NINTH EDITION

EXPLORING WOODWORKING

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Introduction

Exploring Woodworking is designed to assist in learning the fundamentals of working safely and efficiently with hand tools and power tools. In addition, the book acquaints you with the different types of woods and their uses. It also introduces you to the industrial woodworking environment, and describes the technology used today to produce a variety of wood products.

The information included in *Exploring Woodworking* is presented in an easy-to-understand format. New terms are listed at the start of each section and are introduced within that section. This allows you to be introduced to a new term in context, resulting in the best understanding of the material being presented. Safety is stressed throughout the text and is highlighted using a predominant second color. This enables you to easily locate important information regarding the care and safe operation of tools and equipment.

Exploring Woodworking emphasizes the important role that wood and wood by-products play in our everyday lives. Wood is a vital part of our future. Improved technology, conservation, and recycling will be critical to ensuring an adequate supply of wood for the future.

The contents of this book are presented in an orderly and organized manner. Information regarding the materials used in woodworking, safety, and product planning is presented first. Subsequent chapters focus on hand tools, portable power tools, and power woodworking machines, including information on safety and proper use. Updated information in the areas of project construction, wood finishing, lamination, wood bending, and adhesives is also covered. Chapters presenting information on automated manufacturing, entrepreneurship, and career opportunities are also included in this book. Many operations that occur in an industrial setting are different from those that occur in a wood lab. However, the theory and principles of operation remain the same.

The final chapter of *Exploring Woodworking* provides construction details of carefully selected new projects. These projects provide students with exciting, easy, first-time projects to build. A special section also shows simple-to-complex woodworking projects completed by students.

Exploring Woodworking is intended for students in middle schools, junior high schools, and high school career and technology education programs. Since this is a beginning level exploratory woodworking book, it could also be used for adult education classes and by the do-it-yourselfer.

About the Author

Fred W. Zimmerman was Professor Emeritus from Western Illinois University in Macomb, Illinois. Fred earned several degrees, including a bachelor of science degree from Southern Illinois University, a master of science degree from Kent State University, and a doctorate in Industrial Education from Bradley University in Peoria, Illinois. He had extensive experience as both an instructor and woodworker, and was active in the Illinois Vocational Industrial Clubs of America as a judge in the cabinetmaking and millwork areas. Fred was a member of the Illinois Woodworking Teachers Association and a Life Member of the International Industrial Education Association.

Larry J. McWard is a professor in the Industrial Education and Technology department at Western Illinois University. He has earned several degrees, including a bachelor of science degree in Industrial Education and Vocational Education, and a master of science degree in Instructional Technology (Media) from Southern Illinois University. He has also earned a doctorate in Vocational-Technical Education from The Ohio State University. Larry's work experience includes 20 years of teaching experience at the junior high, high school, and university levels. Courses taught include vocational building trades and cabinetmaking. Larry also has 12 years of work experience as a carpenter, cabinetmaker, and general contractor. Larry is actively involved in the National Association of Industrial and Technical Teacher Educators, Association for Career and Technical Education, and is past-president of the Illinois Woodworking Teachers Association.

Don L. Blazek received his bachelor of science degree in Industrial Education from Fort Hays State University in Hays, Kansas, and his master of science degree at Pittsburg State University in Pittsburg, Kansas. He taught in the Shawnee Mission School District #512, located in Overland Park, Kansas. He taught an exploratory industrial education program consisting of materials and processes (wood and plastics), visual communication (drafting, graphic arts, photography, and video production) and manufacturing processes. He served on two federally funded development projects for the development of pilot industrial education programs for middle/junior high schools for the state of Kansas. This SET (Secondary Exploration of Technology) helped lead to the development of the modular concept of teaching technology education. Don also taught woodworking adult education classes at the local community college and woodworking retail store. Over the span of his teaching career, he was actively involved with the Kansas Industrial Education Association, American Industrial Arts Association, and Skills USA. In 1978 he was selected the Outstanding Industrial Education Teacher for the state of Kansas.

Reviewers

The author and publisher wish to thank the following industry and teaching professionals for their valuable input into the development of *Exploring Woodworking*.

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New to This Edition

The following changes have been made to the ninth edition of *Exploring Woodworking* to provide up-to-date information on the latest technology and industrial developments.

- Essential Questions at the beginning of each chapter have been added to get students thinking about the topic before reading the chapter.
- Going Green features have been added to emphasize conservation and recycling practices.
- Images have been updated and added to show current practices and tools.
- Woodworking projects have been updated to reflect current industry trends.
- End-of-Chapter material has been revised and updated to include a Summary and Critical Thinking questions, helping to extend student learning and understanding.

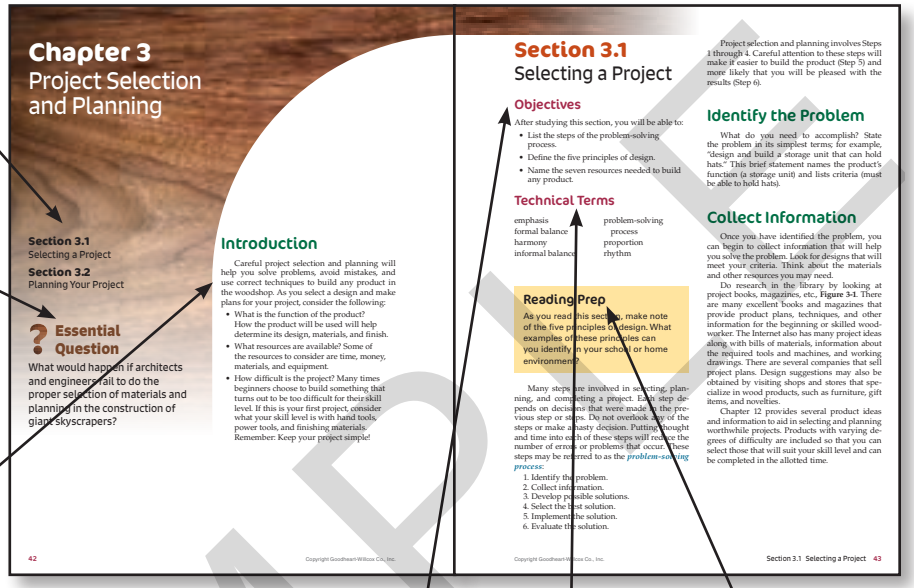
Guided Tour

The instructional design includes student-focused learning tools to help students succeed. This visual guide highlights the features designed for the textbook.

Chapter Outline summarizes the topics that will be covered in the chapter.

Essential Question helps you to connect what you are learning to real-world scenarios.

Introduction provides an overview and preview of the chapter content.



Chapter 3
Project Selection and Planning

Section 3.1 Selecting a Project
Section 3.2 Planning Your Project

Essential Question
What would happen if architects and engineers fail to do the proper selection of materials and planning in the construction of giant skyscrapers?

Introduction

Careful project selection and planning will help you solve problems, avoid mistakes, and use correct techniques to build any product in the woodshop. As you select a design and make plans for your project, consider the following:

- What is the function of the product? How the product will be used will help determine its design, materials, and finish.
- What resources are available? Some of the resources to consider are time, money, materials, and equipment.
- How difficult is the project? Many times beginners choose to build something that turns out to be too difficult for their skill level. If this is your first project, consider what your skill level is with hand tools, power tools, and finishing materials. Remember: Keep your project simple!

Section 3.1
Selecting a Project

Objectives

After studying this section, you will be able to:

- List the steps of the problem-solving process.
- Define the five principles of design.
- Name the seven resources needed to build any product.

Technical Terms

emphasis, formal balance, harmony, informal balance, problem-solving process, proportion, rhythm

Reading Prep

As you read this section, make note of the five principles of design. What examples of these principles can you identify in your school or home environment?

Many steps are involved in selecting, planning, and completing a project. Each step depends on decisions that were made in the previous step or steps. Do not overlook any of the steps or make a hasty decision. Putting thought and time into each of these steps will reduce the number of errors or problems that occur. These steps may be referred to as the *problem-solving process:*

1. Identify the problem.
2. Collect information.
3. Develop possible solutions.
4. Select the best solution.
5. Implement the solution.
6. Evaluate the solution.

Project selection and planning involves Steps 1 through 4. Careful attention to these steps will make it easier to build the product (Step 5) and more likely that you will be pleased with the results (Step 6).

