figure E**.
6. Tape the strips together, staggering alternate strips by one square, as shown in **Figure F**.
7. Cut off the projecting squares.
8. Take the third color of veneer and cut four strips that are 1 3/4" wide and about 20" long. These strips are used to make a border around the checkerboard.


D

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E

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F

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G

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9. Miter and attach the trim veneer around the checkerboard, as shown in **Figure G**.
10. Cut a piece of 3/4" cabinet-grade plywood to 17 1/2" × 17 1/2"; apply veneered edge banding to the edges and trim flush.
11. Brush a layer of white PVA glue on the back of the taped-up veneer panel and to the plywood substrate; allow it to dry completely.
12. Carefully place the veneered panel on the substrate. Moisten the veneer with water, and use a household iron to activate the glue. Use a veneer roller to securely attach the veneer to the substrate.
13. Trim the edges of the veneer flush with the substrate.
14. Moisten and scrape off the veneer tape.
15. Sand and finish as desired.



32

Designing, Drawing, and Planning

You'll Learn

After studying the chapter, the student should be able to:

- Define form and function
- Demonstrate knowledge of the elements and principles of design
- List common design errors
- Explain the decisions that are made as part of the design process
- Identify various historical styles
- Identify various types of drawings
- Explain the importance of a materials list and plan of procedure
- Design and draw up a complete set of plans for a project

INTRODUCTION

Designing a project can be thought of as creating a plan. Like any good plan, the more logical, precise, and detailed it is, the greater the chances of success. An effective design plan will include *drawings,* a *cut list,* and a *plan of procedure.* It will address the questions of form and function and will successfully embody the basic design principles. In this chapter, we investigate project design. We will cover form and function, design elements and principles, common design errors, historical styles, and the information associated with plan drawings.

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FORM AND FUNCTION

The design process begins with a need, a want, or both. Someone needs a bed; they want a four poster. Or someone wants a Shaker table, and it needs to seat eight people. Another person wants a cherry bookcase in the Mission style, but it needs to fit into a certain space, and it must accommodate books of a given size. **Form** can be defined as what the project looks like on completion; that is, its appearance. **Function** is what the piece is designed to do, or its purpose. While form is very important, function should always take precedence over form, unless you are designing a piece that is primarily for display; but for all practical purposes, function is the more important of the two design aspects. A piece of furniture may be very beautiful, but if it does not do what it is supposed to do, it will not fulfill its purpose. The person who wanted a bed will be unhappy if the bed is not designed so that it accepts a standard size mattress. The Shaker table is not functional if it is too small for eight people. And if the Mission bookcase you built will not fit into the space it was meant for, no one will be pleased. But if you design a chair to look pretty but never seat anyone, you have a piece that is not functional, but merely decorative, which was your intent. The thing that distinguishes furniture and cabinetry from art is that it is functional; it serves a purpose. First and foremost, any design must meet its intended purpose.

ELEMENTS OF DESIGN

The **elements of design** are the design's most basic parts. They are *line, shape, mass, color, tone,* and *texture.* These are the simple parts or steps that combine to draw attention.

Lines may be straight, curved, circular, or S-shaped. They reveal a style. A piece that is all straight lines has a very different appearance, or form, than does one with many curving lines.

Shapes are composed of lines, and they reveal a certain style. Shape is seen not only in the overall shape of the product, but also in its component parts. For example, a table may be rectangular in shape but may have a curved apron or round legs. Shapes include squares, rectangles, circles, ellipses, triangles, octagons, and so forth.



DESIGN TIP

Edge profiles and molding treatments can dramatically change the appearance of a piece. Edge treatments may be seen on the edge of a top. Moldings can be a simple profile, or several different profiles of various sizes can be put together to make a complex molding. **Figure 32-1** illustrates some edge profiles. ■

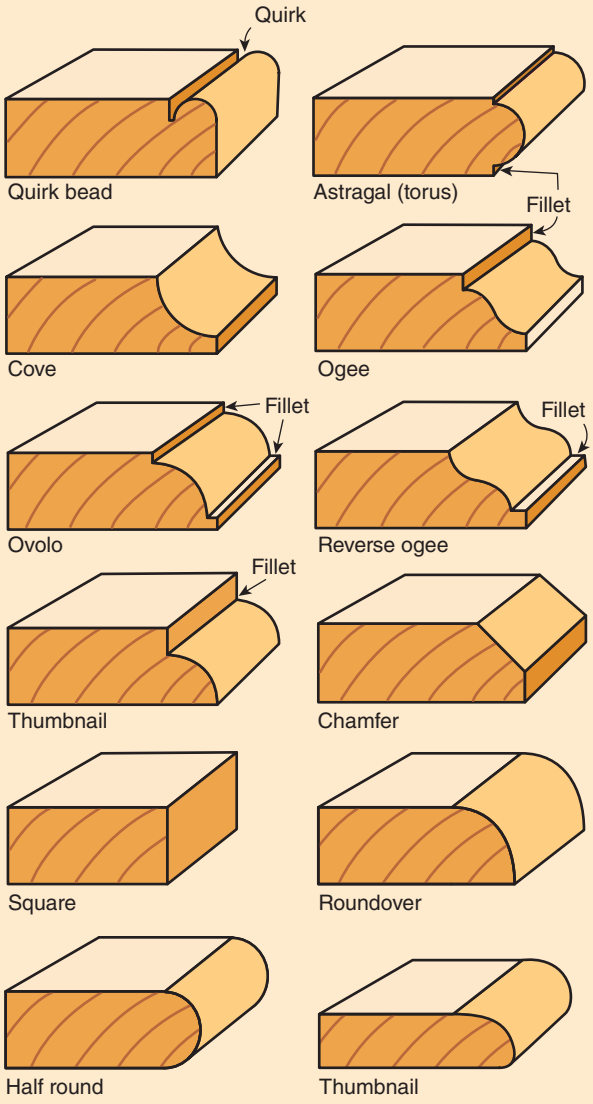


FIGURE 32-1 Edge profiles.

Mass is the relationship between line and shape that gives the appearance of substance. It is a three-dimensional perception involving height, width, and depth. Mass may have either an *open form* or a *closed*


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FIGURE 32-2 Open and closed forms of mass.

form. An example of an **open form** is seen in a chair; though basically rectangular in shape, you can see through the parts, and much of it is open space. An example of a **closed form** is a chest of drawers, where it is not possible to see through the parts. **Figure 32-2** illustrates open and closed forms of mass.

Color is self-explanatory. A scientific explanation is that it is the effect produced on the eye by light waves of different length or frequency. Light transmitted from an object to the eye stimulates different color cones of the retina, thus making possible the perception of various colors in the object. A walnut end table has a different look and feeling than one crafted from maple. Different colors can be used in the same project to create contrast (see **Figure 32-3**).


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FIGURE 32-3 Different colors can be combined in one piece to create visual interest.

Tone may be defined as color quality, such as brightness, deepness, or hue; **contrast** describes differences within a piece, such as between light and dark. Contrast can be created by using different tones of color, by varying the grain within a piece, or by structuring the piece to accentuate the shadows created. One example of contrast is a parquetry project that uses one type of veneer that changes grain direction in adjacent pieces. Another example is chip carving, in which light is reflected differently from the various incised cuts.

Texture is the way a project feels or appears to feel. One example is a chair with a caned seat. The cane obviously has a different texture than the wood of the chair. The same is true of any furniture that has been upholstered. Another, more subtle example has to do with the finish that is used. A table with a high-gloss finish has a different texture than one with a satin finish.

PRINCIPLES OF DESIGN

There are four **design principles**. They are *balance, harmony, repetition,* and *proportion*. **Balance** is the use of space and mass to give a feeling of stability. There are two types of balance: *formal* and *informal*. Furniture or cabinetry exhibiting **formal balance** is symmetrical, which means that the left and right halves of the object, or the upper and lower halves, are mirror images of each other (see **Figure 32-4**). **Informal balance** is asymmetrical (see **Figure 32-5**).

Harmony may be defined as how well all the component parts of a piece work together. It is the


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FIGURE 32-4 Example of formal balance.


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FIGURE 32-5 Example of informal balance.

pleasing relationship of all the elements in a given design. **Repetition** is the device of using one or more elements more than once. Repetition of elements creates rhythm, which draws the viewer's eye to certain areas that accentuate visual harmony (see **Figure 32-6**). Note the repetition of fluting, moldings, and door arches, among other things.

Proportion is the relationship of the parts of an object to each other and to the whole. Examples are height and width relationships or height and length relationships. Generally speaking, a 2:3, 3:5, or 5:8 relationship is more pleasing than a square.

A term frequently used in association with discussions of proportion is the **golden section**, which the ancient Greeks referred to as *phi*. The golden section, or *golden ratio,* is best illustrated by a line segment that has been divided into two unequal sections in such a way that the ratio between the smaller and the larger sections is the same as the ratio between the larger section and the whole. In a line one unit long, the longer section is 0.618, and the shorter section is 0.382. This is considered the perfect proportion, because 0.382 is to 0.618 as 0.618 is to 1.0, a relationship that is sometimes called the **golden mean** (see **Figure 32-8**). The golden rectangle was developed from the golden section. It is any rectangle that has a 1:1.618 ratio between the height and width (see **Figure 32-9**).

In cabinetry and furniture making, the *golden carcass* uses proportions based on the same numbers. You can consider any logical combination that fits your design while maintaining a balance of the most functional and pleasing proportions for your project. For example, if the width is 1.0, the height and depth could both be 0.618. In more practical terms, let us say that the width and height of a table you are building is 30″. If 30″ is multiplied by 0.618, the result would be approximately 18 9/16″, which would be a pleasing table depth. In another example, let us imagine a box that will be constructed in a ratio in which the width will be 1.0, the height will be 0.618, and the depth will be 0.382. This time, imagine the box will be 48″ wide. Its height would be 48″ multiplied by 0.618, which would be 29 11/16″. Its depth would be 48″ multiplied by 0.382, which would be 18 5/16″. Often the golden number is simplified to 5/8, which makes the math a bit more manageable. In this case, the longer section of the golden mean is 0.625 (5/8), and the shorter section is 0.375 (3/8). Going through the two examples above using this method of calculation, the 30″-wide unit turns out to be 18 3/4″ wide and deep, and the 48″-wide object turns out to be 30″ high and 18″ deep.

In cabinet and furniture construction, we are often faced with the question of how to divide areas within a frame — for example, drawers in a chest of drawers. There are several rules of proportion that can be brought to bear on this question. One is the rule of **geometric progression**, in which each successive unit within the frame increases by a constant ratio. For example, in the progression 1, 2, 4, 8, each unit is twice the size of the preceding unit. In the geometric

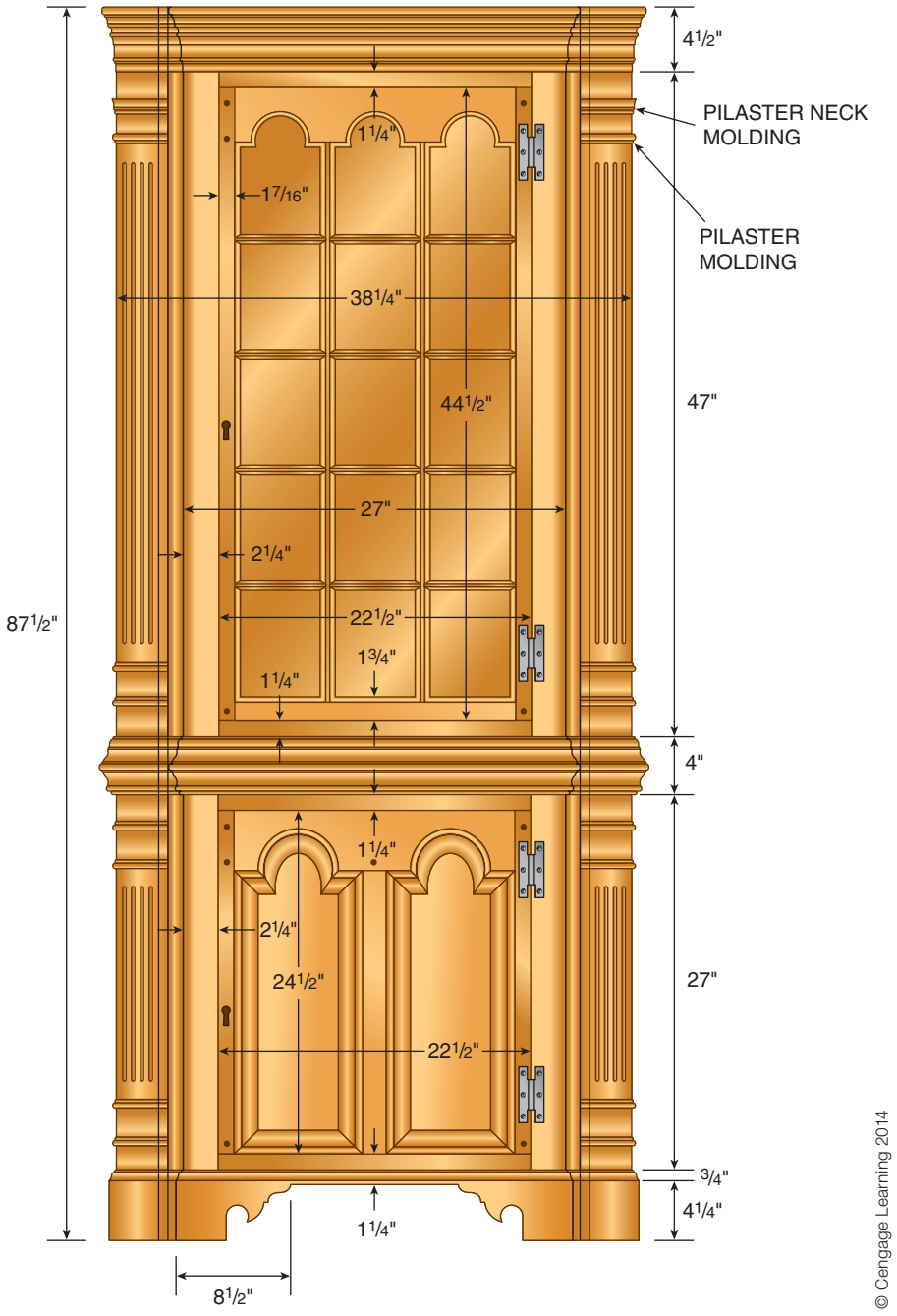


FIGURE 32-6 Repetition of different elements attracts interest.

progression 1, 3, 9, 27, each unit is three times the size of the preceding unit.

An **arithmetic progression** exhibits a constant difference between consecutive units, for example 3, 5, 7, 9, in which 2 is the constant difference. A **harmonic progression** works in fractions in which the reciprocals, or denominators, of the units form an arithmetic progression. An example is 1/2, 1/3, 1/4, 1/5. A fourth type of progression is called a **Fibonacci series**, in which each unit is the sum of the preceding two units (it assumes zero is added to the first number in the series). An example is the series 1, 1, 2, 3, 5, 8, 13.

Other rules for division are illustrated in **Figure 32-10** and **Figure 32-11**. Figure 32-10 represents a **primary vertical mass**, in which an object is taller than it is wide. Figure 32-11 is representative of a **primary horizontal mass**, in which an object is wider than it is high. Other approaches for division include calculating unknowns from known values and through experimentation and trial layouts.



DESIGN TIP

A simple cabinet can achieve different looks based on the door design. Note the five different options illustrated in **Figure 32-7**.

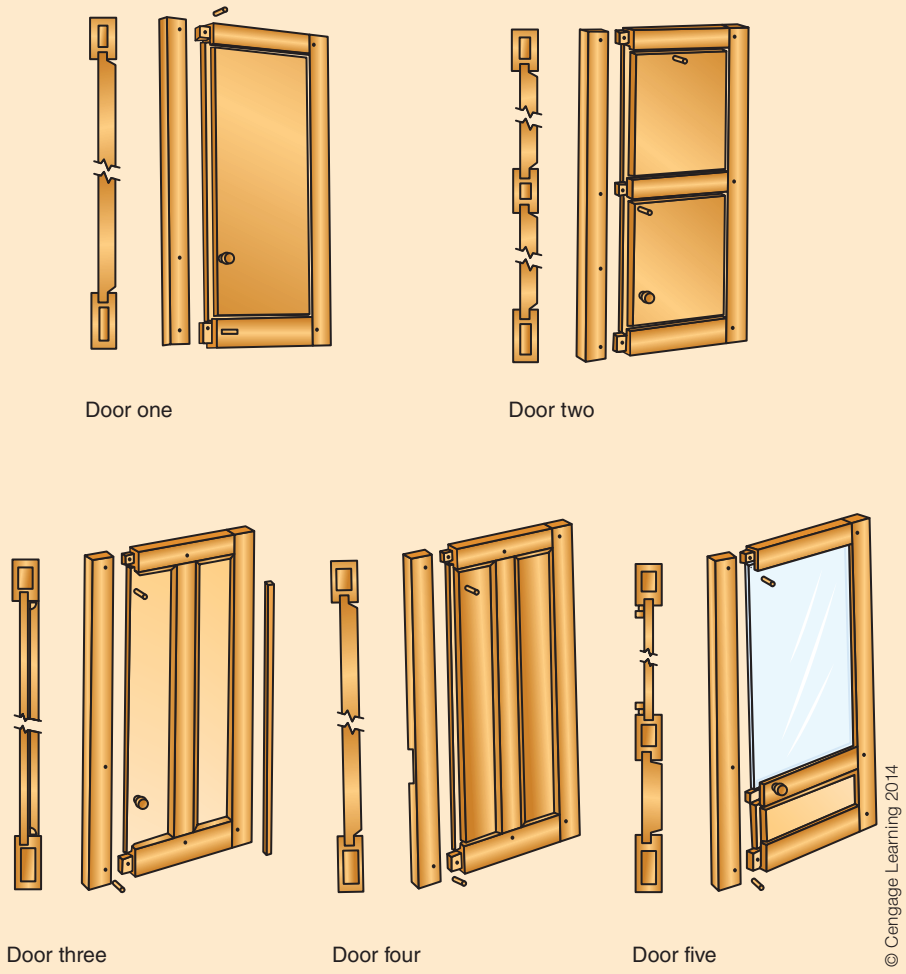


FIGURE 32-7 Different door choices influence the overall look of a cabinet.

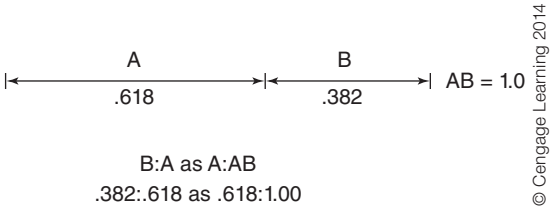


FIGURE 32-8 Golden section.

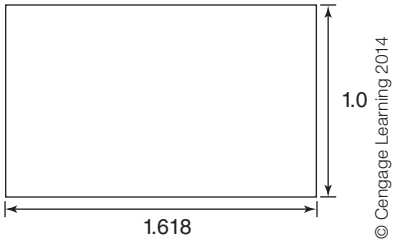
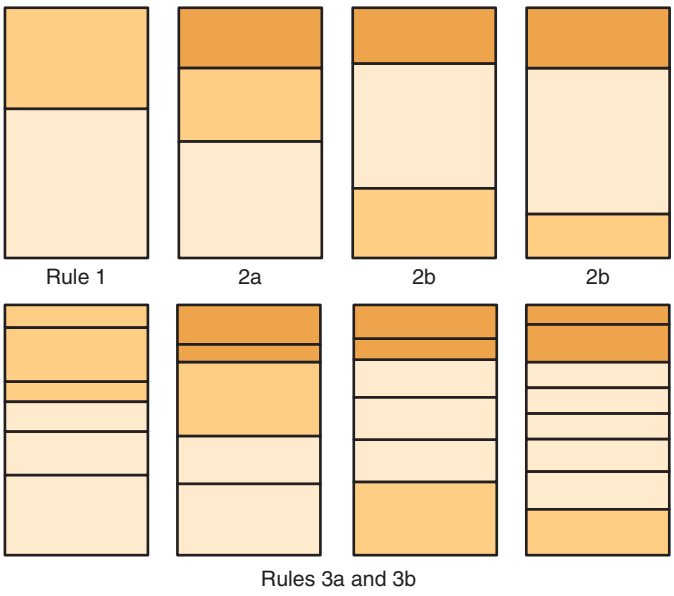


FIGURE 32-9 Golden rectangle.



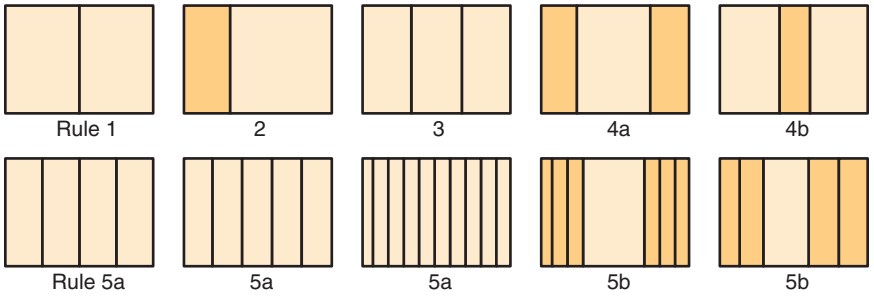
1. Two parts of unequal sizes (major and minor).

2. Three parts of unequal areas:
   a. From bottom to top, the areas will be progressively smaller.
   b. For other arrangements, the major area should be between the other two minor areas.

3. Division into more than three areas:
   a. First separate them according to rules one and/or two.
   b. Then subdivide these masses independently as needed.

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FIGURE 32-10 Ways of dividing a vertical mass.



1. Two equal parts.

2. A major and a minor area but retain balance (informal).

3. Three equal areas.

4. Three divisions with major and minor areas.
   a. One major area between two equal minor areas.
   b. One minor area between two equal major areas.

5. More than three areas.
   a. Areas if equal size and importance.
   b. A large area with a number of smaller equal areas on each side.

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FIGURE 32-11 Ways of dividing a horizontal mass.



DESIGN TIP

A chest of drawers can have its appearance altered significantly simply by modifying the design at the point where the chest contacts the floor. **Figure 32-12** illustrates four different choices for modifying the feet.

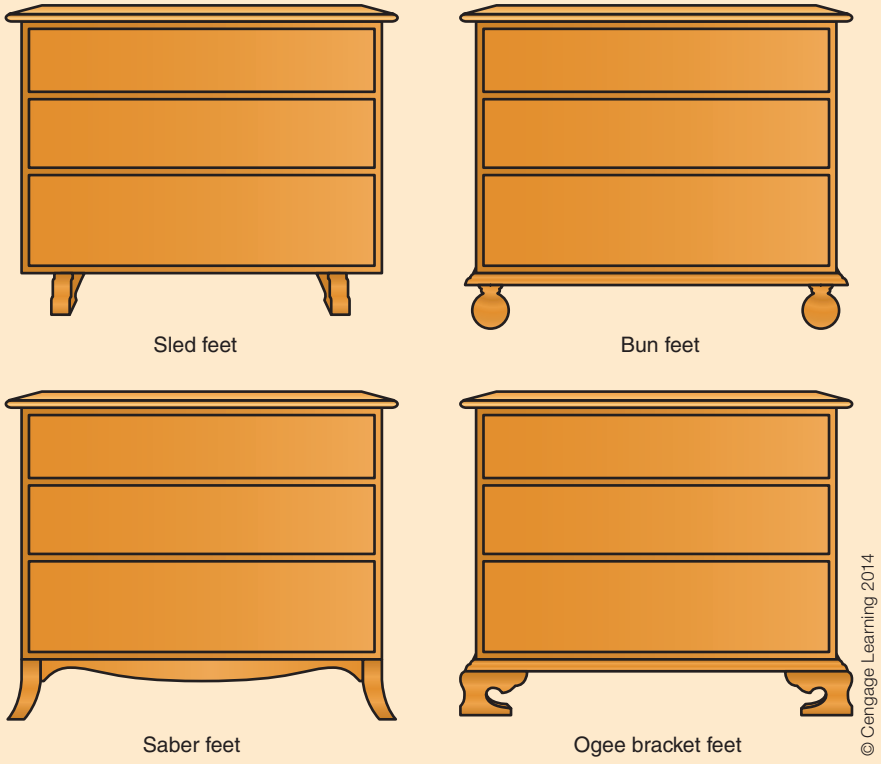


FIGURE 32-12 Options for feet.

