

# INTRODUCTION TO WOODWORKING



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# TABLE OF CONTENTS

## Licensing

### 1: Getting Started in the Woodshop

- 1.1: Welcome to WMT 101
- 1.2: Shop Safety and Expectations
- 1.3: Measuring Wood Accurately

### 2: Understanding Wood and Lumber

- 2.1: Understanding Wood
- 2.2: Hardwood and Softwood
- 2.3: Grain, Figure, and Wood Movement
- 2.4: Lumber Surfaces and Dimensions
- 2.5: Lumber Defects and Warp
- 2.6: Buying Hardwood Lumber
- 2.7: Board Feet and Lumber Cost

### 3: Preparing Lumber

- 3.1: Reading Grain Direction
- 3.2: Radial Arm Saw
- 3.3: Jointer
- 3.4: Planer
- 3.5: The Eight Steps to Squaring Lumber

### 4: Project 1- Cutting Board

- 4.1: Cutting Board Project Overview
- 4.2: Milling and Layout
- 4.3: Cutting and Shaping
- 4.4: Sanding and Finishing

### 5: Shaping and Cutting Wood

- 5.1: Band Saw
- 5.2: Drill Press and Jig Saw
- 5.3: Routers and Router Tables
- 5.4: Files and Rasps
- 5.5: Abrasives and Sanding

### 6: Project 2- Picture Frame

- 6.1: Saw Blade Technology
- 6.2: Table Saw Basics
- 6.3: Ripping and Crosscutting
- 6.4: Lap Joints
- 6.5: Completing the Picture Frame

## **7: Joinery and Adhesives**

- 7.1: Basic Woodworking Joints
- 7.2: Joint Strength and Grain Orientation
- 7.3: Adhesives and Basic Glue-Ups

## **8: Planning a Woodworking Project**

- 8.1: Design Basics
- 8.2: Working Drawings
- 8.3: Bill of Materials
- 8.4: Plan of Procedure

## **9: Project 3- Tool Tote**

- 9.1: Tool Tote Project Overview
- 9.2: Preparing the Box Parts
- 9.3: Dadoes and Grooves
- 9.4: Shaping the Handle
- 9.5: Bottom, Risers, and Final Fitting
- 9.6: Assembly, Sanding, and Finishing

## **10: Finishing Wood**

- 10.1: Preparing Wood for Finish
- 10.2: Oil Finishes

## **11: Review and Resources**

- 11.1: Key Terms
- 11.2: Review Questions
- 11.3: Additional Woodworking Resources
- 11.4: References and Attributions

## **Index**

## **Glossary**

## **Detailed Licensing**

## **Detailed Licensing**

# Licensing

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A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.

# 1: GETTING STARTED IN THE WOODSHOP

1.1: Welcome to WMT 101

1.2: Shop Safety and Expectations

1.3: Measuring Wood Accurately

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# 1.1: Welcome to WMT 101

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## 1.1 Welcome to WMT 101

Welcome to **WMT 101: Introduction to Woodworking**.

Woodworking combines material knowledge, technical skill, problem solving, design, and craftsmanship. In this course, you will learn how to work safely with common woodworking tools and machines while building projects that introduce the fundamental processes used in furniture making and woodworking manufacturing.

The Woodworking Manufacturing Technologies Department at Cerritos College is committed to excellence in woodworking education through creativity, craftsmanship, technical skill, safety, and lifelong learning. Our goal is to provide a learning environment where students from different backgrounds and levels of experience can learn, experiment, and develop confidence in the woodshop.

### What You Will Do

During WMT 101, you will learn to:

- Work safely in a professional woodworking environment.
- Measure, identify, select, and prepare lumber.
- Operate common woodworking machines.
- Mill rough lumber accurately.
- Cut, shape, join, sand, and finish wood.
- Read and develop basic woodworking drawings.
- Plan a project using a bill of materials and plan of procedure.
- Build several projects that develop increasingly complex skills.

You do not need previous woodworking experience to begin this course. What matters is a willingness to learn, follow safe procedures, ask questions, and practice.

### Read It, See It, Do It

This resource is designed to prepare you for work in the lab. Most sections are intentionally short.

Read the assigned material before class so that terms, machines, and processes are already familiar when your instructor demonstrates them. The reading introduces the idea. The demonstration shows how it works. Your time in the shop is where you develop the skill.

### Safety Comes First

Woodworking machines make accurate, repeatable work possible, but they must be understood and used correctly. Students must receive instruction in the safe use of a machine before operating it.

This resource supports that instruction, but it **does not replace the WMT Woodworking Safety Manual, safety test, instructor demonstrations, or individual machine checkouts**.

If you are ever unsure about a tool, machine, setup, or procedure, stop and ask your instructor before proceeding.

### Welcome to the Shop

Woodworking is learned by doing. You will make mistakes, solve problems, develop better judgment, and become more accurate as your experience grows.

Take your time. Work safely. Pay attention to the process.

Let's make something.

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## 1.2: Shop Safety and Expectations

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### 1.2 Shop Safety and Expectations

A woodworking shop is a place to build skills, solve problems, and make things. It is also a working environment with sharp tools, powerful machines, moving material, dust, noise, and other hazards.

Safe work is not separate from good woodworking. **It is part of good woodworking.**

#### Learning Outcomes

After completing this section, you should be able to:

- Describe the basic safety expectations of the WMT Woodshop.
- Identify personal protective equipment and clothing requirements.
- Explain when instructor approval is required.
- Describe your responsibility for maintaining a safe and organized shop.

#### Before You Use a Machine

You must receive instruction in the correct and safe use of a machine **before operating it**.

If you are unsure about a machine, tool, setup, material, or procedure, ask your instructor before continuing.

Some operations are considered **special setups** because they involve greater-than-normal risk. Special setups require approval from an instructor, instructional aide, or embedded tutor before the machine is operated.

Never assume that because you have used a similar machine somewhere else, you automatically know how the equipment in the WMT lab should be used.

#### Dress for the Shop

When working in the lab:

- Wear safety glasses or other required eye protection.
- Tie back or tightly cover long hair.
- Remove jewelry and accessories that could become caught in machinery.
- Secure loose clothing and roll long sleeves above the elbows.
- Do **not** wear gloves while operating woodworking machinery.
- Wear any additional hearing, respiratory, or other protection required for the operation.

Personal protective equipment helps reduce risk, but it does not replace safe operating procedures.

#### Pay Attention to What You Are Doing

Many shop accidents occur when people are distracted, rushed, tired, careless, or overly confident.

When someone is operating a machine:

- Do not distract or startle them.
- Do not crowd or hurry them.
- Give the operator adequate working space.
- Stay aware of moving material and other people in the shop.

If you are operating a machine, your attention should be on the operation until the machine has completely stopped.

If you are ill, fatigued, or taking medication that may affect your ability to operate machinery safely, tell your instructor.

## The Operator Controls the Machine

Except during an instructor-approved special setup, the person operating a machine should start and stop that machine.

Never make measurements, adjustments, or clean a machine while its cutter, blade, or other moving parts are still in motion.

If a machine sounds unusual, vibrates excessively, appears damaged, or is not operating correctly, shut it down and notify your instructor.

Do not attempt to repair or adjust a machine unless you have been specifically instructed and authorized to do so.

## Use Safe Material

Inspect lumber before machining it.

Loose knots, severe cracks, excessive warp, foreign objects, and other defects can make a machining operation unsafe.

Do not machine used lumber that may contain nails, screws, staples, or other hidden metal. Green and treated lumber are also prohibited from normal milling operations in the WMT lab.

When in doubt about a piece of material, ask.

## Keep the Shop Clean

Cleanup is part of woodworking.

A cluttered shop creates trip hazards, hides problems, interferes with machines, and makes it harder for everyone to work safely.

At the end of a work period:

1. Clean the machines and work areas you used.
2. Return tools, guards, pushsticks, jigs, and accessories to their proper locations.
3. Clear scraps and hazards from benches, machines, aisles, and floors.
4. Help with the overall shop cleanup.
5. Continue helping until your instructor dismisses the class.

Professional woodworkers take responsibility for the workspace, not just their own project.

## Report Problems Immediately

Tell your instructor immediately about:

- Injuries or accidents, even if they appear minor.
- Damaged tools or machines.
- Unsafe conditions.
- Spills or trip hazards.
- Unusual machine sounds or vibration.
- Safety procedures you do not understand.

Asking for help is always preferable to guessing.

## The Safety Manual Is Required

This resource introduces safety concepts as they relate to the skills taught in WMT 101. It does **not** replace the **WMT Wood Lab Safety Manual**, the safety test, machine demonstrations, or instructor direction.

Machine-specific safety requirements in the Safety Manual must be followed whenever you use that equipment.

## Check Yourself

1. When should you ask an instructor for help with a machine or procedure?
2. Why are gloves prohibited while operating woodworking machinery?
3. What is a special setup?
4. What should you do if a machine makes an unusual sound or vibration?
5. When is shop cleanup finished?

## 1.3: Measuring Wood Accurately

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### 1.3 Measuring Wood Accurately

Accurate woodworking begins with accurate measurement. A small measuring error can affect the fit of a joint, the size of a project part, or the alignment of several pieces later in the project.

In WMT 101, most measurements are made in **inches and fractions of an inch**.

#### Learning Outcomes

After completing this section, you should be able to:

- Read a ruler or tape measure accurately.
- Identify common fractional-inch markings.
- Recognize equivalent fractions.
- Record measurements correctly in inches.

#### Reading Fractions of an Inch

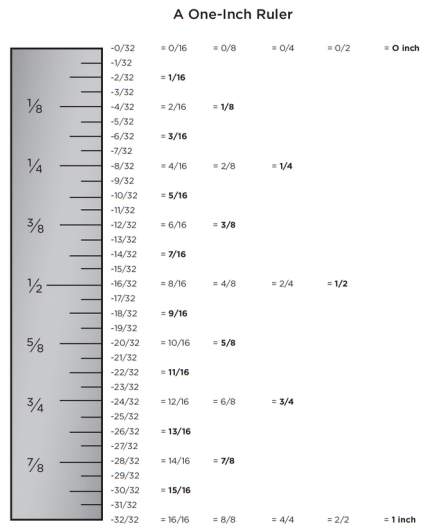
An inch can be divided into smaller, equal parts.

Common divisions include:

- 1/2 inch
- 1/4 inch
- 1/8 inch
- 1/16 inch
- 1/32 inch

The smaller the fraction, the more precise the measurement.

On a ruler divided into thirty-seconds, each small mark represents **1/32 inch**. Longer marks identify common fractions such as 1/16, 1/8, 1/4, and 1/2 inch.



One-inch ruler divided into 32 equal increments, showing equivalent fractions including sixteenths, eighths, quarters, halves, and one whole inch.

Figure: One-inch Ruler

## Equivalent Fractions

The same location on a ruler can often be described by several equivalent fractions.

For example:

$$1/2 = 2/4 = 4/8 = 8/16 = 16/32$$

Other common equivalents include:

Table with measurements and their equivalent fractions

| Measurement | Equivalent Fractions |
|-------------|----------------------|
| 1/8         | 2/16 = 4/32          |
| 1/4         | 2/8 = 4/16 = 8/32    |
| 3/8         | 6/16 = 12/32         |
| 1/2         | 4/8 = 8/16 = 16/32   |
| 5/8         | 10/16 = 20/32        |
| 3/4         | 6/8 = 12/16 = 24/32  |
| 7/8         | 14/16 = 28/32        |

Whenever possible, measurements should be written using the **simplest fraction**.

For example, write **3/4 inch**, not 12/16 inch.

## How to Read a Measurement

When reading a ruler:

1. Find the last whole-inch mark before the measurement.

2. Count the fractional divisions beyond that whole inch.
3. Identify the smallest division being used.
4. Reduce the fraction when necessary.

For example, a measurement that reaches 12 marks past 2 inches on a ruler divided into sixteenths is:

2  $\frac{12}{16}$  inches

Reduce the fraction:

2  $\frac{3}{4}$  inches

## Read the Lines Carefully

Different line lengths help identify the fractions on a ruler.

Typically:

- The longest line marks the whole inch.
- The next longest marks  $\frac{1}{2}$  inch.
- Shorter lines mark quarters.
- Still shorter lines mark eighths.
- The shortest lines may mark sixteenths or thirty-seconds.

Do not rely only on the length of the line. Learn to understand where the fraction falls within the inch.

## Measure Before You Cut

Good woodworking depends on more than simply reading the ruler correctly.

Before machining a part:

1. Confirm the required dimension.
2. Measure carefully.
3. Check the measurement again.
4. Make sure you understand which part of the material must remain after the cut.

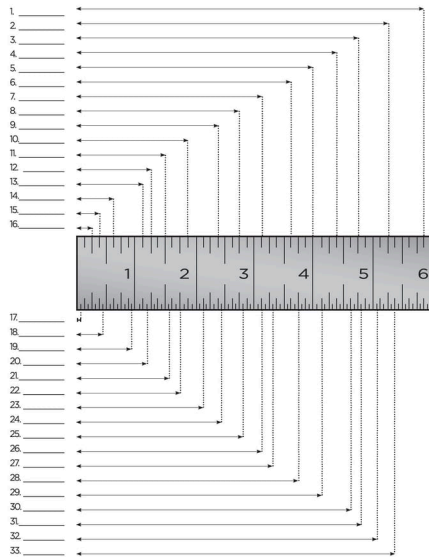
A few extra seconds spent checking a measurement can prevent wasted material and unnecessary rework.

## Practice Your Measurement Skills

If you would like more practice reading fractional measurements, use the exercises below. Try to identify each marked measurement before checking your work.

### Ruler Reading Practice

Use the six-inch ruler to identify the marked measurements.



## Fractions and Measurement Practice

Use the ruler and fraction exercises to practice reading measurements and recognizing equivalent fractions.

Measurement in Inches

1.  $1 = \frac{\quad}{2} = \frac{\quad}{4} = \frac{\quad}{8} = \frac{\quad}{16}$

2.  $1\frac{1}{2} = \frac{\quad}{8} = \frac{\quad}{16}$

3.  $2\frac{3}{4} = \frac{\quad}{4} = \frac{\quad}{8} = \frac{\quad}{16}$

4.  $2\frac{1}{4} = \frac{\quad}{4} = \frac{\quad}{8} = \frac{\quad}{16}$

5.  $1\frac{1}{4} = \frac{\quad}{4} = \frac{\quad}{8} = \frac{\quad}{16}$

6.  $3\frac{1}{2} = \frac{\quad}{2} = \frac{\quad}{4} = \frac{\quad}{8} = \frac{\quad}{16}$

7.  $4\frac{3}{4} = \frac{\quad}{8} = \frac{\quad}{16}$

8.  $2\frac{5}{8} = \frac{\quad}{8} = \frac{\quad}{16}$  CAREFUL ON THESE

## Check Yourself

1. What does each mark represent on a ruler divided into 32 equal parts per inch?
2. What is 8/16 inch in simplest form?
3. What is 12/16 inch in simplest form?
4. Why should a measurement be checked before making a cut?
5. Which is the clearer way to record a measurement: 24/32 inch or 3/4 inch?

## 2: UNDERSTANDING WOOD AND LUMBER

2.1: Understanding Wood

2.2: Hardwood and Softwood

2.3: Grain, Figure, and Wood Movement

2.4: Lumber Surfaces and Dimensions

2.5: Lumber Defects and Warp

2.6: Buying Hardwood Lumber

2.7: Board Feet and Lumber Cost

## 2.1: Understanding Wood

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### 2.1 Understanding Wood

Wood is different from most materials you will use in a shop. It was once part of a living tree, and its structure continues to affect how it looks, cuts, bends, shrinks, sands, glues, and finishes.

Two boards from the same species—and even from the same tree—can behave differently. Learning to read the material is part of becoming a woodworker.

### Learning Outcomes

After completing this section, you should be able to:

- Identify the major parts of a tree that are important to woodworkers.
- Define several basic wood-technology terms.
- Explain how the cellular structure of wood influences its properties.
- Describe why wood varies from board to board.

### Wood Is Made of Cells

Wood is made primarily of long cells arranged generally along the length of the tree.

You can think of many of these cells as tiny tubes bundled together. Their size, shape, arrangement, and direction influence the properties of the lumber produced from the tree.

This fibrous structure helps explain why wood behaves differently depending on the direction in which it is cut, shaped, or stressed.

### Parts of a Tree

Several parts of a tree are especially important to woodworkers.

**Bark** — The protective outer covering of the tree.

**Cambium** — The growing layer that produces new wood and bark.

**Sapwood** — The younger outer wood that conducts water upward through the tree.

**Heartwood** — The older central wood that no longer conducts sap. Heartwood is often darker than sapwood.

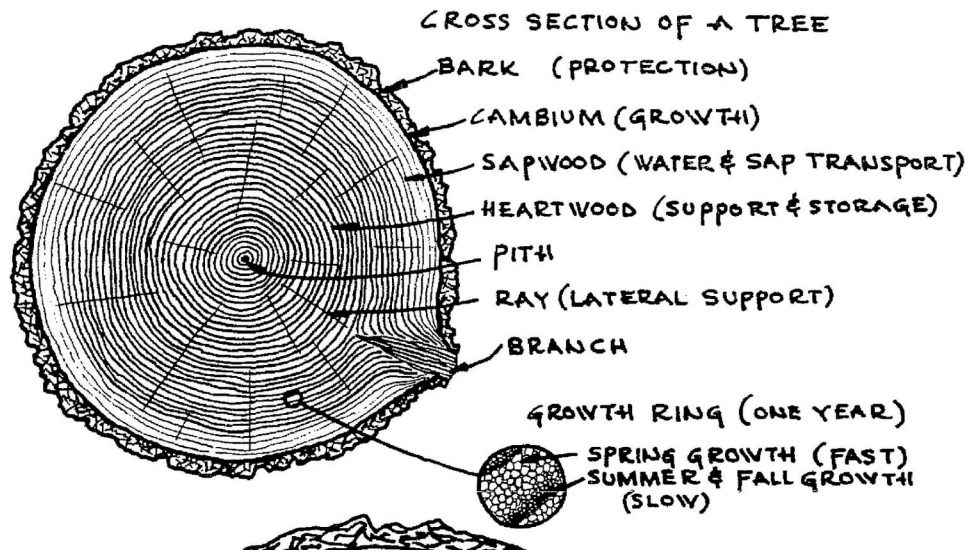
**Pith** — The central portion of the tree around which the earliest growth occurs.

**Growth Ring** — Wood produced during approximately one year of growth.

**Earlywood** — The portion of a growth ring produced earlier in the growing season. It generally has larger cells and lower density.

**Latewood** — The denser portion of the growth ring formed later in the growing season.

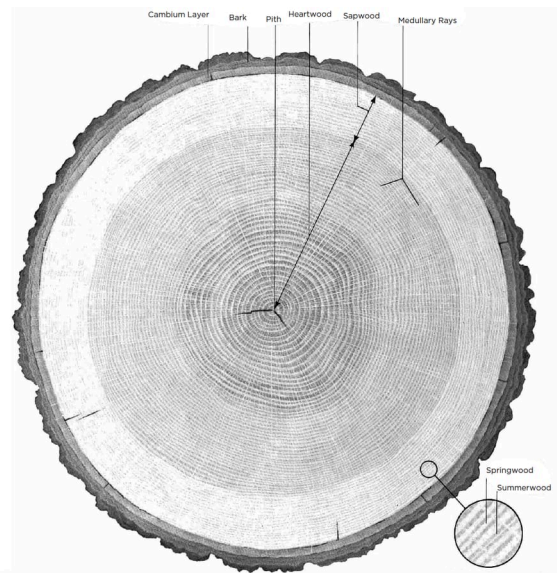
**Wood Ray (Medullary Ray)** — Cellular tissue extending outward from the center of the tree toward the bark. Rays can become a strong visual feature in some species and sawing orientations.



Cross-section of a tree labeled with bark, cambium, sapwood, heartwood, pith, wood rays, and annual growth rings.

Figure: Cross-Section of a Tree

Here's a more realistic image describing similar parts of the tree.



Another cross-section of a tree labeled with bark, cambium, sapwood, heartwood, pith, wood rays, and annual growth rings.

Figure: More realistic cross-Section of a Tree

## Characteristics of Wood

Woodworkers use several terms to describe the material.

**Color** — The natural color of wood is affected by substances within the cell walls and by extractives found especially in heartwood. Some woods also darken when exposed to air and light.

**Texture** — The relative size and uniformity of the cellular structure. Woods with small, closely spaced cells are often described as fine-textured.

**Grain** — A general term describing the arrangement and direction of the wood's cellular structure and growth rings.

**Figure** — The visible pattern created by grain, growth structure, color variation, and other characteristics.

**Density** — Weight per unit volume. In general, denser woods tend to be harder and stronger than less-dense woods.

**Moisture Content** — The amount of water contained in wood relative to its oven-dry weight, expressed as a percentage.

For much indoor woodworking, a moisture content of approximately **6–10%** is generally desirable.

## Why This Matters

The structure of the tree follows the lumber into the shop.

It affects:

- how easily the wood cuts;
- how likely it is to tear out;
- how strong a part may be;
- how the surface looks;
- how the board responds to changes in moisture;
- how it should be oriented in a project; and
- how it accepts a finish.

A good woodworker does not simply force wood into a shape. You learn to understand the material and work with its characteristics.

## Check Yourself

1. What is the difference between sapwood and heartwood?
2. What produces a growth ring?
3. What are wood rays?
4. What is the difference between grain and figure?
5. Why does the cellular structure of wood matter to a woodworker?

## 2.2: Hardwood and Softwood

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### 2.2 Hardwood and Softwood

Trees used for lumber are commonly divided into two broad classifications: **hardwoods** and **softwoods**.

These names can be misleading. They describe the type of tree—not necessarily how physically hard or soft the lumber will be.

#### Learning Outcomes

After completing this section, you should be able to:

- Explain the basic distinction between hardwoods and softwoods.
- Identify common examples of each.
- Explain why the terms hardwood and softwood do not describe actual hardness.
- Recognize that different species have different working properties.

#### Hardwoods

**Hardwoods** come from broad-leafed trees, or angiosperms.

Common hardwoods used in woodworking include:

- Alder
- Ash
- Birch
- Cherry
- Mahogany
- Maple
- Oak
- Poplar
- Walnut

Hardwoods are widely used for furniture, cabinetry, flooring, millwork, architectural woodwork, and many other woodworking applications.

Their cellular structure is generally more complex than that of softwoods.

#### Softwoods

**Softwoods** come from coniferous trees, or gymnosperms. These trees commonly have needles or scale-like leaves.

Examples include:

- Pine
- Fir
- Hemlock

Softwoods are widely used in construction, but they are also used in furniture, millwork, musical instruments, pattern making, and many other forms of woodworking.

## Hardwood Does Not Mean Hard

Do not assume that every hardwood is physically harder than every softwood.

One hardwood species may be relatively soft and easy to machine, while another may be extremely dense and difficult to cut. The same is true of softwoods.

The terms **hardwood** and **softwood** classify the trees from which the lumber came.

When choosing material for a project, consider the properties of the individual species rather than relying only on its classification.

## Species Matter

Different species can vary significantly in:

- color;
- grain;
- texture;
- density;
- hardness;
- strength;
- workability;
- durability; and
- appearance.

These differences are one reason wood selection is an important part of woodworking.

A species that is excellent for a tabletop may not be the best choice for a carved part, outdoor furniture, drawer sides, or a tool handle.

As you gain experience, you will begin to recognize species not only by appearance but also by how they machine, sand, glue, and finish.

## Check Yourself

1. What type of tree produces hardwood?
2. What type of tree produces softwood?
3. Does the term hardwood guarantee that the wood is physically hard?
4. Name three properties that can vary between wood species.
5. Why should you select wood by species and properties rather than classification alone?

## 2.3: Grain, Figure, and Wood Movement

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### 2.3 Grain, Figure, and Wood Movement

Learning to read a board is one of the most important skills you will develop as a woodworker.

Grain direction affects machining. Figure affects appearance. Growth-ring orientation influences how a board looks and how it may respond to changes in moisture.

#### Learning Outcomes

After completing this section, you should be able to:

- Distinguish between grain, texture, and figure.
- Explain why moisture content matters.
- Describe basic methods of drying lumber.
- Identify plainsawn, riftsawn, and quartersawn lumber.
- Explain how growth-ring orientation affects the appearance and behavior of a board.

#### Grain

**Grain** describes the arrangement and direction of the wood fibers and growth structure.

Grain direction matters whenever a cutting edge meets the wood.

Cutting with favorable grain generally produces a cleaner surface. Cutting against unfavorable grain can cause fibers to lift and break ahead of the cutter, producing **tearout**.

Later in this course, you will learn to read grain direction before using machines such as the jointer and planer.

#### Figure

**Figure** is the visible pattern seen on the face or edge of a board.

Figure may result from:

- the orientation of the growth rings;
- anatomical structures such as rays;
- changes in grain direction;
- color variations; or
- unusual growth within the tree.

Figure is one of the reasons wood is such a visually expressive material.

Two boards from the same species can have completely different figure, and choosing how that figure appears in a finished piece is an important part of woodworking and furniture making.

#### Texture

**Texture** describes the relative size and uniformity of the wood's cellular structure.

A fine-textured wood has relatively small, closely spaced cells. Other woods have larger, more open structures.

Texture can influence the appearance of the surface and how the wood sands and finishes.

## Moisture Content

Wood contains water.

**Moisture content** is the weight of the water in the wood compared with the oven-dry weight of the wood, expressed as a percentage.

As wood gains and loses moisture, its dimensions can change.

This is referred to generally as **wood movement**.

Wood movement is important because a project may be built under one set of environmental conditions and later live in another. A woodworker must allow for this movement rather than assuming that wood will remain permanently unchanged.

Understanding wood movement becomes increasingly important as projects become larger and more complex.

## Drying Lumber

Freshly cut wood contains too much moisture for most furniture and cabinet work and must be dried.

There are two basic methods.

**Kiln Drying** — Lumber is dried in a controlled environment using circulated heated air. Most hardwood used for typical furniture woodworking is kiln dried.

**Air Drying** — Lumber is stacked so ambient air can circulate around all surfaces.

Small strips called **stickers** are placed between layers of lumber to create air space.

A traditional rule of thumb is approximately one year of air drying per inch of thickness, although actual drying time depends on species, climate, thickness, airflow, and other conditions.

## How a Log Is Sawn

The orientation of a board within the log affects both its grain pattern and its physical behavior.

Three common terms are:

### Plainsawn or Flatsawn

The board is cut roughly tangent to the growth rings, with the rings generally intersecting the face at less than about 45 degrees.

Plainsawing:

- produces wide boards;
- creates relatively little waste;
- is economical; and
- often produces the familiar cathedral-shaped grain pattern.

### Riftsawn

The growth rings meet the face of the board at approximately 45 degrees.

Riftsawn lumber commonly produces a straighter, more consistent grain pattern on both the face and edge.

## Quartersawn

The growth rings are oriented more nearly perpendicular to the face of the board.

Quartersawn lumber:

- generally produces straight grain;
- is more dimensionally stable;
- can highlight ray structure; and
- can create distinctive figure in species with prominent rays.

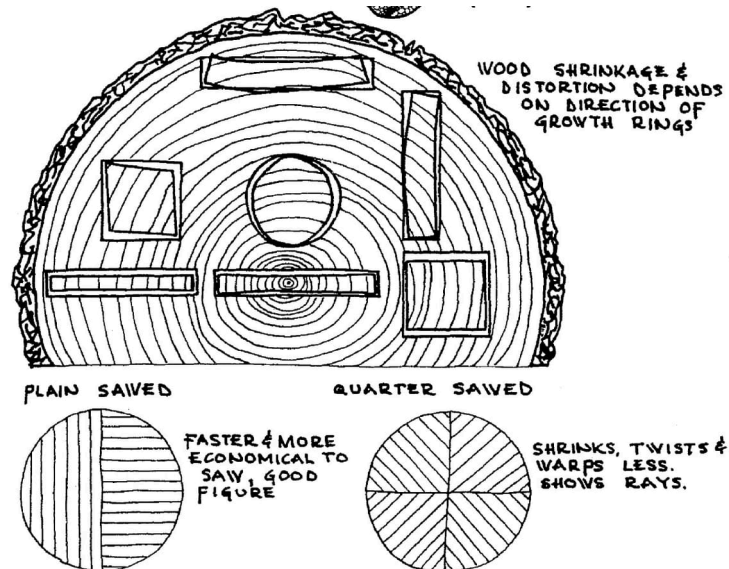


Diagram comparing plainsawn, riftsawn, and quartersawn boards according to the angle of the growth rings to the board face and showing the resulting grain patterns.

Figure: Methods of Cutting Lumber

## Growth Rings and Movement

Wood does not shrink and swell equally in every direction.

The orientation of the growth rings within a board affects how that board tends to change shape as its moisture content changes.

This is one reason two boards cut from different locations in the same log may behave differently.

You will see this again when evaluating **cup, bow, crook, and twist** and when deciding how to orient boards within a project.

## Check Yourself

1. What is the difference between grain and figure?
2. Why does grain direction matter when machining wood?
3. What is moisture content?
4. What are stickers used for when drying lumber?
5. How do plainsawn, riftsawn, and quartersawn lumber differ?
6. Which sawing orientation tends to highlight ray structure?

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## 2.4: Lumber Surfaces and Dimensions

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### 2.4 Lumber Surfaces and Dimensions

A woodworker needs a common vocabulary for describing a board.

Before you can accurately discuss milling, drawings, cut lists, or project parts, you need to know the names of the surfaces and understand how hardwood lumber is sized.

#### Learning Outcomes

After completing this section, you should be able to:

- Identify the face, edge, and end of a board.
- Identify thickness, width, and length.
- Explain common lumber-surfacing terms.
- Interpret quarter-inch hardwood thickness notation.
- Explain the difference between rough and finished dimensions.

#### The Surfaces of a Board

A rectangular board has three pairs of surfaces.

**Faces** — The two broad surfaces of the board.

**Edges** — The two narrow surfaces running along the length of the board.

**Ends** — The two surfaces across the ends of the board, where end grain is visible.

These terms matter because woodworking operations often refer specifically to a face, edge, or end.

For example:

- You may flatten a **face** on the jointer.
- You may straighten an **edge** on the jointer.
- You may square an **end** on a saw.