Identify the Problem

What do you need to accomplish? State the problem in its simplest terms; for example, "design and build a storage unit that can hold hats." This brief statement names the product's function (a storage unit) and lists criteria (must be able to hold hats).

Collect Information

Once you have identified the problem, you can begin to collect information that will help you solve the problem. Look for designs that will meet your criteria. Think about the materials and other resources you may need.

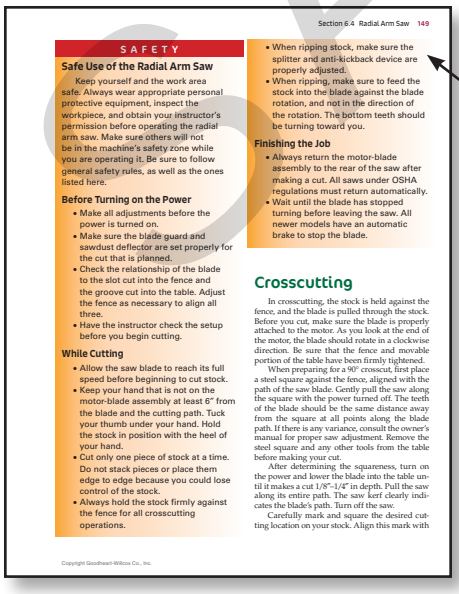
Do research in the library by looking at project books, magazines, etc., Figure 3-1. There are many excellent books and magazines that provide product plans, techniques, and other information for the beginning or skilled woodworker. The Internet also has many project ideas along with bills of materials, information about the required tools and machines, and working drawings. There are several companies that sell project plans. Design suggestions may also be obtained by visiting shops and stores that specialize in wood products, such as furniture, gift items, and novelties.

Chapter 12 provides several product ideas and information to aid in selecting and planning worthwhile projects. Products with varying degrees of difficulty are included so that you can select those that will suit your skill level and can be completed in the allotted time.

Objectives clearly identify the knowledge and skills to be obtained when the chapter is completed.

Technical Terms list the key terms to be learned in the chapter.

Reading Prep helps you prepare to understand the chapter.



SAFETY

Safe Use of the Radial Arm Saw

Keep yourself and the work area safe. Always wear appropriate personal protective equipment, inspect the workpiece, and obtain your instructor's permission before operating the radial arm saw. Make sure others will not be in the machine's safety zone while you are operating it. Be sure to follow general safety rules, as well as the ones listed here.

Before Turning on the Power

- Make all adjustments before the power is turned on.
- Make sure the blade guard and sawdust deflector are set properly for the cut that is planned.
- Check the relationship of the blade to the slot cut into the fence and the groove cut into the table. Adjust the fence as necessary to align all three.
- Have the instructor check the setup before you begin cutting.

While Cutting

- Allow the saw blade to reach its full speed before beginning to cut stock.
- Keep your hand that is not on the motor-blade assembly at least 6" from the blade and the cutting path. Tuck your thumb under your hand. Hold the stock in position with the heel of your hand.
- Cut only one piece of stock at a time. Do not stack pieces or place them edge to edge because you could lose control of the stock.
- Always hold the stock firmly against the fence for all crosscutting operations.
- When ripping stock, make sure the splitter and anti-kickback device are properly adjusted.
- When ripping, make sure to feed the stock into the blade against the blade rotation, and not in the direction of the rotation. The bottom teeth should be turning toward you.

Finishing the Job

- Always return the motor-blade assembly to the rear of the saw after making a cut. All saws under OSHA regulations must return automatically.
- Wait until the blade has stopped turning before leaving the saw. All newer models have an automatic brake to stop the blade.

Crosscutting

In crosscutting, the stock is held against the fence, and the blade is pulled through the stock. Before you cut, make sure the blade is properly attached to the motor. As you look at the end of the motor, the blade should rotate in a clockwise direction. Be sure that the fence and movable portion of the table have been firmly tightened.

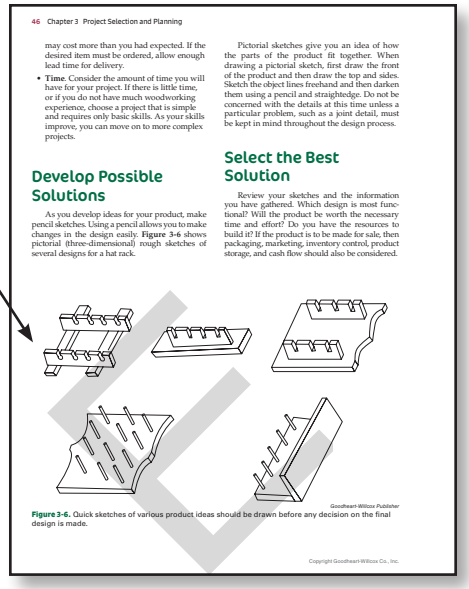
When preparing for a 90° crosscut, first place a steel square against the fence, aligned with the path of the saw blade. Gently pull the saw along the square with the power turned off. The teeth of the blade should be the same distance away from the square at all points along the blade path. If there is any variance, consult the owner's manual for proper saw adjustment. Remove the steel square and any other tools from the table before making your cut.

After determining the squareness, turn on the power and lower the blade into the table until it makes a cut 1/8"–1/4" in depth. Pull the saw along its entire path. The saw kerf clearly indicates the blade's path. Turn off the saw.

Carefully mark and square the desired cutting location on your stock. Align this mark with

Safety Notes alert you to potentially dangerous materials and practices.

Illustrations have been designed to clearly and simply communicate the specific topic.


46 Chapter 3 Project Selection and Planning

may cost more than you had expected. If the desired item must be ordered, allow enough lead time for delivery.

- **Time**. Consider the amount of time you will have for your project. If there is little time, or if you do not have much woodworking experience, choose a project that is simple and requires only basic skills. As your skills improve, you can move on to more complex projects.

Develop Possible Solutions

As you develop ideas for your product, make pencil sketches. Using a pencil allows you to make changes in the design easily. **Figure 3-6** shows pictorial (three-dimensional) rough sketches of several designs for a hat rack.

Pictorial sketches give you an idea of how the parts of the product fit together. When drawing a pictorial sketch, first draw the front of the product and then draw the top and sides. Sketch the object lines freehand and then darken them using a pencil and straightedge. Do not be concerned with the details at this time unless a particular problem, such as a joint detail, must be kept in mind throughout the design process.

Select the Best Solution

Review your sketches and the information you have gathered. Which design is most functional? Will the product be worth the necessary time and effort? Do you have the resources to build it? If the product is to be made for sale, then packaging, marketing, inventory control, product storage, and cash flow should also be considered.

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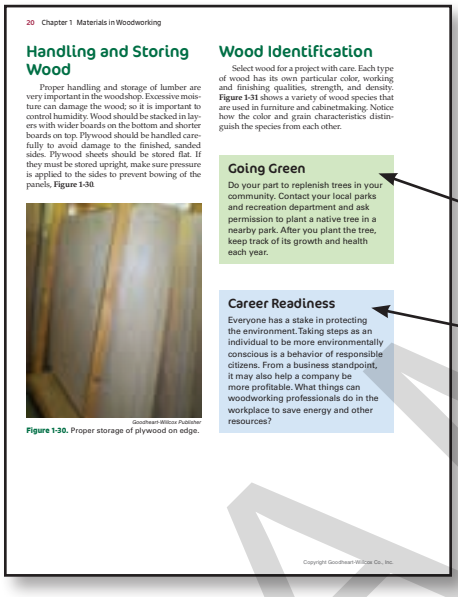
Figure 3-6. Quick sketches of various product ideas should be drawn before any decision on the final design is made.


20 Chapter 1 Materials in Woodworking

Handling and Storing Wood

Proper handling and storage of lumber are very important in the woodshop. Excessive moisture can damage the wood; so it is important to control humidity. Wood should be stacked in layers with wider boards on the bottom and shorter boards on top. Plywood should be handled carefully to avoid damage to the finished, sanded sides. Plywood sheets should be stored flat. If they must be stored upright, make sure pressure is applied to the sides to prevent bowing of the panels, **Figure 1-30**.

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Figure 1-30. Proper storage of plywood on edge.