Common Design Errors

We all see examples of cabinetry and furniture that do not really work, but sometimes we are hard pressed to say exactly why. Usually it is because the designer or builder has made one or more relatively common errors, some of which are easier to spot than others.

One common design error is that the piece has no definite style or is a hodgepodge of various styles. Another error is that the principles of design — namely harmony, repetition, balance, and proportion — have been ignored or violated. A third error is the use of too much decoration, because overuse of decoration is distracting. Three other common errors are more errors of building than they are of design; these include poor selection of materials, poor craftsmanship, and poor finishing.

Design Decisions

We know that form follows function: The piece being designed and built has to serve its purpose. That is the designer's primary objective, but other factors need to be considered and dealt with. Some of these are related to the overall functionality of the piece; others are not.

Factors related to function that need to be considered by the designer include *variables* and *standards*. **Variables** take into account physical differences between people and objects. Suppose you are building a chair for someone. An important variable is the size of the person who will be using the chair. A child's chair will not be the same size as one built for a large adult. Or say you are building a bookcase. If your shelves are spaced 10 inches apart and some



DESIGN TIP

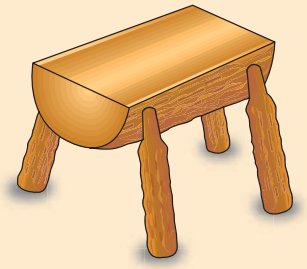
It is important to understand and apply the principles of design and to be familiar with common design errors. There is a shortcut to this process, which involves four questions. They are:

1. Does it work?
2. Is it comfortable?
3. Will it last?
4. Is it attractive?

If these four objectives are met, the piece will be a success. **Figure 32-13** illustrates the objectives of *function, comfort, durability,* and *beauty* in the evolution of a chair.

Function

A simple bench does nothing more than keep one's backside off the floor.



Durability

Adding wedged tenons and a stretcher system will help this chair withstand many years of use and abuse.



Comfort

A back and a contoured seat make the chair a more pleasant place to sit for any length of time.



Beauty

A masterpiece must satisfy the first three objectives while offering timeless appeal.



This tip is courtesy of Michael Dunbar.

FIGURE 32-13 Four design objectives: function, comfort, durability, and beauty.

of the books are 11 inches high, you have missed an important variable that affects the functionality of the bookcase. In these two examples, you can see that both use of the object and human factors influence design decisions.

Many types of cabinets and furniture are built to certain sizes known as **standards**, or standard dimensions. Standards are based on average sizes for children and adults. For example, kitchen cabinet heights are standard at 34 1/2″, or 36″ including the countertop. If you are building base cabinets and violate these standards, fitting in a dishwasher or stove becomes highly problematic, because they are built to conform to these standards. As mentioned at the start of the chapter, another standard that must be adhered to if one is building a bed is the mattress size.

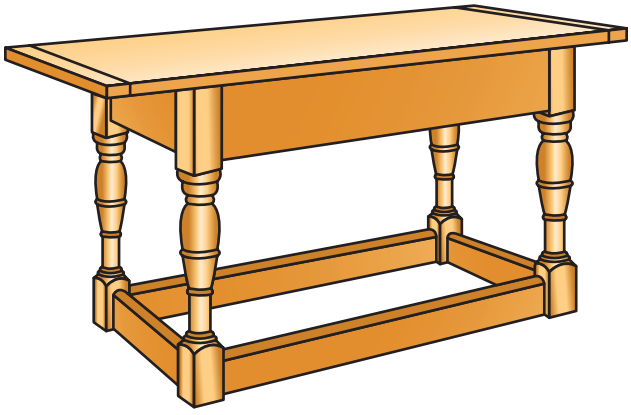
Other design decisions consider the materials that will be used and the means of construction. Material choices include the selection of wood and wood products, hardware, and methods of finishing. These choices may well be dictated by the customer, but as the designer/builder, you should have a kit of samples and a portfolio of your work to share with the customer. Often you may be trying to match existing furniture. If you are building in a certain style and wish to be faithful to that style, your wood and hardware choices may be determined by the style you are imitating.

Construction decisions determine how the piece will be built. These are the joinery decisions. Choices should be made based on strength requirements for the piece. A large door that will be open and shut constantly requires stronger joinery than a small door used infrequently. Joinery decisions may also be influenced by the overall style of the piece. Given a choice of methods that are equal in strength and appearance, choose the one that is less expensive to produce, because time is money.

DESIGN STYLES THROUGH HISTORY

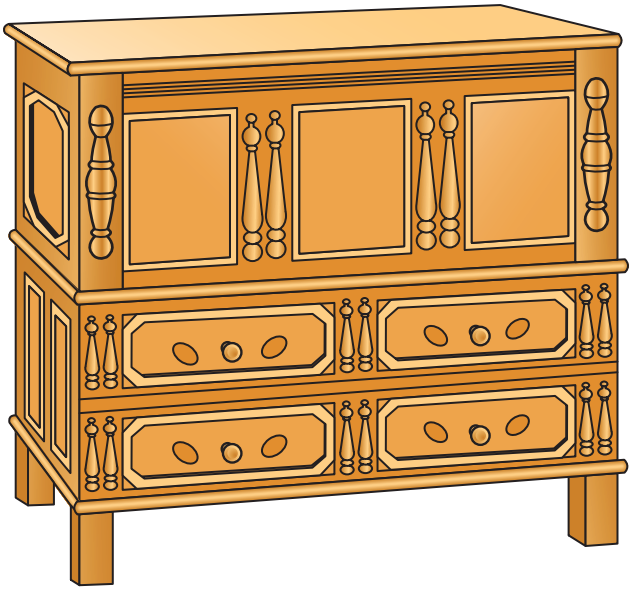
There are many fine books on the history of furniture and cabinetry styles. An abbreviated look at the styles that have shaped American furniture will be covered here, and we will look briefly at a number of styles that have been — and continue to be — important and influential.

The Pilgrim style is sometimes called *Jacobean,* after James I of England. The word *Jacobean* is derived from the Hebrew name of Jacob, which is the original form of the English name James. This style spans the time period from 1640 to 1700 and is a colonial style based on medieval, Renaissance, and English designs. It is sturdy but heavy. Its characteristic features include heavy, simple turnings, extensive carving, split-spindle decorations, and bulky perimeter stretchers (see **Figure 32-14** and **Figure 32-15**).



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FIGURE 32-14 Pilgrim stretcher table.



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FIGURE 32-15 Pilgrim chest.

The William and Mary style is also called *Baroque*. Its era was about 1700 to 1770. It tends to be dark with straight, angular lines and multiple turnings. Features typical of this style include sculptural carvings, paintbrush feet, teardrop pulls, decorative veneers, and vase, trumpet, and ball turnings (see **Figure 32-16** and **Figure 32-17**).

The Queen Anne style was popular from 1725 to 1755. Graceful and fluid curved lines characterized this style. The elegant, S-shaped cabriole leg with a pad foot is a prime style marker. Other characteristics of the Queen Anne style include finials on pediments, butterfly drawer pulls, veneering on drawer fronts and chair splats, and delicately carved shells, leaves, and rosettes (see **Figure 32-18**).

The Chippendale style was named for the London cabinetmaker Thomas Chippendale, and this style



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FIGURE 32-16 William and Mary gate-leg table.



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FIGURE 32-17 William and Mary chest.

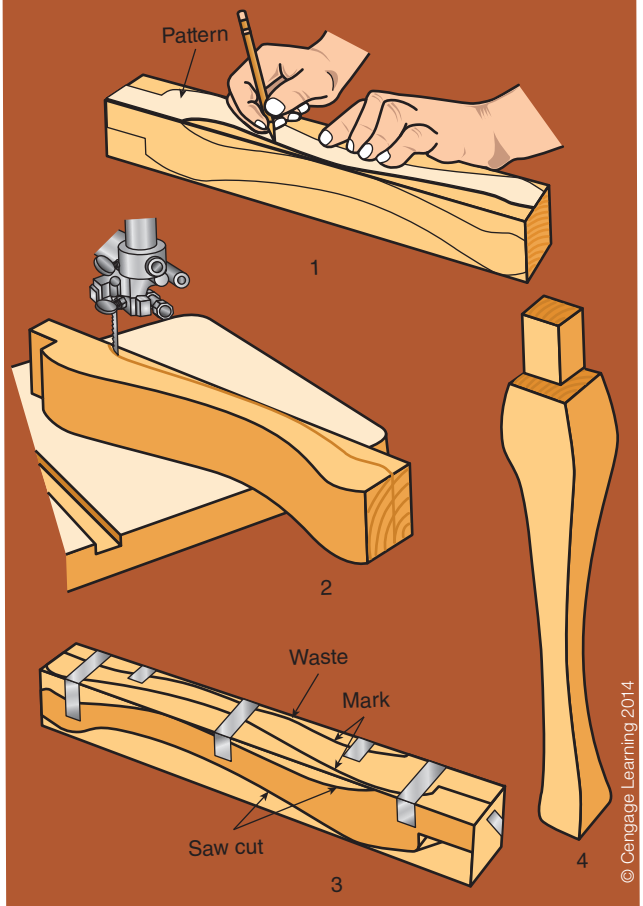


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FIGURE 32-18 Queen Anne highboy.

WOODWORKING TIP:

A cabriole leg can be cut on the band saw; it is a compound cut. A pattern is made on a piece of hardboard or heavy paper, and the pattern is transferred to two adjacent sides of a square piece of stock (see Figure 32-19). The profile is cut on one of the surfaces. The waste is saved and taped back to the stock. Next the leg is turned to its adjacent side and the pattern cut again. Now the work of rounding the leg with planes and rasps can begin.



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FIGURE 32-19 Laying out the cuts for a cabriole leg.

spans the period from 1750 to 1780. Its style markers include bombé and serpentine case forms, pie-crust tabletops, and ball and claw feet. Mahogany and walnut were favored woods, and veneer was rarely used (see **Figure 32-20**).



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FIGURE 32-20 Chippendale bombé chest.



HISTORY FACT

Thomas Chippendale published an influential three-volume text in 1754 titled *The Gentleman and Cabinet-Maker's Directory,* a pattern book based on Queen Anne designs. His designs were heavier and more ornate, and he also often used straight legs. ■

The Federal period, which was prominent from 1780 to 1820, has been called the United States' first homegrown style. It was the beginning of a phase of neoclassicism, looking back to ancient Greece and Rome for its inspiration. Two designers associated with this period are Hepplewhite and Sheraton. Characteristics of the style include thin, tapered legs with spade or arrow feet, tambour fronts, the use of veneer, and delicate inlays (see **Figure 32-21**).

The Empire style was the second wave of neoclassicism, spanning the period from 1815 to 1840. Furniture became heavier and far more ornate, with flamboyant decorative elements. Common design motifs included turned half columns, saber legs, center pedestals, bold carving, gilding, and reeding (see **Figure 32-22**).

The Country style, prevalent from 1690 to 1850, is a catch-all term for furniture produced outside the urban centers. Furniture fashioned in this style

tended to be simplified versions of the rigidly styled forms found in the cities. There is much more emphasis on function than on decoration, and the joinery is often practical and unsophisticated.

Country furniture was made from locally available woods. Pine, cherry, walnut, and poplar were often used. The furniture was frequently painted to make up for a lack of any fancy grain. Typical features found in country furniture are broad face frames, simple moldings, simple scroll cuts, exposed hinges, and wooden pulls or latch closures (see **Figure 32-23** and **Figure 32-24**).

The Pennsylvania Dutch style, seen anywhere from 1690 to 1850, kept alive many of the characteristics of Old World furniture. The Pennsylvania Dutch were German and Swiss immigrants who settled their own communities outside of Philadelphia. The style


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FIGURE 32-21 Federal sideboard.

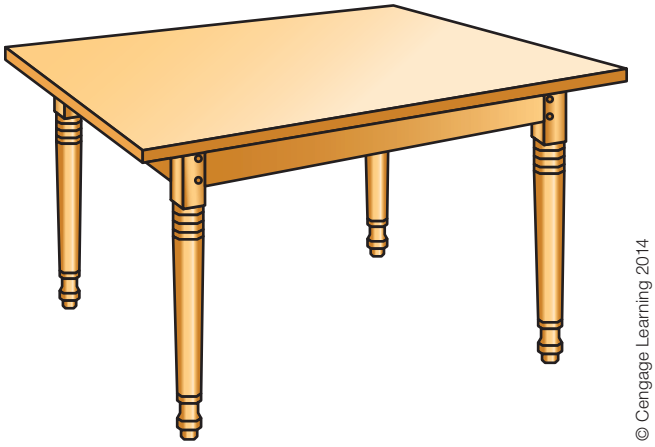

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FIGURE 32-23 Country kitchen table.

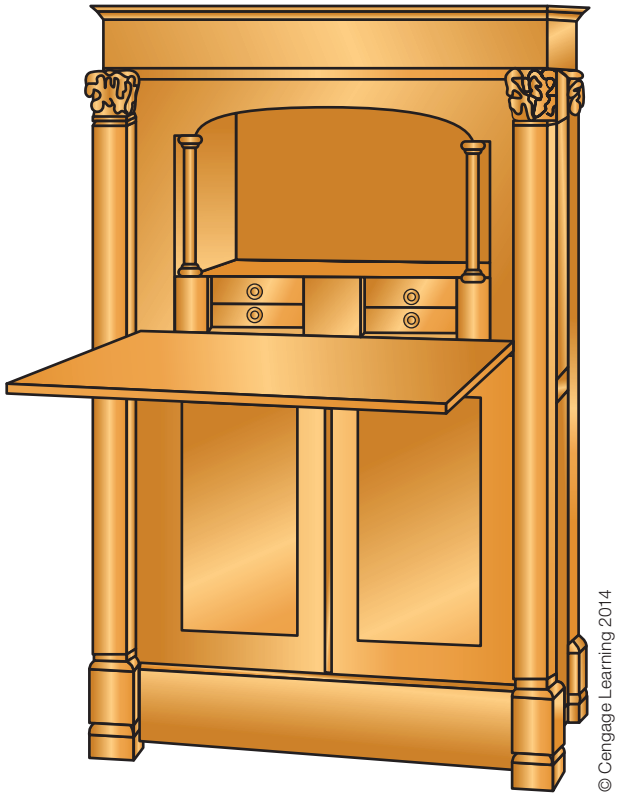

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FIGURE 32-22 Empire fall-front desk.


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FIGURE 32-24 Country jelly cupboard.

they are responsible for is similar to the Country style but is characterized primarily by its highly stylized and colorful folk painting, which harks back to medieval times. The paintings often featured animals, people, fruits, or flowers (see **Figure 32-25**).

The Shakers were a religious sect that produced a much admired style of furniture, which was popular during the period from 1820 to 1870. The Shaker style has simple, clean lines that expressed the values of these people, who were intensely utilitarian and thrifty. They used local woods, and their pieces were often painted, but not in the pictorial, decorative style of the Pennsylvania Dutch. In the main, Shaker furniture is characterized by slender turnings, a lack of ornamental moldings, turned wooden knobs, and plain feet (see **Figure 32-26** and **Figure 32-27**).



HISTORY FACT

The Shakers were a religious sect whose members lived in communities set apart from the rest of the world. Though they have come to be known as Shakers as a result of the dancing that was part of their religious observance, their true name is the United Society of Believers in Christ's Second Appearing. Their religion was based on the principles of celibacy, equality, and communal living. They were an offshoot of the Quakers, and were founded by Ann Lee in the 1770s. At the peak of the Shaker movement in 1850, there were about 5000 members living in 18 different communities. ■



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FIGURE 32-25 Pennsylvania Dutch frame-and-panel chest.



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FIGURE 32-26 Shaker sewing table.



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FIGURE 32-27 Shaker sewing desk.

The Victorian period, from 1840 to 1880, featured several revival styles. They were Gothic Revival, Rococo Revival, and Renaissance Revival. Each produced furniture that was highly ornate (see **Figure 32-28**).

The latter part of the nineteenth century saw the beginning of a reform movement in furniture design. The reformers heavily criticized what they characterized as tasteless designs and misuse of ornamentation. They also were very negative about mass-produced furniture and what they termed the "dominance of the machine." They urged a return to handcrafted furniture without excessive ornamentation. Two styles that developed from this reform movement were Eastlake and Arts and Crafts. A British reformer by the name of Charles Eastlake pioneered a style characterized by incised geometric decorations and moldings. Oak was the wood of choice for this style (see **Figure 32-29**).

The Arts and Crafts period was not just a furniture style but a movement. English designers John Ruskin and William Morris preached the value of restoring handicraft to the making of furniture as an antidote to the Industrial Revolution. The wood most frequently used was white oak, often quartersawn with a fumed finish. Other characteristics of Arts and Crafts furniture include square components, exposed joinery, simple slat backs, and leather upholstery (see **Figure 32-30**). The Arts and Crafts movement sparked the Mission style in America, which took its name from the furniture of the Franciscan missions in California.

The shunning of ornamentation continued well into the twentieth century, and it developed into an aesthetic of functionalism best represented by the International style, which emerged between 1920 and 1960 (see **Figure 32-31**). The Art Deco style of furniture spanned the period from 1925 to 1940. It also was devoid of the intricacies that characterized earlier periods, but it did make use of exotic veneers and materials for embellishment (see **Figure 32-32**).

The Contemporary style grew out of the International style following World War II. It features


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FIGURE 32-28 Victorian chair and table.


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FIGURE 32-29 Eastlake dresser.


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FIGURE 32-30 Arts and Crafts wardrobe.

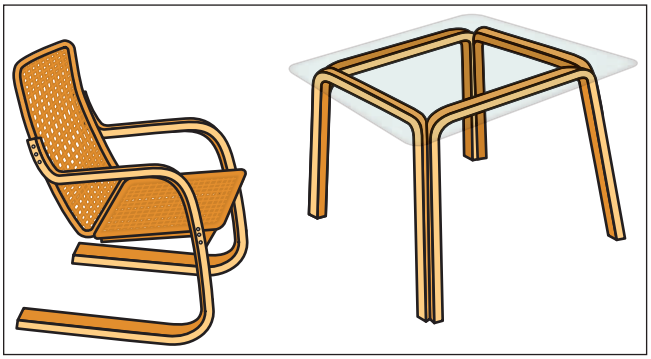

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FIGURE 32-31 International furniture.

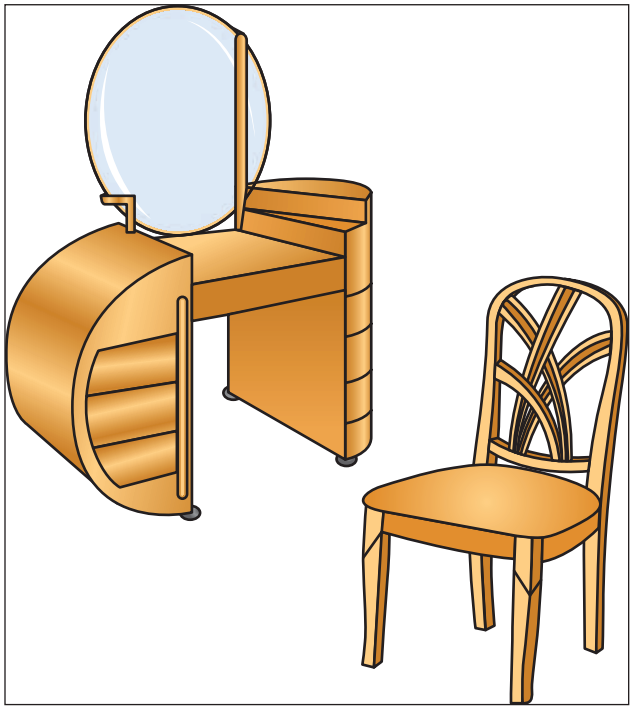

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FIGURE 32-32 Art Deco furniture.

furniture that is versatile, economical, and lacking in ornamentation (see **Figure 32-33**). Some designers, who wished to incorporate older Baroque and neo-classical elements for decoration, developed what is known as the Postmodern style (see **Figure 32-34**). The most recent style development in cabinetry and furniture construction was pioneered by individual craftsmen experimenting with new techniques and materials, as well as those interpreting older styles. Much of this work has been done by individuals in small shops, and so it is termed the Studio or Handicraft Revival style (see **Figure 32-35**).

Studying the styles of the past and present is a good way to begin to develop one's own aesthetic. The more familiar you are with various styles, the more ideas you can bring to bear on your own creations.


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FIGURE 32-33 Contemporary furniture.

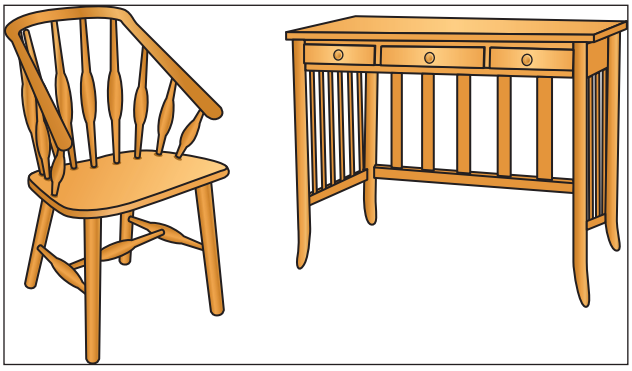

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FIGURE 32-34 Postmodern furniture.

DRAWINGS

Knowledge of the function of a desired piece and familiarity with historical styles help the designer to form ideas. These ideas are communicated to the builder through drawings. Drawing is indeed a means of communication, and it is one that must be clear and concise. Good drawings answer all the questions that arise regarding how a piece is to be built, so they

should include all necessary dimensions and specific information about joinery. Drawings are the link between the design and the building of the piece.

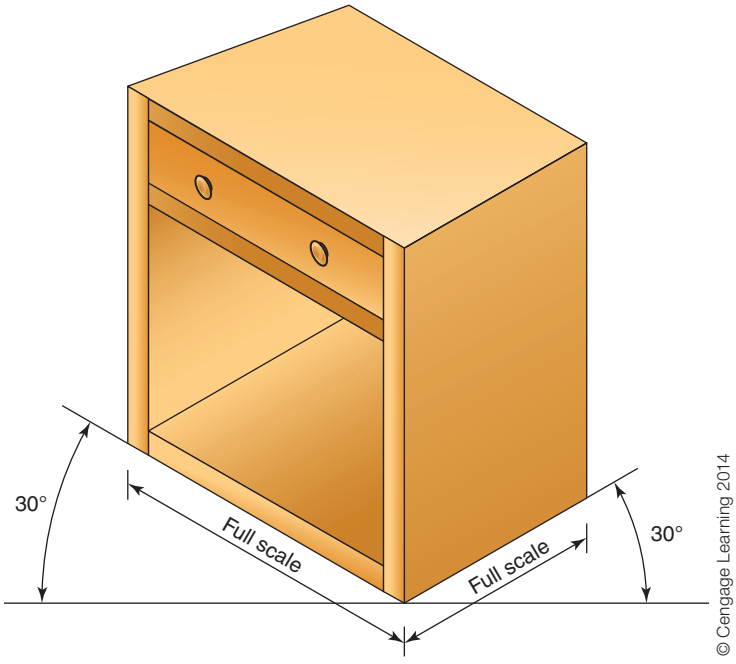
There are different types of drawings which fall into two main categories: *pictorial* and *orthographic*. Objects shown in pictorial drawings appear three dimensional. There are three types of pictorial drawings. The most realistic, and the most difficult to draw, is called a perspective drawing, which uses one or more vanishing points. A second type of pictorial drawing is an **isometric drawing**, which depicts an object as viewed from a corner. Vertical lines are drawn vertically, and horizontal lines are drawn at their true length at a 30° angle from a horizontal baseline (see **Figure 32-36**). The third kind of pictorial drawing is an oblique drawing. The oblique drawing is also called a cabinet drawing; it shows the front view of the object with the sides drawn at half scale at 30° or 45° angle from the baseline (see **Figure 32-37**).