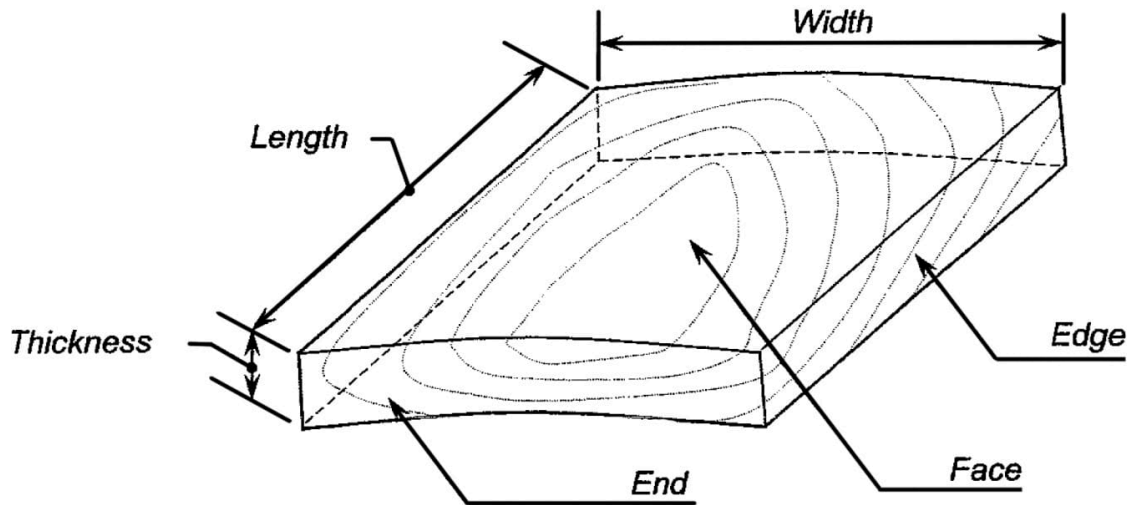


Figure: Board Surfaces and Dimensions

## Dimension Order

Lumber dimensions are listed in this order:

Thickness × Width × Length

For example:

3/4 in. × 6 in. × 14 in.

means:

- 3/4 inch thick;
- 6 inches wide; and
- 14 inches long.

Get into the habit of using this order consistently. You will see it in drawings, cut lists, bills of materials, and project plans throughout woodworking.

## Rough and Surfaced Lumber

**Rough lumber** has not been surfaced smooth after sawing at the mill.

**Surfaced lumber** has had one or more surfaces machined.

Common abbreviations include:

**S1S** — Surfaced one side, usually one face.

**S2S** — Surfaced two sides, usually both faces.

**S3S** — Surfaced three sides, usually both faces and one edge.

**S4S** — Surfaced four sides: both faces and both edges.

You may also see terminology such as:

**SLR1E** — Straight-line ripped one edge.

For example, **S2S SLR1E** describes lumber with both faces surfaced and one edge straight-line ripped.

## Hardwood Thickness: Quarter Notation

Rough hardwood thickness is commonly specified in **quarters of an inch**.

*Hardwood thicknesses compared to nominal rough thicknesses*

| Hardwood Size | Nominal Rough Thickness |
|---------------|-------------------------|
| 4/4           | 1 in.                   |
| 5/4           | 1 1/4 in.               |
| 6/4           | 1 1/2 in.               |
| 8/4           | 2 in.                   |
| 10/4          | 2 1/2 in.               |
| 12/4          | 3 in.                   |

A woodworker would commonly say “**four-quarter**,” “**five-quarter**,” “**six-quarter**,” or “**eight-quarter**.”

## Rough Size Is Not Finished Size

The quarter measurement describes the approximate thickness of the lumber before it is surfaced.

Surfacing always removes some material.

How much is removed depends on how flat and straight the rough board is. A relatively flat board may require little material removal, while a badly warped board may lose considerably more.

For example, you should not expect a rough 4/4 board to remain a full 1 inch thick after both faces have been flattened and surfaced.

Always select rough stock thick enough to reach the required finished dimension after milling.

This is especially important when working with warped or irregular lumber. A board may appear thick enough when rough but become too thin by the time enough material has been removed to make it flat.

## Dimensional Lumber Is Different

Construction lumber follows a different sizing system.

A familiar **2 × 4**, for example, does not finish at 2 inches by 4 inches. Its actual surfaced dimensions are smaller.

Do not confuse construction-lumber terminology with the quarter system commonly used for rough hardwood.

## Check Yourself

1. What are the three types of surfaces on a board?
2. In what order are lumber dimensions written?
3. What does S2S mean?
4. What does S4S mean?
5. What is the nominal rough thickness of 6/4 lumber?
6. Why does rough lumber finish thinner after milling?

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## 2.5: Lumber Defects and Warp

### 2.5 Lumber Defects and Warp

Every board should be inspected before you buy it and again before you machine it.

Defects may affect appearance, yield, strength, machining, or safety.

Some defects can be worked around. Others may make a board unsuitable for a particular project.

### Learning Outcomes

After completing this section, you should be able to:

- Identify the four common types of warp.
- Recognize several common lumber defects.
- Explain how defects affect material selection.
- Inspect a board before machining it.

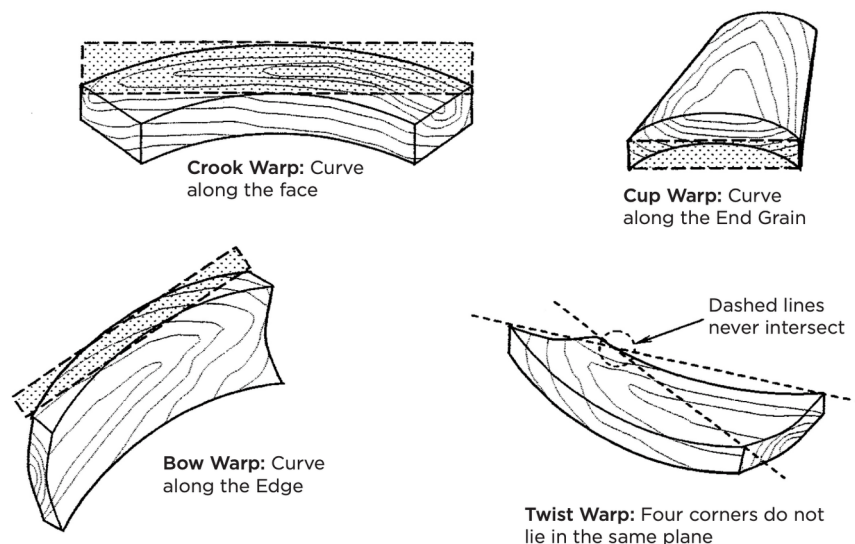
### Four Types of Warp

**Bow** — A lengthwise curve along the face of a board.

**Cup** — A curve across the width of the face.

**Cruck** — A lengthwise curve along the edge of the board. Cruck is sometimes also called crown.

**Twist** — A condition in which the four corners of the board do not lie in the same plane.



Four boards illustrating bow, cup, cruck, and twist, showing the direction of distortion for each type of warp.

Figure: Types of Warp

## Other Common Defects

**Knot** — A portion of a branch or limb that appears in the lumber.

Knots can be visually interesting, but they can also interrupt the grain and affect machining or strength.

**Check** — A crack running along the length of the board that does not extend completely through to the opposite face.

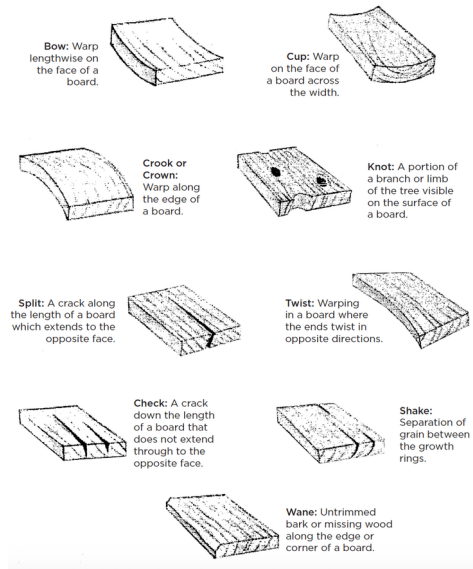
**Split** — A crack that extends through the board to the opposite face.

**Shake** — A separation between growth rings.

**Wane** — Missing wood or remaining bark along an edge or corner of the board.

Other defects may include:

- stains;
- decay; and
- insect damage.



Illustrations of common lumber defects including bow, cup, crook, knot, split, twist, check, shake, and wane.

Figure: Lumber Defects

## Inspect the Whole Board

Do not look only at one face.

Before selecting or machining lumber:

1. Sight down the **face** for bow.
2. Sight down the **edge** for crook.
3. Look across the width for cup.
4. Check whether the corners lie in the same plane to identify twist.
5. Inspect both faces and edges for knots, checks, splits, shake, wane, or other defects.
6. Consider where your project parts can be cut from the board.

As your experience grows, you will learn to look at the entire board as a source of project parts rather than simply as one long rectangular piece of wood.

## Defects Affect Yield

A 10-foot board does not necessarily provide 10 feet of usable project material.

You may need to cut around:

- checks near the ends;
- knots;
- areas of poor grain;
- sapwood or heartwood color differences;
- wane; or
- other defects.

This is one reason woodworkers buy more rough lumber than the exact finished volume shown on a cut list.

## Defects and Safety

Some defects can also make machining more dangerous.

Loose knots, severe splits, or badly warped material may not be safe to run through a particular machine.

Defects may also prevent the stock from sitting securely against a machine table or fence.

When you are unsure whether a board is safe to machine, ask your instructor.

## Check Yourself

1. What is the difference between bow and crook?
2. What type of warp occurs across the width of the board?
3. What is the difference between a check and a split?
4. What is wane?
5. Why should defects be considered when estimating how much lumber to purchase?
6. Why can some defects become a safety concern?

## 2.6: Buying Hardwood Lumber

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### 2.6 Buying Hardwood Lumber

Buying hardwood can feel confusing the first few times.

Unlike buying a standard 2 × 4 at a home center, hardwood may be sold in random widths and lengths, several thicknesses, different grades, and different surfacing conditions.

Learning the vocabulary makes the process much easier.

### Learning Outcomes

After completing this section, you should be able to:

- Explain common hardwood grades.
- Define Random Widths and Lengths.
- Distinguish between rough and surfaced lumber when purchasing.
- Estimate additional material for waste and selection.
- Recognize several common hardwood species and their general properties.

### Common Hardwood Grades

Three grades commonly encountered in furniture and hardwood woodworking are:

1. FAS — Firsts and Seconds
2. Selects
3. No. 1 Common

Hardwood grades are based largely on how much clear, usable material can be cut from a board.

The grade does not tell you whether the board is attractive or useful for your particular project. It describes the amount and size of clear cuttings that can be obtained from it.

### FAS

**FAS** is a high hardwood grade intended to provide a large percentage of clear, usable material.

It is especially useful when a project requires long, wide, or relatively defect-free parts.

Because grading rules can vary somewhat by species and are periodically updated, professional buyers and graders refer to current hardwood grading standards for exact requirements.

For beginning woodworking, the important point is that FAS generally provides larger areas of clear material than the lower grades.

### Selects

**Selects** also provides a high percentage of clear material but may include boards that are narrower or shorter than those typically found in FAS.

One face generally meets a higher grading standard while the opposite face may contain more defects.

Selects can be an excellent choice for furniture and cabinet work.

## No. 1 Common

**No. 1 Common** contains a lower percentage of clear material than FAS or Selects.

That does not mean it is bad wood.

If your project contains smaller parts, you may be able to work around knots and other defects and obtain excellent material from No. 1 Common lumber.

A skilled woodworker buys for the parts the project requires—not simply the highest grade available.

## Random Widths and Lengths

Hardwood is commonly sold in **Random Widths and Lengths**, abbreviated **RWL**.

Instead of every board being exactly the same width and length, boards are sawn to make efficient use of the tree.

Widths and lengths therefore vary.

You may find relatively narrow boards next to much wider boards within the same stack. Lengths can also vary considerably.

When you buy RWL lumber, think about how your project parts will fit within the available boards.

This is different from buying construction lumber, where pieces are usually sold in standardized dimensional sizes.

## Rough or Surfaced?

Hardwood can be purchased in several conditions:

- **Rough** — Not surfaced after sawing at the mill.
- **S1S** — Surfaced one side.
- **S2S** — Surfaced two sides, usually both faces.
- **S3S** — Surfaced three sides, usually both faces and one edge.
- **S4S** — Surfaced four sides.
- **S2S SLR1E** — Surfaced two sides with one edge straight-line ripped.

Surfaced lumber can save milling time, but it gives you less control over the final dimensions and which surfaces are established as your references.

Rough lumber allows you to control the milling process from the beginning. Learning to work from rough lumber is an important professional woodworking skill because it allows you to:

- establish your own flat reference surfaces;
- control the final thickness;
- select the best faces and edges;
- work around defects;
- preserve as much usable thickness as possible; and
- prepare stock specifically for the project.

When buying surfaced hardwood, remember that the board may still be described and priced by its **nominal rough thickness**. For example, a surfaced 4/4 board will usually measure less than a full 1 inch thick because material has already been removed during surfacing.

The amount of finished thickness remaining depends on the original board and how much material was required to make it flat and smooth. Always verify the **actual dimensions** of surfaced lumber before assuming it will work for your project.

## Buy More Than the Finished Cut List

If the finished parts in your project total 10 board feet, buying exactly 10 board feet of rough lumber is usually not enough.

Additional material is needed for:

- defects;
- milling loss;
- random board widths;
- grain and figure selection;
- color matching;
- part orientation; and
- mistakes or unexpected problems.

Depending on the project, you may need substantially more lumber than the finished board-foot total.

A simple project made from small parts may require relatively little extra material. A project requiring long, wide, highly figured, or carefully matched parts may require much more.

The goal is not to buy excessive material. The goal is to purchase enough usable material to complete the project successfully.

## Common Hardwoods

The following species are commonly encountered in furniture and cabinet work.

*Common wood species compared to their grain, characteristics, and uses*

| Species         | General Color and Grain                 | General Working Characteristics | Common Uses and Notes                             |
|-----------------|-----------------------------------------|---------------------------------|---------------------------------------------------|
| <b>Alder</b>    | Light reddish brown; fine, closed grain | Medium-soft; easy to work       | Cabinetry, veneers, toys; takes stain well        |
| <b>Ash</b>      | Light tan; open, coarse grain           | Hard and strong                 | Tool handles, furniture, sporting goods           |
| <b>Birch</b>    | Light brown to tan; fine, closed grain  | Hard; medium workability        | Furniture and veneers                             |
| <b>Cherry</b>   | Light reddish brown; fine, closed grain | Medium hardness; good strength  | Furniture; darkens with age and exposure to light |
| <b>Mahogany</b> | Russet brown; relatively fine grain     | Excellent workability           | Furniture and millwork                            |
| <b>Maple</b>    | Light tan; fine, closed grain           | Hard and strong                 | Furniture, cabinetry, flooring                    |

| Species          | General Color and Grain                            | General Working Characteristics        | Common Uses and Notes                           |
|------------------|----------------------------------------------------|----------------------------------------|-------------------------------------------------|
| <b>Red Oak</b>   | Light brown to reddish brown; open, coarse grain   | Hard and strong                        | Furniture and flooring; prominent rays          |
| <b>White Oak</b> | Light tan to yellow-brown; open, coarse grain      | Hard, strong, and durable              | Furniture and exterior work; prominent rays     |
| <b>Poplar</b>    | Greenish yellow to light brown; fine, closed grain | Medium-soft and easy to work           | Furniture and cabinets, especially painted work |
| <b>Walnut</b>    | Dark brown; generally open grain                   | Medium hardness; excellent workability | Furniture and architectural woodworking         |

You will learn more about species by working with them, machining them, sanding them, finishing them, and seeing how they behave over time.

## Selecting Boards

When choosing a board, do not ask only:

“Is this good lumber?”

Instead ask:

- Is it thick enough after milling?
- Is it wide enough for my parts?
- Can I cut around the defects?
- Is the grain appropriate for the project?
- Do the color and figure work with the other boards?
- Is it straight enough to mill safely?
- Does it contain the clear lengths I need?
- Am I paying for material I cannot use?

Good material selection can save hours of work later.

It can also improve the appearance of the finished project before you make the first cut.

## Check Yourself

1. What are the three common hardwood grades introduced here?
2. Does a lower grade automatically mean the lumber is unsuitable for furniture?
3. What does RWL mean?
4. Why might a woodworker prefer rough lumber?
5. Why do you need to buy more lumber than the finished parts require?
6. Name three characteristics you should consider when selecting a board.

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## 2.7: Board Feet and Lumber Cost

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### 2.7 Board Feet and Lumber Cost

Hardwood lumber is commonly measured and priced by the **board foot**.

If you plan to work professionally with wood, board-foot calculation is a basic trade skill. It allows you to estimate material requirements, compare prices, prepare bills of materials, and determine project cost.

### Learning Outcomes

After completing this section, you should be able to:

- Define a board foot.
- Calculate board footage for one or more pieces.
- Convert feet to inches when necessary.
- Use rough thickness when calculating hardwood volume.
- Estimate lumber cost from a price per board foot.

### What Is a Board Foot?

One **board foot** equals **144 cubic inches** of wood.

The standard example is a board measuring:

1 in. × 12 in. × 12 in.

That equals:

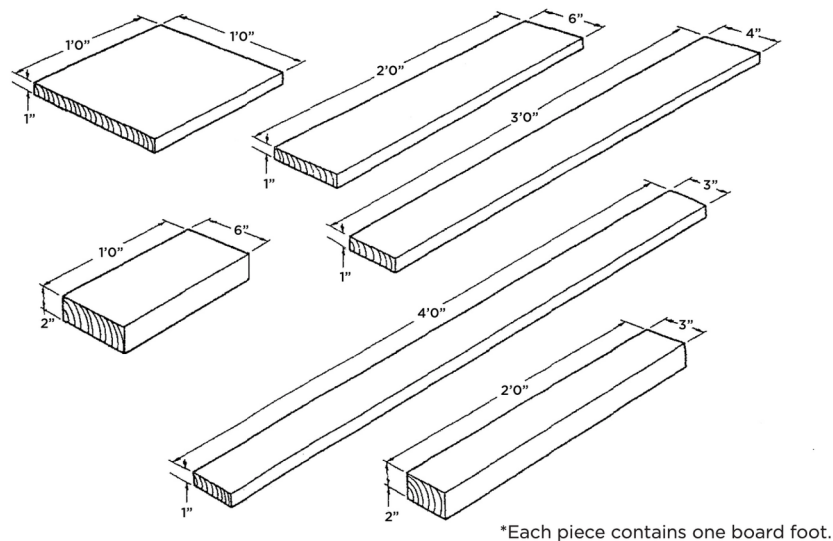
144 cubic inches = 1 board foot

But a board does not need to have those exact dimensions.

These pieces also contain one board foot:

- 2 in. × 6 in. × 12 in.
- 1 in. × 6 in. × 24 in.
- 1 in. × 4 in. × 36 in.

The shape changes, but the total volume remains 144 cubic inches.



Six boards of different dimensions, each containing one board foot of lumber, including 1 × 12 × 12 inches, 2 × 6 × 12 inches, 1 × 6 × 24 inches, 1 × 4 × 36 inches, 1 × 3 × 48 inches, and 2 × 3 × 24 inches.

Figure: Examples of One Board Foot

## The Board-Foot Formula

When thickness, width, and length are all measured in inches:

$$\text{Board Feet} = \text{Quantity} \times \text{Thickness} \times \text{Width} \times \text{Length} \div 144$$

Remember the standard lumber dimension order:

Thickness × Width × Length

## Use the Rough Thickness

When calculating hardwood lumber, use the **nominal rough thickness**.

For example:

- 4/4 = 1 inch
- 5/4 = 1.25 inches
- 6/4 = 1.5 inches
- 8/4 = 2 inches

A surfaced 4/4 board may physically measure less than 1 inch thick, but board footage is normally calculated from its nominal rough thickness.

## Example 1: One Board

Suppose you have one 4/4 walnut board that is:

- 1 inch nominal rough thickness;
- 6.5 inches wide; and
- 8 feet long.

First convert the length to inches:

$8 \text{ ft} \times 12 = 96 \text{ in.}$

Then calculate:

$$1 \times 6.5 \times 96 \div 144 = 4.33 \text{ board feet}$$

The board contains approximately:

4.33 bd. ft.

## Example 2: Multiple Pieces

Suppose you need four pieces of 4/4 lumber, each:

- 1 inch nominal thickness;
- 6 inches wide; and
- 36 inches long.

Calculate:

$$4 \times 1 \times 6 \times 36 \div 144 = 6 \text{ board feet}$$

The calculated material requirement is:

6 board feet

This is before adding an allowance for defects, milling loss, grain selection, and other waste.

## Calculating Cost

Once you know the board footage:

Lumber Cost = Board Feet  $\times$  Price per Board Foot

For example, if the 4.33-board-foot piece from Example 1 were priced at a hypothetical \$8.00 per board foot:

$$4.33 \times \$8.00 = \$34.64$$

Estimated lumber cost:

\$34.64

Actual purchasing methods may involve rounding or other supplier practices, so always understand how your lumber supplier calculates the sale.

## Add for Waste and Selection

The exact board-foot volume of your finished parts is not necessarily the amount you should purchase.

Suppose your cut list contains 10 board feet of calculated material and you decide to allow 30% additional material.

$$10 \times 1.30 = 13 \text{ board feet}$$

You would estimate approximately:

13 board feet to purchase

The appropriate amount of extra material depends on the project, the lumber, and how selective you need to be about defects, grain, color, and figure.

## Check Whether the Answer Makes Sense

Board-foot calculators and reference charts can save time, but you should still understand the formula.

A calculator can give you an answer.

Understanding the formula helps you recognize when that answer does not make sense.

For example, if a calculator tells you that a single 4/4 board measuring 6 inches wide and 8 feet long contains 40 board feet, you should immediately recognize that something is wrong.

Basic estimation is part of professional judgment.

## Practice Your Board-Foot Skills

If you would like more practice, calculate the following:

1. One piece of 4/4 lumber measuring 8 in. wide  $\times$  72 in. long.
2. Two pieces of 5/4 lumber measuring 7 in. wide  $\times$  48 in. long.
3. Three pieces of 8/4 lumber measuring 5 in. wide  $\times$  36 in. long.
4. A 6.5-board-foot board priced at \$9.50 per board foot.
5. A project requiring 12 board feet of calculated material with a 25% additional allowance.

## Check Yourself

1. How many cubic inches are in one board foot?
2. What dimensions make up the traditional one-board-foot example?
3. Which thickness should you use for hardwood board-foot calculations?
4. What must you do if the lumber length is given in feet but the formula uses inches?
5. How do you calculate lumber cost?
6. Why should the amount you purchase usually be greater than the exact board footage of the project parts?

## 3: PREPARING LUMBER

3.1: Reading Grain Direction

3.2: Radial Arm Saw

3.3: Jointer

3.4: Planer

3.5: The Eight Steps to Squaring Lumber

## 3.1: Reading Grain Direction

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### 3.1 Reading Grain Direction

Rough lumber is rarely flat, straight, square, or exactly the size you need. Before it can become part of a woodworking project, it must be **milled**.

Milling is the process of creating reliable reference surfaces and bringing a board to its required thickness, width, and length.

In this chapter, you will work with several of the primary machines used to prepare rough lumber:

- radial arm saw;
- jointer;
- planer; and
- table saw.

You will also learn the standard **Eight Steps to Squaring Lumber**, which brings these machines together into a logical milling sequence.

Before using any machine, you must receive instruction from your instructor and follow the **WMT Wood Lab Safety Manual**. The information in this chapter prepares you to better understand machine demonstrations and milling procedures; it does not replace hands-on instruction or required machine checkouts.

### Additional Resource

If you would like more detail about common woodworking machines, Peter Scheidt's [Introduction to Woodworking Machines](#) ([opens new window](#)) is available as a supplemental open resource.

It provides additional explanations of woodworking machines, their parts, and common operations. Use it to reinforce what you learn in class or to review a machine before working in the shop.

When working in the Cerritos College woodshop, always follow the WMT Wood Lab Safety Manual and your instructor's directions.

### Learning Outcomes

After completing this section, you should be able to:

- Explain why grain direction matters when surfacing lumber.
- Use face grain and end grain to estimate a good feed direction.
- Recognize that grain direction may change within a board.
- Explain what to do when the grain pattern is unclear.

### Cutting With the Grain

Wood has direction.

Because the fibers in a board do not always run perfectly parallel to its surfaces, the direction you feed a board through a cutting machine can affect the quality of the surface you produce.

When a cutting edge moves through wood, the best results usually occur when the cutter works **with the grain**.

When the cutter works against unfavorable grain, fibers may lift ahead of the cutting edge and break away below the intended surface.

This damage is called **tearout**.

Tearout is especially important when using machines such as the:

- jointer;
- planer; and
- router.

The grain in real lumber can be complicated, so there is no method that works perfectly every time. The goal is to learn how to make an informed first choice.

## Look at the Face Grain

Many flatsawn boards show curved grain patterns commonly called **cathedrals**.

Imagine an arrow following the direction of the cathedral pattern.

That imaginary arrow has a **point** and a **tail**.

Do not use the face grain by itself to determine feed direction. The end grain provides additional information.

## Look at the End Grain

Now look at the end of the board.

Imagine another arrow following the direction of the growth rings.

Again, that arrow has a point and a tail.

Compare the imaginary arrow on the face with the imaginary arrow on the end.

## The Point-to-Point / Tail-to-Tail Method

As a starting point, feed the board so that:

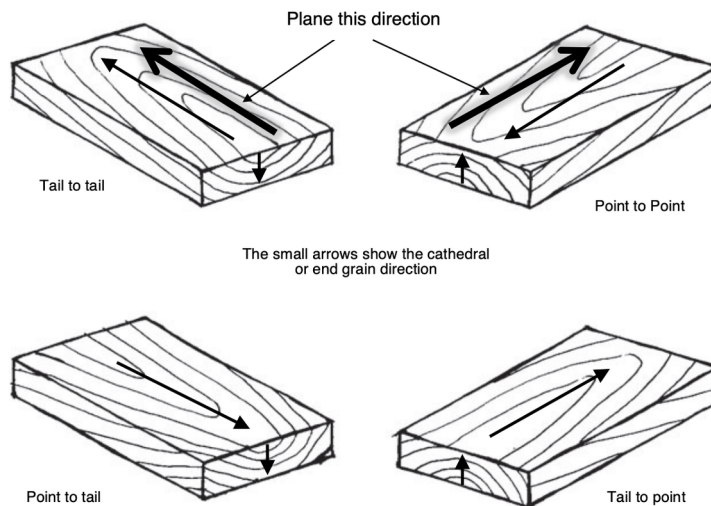
- tail meets tail, or
- point meets point.

These orientations usually indicate a favorable direction for jointing or planing.

When you see:

- point to tail, or
- tail to point,

feeding from the opposite end will usually give a better result.



Four boards showing face-grain and end-grain arrows used to estimate feed direction. Tail-to-tail and point-to-point arrangements indicate the preferred direction for jointing or planing, while point-to-tail and tail-to-point indicate feeding from the opposite end.

Figure: Surfacing Lumber and Grain Direction

## Real Wood Is Not Always Cooperative

The grain may:

- reverse direction;
- curve around a knot;
- change within a single board;
- contain figure that makes the direction difficult to read; or
- show little or no cathedral pattern.

When the direction is unclear, inspect the board carefully and make a light first cut.

If one direction produces excessive tearout, stop and try the opposite direction when the operation allows it.

Experience matters. The more lumber you machine, the better you will become at recognizing grain direction before making a cut.

## Check Yourself

1. Why does grain direction matter when machining wood?
2. What is tearout?
3. What two surfaces can help you estimate grain direction?
4. What does the point-to-point / tail-to-tail method tell you?
5. What should you do when the grain direction is unclear?

## 3.2: Radial Arm Saw

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### 3.2 Radial Arm Saw

The **radial arm saw** is the first machine used in the standard lumber-milling sequence.

Its primary job in WMT 101 is simple:

Cut rough lumber to rough length.

It is not used to bring a board to its final finished length.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the primary purpose of the radial arm saw.
- Identify its major parts.
- Explain why lumber is cut oversize during rough milling.
- Describe the basic safety requirements for using the machine.

### What the Radial Arm Saw Does

On the radial arm saw, the lumber remains stationary against a fence while the motor and blade assembly moves along an overhead support arm toward the operator.

The saw is especially useful for **rough crosscutting** long boards.

In the WMT lab, the radial arm saw is used for rough crosscutting only.

It is **never used for ripping**.

The machine is well suited to rough work, but it is not the machine used when the final length of a project part must be highly accurate.

### Major Parts

Important parts include:

**Table** — Supports the lumber.

**Fence** — Provides a reference surface behind the board.

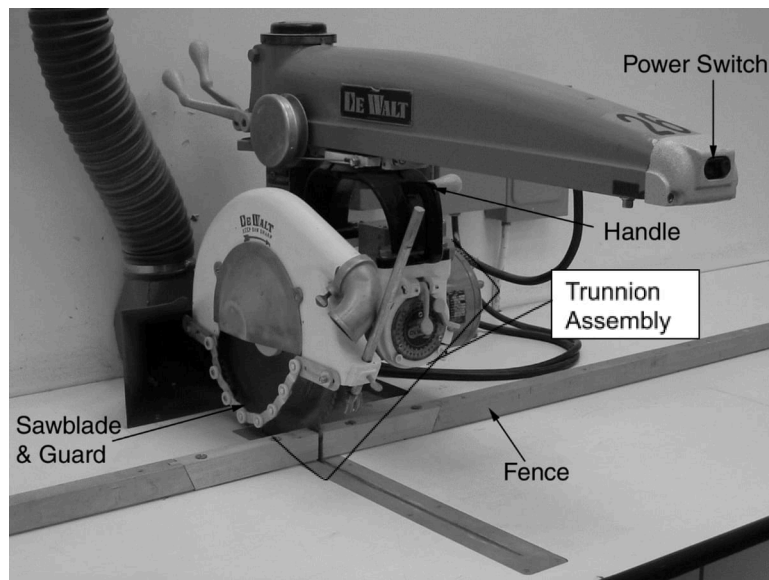
**Support Arm** — The overhead arm along which the saw assembly travels.

**Trunnion Assembly** — The motor, bracket, blade, and related components that move along the arm.

**Blade and Guard** — Perform the cutting operation and help protect the operator.

**Handle** — Used to control the saw during the cut.

**Power Switch** — Starts and stops the machine.



Radial arm saw labeled with blade and guard, fence, handle, trunnion assembly, support arm, and power switch.

Figure: Radial Arm Saw

## Rough-Cutting to Length

During the standard milling sequence, cut the board approximately:

Finished length + 1 inch

That extra material gives you room to square both ends later.

For example, if a finished part will be 18 inches long, the rough blank might initially be cut to approximately:

19 inches

Do not try to make the final finished cut at this stage.

## Before Cutting

Inspect the board.

Consider:

- checks or splits near the ends;
- knots near the cut line;
- severe bow or other warp;
- whether the board sits securely against the fence; and
- whether the piece will be long enough after defects are removed.

Sometimes you must cut beyond an end check before measuring the rough length of the part.

## Basic Operating Principles

When using the radial arm saw:

1. Place the board firmly against the fence.
2. Make sure the board contacts the fence at the cut line.
3. Keep your hands and fingers at least **6 inches from the line of the blade**.

4. Allow the blade to reach full speed.
5. Pull the saw through the stock at a controlled rate.
6. Do not force the saw faster than it can cut.
7. Return the saw completely to the rear of the support arm after the cut.
8. Remove the stock only after the saw has been returned.

Because of the blade's direction of rotation, the saw has a tendency to pull or **climb** into the work. The operator must control the rate of cut.