Wood Identification

Select wood for a project with care. Each type of wood has its own particular color, working and finishing qualities, strength, and density. **Figure 1-31** shows a variety of wood species that are used in furniture and cabinetmaking. Notice how the color and grain characteristics distinguish the species from each other.

Going Green

Do your part to replenish trees in your community. Contact your local parks and recreation department and ask permission to plant a native tree in a nearby park. After you plant the tree, keep track of its growth and health each year.

Career Readiness

Everyone has a stake in protecting the environment. Taking steps as an individual to be more environmentally conscious is a behavior of responsible citizens. From a business standpoint, it may also help a company be more profitable. What things can woodworking professionals do in the workplace to save energy and other resources?

Going Green notes highlight key items related to sustainability, energy efficiency, and environmental issues.

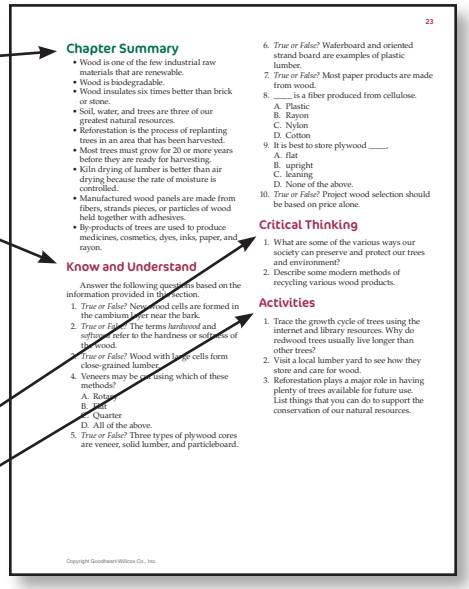
Career Readiness helps you understand what you can anticipate and expect in the workplace.

Chapter Summary provides an additional review tool for you and reinforces key learning objectives.

Know and Understand questions enable you to demonstrate knowledge, identification, and comprehension of chapter material. These review questions are provided both at the end of each section for immediate review of content and as a cumulative review at the end of each chapter.

Critical Thinking questions develop higher-order thinking and problem-solving, personal, and workplace skills.

Activities extend your learning and help you apply knowledge.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Chapter Summary

- Wood is one of the few industrial raw materials that are renewable.
- Wood is biodegradable.
- Wood insulates six times better than brick or stone.
- Soil, water, and trees are three of our greatest natural resources.
- Reforestation is the process of replanting trees in an area that has been harvested.
- Most trees must grow for 20 or more years before they are ready for harvesting.
- Kiln drying of lumber is better than air drying because the rate of moisture is controlled.
- Manufactured wood panels are made from fibers, strands pieces, or particles of wood held together with adhesives.
- By-products of trees are used to produce medicines, cosmetics, dyes, inks, paper, and rayon.

Know and Understand

Answer the following questions based on the information provided in this section.

1. *True or False?* Newly wood cells are formed in the cambium layer near the bark.
2. *True or False?* The terms *hardwood* and *softwood* refer to the hardness or softness of the wood.
3. *True or False?* Wood with large cells form close-grained lumber.
4. Veneers may be cut using which of these methods?
   A. Rotary
   B. Flat
   C. Quarter
   D. All of the above.
5. *True or False?* Three types of plywood cores are veneer, solid lumber, and particleboard.
6. *True or False?* Waferboard and oriented strand board are examples of plastic lumber.
7. *True or False?* Most paper products are made from wood.
8. ____ is a fiber produced from cellulose.
   A. Plastic
   B. Rayon
   C. Nylon
   D. Cotton
9. It is best to store plywood ____.
   A. flat
   B. upright
   C. leaning
   D. None of the above.
10. *True or False?* Project wood selection should be based on price alone.

Critical Thinking

1. What are some of the various ways our society can preserve and protect our trees and environment?
2. Describe some modern methods of recycling various wood products.

Activities

1. Trace the growth cycle of trees using the internet and library resources. Why do redwood trees usually live longer than other trees?
2. Visit a local lumber yard to see how they store and care for wood.
3. Reforestation plays a major role in having plenty of trees available for future use. List things that you can do to support the conservation of our natural resources.

TOOLS FOR STUDENT AND INSTRUCTOR SUCCESS

Student Tools

Student Text

Exploring Woodworking provides the essential knowledge that beginning students require, introducing different woods and their characteristics in addition to basic techniques using hand and power tools.

Workbook

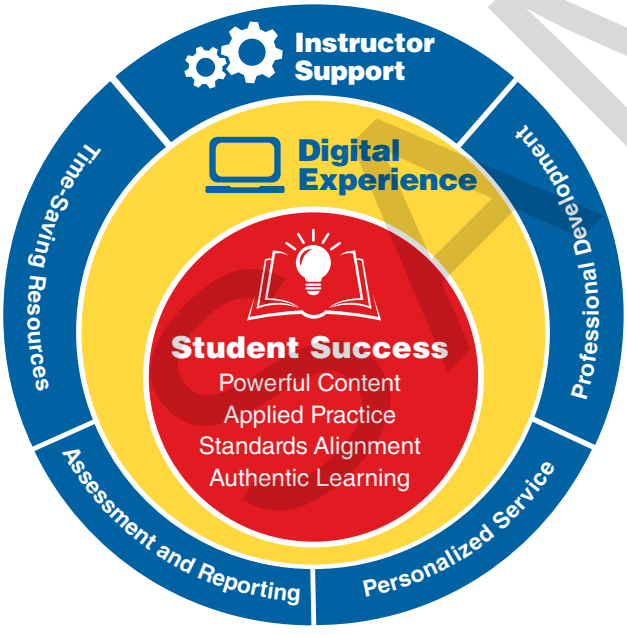
- Includes review questions to help students recall, review, and apply concepts introduced in the book.

G-W Companion Website

For digital users, e-flash cards and vocabulary exercises allow interaction with content to create opportunities to increase achievement.

Online Learning Suite

- Online student text and workbook, along with rich supplemental content, bring digital learning to the classroom.
- All instructional materials are accessible at home, at school, or on the go.



Instructor Tools

LMS Integration

Integrate Goodheart-Willcox content within your Learning Management System for a seamless user experience for both you and your students. EduHub LMS–ready content in Common Cartridge® format facilitates single sign-on integration and gives you control of student enrollment and data. With a Common Cartridge integration, you can access the LMS features and tools you are accustomed to using and G-W course resources in one convenient location—your LMS.

G-W Common Cartridge provides a complete learning package for you and your students. The included digital resources help your students remain engaged and learn effectively:

- **Digital Textbook**
- **Online Workbook content**
- **Drill and Practice vocabulary activities**

When you incorporate G-W content into your courses via Common Cartridge, you have the flexibility to customize and structure the content to meet the educational needs of your students. You may also choose to add your own content to the course.

For instructors, the Common Cartridge includes the Online Instructor Resources. QTI® question banks are available within the Online Instructor Resources for import into your LMS. These prebuilt assessments help you measure student knowledge and track results in your LMS gradebook. Questions and tests can be customized to meet your assessment needs.

Online Instructor Resources (OIR)

- The **Instructor Resources** provide instructors with time-saving preparation tools such as answer keys, editable lesson plans, and other teaching aids.
- **Instructor's Presentations for PowerPoint®** are fully customizable, richly illustrated slides that help you teach and visually reinforce the key concepts from each chapter.
- Administer and manage assessments to meet your classroom needs using **Assessment Software with Question Banks**, which include hundreds of matching, completion, multiple choice, and short answer questions to assess student knowledge of the content in each chapter.

See www.g-w.com/exploring-woodworking-2024 for a list of all available resources.

Professional Development

- Expert content specialists
- Research-based pedagogy and instructional practices
- Options for virtual and in-person professional development

Brief Contents

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Safety

Chapter 3
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- Define the five principles of design.
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Technical Terms

emphasis
formal balance
harmony
informal balance
problem-solving process
proportion
rhythm

Reading Prep

As you read this section, make note of the five principles of design. What examples of these principles can you identify in your school or home environment?

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Collect Information

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Do research in the library by looking at project books, magazines, etc., **Figure 3-1**. There are many excellent books and magazines that provide product plans, techniques, and other information for the beginning or skilled woodworker. The Internet also has many project ideas along with bills of materials, information about the required tools and machines, and working drawings. There are several companies that sell project plans. Design suggestions may also be obtained by visiting shops and stores that specialize in wood products, such as furniture, gift items, and novelties.