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FIGURE 32-35 Studio furniture.

Orthographic drawings, or *orthographic projections* as they are often called, are two dimensional; because they do not show depth, they do not appear "true" to our eye (see **Figure 32-38**). To communicate all the information, more than one orthographic drawing is needed. Typically, there will be a front view, side view, and top view of the object, although a top view is not always necessary. They are oriented on a sheet as shown in **Figure 32-39**. This layout makes dimensions easier to read and makes it easier to mentally translate a two-dimensional drawing into a three-dimensional object. The scale used is the largest possible; common sizes have either 1 1/2 inches or 3 inches equal to a foot. While pictorial drawings are used in the sketching phase of designing a project, orthographic projections are developed for the construction phase; these are called working drawings.

Front, side, and top orthographic projections are important parts of a set of working drawings, but usually by themselves they do not communicate all the necessary information. Often included in a full set of



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FIGURE 32-36 Isometric drawing

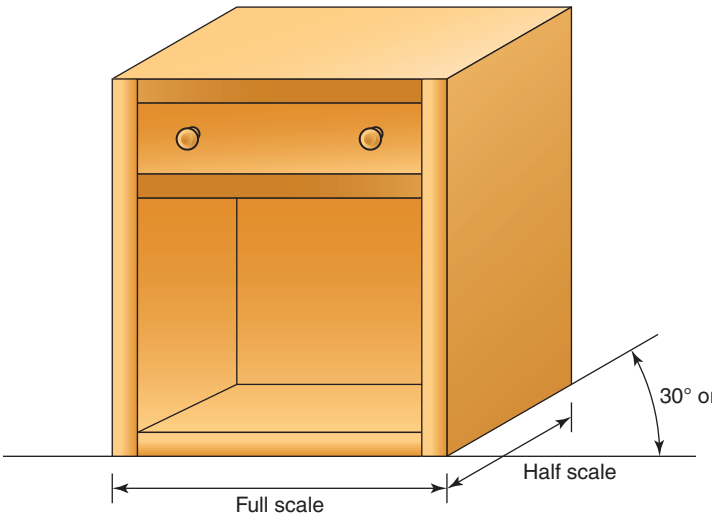


FIGURE 32-37 Oblique or cabinet drawing

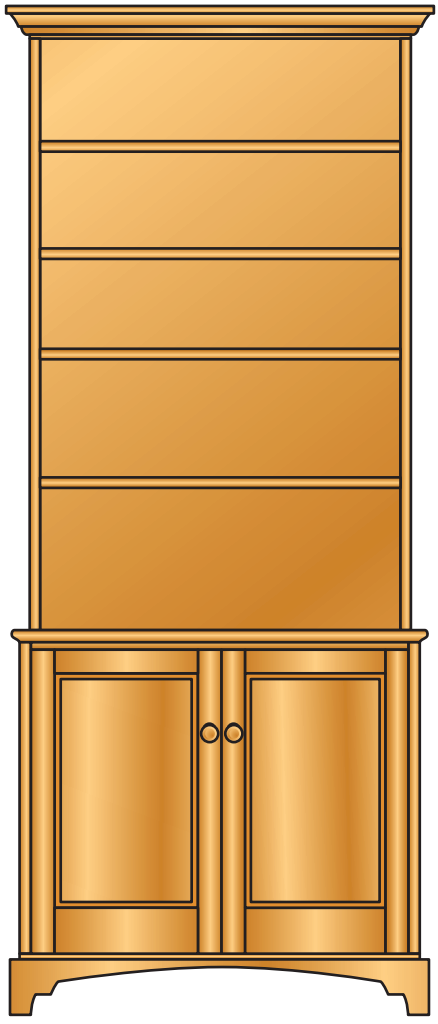


FIGURE 32-38 Orthographic drawing.

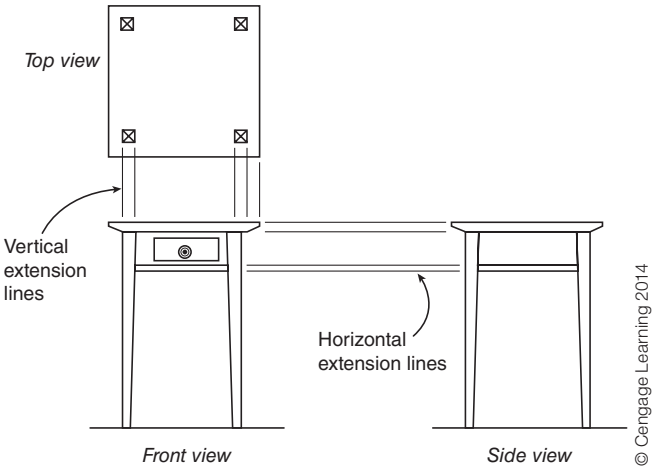


FIGURE 32-39 The front, side, and top views of an orthographic drawing.

drawings will be one or more **section views** that show what the cabinet would look like if part of it were to be cut away. A section view may be a horizontal view or a vertical view, which is indicated on one of the three primary drawings by a section symbol, as shown in **Figure 32-40**. This symbol refers the reader to the section drawing. Because it shows the object as if it were cut along the section line, the section view allows the reader to see interior parts and connections. **Figure 32-41** shows an example of a section drawing. Another important type of drawing is the **detail drawing**, which is often full scale. Typically, the detail will provide specific information regarding joinery connections and moldings or trim (see **Figure 32-42**).

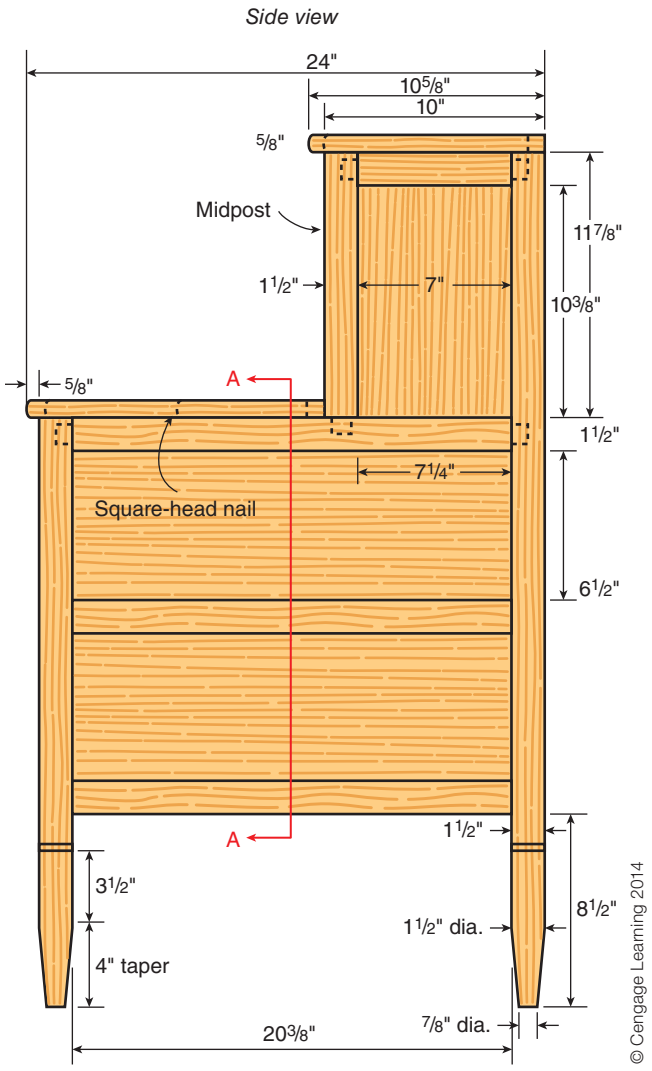


FIGURE 32-40 The section symbol A-A on this orthographic side view (here AA) refers the reader to a section drawing.

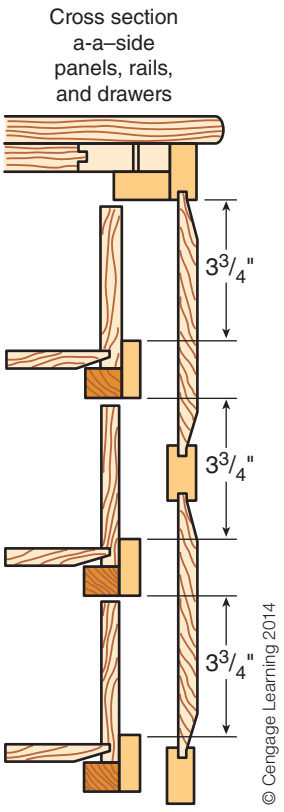


FIGURE 32-41 Section drawing.

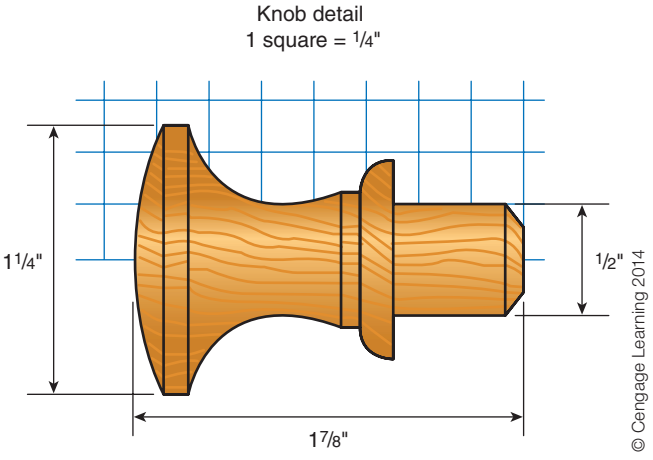


FIGURE 32-42 Detail drawing.

We stated earlier that drawings are a means of communicating information. The language used is the language of lines. Different lines are used for different purposes (see **Figure 32-43**). The lines are:

- Object lines: solid lines that outline an object, sometimes called visible lines
- Extension lines: light lines that extend from the object
- Dimension lines: thin lines placed between extension lines with arrows at either end; they indicate dimensions
- Hidden lines: dotted lines that show the outline of something that cannot be seen
- Centerline: shows the center; it is a broken line of long and short sections.

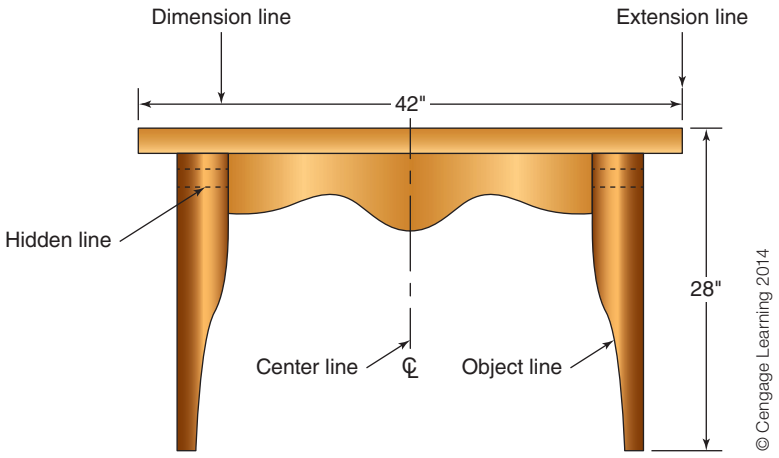


FIGURE 32-43 Languages of lines

Commonly seen abbreviations include:

- CL or C: centerline
- R or RAD: radius
- DIA: diameter
- TYP: typical
- DIM: dimension
- DWG: drawing
- RD: round
- ID: inside diameter
- OD: outside diameter
- MAX: maximum
- MIN: minimum
- NO or #: number

The Bill of Materials and Plan of Procedure

A set of working drawings will include front, side, and perhaps a top view; there may also be section views if needed and detail drawings as necessary. A complete set of drawings will also include a bill of materials and a plan of procedure. A bill of materials, sometimes simply called a materials list, is really two lists. One is a **cut list**, which is a list of all the parts needed for a given project, the number of pieces needed, and the dimensions of each piece. Sometimes each different part is lettered, which makes it easy to keep track of the various pieces, if you letter them as they are made. **Figure 32-44** shows an example of a cut list. The other part of the bill of materials is a list of the hardware and fasteners that will be needed. It may include stain and finish as well.

Table cut list

A Legs (4)	$1–3/4" \times 1–3/4" \times 25"$
B Sides (2)	$3/4" \times 6" \times 14–1/2"$
C Front top rail	$3/4" \times 1–3/4" \times 16–1/2"$
D Front bottom rail	$3/4" \times 1–3/4" \times 16–1/2"$
E Back	$3/4" \times 6" \times 16–1/2"$
F Drop-leaf supports (2)	$3/4" \times 3/4" \times 10"$
G Drawer guides (2)	$3/4" \times 1–1/16" \times 13"$
H Drawer front	$3/4" \times 4–1/2" \times 15"$
J Drawer sides (2)	$3/4" \times 4–1/2" \times 15"–1/4"$
K Drawer back	$1/2"$ x $3–3/8"$ x 14"
L Drawer bottom	$1/4" \times 14" \times 15–1/4"$
M Table top (before joinery)	$3/4" \times 36" \times 19"$
N Dowels (2)	$3/8"$dia. $\times 1–1/2"$

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FIGURE 32-44 Cut list.

Plan of procedure

Legs (A)
1. Square to size.
2. Cut mortises in all legs (six of one size and two of another).
3. Saw and chisel single dovetails on front legs.

Drop-Leaf supports (F)
1. Square to size.
2. Bevel the ends.

Sides (B) and back (E)
1. Square to size.
2. Drill screw pockets.
3. Saw recesses for drop leaf supports (F).
4. Prepare tenons on all ends of (B) and (E).
5. Drill for dowels (N) in parts (B).

Front top rail (C) and bottom rail (D)
1. Square to size.
2. Saw tenons on (C).
3. Prepare dovetails on (F).

Assembly of components (A), (B), (C), (D), and (E)
1. Smooth all surfaces that will receive finish.
2. Glue dowels (N) in sides (B).
3. Assemble and clamp (A), (B), (C), (D), and (E) without adhesive.
4. Inspect for squareness.
5. Disassemble components and lay clamps aside.
6. Coat every surface to be bonded with adhesive.
7. Reassemble, reclamp, and square the assembly.

Decide to make or buy drawer glides (G)
1. If you buy:
   a. Install them on sides (B).
   b. Change dimensions for the width of the drawer as needed.

Drawer
1. Square drawer front (H), sides (J), back (K), and bottom (L) to size.
2. Saw locking rabbet joints on (H).
3. Saw dadoes in (J) to fit the rabbets on (H).
4. Saw dadoes in (J) of (K).
5. Saw grooves in (J) for (L).
6. Assemble the drawer without adhesive.
7. Inspect for squareness.
8. Disassemble the drawer.
9. If you make drawer glides:
   a. Route the dovetail groove in (J).
   b. Square drawer guides (G).
   c. Route the edges of (G) to fit the groove in (J).
   d. Drill screw holes in (G).
10. Smooth all drawer components as necessary.
11. Coat joints (except the groove for [L]) with adhesive.
12. Reassemble with clamps and check for squareness.
13. Allow adhesive to cure and remove clamps.
14. Install the drawer with screw in (G).

Top (M)
1. Square glued workpieces to size.
2. Saw the radii on the four corners.
3. Smooth any rough saw marks.
4. Shape or rout all edges and corners with decorative router bit.
5. Make cuts ro separate the drop leaves.
6. Shape or rout the table joint with matched cutters or bits.
7. Smooth all surfaces as necessary.
8. Install the table hinges with 1/16 in. between the leaves and top.
9. Install the drop-leaf supports (F).
10. Attach (M) to the table assembly with screws in the screw pockets in (B) and (E).

Finish as desired.

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FIGURE 32-45 Plan of procedure.

A cut list also makes estimating the material needed relatively easy. A waste factor and sales tax are added, so you can predict what the cost of materials for your project will be. If you are working from plans that do not include a bill of materials, take the time to make one. If you are drawing your own plans, you will need to make a materials list.

A **plan of procedure** details how the piece is built in a step-by-step manner. If you are working from a given set of plans, it may very well include a plan of procedure (see **Figure 32-45**). If it does not, or if you are drawing up your own plans, you need to develop your own plan of procedure. It is worth the time it takes to write the plan out, because this will help you visualize the process as you write, so you can avoid potential pitfalls by thinking your way through the building process before actually putting tools to wood. The plan of procedure involves selecting the tools you will use and the processes you will undertake, as well as the sequence of operations. When your goal is the completion of a high-quality piece of work, planning is very important, because it will help you avoid wasting both time and materials. Building anything is a step-by-step process, in which one step builds upon another. Having a written plan helps you avoid missing a crucial step.

As you think your way through building something, your major concerns should be safety and

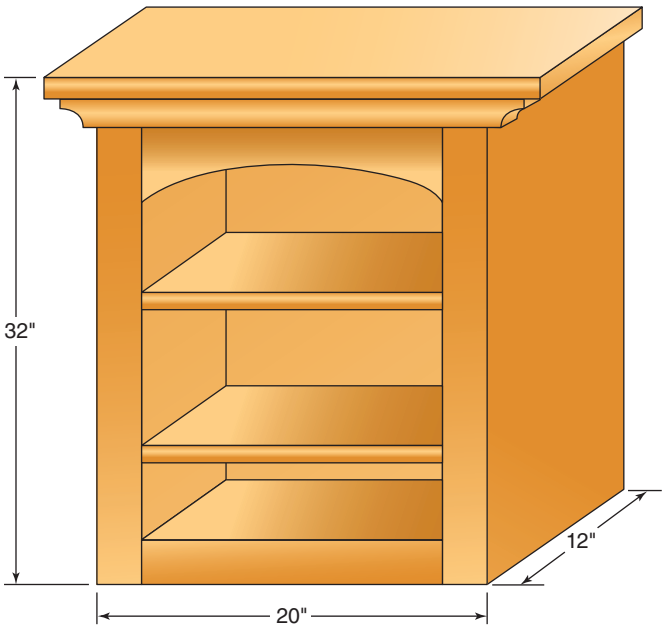
efficiency. As you identify the tools that will be used to build the piece, remember that different tools can do the same job. You should select the least risky, most accurate tool available for your use, and you must consider the appropriate safety equipment needed to use each tool. You also need to determine what blades, cutters, bits, jigs, and fixtures may be required.

Once you have the necessary drawings, a materials list, and a plan of procedure, you must obtain your materials and supplies. Materials are anything that becomes part of the finished product, which may include solid lumber or panel products, hardware, stains, and finishes. You may face decisions regarding whether to make or buy certain components. For example, you could purchase legs for a table that are already turned, or you could choose to turn them yourself. You will have to decide if you want to work with rough-cut lumber or lumber that has been surfaced. Supplies are consumable items, such as sandpaper, glue, biscuits, dowels, and other fasteners. Once you have all your equipment, materials, and supplies at hand, you will be ready to commence your project.

FROM PROJECT CONCEPT TO START OF CONSTRUCTION

Perhaps you've been handed a complete set of drawings with a cut list and a plan of procedure. Maybe you've got all the materials and supplies you'll need, and you are ready to start building. But perhaps your project is starting at the very beginning, with a need for something. In this case, there is a lot to be done before you pick up your tools and start making sawdust. Or you may have a set of plans, but lack a bill of materials and plan of procedure. Even if you already have plans, a bill of materials, and a plan of procedure, you will still need to estimate your costs and obtain the materials. The purpose of this section is to take you through the process from concept to building step by step, by means of a hypothetical example.

You have been asked to build a cabinet to display knickknacks. You start by asking a lot of questions. You want to find out what kind of cabinet is desired. Is it a base cabinet or a wall cabinet? How big? Does



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FIGURE 32-46 Sketch

it need to fit in a certain spot? Having ascertained that your customer wants a wall cabinet of a certain size, you might next ask if it should have a door or not. You find out if they are trying to match existing furniture, and if so, what is that furniture like? This will help determine the cabinet's style. Will it be solid lumber, panel products, or a combination? Should it have shelves? If so, are they adjustable or not? Should it be plain or highly decorated? Once you have answers, you will make a sketch to show the customer. You may sketch it freehand, use graph paper, or use a CAD program. It should be proportional. Based on the information you have gathered, it might look like **Figure 32-46**.

When you show the customer the sketch, you may also take along your box of wood samples with various stains and finishes, so he can make those choices. Any alterations to your sketch are discussed. Based on this information, you can now make your working drawings, as shown in **Figure 32-47**. As you make these drawings, you will be working out its construction details as well. What type of joinery will be used? Is it sufficiently strong?

Once your orthographic drawings are completed, you can use them to write your bill of materials, which will include your cut list, hardware, and fasteners (see **Figure 32-48**). If your project includes

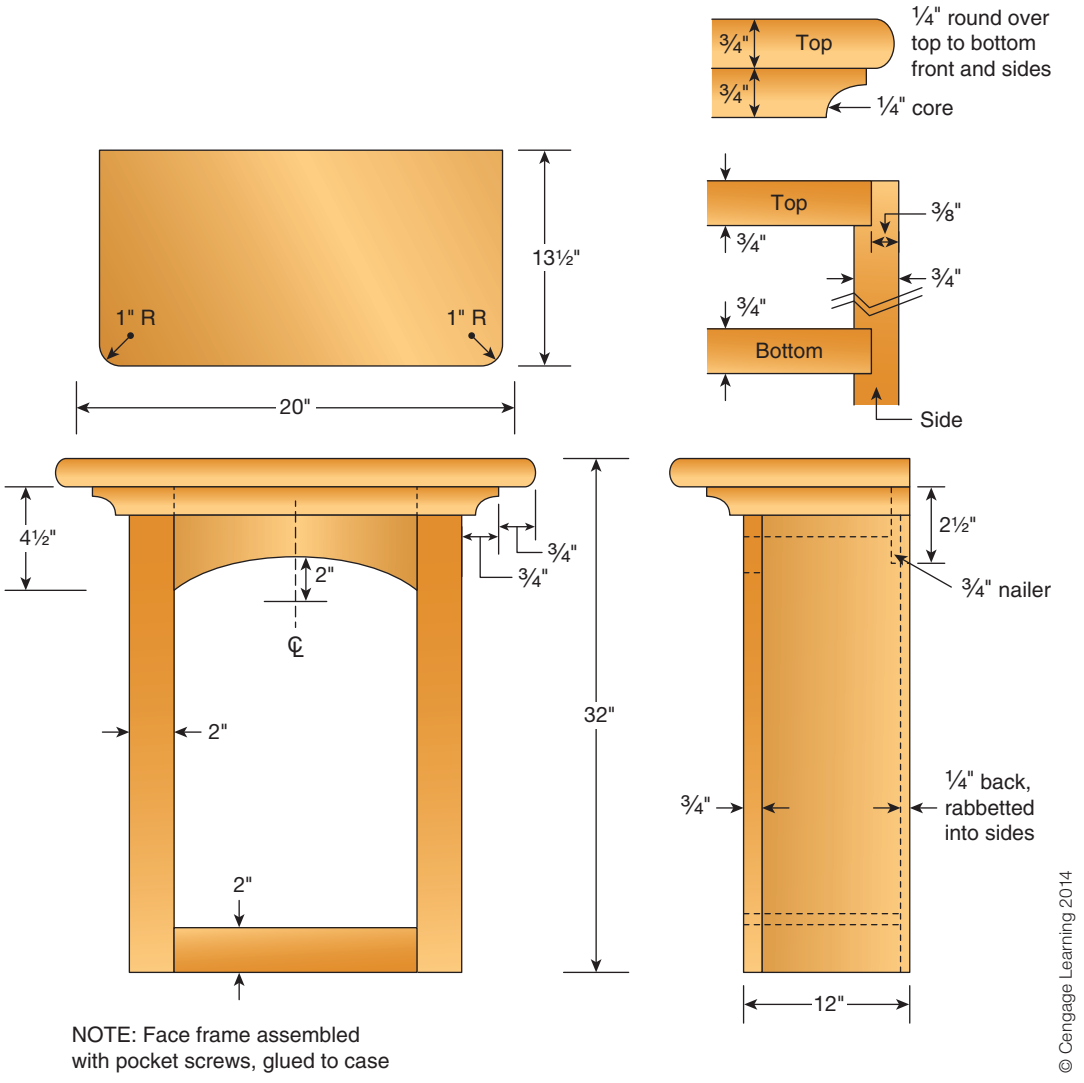


FIGURE 32-47 Working drawings

sheet goods, make a cutting diagram, as shown in **Figure 32-49**. As you were drawing, you were probably thinking about how you would build the table, so you can also write out a plan of procedure (see **Figure 32-50**).