## Important WMT Limits

For normal student use:

- Use the radial arm saw for **rough crosscutting only**.
- Never rip lumber on the radial arm saw.
- Cut only one piece at a time.
- The minimum stock length is **12 inches**.
- Maintain at least a **6-inch margin of safety** from the blade.
- Special setups require instructor approval.

Warped lumber requires extra care because the kerf may close and pinch the blade.

If the board, setup, or cut does not feel secure, stop and ask your instructor.

## Why This Machine Comes First

Long rough boards are harder to flatten accurately than shorter pieces.

Rough-cutting a board close to the length of the required part can:

- reduce the amount of warp in the blank;
- make the board easier to handle;
- reduce unnecessary machining; and
- preserve useful material elsewhere in the original board.

This is why rough crosscutting is the first step in the milling process.

## Check Yourself

1. What is the main purpose of the radial arm saw in WMT 101?
2. Why is a board cut longer than its finished length?
3. What is the minimum stock length for normal use?
4. What is the required margin of safety from the blade?
5. Why should the saw be returned to the rear of the arm before removing the stock?

## 3.3: Jointer

---

### 3.3 Jointer

The **jointer** creates flat and straight reference surfaces.

It is one of the most important machines in the milling process because accurate woodworking depends on having reliable surfaces from which other dimensions can be established.

The jointer is primarily used to:

- flatten one face of a board; and
- straighten and square an edge.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the primary functions of the jointer.
- Identify its major parts.
- Explain why the stable side of a board is placed on the table.
- Distinguish between face jointing and edge jointing.
- Describe the basic safety limits for the jointer.

### Major Parts

Important jointer components include:

**Infeed Table** — Supports the board before it reaches the cutterhead.

**Outfeed Table** — Supports the newly cut surface after it passes the cutterhead.

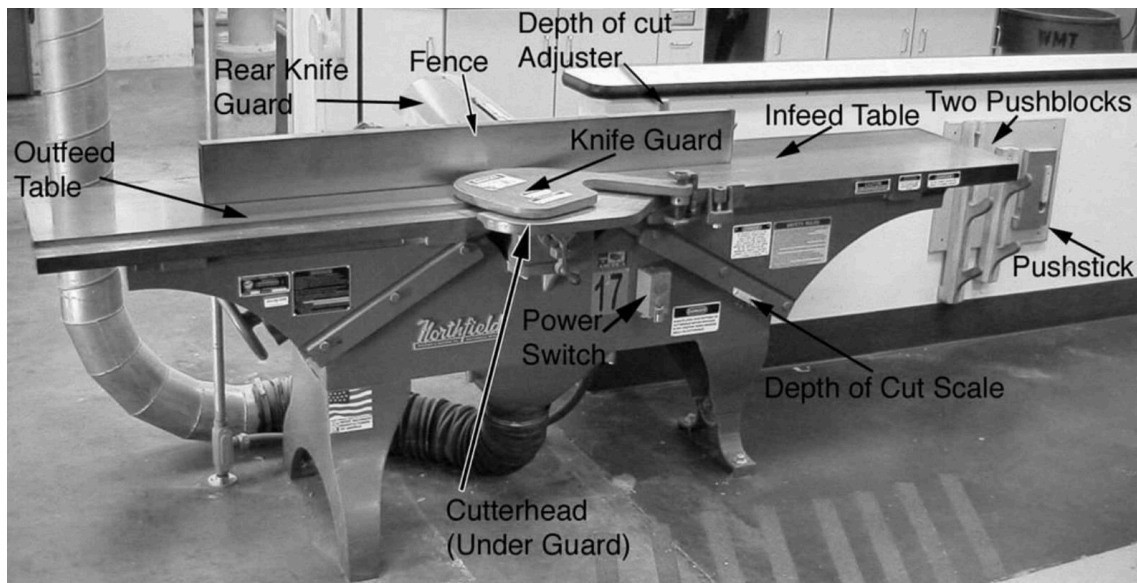
**Cutterhead** — Contains the knives or cutters that remove material.

**Guard** — Covers the cutterhead when it is not occupied by the workpiece.

**Fence** — Provides a reference surface when jointing an edge.

**Depth-of-Cut Adjustment** — Controls how much material is removed.

**Pushstick or Pushblock** — Helps control the board while keeping the operator's hands away from the cutterhead.



Jointer labeled with infeed table, outfeed table, fence, cutterhead and guard, depth-of-cut adjustment, power switch, pushblocks, and pushstick.

Figure: Jointer

## Face Jointing

The first jointer operation in the milling sequence is to create **one flat face**.

A rough board may rock when placed on a flat surface because of cup, bow, or twist.

Place the board with its **most stable side down** on the jointer table.

Often, but not always, this means placing the more concave face toward the table.

The purpose is to keep the board from rocking while it passes over the cutterhead.

Do not press a warped board flat against the table before it reaches the cutterhead. If you force the board flat during the cut, it may spring back to its original shape afterward.

The goal is to remove the high points until the machine creates a truly flat reference surface.

## Edge Jointing

After one face is flat and the opposite face has been planed parallel, the jointer is used again to straighten one edge.

Place the flat face firmly against the fence.

The newly jointed edge should become:

- straight; and
- square to the reference face.

This gives you two dependable reference surfaces:

one flat face + one straight, square edge

These reference surfaces are essential for later table-saw operations.

## Depth of Cut

For most normal jointer operations in the WMT lab:

Typical depth of cut: 1/32 inch

Maximum depth of cut: 1/16 inch

Light cuts are generally easier to control and produce better surfaces.

## Important WMT Limits

For normal student use:

- Minimum stock length: **14 inches**
- Minimum stock thickness for face jointing: **3/8 inch**
- Maintain at least **6 inches** between your body parts and the cutterhead.
- Use a pushstick or pushblock when required.
- Never joint end grain.
- Use only clean, dry lumber.
- Special operations require instructor approval.
- The outfeed table is **never adjusted by students**.

The guard must remain over the cutterhead during operation.

## Never Joint End Grain

End grain should not be jointed on the jointer.

The cutterhead can catch the fibers at the end of the board and break away material suddenly. On narrow pieces, this can be especially dangerous.

Use an appropriate crosscutting method to square ends instead.

## Severely Warped Lumber

A badly warped board may be difficult or unsafe to flatten while it is still wide or long.

One useful strategy is to first:

- rough crosscut it shorter on the radial arm saw; and/or
- rough rip it narrower on the band saw.

Breaking a badly warped board into smaller blanks often removes much of the distortion and makes the stock easier to joint safely.

## What the Jointer Does Not Do

A jointer makes a surface **flat**.

It does not automatically make the opposite face parallel.

If you joint both faces independently, you may create two flat faces that are not parallel to each other.

That is why the planer follows the jointer in the milling sequence.

The jointer establishes the reference.

The planer works from that reference.

## Check Yourself

1. What are the two primary jobs of the jointer?
2. Why is the most stable side placed against the table?
3. What is the typical depth of cut?
4. What is the maximum depth of cut?
5. Why should you not joint both faces of a board independently?
6. Why is end-grain jointing prohibited?

## 3.4: Planer

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### 3.4 Planer

The **planer** makes one face of a board parallel to another and brings the board to a controlled thickness.

It depends on the flat reference face created on the jointer.

This relationship is critical:

The jointer creates flatness.

The planer creates parallel thickness.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the primary function of the planer.
- Explain why a board must have a flat reference face before planing.
- Identify the major parts of the machine.
- Describe how thickness is reduced accurately.
- Explain the major safety limits for planer use.

### How the Planer Works

A board is placed on the planer table with the **jointed face down**.

Feed rollers pull the board through the machine.

A cutterhead above the board removes material from the upper face.

Because the flat reference face rides on the table, the newly cut upper face becomes parallel to it.

Repeated passes reduce the board to the required thickness.

### Major Parts

Important components include:

**Table or Bed** — Supports the board and provides the reference surface.

**Cutterhead** — Removes material from the upper face.

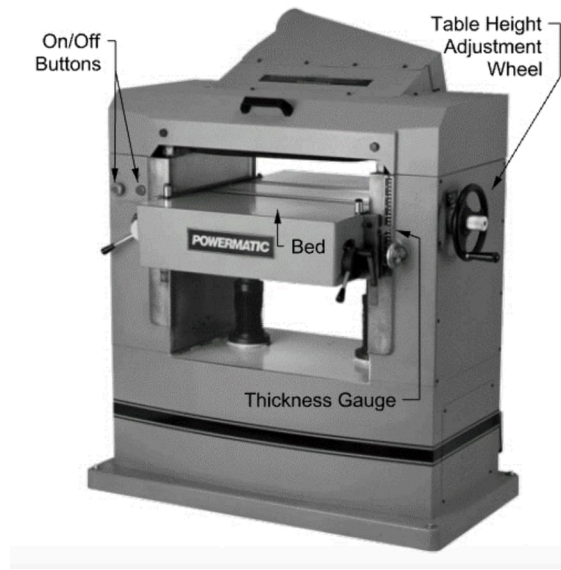
**Infeed Rollers** — Pull the board into the machine.

**Outfeed Rollers** — Help move the board out after cutting.

**Table-Height Adjustment Wheel** — Changes the distance between the table and cutterhead.

**Thickness Gauge** — Indicates the approximate thickness setting.

**Power Controls** — Start and stop the machine.



Thickness planer labeled with table or bed, thickness gauge, table-height adjustment wheel, and on/off controls.

Figure: Planer

## Flat First, Then Parallel

A planer does **not** flatten a warped board by itself.

If a bowed or twisted board is fed into the planer, the rollers may temporarily press the board against the table while it is being cut.

When the board exits, the pressure is released and the board may spring back into its warped shape.

The result may be:

a warped board of even thickness.

This is why the first face must be flattened on the jointer before the board is planed.

## Setting the First Cut

Before feeding the board, find the **thickest part** of the stock.

Set the planer so that the first cut removes only a small amount of material from that thickest area.

Do not make a heavy first cut.

## Depth of Cut

For normal use in the WMT lab:

Maximum material removal per pass: 1/16 inch

Several light passes are better than one heavy pass.

As the board approaches its desired thickness, lighter cuts can help improve surface quality.

## Plane With the Grain

Whenever possible, feed the board so the cutter works with favorable grain direction.

Planing against difficult grain can produce significant tearout.

Use the grain-reading method introduced earlier in this chapter as a starting point.

Never feed a board through the planer **across the grain**.

## Important WMT Limits

For normal student use:

- Remove no more than **1/16 inch per pass**.
- Set the initial cut from the thickest part of the board.
- Stock must be longer than the distance between the infeed and outfeed rollers.
- Minimum stock length is marked on each planer.
- Do not normally plane stock thinner than **1/4 inch**.
- Never place your hands inside the planer.
- Never change the depth after the stock has begun feeding through.
- Do not plane boards with large cracks or loose knots.
- Stand upright and to one side rather than looking directly into the machine while it runs.
- Only the instructor adjusts the feed-roller speed.

Surfacing stock thinner than the normal minimum may require another machine or an instructor-approved special setup.

## Plane Similar Stock from Thickest to Thinnest

If several pieces are different thicknesses, begin with the thickest.

Gradually lower the planer setting as you work toward the thinner pieces.

This reduces unnecessary adjustments and helps maintain a logical workflow.

## Final Thickness

Do not rush to the final dimension.

Measure the board during the process.

As you approach the required thickness:

1. reduce the amount removed per pass;
2. check the actual thickness;
3. inspect the surface; and
4. stop when the required dimension and surface quality have been achieved.

Removing wood is easy.

Putting it back is considerably more difficult.

## Check Yourself

1. What is the primary purpose of the planer?
2. Which face goes down on the planer table?
3. Why must that face already be flat?

4. What is the maximum normal material removal per pass?
5. What can happen if a warped board is planed without first being jointed flat?
6. Why should you plane with the grain?

## 3.5: The Eight Steps to Squaring Lumber

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### 3.5 The Eight Steps to Squaring Lumber

A woodworking project depends on accurate parts.

Before joinery can fit properly, a board must usually have:

- two flat, parallel faces;
- two straight, parallel edges;
- two square ends; and
- the correct thickness, width, and length.

In WMT 101, this is taught as the **Eight Steps to Squaring Lumber**.

The order matters.

Each operation establishes a reference for the next one.

### Learning Outcomes

After completing this section, you should be able to:

- List the eight steps used to square lumber.
- Match each step with the appropriate machine.
- Explain why the operations occur in this order.
- Identify the reference surfaces created during milling.
- Explain why stock remains oversized until later in the process.

### The Basic Idea

You are converting a rough and imperfect board into a rectangular part with controlled dimensions.

Think of the sequence this way:

Length roughly → Face → Thickness → Edge → Width → Edge → End → Length

Or more simply:

Establish references first. Final dimensions come later.

### Step 1 — Rough-Cut to Length + 1 Inch

#### Machine: Radial Arm Saw

Cut the blank approximately 1 inch longer than the final required length.

This:

- makes the board easier to handle;
- can reduce the effects of warp;
- removes unusable material near the ends; and
- leaves extra length so the ends can be squared later.

Do not cut to final length yet.

## Step 2 — Flatten One Face

### Machine: Jointer

Place the most stable side down.

Joint one face until it becomes flat.

This face becomes your first major **reference surface**.

Do not worry about final thickness yet.

## Step 3 — Plane to Desired Thickness

### Machine: Planer

Place the jointed face down against the planer table.

Plane the opposite face until:

- it is parallel to the first face; and
- the board reaches the required thickness.

You now have two flat, parallel faces.

## Step 4 — Straighten One Edge

### Machine: Jointer

Place a flat face against the jointer fence.

Joint one edge straight and square to the face.

You now have:

- a flat reference face; and
- a straight reference edge.

These surfaces are used to guide the stock accurately during later operations.

## Step 5 — Rip to Width + 1/32 Inch

### Machine: Table Saw

Use the straight jointed edge against the rip fence.

Rip the board approximately **1/32 inch wider** than its final required width.

The extra 1/32 inch leaves a small amount of material for the final edge-jointing operation.

The table saw is covered in detail later in this resource.

## Step 6 — Smooth the Ripped Edge

### Machine: Jointer

Return to the jointer and make a light cut on the sawn edge.

Remove the saw marks and bring the board to its final width.

The two edges should now be:

- straight;
- parallel; and
- square to the faces.

## Step 7 — Square One End

### Machine: Miter Saw or Table Saw with Crosscut Sled

Square one end of the board.

This creates the reference end from which final length is measured.

Do not simply measure from the original rough end. That end may not be square.

## Step 8 — Square the Other End to Final Length

### Machine: Miter Saw or Table Saw with Crosscut Sled

Measure from the newly squared reference end.

Cut the opposite end square at the required finished length.

The board should now be:

- flat;
- straight;
- square; and
- dimensioned to finished thickness, width, and length.

## Quick Reference

*Eight-step chart showing the standard sequence for milling rough lumber*

| Step | Process                     | Machine        |
|------|-----------------------------|----------------|
| 1    | Rough-cut to length + 1 in. | Radial arm saw |
| 2    | Flatten one face            | Jointer        |

| Step | Process                           | Machine                          |
|------|-----------------------------------|----------------------------------|
| 3    | Plane to desired thickness        | Planer                           |
| 4    | Straighten one edge               | Jointer                          |
| 5    | Rip to width + 1/32 in.           | Table saw                        |
| 6    | Smooth ripped edge to final width | Jointer                          |
| 7    | Square one end                    | Miter saw or table saw with sled |
| 8    | Square second end to final length | Miter saw or table saw with sled |

## Why the Order Matters

The machines do not all perform the same job.

For example:

- The planer needs a flat face before it can create a parallel face.
- The table saw needs a straight edge before the rip fence can accurately guide the board.
- Final length should not be established until a square reference end exists.

If the reference surfaces are wrong, later measurements and cuts will also be wrong.

Accuracy compounds.

So do errors.

## Mark Your Reference Surfaces

As you mill lumber, it can be helpful to mark the first completed face and edge.

A common practice is to identify:

- the **reference face**; and
- the **reference edge**.

These marks remind you which surfaces should contact fences, tables, or other reference surfaces during later operations.

Your instructor may demonstrate a specific marking system.

## Milling Several Matching Parts

When several parts must finish at the same thickness or width, machine them together whenever practical.

For example, if four pieces must all finish at 3/4 inch thick:

1. prepare all four pieces through face jointing;
2. plane them together through the same thickness settings; and
3. stop when all pieces reach the required dimension.

This improves consistency and reduces unnecessary machine adjustments.

## Advanced Practice: Two-Stage Milling

The standard eight-step process works well for many introductory projects.

For furniture parts requiring greater precision, or for lumber that may move substantially after initial milling, woodworkers may use a **two-stage milling process**.

The idea is to:

1. rough-mill the stock slightly oversized;
2. allow the wood to rest; and
3. mill it again to final dimensions.

One possible sequence is:

1. Remove checked ends.
2. Rough-rip badly warped stock when necessary.
3. Rough-cut to length + 1 inch.
4. Flatten one face.
5. Plane slightly thicker than the final dimension.
6. Straighten one edge.
7. Rip slightly wider than the final dimension.
8. Sticker the stock and allow it to rest.
9. Reflatten the best face if needed.
10. Plane to final thickness.
11. Rejoint one edge if needed.
12. Rip to width + 1/32 inch.
13. Joint to final width.
14. Square one end.
15. Cut the opposite end to final length.

This approach gives the wood an opportunity to release internal stress and change shape before final dimensions are established.

You do not need to use this process for every introductory project, but it is an important professional milling concept.

## Store Milled Lumber Properly

Freshly milled lumber should not be left lying directly on a bench or stacked unevenly for long periods.

When storing lumber for more than a short time, **sticker it** so air can circulate evenly around the pieces. Sticker means stacking boards with small, evenly spaced strips of wood between each layer. Align the stickers vertically so the stack stays supported and flat.

Good storage helps reduce unwanted changes before the parts are assembled.

## Check Yourself

1. Why is the stock left approximately 1 inch long in Step 1?
2. Which machine establishes the first flat reference face?
3. Why does the planer come after the jointer?

4. What two reference surfaces should exist before ripping on the table saw?
5. Why is the board ripped approximately 1/32 inch oversize?
6. Why is one end squared before the board is cut to final length?
7. What is the purpose of two-stage milling?
8. Why should milled lumber be stickered when stored?

## 4: PROJECT 1- CUTTING BOARD

4.1: Cutting Board Project Overview

4.2: Milling and Layout

4.3: Cutting and Shaping

4.4: Sanding and Finishing

## 4.1: Cutting Board Project Overview

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### 4.1 Cutting Board Project Overview

Your first major project in WMT 101 is a **solid-wood cutting board** made from a single piece of hardwood.

The project introduces many of the skills you will use throughout woodworking: selecting lumber, reading grain, milling rough stock, measuring, laying out a design, cutting curves, shaping edges, sanding, and applying a finish.

This is also a design project. You will work within a set of requirements, but the final shape is up to you.

### Learning Outcomes

After completing this project, you should be able to:

- Select an appropriate piece of hardwood.
- Mill rough lumber to a controlled thickness and size.
- Develop and refine a cutting-board design.
- Lay out curves and an interior handle opening.
- Safely cut and shape a solid-wood workpiece.
- Refine a form using files, rasps, spokeshaves, and abrasives.
- Sand a project through 320 grit.
- Apply a food-safe oil finish.

### Project Requirements

Your cutting board must:

- Be made from **one solid piece of hardwood**.
- Not exceed **18 inches long × 9 inches wide**.
- Finish between **1/2 inch and 7/8 inch thick**.
- Include a **handle or interior opening** made using the drill press, jig saw, or a combination of the two.
- Use no more than **two straight lines** in the overall design.
- Be sanded through **320 grit**.
- Be finished with a **food-safe oil finish**.

The goal is not simply to produce a rectangular board with rounded corners. Use the project as an opportunity to think about proportion, curves, transitions, and how the board feels in your hands.

### Hard Lines and Soft Lines

As you develop your design, consider the difference between **hard** and **soft** lines.

A hard line changes direction clearly or abruptly.

A soft line flows gradually from one curve or direction into another.

Using both can give a simple object more visual interest.

Pay particular attention to the transition between the main body of the cutting board and the handle. A smooth transition usually looks and feels more intentional than several unrelated curves joined together.

## Design Before Cutting

Do not commit to your final hardwood immediately.

Sketch several possibilities first.

As you develop the shape, consider:

- How will the board be held?
- Is the handle comfortable?
- Is there enough material around the handle opening to remain strong?
- Do the curves flow into each other?
- Does the board have a clear front, back, or direction?
- Does the grain complement the shape?
- Will the design be practical to cut and sand?

A good design usually becomes clearer through several small revisions rather than one complicated first attempt.

## Design Inspiration

For examples of how a simple cutting board can become a carefully considered object, look at the work of furniture maker **Edward Wohl**.

Use examples as inspiration for proportion, curves, and restraint—not as patterns to copy directly.

## Materials

You will need:

- One piece of hardwood large enough for your design.
- Food-safe oil finish.

Hardwood is available through the CSAW Lumber Room. Ask an instructor, instructional aide, or embedded tutor if you need help selecting or purchasing material.

## Check Yourself

1. Why is the cutting board made from one solid piece of wood?
2. What are the maximum length and width?
3. What is the allowable finished-thickness range?
4. What feature must be included in the design?
5. How many straight lines may the design contain?

## 4.2: Milling and Layout

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### 4.2 Milling and Layout

Before you can shape the cutting board, the rough lumber must be prepared.

The milling skills from Chapter 3 are used to turn rough hardwood into a flat, straight blank that is ready for design and shaping.

#### Learning Outcomes

After completing this section, you should be able to:

- Inspect a rough board before milling.
- Determine grain direction.
- Mill a board to a usable cutting-board blank.
- Select the best face and orientation for the project.
- Transfer a cutting-board design accurately to the wood.

#### Select the Board Carefully

Before milling, examine the entire board.

Look for:

- bow, cup, crook, or twist;
- knots;
- checks or splits;
- wane;
- unusual grain;
- color variation; and
- enough usable material for your design.

Also consider the **appearance** of the board.

A cutting board made from one piece of hardwood gives you an opportunity to use the grain as part of the design. Look at both faces before deciding which side should become the top.

#### Determine Grain Direction

Before jointing and planing, examine the face grain and end grain.

Use the grain-reading method from Chapter 3 to determine a good starting direction for machining.

Mark the grain direction if that helps you remember how the board should be fed through the jointer and planer.

#### Mill the Blank

Use the standard lumber-milling sequence as appropriate for your stock.

Your goal is to produce a blank that is:

- flat;
- parallel in thickness;

- straight;
- square enough for accurate layout; and
- within the required finished-thickness range.

Do not remove more material than necessary.

Remember that your final board must finish between **1/2 inch and 7/8 inch thick**.

## Plan for the Final Shape

The cutting board may be smaller than the rectangular blank you initially mill.

Leave enough material for:

- the outside curves;
- the handle;
- design adjustments; and
- final shaping.

Do not cut away useful material before you are confident about the design.

## Choose the Best Face

Once the blank is milled, examine both faces again.

Consider:

- color;
- figure;
- grain pattern;
- small defects;
- sapwood and heartwood;
- and how the grain works with your proposed design.

Mark the face you want to feature.

## Develop the Layout

Draw the design directly on the wood only after you have worked through the basic shape.

You may find it useful to:

1. Sketch the design on paper.
2. Refine the major curves.
3. Test the handle size and location.
4. Transfer the design to the board.
5. Step back and look at the whole form before cutting.

Use light pencil lines so changes can be made easily.

## Use Centerlines and Reference Marks

Simple reference marks can make freeform designs more controlled.

A centerline can help you judge:

- balance;

- handle placement;
- curve relationships; and
- overall proportion.

The finished board does not need to be symmetrical, but reference lines can still help you make deliberate decisions.

## Lay Out the Handle Opening

The handle should be large enough to use comfortably while leaving enough wood around it for strength.

Before cutting, check:

- its distance from the end of the board;
- the thickness of the material around the opening;
- whether your hand fits comfortably;
- and whether the shape works visually with the outside profile.

Avoid creating thin points or weak areas around the opening.

## Check the Design Before Cutting

Before turning on a machine, ask yourself:

- Is this the final shape I want?
- Have I identified which side of the line is waste?
- Is there enough material around the handle?
- Can the shape be cut safely?
- Are the curves smooth and intentional?
- Do I know which machine or tool will make each part of the cut?

When in doubt, ask your instructor before removing material.

## Check Yourself

1. Why should both faces of the board be examined after milling?
2. Why should you leave extra material while developing the design?
3. What can a centerline help you evaluate?
4. What should you consider when sizing the handle opening?
5. Why should the waste side of a layout line be identified before cutting?

## 4.3: Cutting and Shaping

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### 4.3 Cutting and Shaping

Once the design is laid out, the rectangular blank can begin to become the finished cutting board.

Do not expect one machine to produce the final shape.

The process usually moves from **rough cutting to controlled shaping to final refinement**.

### Learning Outcomes

After completing this section, you should be able to:

- Choose an appropriate tool for a straight or curved cut.
- Cut an interior opening safely.
- Leave material for final shaping.
- Refine curves using hand tools and sanding equipment.
- Evaluate the shape by both sight and touch.

### Cut Close, Not Perfect

When rough-cutting the outside shape, do not try to cut directly on the finished line.

Leave a small amount of material outside the layout line.

That extra material allows you to refine the curve using:

- files;
- rasps;
- spokeshaves;
- stationary sanders; or
- hand sanding.

A rough-cutting machine creates the basic form.

The final shape comes from refinement.

### Cutting the Outside Shape

Depending on the design, the outside profile may involve:

- band saw cuts;
- jig saw cuts; or
- another instructor-approved method.

Plan the cutting sequence before beginning.

For tight curves, you may need to make **relief cuts** so waste can fall away without forcing the blade through an excessively tight turn.

Do not twist or force a blade to follow a curve it cannot safely cut.

## Cutting the Interior Handle Opening

The handle opening requires an **interior cut**, meaning the waste is surrounded by material.

One common method is:

1. Lay out the opening clearly.
2. Drill an entry hole inside the waste area.
3. Insert the jig saw blade through the opening.
4. Cut around the interior shape while staying slightly inside the waste side of the layout line.
5. Refine the opening with files, rasps, or abrasives.

Depending on the design, the drill press may also be used to establish rounded ends or portions of the opening.

Your instructor will demonstrate the appropriate method for your design.

## Protect the Layout Line

The pencil line represents the shape you want to keep.

Whenever possible, leave the line visible during rough cutting.

It is much easier to remove a little more material during shaping than to repair a cut that went too far.

## Files and Rasps

Files and rasps are useful for refining areas that are difficult to reach with machines.

**Rasps** remove material relatively quickly and are useful for developing a shape.

**Files** usually cut more finely and can be used to refine surfaces after the rough shape has been established.

Use the tool that matches the amount of material you need to remove.

## Spokeshaves

A spokeshave can be useful for shaping long outside curves and edges.

Like other cutting tools, it works best when used with favorable grain direction.

If the tool begins tearing the grain rather than cutting it cleanly, change direction or adjust your approach.

## Shape by Touch

Do not evaluate the cutting board only with your eyes.

Run your hand along the perimeter.

Feel for:

- flat spots in curves;
- abrupt transitions;
- bumps;
- sharp corners;
- asymmetry that looks accidental; and
- areas that are uncomfortable to grip.

Your hand will often detect problems that are difficult to see.

## Work From Coarse to Fine

A useful general sequence is:

Saw → Rasp → File or Spokeshave → Coarse Abrasive → Fine Abrasive

Not every area will require every step.

The goal is to use the most efficient tool for the amount of material that still needs to be removed.

Do not spend twenty minutes sanding away material that could have been removed accurately in one minute with a rasp.

## Know When to Stop Shaping

Once the design is resolved, stop changing the form.

Continuing to reshape a nearly finished board can gradually make the project smaller, thinner, or less intentional.

At some point, shaping ends and surface preparation begins.

## Check Yourself

1. Why should you leave material outside the layout line when rough cutting?
2. What is an interior cut?
3. Why might you drill a hole before using the jig saw on the handle?
4. What is the general difference between a rasp and a file?
5. Why should you evaluate the shape with your hands as well as your eyes?

## 4.4: Sanding and Finishing

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### 4.4 Sanding and Finishing

Sanding is not simply the last thing you do before applying finish.

It is the final stage of shaping and surface preparation.

Good sanding preserves the form you worked to create. Poor sanding can flatten curves, round over details unintentionally, or leave scratches that become more visible after finish is applied.

### Learning Outcomes

After completing this section, you should be able to:

- Select an appropriate sanding sequence.
- Sand faces, edges, and interior curves without changing the intended shape.
- Recognize when scratches from a previous grit remain.
- Prepare the cutting board through 320 grit.
- Apply a food-safe oil finish.

### Sanding Does Not Fix Poor Shaping

Before beginning fine sanding, the overall form should already be correct.

Use cutting and shaping tools to establish:

- curves;
- transitions;
- edges; and
- the handle opening.

Use sandpaper to **refine the surface**, not to redesign the project.

### Work Through the Grits

Abrasives are identified by **grit number**.

Lower grit numbers are coarser and remove material more quickly.

Higher grit numbers are finer and remove smaller scratches.

Your exact starting grit depends on the condition of the surface.

A possible progression might include:

80 → 100 → 120 → 150 → 180 → 220 → 320

You may not need every grit in every situation.

What matters is that each grit removes the scratches left by the previous one.

The finished cutting board must be sanded through **320 grit**.

## Do Not Skip Too Far

Moving from a very coarse abrasive directly to a very fine abrasive can leave deep scratches behind.

The fine abrasive may polish the surface without removing them.

When finish is applied, those scratches may become much easier to see.

Before moving to the next grit:

1. Inspect the surface under good light.
2. Look across the grain as well as with it.
3. Feel the surface.
4. Make sure the scratches from the previous grit are gone.

## Sand With the Grain

For final hand sanding on a face, sand in the direction of the grain.

Cross-grain scratches are especially visible after finish is applied.

Curves and interior openings may require different hand motions, but the final surface should be free of obvious scratches.

## Preserve the Shape

Be careful around:

- outside curves;
- transitions;
- the handle;
- thin areas; and
- corners.

Do not allow sanding to flatten a flowing curve or make one side noticeably different from the other unless that difference is intentional.

## Break Sharp Edges

A perfectly sharp machined edge is uncomfortable to handle and easily damaged.

Lightly soften exposed edges.

The goal is generally not to create a large roundover unless your design calls for one. A few controlled passes with fine abrasive may be enough to make the edge comfortable.

## Inspect Before Finishing

Finish makes many surface defects more visible.

Before applying oil:

- remove sanding dust;
- inspect both faces;
- inspect the entire perimeter;
- check the handle opening;
- look for scratches;
- feel for rough areas; and

- make sure you are satisfied with the form.

Do not apply finish simply because you are tired of sanding.

## Food-Safe Oil Finish

The cutting board is finished with an oil appropriate for food-contact use.

Mineral oil is one suitable option for this project.

Your instructor will provide the finish used in class and demonstrate the application process.

In general:

1. Make sure the surface is clean and free of sanding dust.
2. Apply the oil evenly to the faces, edges, and interior opening.
3. Allow the wood to absorb the finish.
4. Remove excess finish as directed.
5. Apply additional coats when appropriate.