Chapter 12 provides several product ideas and information to aid in selecting and planning worthwhile projects. Products with varying degrees of difficulty are included so that you can select those that will suit your skill level and can be completed in the allotted time.

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Figure 3-1. Books, magazines, and the Internet are good sources of ideas for woodworking projects.

Consider Design

As you look at various design ideas or develop your own, keep in mind the five principles of design: proportion, emphasis, rhythm, balance, and harmony.

Proportion is the size relationship of one part to another. It is often expressed as a ratio of a product's dimensions. An odd ratio, such as 1:3 ("one to three") or 2:5 is generally more pleasing than an even ratio, such as 1:4 and 1:2. To determine the ratio, place the shorter dimension over the longer dimension and reduce to lowest terms. For example, a coffee table measuring 18" wide and 42" long has a size ratio of 18/42, which reduces to 3/7. Thus the ratio is 3:7.

Emphasis is the center of interest or the area of greatest importance. For example, **Figure 3-2** shows a table with a unique shape to the top. The unusual shape provides emphasis.

Rhythm is the repetition of a shape, color, or line. For example, a chest of drawers in which all the drawer fronts are the same shape and size displays rhythm, **Figure 3-3**.

Goodheart-Willcox Publisher

Figure 3-2. Individual interests and needs can lead to unique designs.

Goodheart-Willcox Publisher

Figure 3-3. Repetition of the drawer fronts lends rhythm to the design of this furniture piece.

Balance is very important in determining how people perceive a design. There are two types of balance: formal and informal. ***Formal balance*** exists when all of the elements on one side of a design are mirror images of the elements on the other side, **Figure 3-4**. Formal balance gives a design an even appearance. ***Informal balance*** is achieved when the elements of a design are different on each side, but each side still has equal importance, **Figure 3-5**.

Harmony, or unity, is achieved when all the parts, colors, shapes, and textures of an object "get along together." All the design elements look as though they belong, and together they give the product a unified appearance.

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Figure 3-4. The left and right sides of this cabinet are in formal balance.

Goodheart-Willcox Publisher

Figure 3-5. This entertainment center displays informal balance.

Determine Resources

Resources are anything that will be needed to make the product. The resources you will need to build any product include people, information, materials, tools and equipment, energy, money, and time.

- **People**. Will you be building the project by yourself? If so, you will want to select a project that will interest you and be within your skill level. Will you be part of a team? If others will be involved, you will need to discuss who will do what. What skills does each team member have? How can those skills be applied to the project?
- **Information**. You will need information, such as drawings and a plan of procedure. If you have the skill, you may be developing the drawings yourself.
- **Materials**. What supplies will you need for your project? The kind of wood to use depends largely on the function and finish of the product. If an opaque finish such as paint will be applied, an inexpensive wood could be used. A poor grain pattern would not matter, so long as the wood could hold paint well. There is considerable difference in the working qualities of various woods. If you are building your first project, you might want to consider a softer wood such as pine, poplar, gum, or basswood. Working with harder woods such as walnut, oak, and maple requires more skill.
- **Tools and Equipment**. If the tools or equipment required to build a product are not available in the shop, determine whether different tools can be used. For example, rough sawn 4/4 (1") lumber generally should not be purchased if a planer is not available to smooth the surfaces. However, you may be able to use a hand plane to smooth the stock if the piece is small. A less obvious tool consideration relates to designing joints. Do not plan on a locking miter joint or dovetail joints if a shaper or router with the proper cutters is not available. There are many options for a good-quality finish. Some finishes only require a rag or a disposable brush, while others require a moisture-controlled spray area with filtration and high-tech spray equipment.
- **Energy**. If the product you are considering will require power tools and machines, you will need a reliable energy source. Most power tools and machines for woodworking use electricity. Pneumatic tools, such as nailers, are powered by compressed air. The air compressors may use electricity or gasoline.
- **Money**. It is important to consider the cost of the materials that you will use. A product made from oak, walnut, cherry, or mahogany will cost substantially more than one made of pine, fir, cedar, or red gum. Hard-to-find materials and supplies

may cost more than you had expected. If the desired item must be ordered, allow enough lead time for delivery.

- **Time**. Consider the amount of time you will have for your project. If there is little time, or if you do not have much woodworking experience, choose a project that is simple and requires only basic skills. As your skills improve, you can move on to more complex projects.

Develop Possible Solutions

As you develop ideas for your product, make pencil sketches. Using a pencil allows you to make changes in the design easily. **Figure 3-6** shows pictorial (three-dimensional) rough sketches of several designs for a hat rack.

Pictorial sketches give you an idea of how the parts of the product fit together. When drawing a pictorial sketch, first draw the front of the product and then draw the top and sides. Sketch the object lines freehand and then darken them using a pencil and straightedge. Do not be concerned with the details at this time unless a particular problem, such as a joint detail, must be kept in mind throughout the design process.

Select the Best Solution

Review your sketches and the information you have gathered. Which design is most functional? Will the product be worth the necessary time and effort? Do you have the resources to build it? If the product is to be made for sale, then packaging, marketing, inventory control, product storage, and cash flow should also be considered.

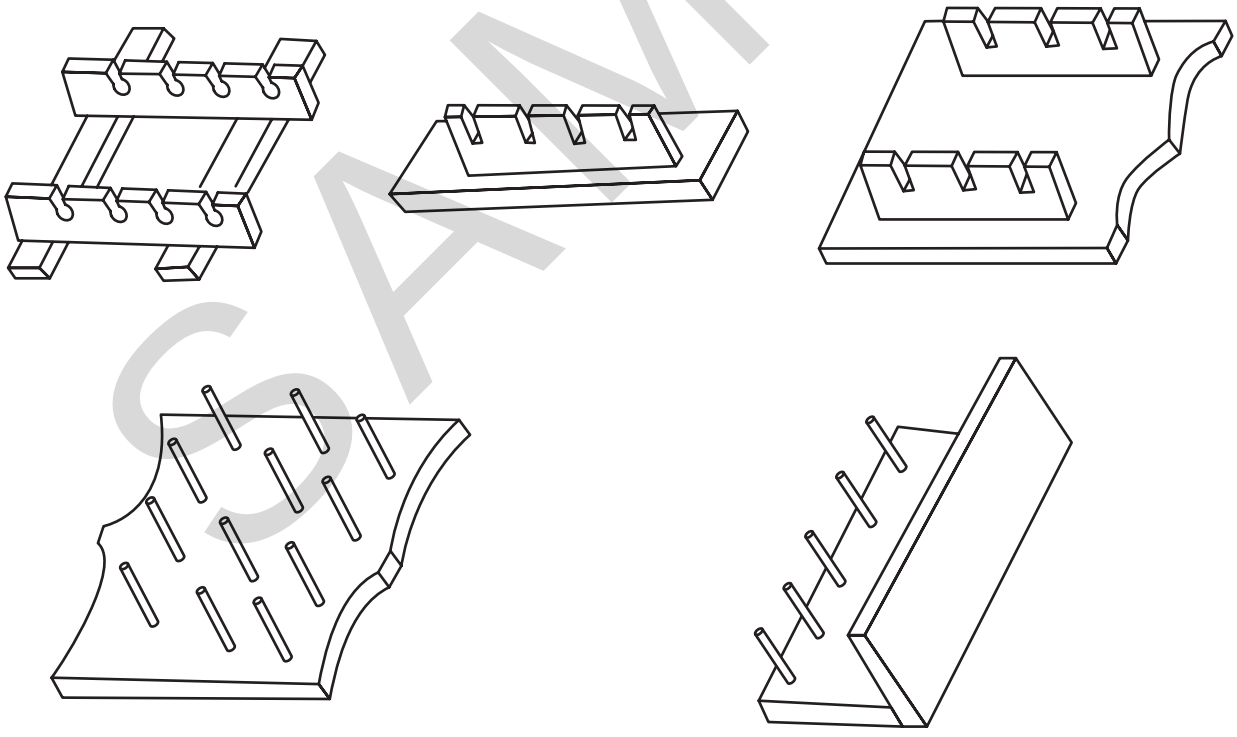

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Figure 3-6. Quick sketches of various product ideas should be drawn before any decision on the final design is made.

