# Apply Your Knowledge

1. Choose three objects you use every day that are made of different materials. State whether the materials used are appropriate for the item. Explain your answer.
2. Collect pictures of objects that are made of layered, fiber, and particle composites. Label the pictures to name the materials used in each composite.
3. Work with two or three classmates to collect samples of five different materials. Choose one material property. As a team, design and build an apparatus to test the materials for the property you have chosen.
4. Search the Internet to find three current applications for smart materials. Write a report describing these applications.
5. Research one career related to the information you have studied in this chapter. Create a report that states the following:
   - The occupation you selected
   - The education requirements to enter this occupation
   - The possibilities for promotion to a higher level
   - What someone with this career does on a daily basis
   - The earning potential for someone with this career

   You might find this information on the Internet or in your library. If possible, interview a person who already works in this field to answer the five points. Finally, state why you might or might not be interested in pursuing this occupation when you finish school.

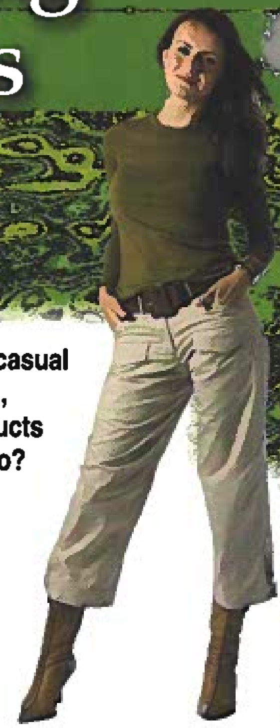
# STEM Applications

1. **SCIENCE** Describe the fundamental difference between thermoplastics and thermoset plastics in terms of the way their molecular chains are formed. Create models of the molecular structures to illustrate this concept.
2. **ENGINEERING** Research the materials used in tires made for specific purposes, such as winter use, summer use, or running while flat. Create a diagram that clearly shows the layers of material used in one type of tire and explain why engineers chose each material.

CHAPTER 5

# Processing Materials

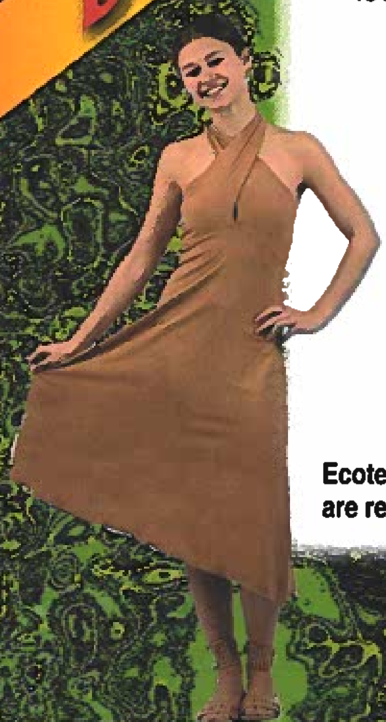
## Better by Design



Bamboo is very suitable for casual clothing. What other clothing, recreational, and home products could be made using bamboo?

### Bonnie Siefers

Bonnie Siefers is an American fashion designer and eco-designer who believes that clothing must look chic and feel luxurious. But Bonnie also believes that fashion designers have a responsibility toward the environment and must begin to use certified organic or eco-friendly fabrics (ecotextiles). So Bonnie designs apparel made from ecoKashmere®, a soft, silky fabric that incorporates the pulp of bamboo grass. The result is clothes that are soft and flowing. Also, because bamboo absorbs water rapidly, it produces fabrics that "wick" moisture at twice the rate of cotton. Bamboo-based fabrics are also highly breathable, anti-static, and naturally antibacterial, making them helpful to people with sensitive or allergy-prone skin.



Ecotextiles such as bamboo, flax, cotton, and jute are renewable, biodegradable, and sustainable.