Given your cut list, which is part of the bill of materials, you can calculate how many board feet of lumber you will need. Allow 20 percent extra as a waste factor (see **Figure 32-51**). Write out orders for your lumber and other supplies, as shown in **Figure 32-52**. Don't forget consumable supplies like glue and sandpaper. With all your orders made up, you can figure out how much your materials will cost. Remember to add sales tax.

You now know the project costs in terms of materials. Now you must figure out what to charge for your work. This is a skill you develop over time. Keeping good records will help you build a sense of how long different operations take. Write up an estimate for your customer. Present the estimate, and if it is agreed upon, you can assemble your materials and supplies and begin to build the cabinet.

	Part Name	Quantity	Thickness	Width	Length	Wood
A	Sides	2	¾″	11 ¼″	31 ¼″	Oak plywood
B	Subtop and Bottom	2	¾″	11″	16 ¼″	Oak plywood
C	Back	1	¼″	16 ¼″	31 ¼″	Oak plywood
D	Shelves	2	¾″	10″	15″	Oak plywood
E	Shelf Trim	2	¾″	¾″	15″	Oak
F	Stiles	2	¾″	2″	31 ¼″	Oak
G	Top Rail	1	¾″	4 ½″	13″	Oak
H	Bottom Rail	1	¾″	2″	13″	Oak
I	Nailer	1	¾	2 ½	15 ½″	Oak
J	Cove molding	¾	¾″	¾″	Approx. 50″	Oak
K	Top	1	¾″	13 ½″	20″	Oak
	Shelf supports	8				
	Pocket screws	8				
	Wood screws #8 × 1 ¼″	4				
	Staples					
	Golden oak stain	Quart				
	Satin polyurethane	Quart				

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FIGURE 32-48 Bill of Materials

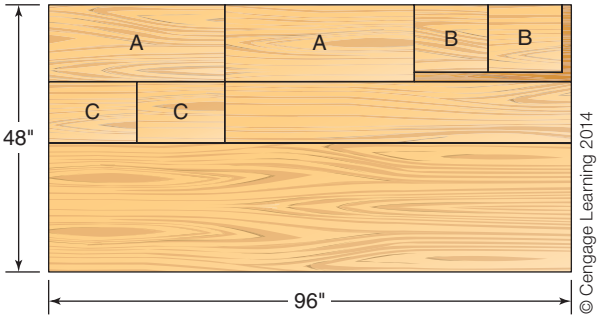


FIGURE 32-49 Cutting diagram for ¾″ plywood

1. Rip and crosscut sides, subtop and bottom, and shelves from ¾ oak plywood.
2. Dado sides for the bottom.
3. Rabbet sides for the subtop and back.
4. Lay out and drill two columns of ¼" holes 5/16" deep on the inside of each side. Space them 2" apart and 2" from either edge.
5. Sand the inside of the subtop and bottom, sides, and back.
6. Assemble case with glue; staple back in place.
7. Plane solid stock to ¾" thick.
8. Joint, rip, and crosscut stock for stiles, rails, nailer, shelf trim, cove trim, and top.
9. Glue up top oversize.
10. Install nailer.
11. Lay out and cut curve in top rail. Sand curve smooth.
12. Assemble face frame with pocket screws, 2 in each joint.
13. Glue and clamp face frame to cabinet.
14. Glue and clamp shelf trim to shelves.
15. Mill enough ¼" cove for approximately 50" of trim.
16. Cut top to size and mill ¼" roundover on the top and bottom of the sides and the front. Leave back square.
17. Attach the top to the case using #8 × 1 ¼" woodscrews driven through oversize holes in the subtop.
18. Miter and attach cove trim to front and sides of cabinet.
19. Sand.
20. Stain.
21. Apply two coats of finish.

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FIGURE 32-50 Plan of Procedure

LUMBER ORDER

Board feet = Number of pieces × (Thickness" × Width" × Length")/144

Note: The thickness of solid hardwood stock is measured by the quarter. S2S stock (surfaced two sides), while actually 13/16" thick, is referred to as 4/4, hence 1" is used in calculating for board feet.

	Part	#	T	W	L	Board Feet
E	Shelf Trim	2	1	¾"	15"	.16
F	Stiles	2	1	2"	31 ¼"	.87
G	Top Rail	1	1	4 ½"	13"	.41
H	Bottom Rail	1	1	2"	13"	.18
I	Nailer	1	1	2 ½	15 ½"	.27
J	Cove molding	¾	1	¾"	Approx. 50"	.26
K	Top	1	1	13 ½	20"	1.88

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Total board feet = 4.03
20% waste factor = 4.03 * .2 = . 81
Total board feet required = 4.84
Buy 5 BF of 4/4 oak

FIGURE 32-51 Calculating board feet

Item	Quantity	Size	Unit Cost	Total Cost
4/4 Oak	5 BF	4′ × 8′		
¾″ oak plywood	1 sheet	4′ × 8′		
¼″ oak plywood	1 sheet			
Shelf supports	8			
Pocket screws	8	#8 × 1 ¼″		
Wood screws #8 × 1 ¼″	4	Quart		
Golden oak stain	1	Quart		
Satin polyurethane	1			
Sandpaper				
Glue				
COST before tax				
TAX				
FINAL COST				

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FIGURE 32-52 Lumber and supplies order



Summary

Designing a project requires a number of steps and concepts that must be considered. Being familiar with design styles of the past and present gives you an inspirational base. All furniture and cabinetry has both a form, which is what it looks like, and a function, which is what it does. Function takes precedence over form. Variables such as who will use the piece and certain standards must be taken into consideration. Design principles should govern the form of the piece, and design decisions must be made throughout the process. A complete set of drawings should give the builder all the information needed to the build the piece. A materials list and a plan of procedure form an integral part of the set of drawings, making a good estimate possible and giving the builder a sequential plan for construction.



Key Terms

arithmetic progression
balance
closed form
color
contrast
cut list
design principles
detail drawing
elements of design
Fibonacci series
form
formal balance
function
geometric progression
golden mean
golden section
harmonic progression
harmony
informal balance
isometric drawing
lines
mass
open form
orthographic drawings
plan of procedure
primary horizontal mass
primary vertical mass
proportion
repetition
section views
shapes
standards
texture
tone
variables



Check Your Knowledge

1. Why should function be given precedence over form?
2. List and give examples of the design elements.
3. List and define the design principles.
4. What are three rules for dividing space within a frame?
5. What are four common design errors?
6. List two design decisions faced by the designer.
7. How does familiarity with various design styles help today's designer?
8. What is the difference between an orthographic drawing and an isometric drawing?
9. How does a cut list help the builder?
10. What is a plan of procedure? What value does a written plan have?



Activities

1. Design an end table or other project.
   - Make a sketch.
   - Draw up the orthographic drawings needed.
   - Make up a bill of materials.
   - Write a plan of procedure.
2. Explain how your project is congruent with each of the design principles.



33

Fabricating Countertops

You'll Learn

After studying the chapter, the student should be able to:

- List various countertop materials
- Cite advantages and disadvantages of different countertop materials
- Explain the process for fabricating a laminate countertop
- Explain the process for fabricating a solid surface countertop

INTRODUCTION

Countertops consist of a flat surface and often a **backsplash**. A backsplash is an upright border behind the countertop that is placed against the wall to protect it (see **Figure 33-1**). Countertops are subject to a lot of wear and abuse. For this reason, the materials used for countertops must be tough, durable, resistant to scratching, and impervious to boiling water and household chemicals. In this chapter, we will look at the various materials that are used for countertop fabrication, along with the advantages and disadvantages of each. Then we will explore countertop fabrication with two materials that can be easily worked with woodworking tools.

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FIGURE 33-1 Countertops consist of a flat surface and often a backsplash.

COUNTERTOP MATERIALS

Numerous materials are used for countertops. Among them are ceramic tile, granite, marble, soapstone, concrete, metal, wood, plastic laminates, and solid surface materials.

Ceramic tile is a product made from clay and other materials; tile is fired in a kiln to harden it. Ceramic tile is easy to clean and durable, although it is somewhat brittle. It is not scarred by hot pans, is relatively inexpensive compared to other countertop choices, and the array of color choices, sizes, textures, designs, and possible patterns is huge. **Figure 33-2** shows an example of a ceramic tile countertop. On the negative side, if the counter surface is uneven, tiles can crack or chip, and grout lines can become stained over time.


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FIGURE 33-2 Ceramic tile countertop.

Granite has become a very popular countertop material. A natural stone found around the world, granite comes in a variety of colors and patterns. No two pieces are identical, so when purchasing more than one piece, they should come from the same source. Granite is typically sold in two thicknesses: 3/4 and 1 1/4 inches. It holds up to heat, and it is beautiful and substantial looking, but it is also very expensive. Granite is heavy, so the cabinets beneath it must be sturdy enough to support the weight. Because granite is also somewhat porous, it will stain if acidic substances, such as lemon or orange juice, sit on it for any length of time. Cooking oil will also stain it. It is necessary to seal granite periodically to prevent staining. Also, most granite countertops are highly polished. Although this is very attractive, it also means that fingerprints and water spots will be highly visible. **Figure 33-3** shows an example of a granite countertop.



SCIENCE CONNECTION

Granite is an igneous rock formed from quartz, feldspar, and mica. It has a crystalline, coarse-grained texture, is extremely hard, and will last indefinitely. ■

Marble is a natural stone, and it is very expensive. It is waterproof, heatproof, and very beautiful. Like granite, marble is porous, stains easily, and must be sealed periodically.

Soapstone, like granite and marble, is a quarried natural stone. It is generally a rich, dark gray in color and very smooth to the touch. It is often seen


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FIGURE 33-3 Granite countertop.

in historic homes but is also used in modern homes. Soapstone is more stain resistant than either granite or marble, but it should still be sealed periodically with either a stone sealant or mineral oil. Stains that do occur are superficial and can be scrubbed or sanded out. Soapstone has long been used as a countertop material in science labs.



SCIENCE CONNECTION

Soapstone is a steatite stone whose primary components are magnesite, dolomite, chlorite, and talc. It is the talc that gives the stone its soft feel, like a dry bar of soap, which gave it its name. Soapstone has been used for thousands of years for a variety of things: tools, vases, sculptures, countertops, sinks, and fireplaces. It retains heat naturally, which has made it a popular choice for masonry fireplaces, woodstoves, and pizza ovens. ■

Concrete is becoming a more popular choice for countertops. It is a construction material that consists of Portland cement, gravel, sand, and water. Although concrete is heavy, recent innovations have resulted in a concrete mix specific for countertops that is more than 30 percent lighter than regular concrete. It is a good choice for unusually shaped areas, and it is often cast in place. It can be color tinted, objects can be set into it if desired, and different textures can be achieved. It is porous, but new additives reduce porosity; it should still be sealed. Concrete is heat and scratch resistant. Negative features include high cost and possible cracking, as well as the need for periodic sealing.

Metal used as a countertop material is frequently seen in commercial or industrial settings, although it has become more common in residences. **Figure 33-4** shows an example of a metal countertop. Commonly used metals are zinc, copper, and stainless steel, and they are often attached to a plywood substrate and are seamless. These metals are nonporous, heat resistant, and durable. They can handle hot pots and will not stain. They are very smooth, easy to clean, and will not chip. However, metal countertops are expensive and noisy. They may dent, and you cannot cut on them without dulling knives. They can be scratched, and they show fingerprints. When cleaning, an abrasive pad should not be used, because it will scratch the surface.

Hard maple is the most commonly used wood for countertops due to its tight grain and exceptional hardness. Wood is a warm material and makes a beautiful surface. It is smooth and easy to clean, will not damage knives, and it acts as a convenient chopping and food preparation area. The wood will be scarred by knives, but the surface can be renewed by sanding it. It must be sealed periodically with mineral oil, which is nontoxic. It can be damaged by water, will stain, and can be scorched by hot pots. A section of countertop may be wood, with the rest of it made from another type of material.

Laminates are the most commonly used material for kitchen countertops (see **Figure 33-5**). Plastic laminate is a synthetic material that was described in Chapter 12. Laminates are available in a wide range of colors, patterns, and finishes. Some of the hundreds of choices simulate the look of stone or wood countertops, and different textures are available. These are attached to a smooth substrate such as particleboard. Laminates are impact resistant, easy to clean, and



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FIGURE 33-4 Metal countertop.



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FIGURE 33-5 Laminate countertop.

inexpensive compared to other countertop materials. On the negative side, laminates can be scorched, chipped, and are difficult to repair. They cannot be cut on or cleaned with harsh abrasives, or they will scratch. Scratches and chipping are highly visible, because the pattern and color is only on the surface of the material. Seams are visible, and water seeping into seams may cause the product to delaminate.

Solid surface material is a synthetic product that consists of a mixture of mineral compounds and polyester or synthetic resins (see **Figure 33-6**). As its name indicates, it is solid throughout, so scratches do not reveal an underlying color or substance that is different from the top, as is the case with plastic laminate. Scratches on solid surface countertops can be sanded out, and dents can be repaired.

Solid surface material is made by several different manufacturers and is available in many different colors and patterns. It can have different finishes, from gloss to matte, and solid surface colors and patterns can be purchased that simulate stone quite successfully. Solid surface material comes in sheets that can be joined in such a way that the countertop appears seamless, and it forms a smooth, uniform surface that is stain resistant. Though moderately expensive, it is not as expensive as natural stone.

Solid surface material has some disadvantages: It is stain resistant, but not stainproof. However, since solid surface is nonporous, stains can be scrubbed or sanded out. To avoid surface scratches, a cutting board should be used. Care must be taken when placing very hot items on the countertop, because it is vulnerable to cracking as it cools down.



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FIGURE 33-6 Solid surface countertop.

GREEN PRACTICES

Remove charged batteries from their chargers, and unplug chargers when not in use.

FABRICATION WITH LAMINATES

Laminates were covered in Chapter 12. In this section, we will cover how to use this material in the fabrication of countertops. Laminates are quite thin and are affixed to a smooth, solid substrate. Laminate is very hard, but it does not have much strength unless it is attached to another material. Plywood, particleboard, or MDF may be used as a substrate for laminates. A smooth, dimensionally stable base is required; particleboard is used extensively.

Before applying laminate, the substrate must be constructed. Since countertops are typically 1 1/2″ thick, the substrate must be built up around its edges, because the material used for countertop cores is 3/4″ thick. Additionally, any joints and cutouts in the core material must be reinforced. Building up the edges of the substrate involves gluing and screwing 3″–4″ wide strips around the perimeter of the bottom of the substrate and at 24″ intervals across its width. The same material that forms the core material can be used for these strips, or 3/4″-thick lumber, such as pine, may be used (see **Figure 33-7**). Joints and cutouts in the substrate are reinforced in the same manner. A common example of a cutout is the opening that is cut for installing the sink (see **Figure 33-8**). If a molding will be attached to the front of the countertop, and any part of the laminate will extend over it, it needs to be installed prior to the laminate being laid (see **Figure 33-9**).

Laminates come in standard widths of 24, 30, 36, 48, and 60 inches. Standard lengths are 5, 6, 8, 10, and 12 feet. In selecting sizes for purchase, plan your layout so that you will have as few seams as possible and the least amount of waste. Laminate can be cut with a handsaw, portable saw, table saw, or router; it can also be scored and snapped. **Figure 33-10** shows a laminate scoring tool and how it is used.

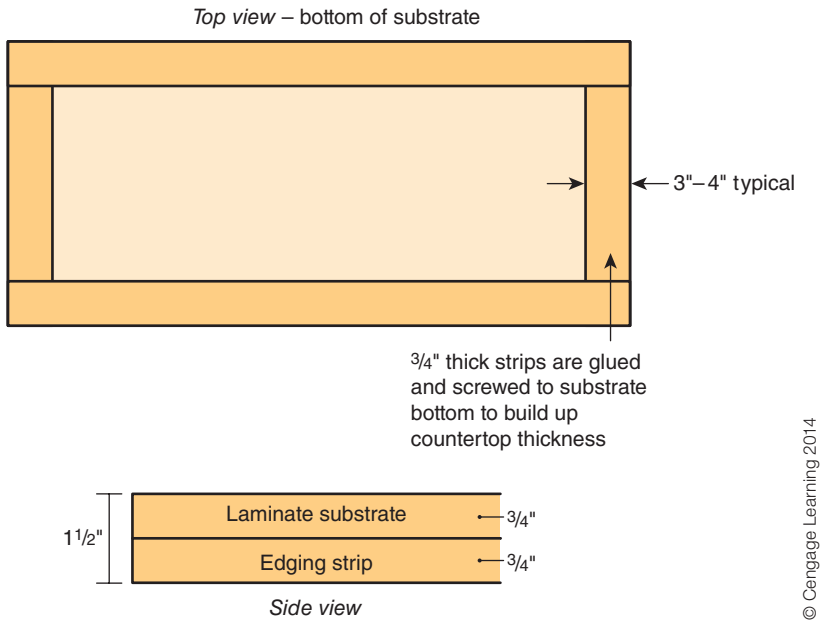


FIGURE 33-7 The bottom edges of the substrate are built up.

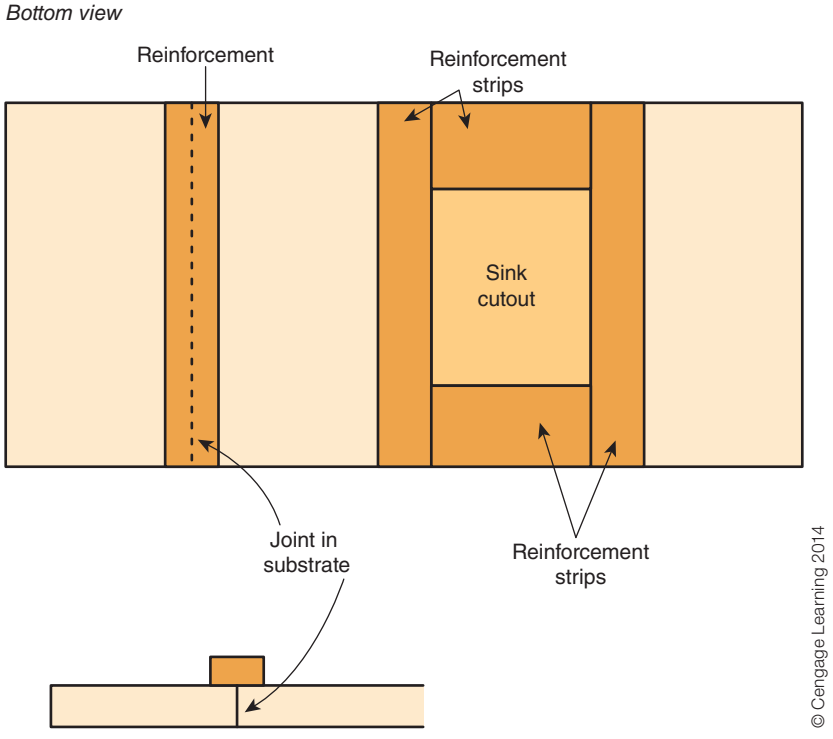
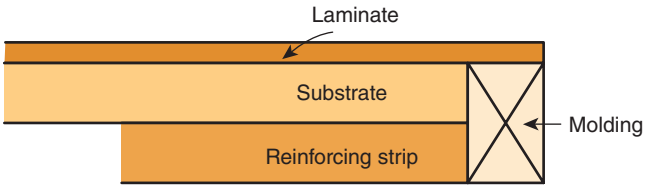


FIGURE 33-8 Joints and cutouts are also reinforced.

When cutting laminate with a portable power saw, it should be cut with the decorative side down to avoid chipping. If a table saw is used, the laminate should be cut with the finish side up (see **Figure 33-11**). In either case, use a fine-toothed blade, such as a plywood blade or a carbide-tipped blade. Triple chip grind blades are recommended for use on the table saw. Laminate dulls cutters quickly, so if much cutting is to be done, carbide blades and bits are recommended.



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FIGURE 33-9 Laminate may extend over molding applied to the counter's edge.

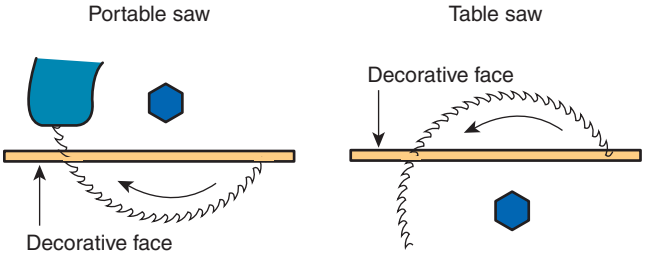


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FIGURE 33-10 Laminate scoring tool.



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FIGURE 33-11 Cutting laminate with a portable saw and on the table saw.

CAUTION

Laminate is a very thin material, so care must be taken when cutting it on the table saw so that it does not slide under the fence and become a potentially dangerous situation for the operator. Attaching a wooden fence to the regular fence and making sure it is tight against the table will prevent this problem.

Laminate pieces are initially cut a bit oversize, from 1/4 to 1/2 inch. They are trimmed after mounting on the substrate with contact cement. The contact cement is applied to both the substrate and the back of the laminate with a brush, roller, or spreader. The surfaces it is applied to should be completely clean, dry, and dust-free. Any particles left on them will be trapped between the laminate and substrate and will interfere with the bond; larger particles will show up as lumps in the final product.

Contact cement should be thoroughly stirred prior to application and must be applied as smoothly as possible. The cement is allowed to dry, and then the laminate is carefully placed on the substrate. When dry, the cement will have a glossy appearance; if there are dull spots, apply more adhesive. The bond is instant upon contact, so there is no room for error.

CAUTION

Some contact adhesives are highly flammable, so appropriate precautions must be taken. Contact adhesives are also hazardous to breathe, so work in a well-ventilated area and wear a respirator.

If laminate will be applied to the edge of the countertop, it should be attached before the top is attached. This way, the laminate placed on the top of the counter laps over the laminate placed on the edge. The seam is not quite as visible, and the joint is less susceptible to water working its way into it (see **Figure 33-12**). As with the top piece, this strip of laminate is applied slightly oversize and then trimmed even with the substrate (see **Figure 33-13**).

The order in which laminate is applied to a surface depends on the amount of wear each surface will get and on appearance. The top of a counter receives the most wear, so this piece is applied last. When laminating doors or drawer fronts, the back, if it is to be laminated, is laminated first; next, the bottom edge

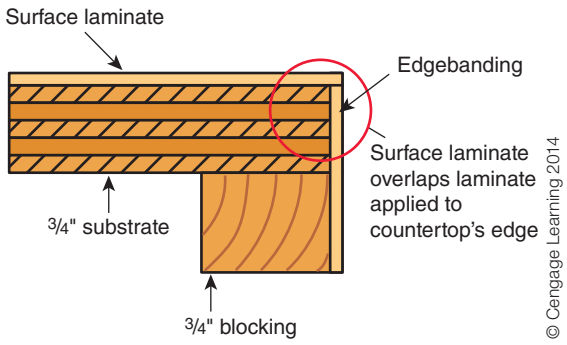


FIGURE 33-12 Laminate applied to the countertop's edges is applied before the top piece of laminate.