Oil will deepen the color of the wood and make the grain and figure more visible.

## A Cutting Board Will Be Used

A cutting board is a functional object.

It may eventually develop:

- knife marks;
- stains;
- dents;
- and other evidence of use.

That is normal.

The goal of the project is not to create an object too precious to use. The goal is to make a well-designed, carefully crafted object that works.

## Project Complete

Before considering the project finished, confirm that:

- the board is made from one piece of hardwood;
- the dimensions meet the project requirements;
- the handle opening is complete;
- the form is intentional and comfortable;
- all surfaces are sanded through 320 grit;
- the board is clean and free of visible sanding scratches; and
- the food-safe oil finish has been applied properly.

Then use it.

## Check Yourself

1. Why should the final form be established before fine sanding begins?
2. What should each abrasive grit remove?
3. Why are cross-grain scratches a problem?

4. Why should sharp edges be softened slightly?
5. What should you inspect before applying finish?
6. What is one appropriate finish for this project?

## 5: SHAPING AND CUTTING WOOD

5.1: Band Saw

5.2: Drill Press and Jig Saw

5.3: Routers and Router Tables

5.4: Files and Rasps

5.5: Abrasives and Sanding

## 5.1: Band Saw

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### 5.1 Band Saw

The **band saw** is one of the most useful machines for shaping wood.

Unlike a table saw, which is primarily used for straight cuts, the band saw can follow curves. It is also used for rough ripping and **resawing**, which means cutting a board through its thickness to make thinner pieces.

The band saw is a **rough-cutting and shaping machine**. It is not intended to leave a finished surface.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the primary uses of the band saw.
- Identify the major parts of the machine.
- Explain why relief cuts are useful.
- Describe the basic WMT safety requirements for band-saw use.
- Explain the difference between cutting a curve and resawing.

### How the Band Saw Works

A band saw uses a continuous loop of narrow steel blade running over wheels above and below the table.

At the cutting area, the blade moves downward through the table.

Because the blade is narrow, it can follow curves that would be impossible to cut safely on many other woodworking machines.

### Major Parts

Important parts include:

**Blade** — The continuous cutting band.

**Table** — Supports the workpiece.

**Upper Blade Guide** — Supports the blade above the work.

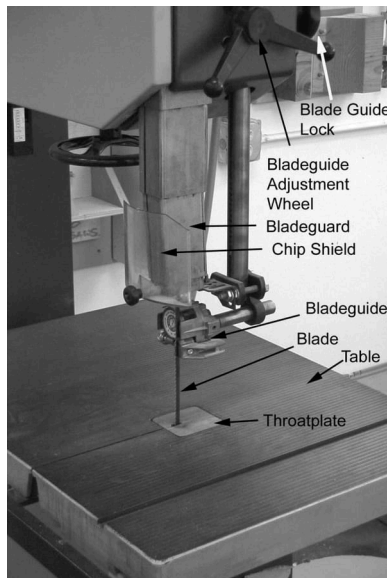
**Blade Guard** — Covers the exposed portion of the blade above the workpiece.

**Guide Adjustment** — Raises or lowers the upper guide and guard.

**Throat Plate** — Surrounds the blade where it passes through the table.

**Power Switch** — Starts and stops the machine.

**Brake** — Helps bring the blade to a controlled stop after the power is turned off.



Band saw labeled with blade, table, throat plate, upper blade guide, blade guard, guide adjustment, and guide lock.

Figure: Band Saw

## Adjust the Guide Before Cutting

Before turning on the machine, lower the upper guide and guard to approximately:

1/4 inch above the workpiece

The guide should be close enough to support the blade while still allowing the work to move freely.

Never adjust the blade guide while the saw is running.

## Cutting Curves

Plan curved cuts before turning on the machine.

The tighter the curve, the more difficult it is for the blade to follow.

Do not force or twist the workpiece against the blade.

Instead:

- approach the layout line gradually;
- use smooth forward movement; and
- make **relief cuts** when necessary.

## Relief Cuts

A **relief cut** is a cut from the waste edge toward the finished layout line.

Relief cuts divide a large waste area into smaller sections.

As the curved cut progresses, the small waste pieces fall away instead of trapping the blade or forcing you to make an excessively tight turn.

Relief cuts are especially useful for:

- long curves;
- tight curves; and
- shapes with changing radii.

## Leave the Line

As with other rough-shaping operations, do not try to make the band saw produce the final finished surface.

Cut close to the layout line while leaving a small amount of material for later shaping and sanding.

The band saw establishes the form.

Files, rasps, spokeshaves, and abrasives refine it.

## Backing Out of a Cut

Do not pull a workpiece backward out of a cut while the blade is running.

Backing out can pull the blade off the wheels.

If the stock becomes trapped or you need to back out of a long cut:

1. Turn off the power.
2. Wait until the blade stops completely.
3. Remove the work carefully.
4. Ask your instructor for assistance if the piece does not release easily.

## Margin of Safety

Maintain at least a:

4-inch margin of safety

between your fingers or other body parts and the blade.

Use a pushstick or other guide when a cut would place your hands too close to the blade.

## Resawing

**Resawing** means cutting through the thickness of a board to produce thinner pieces.

For example, a thick board might be resawn into two thinner boards.

Resawing requires:

- a straight edge against the table;
- a flat face against the resaw fence; and
- a pushstick.

Resawing is an instructor-approved setup in the WMT lab.

## Irregular and Round Stock

Round or irregularly shaped material can rotate unexpectedly when it contacts the blade.

Cylindrical or irregular work must be supported with an appropriate jig, such as a **V-block**, and treated as a special setup.

Never attempt to hold a round object directly on the table and cut it freehand.

## Important WMT Limits

For normal use:

- Adjust the upper guide to about **1/4 inch above the stock** before starting.
- Maintain a **4-inch margin of safety**.
- Allow the blade to reach full speed before cutting.
- Do not adjust the machine while it is running.
- Do not back work out while the blade is moving.
- Keep guards and doors in place.
- Use a pushstick when required.
- Resawing and unusual setups require instructor approval.
- Do not stand directly to the right side of the band saw while it is running.
- If you hear an unusual clicking sound, shut the machine off and notify your instructor.

## Check Yourself

1. Why is the band saw considered a rough-cutting machine?
2. What is the purpose of a relief cut?
3. How high should the upper guide normally be above the work?
4. What is the required margin of safety?
5. Why should you not back a workpiece out while the blade is running?
6. What is resawing?

## 5.2: Drill Press and Jig Saw

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### 5.2 Drill Press and Jig Saw

The drill press and jig saw perform very different jobs, but they are often used together when creating shapes.

The **drill press** produces controlled holes.

The **jig saw** can begin inside a drilled hole and cut an enclosed or curved shape.

This combination is especially useful for features such as the interior handle opening in the cutting-board project.

### Learning Outcomes

After completing this section, you should be able to:

- Identify the major parts of a drill press.
- Select a basic drilling approach for a woodworking operation.
- Explain the importance of securing the workpiece.
- Use a backer board when appropriate.
- Explain how a drilled starter hole can be used with a jig saw.
- Describe the basic safe-use principles for both tools.

### Drill Press

#### What the Drill Press Does

A drill press holds a rotating bit vertically above a work table.

The operator lowers the bit into the work using a feed handle.

Compared with a hand-held drill, the drill press makes it easier to:

- drill perpendicular holes;
- control hole location;
- use larger bits;
- repeat a hole depth; and
- hold the work securely.

### Major Parts

Important parts include:

**Head and Motor** — Drive the spindle.

**Chuck** — Holds the drill bit.

**Chuck Key** — Tightens or loosens many drill-press chucks.

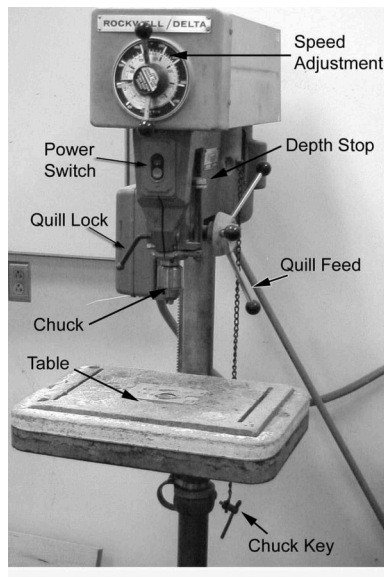
**Table** — Supports the work.

**Quill and Spindle** — Move the rotating bit up and down.

**Feed Handle** — Lowers the bit into the work.

**Depth Stop** — Limits how far the bit travels.

**Power Switch** — Starts and stops the machine.



Drill press labeled with power switch, chuck, chuck key, table, quill feed handle, depth stop, quill lock, and speed adjustment.

Figure: Drill Press

## Choose the Correct Bit

Use a bit appropriate for the hole you need.

Common woodworking drilling operations may involve different styles of bits for:

- small pilot holes;
- larger clean holes;
- flat-bottomed holes; or
- starter holes for interior cuts.

Do not use a dull or damaged bit.

Ask your instructor if you are uncertain which bit is appropriate.

## Secure the Work

A drill bit can grab a workpiece and cause it to rotate.

Use clamps or a drill vise whenever the size or shape of the work requires additional control.

Never assume that a small piece will be safe simply because you can hold it with your hand.

## Remove the Chuck Key

After installing a drill bit:

Remove the chuck key before turning on the drill press.

A chuck key left in the chuck can be thrown from the machine when it starts.

Make removing the key part of your normal setup routine.

## Drill Speed

Larger drill bits generally run at slower spindle speeds.

Smaller bits generally run faster.

The method for changing spindle speed varies among machines, so check with your instructor before making speed adjustments.

## Use a Backer Board

When drilling completely through a workpiece, place a **backer board** underneath when appropriate.

A backer board:

- supports the fibers as the bit exits;
- reduces tearout; and
- prevents the bit from cutting into the machine table.

## Clear Chips

When drilling a deep hole, periodically raise the bit to clear chips.

Do not use your fingers to clear chips while the spindle is moving.

## Breaking Through the Bottom

As the bit approaches the bottom of a through-hole, reduce the feed pressure.

This helps reduce tearout and gives you better control as the bit exits the workpiece.

## Important Drill-Press Practices

- Make sure the table and head are secure.
- Install the bit correctly.
- Remove the chuck key.
- Secure small or irregular work.
- Keep hands away from the rotating spindle and bit.
- Use a backer board when appropriate.
- Stop the drill press before removing the workpiece.
- Uses other than normal drilling require instructor approval.

## Jig Saw

A **jig saw** is a hand-held power saw with a narrow blade that moves rapidly up and down.

It is useful for:

- curved cuts;
- irregular shapes; and
- interior cutouts.

The jig saw used in WMT 101 is taught through instructor demonstration and the general WMT portable-power-tool safety rules.

## Interior Cuts

One of the most useful jig-saw techniques is beginning a cut inside a workpiece.

For example, to cut a handle opening:

1. Lay out the opening.
2. Drill a starter hole inside the waste area.
3. Insert the jig-saw blade through the hole while the tool is off.
4. Position the saw base securely on the work.
5. Start the tool and cut toward the layout line.
6. Leave a small amount of material for later shaping.

The starter hole must be large enough for the blade to enter without forcing it.

## Basic Jig-Saw Practices

- Receive an instructor demonstration before use.
- Secure the workpiece so it cannot move.
- Keep the saw base supported on the work.
- Keep hands away from the blade and below the cutting area.
- Disconnect the tool from power before changing the blade or making adjustments.
- Do not force the blade through a tight turn.
- Allow the blade to stop before setting the tool down.

The jig saw creates a rough cut. Refine the surface afterward with appropriate hand tools or abrasives.

## Check Yourself

1. Why is a drill press useful for accurate woodworking?
2. Why must the chuck key be removed before starting the machine?
3. Why might you use a backer board?
4. Why should a large drill bit generally rotate more slowly than a small bit?
5. How can a drill press and jig saw be used together to create an interior opening?
6. Why should the jig saw cut slightly into the waste rather than directly on the final line?

## 5.3: Routers and Router Tables

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### 5.3 Routers and Router Tables

Few woodworking tools are as versatile as the **router**.

A router uses a high-speed rotating bit to cut and shape wood.

Routers can be used to:

- shape edges;
- cut profiles;
- trim material;
- follow templates;
- cut grooves; and
- perform many other operations.

The same basic router motor can be used as a hand-held tool or mounted beneath a router table.

### Learning Outcomes

After completing this section, you should be able to:

- Identify the basic parts of a router.
- Explain the difference between a hand-held router and router table.
- Explain why feed direction matters.
- Describe why several light cuts are better than one heavy cut.
- Explain basic bit installation and work-holding principles.

### Hand-Held Router

#### Major Parts

A router includes:

**Motor** — Rotates the bit at high speed.

**Collet** — Clamps the router bit to the motor shaft.

**Bit** — Performs the cutting operation.

**Base** — Supports and guides the router over the workpiece.

**Depth Adjustment** — Controls how far the bit projects below the base.

**Power Switch** — Starts and stops the motor.

Routers may have a fixed base or a plunge base.

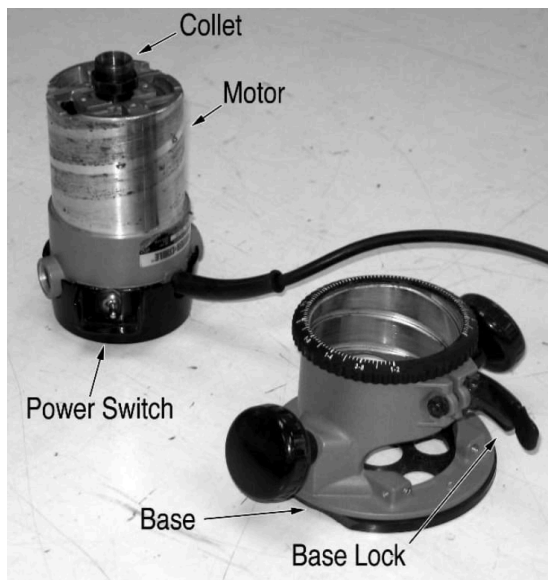


Figure: Hand-Held Router

## Installing a Router Bit

Before changing a bit:

Disconnect the router from power.

Insert the router-bit shank securely into the collet, but do not bottom it out completely.

When possible, insert the bit fully and then pull it back approximately **1/8 inch** before tightening the collet.

Make sure:

- the bit is secure;
- the collet is properly tightened; and
- the motor is locked firmly in the base.

## Starting the Router

Before switching on the router:

- secure the workpiece;
- place the router base firmly on the work; and
- make sure the bit is not touching the material.

Do not start a hand-held router while holding it unsupported in the air.

Be prepared for the starting torque of the motor.

## Feed Direction

Router feed direction is important.

In most normal operations, the cutting action should oppose the movement of the router or workpiece.

This gives the operator greater control and helps prevent the cutter from pulling itself uncontrollably along the work.

For fence-guided operations, the feed direction should also cause the cutter action to press the work toward the fence.

Your instructor will demonstrate the correct direction for each setup.

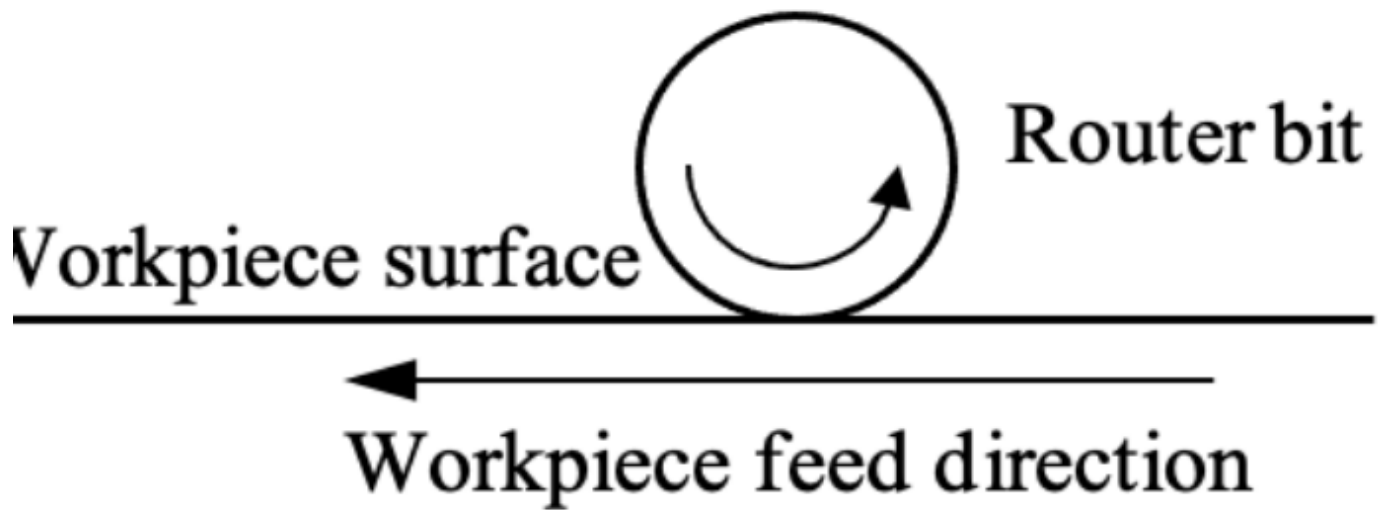


Diagram showing a router bit rotating against the direction in which the router or workpiece is fed during a controlled routing operation.

Figure: Router Feed Direction

## Light Cuts

Do not try to remove a large amount of material in one pass.

Several light cuts are better than one heavy cut.

Light cuts:

- reduce stress on the router;
- improve control;
- reduce burning and tearout;
- produce a better surface; and
- reduce the chance of the bit grabbing the work.

Do not overload the motor or allow its speed to bog down.

## Secure the Work

A hand-held router applies considerable force to the workpiece.

Clamp or otherwise secure the work so it cannot move during routing.

## Router Table

A router can also be mounted upside down beneath a table.

The bit projects upward through the tabletop while the workpiece moves past it.

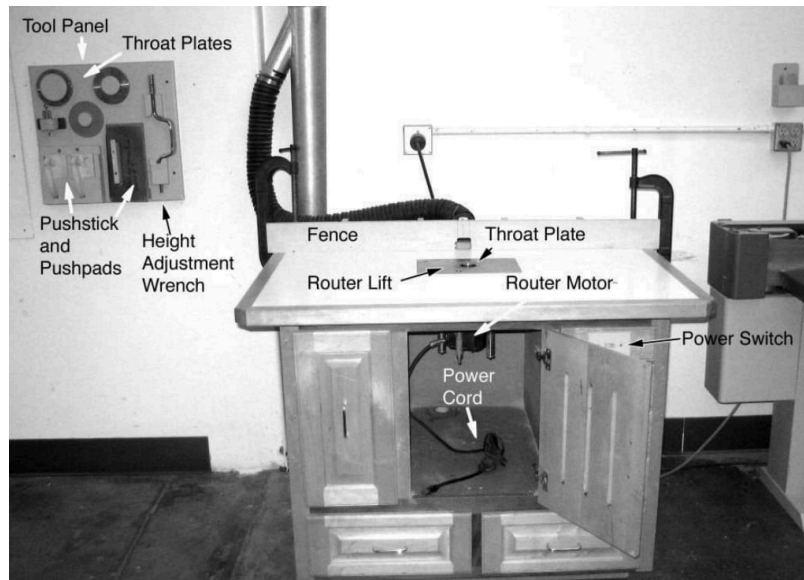
This arrangement is called a **router table**.

## Why Use a Router Table?

The router table provides a large, stable reference surface and can make small or narrow parts easier to control.

The table normally includes:

- a fence;
- a throat plate;
- a router lift or height adjustment;
- a power switch; and
- pushsticks or other work-control devices.



Router table labeled with fence, throat plate, router lift, router motor, power switch, height-adjustment wrench, and pushsticks.

Figure: Router Table

## Throat Plates

Use the throat plate that leaves the **smallest practical opening** around the router bit.

A smaller opening provides better support for the workpiece.

## Small and Narrow Parts

When routing small or narrow parts, additional control may be required.

Use appropriate:

- pushsticks;
- backer boards;
- fences; and
- other instructor-approved supports.

Do not place your fingers close to the rotating bit.

## Router Safety Principles

For normal router use:

- Disconnect power before changing bits.
- Make sure the bit is securely installed.
- Use only bits intended for high-speed routers.
- Secure the workpiece.
- Keep hands and loose clothing away from the bit.
- Use the correct feed direction.
- Use slower speeds when required for larger bits.
- Take several light cuts instead of one heavy cut.
- Do not overload the motor.
- Use appropriate support for small parts.

## Check Yourself

1. What does the collet do?
2. Why should a router bit not be bottomed completely in the collet?
3. Why is feed direction important?
4. Why are several light passes better than one heavy pass?
5. What is the main difference between hand-held routing and router-table routing?
6. Why should a small throat-plate opening be used around the router bit?

## 5.4: Files and Rasps

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### 5.4 Files and Rasps

Machines are excellent for removing material quickly, but many woodworking shapes still require hand tools.

**Files and rasps** allow you to work directly on a surface and remove material exactly where it is needed.

They are especially useful for:

- refining curves;
- shaping interior openings;
- correcting small irregularities;
- blending transitions; and
- preparing a shape for sanding.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the difference between a file and a rasp.
- Identify several useful file and rasp shapes.
- Choose a tool appropriate to a flat, convex, or concave surface.
- Use files and rasps as part of a coarse-to-fine shaping sequence.
- Recognize when to stop shaping and begin sanding.

### Rasps

A **rasp** has relatively large, raised cutting teeth.

Rasps remove wood quickly.

They are useful when a saw cut has established the rough shape but significant material still needs to be removed.

A rasp is generally used **before** a file or fine abrasive.

### Files

A **file** has smaller cutting teeth and generally leaves a smoother surface than a rasp.

Files are useful for refining a shape after the rough work has been completed.

Depending on the type, a file may be used on wood, metal, or other materials.

Keep woodworking files clean and in good condition so they continue to cut effectively.

### Common Shapes

A few shapes cover many woodworking situations.

**Flat File or Rasp** — Useful for flat surfaces and outside edges.

**Half-Round File or Rasp** — Has one flat side and one curved side. Useful for both flat surfaces and curves.

**Round File** — Useful for holes and tight concave curves.

Different sizes and cuts remove material at different rates.

Choose a tool that roughly matches the shape you are trying to create.

## Match the Tool to the Surface

For a:

**Flat surface** — Use the flat face of an appropriate file.

**Convex outside curve** — A flat or half-round tool may work well.

**Concave inside curve** — Use the curved side of a half-round tool or a round file.

Trying to force a flat tool into a tight inside curve can create unwanted flat spots.

## Secure the Work

The workpiece should be stable while filing or rasping.

Whenever practical, secure it with:

- a vise;
- clamps; or
- another appropriate work-holding method.

A secure part allows better control of the tool and better feedback from the cut.

## Work From Coarse to Fine

A good shaping sequence might be:

Band Saw → Coarse Rasp → Fine Rasp → File → Abrasive

Not every project needs every step.

Choose the tool based on how much material remains.

If you still need to remove 1/8 inch of wood, fine sandpaper is probably not the efficient tool.

If the shape is already correct and only small tool marks remain, a coarse rasp may remove too much.

## Use the Entire Tool

When possible, make long controlled strokes that use much of the cutting surface.

Repeatedly using one small section of a file or rasp wears that area quickly and can make it more difficult to produce a smooth surface.

## Check the Shape Frequently

Stop often.

Look at the work from different angles.

Run your hand across the surface.

Check for:

- flat spots;
- bumps;
- abrupt transitions;
- uneven curves; and
- areas where too much material has been removed.

Hand shaping works best when you remove a little material and reevaluate often.

## Know When to Switch Tools

The goal is not to make the wood perfectly smooth with a rasp or file.

Once the **shape is correct**, move to abrasives.

Do not continue filing simply because tool marks remain if the next sanding step can remove them efficiently.

## Check Yourself

1. What is the basic difference between a rasp and a file?
2. Which tool would usually be used first?
3. Why is a half-round tool useful in woodworking?
4. What tool shape works well on an inside curve?
5. Why should the workpiece be held securely?
6. When should you stop filing and begin sanding?

## 5.5: Abrasives and Sanding

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### 5.5 Abrasives and Sanding

Sandpaper is not simply paper that scratches wood.

An abrasive is a **cutting tool** made from many small, hard particles attached to a backing.

Each particle removes a tiny amount of material.

Sanding is most effective when you treat it as a controlled cutting process rather than as endless rubbing.

### Learning Outcomes

After completing this section, you should be able to:

- Explain what abrasive grit numbers mean.
- Choose an appropriate starting grit.
- Use a logical grit progression.
- Explain why skipping grits can leave scratches behind.
- Sand with and across grain appropriately during different stages.
- Identify the primary uses of common stationary sanders.
- Describe basic WMT stationary-sander safety requirements.

### Understanding Grit

Abrasives are identified by **grit number**.

In general:

- lower numbers are coarser;
- higher numbers are finer.

Coarse abrasives remove material quickly and leave relatively deep scratches.

Fine abrasives remove less material and leave smaller scratches.

### Start With the Right Grit

Do not automatically begin with the coarsest abrasive available.

Choose the coarsest grit that is actually necessary to remove the marks or irregularities on the surface.

If the surface is already well prepared, starting too coarse creates scratches that you then have to remove.

### A Typical WMT Progression

A common progression might be:

P80 or P100 → P120 → P150 → P180 → P220 or P240 → P320

The exact starting grit depends on the condition of the work.

## Do Not Skip Grits

Each grit should remove the scratches created by the previous grit.

If you skip too many steps, the finer abrasive may not efficiently remove the deeper scratches.

For example, moving directly from a very coarse grit to P320 may make the surface feel smoother while deep scratches remain underneath.

Those scratches often become much more visible after finish is applied.

The goal is not to use every grit ever made.

The goal is to progress in reasonable steps.

## How Do You Know When to Change Grits?

Do not move to the next grit just because you have sanded for a certain amount of time.

Move on when:

- the previous tool marks are gone;
- the scratches are consistent with the current grit; and
- the shape is correct.

Inspect the work under good light.

A low-angle light can make scratches easier to see.

## Sanding With the Grain

For final hand sanding on visible faces, sand **with the grain**.

Cross-grain scratches are especially noticeable after finish is applied.

Earlier shaping or machine sanding may not always follow the grain exactly, but the final hand-sanding passes should remove visible cross-grain scratches.

## Use a Sanding Block

On flat surfaces, wrap the abrasive around a sanding block when appropriate.

A block:

- keeps the surface flatter;
- spreads pressure over a larger area; and
- reduces the tendency of your fingers to create grooves or rounded areas.

For curves, use a block or backing shape that matches the surface.

## Keep the Shape

Sanding can change the form of a project.

Be careful not to:

- flatten a flowing curve;

- round over a crisp feature accidentally;
- make one edge thinner than another; or
- enlarge an opening unevenly.

The shape should already be correct before fine sanding begins.

## Stationary Sanders

Stationary sanders remove material much faster than hand sanding.

They are useful for shaping and refining, but they can also ruin a part quickly if used carelessly.

## Disc and Combination Sanders

A disc sander uses an abrasive disc mounted to a rotating plate.

Some machines also include a vertical sanding belt.

These machines are useful for:

- straight edges; and
- outside, or **convex**, curves.

They are **not** used to square stock or create precision joinery.

## Disc-Sander Direction

Only use the **downward-traveling side** of the disc.

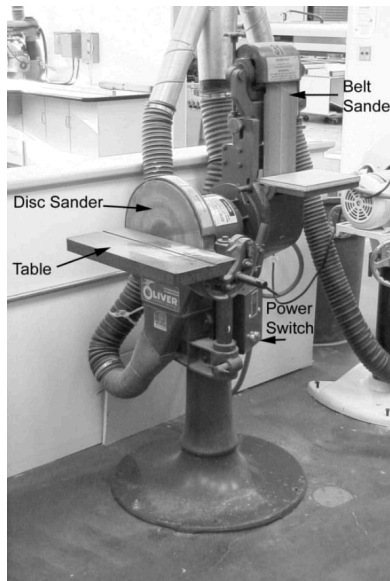
On that side, the disc pushes the workpiece down toward the table.

Using the upward-moving side can lift the work from the table and reduce control.

## Disc/Belt Sander Safety

- Hold the work securely against the table.
- Maintain at least **2 inches** between your fingers and the abrasive.
- Use moderate pressure.
- Keep the work moving.
- Do not force the work against the abrasive.
- Notify your instructor if a disc or belt is loose, damaged, or not tracking correctly.

Too much pressure creates heat, damages abrasives, and can make the work harder to control.



Combination stationary sander showing the abrasive disc, vertical sanding belt, work table, and power switch.

Figure: Disc and Combination Sander

## Oscillating Spindle Sander

The spindle sander is designed primarily for **inside, or concave, curves**.

A cylindrical sanding sleeve rotates while moving up and down.

The oscillating motion spreads wear and heat over more of the abrasive surface.

### Choose the Largest Practical Spindle

Use the largest spindle that comfortably fits the curve.

A spindle that is much smaller than the curve tends to create:

- uneven surfaces;
- small dips;
- more abrasive wear; and
- more work.

### Spindle-Sander Practices

- Feed the work against the direction of spindle rotation.
- Use moderate pressure.
- Use the throat plate that leaves the smallest opening around the spindle.
- Hand-tighten the spindle as directed.
- Return spindles, throat plates, and tools to their proper locations.
- Notify your instructor when an abrasive sleeve is badly worn.

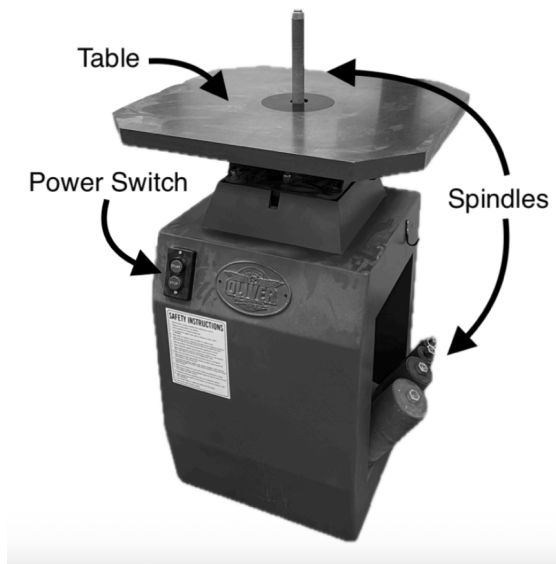


Figure: Oscillating Spindle Sander

## Wide-Belt Sander

The wide-belt sander is used for **finish smoothing** flat material.

It is not intended to remove large amounts of wood like a planer.

When used in WMT, it should remove only small amounts of material through several light passes.

Students must be checked out on the machine before using it.

Use the planer first when substantial thickness must be removed.

## Edge Sander

The edge sander is a long horizontal sanding belt used primarily for sanding **edge grain**.

It is useful for long edges and some outside shaping operations.

The edge sander removes material quickly, so use controlled pressure and keep the work moving.

Follow the instructor demonstration and WMT machine-specific limits whenever using it.