*"A pure, natural environment is vital to children of all ages. Organic [textiles] are not only gentle on the skin, but also safer for the people who make the clothes, for the farmers who grow the crops, and for the environment."* —Bonnie Siefers

## Reading Target

### Summarizing Information

A *summary* is a short paragraph that describes the main idea of a selection of text. Making a summary can help you remember what you read. As you read each section of this chapter, think about the main ideas presented. Then use the Reading Target graphic organizer at the end of the chapter to summarize the chapter content.

## Key Terms

*adhesion*
*bending*
*casting*
*chemical joining*
*chiseling*
*coatings*
*cohesion*
*development*
*drilling*
*filing*
*finishing*
*forming*
*heat joining*
*jig*
*laminating*
*marking out*
*mechanical joining*
*molding*
*planing*
*sawing*
*shearing*
*volatile organic compounds (VOCs)*

## Objectives

After reading this chapter, you will be able to:

- Demonstrate responsible and safe work attitudes and habits.
- Design and shape a product using the correct tools and processes.
- Select the correct materials and methods for joining materials.
- Recall methods for applying a finish to a material.

**Useful Web sites:**
www.jonano.com
www.bambooclothing.co.uk/why_is_bamboo_better.html

The tools and equipment needed to make a product depend on the design and the materials to be used in the product. This chapter describes the types of tools needed to shape various types of materials. Before you actually use the tools, however, you must learn how to use them safely.

# Learning to Work Safely

As you design and make products, you will use various materials, hand tools, and machine tools. General rules for safety are included in Appendix B. You should also follow the manufacturer's instructions carefully to help avoid injury. However, you can also take an active role in your own safety by planning carefully. To avoid hurting yourself or others or damaging tools or equipment, you need to learn about:

- Hazard identification
- Risk identification
- Risk management

This means that before using any tool or machine, you should ask yourself the following questions:

- What are the hazards?
- What are the risks?
- How will I manage these risks?

For example, when you are using a band saw, the hazards are the sharp stationary blade and moving blades. The risks are that you can cut your fingers, both on the stationary blade and even more seriously on the moving blade. Also, long hair or loose clothing can become entangled in the moving blade. You can manage these risks keeping your fingers at least four inches (10 cm) away from the blade, tying your hair back, and not wearing loose clothing or jewelry.

This approach to working safely is applicable every time you use a hand tool, a machine tool, and materials. It also applies to situations you will encounter at home or elsewhere. Working safely is your responsibility!

# Shaping Materials

When you have designed your product and have chosen the material, you are ready to make the product by following several carefully thought-out steps. These steps include marking out, cutting and shaping, joining and finishing.

# Technology Application

## Game Design

All products are designed with safety in mind, and safety factors are foremost in the mind of designers. Power tools have guards to protect the operator from moving blades or belts. Motorized vehicles need keys and often pressure on the brake pedal to start them. A lawn mower automatically stops if the handle is released.

Safety is equally important for items used in the kitchen. Although kitchen tools and equipment are designed for safe use, there is always an element of danger and a need for the user to be cautious and alert.

### Technology Activity

One of the primary safety problems in a kitchen occurs when small children are present. Children often don't know when or where danger exists. Your task is to design and make a game similar to Chutes and Ladders® to teach young children, 2 to 4 years old, the dangers of touching items found in the kitchen. Follow these steps:

1. On an 8½ × 11 sheet of graph paper, draw nine vertical lines and nine horizontal lines to create a grid of 1-inch squares. You will have a total of 64 squares.
2. Think of four things that a young child might do that could result in an accident; for example, "grabbing the blade of a sharp knife."
3. Think of four things that a young child might do to avoid an accident; for example, "staying away from a hot stove."
4. Decide on the length of four chutes and four ladders and draw them on the game, spacing them out evenly.
5. Print the accident-causing and accident-avoiding messages in small letters in the appropriate squares. The events that might result in an accident will be in the square at the top of a chute. The events that could avoid an accident will be in the square at the bottom of a ladder.
6. Design at least two player pieces to be used in the game. How will you make them? Be sure to take the age of the children into consideration when you specify the size of the pieces. They must not be a choking hazard.
7. Decide on a way to determine the number of squares a player advances.
8. Ask a friend or classmate to help you test the game by playing it.
9. Based on your experience and your classmate's comments, decide how you can improve this board game. Should you add art? How could you make the game board more durable?