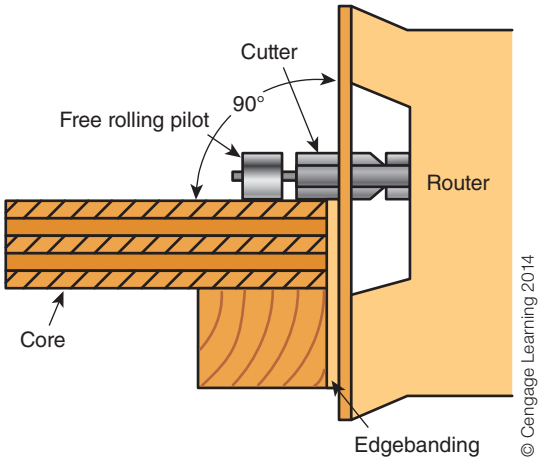


FIGURE 33-13 Trimming the edging laminate.

is laminated, then the sides, the top edge, and finally the front. This offers the most protection for the door or drawer front, and this order of installation ensures that the seams are not visible when the door or drawer is closed (see **Figure 33-14**). If the edge of the counter is rounded, warming the edge strip of laminate with a heat gun or iron will make it flexible enough to ease around the curve (see **Figure 33-15**).

GREEN PRACTICES

Choose to use a low VOC content waterborne contact cement, which is also nonflammable.

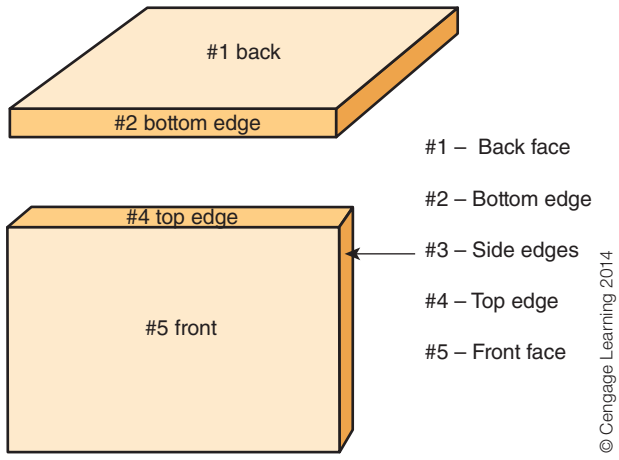


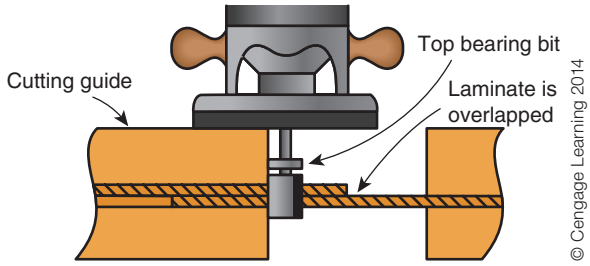
FIGURE 33-14 Order of laminate installation for a door or drawer front.



FIGURE 33-15 Heating laminate makes it easier to work around a curve.

If the surface laminate needs to be pieced, it is very important to get the best joint possible. Not only must the joint be inconspicuous, but the better the joint, the less likely it is that water will work its way into the seam and cause lifting and laminate failure. The best way to ensure a good joint is to cut both of the adjoining laminate pieces at the same time. The ends of the two pieces are overlapped by an inch or so, secured between cleats attached to a workbench, and then cut flush simultaneously with a straight bit in a router (see **Figure 33-16**). Seams near a sink area should be avoided, because of the potential for water damage.

When applying laminate to a large area, such as the top surface of a countertop, use heavy paper as a slip-sheet, or place clean, thin strips of wood or dowel rods across it at approximately 8-inch intervals (see **Figure 33-17**). This prevents the laminate from



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FIGURE 33-16 Adjoining pieces of laminate are cut simultaneously for a good joint.


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FIGURE 33-17 A slip-sheet, thin strips of wood, or venetian blind slats are used when laminate is applied to a large surface.

coming into contact with the substrate. The slip-sheet is gradually pulled out as the laminate is pressed in place. The sticks work the same way. After initial contact, pressure is applied to the laminate with a hand roller (see **Figure 33-18**). Work from the center to each edge, making sure that every bit of the surface receives equal pressure.

Once the laminate has been securely attached to the substrate, the waste protruding past the edge of the surface is trimmed off. This is typically done with a laminate trimmer, using a piloted flush-cut bit (see **Figure 33-19**).

WOODWORKING TIP:

Slats from venetian blinds work well to separate the laminate and its substrate as it is bonded together.


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FIGURE 33-18 Pressure is applied with a roller.

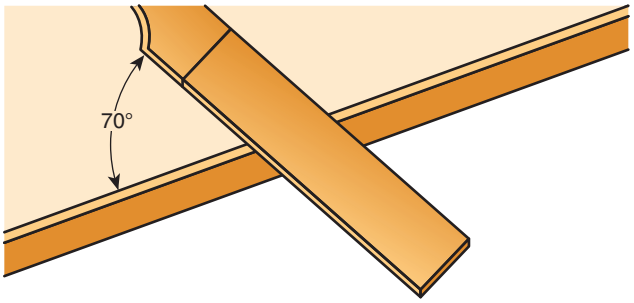

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FIGURE 33-19 Trim off the overhanging laminate.

Once the laminate has been secured to the substrate and trimmed flush, the edge of the laminate is beveled. Prior to beveling, the edge is very sharp. Beveling can be done with a mill file or a router. This eases the edge and extends its life (see **Figure 33-20** and **Figure 33-21**). Sometimes edges are attached to the countertop after the top is laminated. The edges may be wood, metal, or plastic (see **Figure 33-22**).

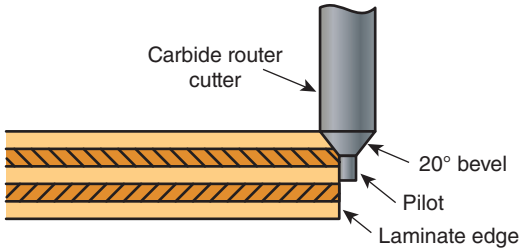
CAUTION

The edges of laminate are very sharp, so wear gloves when handling it.



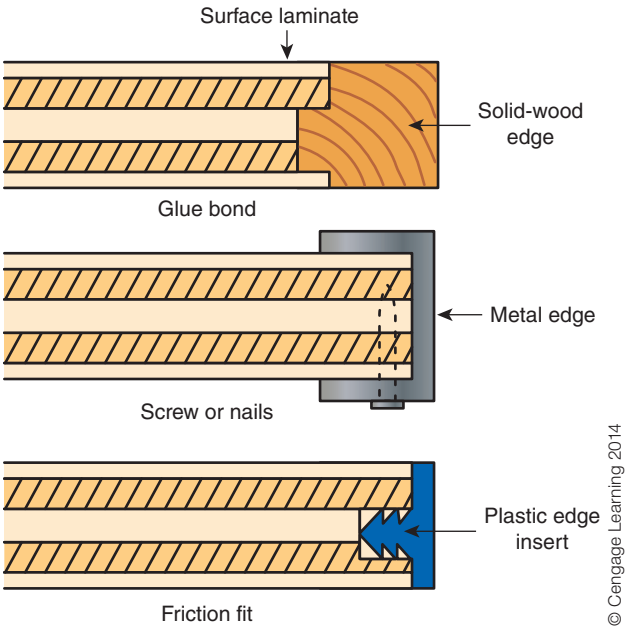
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FIGURE 33-20 Beveling the edge with a mill file.



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FIGURE 33-21 Beveling the edge with a router.



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FIGURE 33-22 Wood, metal, or plastic edges may be applied after the top surface is laminated.

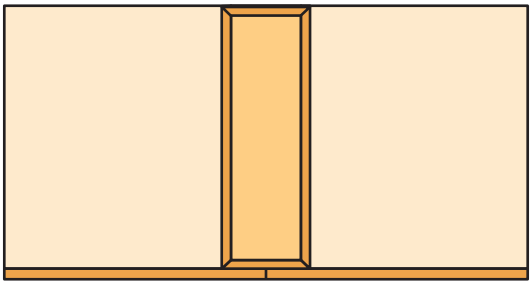
In order to achieve a long-lasting laminate bond, the bottom of the substrate must be sealed, so it will not absorb moisture. Because the laminated top will not absorb moisture, this inequality can cause delaminating problems later. A thin liner sheet of laminate can be applied to the bottom of the countertop, or it can be sealed with several coats of finish.

Fabrication with Solid Surface Material

Solid surface materials were covered in Chapter 12. They can be worked with woodworking tools, although carbide blades and bits are strongly recommended. Triple-chip grind saw blades should be used for the smoothest cuts. A router, preferably 3 horsepower or greater, is required.

The placement of seams in solid surface countertops is important. No seams should be placed within an inch of any corner or within 3 inches of a dishwasher or stove. All seams must be reinforced with a 4-inch-wide seam support made of solid surface material glued in place. The seam supports are beveled to 45 degrees along each edge (see **Figure 33-23**).

When joining two pieces of solid surface material, the adjoining edges are first machined using a router fitted with a sharp straight bit and a straightedge. The seam should fit tightly when dry fit. The area to be joined is cleaned thoroughly with a clean white rag and denatured alcohol. The sheet is placed face down, and glue blocks are attached with hot melt adhesive (see **Figure 33-24**). The two pieces to be joined are separated about 1/4 inch, and the seam is filled with a two-part adhesive applied with a special gun. The adhesive consists of a catalyst and a color that is made to match the solid surface material. When dry, these form a chemical bond that becomes one with the sheet. The two pieces to be joined are pushed together, and then the seam is clamped (see **Figure 33-25**). Clamps should be snug but not over-tightened; when a clamp is too tight, it will squeeze too much of the adhesive out of the joint, causing a weak seam.



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FIGURE 33-23 Seam support for solid surface countertops.

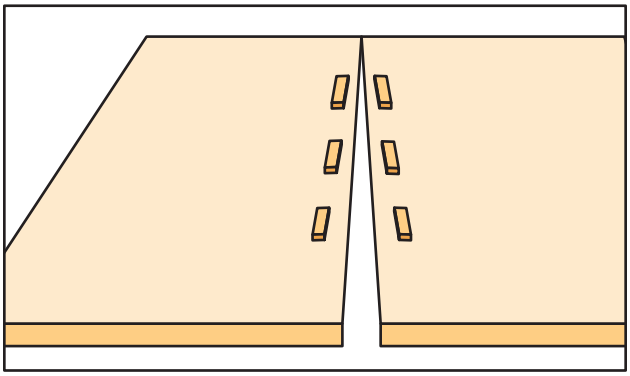

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FIGURE 33-24 Clamping blocks are attached to the two pieces with hot melt adhesive.

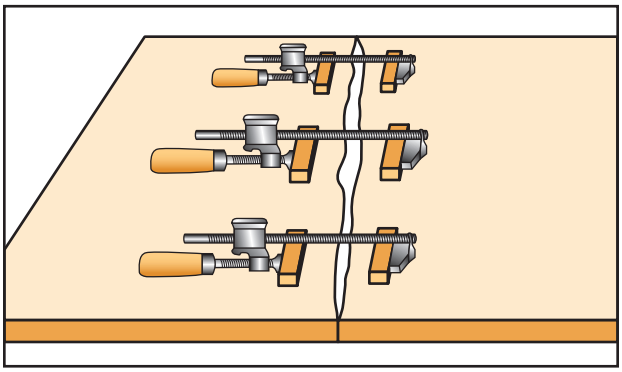
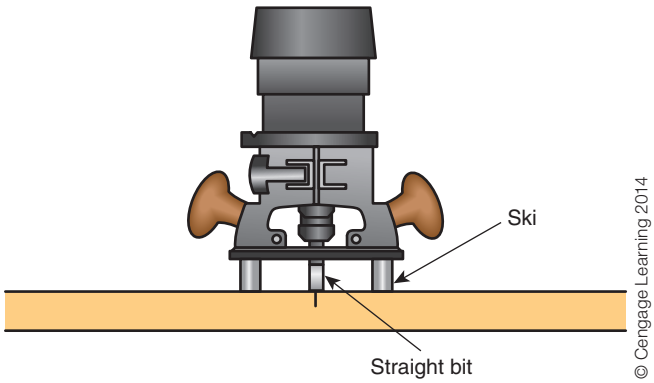

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FIGURE 33-25 The two pieces are slid together and clamped.



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FIGURE 33-26 A ski router is used to remove squeeze-out.

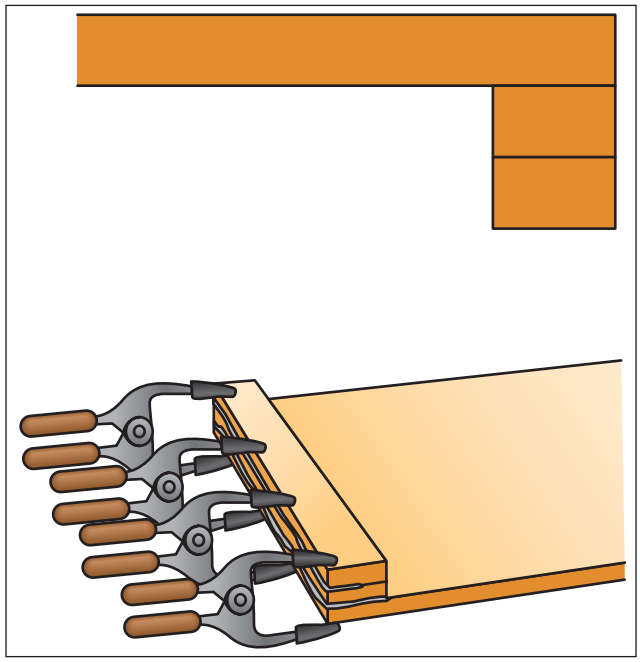

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FIGURE 33-27 A drop edge fabricated using the stacking method.

The adhesive cures rapidly, and after 15 minutes, the clamps can be removed. The squeeze-out is removed with a router mounted on two blocks of wood, called *skis,* and a straight bit (see **Figure 33-26**). It is important that seaming be done on a flat surface. After the excess adhesive is routed off, the reinforcing strip is attached using the same adhesive.

Reinforcement is also required at inside corners and at any cutout. Blocks of solid surface material, a minimum of 5 inches square at corners and 3 inches square at the corners of cutouts, are glued in these areas with the same adhesive used for seam joints. All inside corners must be routed to a minimum radius of 1/2 inch to reduce stress. Solid surface material has some of the same properties as stone, one of which is that it will crack. Avoiding 90-degree corners helps alleviate this potential problem.

A drop edge can be placed on the countertop using one of two methods. The stacking method is stronger and is preferred. A sandwich consisting of two narrow strips of solid surface material is glued to the counter edge (see **Figure 33-27**). Spring clamps placed at 3-inch intervals hold them in place while the adhesive dries. After the excess glue has dried, it is cleaned off with a straight, piloted router bit, as shown in **Figure 33-28**. The stacking method provides the option of inserting another color (see **Figure 33-29**). Inlays of other materials, such as wood, metal, or laminate, are also possible. These should be inserted in a routed groove (see **Figure 33-30**). They are held in place with silicone.

The second method is called a *vertical drop edge,* in which a single piece of solid surface material placed on edge is adhered to the countertop. This style of

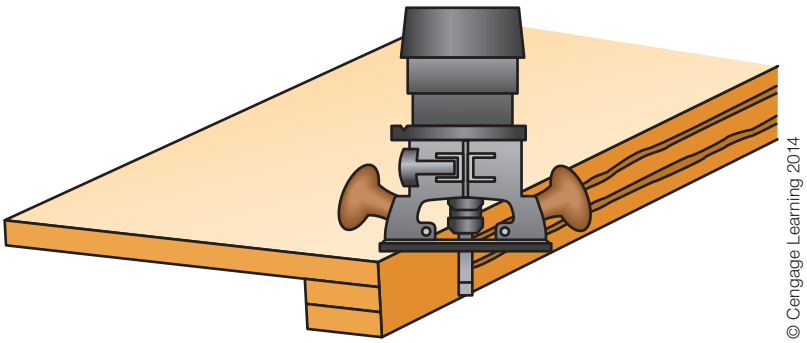

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FIGURE 33-28 Excess dried adhesive is cleaned off with a piloted straight bit.

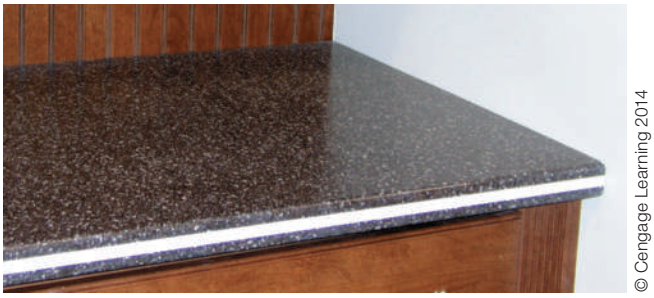
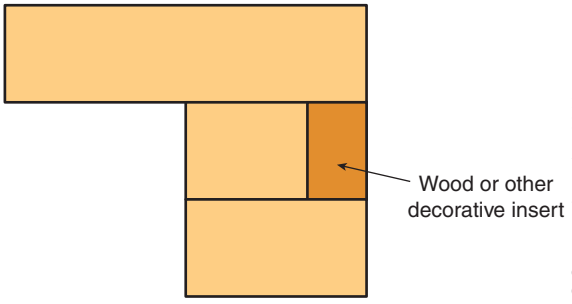

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FIGURE 33-29 The stacking method allows for insertion of a different color.

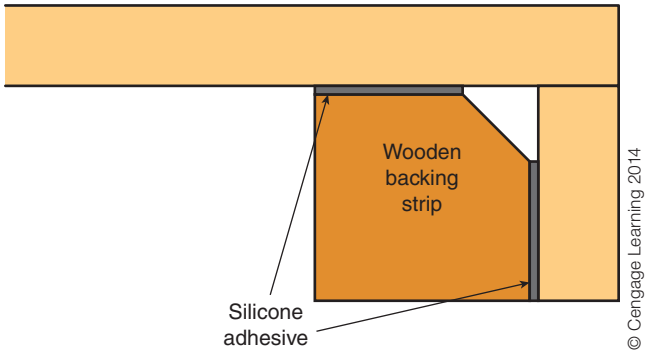


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FIGURE 33-30 Materials other than solid surface are inserted into a routed groove.

edge should be reinforced with a wooden backing strip to increase its strength. The backing strip is held in place with silicone (see **Figure 33-31**). The inside corner of the backing strip is chamfered to be sure it fits snugly in place.

A wooden web-support system is attached to the bottom of the countertop with silicone adhesive. The web support is a permanent part of the countertop; it supports the top and the weight loads placed on it and distributes the weight to the kitchen cabinets. A web support is usually 1 inch thick and 4 inches wide, and it goes on the bottom of the countertop around



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FIGURE 33-31 A drop edge created using the vertical method.

the perimeter. Corners require extra support, as do any cutouts (see **Figure 33-32**). Recommended web-support materials include MDF, particleboard, and plywood. Lumber, such as pine or poplar, can also be used. Sections that are joined and have a seam support beneath them get a half-inch-thick web support.

Solid surface countertops can have a profile routed on their edge. **Figure 33-33** through **Figure 33-35** show some examples. This is done with a carbide bit in a router. Sinks made of solid surface material can be purchased and affixed to the bottom of the countertop to become an integral part of the counter (see **Figure 33-36**).

Solid surface countertops are attached to cabinets with dabs of silicone, rather than continuous beads. No mechanical fasteners should be used. If a backsplash is to be installed, it is attached to the countertop after installation with a bead of silicone (see **Figure 33-37**). It is attached to the wall in the same manner. Because silicone residue can be a problem, silicone squeeze-out should be thoroughly removed, leaving only a small, inside corner bead.

Solid surface countertops can be sanded to the desired finish, which can range from matte to very glossy.

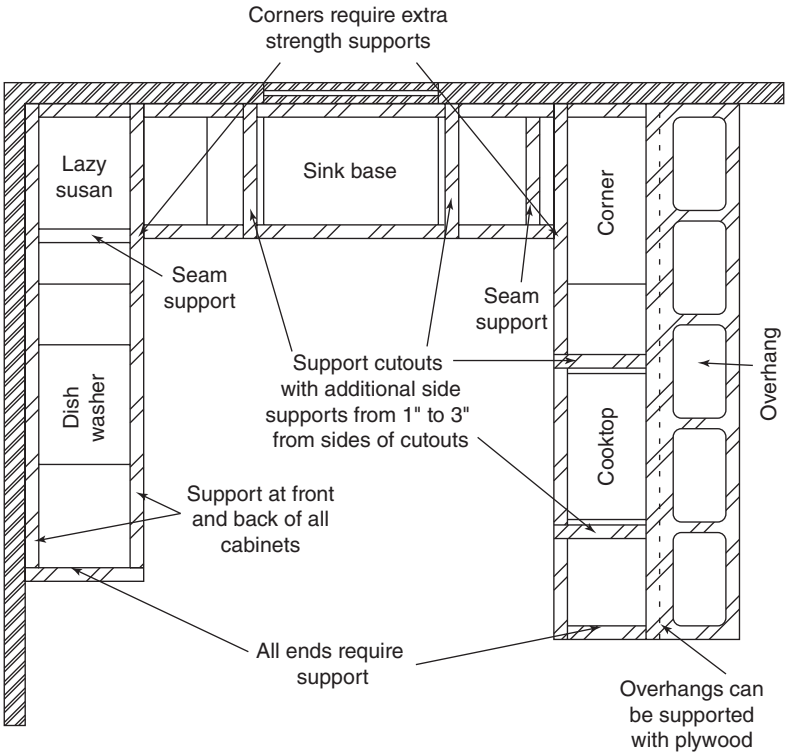


FIGURE 33-32 Web support for solid surface material.



FIGURE 33-33 Rounded edge.



FIGURE 33-34 Chamfered edge.

A mesh pad with a foam core and a random-orbit sander with dust collection should be used. A matte finish is most forgiving; a mirror finish shows scratches most readily. Different manufacturers recommend different types of sanding materials, so the manufacturer's recommendations should be consulted. Between sanding steps, dust should be thoroughly removed with glass cleaner, denatured alcohol, or a tack cloth.

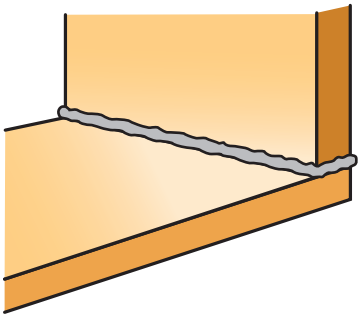


FIGURE 33-35 Ogee edge.

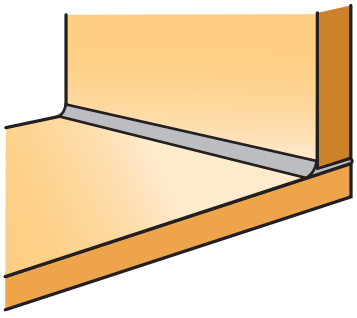


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FIGURE 33-36 Integral sink.



A bead of silicone is applied to the bottom and back of the backsplash and then it is set in place.



Excess silicone squeeze out must be thoroughly removed, and remainder smoothed.

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FIGURE 33-37 Backsplash is adhered to the countertop and wall with a continuous bead of silicone.



Summary

Countertops are subject to significant wear and tear, which they must be able to withstand. Various materials are used for countertops, including different natural stones, ceramic tile, concrete, metal, wood, plastic laminate, and solid surface materials. Each has advantages and disadvantages. The two types of countertops most frequently fabricated by cabinetmakers are plastic laminate countertops and solid surface countertops. These are usually partially or completely built in the shop and then transported to the job site. Both types can be constructed using tools typically found in a woodworking shop.