Implement the Solution

The next step in the problem-solving process is to implement the solution; in this case, to construct the product. Planning does not stop here. Continue to think ahead and plan throughout the project. Good planning will allow many tasks to be performed at one time. For example, shaping activities may proceed while another part of the product is being glued. If you are making products for sale and have a tight budget or a cash flow problem, it may be necessary to purchase certain parts of the product as needed rather than all at once. A good work flow can be accomplished only by thorough planning.

Evaluate the Solution

This last step is frequently overlooked, but it is essential if you want to continually grow and develop skills in woodworking. Determine the overall success of your project. Consider the obvious: Does the product fulfill the needs that the original problem statement identified? If you answer yes, then you have achieved success; but it is necessary to evaluate other factors to determine the degree of success. What is the overall appearance? Is the finish adequate? Are the joints tight? Were the cost and effort reasonable? This kind of evaluation allows for modification of future products and personal growth as a woodworker.

Know and Understand

Answer the following questions based on the information provided in this section.

1. _____ is the size relationship of one part to another.
   A. Emphasis
   B. Proportion
   C. Rhythm
   D. Harmony
2. _____ is the center of interest or the area of greatest importance on a product.
   A. Emphasis
   B. Proportion
   C. Rhythm
   D. Harmony
3. *True or False?* The repetition of shape, color, or line creates harmony.
4. *True or False?* In informal balance, all of the elements on one side of a design are mirror images of the elements on the other side.
5. In _____ balance, the design elements are different on each side.
   A. formal
   B. equal
   C. informal
   D. unity
6. _____ is achieved when all of the design elements work together so the product has a unified appearance.
   A. Balance
   B. Harmony
   C. Proportion
   D. Success

Section 3.2
Planning Your Project

Objectives

After studying this section, you will be able to:

- Describe the concept of scale.
- Read and use working drawings.
- Name and describe five types of lines commonly used on working drawings.
- Calculate board feet, square feet, and lineal feet.
- Prepare a bill of materials for your project.
- Make a stock cutting list for your project.
- Prepare a plan of procedure for constructing your project.

Technical Terms

bill of materials
board foot
center line
dimension line
exploded assembly drawing
extension line
invisible line
length
plan of procedure
scale
stock cutting list
thickness
visible line
width
working drawing

Reading Prep

As you read this section, think of a complex project or task you completed that required planning, calculations, and other preparations. How do the topics discussed in this section relate to your project or task?

Once you have decided on the product design, you may be eager to begin construction right away, but good preparation at this stage will pay off. You will run into fewer problems and delays if you take the time to "plan your work and then work your plan." Make sure you have working drawings, a bill of materials, a stock cutting list, and a plan of procedure.

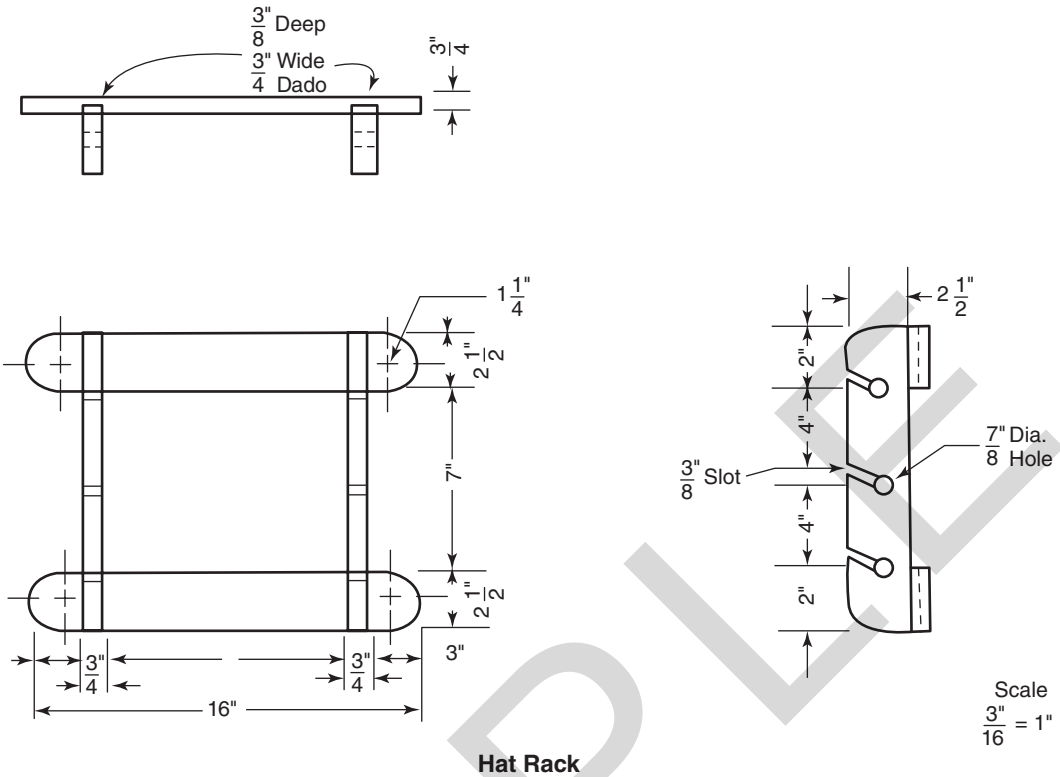
Obtain Working Drawings

In order for you to construct a product, you will need to have accurate working drawings. A *working drawing* indicates the exact size and shape of each part and provides other details necessary to construct a product. **Figure 3-7** shows a working drawing for the hat rack. Compare this drawing with the finished product in **Figure 3-8**.

If you have drafting skills, you can make the working drawings yourself. Revise your rough sketch to include the overall size, the sizes of individual parts, the types of joints, and any other details. The working drawings can be completed by manual drafting methods using a drawing board and straightedge, triangles, scale, and pencil, **Figure 3-9**. Another method, which is somewhat faster, is to use computer-aided design (CAD) software, **Figure 3-10**. Working drawings can also be obtained from books and magazines and on various Internet websites. Plans can also be purchased from various companies that provide a wide range of project ideas.

Views

A view shows an object from one direction. Most objects have six possible views: top, front, back, left side, right side, and bottom. If there is a slanted surface, another (auxiliary) view may be needed. Working drawings commonly consist of one, two, or three views. Most product plans will require at least two views. A three-view drawing will usually show the product from the front, the top, and the right side (end-view). These views will also show the precise dimensions of the parts. **Figure 3-7** is a three-view drawing.



Hat Rack

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Figure 3-7. Final working drawings provide size and construction information.

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Figure 3-8. This hat rack was built according to the working drawings in Figure 3-7.

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Figure 3-9. Manual drafting techniques and tools can be used to make the working drawings for your project.

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Figure 3-10. A fast and easy way to complete working drawings is to use CAD software.

Scale

Most working drawings are done to *scale*. This means they are drawn at a smaller (or larger) size than the actual product but with the same proportions. The dimensions that are written on the drawing show the product's actual size. A final working drawing may be drawn to scale using 1/4" grid paper, **Figure 3-11**. Each 1/4" square might represent 1" or 6" or, for a really large item, 12". Select a scale for your working drawings that will show the necessary details. Full-size plans may be required for some products.

Lines

In any working drawing you will see several kinds of lines. For example, the working drawing for the hat rack in **Figure 3-7** includes most of the following lines:

- *Visible line*. A visible line, or outline, shows the shape of the object. It is drawn as a solid line.
- *Invisible line.* An invisible, or hidden, line indicates the outline of pieces that cannot be seen from the surface. For example, a top view of a table might use hidden lines to show the position of the table legs. Hidden lines look like a series of dashes.
- *Center line.* This type of line marks the object's center, dividing it into two equal parts. Center lines are made of long and short dashes.
- *Extension line.* This line extends out from the outline. Usually, a pair of extension lines is used, and dimensions are placed between the two extension lines.
- *Dimension line.* This line usually has an arrowhead at each end to indicate where a dimension begins and ends. Dimension lines are placed between extension lines, and the dimension figure is written within or above the dimension line. If there is too little space, the dimension line and the dimension itself may be placed outside the extension lines.

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Figure 3-11. Drawing grid paper can be purchased at any drafting or art supply store.