# Marking Out

The first step in making a product is called *marking out*. Marking out involves measuring material and marking it to the dimensions on your drawing. You should do this carefully for two reasons. First, your marks must be accurate so that the pieces fit together. Second, materials are expensive. Making mistakes wastes time and money.

Most marking out starts from a straight edge. To make a straight edge on wood, a plane is used. Plastic and metal are filed. When wood is used, this edge is the face edge, and the best side is the face side. See Figure 5-1. Lines should be easily seen. To be accurate, they must be thin. They should be marked as shown in Figure 5-2.

# Sawing

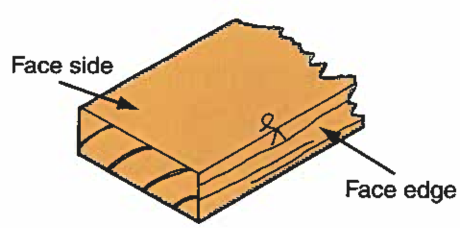
*Sawing* removes material quickly. All saws have a row of teeth. They chip or cut away the material. The part of the tool that cuts must be harder than the material being cut. Some saws are designed for cutting wood and others for cutting metal. See Figure 5-3. Plastics and composites are usually cut using saws designed for cutting wood and metal.

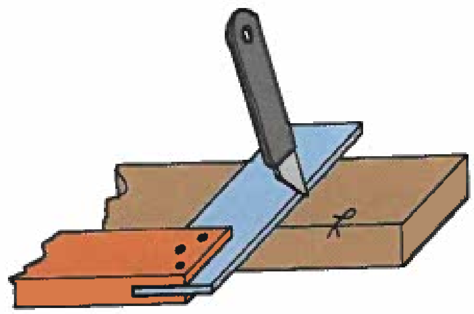
# Filing and Planing

Small amounts of material may be removed by *filing* and *planing*, as shown in Figure 5-4. Files are mainly used on metal. A special type of file, called a *rasp*, is used on wood. Most filing is done while the work is held in a vise. In straight or cross filing, you push the file across the work straight ahead or at a slight angle. Never run your fingers over a newly filed surface. Sharp burrs on the workpiece may cause a severe cut.

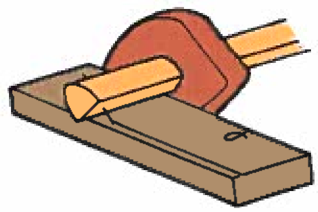
Various types of planes produce smooth, flat surfaces on wood. Planing requires that the wood piece be held in a vise. When properly adjusted, a plane should take off fine shavings from the piece of wood. Planing removes the small ridges left by a power planer or saw. This saves having to remove them with sandpaper—a slower process.

**Figure 5-1.** Mark lumber on both the face side and the face edge.

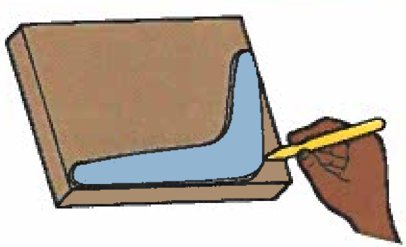




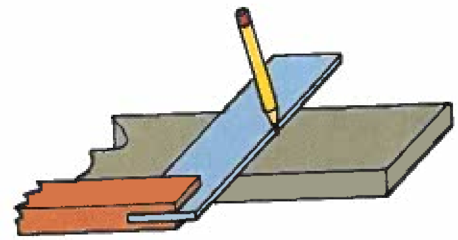
**Marking wood to length**
Use a try square.
Hold the handle firmly against the face edge of the wood.
Mark a line with a marking knife.
Always use the outside edge of the square.