Key Terms

backsplash
ceramic tile
concrete
granite
marble
soapstone

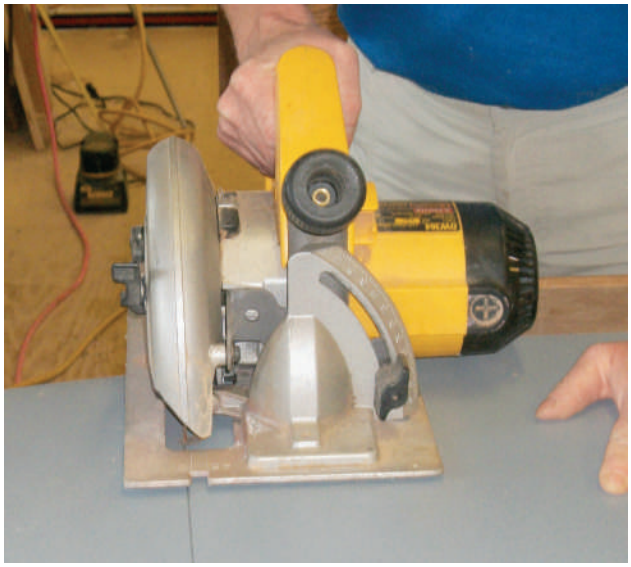


Check Your Knowledge

1. What types of abuse are kitchen countertops subjected to?
2. List five materials used for countertops, and cite advantages and disadvantages of each.
3. When cutting plastic laminate on the table saw, should the good face be up or down?
4. Name one place on a countertop where seaming should be completely avoided when using plastic laminates.
5. Why is a mirror finish on a stone or solid surface countertop less durable than a flatter finish?
6. How is the best joint achieved when creating a seam with plastic laminates?
7. Why is it so important for the substrate and the back of the laminate to be completely clean and free of any debris before contact cement is applied?
8. What are two methods for putting edges on a solid surface countertop? Which is stronger?
9. What areas of a solid surface countertop need reinforcement?
10. If you are working with a tight budget, what countertop material will give you the best results for the least amount of money?



What's Wrong with This Picture?



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BUILD IT!

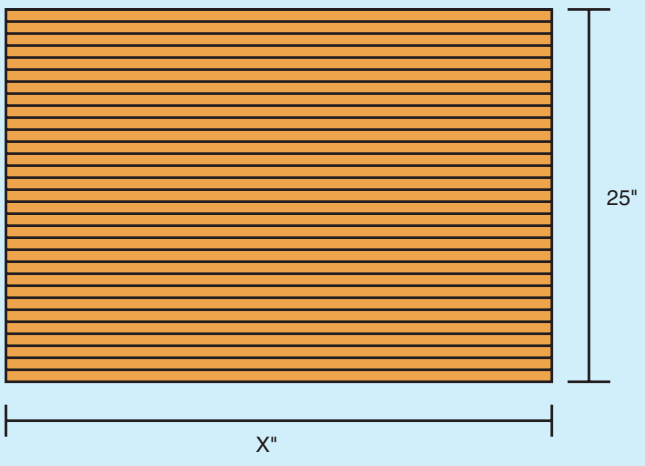
Butcher-Block Countertop Section



A

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Top view



Using 4/4" stock

Note: 4/4" stock is 13/16" thick after dressing

25" ÷ 13/16" (0.8125) = 30.77

= 31 pieces

Using 5/4" stock

Note: 5/4" stock is 1 1/16" thick after dressing

25" ÷ 1 1/16" (1.0625) = 23.53

= 24 pieces

B

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Figure A shows a section of butcher-block countertop.

TOOLS REQUIRED

- Measuring tool
- Miter saw
- Table saw
- Plane
- Sander

MATERIALS REQUIRED

- 4/4 or 5/4 hard maple, surfaced two sides
- Glue
- Mineral oil

STEPS

1. Decide the length of the countertop you want to make. Figure out how many pieces you will need by dividing the desired width of the countertop by the thickness of the boards. Cut the boards an inch longer than the desired length. see **Figure B**.
2. Joint and rip boards to 1 9/16".
3. Glue up and clamp boards face to face, alternating clamps on the top and bottom of the assembly, taking care to keep the top edges aligned as closely as possible.
4. Remove glue squeeze-out with a chisel and then plane and sand both sides of the assembly smooth.
5. Cut to final width and length.
6. Finish with mineral oil.

PROJECT CHALLENGE

Laminated Countertop Section

Figure A shows a section of laminated countertop.

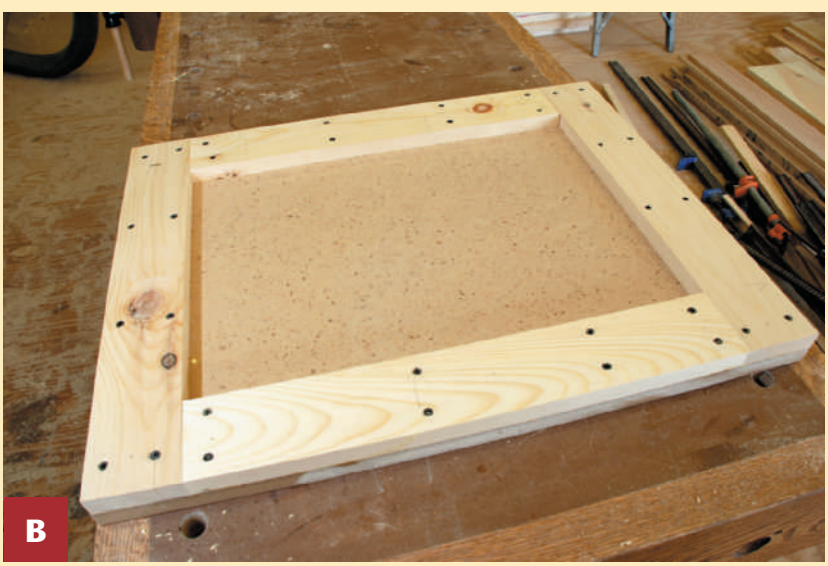
STEPS

1. Decide what size your countertop will be and cut a piece of MDF or particleboard to that size.
2. Rip 3″-wide strips of substrate material, or 3/4″ pine, and glue and screw to the bottom of the substrate, as shown in **Figure B**.
3. Make sure all edges are flush. Trim if necessary.
4. Cut slightly oversized strips of laminate to cover the edges.
5. Make sure all surfaces are clean; apply contact cement to the edges of the countertop substrate and the backs of the laminate strips. Allow the adhesive to dry.



A

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B

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C

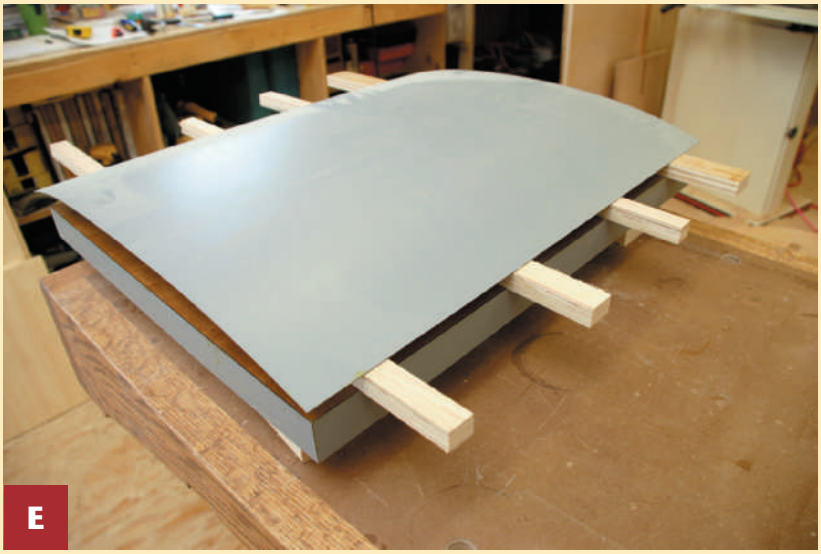
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D

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6. Carefully attach laminate strips, and use the roller to secure them, as shown in **Figure C**. Place the front strip on last.
7. Using a flush trim bit in a router or a laminate trimmer, trim edges flush, as shown in **Figure D**.
8. Cut a piece of laminate 1/2" oversize for the top.
9. Make sure the top of the counter and the back of the laminate are clean and free of dust, and apply contact cement to both. Allow it to dry.

10. Set wood strips or dowels on the substrate and align laminate over them, as shown in **Figure E**.
11. Remove wood strips one at a time, pressing laminate down to the substrate, as shown in **Figure F**.



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G

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H

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12. Using the roller and working from the center out, apply even pressure over the entire surface, as shown in **Figure G**.
13. Trim the overhanging edges with a flush trim bit, as shown in **Figure H**.

14. File the edges smooth, as shown in **Figure I**.
15. Finish the bottom of the countertop with a couple of coats of finish.



I

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34

Running Your Own Business

You'll Learn

After studying the chapter, the student should be able to:

- List the qualities of a successful entrepreneur
- Define the advantages and disadvantages of running your own business
- Explain the importance of good communication skills
- Describe various types of business structures
- Define the key aspects of a business plan
- Explain the importance of good record keeping

INTRODUCTION

The idea of running your own business may be an appealing one. The reasons commonly stated by people wishing to work for themselves are varied. They want to be their own boss, or they want financial independence, creative freedom, or the ability to fully use their skills and knowledge. These are all valid reasons for wanting to run your own business, but making the decision to work for yourself is a big step and not one to be taken lightly. In this chapter, we will explore the concept of entrepreneurship, the advantages and disadvantages of running your own business, the importance of good communication skills, various business structures, key aspects of a business plan, and the record keeping that is essential to business success.

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ENTREPRENEURSHIP

An **entrepreneur** is a person who assumes the responsibility and the risk for a business operation, with the expectation of making a profit. Before making the decision to work for yourself, you need to determine if you have the characteristics of a successful entrepreneur. Being a highly skilled craftsperson by itself is not enough. Activities that you will be engaged in as a business owner go beyond craftsmanship; they include accounting, marketing, sales, publicity, research, scheduling, purchasing, and management.

Successful business owners share a set of skills. They are self-starters, they can get along with many different personality types, and they are able to develop working relationships with various types of people. Successful business owners are motivated, and they are comfortable taking risks and making decisions. They tend to have good planning and organizational skills, and they are willing to work hard for long hours. They are committed to their idea, and they are patient; they understand that it may take a while to get a business going and that it may be financially difficult for some time until the business is established.

Questions you might ask yourself when evaluating your potential to own and run a business include the following:

- Are you self-motivated?
- Can you set and achieve goals?
- Do you work well independently?
- Do you believe in your product?
- Do you believe in yourself?
- Are you a "people person"?
- Can you accept criticism?

If you can answer all or most of these questions affirmatively, and you are willing and able to work hard and endure periods of insecurity, you have what it takes to be a business owner.

STARTING YOUR BUSINESS

So you believe you have what it takes to run a business. What's next? You need to define what your start-up needs are. These include your product, work facility, and marketing plan. Taxes, insurance, and liability issues, as well as a basic understanding of the different types of business organization, must also be considered.

You first need to decide what your product, or products, will be. A phrase often heard in articles about starting a business is "find a need and fill it." This is sound advice. Also consider whether the work you choose to do is something you would enjoy doing day in and day out. Before you choose your market, you must evaluate the competition. If your idea is to build custom kitchen cabinets for homes in your area, and there are already a good number of people doing just that, it might not be the best idea. Also, you must possess the technical skills to do a superior job of building whatever it is you have chosen to produce. Formal study or apprenticeship can increase your skills, and even if you are already proficient, you can always learn more and better ways of doing things. Continual education should be something you enjoy.

You need a place to work and the necessary tooling to build your product. If you do not already have these tools, acquiring them can be an expensive part of your start-up process. However, depending on what your product is, you may not need a whole shop full of tools at the outset. Do you have a place to work? Perhaps your garage or basement can be set up as a shop. Or maybe you can share shop space with another woodworker or cabinetmaker and share costs that way.

Marketing is the task of promoting and selling your product. Will you be selling directly to a customer, or will you pursue sales through retailers? If you sell directly to the customer, some areas to consider might be festivals, craft shows, exhibitions, or commissioned work. If you choose to sell through a retailer, you may want to approach galleries or specialty stores to sell your product; but if you go this route, remember that the gallery owner or retailer has to make a profit, too, so a percentage of each sale will go to them. This may be worthwhile to you, because they will do much of the marketing, but then it may not.

You may wish to pursue both avenues. In either case, you should have business cards and a portfolio of your work. You may wish to have brochures made up, or you may consider selling products through your own Web site.

Tax issues are affected by the type of business structure you choose; we will discuss these in the next section. Regardless of the type of organization, however, you will face certain taxes. You will need to pay federal, state, and FICA (Social Security) taxes. If you have employees, you need to report their earnings

and pay a portion of their FICA costs. In addition to the detailed information available on the Internal Revenue Service (IRS) Web site regarding tax laws, the IRS also conducts Small Business Tax Workshops that discuss the tax requirements for small businesses. Visit the website at *www.IRS.gov* or contact the IRS for information on workshops in your area.

Insurance considerations include liability insurance, health insurance, and Workers' Compensation, if you have employees. Health insurance costs are very high, and along with other business costs, these must be figured into your estimates as you consider how much to charge for your product. Liability insurance is another cost to be evaluated. You will want to have insurance on your shop and tools, as well as insurance to cover you in the event of an injury related to your product.

Structuring a Business

Several different forms of business are possible, including sole proprietorships, partnerships, corporations, and limited liability companies. Each has different tax implications, varying levels of control over the workings of the business, and varying levels of vulnerability to lawsuits.

The simplest form of business structure is a **sole proprietorship**, and most small businesses start out this way. There is one owner, usually the person who has the responsibility of running the business. The sole proprietor owns all the assets of the business and all profits generated by it. He also has complete responsibility for any liabilities and debts. Legally, the sole proprietor and the business are one and the same.

There are several advantages to a sole proprietorship: It is the easiest and least expensive business structure to set up and dissolve. The owner has complete control over all decisions, and the profits belong to the owner alone. The primary disadvantage to a sole proprietorship as a business structure is that the owner has unlimited liability and is legally responsible for all debts of the business. Not only are business assets at risk, but personal assets are as well.

In a **partnership** structure, two or more people own the business. A partnership is also relatively easy to set up, but this requires agreement among the partners. Like a sole proprietorship, the partners receive all the profits, but they are also responsible for all liabilities. By default, profits and liabilities are shared equally, as are responsibilities. However, in setting up the partnership, another arrangement can be specified. A business may benefit from partners who have different and complementary skills, so one partner may be allowed greater profits than another. However, partnerships can suffer when partners disagree. Since partners are jointly and severally liable, if taxes are owed when the business dissolves, and only one partner has money left over, that partner can be held responsible for the entire debt.

When profits are shared among the partners, it is known as a **general partnership**. Another type of partnership is the **limited partnership**. In this setup, certain partners may have limited liability. In other words, the extent to which they are responsible for the business's debts is limited to the amount of their investment, and they are not personally liable. Their input regarding decisions is also limited. The managing partner or partners do most of the decision making, but they also have full liability. This form of business is more complex to set up than a general partnership.

The third major type of business structure is the **corporation**. A corporation is chartered by a state, often, but not always, the state in which it is located. Unlike a sole proprietorship or a partnership, a corporation is considered an entity unto itself, apart from the people who own it. This means that although the corporation can be taxed or sued, its owners, called *shareholders,* are not personally liable for the corporation's debts. The corporation is run by a board of directors, which is elected from among the shareholders. Business profits are shared among the shareholders, and corporations do not dissolve when ownership changes.

Corporations are harder to set up than the other types of business structures covered earlier. It is lengthier process, and more expensive. There are two main types of corporations: C corporations and S corporations.

A fourth type of business structure is the **limited liability company (LLC)**. This is a relatively new business structure that is a hybrid between a partnership and a corporation. It has the limited liability features of a corporation and the operational flexibility of a partnership.

The Business Plan

In the same way that having a plan of procedure is a critical element in building a project, having a business plan answers many of the questions that will arise in the course of starting your business. As you first ponder the idea of starting a business, begin by jotting down ideas to answer the questions *what, when, where, why,* and *how.* Later, these ideas can be formalized into a business plan, which will be a necessity if you plan

to apply for loans to start your business. Examples of each of these questions are listed below.

- *What* is your product?
- *When* will you have everything in place to begin?
- *Where* will you make your product?
- *Why* do you want to run a business?
- *How* will you finance the start-up of your business?

Certainly there are other questions that fall into each of these categories, but these are a few you must consider in the initial planning stage. If you are reasonably confident and secure about your answers to these questions, you may get started on a small scale as a sole proprietor or as a partnership. As the business grows and changes, continue to refine your ideas and think through what lies ahead. At this point, you may begin to formalize your plan. In essence, your plan should tell potential financial backers where you have been, where you are at present, and where you are headed.

A formal business plan should contain the following features:

1. Business objectives
   - Reasons for starting and operating your business
   - The niche, need, and function it will fill
2. Business form
   - Legal form of business
   - Organization
   - Licenses and permits
3. Résumés of yourself and other key individuals
   - What you will bring to the business
   - What other key individuals will bring to the business
4. Product
   - What you will produce
5. Production plan
   - How you will produce what you plan to sell
6. Materials
   - Supplies and raw goods needed
7. Production facilities
   - The plant needed to produce what you plan to sell
8. Equipment
   - Inventory
   - Planned purchases
9. Marketing plan
   - How you will sell your product
10. Major outlets or clients
    - Who you will sell to or through
    - How you will sell: wholesale, retail, or consignment
11. Competition
    - What others are doing that may be similar
    - Why your product is better
12. Financials
    - Past and current results, operating statement, balance sheets
    - Forecast of future results and financial projections
13. Copies of past business tax returns
14. Business references
    - Banks
    - Suppliers
    - Personal references

Communication Skills and Marketing

The importance of good communication skills in running a business cannot be overestimated. A business owner must be able to communicate clearly and effectively with customers, of course, but also with suppliers, employees, and other professionals, such as accountants, lawyers, and bankers. Communication is a key part of the people skills mentioned earlier. You have to be able to communicate with all kinds of people, some of whom may have very different cultural backgrounds and beliefs than you do, in a positive and effective manner. Behave professionally at all times, treating all people with courtesy and respect. Do not use derogatory or offensive language or raise your voice in anger.

In addition to treating those with whom you are interacting respectfully and demonstrating cultural sensitivity, your communication skills will be

strengthened by avoiding some communication barriers that are fairly common. These include:

1. *Lack of enthusiasm or interest:* If you don't think this information/product/message is important, why should your listener?
2. *Lack of focus:* You need to be clear about the information you are conveying. Be succinct and to the point. Don't overwhelm someone with details before they have grasped the essential concept.
3. *Lack of eye contact:* This makes your listener feel invisible and unimportant. You want to build trust with the person with whom you are communicating, and eye contact is critical to this.
4. *Lack of connection:* You need your listener to want to understand you. This is done by conveying information in a nonthreatening and friendly way. It is also important for you to determine if your listener understands what you are trying to say. Do this by asking questions. Showing interest in someone stimulates their interest in your message.

Good communication skills are the foundation of promoting and marketing your business. One thing you will certainly want to do to promote your business is to have business cards made up; carry them and hand them out liberally. Your business card should clearly state what your business is, who you are, and how to contact you. Ask people who have purchased your services if they will recommend your work to others, and leave them some of your cards.

It is also a good idea to have a portfolio of your work to show potential customers. You may ask past customers if they are willing to serve as references to future customers. A portfolio that is professionally presented says a lot about you and the level of care you will bring to your work.

Once you have made contact with a potential customer, you need to follow up in a timely manner when getting sketches and estimates to them or returning calls, and you must follow through as promised. Being dependable is very important. When discussing what types of wood and finishes will be used, it is very useful to have a sample box that you can show to potential customers. It is also very important to put such details in writing when providing your customers with an estimate or when they place their order.

If you do commissioned work or sell at galleries or craft shows, your work should be signed, and business cards should be included with the sale. If people like your work and are pleased with your attention to their needs, they are likely to recommend you to friends. You must be professional and courteous at all times, even when people are difficult or demanding. If you display at shows, you will want to have professional signage and an attractive display that encourages people to stop at your exhibit. You should remain there and be friendly, as a good host would be.

As your business gets underway, it may be appropriate and useful to put together a flyer or brochure of your work. You may wish to advertise in local papers. Contacting the print or radio media about your work may result in a story that will spread the word about your business and lead to more work.

When you have finished a job or sold a piece, it is a good idea to write a note to thank the customer for the business and ask them to recommend you to friends. The happier they are with you and your work, the more likely they are to give you a positive referral. It is equally true that if they are not happy, they will tell their friends. To build a successful business, you must build a reputation for being a good craftsperson, one who is honest and dependable. The customer is your employer; remember that even when it is difficult, or when you are having a bad day. Strive always to be considerate and interested in the customer's concerns; this is an important part of building a reputation that will bring you further work.

Record Keeping

Keeping careful and accurate records will help you not only at tax time, but also when determining pricing and creating accurate estimates. As tedious as it may be to you to track every step of a job or project, it will pay dividends in the future. Each piece you build and each job you undertake should have a detailed paper trail with it, which must include all materials purchased and any time spent engaged in the various tasks associated with it. It is not particularly difficult to estimate the material costs of any given job, but estimating the time it takes to complete a project is a skill that takes some practice to acquire. The tendency is to underestimate how long anything will take. By keeping a log of the time spent doing various tasks, you will have a reference for the future that will prove enormously useful. Do not be discouraged if you do not make the money that you had hoped to at first. It takes time and experience to grow a business.



Summary

Starting and running your own business is a complex undertaking. You must have the physical and emotional stamina to do it. You have to believe in your product, be good at what you do, and be enthusiastic about it, and you must have the skills to deal effectively with a variety of people with different personalities. It is likely that you will start out small at first, perhaps as a sole proprietor or as a member of a partnership. Keeping good records and cultivating good relationships with suppliers and customers will spread the word that you are dependable and do quality work. Building a portfolio of your work and being able to discuss it in a knowledgeable manner in a way that is easy to understand will lead to more work. Always put your best foot forward, and remember that it is as easy to create negative publicity about yourself and your business as it is to create positive publicity. Running your own business is a lot of work, but it can be very rewarding.



Key Terms

corporation
entrepreneur
general partnership
limited liability company (LLC)
limited partnership
marketing
partnership
sole proprietorship



Check Your Knowledge

1. Why would a person want to work for himself?
2. List advantages and disadvantages of running your own business.
3. What are some of the characteristics of a successful business owner?
4. What are the four business structures, and how do they differ?
5. What is the easiest and least expensive form of business to set up?
6. What are the advantages and disadvantages of a partnership?
7. What is a business plan, and why is it important?
8. Why are good communication skills so important for a business owner?
9. List several ways of marketing yourself and your work.
10. How will keeping good records help you?



Activities

1. Make an appointment to visit someone who owns and runs a woodworking business. Ask them how they got started and what their business is like today.
2. Do further research on starting your own business and what is entailed in such an undertaking. A good resource is the Small Business Association (SBA), which can be found online at *www.sba.org*.
3. Collect and critique business cards. Design one of your own.
4. Pick an area of woodworking that is interesting to you, and design a simple business plan. Estimate what you would need to get started.
5. Do you have the qualities necessary to be a successful entrepreneur? If you lack one or more of the qualities needed, are there ways you can compensate for those that may be missing?

Glossary

A

absolute humidity The actual amount of moisture in the air.

actual size The size that a board actually is; for example a 1 × 8 × 8 is actually 3/4" × 7 1/4" × 8'.

aliphatic resin A type of PVA, it is a thermoplastic adhesive that is yellow in color and stronger than white glue.

ambering A yellow tint imparted by varnish finishes.

anchor A kind of fastener used to secure a project in place in hollow or concrete walls.

aniline dye A type of water stain that comes in a powder form; it is added to boiling water and allowed to cool.

animal glue An adhesive manufactured from the hooves, hides, and bones of animals.

anisotropic Changes in dimension; differs depending on grain.

annual rings The amount of growth generated by a tree each year.

apprentice A person bound by legal agreement to work for another for a specific amount of time in return for instruction in a trade or craft.

apron Horizontal piece running between table legs that supports the top.

arbor Shaft that holds a saw blade.

arithmetic progression A measure showing a constant difference between consecutive units.

armchair Chair similar in structure to a side chair, except that it has arms and also tends to have a somewhat larger seat.

armoire A large, often ornate cabinet or wardrobe.

astragal A strip of wood attached to either the front or back of one door in a pair of doors to eliminate a visible gap between the two doors.