Your working drawings should include all of the dimensions needed to construct your product. When you are reading a drawing, it is important that you read *all* dimensions so you can complete an accurate bill of materials. Once you are ready to begin layout, carefully transfer the exact measurement of each part to the workpiece.

If you select a product plan from a book, magazine, or website, the drawing might have dual dimensions on it. Dual dimensions show customary dimensions at the bottom and metric dimensions at the top, **Figure 3-12**.

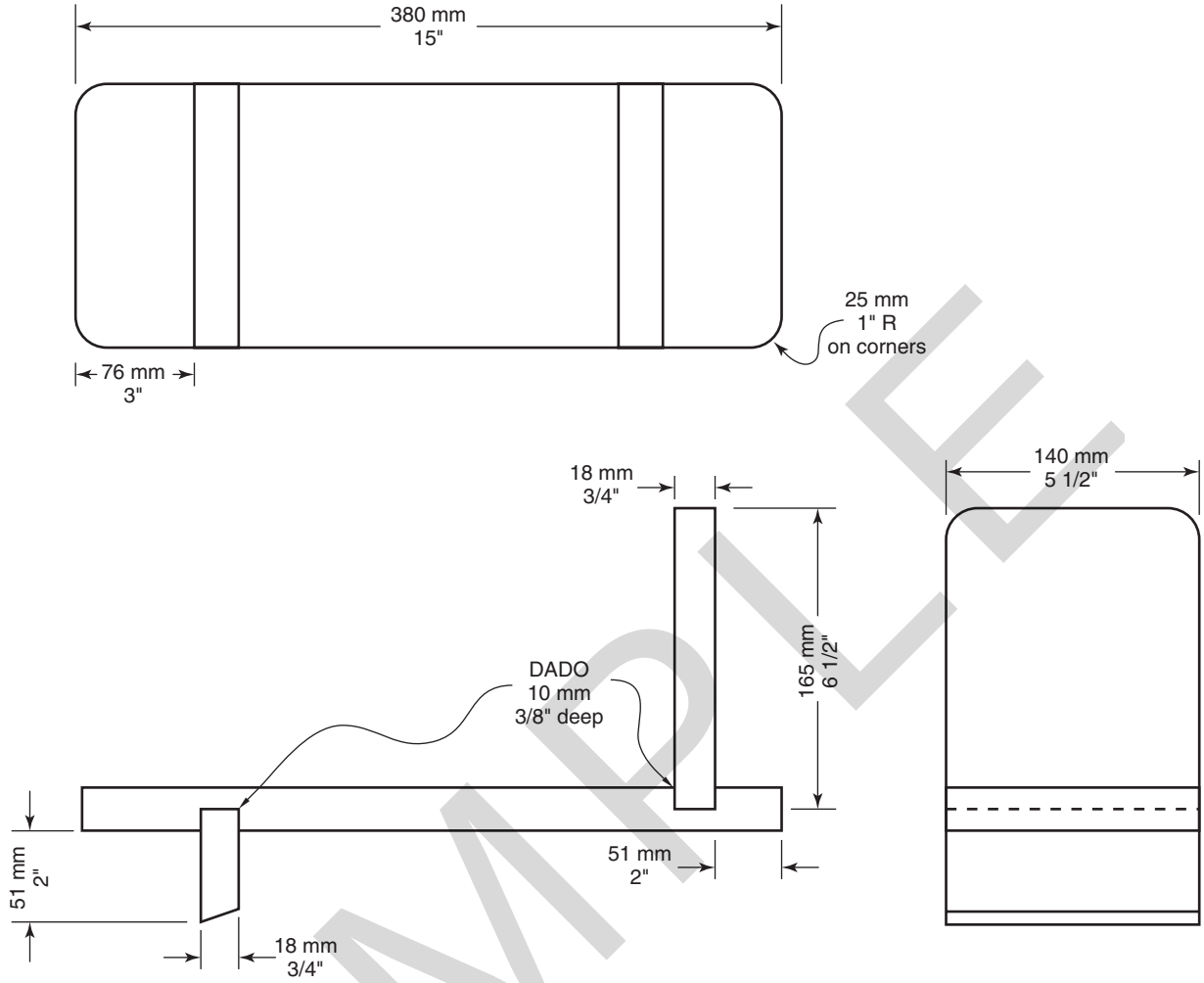

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Figure 3-12. Dual measurements can be found on some product plans.

Some plans in magazines or books will also show other types of drawings in addition to working drawings. A common example is the *exploded assembly drawing*. This type of drawing shows a pictorial of all the parts and how they will go together when assembled. **Figure 3-13** shows the exploded assembly drawing of the hat rack.

Figure Lumber Needs

You can use the working drawings to determine how much wood you will need for your project. Lumber is sold by the board foot, square foot, or lineal foot.

Lumber dimensions are listed in the order of thickness (T), width (W), and length (L). The *thickness* is the distance that is perpendicular to both the width and length. The *width* is the distance across the grain of the wood. The *length* is the distance along the grain of the wood.

Calculating Board Feet

The *board foot* (bd. ft.) is the basic unit of measure for all lumber. A board foot is equal to a piece of lumber measuring 1" or less in thickness, 12" wide, and 12" (1') long. Thus, a board foot is equal to 144 square inches (sq. in.), **Figure 3-14**. Nominal (rough-sawn) sizes are used in computing board feet. Lumber that is 1" thick or less is considered to be 1". For example, a board that is

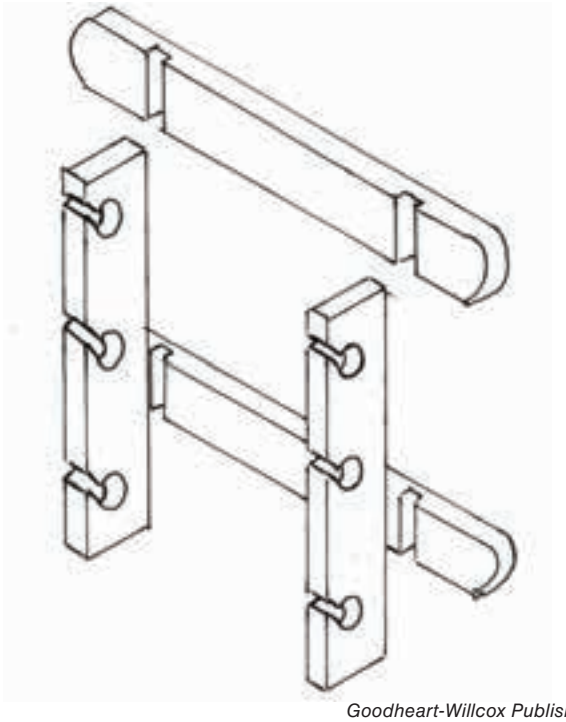

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Figure 3-13. An exploded assembly drawing makes it easy to see how all of the parts will fit together.

1/4" thick is considered to be 1" thick when computing board feet. Lumber that is thicker than 1" is rounded up to the next quarter inch. For example, a board that is 1 1/8" thick is figured to be 1 1/4" thick, and a board that measures 1 3/8" thick is figured as 1 1/2" thick.

To calculate the board feet for small pieces of lumber, multiply the thickness (in inches) times the width (in inches) times the length (in inches) and divide the result by 144. If there are several pieces of lumber all the same size, multiply the number of board feet by the number of pieces. The board foot formula is usually shown as:

$$\text{Bd. ft.} = \frac{\text{T}'' \times \text{W}'' \times \text{L}''}{144}$$

Example: Compute the board foot measure of 3 pieces of wood measuring 1/2" × 6" × 9".

Substituting in the above formula:

$$\text{Bd. ft.} = \frac{3 \text{ pieces} \times 1 \times 6 \times 9}{144}$$

$$\text{Bd. ft.} = 1.125$$

The board feet for long pieces of wood are calculated by multiplying the thickness (in inches) times the width (in inches) times the length (in feet) and dividing the result by 12. This board foot formula is usually shown as:

$$\text{Bd. ft.} = \frac{\text{T}'' \times \text{W}'' \times \text{L}'}{12}$$

Example: Compute the board foot measure of 2 pieces of wood each measuring 1 1/4" thick by 4" wide by 4' long.

Substituting in the previous formula:

$$\text{Bd. ft.} = \frac{2 \text{ pieces} \times 1.25 \times 4 \times 4}{12}$$

$$\text{Bd. ft.} = 3.33$$

It may be easier to figure board feet as square feet (sq. ft.) first and then multiply by the thickness of the board. In this case, remember to multiply feet by feet and inches by inches.