## Power Sanders

Hand-held power sanders can speed up surface preparation, but they do not replace careful inspection.

Keep the sander moving and allow the abrasive to cut.

Excessive pressure:

- creates heat;
- reduces abrasive life;
- may produce uneven surfaces; and
- can leave visible sanding patterns.

Finish with appropriate hand sanding when necessary.

## Before Moving On

Before declaring a surface ready for finish:

1. Inspect it under good light.
2. Look for scratches from the previous grit.
3. Feel the surface with your hand.
4. Check corners and transitions.
5. Make sure the shape has not changed unintentionally.
6. Remove sanding dust.

A finish does not hide poor sanding.

It usually makes poor sanding easier to see.

## Check Yourself

1. What does a lower grit number indicate?
2. Why should you not skip too many grits?
3. When should you move to the next grit?
4. Why is a sanding block useful on flat surfaces?
5. Which side of a disc sander should be used?
6. Which stationary sander is best suited to inside curves?
7. Why should the largest practical spindle be used?
8. What is the purpose of a wide-belt sander?
9. Why can excessive pressure make sanding less effective?

## 6: PROJECT 2- PICTURE FRAME

6.1: Saw Blade Technology

6.2: Table Saw Basics

6.3: Ripping and Crosscutting

6.4: Lap Joints

6.5: Completing the Picture Frame

## 6.1: Saw Blade Technology

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### 6.1 Saw Blade Technology

A table saw can make many different kinds of cuts, but the quality and safety of the cut depend partly on using an appropriate blade.

Saw blades differ in:

- number of teeth;
- tooth shape;
- gullet size;
- kerf width; and
- intended use.

Understanding a few basic blade types will help you recognize why one blade may cut differently from another.

### Learning Outcomes

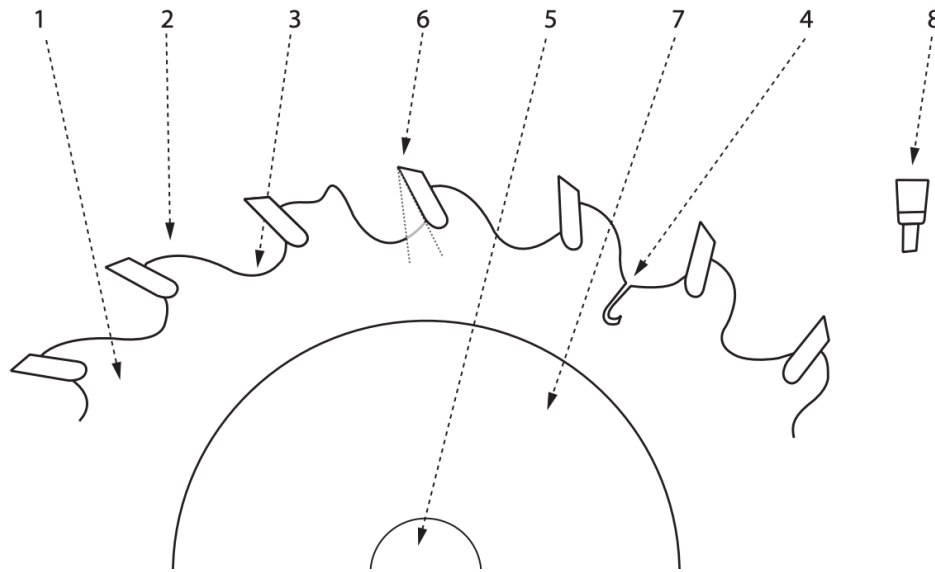
After completing this section, you should be able to:

- Identify several major parts of a circular saw blade.
- Explain the difference between rip, crosscut, and combination blades.
- Describe how tooth count affects cutting.
- Recognize several common tooth-grind patterns.
- Explain why the appropriate blade should be selected for the operation.

### Major Parts of a Saw Blade

Important terms include:

1. **Plate** — The circular body of the blade.
2. **Shoulder** — The part of the plate directly behind each tooth which provides support for the tooth.
3. **Gullet** — The open space in front of a tooth that provides room for chips.
4. **Expansion Slot** — A slot in the blade plate that helps manage heat and movement during cutting.
5. **Bore** — The hole in the center of the blade that fits over the saw arbor.
6. **Hook or Rake Angle** — The angle of the front face of the tooth. This affects how aggressively the tooth enters the material.
7. **Tensioning Ring** — The area in the blade where it is pre-tensioned for maximum flatness over a broad temperature range and operational speed.
8. **Kerf** — The width of the cut produced by the blade.
9. **Tooth** — The cutting portion around the outside edge of the blade.



Circular saw blade labeled with plate, tooth, gullet, bore, kerf, expansion slot, and hook or rake angle.

Figure: Circular Saw Blade Terminology

## Tooth Count and Gullet Size

Tooth count affects how a blade cuts.

In general:

- **Fewer teeth** create larger chips and allow faster chip removal.
- **More teeth** create smaller chips and can produce a smoother cut.

Gullet size changes along with tooth count.

A blade with relatively few teeth usually has larger gullets to carry away the larger chips produced during cutting.

A blade with many teeth typically has smaller gullets because each tooth removes less material.

More teeth are not automatically better. The blade should match the operation.

## Tooth Grind

The **tooth grind** describes the shape and arrangement of the cutting edges on the blade teeth.

Different tooth shapes cut wood fibers and other materials in different ways.

### Flat Top Grind — FTG

Each tooth has a relatively flat cutting edge across the top.

FTG teeth remove material efficiently and are commonly used on **rip blades**.

They are well suited to cutting with the grain, where rapid chip removal is important.

### Alternate Top Bevel — ATB

The tops of the teeth are beveled, alternating from one side of the blade to the other.

This alternating slicing action helps sever wood fibers cleanly and is commonly used on **crosscut blades**.

## Triple Chip Grind — TCG

Two different tooth profiles alternate around the blade.

One tooth removes material through the center portion of the kerf, while the following tooth helps clean the sides.

TCG blades are commonly used for **manufactured materials, veneers, and other applications where a durable cutting pattern is useful**.

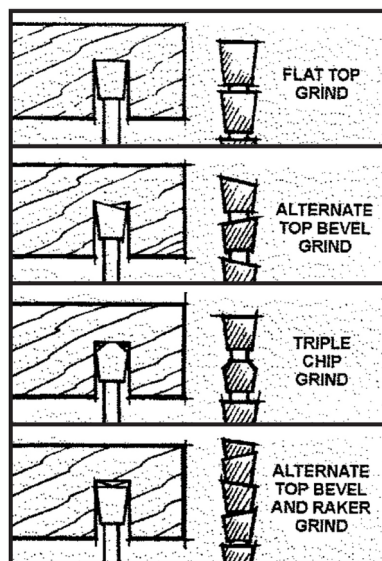
## Alternate Top Bevel with Raker — ATBR

Groups of alternating beveled teeth are combined with a flat-topped raker tooth.

This arrangement combines characteristics useful for both ripping and crosscutting and is commonly found on **combination blades**.

You do not need to memorize every tooth pattern available. Many specialized blades exist.

The important idea is that **tooth shape, tooth count, and gullet size are selected to match the material and the type of cut being made**.



Four diagrams comparing common circular saw blade tooth shapes: flat top grind with flat-topped teeth for ripping, alternate top bevel with teeth beveled in alternating directions for crosscutting, triple chip grind with alternating tooth profiles for manufactured materials, and alternate top bevel with a flat raker tooth for combination cutting.

Figure: Common Saw Blade Tooth Grinds

## Common Blade Types

For introductory woodworking, three blade types are especially useful to recognize:

- rip blades;
- crosscut blades; and
- combination blades.

## Rip Blade

A **rip blade** is designed primarily for cutting in the same general direction as the wood grain.

A typical 10-inch rip blade may have approximately **18–24 teeth**.

Rip blades commonly have:

- relatively few teeth;
- large gullets; and
- an aggressive cutting geometry such as FTG.

The larger spaces between the teeth allow the blade to remove the long chips produced during ripping.

Rip blades cut efficiently with the grain, but they generally do not produce the cleanest crosscuts.

## Crosscut Blade

A **crosscut blade** is designed primarily for cutting across the grain.

Crosscut blades commonly use an **ATB tooth grind** and have more teeth than rip blades.

Some 10-inch crosscut blades may have as many as approximately **80 teeth**.

The larger number of teeth means each tooth removes a smaller amount of material, helping produce a cleaner surface across the grain.

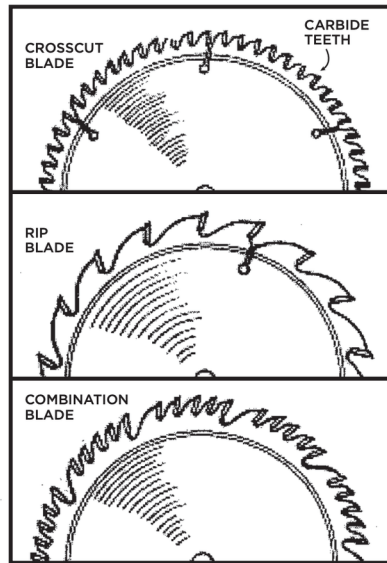
## Combination Blade

A **combination blade** is designed to perform both ripping and crosscutting reasonably well.

A common 10-inch combination blade may have approximately **50 teeth** and use an ATBR-style tooth arrangement.

A combination blade is useful when one saw must perform several different cutting operations without frequent blade changes.

It may not equal a specialized rip blade for fast ripping or a specialized crosscut blade for the cleanest crosscut, but it provides a useful balance between the two.



Three circular saw blades comparing blade types. The crosscut blade has many closely spaced teeth, the rip blade has fewer larger teeth with larger gullets, and the combination blade has an intermediate number and arrangement of teeth for both ripping and crosscutting.

Figure: Common Circular Saw Blade Types

## Choosing a Blade

Before selecting a blade, consider:

- Are you ripping or crosscutting?
- Are you cutting solid wood or a manufactured material?
- Is cutting speed or surface quality more important?
- How thick is the material?
- Is the blade sharp and appropriate for the machine?

The correct blade still requires correct machine setup and safe operating technique.

A dull, damaged, or inappropriate blade can produce poor results even when the rest of the setup is correct.

## Check Yourself

1. What is the gullet of a saw blade?
2. What is kerf?
3. What generally happens to gullet size as the number of teeth increases?
4. Which tooth grind is commonly associated with ripping?
5. Which tooth grind is commonly associated with crosscutting?
6. Why does a rip blade generally have fewer teeth than a crosscut blade?
7. What is the purpose of a combination blade?
8. Why is a high tooth count not automatically better for every operation?

## 6.2: Table Saw Basics

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### 6.2 Table Saw Basics

The **table saw** is one of the most important machines in a woodworking shop.

It is used primarily for accurate straight cuts, especially:

- ripping;
- crosscutting;
- cutting sheet goods; and
- machining some types of joinery.

Because the blade projects through the table and the workpiece is moved through the cut, good reference surfaces and careful work control are essential.

### Learning Outcomes

After completing this section, you should be able to:

- Identify the major parts of a table saw.
- Explain the difference between using the rip fence and a crosscut sled or miter gauge.
- Explain the purpose of the riving knife.
- Describe basic table-saw safety practices.
- Explain what kickback is and how proper technique helps prevent it.

### Major Parts

Important parts include:

**Table** — Supports the workpiece.

**Blade** — Performs the cutting operation.

**Rip Fence** — Guides material during ripping.

**Fence Lock** — Secures the fence in position.

**Riving Knife** — A thin metal plate behind the blade that helps keep the kerf from closing and reduces the chance of kickback.

**Throat Plate** — Surrounds the blade opening in the table.

**Blade-Height Adjustment** — Raises and lowers the blade.

**Blade-Tilt Adjustment** — Changes the blade angle.

**Crosscut Sled or Miter Gauge** — Guides work across the blade during crosscutting.

**Pushstick** — Helps control narrow material while keeping the operator's hands farther from the blade.

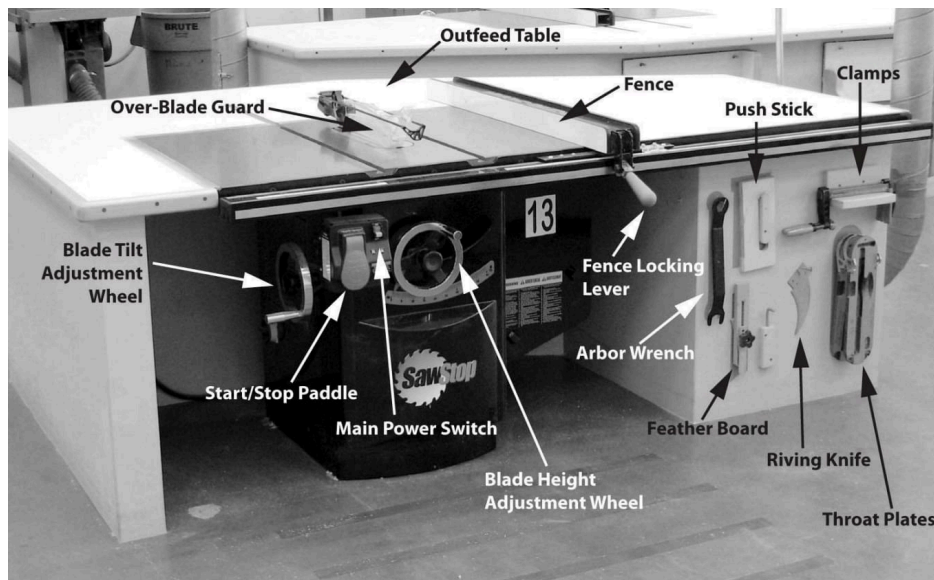


Table saw labeled with blade, rip fence, fence lock, riving knife, throat plate, blade-height adjustment, blade-tilt adjustment, pushstick, power controls, and outfeed table.

Figure: Table Saw

## The SawStop System

The table saws in the WMT lab are SawStop cabinet saws.

The SawStop system monitors the blade and can activate a brake if the spinning blade contacts conductive material such as the human body.

The brake can stop and retract the blade extremely quickly.

This safety system can reduce the severity of some blade-contact injuries, but it does **not** make unsafe table-saw practices acceptable.

You must still:

- maintain proper hand position;
- use the correct guide;
- avoid kickback;
- use pushsticks when required; and
- follow all normal table-saw procedures.

## Fence or Sled?

The two most common table-saw guides have different jobs.

Rip Fence — Used for ripping

The material moves parallel to the blade and is guided by the fence.

Crosscut Sled or Miter Gauge — Used for crosscutting

The workpiece is supported while moving across the blade.

Do not freehand a cut on the table saw.

Every normal cut must use an appropriate fence, sled, miter gauge, jig, or other instructor-approved guide.

## Blade Height

For normal cutting, the blade should project only enough above the stock to clear the material.

A typical WMT setting is approximately:

1/4 to 3/8 inch above the stock

Do not raise the blade unnecessarily high.

## Riving Knife

The **riving knife** travels behind the blade.

Its job is to help prevent the freshly cut kerf from closing around the back of the blade.

This helps reduce the risk of **kickback**.

The riving knife should remain installed unless your instructor has approved its removal for a specific special setup.

## What Is Kickback?

**Kickback** occurs when the operator loses control of a workpiece and the saw throws the material with considerable force.

Kickback can happen when:

- stock binds against the blade;
- the kerf closes;
- material becomes trapped;
- the workpiece twists during the cut; or
- an uncontrolled piece contacts the back of the blade.

Good stock preparation, correct guides, proper body position, and control of the workpiece all help reduce this risk.

## Pushsticks

A pushstick keeps your hand farther from the blade while allowing you to maintain control of the workpiece.

In the WMT lab, use a pushstick when ripping material **6 inches wide or narrower**.

A pushstick is not a substitute for good technique. The workpiece must still be controlled against the table and fence.

## Important WMT Practices

For normal use:

- You must receive a table-saw demonstration and checkout before use.
- Use the rip fence for ripping.
- Use a sled or miter gauge for crosscutting.
- Never make freehand cuts.
- Keep the riving knife in place unless an instructor approves its removal.
- Never reach or pass material over a spinning blade.
- Make adjustments only when the blade is completely stopped.
- Use a pushstick when required.
- Keep control of the material between the blade and fence.

- Do not back a workpiece away from a moving blade.
- Special setups require instructor approval.

If a cut does not feel correct, stop.

Do not try to solve a table-saw problem while the blade is spinning.

## Check Yourself

1. What is the main purpose of the rip fence?
2. What guides a normal crosscut?
3. What is the purpose of the riving knife?
4. What is kickback?
5. When is a pushstick required in the WMT lab?
6. Why should you never make a freehand table-saw cut?

## 6.3: Ripping and Crosscutting

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### 6.3 Ripping and Crosscutting

**Ripping** and **crosscutting** are two of the most fundamental table-saw operations.

The terms describe the relationship between the cut and the grain direction.

Understanding the difference also tells you which machine guide should be used.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the difference between ripping and crosscutting.
- Select the appropriate table-saw guide for each operation.
- Explain why a straight reference edge is required for ripping.
- Describe a basic sequence for preparing picture-frame stock.
- Explain why repeated parts should be machined together when practical.

### Ripping

A **rip cut** runs generally in the same direction as the grain.

The rip fence guides the workpiece.

For an accurate rip cut, the edge against the fence must already be:

- straight; and
- suitable as a reference surface.

This is why lumber is jointed before ripping.

If a crooked edge is placed against the fence, the board may move unpredictably during the cut.

### Rip to Width

When preparing frame stock, ripping establishes the width of the frame members.

Your instructor will have the definitive parameters for the frame project, but generally, frame parts should be **no wider than 2 1/2 inches**.

The actual width depends on:

- the size of the artwork;
- the proportions of the finished frame; and
- the design you choose.

A small picture usually does not need a massive frame.

Keep the proportions appropriate to what you are framing.

## Crosscutting

A **crosscut** runs across the grain.

On the table saw, crosscuts are made using:

- a crosscut sled; or
- a miter gauge.

The rip fence is not used in the normal way to guide a crosscut because the offcut can become trapped between the fence and blade.

If a fence is used as part of a repeated-length setup, your instructor will demonstrate the required clearance-block method.

## Square One End First

Before cutting a part to final length:

1. Square one end.
2. Measure from that reference end.
3. Cut the opposite end to final length.

This is the same reference-surface logic used during lumber milling.

Do not measure final length from an end that has not been squared.

## Prepare Matching Parts Together

A picture frame contains pairs of matching parts.

When practical:

- mill all frame stock to the same thickness together;
- rip matching pieces at the same fence setting; and
- use consistent setups for repeated cuts.

This reduces unnecessary variation between parts.

## Keep the Project Manageable

The dimensions of the frame depend on what you are framing.

There is no single required length and width.

However, keep the project reasonably small.

A smaller frame:

- requires less material;
- is easier to machine;
- is easier to glue accurately;
- requires less sanding; and
- is more likely to be completed carefully within the available class time.

The goal is to learn the processes—not to make the largest frame possible.

## Check Yourself

1. What is the difference between ripping and crosscutting?
2. What guides a rip cut?
3. Why must the edge against the rip fence be straight?
4. What guides a crosscut?
5. Why should one end be squared before measuring final length?
6. Why is keeping the picture frame reasonably small a good idea?

## 6.4: Lap Joints

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### 6.4 Half-Lap Joints

The corners of the picture frame are joined using **half-lap joints**.

A half-lap joint is made by removing approximately half the thickness from each of two overlapping pieces.

When the parts are assembled, the combined joint returns to approximately the original thickness of the stock.

### Learning Outcomes

After completing this section, you should be able to:

- Explain how a half-lap joint is constructed.
- Identify the shoulder and lap surfaces.
- Explain why the joint is stronger than a simple end-grain butt joint.
- Lay out a half-lap based on the actual stock dimensions.
- Evaluate the fit of a completed joint.

### How the Joint Works

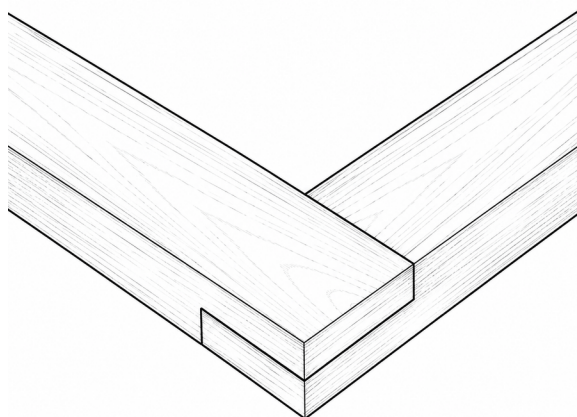
Imagine two pieces crossing each other.

If they were simply placed on top of one another, the joint would be twice as thick as either piece.

Instead, remove approximately half the thickness from each piece.

The remaining sections overlap.

The two parts then fit together at approximately the same overall thickness as the original material.



Two frame members with half their thickness removed at the ends so the recessed areas overlap and form a flush corner joint.

Figure: Half-Lap Joint

## Why Use a Half-Lap?

A half-lap joint provides:

- a large glue surface;
- mechanical support from the overlapping parts;
- good alignment;
- a relatively simple construction process; and
- a visible expression of how the frame is joined.

Compared with simply gluing the end of one board to the face or edge of another, the half-lap creates much more useful glue area.

## Layout From the Actual Stock

Do not assume every board is exactly the nominal thickness.

Measure the **actual thickness** of the frame stock before laying out the joint.

The goal is for each lap to remove approximately half the thickness.

For example, if the stock is  $\frac{3}{4}$  inch thick, each lap will be approximately:

$\frac{3}{8}$  inch deep

But if the actual stock is slightly thinner or thicker, the joint should be adjusted accordingly.

## Joint Length

The length of the lap generally corresponds to the width of the mating frame member.

Transfer the actual part width carefully.

Accurate shoulders are important because they establish the location of the joint.

## A Good Half-Lap Fit

A properly fitted half-lap should:

- seat fully;
- have shoulders that meet cleanly;
- lie reasonably flush across the faces;
- remain square; and
- not require excessive force to assemble.

A joint that must be hammered together is too tight.

A joint with large gaps is too loose.

The goal is a **close, controlled fit**.

## Test Before Gluing

Dry-fit the frame before applying glue.

Check:

- all four joints;
- overall squareness;
- whether the faces sit flush;
- whether the frame lies flat;
- and whether the opening is the correct size for what you are framing.

Correct problems before glue is introduced.

Glue adds time pressure.

The best time to solve a joint-fitting problem is during the dry fit.

## Check Yourself

1. How much thickness is approximately removed from each member of a half-lap?
2. Why does the completed joint return to approximately the original stock thickness?
3. Why should the actual stock thickness be measured before machining the lap?
4. What determines the length of the lap?
5. What should you check during a dry fit?
6. Why is a half-lap stronger than a simple end-grain butt joint?

## 6.5: Completing the Picture Frame

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### 6.5 Completing the Picture Frame

The picture frame project combines accurate milling, table-saw work, half-lap joinery, glue-up, routing, chisel work, sanding, and finishing.

Unlike the cutting board, the dimensions are not fixed.

The frame should be designed around **what you intend to frame**.

### Learning Outcomes

After completing this project, you should be able to:

- Size frame parts to fit a specific piece of artwork or photograph.
- Prepare frame stock within the project limits.
- Construct four half-lap corner joints.
- Glue the frame square and flat.
- Rout a rear rabbet for glass or acrylic, artwork, and backing.
- Square routed rabbet corners with a chisel.
- Apply an optional routed edge profile.
- Sand through 320 grit.
- Apply an appropriate finish and hanging hardware.

### Project Requirements

Your picture frame should:

- Be sized appropriately for the artwork, photograph, or object being framed.
- Use solid-wood frame parts between **5/8 inch and 7/8 inch thick**.
- Use frame members no wider than **2 1/2 inches**.
- Use **half-lap joints at all four corners**.
- Include a rear rabbet sized for the chosen glazing and backing.
- Be sanded through **320 grit**.
- Receive an appropriate finish.
- Include appropriate hanging hardware.

Keep the project reasonably small so that you can complete each operation carefully within the available class time.

### Start With What You Are Framing

Before cutting frame parts, determine the size of the item you intend to display.

Measure:

- artwork width;
- artwork height;
- glass or acrylic thickness;
- backing thickness; and
- any additional clearance needed for assembly.

The frame opening and rabbet must be designed around these components.

Do not design the frame first and hope the contents fit later.

## Prepare the Frame Stock

Mill the stock flat, straight, and square.

The finished thickness should be between:

5/8 inch and 7/8 inch

The finished width should not exceed:

2 1/2 inches

Choose dimensions that look appropriate for the size of the artwork.

## Cut the Parts

Prepare the two horizontal and two vertical frame members.

Use accurate ripping and crosscutting procedures.

Make sure:

- matching parts are equal in length;
- ends are square;
- widths are consistent; and
- all four parts are made from properly milled stock.

## Machine the Half-Laps

Lay out and cut the half-lap joints at each corner.

Dry-fit the frame.

Before gluing, check:

- joint fit;
- squareness;
- flatness;
- overall outside dimensions; and
- the size of the opening.

Do not proceed until all four corners fit correctly.

## Glue-Up

Once the dry fit is satisfactory, glue the frame.

Your instructor will demonstrate the glue-up and clamping method used in class.

During assembly:

1. Apply an appropriate amount of glue to the joint surfaces.
2. Assemble all four corners.
3. Clamp the frame securely.
4. Check the diagonals or use another appropriate method to confirm squareness.

5. Make sure the frame lies flat.
6. Clean excess glue as directed.
7. Allow the adhesive to cure before further machining.

Do not assume that clamps automatically make a frame square.

You must check it.

## Cut the Rear Rabbet After Glue-Up

The rabbet that holds the glass or acrylic, artwork, and backing is cut **after the frame has been glued together**.

This allows the rabbet to continue around the entire inside perimeter of the completed frame.

A rabbeting bit in a router is used to establish the recess.

Your instructor will demonstrate the setup.

## How Deep Should the Rabbet Be?

There is no single required rabbet depth.

The depth depends on what must fit inside the frame.

Consider the combined thickness of:

- glass or acrylic;
- artwork or photograph;
- matting, if used;
- backing; and
- any method used to retain the contents.

The rabbet must be deep enough to hold these materials without unnecessarily weakening the frame.

Measure the actual materials you are using.

Do not guess.

## Square the Rabbet Corners

A rotating router bit leaves rounded inside corners.

If the glass, acrylic, or backing has square corners, the rounded router corners must be corrected.

Use a sharp chisel to carefully square the corners of the rabbet.

Work from the established routed surfaces.

Remove only the material necessary to create a clean square corner.

Your instructor will demonstrate the technique before you begin.

## Optional Edge Profile

A routed profile may be added to the visible edge of the frame.

This is optional.

A profile can:

- soften the edge;
- create a shadow line;
- add visual detail; or
- help establish the character of the frame.

More decoration is not automatically better.

Choose a profile that works with the frame proportions and the artwork being displayed.

Your instructor will demonstrate appropriate router bits and setups.

## Sanding

Sand the completed frame through:

320 grit

Pay particular attention to:

- half-lap joints;
- routed profiles;
- inside edges;
- rabbet corners;
- end-grain areas; and
- transitions between surfaces.

Do not sand so aggressively that you destroy the fit or appearance of the joints.

## Finish Options

Two basic finish approaches are appropriate for this project.

Oil Finish

You may use the same type of oil finish used on the cutting-board project.

This is simple to apply and emphasizes the natural wood.

Shellac

A shellac finish is another option.

Shellac dries quickly, making it useful for a project that needs to move through finishing within the course schedule.

Your instructor will demonstrate the finish being used and the appropriate application process.

## Install the Glazing and Backing

Once the finish has cured sufficiently, assemble the frame with:

- glass or acrylic;
- artwork;
- backing; and
- the appropriate retaining method.

Handle glass carefully and follow your instructor's directions.

## Hanging Hardware

Hanging hardware will be provided or demonstrated in class.

The appropriate hardware depends partly on:

- frame size;
- frame weight; and
- orientation.

Install the hardware carefully so the frame hangs securely and level.

## Final Check

Before considering the project complete, confirm that:

- the frame is square;
- the half-lap joints fit cleanly;
- the frame lies flat;
- the artwork fits correctly;
- the rabbet is deep enough for all components;
- the rabbet corners are clean;
- the surfaces are sanded through 320 grit;
- the finish is complete; and
- the hanging hardware is securely installed.

A well-made frame should support the work inside it without drawing unnecessary attention away from it.

## Check Yourself

1. What determines the overall size of the picture frame?
2. What is the allowable thickness range for the frame stock?
3. What is the maximum width of the frame members?
4. What joint is used at the corners?
5. Why is the rear rabbet cut after glue-up?
6. What determines the required rabbet depth?
7. Why must the routed rabbet corners be squared with a chisel?
8. Is a routed edge profile required?
9. To what grit should the frame be sanded?
10. What two finish options are introduced for this project?

## 7: JOINERY AND ADHESIVES

7.1: Basic Woodworking Joints

7.2: Joint Strength and Grain Orientation

7.3: Adhesives and Basic Glue-Ups

## 7.1: Basic Woodworking Joints

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### 7.1 Basic Woodworking Joints

Woodworking joints connect two or more pieces of material.

Some joints are simple. Others are complex. Some are designed mainly for strength, while others also provide alignment, appearance, or resistance to movement.

There is no single “best” woodworking joint. The appropriate joint depends on the material, the forces acting on the project, the tools available, and the appearance you want.

### Learning Outcomes

After completing this section, you should be able to:

- Identify several common woodworking joints.
- Explain the basic purpose of each joint.
- Recognize the difference between a butt joint and a joint with interlocking geometry.
- Explain why different projects require different types of joints.

### Butt Joints

A **butt joint** is the simplest type of woodworking joint.

Two prepared surfaces are placed directly against each other and joined with adhesive, fasteners, or both.

Common butt-joint arrangements include:

- edge to edge;
- face to face;
- end to edge;
- end to face; and
- edge to face.

An edge-to-edge joint is commonly used to create a wider panel from narrower boards.

A face-to-face joint is used when laminating pieces to create a thicker part.

End-grain butt joints generally have less useful glue surface than long-grain joints and often require another joint form or mechanical reinforcement.

### Half-Lap Joint

In a **half-lap joint**, approximately half the thickness is removed from each of two overlapping pieces.

When assembled, the joint returns to approximately the original stock thickness.

Half-lap joints provide:

- a large glue surface;
- good alignment;
- mechanical support; and
- relatively simple construction.

You used half-lap joints in the picture-frame project.

## Dado Joint

A **dado** is a groove cut across or through the surface of a piece of material.

Another piece fits into the groove.

Dados are commonly used for:

- shelves;
- partitions;
- cabinet construction; and
- box structures.

The dado provides mechanical location as well as additional glue surface.

## Rabbet Joint

A **rabbet** is an L-shaped recess cut along the edge or end of a board.

Rabbets are commonly used in:

- boxes;
- drawers;
- cabinet backs;
- frames; and
- case construction.

A rabbet can help locate one part against another while providing more glue area than a simple butt joint.

You also used a rabbet to hold the glazing and backing in the picture-frame project.

## Miter Joint

A **miter joint** joins two angled surfaces.