B

back cutting A method of stay-log cutting; veneer is cut from the flat side of the flitch.

backing laminate A 1/50 inch-thick covering applied to the backs of panels to control warping.

backsaw Refers to a group of woodworking saws that have a stiffening rib on the edge opposite the cutting edge.

backsplash An upright border behind the countertop that is placed against the wall to protect it.

balance The use of space and mass to give a feeling of stability.

band clamp A holding device similar to a web clamp, except the strap is either metal or 2-inch-wide cloth strapping.

bandings Decorative strips that have a design, which may be very intricate, made up of two or more species of wood.

band saw A saw that gets its name from its blade, which rides on wheels and cuts downward; it consists of a narrow, continuous band of toothed metal.

bar clamp A holding device consisting of a bar with two jaws, one that is fixed and the other moveable.

bark The outermost layer of a tree, made up of dead cells; it protects the tree.

bark pocket Bark material that was enclosed as a tree grew.

barrel hinge A hidden hinge consisting of two barrels mortised into the door and frame and connected by a lever mechanism.

base cabinet A cabinet that sits on the floor; the term is usually used to refer to kitchen cabinets.

bathroom vanity Cabinet that contains a sink for installation in a bathroom.

beam compass Simplified shop-made version of trammel points consisting of a flat piece of stock with two or more holes drilled in it, one of which holds a finish nail to anchor the compass and the other a pencil tip to mark the arc or circle desired.

bedframe Another term for bedstead.

bedstead Refers to the framework of a bed.

belt sander A sanding tool that consists of a motor that turns a pair of drums on which a loop of sandpaper is affixed; the most aggressive of the sanders.

bench An early form of seating, it provides space for more than one occupant and may or may not have a back.

bench dogs Small, moveable jaw faces that mount in holes in a benchtop to extend the capacity of a vise.

bench plane A smoothing tool with a cutting iron embedded with the bevel facing down and attached to a chipbreaker; comes in various sizes, often denoted by number, with a larger number indicating a larger plane.

benchtop table saw Smallest, lightest, and least expensive of the table saws; it's highly portable.

bench vise A part of the woodworker's bench used to secure items; consists of two wooden or wood-faced metal jaws that are flush with the benchtop; one jaw is fixed and the other is moved by means of a screw mechanism.

bevel An angled cut made along an edge or end of a board.

bevel square A layout tool that has a head and a blade that can be set at any angle to the head.

biscuited miter An angled cut similar to a splined miter, but instead of a groove being machined, biscuit slots are cut intermittently along the joint of a simple miter; biscuits are inserted and glued up with the corner.

biscuit joiner Another name for a plate joiner.

biscuits Another, more common name for plates.

blanket chest The simplest form of chest, it offers the least possibility for organization.

blind-dado housing A dado that is stopped short of both the front and the back of the case.

blind mortise and tenon The most common mortise-and-tenon joint, it appears to be a butt joint when assembled, because neither mortise nor tenon are visible.

block plane Smaller than the bench plane, a smoothing tool with a cutting iron held in the plane with the bevel up; it has no chipbreaker.

blue stain A discoloration caused by a mold or fungus.

board foot A unit of volume measurement equivalent to a piece of wood 12" long, 12" wide, and 1" thick.

bolt A fastener with a head at one end designed to be inserted through holes in assembled parts and secured with a nut.

bond coat The first coat of adhesive applied to the backing on which the abrasive grains are placed.

book match A veneer pattern made by "opening" consecutive leaves, as they come from the flitch, like a book.

bound water Moisture that saturates the wood fibers in cell walls.

bow A curve along the face of a board from end to end.

bowl gouge A deep fluted gouge used to turn the inside and outside of bowls and vessels.

box joint Also called a finger joint or a comb joint, it consists of interlocking tenons and notches in the end of adjoining boards.

box nail A fastener similar to a common nail, but thinner and with a smaller head; rarely seen in woodworking.

brace A drilling tool, sometimes called a brace and bit, it consists of a chuck, a top spindle, and a U-shaped crank outfitted with another spindle.

brad A fastener shaped like a finish nail but thinner and shorter.

bridle joint A type of slip joint in which the end of one piece is joined to a place in the second piece other than its end.

built-up finish A coating that lays on the surface of wood rather than penetrating into it.

bureau Another name for a dresser.

Bureau of Labor Statistics Provides information on wages by area and occupation, employee benefits, and state and local wages.

burl A lump on a tree formed by new growth after an injury.

burnisher A steel rod used to turn a burr.

burr A sharp hook of metal.

butt Wood at the base of a tree, it is also called the stump.

butted case joint A joint attaching the end grain of one piece to the face grain of an adjacent piece; fasteners are required.

butterfly key A double-dovetail shaped piece of wood that is inset into two main pieces to help lock them together.

butt hinge Two leaves connected by a pin, which may or may not be removable.

button block A wooden shop-made tabletop fastener.

C

cabinet grade plywood Wood material fabricated with fine veneer faces over a core.

cabinet scraper A smoothing tool, sometimes called a scraper plane, that holds a card scraper in a metal plane body.

cabinet table saw The heaviest, most powerful, and most accurate table saw; it has an enclosed base.

cam An eccentrically shaped wheel with a pin in its base.

cambium A thin layer inside the bark where all a tree's growth takes place.

cant A squared-up blank cut from a log.

carcass Another term for a case.

card scraper A piece of carbon steel used to remove fine shavings of wood.

carriage bolt A fastener that has a rounded head with a square shoulder.

carving in the round Carving method that starts with a block of wood and takes away material to leave a figure.

case hardening Improper drying of wood; the inside of the board is under tension and will react unpredictably when cut.

case joints Joints used to build boxes; wood is joined together end to end across its width, joining end grain to face grain.

casework Any enclosed structure constructed using case joints.

casing nail A fastener used for attaching door and window trim; it has a cone-shaped head that can be set beneath the surface of the wood.

caster A type of wheel that allows cabinets or carts to be rolled from place to place.

catch Device used for holding a door closed; it is located inside a door and is invisible when the door is closed.

cauls Sturdy boards between which glued veneer and substrate are clamped.

C-clamp Metal clamp shaped like the letter C with a screw that is tightened to create the clamping pressure.

ceramic tile A kiln-fired product made from clay and other materials.

chair A piece of furniture consisting of a seat, legs, back, and sometimes arms; designed to accommodate one person.

chamfer An angled cut made partway across the edge or end of a board.

check A crack in wood, like a split but shorter; found at the ends of seasoned boards.

chemical resistance A measure of how an adhesive will stand up to chemical assaults.

chemical stain A grain-raising stain that consists of chemicals in powder or crystal form dissolved in water; it combines chemically with the wood to produce a permanent color.

chest of drawers A chest holding a number of drawers.

chest-on-chest One chest placed on top of another, usually with drawers.

chip carving A type of carving in which knives are used to remove small chips of wood.

chippers Interior blades of stacked dado sets available in different thicknesses.

chisel A metal tool with a sharp, beveled edge; used to cut and shape wood.

chuck The part of a drill that holds the drill bit; clamping device for holding a drill bit.

circular saw A circular saw blade powered by a motor; used to cut wood and other materials.

clamp A device used to hold an object in a fixed position.

clearance hole A space that provides room for the shank of the screw.

closed form An object that cannot be seen through, for example, a chest of drawers.

coated abrasive Commonly called sandpaper, grains of a natural mineral or synthetic substances bonded to a backing.

cohesion The extent to which the glue sticks to itself.

collet Located at the end of the router motor shaft, a device that holds the router bit in place.

color The effect produced on the eye by light waves of different length or frequency.

combination finish A coating made of a blend of oils and phenolic resins; sometimes called synthetic penetrating finish.

combination saw A saw designed to do both ripping and crosscutting, although it is not ideally suited for either operation.

combination square A square that consists of two parts, a rule and a head; measures 90° and 45° angles.

common nail A fastener with a round head and a thick cross section compared to other nails; primarily used in framing, or where the appearance of the head will not matter.

compass A V-shaped device for marking out circles or circular arcs consisting of two legs hinged at the end. One leg is equipped with a pencil or other marking device and the other ends in a sharp point which acts as a pivot around which the drawing leg is moved.

compound miter cut A combination of a miter and a bevel cut.

compound miter saw A saw with a blade that can be tilted to make bevel cuts.

compressor system A machine that uses a compressor, a regulator to adjust air pressure, water and dirt filters, and a spray gun to keep any contaminants in the air line out of the finish.

computerized numerical controls (CNC) A computer program that sets a sequence of operations to be performed automatically by a machine.

concrete A construction material that consists of Portland cement, gravel, sand, and water.

conical screw A plastic anchor suitable for attaching relatively light objects to a hollow wall.

coniferous A cone-bearing tree that reproduces by means of seeds on its cones; a softwood.

contact cement An adhesive that must be applied to both surfaces to be bonded and then allowed to dry; the items to be bonded are then brought into contact with each other and an immediate bond is formed without clamping.

contractor's table saw A saw that is larger than the benchtop saw; it has an attached, open stand.

contrast The difference in a piece between light and dark.

coopering A method of joining beveled wood strips edge to edge to create a curve.

cope-and-stick joint A more elegant and stronger version of the groove-and-stub tenon joint.

coping saw A thin blade held in a U-shaped frame with an attached handle; used for cutting intricate shapes and interior cutouts.

core material The solid substrate to which veneer is affixed.

corner joint Connecting two pieces by joining the edge of one board to the face of another.

corporation A business form chartered by a state and owned by shareholders who share the profits but who are not liable for the debts of the business.

counterbore A drilled flat-bottomed hole recessed below the surface that can be plugged.

countersink A tapered hole with a wide outer portion that allows the screw to sit flush with or below the surface of the surrounding material.

crest rail The top piece of the chair back.

crook A curve along the edge of a board.

cross banding A technique used to set off a center panel; a veneered border around a central section.

crosscut A cut across the grain that affects the length of a piece.

crosscut saw A saw specifically designed for making cuts across the grain; each tooth is beveled and angled back.

crotch Part of a tree located where a branch separates from the main trunk.

crown The high point of a board when viewed along its edge.

cup A curve across the width of a board.

cup hinge Another name for a European hinge.

curing time The length of time it takes for an adhesive to be fully cured.

cut list A list of all the parts needed for a given project, the number of pieces needed, and the dimensions of each piece.

cutter A blade fit onto the spindle of a shaper that does the actual cutting of the material.

cutter head A cylinder that holds jointer knives, located between the infeed and outfeed tables.

cutting circle A circle made by the outer surface of the knives in a cutter head.

cyanoacrylate Often called superglue or CA, an expensive adhesive only practical for small gluing jobs; it dries very quickly and offers tremendous strength.

D

dado Three-sided groove.

dado-and-rabbet joint A rabbet cut in one member that fits into a dado cut in an adjoining member.

dado-and-spline housing Dados milled in two joining pieces with a spline fit and glued between them.

dado blade A saw blade used to make recesses of various widths.

deciduous A tree that loses its leaves and reproduces by means of encased seeds or nuts; a hardwood.

design principles Elements to be considered in designing a project: balance, harmony, repetition, and proportion.

detail drawing A graphic representation, often drawn full scale, that typically shows information regarding joinery connections and moldings or trim.

disc sander A sanding tool that turns an abrasive disc of sandpaper.

dividers A compass with two metal legs, one of which can be removed and replaced with a pencil.

double-rabbet joint Connecting two pieces when both adjoining members are rabbetted.

dovetail joint A joint that consists of angled tenons in one piece that fit into recesses in the second piece; it provides a mechanical lock so that the joint can only be pulled apart in one direction.

dovetail saw Small backsaw used for cutting dovetails.

dowel A round, usually wooden pin that fits tightly into corresponding holes to fasten or align two adjacent pieces.

dozuki saw A Japanese backsaw with a straight, rattan-covered handle; cuts on the pull stroke, rather than on the push stroke like most Western saws.

drawer slides Metal or wooden runners that allow a drawer to open and close easily.

drawknife A knife with a handle at each end of the blade; used to shave a surface.

dresser Often part of a bedroom suite, it is a low and wide chest of drawers.

drill Pistol-shaped tool that may be electric or battery-powered; used for boring holes.

drill bit A shank and a tip fit onto a drill; used for creating a hole.

drill press A fixed type of drill consisting of a base, column, adjustable table, spindle, and drill head.

drop-front support A stop on a desk surface that keeps it from traveling farther down than desired and helps support it.

drop-leaf hinge A metal device consisting of two parts, one attached to the table and the other to the leaf, which allows the leaf to be raised.

drop-leaf support A structure that holds a table leaf in the upright position, level with the rest of the table.

drop-leaf table Any table that has leaves hinged to the tabletop that hang vertically when not in use.

dry-heat bending A method of bending wood, also called hot-pipe bending, that involves bending thin strips of wood that have been soaked in water over a hot pipe.

E

earlywood Tree growth early in the season.

easy chair Lower in height than side chairs or armchairs, a large, well-upholstered chair that is comfortable for relaxing rather than for working or eating at a table.

edge grain The grain along the edge of a board.

edge-lap joint A connecting point used primarily to link stretchers that cross; a notch cut in the edge of each of the adjoining members allows them to interlock.

elements of design The most basic parts of the design: line, shape, mass, color, tone, and texture.

end grain The grain found at the end of a board.

entrepreneur A person who assumes the responsibility and the risk for a business operation with the expectation of making a profit.

epoxy cement A two-part waterproof adhesive that sets very quickly and will bond unlike materials together; little or no clamping is necessary.

equilibrium moisture content (EMC) A measurement reached when the moisture content of wood is equal to the moisture content of the surrounding air.

escutcheon A decorative plate covering a keyhole.

escutcheon pin Small brass nails with round heads that are used for decorative purposes or to attach small hardware.

European cabinet A cabinet without a face frame, first introduced in Europe.

European hinge A concealed hinge consisting of a cup that is attached to the door and a mounting plate that goes on the cabinet; these two pieces are connected by an arm.

expansion anchor A fastener consisting of an expandable sleeve, a machine screw, and a fiber washer.

F

face frame A solid wood border attached to the front of a cabinet assembly. Used to finish the front of a case, both stiffening it and setting off areas for doors and drawers.

face grain The grain on the face of a board.

faceplate A flat, metal disc that attaches to the head-stock spindle.

faceplate turning Method of turning wood on a lathe where the grain of the piece being turned is perpendicular to the lathe bed.

fair curve A curve without flat spots.

feather board Wood used to keep work down on a machine table and against a fence.

fence A metal or wood piece that provides support for an item being cut, and is normally perpendicular to the bed.

fiberboard Material that consists of wood fibers mixed with resin and bound together by radio-frequency adhesion or heat.

fiber saturation point The point at which all the free water in wood is gone and the moisture content has reached 28 percent.

Fibonacci series Measurements where each unit is the sum of the preceding two units.

file A flat bar of steel, usually fitted with a handle that has had sharp parallel lines scored into it before the steel is hardened; used for smoothing.

finial An ornamental terminating point seen on a post, a piece of furniture, or a hinge.

finish nail Like casing nails, fasteners typically set beneath the surface of the wood that have a barrel-shaped head.

fixed-base router A router whose bit protrudes beneath the router base plate; sometimes called a standard router.

flap hinge A metal hinge used with drop fronts, it is mortised into the desk body and drop front; allows the desk front to travel down but stops it at 90 degrees.

flat-panel door A door with stiles, rails, and a flat panel that is typically 1/4" veneered plywood.

flatsawn Another term for plainsawn.

flat slicing A method of cutting where the peeler block is cut in half lengthwise then attached to a table, which is moved up and down against a stationary knife; also known as plain slicing.

flitch Half of a peeler block; also refers to a stack of consecutively cut veneer leaves.

flush cut saw A saw with a thin, flexible blade; used for trimming projections flush with a surface.

folding-leaf hinge A connection device suitable only for narrow leaves, it acts as both a hinge and a support.

footboard Board or panel forming the foot of a bedstead.

foot rail A wooden strip that connects the two posts at the foot of the bedframe.

form A project's appearance upon completion.

formal balance A look achieved when the left and right halves of an object, or the upper and lower halves, mirror each other.

formed hinges Connection hardware, also called bent or wrap-around hinges, that has one leaf bent to fit around the frame, and the other leaf either flat or bent and screwed to the back of the door.

frame-and-panel construction Consists of panels created using solid wood as a frame that enclose a panel, which may be either solid wood or a manufactured panel product.

frame butt joint Connecting two pieces of wood when the end of one piece joins to the edge of another; it requires reinforcement.

frame joint Used in the construction of frames; the end grain of one board is connected to the edge grain of another.

free water 72 percent of the water in a tree; it fills the tree's cell cavities.

French polish A fine finish that is a combination of shellac and boiled linseed oil.

fret saw A saw similar to a coping saw, but with a much deeper throat.

full-lap joint A joint with material removed from only one member.

function A project's purpose; what it is designed to do.

futon bed Combination sofa and bed with a special flexible mattress.

G

gain A shallow mortise cut for hinge leaves.

gel stain A stain with the consistency of jelly that is applied with a brush or clean cloth.

general partnership A business arrangement in which profits, responsibilities, and liabilities are shared among the partners.

general purpose laminate A 1/16 inch-thick covering attached to surfaces that will have heavy use, such as kitchen countertops.

gent's saw The smallest of the backsaws; it has a straight, turned handle which is in line with the blade.

geometric progression A measurement where each successive unit within a frame increases by a constant ratio.

glide A supporting material that usually has a smooth felt or plastic bottom, and is nailed or screwed to the bottom of furniture to allow the furniture to move easily without damaging the floor.

glue blocks Triangular or square pieces of wood used to strengthen and support two adjoining surfaces.

golden mean Another term for the golden section; it is considered the perfect proportion.

golden section A line segment that has been divided into two unequal sections in such a way that the ratio between the smaller and the larger section is the same as the ratio between the larger section and the whole.

gouge A tool used to cut and shape wood; it is similar to a chisel, except that the end is curved rather than flat.

grader The person who inspects each board and determines its quality or grade.

grain raising Anything applied to the wood that leaves the wood feeling rough after it has dried.

granite A natural stone that is a popular countertop material.

grinder A machine tool that uses an abrasive wheel as a cutting device.

grit system A measurement that indicates the coarseness of abrasive grains and, consequently, the coarseness of sandpaper.

groove-and-stub tenon joint A joint with a short tenon milled in one piece to fit into a groove machined in the mating piece.

groundwork Another name for the substrate or core material to which veneer is attached.

guide blocks Wooden blocks located on either side of the blade to prevent the blade from deflecting from side to side.

H

half-blind dovetail A joint where the socket that the tail fits into is cut only partway through the adjoining board with the result that the joint can only be seen from one side.

half-lap joint A joint where both adjoining members are notched to accept each another.

half-round cutting A method of stay-log cutting; veneer is cut from the rounded side of the flitch.

hammer A pounding tool with a handle and a perpendicularly attached metal head.

hand drill A small, portable drill held and operated by hand.

handle Attachments on chests and trunks to allow the chest to be lifted easily.

hand screw A fastener that consists of two wooden, parallel jaws connected by two screws.

hand tool A tool that is powered only by hand.

hanger bolt A fastener with a wood screw thread on one end and a metal screw thread on the other.

hardboard Another term for high-density fiberboard.

hardwood A more complex, later evolving tree; deciduous.

harmonic progression A measurement system utilizing fractions in which the reciprocals of the units form an arithmetic progression.

harmony The pleasing relationship of all the elements in a design.

haunched mortise and tenon A connection where a tongue projects from the tenon's shoulder between the edge of the tenon and the edge of the rail, and fits into a through groove milled on the stile.

headboard A structure attached to the head of a bedstead to retain the pillows and bed linens; frequently has aesthetic as well as utilitarian value.

head rail A piece that connects the two posts at the head of the bedframe.

head saw A saw with a large circular blade that saws tree lengths into rectangular "blanks."

headstock A part of a lathe that supports lathe work on the left side of the machine bed; contains the spindle.

heartwood Part of a tree comprised of dead cells that were formerly sapwood; it provides the structural support for the tree.

heat resistance A measure of how well an adhesive will hold up to heat.

hide glue A frequently used name for animal glue.

high-density fiberboard An extremely rugged material that is often used for drawer bottoms and cabinet backs.

high-solvent contact cement An adhesive that sets quickly and make a very strong bond, but they are highly flammable and toxic.

hinge A jointed or flexible device that allows the turning or pivoting of a part on a stationary frame.

holdfast A holding device that consists of a metal shaft that mounts in a bench hole and an arm that holds an item down to the bench.

honeycombing A severe case of case hardening, in which the tension between the inside and surface of the board becomes so great that cracks develop in the core, which may or may not be evident from the outside.

hook angle Angle of a saw tooth in relation to the centerline of the blade.

hot-melt adhesive A solid adhesive that is applied with a glue gun, which melts it; good for temporarily bonding objects together.

housed joint A type of case joint required when a case has dividers or shelves in it; its function is to hold these dividers and shelves in place.

HVLP High volume, low pressure.

hybrid table saw It occupies the middle ground between contractor and cabinet saws.

I

informal balance The left and right or top and bottom of the piece are not symmetrical, but the piece is balanced visually in some other way.

inlay A decoration of a surface made by laying wood or veneer into a recess in the work so that it is flush with the surrounding wood.

intarsia A decoration method similar to inlay work except that the material set into the recess created in the ground surface is not flush with the surface but stands proud.

internship Supervised, practical training undertaken by a student or recent graduate.

interview A formal meeting, usually in person, arranged for the assessment of the qualifications of a job applicant.

invisible hinge or concealed hinge A hinge that is completely hidden when the door is closed.

isometric drawing A project drawn as it is seen from a corner to show depth; also called an isometric projection.

J

jig A purchased or shop-made device that makes a job safer and easier; any custom-made accessory that increases the accuracy, speed, or safety of a task.

jigsaw A saw employing a straight blade, used primarily for cutting curves.

jointer Machine used to produce a flat surface on a board.

joint fasteners A device to mechanically fasten a joint together.

journeyman A person who has fully served an apprenticeship in a trade or craft and is a qualified worker in a master's employ.

K

kerf The gap created as the saw cuts.

kerfing A method of dry bending that involves sawing kerfs across the grain in one face of the material to be bent.

keyed miter A simple mitered corner that is built and assembled, with slots cut into the miter from the outside, which are then fitted with strips of wood that are glued in place.

kickback When a piece of wood is caught in the blade and thrown violently toward the rear of the saw.

kink A deviation along the board caused by a knot or irregular grain pattern.

kneehole desk Also known as a pedestal desk, it has two chests of drawers that support the desktop; the pedestals are typically joined by rails, which may house a small desk over the kneehole.

knife hinge A metal connection piece similar to pivot hinges but smaller and not as strong.

knob A device used for opening doors and drawers, it is fastened in one place.

knockdown (KD) fasteners Fasteners used in the construction of cabinets or furniture that can be readily assembled; also called RTA fasteners.

knot Seen on a board, it is a portion of a branch that was part of the tree at one time.

L

labor union An organization of wage earners formed for the purpose of serving the members' interest with respect to wages and working conditions.

lacquer A built-up finish that is available in natural and synthetic forms.

lacquer stain A wood coloring agent, purchased in a concentrated form and then thinned down with lacquer to the desired color; using a lacquer stain is essentially coloring the finish.

lag screw A heavy screw with a square or hexagonal bolt head.

lag shield An anchoring device used in solid concrete walls in conjunction with a lag screw.

lamina Thin layers of wood in a bent lamination.

laminated bends Thin layers of stock that have been coated with glue and bent around a form.

laminate trimmer A small router often used for trimming laminate.

latch A fastener that holds a door shut but is mounted on the outside and therefore visible.

latewood Tree growth later in the season.

lathe A tool that spins a block of material, so that when tools are applied to the block, it can be shaped to produce an object that is symmetrical around the axis of rotation.

lead and plastic anchors Light-duty anchors made of lead or plastic used in solid concrete walls.

leaf A piece of veneer cut from the log; successive leaves make up a flitch.

leveler A device that allows a cabinet or table to be adjusted until it is level.

lid support Hardware used with chests and trunks to keep the lid from slamming shut.

limited liability company (LLC) A business structure that is a hybrid between a partnership and a corporation; it has the limited liability features of a corporation and the operational flexibility of a partnership.

limited partnership Form of business when most of the partners have limited liability and the managing partner does most of the decision making and has full liability for the debts of the business.

line A drawn notation that may be straight, curved, circular, or S-shaped.

liner laminate A 1/50 inch-thick material, it is used to line the interiors of cabinets.

linseed oil A penetrating finish that is extracted from the seeds of the flax plant.

lock miter A joint that combines the appearance of a miter joint with the strength of a rabbet-and-dado joint.

lock miter joint A positioned joint that creates a lock, aiding greatly in assembling the joint; it is mostly used to create corner joints but may also be used as a joint in constructing panels.

longitudinal grain Grain that runs the length of a board.

loose mortise and tenon A joint usually milled with a plunge router; mortises are milled in both pieces to be joined with the tenon on a separate piece of wood.

loveseat A small couch.