Example: Compute the board foot measure of 1 piece of white pine that measures 3/4" thick by 4" wide by 3' long.

First, multiply the width by the length to obtain square feet. Since the width is given in inches and the length in feet, convert one of the measurements so that both are in inches or both are in feet. For example, 4" equals 4/12.

$$4/12 \times 3 = 1 \text{ sq. ft.}$$

The pine board is 3/4" thick. Recall that lumber 1" thick or less is considered to be 1". The board feet calculation is therefore:

$$\text{Bd. ft.} = 1 \text{ piece} \times 1 \text{ sq. ft.} \times 1 = 1 \text{ bd. ft.}$$

There is another formula for figuring board feet. This formula multiplies the thickness, width, and length (all in inches) by 0.007.

$$\text{Bd. ft.} = \text{No. of pieces} \times \text{Thickness} \times \text{Width} \times \text{Length} \times .007$$

Example: Compute the board feet for the following items: 4 pieces, each 3/4" thick, 6" wide, and 28" long.

Substituting in the above formula:

$$\text{Bd. ft.} = 4 \times 1 \times 6 \times 28 \times .007$$

$$\text{Bd. ft.} = 4.7$$

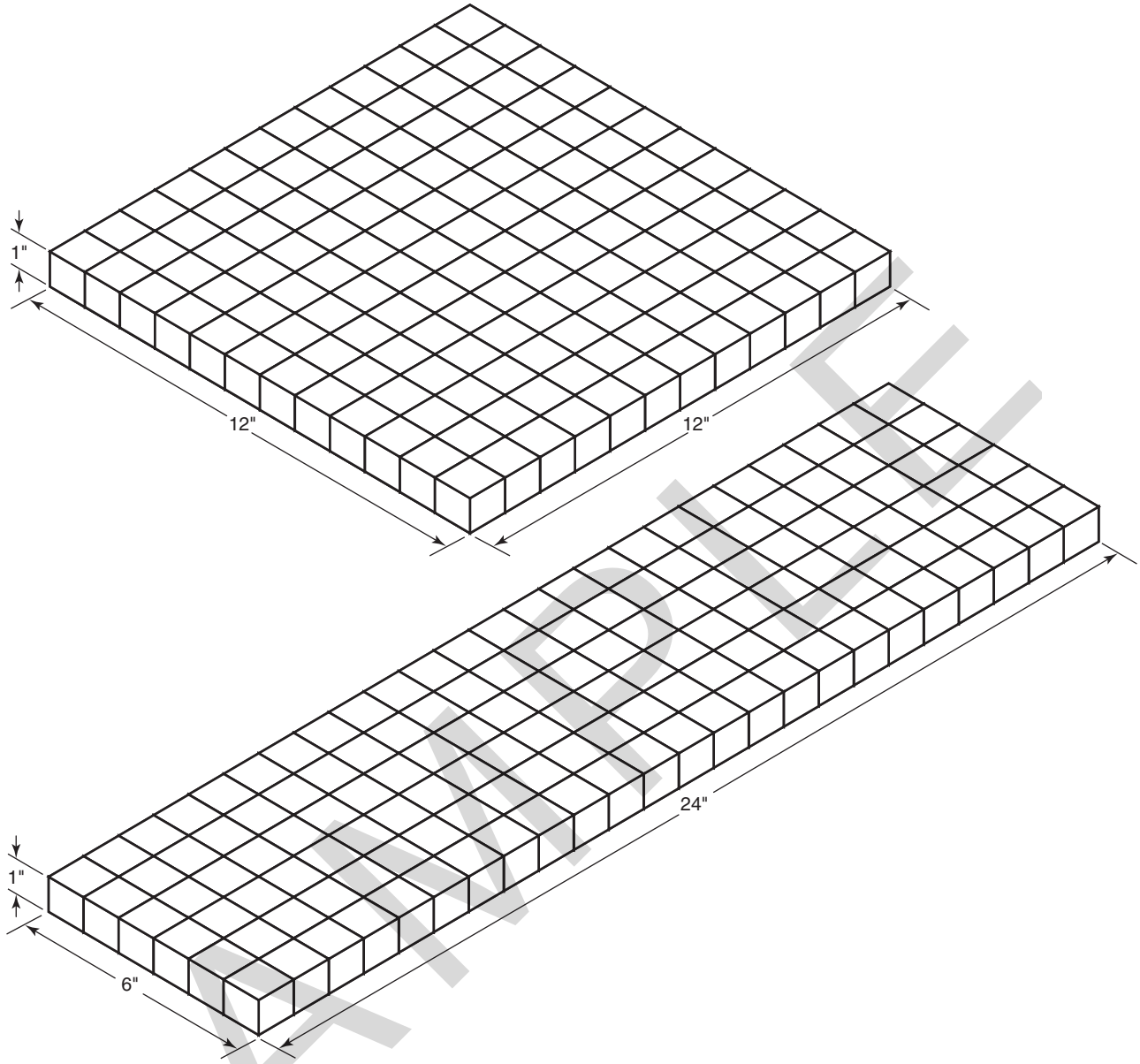

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Figure 3-14. Though different in shape, both of these boards equal one board foot.

Calculating Square Feet

Another method used to measure and sell wood products is to calculate square feet. Square foot measure is usually applied to sheet stock, such as plywood and paneling. It can also apply to milled lumber, such as tongue-and-groove flooring.

The square foot is a unit of area. Area is calculated by multiplying width times length. A piece of stock that is 1' wide and 1' long has an area of 1 sq. ft. Square inches are also a unit of area. A piece of stock measuring 4" × 6" has an area of 24 sq. in. When you calculate area, the width and length must be measured in the same units, not width in inches and length in feet. In **Figure 3-15**, you see a drawing of one full sheet of plywood (4' wide × 8' long). The area of this sheet is 4 × 8, which equals 32 sq. ft.

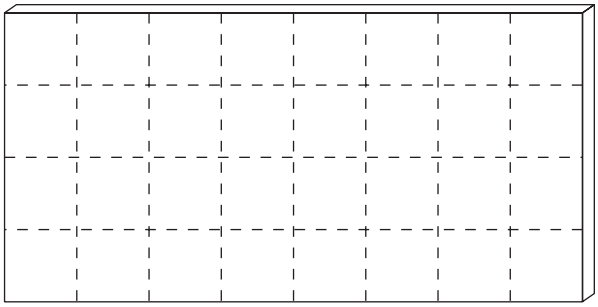
Example: Compute the number of square feet in a sheet of paneling measuring 4' × 4'.

Area = 4 × 4 = 16 sq. ft.

Example: Compute the number of square feet in a sheet of paneling measuring 4' × 60".

Area = 4 × 5

= 20 sq. ft.



Square feet = length in feet × width in feet
4' × 8' full sheet of plywood = 32 square feet

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Figure 3-15. Plywood and other sheet stock is sold by the square foot.

Calculating Lineal Feet

The final method of measurement used in woodworking is the lineal foot, or running foot. This measurement is simply the actual length of the material stated in feet. The width and thickness are not included. Most milled lumber, such as molding, is measured and sold by the lineal foot, **Figure 3-16**. Suppose a certain type of molding is to be used in your project and the cost is $1.50 per lineal foot. Multiply the total length you need (for example, 10') by $1.50. The cost of the molding will be 10 × $1.50, which equals $15.00.

Prepare a Bill of Materials

A *bill of materials* lists the amounts, sizes, and costs of all the wood, fasteners, and other supplies needed to build the product. **Figure 3-17** shows a bill of materials for the hat rack. Both rough and finish dimensions are included in the bill of materials. Board foot measure and costs are computed based on the rough size dimensions. Rough size dimensions allow for extra stock to be removed in trimming and smoothing the parts to their finish sizes. Use the following general guidelines to figure rough size dimensions.

- Add 1/16" to 1/8" to the finish size thickness.
- Add 1/4" to the finish size width.
- Add 1/2" to the finish size length.

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Figure 3-16. Molding strips and trim material are sold by the lineal foot.

Make a Stock Cutting List

A *stock cutting list* is made by grouping similar rough sizes of stock listed in the bill of materials. The dimensions shown in the stock cutting list are rough sizes only, **Figure 3-18**. The stock cutting list allows you to conserve both time and materials.