A common example is two pieces cut at 45 degrees and joined to create a 90-degree corner.

Miter joints can hide end grain and create a clean appearance.

However, a simple glued miter does not provide much mechanical interlocking, so miters are often reinforced in more advanced work.

## Mortise-and-Tenon Joint

The **mortise-and-tenon joint** is one of the most important traditional furniture joints.

The **mortise** is a recess or opening cut into one piece.

The **tenon** is a projecting portion on the mating piece.

The tenon fits into the mortise.

Mortise-and-tenon joints provide:

- substantial long-grain glue area;
- mechanical alignment; and

- resistance to forces that might pull or rack the joint.

They are commonly used in table, chair, frame, and furniture construction.

## Box or Finger Joint

A **box joint**, sometimes called a **finger joint**, uses a series of alternating rectangular fingers.

The fingers from the two pieces interlock.

This creates:

- substantial glue surface;
- mechanical alignment; and
- a distinctive visible pattern.

Box joints are commonly used for boxes, drawers, and casework.

## Dovetail Joint

A **dovetail joint** uses interlocking pins and tails.

The angled geometry prevents the pieces from pulling apart in one direction even before glue is added.

Dovetails are commonly associated with drawer construction and fine furniture.

They are strong, visually distinctive, and require careful layout and fitting.

## Dowels

A **dowel** is a cylindrical piece of wood used to help connect or align parts.

Dowels can:

- reinforce some joints;
- help locate mating parts;
- assist with alignment during glue-up; or
- act as visible or hidden mechanical pins.

In some edge-to-edge glue-ups, dowels are used more for alignment than for additional strength.

## Choosing a Joint

When choosing a joint, ask:

- What forces will act on the joint?
- What grain directions are being connected?
- How much glue surface will the joint provide?
- Does the joint help align the parts?
- Will the joint be visible?
- Can the joint be made accurately with the available tools?
- Is the additional complexity actually necessary?

The most complicated joint is not automatically the best joint.

A well-made simple joint is usually better than a poorly fitted complicated one.

## Check Yourself

1. What is a butt joint?
2. What material is removed to create a half-lap joint?
3. What is the difference between a dado and a rabbet?
4. What are the two parts of a mortise-and-tenon joint?
5. Why are box joints strong?
6. What mechanical feature distinguishes a dovetail joint?
7. Why might dowels be used in an edge-to-edge glue-up?

## 7.2: Joint Strength and Grain Orientation

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### 7.2 Joint Strength and Grain Orientation

A joint is only useful if it can withstand the forces placed on it.

Three major factors affect the strength and performance of a woodworking joint:

1. Mechanical properties of the joint
2. Adhesive surface area
3. Grain orientation

Understanding these factors helps explain why traditional woodworking joints developed the way they did.

### Learning Outcomes

After completing this section, you should be able to:

- Identify three major factors that influence joint strength.
- Explain why grain orientation matters in a glued joint.
- Distinguish between long-grain and end-grain glue surfaces.
- Explain why a close-fitting joint is important.
- Recognize how joint geometry can improve strength and alignment.

### Mechanical Properties

The **mechanical properties** of a joint come from its physical shape.

Some joints rely almost entirely on adhesive.

Others contain shoulders, fingers, pins, tenons, or other features that mechanically resist movement.

For example:

- A half-lap has shoulders that help locate the two parts.
- A mortise-and-tenon joint physically houses one piece inside another.
- A dovetail resists being pulled apart because of its angled interlocking shape.

The geometry of the joint can help resist forces even before adhesive is considered.

### Adhesive Surface Area

Glue works at the surfaces where the two pieces meet.

A joint with more useful mating surface generally provides more opportunity for the adhesive to create a strong bond.

This is one reason many woodworking joints are designed to create larger areas of contact.

A dado, half-lap, or mortise-and-tenon joint generally provides more glue surface than simply placing the end of one board against another.

### Grain Orientation

Wood does not behave the same in every direction.

For gluing, an important distinction is between:

- **long grain** — face and edge surfaces where the wood fibers run along the surface; and
- **end grain** — the ends of the fibers.

## Long-Grain Glue Joints

A properly prepared **long-grain-to-long-grain** glue joint can be very strong.

Examples include:

- edge-to-edge panel glue-ups;
- face-to-face laminations; and
- many surfaces inside traditional joints.

Good surface preparation and close contact allow the adhesive to bond effectively between the pieces.

## End-Grain Glue Joints

End grain presents a different surface.

The open ends of the wood fibers can absorb adhesive readily, but a simple end-grain-to-long-grain connection generally does not provide the same useful bonding condition as a well-fitted long-grain joint.

This is one reason furniture joints often use additional geometry.

A mortise and tenon, dado, rabbet, lap, dowel, or other joint can create more useful long-grain contact while also adding mechanical support.

## A Joint Must Fit

Glue should bond two properly fitted surfaces.

It should not be expected to repair inaccurate joinery.

A strong joint begins with parts that:

- fit closely;
- contact each other over the intended surfaces;
- align correctly; and
- do not require excessive force to assemble.

Large gaps reduce the amount of actual wood-to-wood contact.

Adding more glue does not turn a poorly fitted joint into a good one.

## Too Tight Is Also a Problem

A joint can also be too tight.

If excessive force is required to assemble the parts:

- the wood may split;
- the joint may be difficult to position;
- adhesive may be scraped away during assembly; or
- the parts may distort.

A good joint should fit closely and assemble with controlled pressure.

## Strength Is More Than Glue

When evaluating a joint, think about the entire system.

Ask:

- Is the grain oriented appropriately?
- Is there enough useful glue area?
- Does the geometry resist the forces on the joint?
- Do the mating surfaces fit closely?
- Is the joint appropriate for the material?

Good joinery combines accurate machining with an understanding of how wood behaves.

## Check Yourself

1. What are the three major factors affecting joint strength?
2. What is meant by the mechanical properties of a joint?
3. Why is long-grain-to-long-grain gluing generally effective?
4. Why are simple end-grain glue joints usually less desirable?
5. Why should glue not be used to fill large gaps?
6. What problems can occur if a joint is too tight?

## 7.3: Adhesives and Basic Glue-Ups

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### 7.3 Adhesives and Basic Glue-Ups

Most woodworking projects eventually reach a point where separate parts must become one assembly.

In WMT 101, the primary adhesives used are **Titebond Original** and **Titebond III**.

Both are woodworking glues in the PVA family and are appropriate for many common solid-wood assemblies.

Later woodworking courses may introduce other adhesives for more specialized applications.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the basic purpose of woodworking adhesive.
- Identify the two primary glues used in WMT 101.
- Recognize several common adhesive types used in woodworking.
- Prepare parts for a successful glue-up.
- Explain the importance of dry fitting, clamping, alignment, and cure time.

### Adhesives Used in WMT 101

#### Titebond Original

**Titebond Original** is commonly used for interior woodworking assemblies.

It is useful for many:

- furniture joints;
- edge-to-edge glue-ups;
- frame assemblies; and
- general classroom projects.

It develops strength relatively quickly and is easy to use for typical indoor woodworking.

#### Titebond III

**Titebond III** is another PVA woodworking adhesive.

It provides greater water resistance than standard interior woodworking glue and has a somewhat longer working time, which can be useful for assemblies requiring more time to position and clamp.

In WMT 101, your instructor will specify which adhesive is appropriate for the project.

### Other Common Woodworking Adhesives

You may encounter other adhesives as you continue in woodworking.

## Adhesives and their uses

| Adhesive Type        | Common Uses                                                            |
|----------------------|------------------------------------------------------------------------|
| PVA woodworking glue | General furniture, cabinet, and solid-wood assembly                    |
| Polyurethane glue    | Some moisture-resistant and mixed-material applications                |
| Epoxy                | Gap-tolerant bonding, repairs, difficult materials, specialty work     |
| Cyanoacrylate (CA)   | Small repairs, quick positioning, jigs, and specialized applications   |
| Contact adhesive     | Laminates and surfaces that must bond immediately on contact           |
| Hide glue            | Traditional furniture work, restoration, and specialized assembly      |
| Hot-melt adhesive    | Temporary holding, jigs, patterns, and some nonstructural applications |

You do not need to master all of these in WMT 101.

The purpose of this table is to recognize that **different adhesives are designed for different jobs**.

Do not substitute an unfamiliar adhesive without understanding its properties and receiving instructor approval.

## Dry-Fit First

Before opening the glue bottle:

Assemble the project without glue.

This is called a **dry fit**.

During the dry fit, confirm:

- all parts are present;
- joints fit properly;
- clamps fit where needed;
- the assembly can be brought square;
- you understand the assembly order; and
- you can complete the glue-up within the available working time.

Glue-up is not the time to discover that a part does not fit.

## Prepare Before You Apply Glue

Before starting:

1. Arrange the parts in assembly order.
2. Gather the required clamps.
3. Prepare cauls or blocks if needed.
4. Have measuring and squaring tools nearby.
5. Protect the work surface when appropriate.
6. Make sure the mating surfaces are clean.
7. Review the assembly sequence.

Once glue is applied, the available working time becomes limited.

Preparation reduces unnecessary rushing.

## Apply Enough Glue

Apply enough adhesive to create a **thin, continuous film across the mating surface**.

The goal is complete coverage.

Too little glue can leave dry areas.

Too much glue creates unnecessary squeeze-out and cleanup.

Do not use extra glue as a substitute for poor-fitting parts.

## Spread the Glue

Spread the adhesive evenly over the intended bonding surface when necessary.

Pay particular attention to:

- edges;
- corners; and
- areas that may have received too little adhesive.

The entire intended glue surface should participate in the joint.

## Assemble the Parts

Bring the mating pieces together while the adhesive remains workable.

Make sure:

- joints are fully seated;
- parts are aligned;
- reference faces remain flush; and
- the assembly has not shifted while clamps are being added.

## Clamp Pressure

Clamps hold the pieces in close contact while the adhesive cures.

The goal is **firm, even pressure**.

More clamp pressure is not automatically better.

Excessive pressure can:

- distort an assembly;
- damage soft wood;
- cause joints to shift;
- bow parts; or
- squeeze out unnecessary amounts of adhesive.

Use enough pressure to bring the mating surfaces into full contact.

## Clamp Placement

Place clamps so the pressure supports the intended shape of the assembly.

Whenever possible:

- distribute clamps evenly;
- place pressure near the joints;
- alternate clamp positions when useful; and
- watch for parts being pulled out of alignment.

More clamps are useful only if they are helping.

## Cauls

A **caul** is a temporary piece used to distribute clamp pressure or help maintain alignment.

Cauls may be used to:

- keep surfaces flush;
- spread pressure over a larger area;
- protect the project from clamp marks; or
- help keep an assembly straight.

Not every glue-up requires cauls, but they are useful tools when an assembly becomes more complex.

## Check Square Before the Glue Sets

After applying clamps, inspect the assembly.

Check:

- squareness;
- alignment;
- flatness;
- joint closure; and
- overall dimensions.

For rectangular assemblies, comparing the two diagonal measurements can help determine whether the assembly is square.

If the diagonals are equal, the assembly is generally square.

Make adjustments while the adhesive is still workable.

## Squeeze-Out

A small amount of glue appearing at the joint line is normal and usually indicates that adhesive coverage reached the edge.

Large amounts of squeeze-out often mean more glue was applied than necessary.

Follow your instructor's demonstration for the appropriate cleanup method.

The important point is that cured glue left on a visible surface can interfere with sanding and finishing.

## Allow the Adhesive to Cure

Do not remove clamps simply because the glue has stopped looking wet.

Adhesives require time to develop strength.

Follow:

- the adhesive manufacturer's instructions;
- the conditions in the shop; and
- your instructor's directions.

Temperature, humidity, wood species, joint type, and adhesive type can all affect working and cure time.

When in doubt, allow more time rather than less.

## Glue-Up Sequence

A basic glue-up can be summarized as:

Dry-fit → Prepare/Adjust → Apply glue → Assemble → Clamp → Check → Clean up squeeze out → Cure → More Clean up/Touch up

The actual procedure will vary with the project, but the principles remain similar.

## Professional Habit: Slow Down Before the Glue Comes Out

The best glue-ups often feel uneventful.

That is usually because the work was done beforehand:

- the parts fit;
- the clamps were ready;
- the sequence was understood; and
- the problems were solved during the dry fit.

Good preparation makes glue-up controlled rather than frantic.

## Check Yourself

1. What two woodworking glues are primarily used in WMT 101?
2. Why should an assembly be dry-fitted before gluing?
3. What should the glue film look like on the mating surface?
4. Why is excessive clamp pressure unnecessary?
5. What is a caul?
6. Why should squareness be checked immediately after clamping?
7. Why can dried glue create problems during finishing?
8. Why should adhesive cure time not be rushed?

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## 8: PLANNING A WOODWORKING PROJECT

8.1: Design Basics

8.2: Working Drawings

8.3: Bill of Materials

8.4: Plan of Procedure

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## 8.1: Design Basics

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### 8.1 Design Basics

Woodworking begins before you turn on a machine.

A good project starts with an idea, but that idea must eventually become something that can actually be built.

**Design** is the process of deciding what an object should do, how it should look, how it will be made, and what materials and processes will be used.

Good design is not simply making something look interesting. It brings together **function, appearance, materials, construction, and craftsmanship**.

### Learning Outcomes

After completing this section, you should be able to:

- Identify several questions that should be considered before beginning a project.
- Explain the relationship between function, appearance, and construction.
- Develop several possible solutions before committing to one design.
- Recognize how materials, tools, time, and skill affect design decisions.
- Explain why planning before cutting wood can save time and material.

### Begin With the Purpose

Before designing an object, ask:

What is this supposed to do?

Consider:

- Who will use it?
- Where will it be used?
- What does it need to hold, support, protect, or display?
- How large should it be?
- Does it need to move, open, close, fold, or carry something?
- How strong does it need to be?

A project that does not perform its intended function is not successful simply because it looks good.

### Function

**Function** describes how well the object performs its intended job.

A functional design should consider:

- size;
- strength;
- stability;
- comfort;
- access;
- durability; and
- how the user interacts with it.

For example, the handle on a tool tote must do more than look good. It must provide enough clearance for a hand, remain comfortable under load, and be connected strongly enough to carry the tote.

## Appearance

Appearance includes:

- proportion;
- balance;
- line;
- shape;
- grain;
- color;
- texture; and
- visual relationships between parts.

Wood adds another design element because the material itself has grain and figure.

The direction and appearance of the grain can become part of the design.

## Construction and Craftsmanship

A design must also be buildable.

Consider:

- What joinery is appropriate?
- Will the wood be able to move with changes in moisture?
- Can the parts be machined safely?
- Are the required tools available?
- Can the project be assembled?
- Can surfaces be sanded and finished after assembly?
- Can you complete the project with the time and skills available?

A beautiful idea that cannot reasonably be constructed is not yet a complete design.

## Design Within Constraints

Every project has constraints.

These may include:

- maximum dimensions;
- available lumber;
- required joinery;
- available machines;
- cost;
- available class time; and
- your current level of experience.

Constraints are not necessarily limitations on creativity.

They give the design a problem to solve.

The cutting-board project, for example, allowed considerable freedom within specific requirements. The challenge was to make individual design decisions while still producing a functional object.

## Develop More Than One Idea

Do not become attached to the first idea you draw.

A useful design process is:

1. Identify the requirements.
2. Make several quick sketches.
3. Compare the ideas.
4. Select one or two promising directions.
5. Refine proportions and details.
6. Consider materials and joinery.
7. Identify possible construction problems.
8. Develop enough information to begin planning the build.

Early sketches do not need to be beautiful.

Their purpose is to help you think.

## Changes Are Cheaper Before You Cut

Changing a pencil line is easy.

Changing a board after you have cut it too short is more difficult.

Planning allows you to find problems before they become expensive mistakes.

Before beginning a project, try to answer:

- What are the major parts?
- How do they connect?
- What dimensions matter most?
- Which dimensions can be determined later from the actual project?
- What operations must happen before others?
- Where are the difficult or risky steps?

You do not need to predict everything.

You do need to think far enough ahead that the next few steps make sense.

## Prototype When It Helps

Sometimes a quick model or test piece communicates more than another drawing.

Useful prototypes may include:

- a cardboard model;
- a full-size paper shape;
- a scrap-wood joint;
- a test curve;
- a router setup on scrap material; or
- an extra project part made before the final one.

A prototype gives you a low-cost opportunity to learn before working on the finished material.

## Check Yourself

1. What is the first question to ask when beginning a design?
2. What are three factors that contribute to the appearance of a woodworking project?
3. Why must construction be considered during design?
4. How can constraints help a design?
5. Why should you develop more than one initial idea?
6. When might a prototype be useful?

## 8.2: Working Drawings

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### 8.2 Working Drawings

A **working drawing** communicates how a project is supposed to be built.

The goal is not to make an impressive drawing.

The goal is to communicate the design clearly enough that a competent woodworker who has never seen the project could understand what to make.

Imagine handing your drawing to:

- another student across the shop;
- an employee in a production facility;
- a cabinetmaker in another state; or
- a manufacturer on the other side of the world.

If that person cannot understand the design without asking you what you meant, the drawing probably needs more information.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the purpose of a working drawing.
- Identify common views used to describe a three-dimensional object.
- Explain the importance of dimensions and notes.
- Recognize several common drawing-line conventions.
- Evaluate whether a drawing communicates enough information to build a project.

### Drawings in WMT 101

Formal working drawings are **not required for every WMT 101 project**, but they are strongly recommended as projects become more complex.

The provided project drawings demonstrate how multiple views, dimensions, and details can communicate a design.

Even when you are working from an existing drawing, learning to read it is an important woodworking skill.

### Why Draw?

A working drawing allows you to:

- understand the project before cutting material;
- identify the major parts;
- see how parts relate to one another;
- determine important dimensions;
- think through joinery;
- plan the construction sequence;
- identify missing information; and
- communicate your design to someone else.

A drawing is a communication tool.

## Three-View Drawings

Many woodworking projects can be described using three basic views:

**Front View** — Shows the object as viewed from the front.

**Top View** — Shows the object from above.

**Side or End View** — Shows the object from one side or end.

Each view communicates two dimensions.

Together, the views help describe the object's:

- height;
- width;
- depth;
- part locations; and
- relationships between components.

## Isometric or Perspective Views

An **isometric** or perspective-style view shows several sides of the project at once.

This can make the overall form easier to understand.

However, a perspective view by itself may not provide enough information to build the project accurately.

Use it to help communicate the form—not as a replacement for necessary dimensions and details.

## Dimensions

A working drawing should include the dimensions needed to build the project.

Useful dimensions may include:

- overall height, width, and length;
- material thickness;
- part widths and lengths;
- joint locations;
- groove or dado locations;
- hole locations;
- clearances; and
- important relationships between parts.

Do not add dimensions simply to fill the page.

Include information that helps someone build the project accurately.

## Dimension From Useful References

Think carefully about where a dimension begins.

Whenever possible, dimensions should relate to surfaces or features that can actually be established and measured during construction.

Good dimensioning reduces the chance of accumulated errors.

## Common Line Types

You may encounter several basic drawing conventions.

**Object Line** — A solid line showing a visible edge of the object.

**Hidden Line** — A dashed line showing an edge or feature hidden behind another surface.

**Centerline** — Identifies the center of a symmetrical feature, hole, or part.

**Dimension Line** — Shows the distance between two points or features.

You do not need to become a professional drafter in WMT 101, but you should be able to interpret these basic conventions.

## Full Size or Scaled

Small objects can sometimes be drawn full size.

Larger projects are often drawn at a reduced **scale**.

For example:

1 inch on the drawing = 4 inches on the actual project

Whatever scale you use, the written dimensions represent the actual project size.

Do not measure a printed drawing and assume the printout is perfectly to scale unless it is specifically intended for that purpose.

## Hand Drawing or Digital Drawing

A useful working drawing can be created with:

- pencil and paper;
- graph paper;
- CAD software;
- 3D modeling software; or
- another method that communicates the necessary information.

The tool is less important than the clarity of the information.

A carefully drawn pencil sketch with good dimensions can be more useful than a sophisticated computer model that leaves out critical construction details.

## Drawings Are Not the Construction Sequence

A drawing shows **what the project should become**.

It does not necessarily show **the order in which you should build it**.

A finished drawing may show every component at its final dimension, but that does not mean every piece should be cut to final size before assembly begins.

Sometimes it is more accurate to fit later parts to the project as it develops.

The drawing provides the destination.

The plan of procedure provides the route.

## Check Yourself

1. What is the primary purpose of a working drawing?
2. What are the three common views in a three-view drawing?
3. Why might an isometric view be useful?
4. What information should dimensions communicate?
5. What is a hidden line?
6. Does a drawing necessarily show the correct order for building the project?
7. What matters more: the drawing method or the clarity of the information?

## 8.3: Bill of Materials

---

### 8.3 Bill of Materials

A **Bill of Materials**, often abbreviated **BOM**, is a list of the parts and materials needed to build a project.

A good BOM connects the design to the actual lumber you need to purchase and prepare.

It can help you determine:

- what parts are required;
- how many of each part you need;
- what material each part uses;
- finished part dimensions;
- rough material dimensions;
- board-foot requirements; and
- estimated material cost.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the purpose of a Bill of Materials.
- Distinguish between finished size and rough size.
- Organize project parts by quantity, material, and dimensions.
- Estimate rough lumber requirements from finished parts.
- Use board-foot calculations as part of project planning.

### Start With the Parts

Break the project into its individual components.

For a tool tote, for example, the major parts might include:

- long sides;
- short sides;
- bottom components;
- risers;
- handle; and
- other small parts.

Each distinct part should have its own line in the BOM.

### Useful BOM Information

A practical woodworking BOM may include:

example information on a BOM

| Part         | Material | Quantity | Finished Thickness | Finished Width | Finished Length | Rough Thickness | Rough Width | Rough Length |
|--------------|----------|----------|--------------------|----------------|-----------------|-----------------|-------------|--------------|
| Example Part | Hardwood | 2        | 3/4 in.            | 3 in.          | 18 in.          | 4/4             | 3 1/2 in.   | 19 in.       |

Additional columns may include:

- board feet;
- extra material allowance;
- unit cost;
- total cost; and
- notes.

Not every project needs every column.

Use the information that helps you plan the work.

## Finished Size

The **finished size** is the dimension the completed part should have after milling and machining.

Dimensions are normally listed:

Thickness × Width × Length

For example:

3/4 in. × 3 in. × 18 in.

## Rough Size

The **rough size** is the amount of material you plan to begin with before final milling.

Rough stock should usually be larger than the finished part so you have material available to:

- flatten faces;
- straighten edges;
- square ends; and
- remove defects.

A common starting allowance for many WMT parts is approximately:

- 1/2 inch extra in width; and
- 1 inch extra in length.

The appropriate rough thickness is selected from available nominal hardwood sizes such as 4/4, 5/4, 6/4, or 8/4.

These are planning allowances, not absolute rules.

A badly warped board or a part requiring special grain selection may require more material.

## Board-Foot Estimate

Once the rough dimensions are known, calculate the approximate board footage.

Remember:

Board Feet = Quantity × Rough Thickness × Rough Width × Rough Length ÷ 144

Use inches for the dimensions.

The BOM connects the board-foot calculation from Chapter 2 to an actual project.

## Add Extra Material

The calculated volume of the rough parts is not necessarily the exact amount of lumber you should purchase.

Additional material may be required for:

- defects;
- milling loss;
- grain selection;
- color matching;
- layout within random-width boards;
- test pieces; and
- mistakes.

Your BOM may include an **extra-material allowance** to account for these realities.

## Test Pieces Are Material Too

When a project uses a new joint or machine setup, include enough material for testing.

A test piece can be more valuable than trying to save every last inch of lumber.

It allows you to:

- verify a setup;
- check a joint fit;
- test a router depth;
- practice an operation; and
- make a mistake somewhere other than the finished project.

Plan for practice.

## A BOM Is a Plan, Not a Command

A Bill of Materials is an estimate of the parts you expect to need.

It does **not** mean that every part should immediately be cut to its exact final dimension.

As a project develops, some dimensions may be more accurately determined from the project itself.

For example, two opposite sides being **exactly the same length** may be more important than both pieces matching a theoretical dimension perfectly.

The BOM gets you started.

Good woodworking judgment still guides the build.

## Check Yourself

1. What is the purpose of a Bill of Materials?
2. What is the difference between finished size and rough size?
3. Why should rough dimensions normally be larger than finished dimensions?
4. Why might a BOM include an extra-material allowance?
5. Why should test material be considered when estimating lumber?
6. Does a BOM mean that every part should be cut to final size before construction begins?

## 8.4: Plan of Procedure

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### 8.4 Plan of Procedure

A **Plan of Procedure**, or **POP**, describes how you intend to build the project.

If a working drawing communicates **what** you are making, the Plan of Procedure communicates **how you plan to make it**.

A useful POP identifies the major operations in a logical sequence and connects those operations to the appropriate tools, machines, setups, and reference surfaces.

### Learning Outcomes

After completing this section, you should be able to:

- Explain the purpose of a Plan of Procedure.
- Organize woodworking operations into a logical sequence.
- Identify which operations depend on earlier steps.
- Pair processes with appropriate tools or machines.
- Recognize when a plan should be adjusted as the project develops.

### Plan Before You Cut

A woodworking project contains dependencies.

For example:

- You need a flat face before planing to thickness.
- You need a straight edge before ripping accurately.
- A groove may need to be cut before an assembly is glued.
- One part may need to be measured from an already assembled section.
- Sanding some surfaces may be easier before final assembly.

A Plan of Procedure forces you to think about these relationships before you begin.

### A Simple POP Format

A Plan of Procedure can be a straightforward table.

*Example POP*

| Process                     | Tool or Machine |
|-----------------------------|-----------------|
| Select and rough-cut lumber | Radial arm saw  |
| Flatten one face            | Jointer         |
| Plane to thickness          | Planer          |

| Process               | Tool or Machine                  |
|-----------------------|----------------------------------|
| Rip to width          | Table saw                        |
| Cut joinery           | Appropriate machine or hand tool |
| Dry-fit assembly      | Clamps and measuring tools       |
| Sand parts            | Sanders and hand abrasives       |
| Glue assembly         | Glue and clamps                  |
| Final sand and finish | Abrasives and finish supplies    |

Your actual POP should describe the specific project rather than remain this general.

## Think in Subassemblies

Large projects become easier to understand when they are divided into smaller sections.

For example, a tool tote might be planned as:

- bottom;
- sides and ends;
- risers;
- handle; and
- final assembly.

Each subassembly can have its own short sequence.

This makes the project easier to manage and helps identify which parts depend on others.

## Pair the Process With the Tool

Writing only:

“Make the joint.”

is not very useful.

Instead, think through:

- What joint?
- Which surfaces are references?
- Which machine or tool?
- What setup is required?
- Does the operation require a stop block, jig, fence, template, or test piece?

- What must already be completed before this step?

The more clearly you understand the operation before entering the shop, the less time you spend deciding what to do while standing in front of a machine.

## Matching Can Matter More Than a Number

Woodworking is not always about making every part match a theoretical dimension perfectly.

Sometimes relationships between parts matter more.

For example:

- two sides should match each other;
- two ends should match each other;
- a bottom should fit the opening that actually exists;
- a handle should fit between the risers that were actually installed.

This is sometimes called **relative dimensioning**.

The developing project itself can become the most accurate measuring tool.

## Measure From the Work When Appropriate

Suppose a drawing says a bottom should be a particular width.

After the box frame is assembled, the actual opening may differ slightly from the theoretical drawing because of normal machining and assembly variation.

Rather than blindly cutting the bottom to the original number, it may be better to:

1. assemble the frame;
2. verify that the frame is square;
3. measure the actual opening;
4. determine the required clearance; and
5. fit the bottom to the project.

This does not mean drawings are unimportant.

It means the plan should recognize when **actual project dimensions become more useful than theoretical ones**.

## Story Sticks, Templates, and Spacers

Not every dimension needs to be transferred as a number.

Woodworkers often use physical references.

A **story stick** records important locations or dimensions directly on a strip of material.

A **template** provides a repeatable shape or location.

A **spacer** establishes a consistent distance.

These tools can reduce measurement errors and make repeated parts more consistent.

## Plan for Test Cuts

If an operation involves a new setup:

test it before cutting the finished part.

Your POP can include steps such as:

- prepare test stock;
- make test cut;
- check fit;
- adjust setup;
- repeat if necessary;
- machine project parts only after the setup is correct.

This is especially useful for:

- dados;
- rabbets;
- finger joints;
- router setups;
- mortises and tenons; and
- repeated cuts using stop blocks.

## Dry-Fit Is Part of the Procedure

Include dry fitting in the plan.

Before glue-up:

- assemble the parts;
- check joint fit;
- verify squareness;
- confirm dimensions;
- prepare clamps; and
- rehearse the assembly sequence.

A POP should include the steps that prevent problems—not just the steps that remove wood.

## The Plan Can Change

A Plan of Procedure is not a contract with your earlier self.

Wood moves.

Measurements vary.

A part may need to be remade.

You may discover a better sequence.

When the project changes, update the plan.

The value of planning is not that everything happens exactly as predicted.

The value is that you have thought through the project well enough to recognize what should happen next when something changes.

## Communicate the Process

A good Plan of Procedure should be clear enough that another competent woodworker can understand the intended sequence.

Like a working drawing, it is a form of communication.

If someone else can understand:

- what you are building;
- which operations occur;
- what tools are needed; and
- how the steps relate to one another,

then you have probably planned the project well.

## Check Yourself

1. What is the difference between a working drawing and a Plan of Procedure?
2. Why should processes be placed in a logical sequence?
3. Why is it useful to divide a project into subassemblies?
4. What is relative dimensioning?
5. When might the actual project be a better reference than the original drawing?
6. What are story sticks, templates, and spacers used for?
7. Why should test cuts appear in a Plan of Procedure?
8. Why is dry fitting part of the construction process?
9. Should a Plan of Procedure ever be changed after work begins?

## 9: PROJECT 3- TOOL TOTE

9.1: Tool Tote Project Overview

9.2: Preparing the Box Parts

9.3: Dadoes and Grooves

9.4: Shaping the Handle

9.5: Bottom, Risers, and Final Fitting

9.6: Assembly, Sanding, and Finishing

## 9.1: Tool Tote Project Overview

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### 9.1 Tool Tote Project Overview

The **tool tote** is the most complex project in WMT 101.

It brings together many of the skills introduced earlier in the course:

- milling rough lumber;
- working from drawings and a Bill of Materials;
- planning a sequence of operations;
- machining joinery;
- making an edge-glued panel;
- cutting grooves and dadoes;
- fitting parts to an assembly;
- shaping curves;
- using adhesives and fasteners;
- sanding; and
- finishing.

The reference tote is approximately **18 inches long × 9 inches wide** at the box. The risers and handle extend above the box and determine the overall height of the completed project.

The exact appearance may vary. Your instructor may also demonstrate different approaches to some of the joinery.