LVHP Low volume, high pressure.

M

mallet A type of hammer with a softer, larger head than the steel heads found on most hammers.

marble A type of natural stone used for countertops.

marketing How a product is promoted and sold.

marking gauge A tool used for scribing a line parallel to a reference edge; made up of a beam, a moveable headstock, and a marking implement.

marking knife A knife with a thin blade and a sharp point used in layout work.

marquetry The creation of decorative patterns and pictures from pieces of veneer that are taped together and then glued to a core.

mass A three-dimensional perception involving height, width, and depth; it is the relationship between line and shape.

master A worker qualified to teach apprentices and carry on the trade independently.

mechanical adhesion The bonding between an adhesive and wood fibers.

medium-density fiberboard Commonly referred to as MDF, a stable wood material with a very smooth surface.

medullary rays Markings that run horizontally across a cross section of the tree, like spokes on a wheel; carry water and nutrients within a live tree.

melamine A thermally fused, resin-saturated paper finish applied over a particleboard core.

miter A cut made across the face of a board at an angle other than 90°.

miter clamp A holding device specifically designed for clamping miter joints.

mitered case joint A joint that consists of two adjacent pieces, each of which has its edge beveled at an angle, typically 45°.

mitered frame joint Also called a plain miter, adjoining joint members each cut at a 45° angle to form a right-angle corner.

mitered half lap A joint that combines the strength of a half-lap joint with the appearance of a miter joint.

miter gauge A tool that consists of a metal bar and attached adjustable protractor head that supports material for crosscutting.

miter-gauge slot A groove milled in the saw table to position and guide a miter gauge or sled.

miter saw A power tool used to make quick, accurate crosscuts; the largest of the backsaws at 20" to 30" long; used in a wooden miter box or in a metal frame used for making crosscuts at an angle.

Moh's scale A measurement that rates minerals for hardness.

molder head A tool used for shaping operations on the table saw; consists of a cutter head with three matching knives.

molly screws Common name for an expansion anchor.

mortise Recess into which a tenon fits.

mortise-and-tenon joint Joint consisting of a hole (mortise) in one piece into which a projecting tab (tenon) milled in the mating piece fits.

mortise gauge A type of marking gauge that scribes two parallel lines simultaneously.

mortising chisel A square, hollow chisel with a drill bit in its center.

mortising machine Dedicated machine for making mortises; uses a drill bit housed in a hollow chisel.

mullion A vertical member, like a stile, which fits between rails.

multiple-tenon joint Joint consisting of two or more tenons and corresponding mortises.

muntin A centered wooden strip installed in wide drawers to prevent sagging of the bottom.

N

nail set Tapered piece of metal used in conjunction with a hammer for driving nails beneath the surface of the wood; small metal punch used to set nails beneath the surface of the wood.

natural adhesives Adhesives made from materials such as bones, blood, hides, eggs, vegetables, and milk.

neoprene-based contact cements They are nonflammable and nontoxic; they do not pose health hazards, nor do they emit dangerous VOCs.

nominal size The size that a board is said to be; for example, a $1 \times 8 \times 8$.

O

Occupational Outlook Handbook Government-provided information on the nature of employment, working conditions, training and advancement, job outlook, earnings, related occupations, and sources of additional information.

open face Usually the back of the veneer; it has tiny checks in it from slicing.

open form An object that one can see through; a dining chair is one example of an open form.

open time Another term used for pot life. See **pot life**.

orthographic drawing A two-dimensional drawing that does not show depth.

P

pad sander A smoothing tool, sometimes called a finishing sander, that has a pad over which sandpaper is affixed.

palm sander A type of pad sander that takes a quarter- to half-sheet of sandpaper.

parquetry The creation of geometric patterns or motifs through the use of symmetrically shaped pieces of veneer.

particleboard Wood material that consists of small wood flakes, chips, and shavings bonded together with adhesives.

parting tool A pointed tool used for separating material from the lathe and for defining areas to be turned.

partnership An arrangement in which two or more people own a business and the profits and responsibilities are shared.

paste wood filler Material made from quartz powder or silica mixed in a binder used to fill the large, open pores of certain woods and to level a surface prior to applying a built-up topcoat.

pedestal table A table with a top supported by a central pillar rising out of a base.

peeler blocks Logs that have been debarked, cut to length, and then softened by immersion in hot water or by steaming.

pegged mortise and tenon A joint made with holes drilled through an assembled mortise-and-tenon joint, with pegs tapped into the holes.

penetrating finish An oil that is absorbed into the wood.

penetrating oil stain A wood coloring agent consisting of coal-tar dyes dissolved in a thinner.

pew Essentially a bench with a back, usually seen in ecclesiastical settings.

phloem In a tree, the outer part of the cambium; creates new bark cells.

piano hinge Type of butt hinge that is continuous.

pigmented oil stain A wood coloring agent made up of four components: color, thinner, oil, and a dryer.

pilaster A vertically installed strip with slots that holds shelf supports.

pilot hole A hole drilled into the wood that makes it easier to drive a nail or screw.

pin A narrow piece of material found on the second board of the dovetail joint; it fits into the spaces between the tails on the first piece.

pin hinge A hinge with the mounting plates fastened to the back of a flush mount door; protruding pins fit into holes drilled in the cabinet.

pipe clamp A holding device similar in construction to a bar clamp; the jaws are mounted on a pipe, usually with a 1/2-inch or 3/4-inch diameter.

pitch pocket An opening in wood containing resin, which may be solid or liquid.

pith The very center of the tree.

pivot hinge A hinge consisting of two plates riveted together with a nylon washer between the two plates to reduce friction.

plainsawn Boards sawn from a cant.

plan of procedure Written details specifying how a piece is to be built in a step-by-step manner.

plane A tool with an adjustable cutter attached to a firm body; used for flattening, smoothing, and reducing the thickness of wood.

plasticizing Softening wood lignin through heating, soaking in hot water, or steaming in order to bend wood.

plastic laminate A type of waterproof, durable synthetic veneer that is applied to a substrate.

plastic resin adhesive An adhesive comprised of urea resins, is it also called urea, or urea formaldehyde; comes in powder form and is mixed with water.

plastic toggle A one-piece plastic anchor for hollow walls, similar to a toggle bolt.

plate joiner A tool used to join two pieces of material together.

platen A flat panel that has been kerfed to a depth of about 1/8 inch at 2-inch intervals along both its length and its width; it is used with a vacuum press to help create a better vacuum inside the bag.

plate Compressed, football-shaped piece of wood used with a plate joiner; comes in three common sizes.

platform bed Simplest form of bed, consisting of a box base supporting a platform that holds the mattress.

plug cutter Bit used in the drill press that comes in different sizes to cut plugs for hiding counterbored screws.

plunge router A router that is set on the material; the bit is then lowered into it.

pneumatic tools Tools driven by compressed air.

pocket-hole joint A butt joint reinforced by screws, which are installed from the back of the frame.

polyurethane A synthetic varnish made up of plastics and solvents.

polyurethane glue A strong thermoset adhesive, which is highly water and heat resistant.

polyvinyl acetate A thermoplastic adhesive usually referred to as white glue.

positioned joint A profile milled on each of the adjoining boards so that they fit together flush.

post-forming laminate A coating made with flexible resins that allow it to be bent around curved surfaces.

postmaster's desk A piece of furniture also known as a plantation desk; it has many little cubbies and is a combination of a table and cupboard.

pot life The amount of time allotted for applying an adhesive.

primary horizontal mass An object that is wider than it is high.

primary vertical mass An object that is taller than it is wide.

proportion The relationship of the parts of an object to each other and to the whole.

pull A handle used for opening doors and drawers, it is fastened in two places.

pumice A loose abrasive used for polishing; made from finely ground lava.

push stick A shaped wood or plastic device that allows the operator to move material past the blade safely.

Q

quarter slicing A method of cutting wood where the peeler block is cut into quarters before slicing.

R

rabbet Two-sided groove running along the edge or end of a board.

racking loads Loads which would move a case or box out of square.

radial arm saw A circular saw blade directly driven by an electric motor, which is held in an adjustable yoke sliding along a horizontal (radial) arm above a horizontal table surface.

radial grain A board showing radial grain on its face that was cut along a radius running from the center of the tree outward.

rail Horizontal member of a frame.

rail joints Joints similar to frame joint in that end grain is being joined to long grain; unlike frame construction, the members being joined are not the same thickness.

rail Horizontal member of a frame that fits between stiles.

raised-panel door A door with stiles, rails, and a solid wood panel, usually 3/4" thick, which has a profile milled on its edges.

rasp A bar of steel that may be flat or rounded, usually fitted with a handle, that has sharp, raised, triangular-shaped projection; used for shaping wood.

relative humidity The ratio of actual moisture in the air to the maximum amount of water the air will hold at its current temperature.

relief carving Background material cut away to leave a design.

repetition Using one or more elements in a design more than once to create rhythm, which creates interest that draws the viewer's eye.

resaw Cutting a board into thinner pieces; a cut affects the thickness of a board.

resorcinal resin A two-part adhesive that is completely waterproof.

resumé A brief account of one's professional or work experience and qualifications.

reveal Method that allows part of the piece being covered to show.

riffler A curved tool that is double-ended; may be either rasp or file cut.

rift cutting A method of stay-log cutting; peeler blocks are quartered and veneer cuts are made at a 45° angle to the annual rings.

rip cut A cut made with the grain that affects the width of a piece.

rip fence The fence on the table saw is often referred to as a rip fence, which supports the stock when rip cuts are made.

rip saw A saw specifically designed for making cuts with the grain; each tooth has a flat front edge and is not angled to prevent the saw from wandering.

ripping It is a process of cutting a board in the direction of the grain.

rocking chair A chair with two curved pieces of wood attached to the bottom of the legs.

rolltop desk Also called a tambour desk, furniture characterized by a tambour curtain that pulls down to completely enclose the writing surface.

rotary cutting A cutting method where the log is turned on a lathe and rotated against a stationary knife.

rottenstone A loose abrasive used for polishing; made from soft limestone ground into a powder.

rough layout Drawing method where component pieces are marked out larger than they will be once they are machined.

roughing-out gouge Wide gouge used for initial rounding of material and rough shaping.

roughsawn Lumber that is sawn but not planed.

router A shaping tool that consists of a vertically mounted motor, which turns a bit that is extended through a baseplate.

router plane A hand tool with a chisel-like cutter; used to level square-sided recesses and to cut dadoes.

router table A piece of equipment that holds the router in an inverted position beneath a table so that material may be brought to the router.

rungs Wood run between the legs of a chair to connect them.

ryoba saw Ryoba means "double" in Japanese. It has teeth on both sides of the blade; one side has crosscut teeth for cutting across the grain, and the other has rip teeth for cuts made with the grain

S

S2S Surfaced two sides.

sapwood Living part of the tree that carries water and nutrients.

scoring Cutting the top layer of the wood with a knife to prevent splintering.

scratch stock A tool that holds a sharp cutter, which is moved back and forth to scrape a groove.

screw A threaded metal fastener that ends in a sharp point.

screwdriver A tool with a head or tip, shaft, and handle; used to tighten or loosen screws.

scroll chuck A device that holds lathe work by means of three or four jaws that open and close in unison.

scroll saw A small saw for intricate curved work; uses a fine reciprocating blade.

secretary A combination desk and bookcase; like the slant-top desk, it is a chest of drawers with a fold-down writing surface that also supports a cupboard for books.

section view A drawing of what an object would look like if part of it were to be cut away.

segment lamination Also called brick stacking, a method for making curves that uses short pieces of solid stock that are stacked in staggered rows.

semi-concealed hinge Hardware that consists of a decorative part that mounts to the face of the cabinet frame and a hinge that is hidden behind the door.

set The deflection of the teeth of a saw from the blade.

set time The amount of time it takes for the solvent in the adhesive to evaporate.

shake A crack caused by a separation between the annual growth rings.

Shakers A utopian Christian religious sect that flourished in the United States in the late 1700s and 1800s.

shape A figure composed of lines, it reveals a certain style.

shaper A tool with a table through which a spindle, which holds a cutter, projects.

shelf life The length of time an adhesive remains usable; also called storage life.

shelf supports Devices fit into pilasters or drilled holes to support shelves.

shellac A natural, built-up finish that may be purchased premixed or as flakes; it is produced from a natural resin called lac.

shiplap joint Joint that has rabbets cut into the opposite faces of adjoining boards.

side chair A chair without arms, typically used at a table or desk.

side rail Wood that run the length of a bed between the posts; usually removable to facilitate dismantling the bed.

silica A type of sand that causes less light to be reflected, making the finish appear less shiny; the amount of silica added to a finish determines its sheen.

simple miter A joint where the ends of each piece are cut at a 45° angle and butted together.

single-rabbet joint A case corner joint with one member rabbetted and the other butted into it.

size coat The second coat of adhesive on the backing; it is applied on top of the abrasive grains and locks them in place.

skew chisel Chisel with an angled edge, beveled on both the top and bottom.

slab wood The cutoffs created when a log is turned into a cant.

slant-front desk Also called a drop-front desk, its construction is like that of a chest-of-drawers: the front is hinged and opens to create a writing surface.

slant-top desk Also known as a schoolmaster's desk or a stand-up desk, it is designed to be used by someone standing at it, rather than sitting.

slats Wood run between the side rails that supports the box springs on a bed.

sliding compound angle miter saw A saw that combines the features of a sliding miter saw and compound miter saw.

sliding dovetail joint A more elaborate version of the dado joint, in which the shelf or divider has a dovetail-shaped tongue milled on its end that fits into a correspondingly shaped dado on the case.

sliding half-dovetail A variation on the sliding dovetail, this joint has just one sloping side.

sliding miter saw A saw with a greater crosscutting ability than the simple miter saw, because the blade housing can be drawn out on slides to the operator before being dropped into the work.

sliding T-bevel Another name for a bevel square.

slip joint A joint where the end of one piece is joined to the end of its mating piece through a recess milled into one piece; material is removed from the other so that what remains slips into a recess machined in the first piece.

slip pattern A veneer pattern made by arranging consecutive leaves from a flitch side by side.

snipe An extra stepped cut made at the end of a board being jointed, resulting from the outfeed table being set too low.

soapstone A natural, quarried stone used for countertops.

socket The recess into which a tail or pin will fit.

sofa Also called a couch, it is a larger version of an easy chair that is meant for more than one occupant.

softwood A simpler, earlier type of tree; a conifer.

sole Bottom surface of a plane.

sole proprietorship The simplest form of business structure in which the owner owns all the assets of the business, keeps all profits generated by it, and has complete responsibility for any liabilities and debts.

solid surface material An acrylic material which is manufactured into flat sheet panels.

Soss hinge A hinge similar to a barrel hinge but with leaves.

specific adhesion The molecular attraction between glue and wood.

Speed Square A three-sided, triangular-shaped measuring tool used to lay out right angles and angles needed for roofs and stairs.

spindle A splat that is turned, not shaped.

spindle gouge Smaller gouge used for detail work.

spindle turning Method of turning work on a lathe where the grain of the piece being turned runs parallel to the bed of the lathe.

spirit stain A powder dye that is dissolved in denatured alcohol, ethyl alcohol, or acetone.

splat A piece of wood running between the seat and the crest rail, which functions to support the back; it is often shaped but not turned.

spline A strip of wood that fits into two matching grooves; one is machined into each adjoining piece.

splined miter A simple miter joint with a groove is milled into each adjoining part, into which a spline is fit and glued up with the corner.

split A crack along the grain that travels the length of the wood; caused by a separation of wood fibers.

split-fast anchor A one-piece steel fastener used in solid concrete walls with two sheared, expanded halves at the base.

splitter or riving knife A device, narrower than the thickness of the saw blade that sits behind the blade and in line with it and prevents a piece being ripped from pinching back together after the cut.

spokeshave A metal blade held in a frame; used for rounding surfaces.

spring clamp A holding device that works by the same action as clothespin and is similarly shaped.

springwood Another term for earlywood.

square A T-shaped or L-shaped tool for drawing or testing right angles.

stacked dado A saw blade with two outside blades and inside chippers of various widths.

stack method Also called the overlapping method; a way of cutting the pieces for a marquetry project all at the same time, rather than individually.

standards Accepted guidelines based on average sizes for children and adults.

standard router Another name for a fixed-base router.

staple A piece of wire in the shape of a square bracket, typically driven by a pneumatic fastener; used where it will not be seen.

staves Edge-beveled pieces used in coopering.

stay-log cutting A method of cutting where a log or flitch is mounted on a lathe with an eccentric chuck and then swung against the knife.

steel tape A measuring tool which retracts into a metal case.

stile Vertical member of a frame.

stool Like a bench, a historically early type of seating but designed for one person.

stop block Block of wood clamped to a fence or miter gauge to make repetitive cuts of the same length and to limit cuts.

stopped-dado housing A dado in a case that stops short of the front of the case.

strap hinge Hardware with two long straps or one strap and a butt hinge leaf; used on trunks and flush doors with face frames.

stretcher Wood that runs between rungs and connects them.

strings Thin, narrow strips of wood that are used as inlays.

summerwood Another term for latewood.

surface hinge A completely visible hinge that is mounted on the surface of the door and the surface of the cabinet.

swaged A butt hinge that is shaped for a closer fit.

synthetic adhesives Adhesives created through a chemical process.

T

32-millimeter cabinet Another term for a European style cabinet, based on the spacing of the holes in the cabinet.

table A piece of furniture which is composed of a horizontal surface supported by a base.

table-extension slides Either wood or metal strips that are used in pairs on extension tables to open the table for the accommodation of table leaves.

table locks Fasteners that align and secure table leaves to the main table and to one another.

table pins Pieces used to align table leaves with the main table and other leaves.

table saw A motorized, circular saw blade mounted on an arbor, which protrudes through a table.

tail The angled tenon found on one board of the two that form a dovetail joint.

tailstock Part of a lathe that supports work on the right side of the bed.

tangential grain A board exhibiting tangential grain on its face; it was cut tangent to the tree's annual rings.

tannin A chemical compound found in wood.

taper A gradual reducing in the thickness or width of a piece from one end to another.

tenon Projecting tab that fits into a mortise.

tenoning jig Device on a table saw to make the vertical cuts in tenon manufacture.

tenon saw Mid-sized backsaw used for cutting tenons.

test cut A cut made to check the setup of a machine.

texture The way a project feels or appears to feel.

thermoplastic Adhesives dispersed through a water system.

thermosetting Adhesives that cure through a chemical reaction.

thickness planer A machine used to create boards that are of an even thickness throughout their length.

threaded inserts Hardware used with machine screws or bolts in situations where frequent assembly and disassembly may occur.

throat depth The vertical distance from a table to a guide post when raised to its highest position.

throat plate Also called an insert, it is a removable piece through which the saw blade protrudes.

throat width The horizontal distance from a blade to a support column.

through dado housing A dado that runs all the way through the case.

through dovetail A joint where the socket that the tail fits into is cut all the way through the adjoining board so that the joint is visible when looking at either of the two boards that comprise it.

through mortise and tenon A joint that has a mortise that goes all the way through the stile.

thrust bearing A metal piece that sits behind the blade and prevents it from walking backwards.

tight face Usually the front of the veneer; the face absent of knife checks.

toggle bolt A fastener consisting of a bolt and a spring-loaded toggle, used to secure objects to hollow walls.

toggle clamp A holding device characterized by a quick-release mechanism that allows pressure to be quickly applied or released.

tone The quality of color, such as the brightness, depth, and hue.

tongue-and-dado housing A housing with a dado in the case and a tongue with shoulders on both sides on the shelf or divider.

tongue-and-groove joint A joint with a tongue machined on the edge of one piece and a matching groove on the piece adjacent to it.

tool guard Safety device designed for use with specific tools that keeps the operator's hands from getting dangerously close to spinning blades, bits, and cutters.

toothing plane A tool with grooves in the planing iron; it is used to roughen solid wood substrate so that veneer will adhere to the substrate better.

TPI Teeth per inch.

trammel points Two sliding sockets holding steel or pencil points that are attached to a metal or wood rod; used for marking out large arcs and circles.

trestle table Sometimes built as a knockdown table, it consists of two leg assemblies, called trestles, that support the tabletop and are connected by a stretcher.

try square A tool used for measuring and marking square work, it is comprised of a metal straightedge set at a right angle to a straight piece.

tung oil A penetrating finish that is made from the seeds in the fruit of the tung tree.

tusk-tenon joint A joint where the tenon extends through its mortise and beyond. The tenon itself has a mortise through it, which allows the insertion of a removable wedge that locks the joint together.

twin-tenon joint A joint used to join a drawer rail to a leg.

twist A board that looks as though it is spiraling.

U

universal plug A light-duty nylon anchoring device used in hollow walls.

V

vacuum clamping A method of holding material in place using atmospheric pressure.

vanity panel Also called a modesty panel, material that covers the kneehole on the far side of a pedestal desk.

variables Physical differences between people and objects.

varnish stain A combination stain and varnish.

veneer A thin slice of a log or timber.

veneer hammer A tool used to press veneer down against the core material once the adhesive is in place.

veneering The process of affixing a thin layer to some type of solid substrate.

veneer punch A tool used to repair defects in veneer, it has cutter which cuts an irregularly shaped hole.

veneer saw A saw used with a straightedge to cut veneer, it has a very thin, curved blade and teeth with no set.

veneer tape A gummed paper that may or not be perforated; it is used to hold cut veneer pieces together until after they are glued; available in different widths, it is attached to the edges of panel products to disguise the fact that they are not solid materials.

vertical-surface laminate Material 1/32" thick that is adhered to the sides and other outside surfaces of cabinets that are subject to less wear than countertops.

volatile organic compounds (VOCs) Compounds that are released into the atmosphere by spraying lacquers and varnishes.

W

wall cabinet A cabinet that hangs on the wall, usually referring to a kitchen cabinet.

wane The presence of bark or absence of wood on corners or edges.

warp Any deviation from a true flat surface that results from uneven shrinkage; a general term that includes bow, crook, cup, twist, and kink.

water resistance An adhesive's ability to withstand wetness.

water stain A wood coloring agent that consists of a color dissolved in a thinner of pure water.

waterwheel A wheel propelled by falling or running water used to power machinery.

wax stain A penetrating oil stain or a pigmented oil stain to which wax and a drier have been added.

web clamp A holding device consisting of a cloth strap that is about an inch wide and a screw or ratchet mechanism for tightening.

web frame A structure installed inside a case that ties the case together and supports and separates drawers.

wedged mortise and tenon A joint where the tenon has a kerf sawn into it, and a wedge is inserted to force the tenon tight against the mortise.

wind Another term for a twist.

window method A way of cutting veneer for a picture that involves using a pattern copied onto cardboard, in which individual pieces of the picture are cut out of the cardboard and used as a template to cut out individual pieces of veneer.

wobble dado A single blade that oscillates back and forth as it spins to create a recess.

wooden rule A folding measuring tool typically 6" or 8" long.

writing desk Also called a writing table, it is essentially a table with drawers.

X

xylem The inner part of the cambium in a tree; creates cells that become sapwood.

Y

Yankee push drill A drill that works by pushing on the top of the tool to turn the bit and cut a hole; can be used one-handed and usually has a magazine in the handle for holding bits.

Z

Z-clip Type of metal tabletop fastener.

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