Prepare a Plan of Procedure

A *plan of procedure* lists the steps for building a product. The plan enables you to "think through" the processes needed to construct the product before you actually start working. You'll be able to organize tasks so that time and materials are saved, and you may detect minor errors in the drawings, bill of materials, or stock

BILL OF MATERIALS

Name_____ Planning Date_____ Completion Date_____

Project Hanging Hat Rack

Tools Needed: Table Saw, Scroll Saw or Band saw, Jointer, Drill Press, 7/8" Spade Bit, Portable Belt Sander, Finishing sander, C-clamps, Glue, Compass, pencil, Try Square, 1" Brush, Wiping rags, Hanging bracket

No. of pieces	Name of piece	Rough Size	Finish Size	Kind of wood	Number of board Feet	Cost of Board Ft.	Cost
1	Top of rack (A)	¾"x 3"x17"	¾"x2 ½"x 16"	Pine	.33	$2.00	$.66
1	Bottom of rack (B)	¾"X 3"X17"	¾"2 ½"x16"	Pine	.33	$2.00	$.66
1	Hat holder (C)	¾" x 3" X 13"	¾" X 2 ½"X 12	Pine	.25	$2.00	$.50
1	Hat holder (D)	¾"x 3"x 13"	¾" x 2 ½"x12	Pine	.25	$2.00	$.50
						Total Stock Cost	$2.32

Hardware and Other Material

No. of Pieces	Description	Size	Unit Cost	Cost
2	#150 grit sandpaper	9" x 11"	$.50	$1.00
2	#220 grit sandpaper	9" x 11"	$.50	$1.00
2	#100 grit sandpaper	9 x 11"	$.50	$1.00
2	Danish Oil wipe on finish		$1.00	$1.00
1	Hanging Bracket		$2.00	$2.00
			Total Cost of hardware and Other Material	$6.00
			Total Product Cost	$8.32

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Figure 3-17. The bill of materials lists the stock, hardware, and other supplies needed to build a product. Note that it also shows the cost.

Rough Stock Cutting List for Hat Rack

No. of Pieces	Name of Pieces	Rough Size	Kind of Wood
2	Top and Bottom of Hat Rack	3/4" × 4" × 18"	Pine
2	Right and Left Side for Hanging Hats	3/4" × 4" × 13"	Pine

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Figure 3-18. The stock cutting list shows rough sizes.

cutting list. Mistakes are much easier to change on paper than with materials. In addition, ways to improve a product design or construction may also be found. A plan of procedure should describe the steps briefly but clearly.

The following plan of procedure is for a hat rack. Making this hat rack is an ideal project for any beginning woodworker. It combines the use of several hand tools, power tools, fastening methods, and finishing techniques. Doing this project will also give you experience with following a plan of procedure. The things you learn from this project will help you in the design, planning, and construction of future projects. Refer again to **Figure 3-8**, which shows the completed product.

Plan of Procedure for the Hat Rack

1. Check your working drawing, bill of materials, and stock cutting list carefully. See **Figures 3-7**, **3-17**, and **3-18**.
2. Select the stock according to the stock cutting list. To reduce waste, try to find already-cut stock near the correct sizes.
3. If the stock is not 3/4" thick, then plane the stock to finish thickness.
4. Cut all the pieces to rough size.

5. Saw all the pieces to finish width and length as indicated in the plans. **Figure 3-19** shows all of the pieces: A and B are the backs; C and D are hat holders.
6. Set up the table saw with a dado head attachment and cut dado joints on parts A and B according to the plans. The dado joint should be 3/4" wide and 3/8" deep.
7. Lay out the location of the 7/8" holes to hold the hats on parts C and D.
8. Using the drill press and a 7/8" spade bit, drill the holes. Make sure you drill into the wood half way, and then turn the wood over and drill out the rest of the hole. This prevents the wood from slitting out when drilling.
9. Once you have all of the 7/8" holes drilled, then lay out the 3/8" wide slots that are designed to hold the hats in place on the rack. These are cut at an angle according to the plans.
10. Using the band saw, cut the slots for each one of the holes according to the plans.
11. Next, lay out a 1" radius on the front of the top and bottom of parts C and D.
12. Use the band saw or scroll saw to cut the 1" radius rounded corner.
13. Using a compass, lay out a 1 1/4" radius on both ends of parts A and B according to the plans. Cut the wood stock using the band saw or scroll saw.
14. Sand all of the pieces with #150 grit sandpaper and then #220 grit sandpaper.
15. You are now ready to assemble the project. Apply a small amount of aliphatic resin glue to the dado joint on parts A and B. Position parts C and D into dado joints.
16. Using small C-clamps, clamp each piece into place.
17. Check the inside of the glued frame for squareness using a try square.
18. After the glue has dried, remove the C clamps. For extra strength, drill holes and use 1 1/2" wood screws to secure top and bottom pieces to the sides.
19. Select a desirable finish and apply it following the manufacturer's instructions. Select the type of finish that you want for your finished project. Refer to the finishing material covered in Section 9.3 (Finishing Techniques). Apply the stain and/or finish to all the pieces.
20. Select the proper hanging hardware that you desire to mount your hat rack to the wall.

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Figure 3-19. These are the pieces for the hat rack.

Career Readiness

To become career ready, it is necessary to utilize critical-thinking skills in order to solve problems. Give an example of a problem that you needed to solve that was important to your success at work or school. What actions did you take in the problem-solving process to arrive at a solution?

Chapter Summary

- Many steps are involved in selecting, planning, and completing a project.
- Doing research in the library will help in your selection of a project that is suitable to make in the woodshop.
- Proper design factors should be considered when selecting a project to construct.
- In order to construct a project, one must complete an accurate working drawing.
- Since your project might be too large to fit onto a piece of paper, learn to use the method of scaling your working drawing.

- In order to determine if your project is suitable for your budget, accurately figuring out the amount of board feet and/or square feet is important.
- Prepare a full plan of procedures to help you complete any project.

Know and Understand

Answer the following questions based on the information provided in this section.

1. A working drawing indicates the exact size and _____ of each part of a product.
   A. shape
   B. width
   C. length
   D. depth
2. *True or False?* Large objects have to be drawn at a smaller size in order to fit on the paper. This is called drawing to scale.
3. A(n) _____ line, or outline, on a working drawing will show the shape of the object.
   A. invisible
   B. visible
   C. center
   D. dimension
4. A(n) _____, or hidden, line will show the outline of pieces that cannot be seen from the surface.
   A. visible
   B. dimension
   C. center
   D. invisible
5. *True or False?* A center line divides an object into two equal parts.
6. *True or False?* Extension lines extend out from the object's outline.
7. _____ lines have arrowheads on the ends and show where a measurement begins and ends.
   A. Extension
   B. Scale
   C. Dimension
   D. Assembly
8. A(n) _____ drawing shows how all the parts of a product will fit together.
   A. working
   B. assembly
   C. extension
   D. scale
9. The formula for calculating board feet is
   A. T" × W" × L" × .007
   B. T" × W" × L" + 144
   C. T" × W" × L" × 2.25
   D. None of the above.
10. Long lumber less than 1" thick is figured the same as if it were _____ thick.
    A. 1/2"
    B. 3/4'
    C. 1"
    D. None of the above.
11. The number of square feet in a sheet of plywood with the following measurements, 1/4"T, 12"W, 60"L, is:
    A. 5
    B. 2
    C. 10
    D. 8
12. *True or False?* Rough size dimensions allow for extra stock to be removed in smoothing parts to finish sizes.
13. *True or False?* The stock cutting list shows the amounts, sizes, and costs of all the materials and supplies needed to build a product.
14. The steps for building a product are listed in the ____.
    A. bill of materials
    B. plan of procedure
    C. stock cutting list
    D. working drawing plans

Critical Thinking

1. Make a list of various books, magazines, or other sources where you might be able to get ideas for selecting projects to make in the woodworking shop.
2. Why is it important to have a detailed drawing, material list, and plan of procedure for making any project?

Activities

1. Select several pieces of wood of various sizes and compute the board foot measure of each piece. Compute the cost of each piece based on current prices.
2. How do we decide whether something has good or bad design? Make a chart showing characteristics of good and bad design.