### Learning Outcomes

After completing this project, you should be able to:

- Plan a multi-part woodworking project.
- Prepare matching box parts from rough hardwood.
- Create and fit appropriate corner joinery.
- Make a solid-wood bottom panel.
- Cut grooves and dadoes accurately.
- Fit risers and a solid hardwood handle.
- Use relative dimensions to fit parts to the actual project.
- Dry-fit and assemble a multi-part project.
- Sand through 320 grit.
- Apply the provided oil finish.

### Major Parts

The tool tote has several major components:

**Long Sides** — The two longer walls of the box.

**Short Ends** — The two shorter walls of the box.

**Bottom Panel** — A solid-wood panel that fits into grooves in the box.

**Risers** — Two vertical supports attached near the ends of the tote.

**Handle** — A single piece of solid hardwood fitted between the risers.

An optional removable tray may also be added.

## Reference Dimensions

A typical WMT 101 tote uses approximately:

- **5/8-inch-thick** stock for the box sides and ends;
- an **18-inch** long box;
- a **9-inch** wide box;
- a box body approximately **6 inches high**;
- risers approximately **12 inches long**; and
- a solid hardwood handle spanning the tote.

These dimensions provide a useful starting point.

They do not mean every part should be cut to final size before construction begins.

Some dimensions are best determined from the actual project as it develops.

## Corner Joinery

The four corners of the box require appropriate woodworking joints.

A single-finger or box-joint form is commonly used, but your instructor may choose another suitable joint or demonstrate a different construction method.

Whatever joint is used, it should:

- align the sides and ends;
- provide adequate strength;
- allow the box to assemble squarely; and
- be appropriate for the stock and available machines.

Focus on understanding **why the joint works** and how to fit it accurately rather than memorizing one procedure as the only possible method.

## Plan Before You Begin

The tool tote has enough parts and operations that working without a plan can create unnecessary problems.

Before machining:

- review the project drawing;
- review the Bill of Materials;
- identify the major subassemblies;
- think about which parts must match;
- identify dimensions that can be determined later from the actual assembly; and
- review the major steps with your instructor.

This is where the planning skills from Chapter 8 become useful.

## Build in Subassemblies

Think of the tote as several smaller projects:

1. Box sides and ends
2. Bottom panel
3. Risers
4. Handle

5. Final assembly
6. Optional tray

Complete and fit these components in a logical sequence rather than trying to manufacture every part at once.

## Check Yourself

1. What are the major components of the tool tote?
2. What is the approximate footprint of the reference tote?
3. What determines much of the overall height?
4. Is one specific corner joint required in every section of WMT 101?
5. Why is it useful to think of the tote as several subassemblies?
6. Why should some dimensions be determined later in the build?

## 9.2: Preparing the Box Parts

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### 9.2 Preparing the Box Parts

The main box begins with four matching pieces:

- two long sides; and
- two short ends.

These pieces form the frame that will eventually hold the floating bottom panel.

Accuracy matters, but **matching parts** is often more important than making each part independently match a theoretical number.

### Learning Outcomes

After completing this section, you should be able to:

- Select suitable stock for the box.
- Mill the box parts to a consistent thickness and width.
- Produce matching pairs of sides and ends.
- Consider grain and appearance when laying out parts.
- Prepare and fit the corner joinery demonstrated by your instructor.

### Select the Stock

Before milling, examine the lumber for:

- warp;
- knots;
- checks;
- usable length;
- grain direction;
- color; and
- figure.

Whenever possible, consider how the boards will look next to one another in the finished tote.

This is a functional project, but thoughtful grain selection still improves the result.

### Mill the Parts Together

Prepare the stock using the standard milling sequence.

The box parts typically finish at approximately:

5/8 inch thick

and approximately:

6 inches wide

Mill the parts together whenever practical so they remain consistent.

If one side is 5/8 inch thick and the other is noticeably different, later joinery and assembly become more difficult.

## Do Not Make Short Parts Too Early

A finished short end may be approximately 9 inches long, but a board that short may not be suitable for every milling operation.

Mill stock at safe, manageable lengths first.

Crosscut shorter parts after the required surfacing operations have been completed.

Always follow the minimum stock dimensions for the machines being used.

## Matching Long Sides

The two long sides should be the same length.

A small difference from the drawing may be less important than a mismatch between the pair.

For example, two sides that are both slightly shorter than the reference dimension can still make a square box.

Two sides of different lengths cannot.

## Matching Ends

The same principle applies to the short ends.

Make the two ends:

- the same thickness;
- the same width; and
- the same length.

Matching opposite parts helps the box assemble squarely.

## Grain Continuity

If the material allows it, think about cutting the sides and ends from related areas of the same board.

This can allow the grain pattern to visually continue around the tote.

Continuous grain is not required, but it introduces an important furniture-making idea:

part layout affects appearance.

## Lay Out the Corner Joinery

After the parts are milled and matched, lay out the corner joints clearly.

Mark:

- reference faces;
- reference edges;
- matching corners; and
- waste areas.

Do not rely on memory once several similar parts are on the bench.

## Machine the Joint

Your instructor will demonstrate the corner-joint method used in your section.

Depending on the method, the operation may involve:

- table saw;
- crosscut sled;
- stop blocks;
- band saw;
- router table;
- chisels;
- files; or
- another approved setup.

The important goals are:

- consistency;
- clean shoulders;
- close-fitting mating surfaces; and
- a joint that assembles without excessive force.

## Test Before Committing

Use test material when appropriate.

A test piece allows you to:

- verify a machine setup;
- confirm depth or width;
- understand the sequence; and
- make adjustments before cutting a finished project part.

This is especially valuable when several joints depend on the same setup.

## Dry-Fit the Box

Before cutting the bottom grooves or applying glue, assemble the four box parts without adhesive.

Check:

- joint fit;
- matching side lengths;
- matching end lengths;
- flatness; and
- squareness.

Measure both diagonals.

If the diagonals are equal, the rectangular assembly is generally square.

Solve fit problems before moving to the next operation.

## Check Yourself

1. Why should the box parts be milled together when practical?
2. Why should short finished pieces not necessarily be cut short before milling?

3. Why is matching opposite parts important?
4. What is continuous grain?
5. Why should waste areas be marked before machining joinery?
6. Why should the box be dry-fitted before continuing?

## 9.3: Dadoes and Grooves

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### 9.3 Dadoes and Grooves

The tool tote uses recessed cuts to locate and support other components.

Two important terms are:

**Dado** — A recess cut across the surface of a board.

**Groove** — A recess cut generally in the same direction as the grain.

In the tote, recessed cuts are used to:

- support the bottom panel; and
- locate the risers.

### Learning Outcomes

After completing this section, you should be able to:

- Distinguish between a dado and a groove.
- Explain the purpose of the bottom groove.
- Explain why the bottom panel is allowed to float.
- Describe the purpose of the riser dados.
- Explain the basic idea of self-centering a dado or groove.

### The Bottom Groove

A groove is cut along the inside lower portion of the box sides and ends.

A typical bottom groove is approximately:

1/4 inch wide

The exact location and depth will be demonstrated by your instructor.

The groove captures the edges of the bottom panel and supports it inside the box.

### Through and Stopped Grooves

Depending on the corner joinery and construction sequence, some grooves may be able to continue completely through a part.

Others may need to stop before reaching an exposed end.

A **stopped groove** ends before it reaches the edge of the workpiece.

The goal is to support the panel without leaving an unwanted groove visible on the exterior of the tote.

### The Bottom Must Move

The bottom is made from solid wood.

Solid wood expands and contracts across the grain as moisture conditions change.

For that reason, the bottom is fitted into the grooves but is **not glued around its perimeter**.

The panel must be able to move slightly inside the box.

This is called a **floating panel**.

## Fit, Do Not Force

The bottom should fit into the grooves without excessive force.

A fit that is too tight may prevent normal wood movement or make assembly difficult.

A fit that is too loose may allow the panel to rattle.

Aim for a controlled fit that allows the project to assemble normally.

## Riser Dados

The short ends of the tote receive recessed areas for the risers.

These dados help:

- locate the risers;
- keep them aligned;
- increase the joint area; and
- resist movement.

The riser fit should be established carefully.

The dado can be cut first and the riser fitted to the opening rather than relying only on a theoretical dimension.

## Self-Centering

A useful woodworking technique is to create a centered feature by making matching cuts from opposite orientations.

The basic idea is:

1. Make a cut near the center.
2. Rotate or flip the workpiece.
3. Make the same cut from the opposite reference side.
4. Adjust the setup gradually until the feature reaches the desired width.

Because the same reference surfaces are used from both directions, the final opening remains centered.

Your instructor may use this approach for the riser dados or other centered features.

## Sneak Up on the Fit

Do not remove the final amount of material all at once.

Make a test cut.

Check the fit.

Adjust slightly.

Test again.

Small changes to a stop block or machine setting can produce noticeable changes in a joint.

Once a dado is too wide, the removed material cannot be put back.

## Label the Parts

Before moving on, keep track of:

- inside and outside faces;
- left and right ends;
- reference edges;
- riser locations; and
- any matched grain relationships.

These marks may become less visible during sanding, so think ahead about when they will still be needed.

## Check Yourself

1. What is the basic difference between a dado and a groove?
2. What does the bottom groove do?
3. Why is the bottom panel not glued around its edges?
4. What is a floating panel?
5. What do the riser dados accomplish?
6. How can cutting from opposite orientations help center a feature?
7. Why should you sneak up on a final fit?

## 9.4: Shaping the Handle

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### 9.4 Shaping the Handle

The tool tote handle is made from **one solid piece of hardwood**.

The handle provides the main carrying surface of the project, but it is also one of the strongest visual elements.

Its shape should be:

- comfortable;
- strong;
- appropriate to the tote; and
- visually intentional.

### Learning Outcomes

After completing this section, you should be able to:

- Select stock suitable for a solid handle.
- Design a handle that balances strength and appearance.
- Fit the handle into the risers.
- Shape the handle using appropriate cutting and shaping tools.
- Prepare the handle for final assembly.

### Begin With Sound Material

The handle will carry the weight of the completed tote and anything placed inside it.

Choose hardwood that is:

- straight-grained;
- free from major cracks;
- free from loose knots; and
- large enough for the intended shape.

Avoid placing major defects in narrow or highly stressed areas.

### Fit the Structure Before Final Shaping

The handle fits into notches at the tops of the risers.

Before finalizing the handle shape:

1. Fit the risers to the box.
2. Establish the spacing between the risers.
3. Determine the actual handle length.
4. Lay out the handle-to-riser connection.
5. Dry-fit the structural parts.

This is another example of **relative dimensioning**.

The actual tote tells you the most useful final handle dimension.

## Handle-to-Riser Fit

The handle is seated into notches in the risers.

The fit should:

- locate the handle securely;
- keep it centered;
- provide solid contact; and
- allow the parts to assemble without excessive force.

Final attachment will use **glue and screws**.

Your instructor will demonstrate the screw location, pilot-hole procedure, and assembly method.

## Design the Shape

Once the structural fit is established, develop the handle profile.

Consider:

- hand comfort;
- thickness at the gripping area;
- transitions near the risers;
- overall proportion;
- grain direction; and
- strength.

Avoid making the handle unnecessarily thin in areas that carry load.

## Make a Template if Helpful

A full-size paper, cardboard, or thin-sheet template can help you evaluate the handle before cutting the final hardwood.

A template makes it easier to:

- compare both ends;
- evaluate curves;
- adjust proportions;
- locate the grip; and
- transfer the shape accurately.

It can also provide a pattern if a handle must be remade.

## Rough-Cut the Profile

Use the band saw or another instructor-approved method to rough-cut the handle.

Stay slightly outside the final line.

Do not force the blade through tight curves.

Use relief cuts when needed.

## Refine the Shape

Refine the handle using tools appropriate to the form.

These may include:

- rasps;
- files;
- spokeshaves;
- stationary sanders;
- hand sanding; or
- other instructor-approved tools.

Work from coarse shaping toward finer refinement.

## Shape by Feel

A handle is meant to be held.

Do not evaluate it only visually.

Grip it.

Move your hand along it.

Look for:

- uncomfortable sharp transitions;
- thin weak areas;
- flat spots;
- awkward changes in curve; and
- places where the hand naturally wants more clearance.

A small change in shape can make a large difference in comfort.

## Leave Final Sanding for Later

Bring the handle close to its final form, but remember that it still needs to be fitted into the complete project.

Do not remove so much material that later adjustments become impossible.

Final sanding will continue during the finishing stage.

## Check Yourself

1. Why is straight-grained stock desirable for the handle?
2. Why should the risers be fitted before determining final handle length?
3. How is the handle attached to the risers?
4. Why might a full-size template be useful?
5. Why should you leave the layout line during rough cutting?
6. Why should a handle be evaluated by touch as well as sight?

## 9.5: Bottom, Risers, and Final Fitting

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### 9.5 Bottom, Risers, and Final Fitting

As the tote progresses, more dimensions should come from the **actual assembly** rather than from the original drawing alone.

This is especially important for the bottom, risers, and handle.

The drawing communicates the design.

The partially built project provides the most accurate information for final fitting.

### Learning Outcomes

After completing this section, you should be able to:

- Fit a floating bottom panel to the assembled box.
- Explain why the bottom is made slightly differently from the box walls.
- Fit risers to the actual dados.
- Use the assembled project to determine later dimensions.
- Dry-fit the major components before final assembly.

### Make the Bottom Panel

The tote bottom is a solid-wood panel made by edge-gluing narrower boards.

Prepare the panel **oversized** at first.

Do not immediately cut it to final length and width.

After the glue has cured:

1. Remove excess glue.
2. Flatten the panel as required.
3. Bring it to the desired thickness.
4. Keep it oversized until the box opening can be measured.

A typical finished panel is approximately **1/2 inch thick**.

### Why Make a Panel?

Commercial hardwood may not be wide enough to produce the entire bottom from one board.

Edge gluing allows narrower boards to become one wider panel.

It also reinforces a fundamental furniture-making skill that will be used in many later projects.

### Measure the Actual Box

Dry-assemble the box.

Make sure it is square.

Then measure the opening where the bottom will fit.

Measure in more than one location.

Do not assume the opening is perfectly identical at every point.

Use the actual assembly to determine the final bottom dimensions.

## Fit the Panel Edges

The bottom is thicker than the groove that captures it.

Its edges therefore need to be reduced or profiled so they fit into the groove while leaving the center of the panel thicker.

Your instructor will demonstrate the router-table setup used for this operation.

Use offcuts or test pieces to establish the correct fit before machining the finished bottom.

## Allow for Movement

The center panel must be able to expand and contract across its width.

Do not make the fit so tight that the panel is locked in place.

Do not glue the panel into the groove.

The bottom should remain free to move.

## Fit the Risers

Fit each riser to its dado.

The goal is a controlled fit:

- not loose;
- not forced;
- seated completely; and
- aligned vertically.

If the dado has already been established, fit the riser to the actual dado rather than relying on a theoretical width.

## Match the Risers

The two risers should work as a pair.

Check:

- height;
- width;
- thickness;
- shape;
- alignment; and
- handle location.

A small difference between them can become very visible once the handle connects the two.

## Dry-Fit the Entire Tote

Before final sanding or glue-up, assemble:

- sides;
- ends;
- bottom;
- risers; and
- handle.

Check the whole project.

Look for:

- square corners;
- joints that seat completely;
- a bottom that fits without binding;
- risers that stand correctly;
- a handle that sits properly in both notches; and
- a tote that rests flat.

This is the final opportunity to correct many fitting problems before adhesive and screws make the relationships permanent.

## Optional Tray

A removable tray may be added if time and the instructor permit.

Treat it as an **optional extension**, not something that should interfere with completing the main tote successfully.

Finish the primary project first.

A well-made completed tote is more valuable than an unfinished tote with several added features.

## Check Yourself

1. Why should the bottom panel initially be made oversized?
2. Why is it useful to measure the actual assembled box before sizing the bottom?
3. Why are test pieces useful when fitting the bottom to the groove?
4. Why is the bottom not glued into place?
5. Should a riser be fitted to a theoretical dimension or the actual dado when possible?
6. What should be checked during the complete dry fit?
7. Is the removable tray required?

## 9.6: Assembly, Sanding, and Finishing

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### 9.6 Assembly, Sanding, and Finishing

The final stage brings the individual components together.

By this point, the major fitting problems should already have been solved.

Final assembly should be controlled rather than experimental.

#### Learning Outcomes

After completing this section, you should be able to:

- Prepare the tote for final assembly.
- Assemble the box while keeping the bottom free to move.
- Attach the risers and handle using the demonstrated method.
- Sand the completed project through 320 grit.
- Apply the provided Osmo oil finish.
- Inspect the completed tote for fit, function, and craftsmanship.

#### Sand Before Assembly When It Helps

Some surfaces become difficult to reach after assembly.

Before gluing, consider sanding:

- interior box surfaces;
- the inside faces of the risers;
- areas around joints;
- the bottom panel; and
- portions of the handle that will be difficult to reach later.

Do not sand mating joint surfaces so much that the fit changes.

#### Prepare for Glue-Up

Before applying adhesive:

1. Complete a full dry fit.
2. Gather the clamps.
3. Confirm the assembly sequence.
4. Protect the work surface.
5. Make sure all parts are labeled and correctly oriented.
6. Have measuring tools nearby.
7. Make sure the floating bottom is ready.

Do not begin glue-up until you understand the sequence.

#### Assemble the Box

Apply adhesive only to the intended corner-joint surfaces.

Do **not** glue the floating bottom into its grooves.

Assemble the sides and ends around the bottom panel.

Clamp the box as demonstrated.

Check:

- joint closure;
- squareness;
- diagonal measurements;
- flatness; and
- whether the bottom remains properly seated.

Make adjustments while the adhesive is still workable.

## **Allow the Box to Cure**

Do not rush to attach the remaining components.

Allow the box assembly to cure as directed by your instructor and the adhesive manufacturer.

Once cured, remove the clamps and inspect the assembly.

Clean up glue residue carefully.

## **Attach the Risers**

The risers fit into the prepared dados at the ends of the box.

They are attached using the method demonstrated in class.

Make sure they:

- seat fully;
- remain aligned;
- match each other; and
- support the handle correctly.

## **Attach the Handle**

Fit the solid hardwood handle into the riser notches.

The handle is attached with:

- adhesive; and
- screws.

Drill pilot and clearance holes as demonstrated.

The screws reinforce the connection, but accurate joinery and proper fit should establish the position of the handle.

Do not use screws to pull a poorly fitted assembly into place.

## **Shape the Completed Tote**

After assembly, inspect the project as a whole.

The tote does not need to remain visually boxy.

Refine appropriate areas by:

- softening sharp edges;
- blending transitions;
- refining the risers;
- refining the handle;
- removing small glue remnants; and
- correcting minor surface irregularities.

Do not reshape structural joints to the point that they become weak or visibly inconsistent.

## Sand Through 320 Grit

Sand the project through:

320 grit

Use a logical grit progression and do not skip large steps.

Pay particular attention to:

- end grain;
- joints;
- inside corners;
- edges;
- the risers;
- the handle; and
- areas where glue may have sealed the surface.

A finish will reveal scratches and glue residue that may be difficult to see on bare wood.

## Inspect Before Finishing

Before applying finish:

- remove all sanding dust;
- inspect under good light;
- check the handle for comfort;
- make sure the tote sits flat;
- confirm the bottom can move;
- inspect the joinery;
- and make sure you are satisfied with the shape.

Finish should be the final step, not a way to hide incomplete surface preparation.

## Apply the Provided Finish

The tool tote is finished with the a **finish provided in class (like Osmo oil)**.

Your instructor will demonstrate the application procedure.

Follow:

- the instructor demonstration;
- the product directions;
- appropriate drying time; and

- all finishing-safety procedures.

Apply the finish evenly and remove excess material as directed.

## Oily Rags and Applicators

Oil-finish materials must be handled and disposed of according to WMT shop procedures.

Do not leave oily rags or applicators piled on a bench or placed casually in a trash container.

Follow your instructor's directions for safe disposal.

## Final Inspection

Before calling the tool tote complete, check:

- Are the box joints fully seated?
- Is the box square?
- Does the tote sit flat?
- Does the bottom fit properly and remain free to move?
- Are the risers aligned?
- Is the handle secure and comfortable?
- Are screws properly installed?
- Are all surfaces sanded through 320 grit?
- Is the finish even?
- Are there visible glue marks or sanding scratches?
- Does the tote function as intended?

This project is not only an exercise in making a box with a handle.

It is an exercise in **planning, sequencing, fitting, adjusting, and bringing many woodworking processes together into one finished object.**

## Check Yourself

1. Why might some sanding be completed before final assembly?
2. Which surfaces receive glue during box assembly?
3. Why is the bottom not glued into the grooves?
4. Why should screws not be used to force poorly fitted parts together?
5. To what grit should the completed tote be sanded?
6. What finish is provided for the project?
7. Why must oily finishing materials be disposed of properly?
8. What should be included in the final project inspection?

## 10: FINISHING WOOD

10.1: Preparing Wood for Finish

10.2: Oil Finishes

# 10.1: Preparing Wood for Finish

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## 10.1 Preparing Wood for Finish

A finish can change the color, depth, and appearance of wood, but it does not hide poor surface preparation.

In fact, finish often makes scratches, glue residue, dents, and other defects **more visible**.

Good finishing begins before the finish container is opened.

### Learning Outcomes

After completing this section, you should be able to:

- Inspect a project before finishing.
- Prepare wood through an appropriate sanding sequence.
- Explain why sanding scratches must be removed before moving to a finer grit.
- Raise the grain before final surface preparation when appropriate.
- Remove sanding dust before applying finish.
- Recognize common surface problems that become visible after finishing.

### Finish Starts With the Surface

Before applying finish, inspect the entire project.

Look for:

- machine marks;
- sanding scratches;
- glue residue;
- dents;
- torn grain;
- rough end grain;
- pencil marks;
- sharp edges that should be softened;
- uneven curves; and
- areas that were difficult to reach during earlier sanding.

Correct these problems before finishing.

Once finish is applied, many of them become harder to repair.

### Sand Through the Grits

Use a logical sanding progression.

A common WMT sequence may include:

P80 or P100 → P120 → P150 → P180 → P220 or P240 → P320

You may not need to begin with the coarsest grit if the surface is already well prepared.

Each grit has one main job: **remove the scratches left by the previous grit**.

Do not move to a finer abrasive until the previous scratches and tool marks are gone.

Skipping too many grits usually creates more work rather than saving time.

## Sand With the Grain

Final hand sanding on visible flat surfaces should generally follow the direction of the grain.

Cross-grain scratches can be difficult to see on unfinished wood but become obvious after oil is applied.

Use good lighting and inspect the surface from several angles.

## Pay Attention to End Grain

End grain often absorbs finish differently from face or edge grain.

It can also become noticeably darker if it remains rougher than the surrounding surfaces.

Sand end grain carefully and consistently.

Do not assume that because an end feels smooth, it has been prepared to the same level as the rest of the project.

## Remove Glue Completely

Dried glue can prevent finish from penetrating the wood evenly.

A glue spot that is nearly invisible before finishing may appear as a pale or uneven area after finish is applied.

Inspect carefully around:

- glue joints;
- inside corners;
- clamped areas; and
- places where squeeze-out occurred.

Remove glue without damaging the surrounding wood.

## Raise the Grain

Water can cause small wood fibers at the surface to swell and stand up.

Before final finishing, your instructor may have you **raise the grain**.

A basic process is:

1. Lightly dampen the wood with clean water.
2. Wet the surface evenly rather than soaking it.
3. Allow the wood to dry **completely**.
4. Lightly sand the raised fibers with the final abrasive grit.
5. Remove the sanding dust.

The goal is to cut off the raised fibers without significantly reshaping the surface.

## Let the Wood Dry

Do not apply finish to wood that is still damp from grain raising or cleaning.

Allow the project to dry thoroughly.

This is especially important if water, a damp cloth, or compressed air that may contain moisture has been used during final preparation.

When in doubt, give the project more time to dry.

## Remove the Dust

Sanding dust left on the project can become mixed into the finish.

Before finishing:

- vacuum the project when appropriate;
- use a clean brush;
- use compressed air only as directed;
- wipe surfaces using the method demonstrated by your instructor; and
- inspect corners, grooves, joints, and other areas where dust collects.

Compressed air can move dust from one place to another, so use it thoughtfully and follow shop procedures.

## Inspect Under Good Light

Before applying finish, look across the surface rather than only straight down at it.

Low-angle light can reveal:

- scratches;
- glue;
- uneven sanding;
- dents; and
- surface waves.

Your hands are useful too.

Run your fingers across curves and transitions.

A surface can sometimes **feel wrong before it looks wrong**.

## Final Surface Check

Before finishing, ask:

- Are all machine marks gone?
- Are scratches from earlier grits gone?
- Is all glue removed?
- Are the edges treated consistently?
- Is the end grain properly prepared?
- Has the raised grain been removed?
- Is the wood completely dry?
- Is the project free of sanding dust?

If the answer is yes, you are ready for finish.

## Check Yourself

1. Why does finish often make surface defects more noticeable?

2. What should each sanding grit remove?
3. Why should you avoid skipping too many grits?
4. Why can dried glue create a problem during finishing?
5. What does it mean to raise the grain?
6. Why must the wood dry completely before finish is applied?
7. What should you inspect before opening the finish container?

## 10.2: Oil Finishes

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### 10.2 Oil Finishes

Oil finishes are useful when you want the wood to remain visually and physically close to its natural character. There are many other types of finishes, and you are encouraged to check those out by enrolling in a finishing class we offer.

All finishes can deepen the color of the wood, emphasize grain and figure, and create a surface that is pleasant to touch.

In WMT 101, you will encounter two basic applications:

- a **food-safe oil** for the cutting board; and
- an **instructor-supplied furniture oil finish**, such as an Osmo product or similar finish, for projects such as the tool tote.

Always use the finish supplied or approved by your instructor.

### Learning Outcomes

After completing this section, you should be able to:

- Explain how an oil finish changes the appearance of wood.
- Distinguish between the finishes used on different WMT 101 projects.
- Prepare a surface for an oil finish.
- Follow the basic principles of applying and removing excess finish.
- Explain why drying and curing time matter.
- Dispose of oil-finish materials safely.

### What an Oil Finish Does

Oil finishes generally enhance the natural appearance of wood rather than covering it with an opaque coating.

After oil is applied, you may notice:

- darker or richer color;
- stronger contrast between earlywood and latewood;
- more visible figure;
- deeper-looking grain; and
- increased visual variation between heartwood and sapwood.

This is why flaws that were difficult to see during sanding can suddenly become obvious.

### Not All Oil Finishes Are the Same

The term **oil finish** covers several different products.

Some are primarily oils.

Others contain oils combined with waxes, resins, solvents, or other ingredients.

These products may have very different:

- application methods;
- drying times;
- number of coats;

- durability; and
- maintenance requirements.

Do not assume that the instructions for one oil finish apply to another.

Follow the product directions and your instructor's demonstration.

## Cutting-Board Finish

The cutting board receives a **food-safe oil finish** supplied or approved for the project.

Mineral oil is one suitable example.

The finish should be applied to:

- both faces;
- all edges;
- end grain; and
- the inside of the handle opening.

End grain may absorb finish more quickly than the faces and may require additional attention.

The goal is even coverage throughout the board.

## Furniture Oil Finish

Projects such as the tool tote may receive an **instructor-supplied oil finish**, such as Osmo or a similar product.

These finishes are used differently from mineral oil.

The exact procedure depends on the product being used.

Your instructor will demonstrate:

- how much finish to apply;
- what applicator to use;
- how long the finish should remain on the surface;
- whether excess must be removed;
- how many coats are appropriate; and
- how long the finish must dry or cure.

## Thin and Even Is Usually Better

With many oil finishes, applying excessive material does not improve the result.

Too much finish can:

- remain sticky;
- dry unevenly;
- collect in corners;
- create shiny patches;
- lengthen drying time; and
- require additional cleanup.

Apply the finish as demonstrated rather than trying to build a heavy layer.

## Watch Corners and Details

Finish can collect in:

- inside corners;
- grooves;
- joinery;
- routed profiles;
- around screws or plugs; and
- other recessed areas.

Inspect these areas before leaving the project to dry.

Remove excess finish as directed.

## Allow the Finish to Dry

Drying time is part of the finishing process.

Do not apply another coat simply because you are ready to continue working.

Allow the finish to dry or cure according to:

- the manufacturer's instructions;
- the shop conditions; and
- your instructor's directions.

Temperature and humidity can affect drying time.

A finish that feels dry on the surface may not yet be fully cured.

## Do Not Rush the Last Step

Finishing often happens near the end of the semester when students are trying to complete projects.

That is exactly when rushing can create problems.

Putting a project away too soon, stacking finished parts together, or adding another coat before the previous one has dried can damage work that took weeks to build.

Give the finish the time it needs.

## Oil-Finish Rag Safety

Materials containing drying oils can generate heat as they cure.

If oily rags are piled together, that heat can build and create a **spontaneous-combustion fire hazard**.

In the WMT lab:

Rags or other materials that have absorbed oil-based finishing products must be placed in the approved red metal waste container with a lid.

Do not:

- leave oily rags on a workbench;
- stuff them into your project;
- put them in your bag;

- pile them together; or
- place them in an ordinary trash container.

Follow the finishing-area procedures demonstrated by your instructor.

## Maintain the Finish

Some oil-finished objects can be refreshed later as the surface becomes worn or dry.

The appropriate maintenance depends on the original finish.

Before adding another product, identify what finish is already on the object and make sure the products are compatible.

For a cutting board, maintenance may simply involve applying additional food-safe oil when the wood appears dry.

## The Finish Should Support the Wood

Finishing is not about making every piece of wood look the same.

A good clear finish allows the characteristics you selected earlier in the project—grain, figure, color, and texture—to remain visible.

The work you did selecting lumber, laying out parts, shaping, and sanding should still be evident when the project is finished.

## Check Yourself

1. How can an oil finish change the appearance of wood?
2. Why should you not assume all oil finishes are applied the same way?
3. What type of finish is used on the cutting board?
4. What type of finish may be supplied for the tool tote?
5. Why can applying too much finish create problems?
6. Why must drying time be respected?
7. Where must oil-finish rags be disposed of in the WMT lab?
8. Why can oily rags become a fire hazard?

## 11: REVIEW AND RESOURCES

11.1: Key Terms

11.2: Review Questions

11.3: Additional Woodworking Resources

11.4: References and Attributions

# 11.1: Key Terms

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## 11.1 Key Terms

Woodworking has its own technical vocabulary. Knowing the terms helps you understand drawings, communicate with other woodworkers, follow demonstrations, purchase materials, and work safely.

Use this section as a reference throughout WMT 101 and in later woodworking courses.

### A–B

**Abrasive** — A hard cutting material used to remove small amounts of material from a surface. Sandpaper is made by attaching abrasive particles to a backing.

**Air Drying** — Drying lumber by stacking it so natural air can circulate around the boards.

**Alternate Top Bevel (ATB)** — A circular saw blade tooth grind in which alternating teeth are beveled in opposite directions. Commonly used for crosscutting.

**Alternate Top Bevel with Raker (ATBR)** — A saw blade tooth arrangement combining alternating beveled teeth with a flat-topped raker tooth. Commonly used on combination blades.

**Band Saw** — A woodworking machine that uses a continuous narrow blade running over wheels. Used for curved cuts, rough shaping, ripping, and resawing.

**Bark** — The protective outer covering of a tree.

**Bill of Materials (BOM)** — A list of the parts and materials required for a project, often including quantities, dimensions, rough sizes, board footage, and cost.

**Board Foot** — A unit used to measure hardwood volume. One board foot equals 144 cubic inches.

**Bow** — Lengthwise curvature along the face of a board.

**Butt Joint** — A joint in which two prepared surfaces meet directly without interlocking joint geometry.

### C–D

**Cambium** — The growing layer of a tree that produces new wood and bark.

**Caul** — A temporary piece used during clamping to distribute pressure, maintain alignment, or protect a project surface.

**Check** — A crack running along a board that does not extend completely through to the opposite face.

**Combination Blade** — A circular saw blade designed to perform both ripping and crosscutting reasonably well.

**Concave** — Curving inward.

**Convex** — Curving outward.

**Crook** — Lengthwise curvature along the edge of a board. Sometimes called crown.

**Crosscut** — A cut made generally across the direction of the wood grain.

**Crosscut Blade** — A circular saw blade designed primarily for cutting across the grain.

**Crosscut Sled** — A table-saw accessory that supports and guides a workpiece accurately across the blade.

**Cup** — Curvature across the width of a board.

**Dado** — A groove or recess cut across the surface of a board to receive another part.

**Density** — The weight of a material relative to its volume.

**Dry Fit** — Assembling parts without adhesive to check fit, alignment, squareness, and assembly sequence.

## E–G

**Earlywood** — The portion of a growth ring produced earlier in the growing season. It generally has larger cells and lower density.

**Edge** — One of the narrow longitudinal surfaces of a board.

**End** — The surface across the end of a board where end grain is visible.

**End Grain** — The exposed ends of wood fibers, usually visible at the ends of a board.

**Expansion Slot** — A slot cut into a circular saw blade plate to help control distortion caused by heat.

**Face** — One of the two broad surfaces of a board.

**Face Grain** — Grain visible on the broad face of a board.

**FAS** — Firsts and Seconds, a high hardwood lumber grade intended to provide a large percentage of clear usable material.

**Figure** — The visible pattern created by grain, growth structure, color, rays, and other characteristics of wood.

**File** — A hand tool with cutting teeth used to refine and smooth wood or other materials.

**Flat Top Grind (FTG)** — A saw blade tooth grind with flat-topped teeth, commonly used for ripping.

**Floating Panel** — A solid-wood panel fitted into a frame or groove without being glued around its perimeter so it can expand and contract.

**Grain** — The arrangement and direction of wood fibers and growth structure.

**Groove** — A recessed channel cut generally in the same direction as the grain.

**Growth Ring** — Wood produced during approximately one year of tree growth.

**Gullet** — The open space in front of a saw blade tooth that provides room for chip removal.

## H–L

**Half-Lap Joint** — A joint in which approximately half the thickness is removed from each of two overlapping parts.

**Hardwood** — Wood from broad-leafed trees, or angiosperms. The term describes botanical classification rather than actual hardness.

**Heartwood** — Older central wood in a tree that no longer conducts sap and is often darker than sapwood.

**Hook or Rake Angle** — The angle of the front face of a saw tooth relative to a radial line through the blade.

**Jig** — A device used to guide a tool or workpiece during a specific operation.

**Jig Saw** — A portable saw with a narrow reciprocating blade used for curved, irregular, and interior cuts.

**Jointer** — A machine used primarily to flatten the face of a board and straighten and square an edge.

**Kerf** — The width of a cut made by a saw blade.

**Kiln Drying** — Drying lumber in a controlled environment using circulated heated air.

**Knot** — A portion of a branch or limb contained within lumber.

**Latewood** — The denser portion of a growth ring formed later in the growing season.

**Long Grain** — Wood surfaces where the fibers run generally parallel to the surface, such as the face or edge of a board.

## M–P

**Medullary Ray / Wood Ray** — Cellular tissue extending outward from the center of a tree toward the bark.

**Miter Joint** — A joint created by joining angled surfaces, commonly two 45-degree cuts forming a 90-degree corner.

**Moisture Content** — The amount of water contained in wood relative to its oven-dry weight, expressed as a percentage.

**Mortise** — A recess or opening designed to receive a tenon.

**Mortise-and-Tenon Joint** — A joint in which a projecting tenon fits into a matching mortise.

**Nominal Thickness** — A named lumber size that may differ from the actual finished dimension, such as 4/4 hardwood.

**Pith** — The central portion of the tree around which the earliest growth occurs.

**Plan of Procedure (POP)** — A planned sequence of construction operations, often identifying the tools or machines required for each step.

**Planer** — A machine used to make one board face parallel to another and bring lumber to a controlled thickness.

**Plainsawn / Flatsawn** — Lumber cut with the growth rings oriented generally less than about 45 degrees to the board face.

**PVA Glue** — Polyvinyl acetate adhesive commonly used for woodworking. Titebond Original and Titebond III are examples used in WMT 101.

**Pushstick** — A device used to help control a workpiece while keeping the operator's hands farther from a cutter or blade.

## Q–S

**Quarter Notation** — The traditional system for describing rough hardwood thickness, such as 4/4, 6/4, and 8/4.

**Quartersawn** — Lumber cut so the growth rings are oriented more nearly perpendicular to the board face.

**Rabbet** — An L-shaped recess cut along the edge or end of a board.

**Random Widths and Lengths (RWL)** — A common way hardwood is sold, with individual boards varying in width and length.

**Rasp** — A hand-shaping tool with relatively large cutting teeth used to remove wood quickly.

**Reference Edge** — A straight, controlled edge used as a basis for later measurements and machining.

**Reference Face** — A flat surface used as a basis for later measurements and machining.

**Relief Cut** — A cut made into waste material to make a curved band-saw or jig-saw cut easier to complete.

**Resawing** — Cutting through the thickness of a board to produce thinner pieces.

**Riftsawn** — Lumber with growth rings oriented at approximately 45 degrees to the face.

**Rip Cut** — A cut made generally in the same direction as the wood grain.

**Rip Blade** — A circular saw blade designed primarily for cutting with the grain.

**Rip Fence** — The adjustable table-saw fence used to guide material during ripping.

**Rough Lumber** — Lumber that has not been surfaced smooth after sawing at the mill.

**Router** — A high-speed cutting tool used for shaping edges, following templates, trimming material, and cutting profiles, grooves, and other features.

**Router Table** — A stationary setup in which a router is mounted beneath a table with the bit projecting upward.

**Sapwood** — Younger outer wood that conducts water upward through a living tree.

**S1S / S2S / S3S / S4S** — Lumber-surfacing abbreviations meaning surfaced one, two, three, or four sides.

**Selects** — A hardwood lumber grade providing a high percentage of clear material, often in somewhat smaller board sizes than FAS.

**Shake** — A separation between growth rings.

**Softwood** — Wood from coniferous trees, or gymnosperms.

**Special Setup** — A machine operation outside normal use that requires instructor approval before the machine is operated.

**Split** — A crack extending completely through a board.

**Sticker** — A small dry strip placed between layers of stacked lumber to provide support and allow air circulation.

**Sticking** — Stacking lumber with aligned stickers between layers to support the boards and allow air circulation.

**Surfaced Lumber** — Lumber that has had one or more faces or edges machined smooth.

## T-W

**Tearout** — Damage caused when wood fibers lift and break ahead of a cutting edge.

**Tenon** — A projecting portion of a woodworking joint designed to fit into a mortise.

**Texture** — The relative size and uniformity of the cellular structure of wood.

**Throat Plate** — The removable plate surrounding a blade, bit, or spindle where it passes through a machine table.

**Triple Chip Grind (TCG)** — A saw blade tooth pattern using alternating tooth profiles, commonly used for manufactured materials and specialized cutting.

**Twist** — Warp in which the four corners of a board do not lie in the same plane.

**Wane** — Missing wood or remaining bark along the edge or corner of a board.

**Warp** — A general term for distortion in lumber, including bow, cup, crook, and twist.

**Wood Movement** — Dimensional change in wood caused primarily by changes in moisture content.

**Working Drawing** — A drawing that communicates enough information about a project's size, shape, parts, and construction for it to be built.



## 11.2: Review Questions

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Use these questions to review the major concepts introduced throughout WMT 101.

The questions are not intended to replace machine demonstrations, required safety testing, or hands-on practice.

### Safety and Shop Practice

1. When should you ask an instructor for help with a machine or setup?
2. Why are gloves prohibited while operating woodworking machinery?
3. What should you do if a machine makes an unusual sound or vibration?
4. What is a special setup?
5. Why is cleanup considered part of woodworking?

### Measurement, Wood, and Lumber

6. How many cubic inches are in one board foot?
7. What is the standard order for writing lumber dimensions?
8. What is the difference between hardwood and softwood?
9. What is the difference between heartwood and sapwood?
10. What is the difference between grain and figure?
11. Why does grain direction matter when machining wood?
12. What is moisture content?
13. What is the difference between plainsawn, riftsawn, and quartersawn lumber?
14. What do 4/4, 6/4, and 8/4 mean?
15. What does S4S mean?
16. What is the difference between bow, cup, crook, and twist?
17. Why should you normally buy more rough lumber than the calculated volume of the finished project parts?

### Preparing Lumber

18. What is tearout?
19. What is the main purpose of the radial arm saw in the WMT 101 milling sequence?
20. What are the two primary jobs of the jointer?
21. Why should the most stable side of a warped board be placed against the jointer table?
22. What does the planer do that the jointer does not?
23. Why must a board have one flat face before it is run through the planer?
24. Put these operations in the correct order: straighten one edge, plane to thickness, flatten one face, rough-cut to length.
25. Why is a board left slightly oversize during several stages of milling?

### Cutting and Shaping

26. What is the primary advantage of the band saw when compared with a table saw?
27. What is a relief cut?
28. Why should you leave the layout line visible during rough cutting?
29. Why might you drill a starter hole before making an interior jig-saw cut?
30. What is the difference between a rasp and a file?
31. Why should you use several light router cuts instead of one heavy cut?
32. Which stationary sander is commonly used for inside or concave curves?
33. Which side of a disc sander should be used?
34. Why should you avoid skipping too many abrasive grits?

## Saw Blades and Table Saw

- 35. What is the gullet of a circular saw blade?
- 36. What is kerf?
- 37. Why do rip blades usually have fewer teeth and larger gullets than crosscut blades?
- 38. What is the purpose of a combination blade?
- 39. What is the difference between ripping and crosscutting?
- 40. Which table-saw guide is normally used for ripping?
- 41. Which guide is normally used for crosscutting?
- 42. What is the purpose of a riving knife?
- 43. What is kickback?
- 44. Why should you never make a freehand table-saw cut?

## Joinery and Adhesives

- 45. What is a butt joint?
- 46. How is a half-lap joint constructed?
- 47. What is the difference between a dado and a rabbet?
- 48. What are the two parts of a mortise-and-tenon joint?
- 49. Why are long-grain glue joints generally stronger than simple end-grain glue joints?
- 50. What three broad factors influence the strength of a woodworking joint?
- 51. Why should a project be dry-fitted before glue is applied?
- 52. What is a caul?
- 53. Why is excessive clamp pressure unnecessary?

## Planning a Project

- 54. What three broad areas should a woodworker consider when evaluating a design?
- 55. What is the purpose of a working drawing?
- 56. What is the purpose of a Bill of Materials?
- 57. What is the difference between finished size and rough size?
- 58. What is the purpose of a Plan of Procedure?
- 59. What is relative dimensioning?
- 60. Why might the partially built project provide a better final dimension than the original drawing?
- 61. Why are test pieces useful?

## Tool Tote and Wood Movement

- 62. Why is the solid-wood bottom of the tool tote not glued into its grooves?
- 63. What is a floating panel?
- 64. Why should opposite sides of a box match each other closely even if they vary slightly from the theoretical drawing dimension?
- 65. Why should the tote be dry-fitted before final assembly?
- 66. Why is it useful to fit the handle after the risers have been located on the actual tote?

## Sanding and Finishing

- 67. Why does finish often make surface defects easier to see?
- 68. What should each successive abrasive grit accomplish?
- 69. Why is dried glue a problem during finishing?
- 70. What does it mean to raise the grain?
- 71. Why must wood be thoroughly dry before finish is applied?
- 72. Why should oil finishes be applied according to the specific product directions?
- 73. Where must oil-finish rags be disposed of in the WMT lab?

74. Why can oily rags become a fire hazard?

## Board-Foot Practice

75. Calculate the board footage of one piece of 4/4 lumber measuring 8 inches wide × 72 inches long.
  76. Calculate the board footage of two pieces of 5/4 lumber, each 7 inches wide × 48 inches long.
  77. Calculate the board footage of three pieces of 8/4 lumber, each 5 inches wide × 36 inches long.
  78. What is the cost of 6.5 board feet of lumber priced at \$9.50 per board foot?
  79. A project requires 12 board feet of calculated material. How much should you plan for if you add a 25% material allowance?
- 

## Answer Key

1. Whenever you are unsure about a machine, setup, material, or procedure, and whenever an operation requires instructor approval.
2. Gloves can become caught in moving machinery and can reduce control and dexterity.
3. Stop the machine safely and notify the instructor.
4. An operation outside normal machine use that requires instructor approval before operation.
5. A clean shop reduces hazards, protects equipment, improves workflow, and is part of professional practice.
6. 144 cubic inches.
7. Thickness × Width × Length.
8. Hardwood comes from broad-leaved angiosperms; softwood comes from coniferous gymnosperms. The terms do not directly describe physical hardness.
9. Sapwood is younger outer wood involved in water transport; heartwood is older central wood that no longer conducts sap.
10. Grain describes the arrangement and direction of wood structure; figure is the visible pattern created by grain and other characteristics.
11. Cutting with favorable grain generally reduces tearout and improves surface quality.
12. The amount of water in wood relative to its oven-dry weight, expressed as a percentage.
13. They describe different orientations of the growth rings relative to the board face.
14. Nominal rough hardwood thicknesses: 4/4 = 1 inch, 6/4 = 1 1/2 inches, and 8/4 = 2 inches.
15. Surfaced four sides.
16. Bow curves along the face lengthwise; cup curves across the face; crook curves along the edge; twist places the corners in different planes.
17. Additional material is needed for defects, milling loss, random widths, grain selection, test pieces, and possible mistakes.
18. Wood fibers lifting and breaking ahead of the cutter.
19. Rough crosscutting lumber to approximately the needed length.
20. Flattening a face and straightening/squaring an edge.
21. A stable surface reduces rocking and allows the jointer to remove the high areas until a flat reference surface is created.
22. The planer makes one face parallel to the reference face and brings the board to controlled thickness.
23. The planer follows the surface placed against its table. If that surface is warped, the planer may simply produce a warped board of even thickness.
24. Rough-cut to length → flatten one face → plane to thickness → straighten one edge.
25. Oversize material provides room for flattening, squaring, smoothing, and final fitting.
26. The narrow blade allows curved and irregular cuts.
27. A cut into waste material that helps divide the waste and allows the blade to follow a curve more easily.
28. The line preserves the intended final shape and leaves material for later refinement.
29. The starter hole allows the jig-saw blade to begin a cut inside the workpiece.
30. A rasp removes material more aggressively; a file generally cuts more finely.
31. Light cuts improve control, reduce stress on the tool, and usually produce a cleaner surface.
32. Oscillating spindle sander.
33. The downward-traveling side.
34. Each grit must remove the scratches from the previous grit. Skipping too far can leave deep scratches behind.
35. The space in front of each tooth that provides room for chips.
36. The width of the cut produced by the blade.
37. Ripping produces larger chips that need more space for removal.
38. To provide a useful balance between ripping and crosscutting.

39. Ripping runs generally with the grain; crosscutting runs across it.
40. Rip fence.
41. Crosscut sled or miter gauge.
42. It helps prevent the kerf from closing around the rear of the blade and reduces kickback risk.
43. Loss of control in which a workpiece is thrown by the saw with considerable force.
44. The workpiece must be controlled by an appropriate fence, sled, miter gauge, jig, or other approved guide.
45. A simple joint in which prepared surfaces meet directly.
46. Approximately half the thickness is removed from each of two overlapping parts.
47. A dado is located within the surface of a board; a rabbet is an L-shaped recess at an edge or end.
48. Mortise and tenon.
49. Long-grain surfaces provide more effective adhesive contact than a simple end-grain connection.
50. Mechanical properties, adhesive surface area, and grain orientation.
51. To check fit, alignment, squareness, clamps, and assembly sequence before working time becomes limited.
52. A temporary piece used to distribute pressure, maintain alignment, or protect a surface during clamping.
53. The goal is full contact between mating surfaces. Excessive pressure can distort the assembly, damage the wood, or cause parts to shift.
54. Function, appearance, and construction/craftsmanship.
55. To communicate enough information about the project's size, shape, parts, and construction for it to be built.
56. To identify the required parts, materials, quantities, dimensions, and material requirements.
57. Finished size is the required completed dimension; rough size includes additional material needed for milling and fitting.
58. To organize the construction operations into a logical sequence.
59. Determining dimensions from relationships between actual parts rather than relying only on numerical measurements.
60. Normal machining and assembly variations can make the actual project a more accurate reference for later-fitting parts.
61. They allow setups, joints, cuts, and techniques to be tested before risking finished project material.
62. The solid-wood bottom must be allowed to expand and contract across the grain.
63. A solid-wood panel held in a frame or grooves while remaining free to move with moisture changes.
64. Matching opposite parts helps the assembly remain square even if the finished dimension varies slightly from the original plan.
65. To verify all joints, the bottom, risers, handle, squareness, and assembly sequence before glue is applied.
66. The actual riser spacing provides the most useful final dimension for the handle.
67. Clear finish increases contrast and often reveals scratches, glue, dents, and uneven sanding.
68. Remove the scratches produced by the previous grit.
69. Glue can prevent finish from penetrating evenly and may appear as a pale or uneven area.
70. Lightly wetting the wood so loose surface fibers swell, allowing them to be cut off after the wood dries.
71. Moisture trapped in the wood can interfere with finish performance.
72. Different oil products have different formulations, application methods, drying times, and coat requirements.
73. In the approved red metal oily-rag waste container with a lid.
74. Drying oils cure through oxidation and generate heat; piled oily rags can accumulate enough heat to ignite.
75. 4 board feet ( $1 \times 8 \times 72 \div 144 = 4$ )
76. Approximately 5.83 board feet ( $2 \times 1.25 \times 7 \times 48 \div 144 = 5.83$ )
77. 7.5 board feet ( $3 \times 2 \times 5 \times 36 \div 144 = 7.5$ )
78. \$61.75 ( $6.5 \times \$9.50 = \$61.75$ )
79. 15 board feet ( $12 \times 1.25 = 15$ )

## 11.3: Additional Woodworking Resources

---

### 11.3 Additional Woodworking Resources

WMT 101 is an introduction. Woodworking includes many additional materials, tools, processes, specialties, and approaches that cannot be covered fully in one course.

The following resources can help you continue learning.

#### WMT Wood Lab Safety Manual

The **WMT Wood Lab Safety Manual** contains the machine-specific safety requirements and operating limits used in the Cerritos College woodworking labs.

The manual, instructor demonstrations, required safety testing, and machine checkouts always take precedence over general information in this resource when you are working in the WMT lab.

#### Introduction to Woodworking Machines

Peter Scheidt's *Introduction to Woodworking Machines* provides additional explanations of common woodworking machines, machine parts, and woodworking operations.

**Scheidt, Peter. *Introduction to Woodworking Machines*. Iowa State University Digital Press ([opens new window](#)).**

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#### Additional Reading

The following books provide useful opportunities for deeper study.

**Carpenter, Tom, editor. *The Complete Book of Woodworking*.**

A broad introduction to tools, techniques, shop practices, and woodworking projects.

**Hoadley, R. Bruce. *Understanding Wood: A Craftsman's Guide to Wood Technology*.**

A detailed reference on wood structure, moisture, movement, and material behavior.

**Jackson, Albert, David Day, and Simon Jennings. *The Complete Manual of Woodworking*.**

A highly visual reference covering tools, joinery, materials, and woodworking processes.

**Korn, Peter. *Woodworking Basics: Mastering the Essentials of Craftsmanship*.**

A project-based introduction emphasizing fundamental skills, accuracy, and craftsmanship.

**Molzahn, Patrick A., William D. Umstattd, and Charles W. Davis. *Modern Cabinetmaking*.**

A comprehensive textbook covering woodworking technology, machinery, cabinetry, construction, and professional practices.

**Pekovich, Michael. *The Why and How of Woodworking: A Simple Approach to Making Meaningful Work*.**

A resource connecting design decisions, craftsmanship, workflow, and the experience of making furniture.

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#### References Consulted During Development

Carpenter, T. (Ed.). (2001). *The complete book of woodworking*. Landauer Publishing.

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Hoadley, R. B. (2000). *Understanding wood: A craftsman's guide to wood technology* (2nd ed.). Taunton Press.

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Pekovich, M. (2018). *The why and how of woodworking: A simple approach to making meaningful work*. Taunton Press.

Scheidt, P. (2026). *Introduction to woodworking machines*. Iowa State University Digital Press. ([Link to resource, opens new window](#))

#### Cerritos College WMT Instructional Materials

Machine photographs, woodworking diagrams, measurement exercises, lumber illustrations, saw-blade diagrams, project drawings, and related instructional graphics in this resource were originally developed by faculty in the **Cerritos College Woodworking Manufacturing Technologies program** for departmental instructional materials and the WMT Wood Lab Safety Manual over multiple decades.

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## INDEX

No index terms found.

## GLOSSARY

### A

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#### **Abrasive**

|

A hard cutting material used to remove small amounts of material from a surface. Sandpaper is made by attaching abrasive particles to a backing.

#### **Air Drying**

|

Drying lumber by stacking it so natural air can circulate around the boards.

#### **Alternate Top Bevel (ATB)**

|

A circular saw blade tooth grind in which alternating teeth are beveled in opposite directions. Commonly used for crosscutting.

#### **Alternate Top Bevel with Raker (ATBR)**

|

A saw blade tooth arrangement combining alternating beveled teeth with a flat-topped raker tooth. Commonly used on combination blades.

### B

---

#### **Band Saw**

|

A woodworking machine that uses a continuous narrow blade running over wheels. Used for curved cuts, rough shaping, ripping, and resawing.

#### **Bark**

|

The protective outer covering of a tree.

#### **Bill of Materials (BOM)**

|

A list of the parts and materials required for a project, often including quantities, dimensions, rough sizes, board footage, and cost.

#### **Board Foot**

|

A unit used to measure hardwood volume. One board foot equals 144 cubic inches.

### **Bow**

|

Lengthwise curvature along the face of a board.

### **Butt Joint**

|

A joint in which two prepared surfaces meet directly without interlocking joint geometry.

## **C**

---

### **Cambium**

|

The growing layer of a tree that produces new wood and bark.

### **Caul**

|

A temporary piece used during clamping to distribute pressure, maintain alignment, or protect a project surface.

### **Check**

|

A crack running along a board that does not extend completely through to the opposite face.

### **Combination Blade**

|

A circular saw blade designed to perform both ripping and crosscutting reasonably well.

### **Concave**

|

Curving inward.

### **Convex**

|

Curving outward.

### **Crook**

|

Lengthwise curvature along the edge of a board. Sometimes called crown.

### **Crosscut**

|

A cut made generally across the direction of the wood grain.

### **Crosscut Blade**

|

A circular saw blade designed primarily for cutting across the grain.

### **Crosscut Sled**

|

A table-saw accessory that supports and guides a workpiece accurately across the blade.

### **Cup**

|

Curvature across the width of a board.

## **D**

---

### **Dado**

|

A groove or recess cut across the surface of a board to receive another part.

### **Density**

|

The weight of a material relative to its volume.

### **Dry Fit**

|

Assembling parts without adhesive to check fit, alignment, squareness, and assembly sequence.[Edit section](#)

## **E**

---

### **Earlywood**

|

The portion of a growth ring produced earlier in the growing season. It generally has larger cells and lower density.

### **Edge**

|

One of the narrow longitudinal surfaces of a board.

**End**

|

The surface across the end of a board where end grain is visible.

**End Grain**

|

The exposed ends of wood fibers, usually visible at the ends of a board.

**Expansion Slot**

|

A slot cut into a circular saw blade plate to help control distortion caused by heat.

**F**

---

**Face**

|

One of the two broad surfaces of a board.

**Face Grain**

|

Grain visible on the broad face of a board.

**FAS**

|

Firsts and Seconds, a high hardwood lumber grade intended to provide a large percentage of clear usable material.

**Figure**

|

The visible pattern created by grain, growth structure, color, rays, and other characteristics of wood.

**File**

|

A hand tool with cutting teeth used to refine and smooth wood or other materials.

**Flat Top Grind (FTG)**

|

A saw blade tooth grind with flat-topped teeth, commonly used for ripping.

**Floating Panel**

|

A solid-wood panel fitted into a frame or groove without being glued around its perimeter so it can expand and contract.

## G

---

### Grain

|

The arrangement and direction of wood fibers and growth structure.

### Groove

|

A recessed channel cut generally in the same direction as the grain.

### Growth Ring

|

Wood produced during approximately one year of tree growth.

### Gullet

|

The open space in front of a saw blade tooth that provides room for chip removal.[Edit section](#)

## H

---

### Half-Lap Joint

|

A joint in which approximately half the thickness is removed from each of two overlapping parts.

### Hardwood

|

Wood from broad-leafed trees, or angiosperms. The term describes botanical classification rather than actual hardness.

### Heartwood

|

Older central wood in a tree that no longer conducts sap and is often darker than sapwood.

### Hook or Rake Angle

|

The angle of the front face of a saw tooth relative to a radial line through the blade.

## J

---

### **Jig**

|

A device used to guide a tool or workpiece during a specific operation.

### **Jig Saw**

|

A portable saw with a narrow reciprocating blade used for curved, irregular, and interior cuts.

### **Jointer**

|

A machine used primarily to flatten the face of a board and straighten and square an edge.

## K

---

### **Kerf**

|

The width of a cut made by a saw blade.

### **Kiln Drying**

|

Drying lumber in a controlled environment using circulated heated air.

### **Knot**

|

A portion of a branch or limb contained within lumber.

## L

---

### **Latewood**

|

The denser portion of a growth ring formed later in the growing season.

### **Long Grain**

|

Wood surfaces where the fibers run generally parallel to the surface, such as the face or edge of a board.[Edit section](#)

## M

---

### **Medullary Ray / Wood Ray**

|

Cellular tissue extending outward from the center of a tree toward the bark.

### **Miter Joint**

|

A joint created by joining angled surfaces, commonly two 45-degree cuts forming a 90-degree corner.

### **Moisture Content**

|

The amount of water contained in wood relative to its oven-dry weight, expressed as a percentage.

### **Mortise**

|

A recess or opening designed to receive a tenon.

### **Mortise-and-Tenon Joint**

|

A joint in which a projecting tenon fits into a matching mortise.

## **N**

---

### **Nominal Thickness**

|

A named lumber size that may differ from the actual finished dimension, such as 4/4 hardwood.

## **P**

---

### **Pith**

|

The central portion of the tree around which the earliest growth occurs.

### **Plainsawn / Flatsawn**

|

Lumber cut with the growth rings oriented generally less than about 45 degrees to the board face.

### **Plan of Procedure (POP)**

|

A planned sequence of construction operations, often identifying the tools or machines required for each step.

### **Planer**

|

A machine used to make one board face parallel to another and bring lumber to a controlled thickness.

### **Pushstick**

|

A device used to help control a workpiece while keeping the operator's hands farther from a cutter or blade.[Edit section](#)

### **PVA Glue**

|

Polyvinyl acetate adhesive commonly used for woodworking. Titebond Original and Titebond III are examples used in WMT 101.

## **Q**

---

### **Quarter Notation**

|

The traditional system for describing rough hardwood thickness, such as 4/4, 6/4, and 8/4.

### **Quartersawn**

|

Lumber cut so the growth rings are oriented more nearly perpendicular to the board face.

## **R**

---

### **Rabbet**

|

An L-shaped recess cut along the edge or end of a board.

### **Random Widths and Lengths (RWL)**

|

A common way hardwood is sold, with individual boards varying in width and length.

### **Rasp**

|

A hand-shaping tool with relatively large cutting teeth used to remove wood quickly.

### **Reference Edge**

|

A straight, controlled edge used as a basis for later measurements and machining.

### **Reference Face**

|

A flat surface used as a basis for later measurements and machining.

### **Relief Cut**

|

A cut made into waste material to make a curved band-saw or jig-saw cut easier to complete.

### **Resawing**

|

Cutting through the thickness of a board to produce thinner pieces.

### **Riftsawn**

|

Lumber with growth rings oriented at approximately 45 degrees to the face.

### **Rip Blade**

|

A circular saw blade designed primarily for cutting with the grain.

### **Rip Cut**

|

A cut made generally in the same direction as the wood grain.

### **Rip Fence**

|

The adjustable table-saw fence used to guide material during ripping.

### **Rough Lumber**

|

Lumber that has not been surfaced smooth after sawing at the mill.

### **Router**

|

A high-speed cutting tool used for shaping edges, following templates, trimming material, and cutting profiles, grooves, and other features.

### **Router Table**

|

A stationary setup in which a router is mounted beneath a table with the bit projecting upward.

**S1S / S2S / S3S / S4S**

|

Lumber-surfacing abbreviations meaning surfaced one, two, three, or four sides.

**Sample Word 1** | Sample Definition 1

**Sapwood**

|

Younger outer wood that conducts water upward through a living tree.

**Selects**

|

A hardwood lumber grade providing a high percentage of clear material, often in somewhat smaller board sizes than FAS.

**Shake**

|

A separation between growth rings.

**Softwood**

|

Wood from coniferous trees, or gymnosperms.

**Special Setup**

|

A machine operation outside normal use that requires instructor approval before the machine is operated.

**Split**

|

A crack extending completely through a board.

**Sticker**

|

A small dry strip placed between layers of stacked lumber to provide support and allow air circulation.

**Stickering**

|

Stacking lumber with aligned stickers between layers to support the boards and allow air circulation.

## Surfaced Lumber

|

Lumber that has had one or more faces or edges machined smooth.[Edit section](#)

## T

---

### Tearout

|

Damage caused when wood fibers lift and break ahead of a cutting edge.

### Tenon

|

A projecting portion of a woodworking joint designed to fit into a mortise.

### Texture

|

The relative size and uniformity of the cellular structure of wood.

### Throat Plate

|

The removable plate surrounding a blade, bit, or spindle where it passes through a machine table.

### Triple Chip Grind (TCG)

|

A saw blade tooth pattern using alternating tooth profiles, commonly used for manufactured materials and specialized cutting.

### Twist

|

Warp in which the four corners of a board do not lie in the same plane.

## W

---

### Wane

|

Missing wood or remaining bark along the edge or corner of a board.

### Warp

|

A general term for distortion in lumber, including bow, cup, crook, and twist.

**Wood Movement**

|

Dimensional change in wood caused primarily by changes in moisture content.

**Working Drawing**

|

A drawing that communicates enough information about a project's size, shape, parts, and construction for it to be built.

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