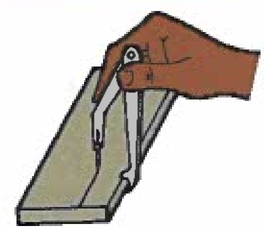
**Marking wood to width**
Use a marking gauge.
Press the stock of the gauge firmly against the wood.
Tilt the gauge in the direction you will push it.
Practice on scrap wood (the gauge is a difficult tool to use).



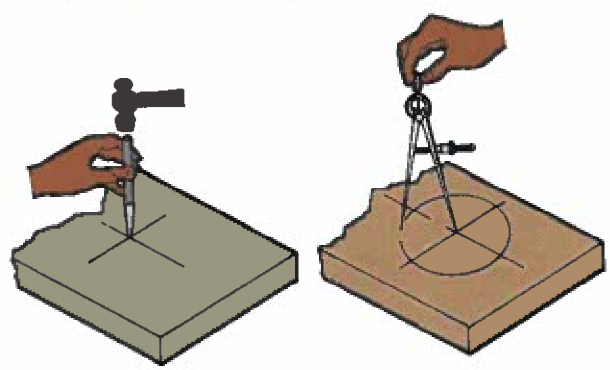
**Using templates for irregular shapes**
Draw and cut out the shape in paper or cardboard. This is called a *template.*
Hold the template to the material and draw carefully around it.
When drawing on wood, take careful note of the grain direction.
When many pieces of the same shape are to be made, use masonite to make the template.



**Marking metal to length**
Coat the metal with marking blue.
Use an engineer's square.
Hold the handle firmly against the straight edge of the metal.
Mark a line using a scriber.
Always work on the outside of the square.

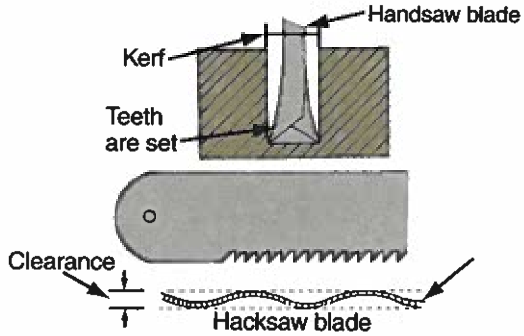


**Marking metal to width**
Use an odd-leg caliper.
Press the stepped leg of the caliper against the straight edge.

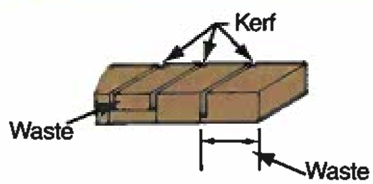


**Drawing circles**
Mark the center of the hole with a center punch on metal and an awl on wood.
Use a compass on wood.
Use dividers on metal.

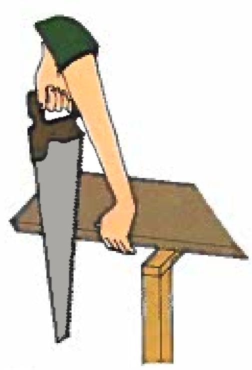
**Figure 5-2.** Procedures for marking out.



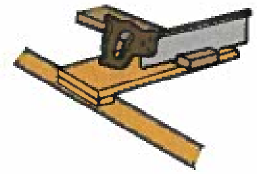

**Saws need clearance**
Teeth are bent in alternative directions; this is called *set*.
The kerf made by the teeth is wider than the blade thickness.
Teeth usually point away from the handle and material is cut on the push stroke.
The teeth on hacksaw blades are too small to be set. Clearance is achieved by stamping a wavy edge on the blade.




**Sawing techniques**
Never cut on the line; the kerf is made touching the line but on the waste side.
Stand with your hand and arm in line with the saw cut.
Use your thumb at the side of the blade when you start the cut.
Always use the full length of the blade.
At the end of the cut, support the work underneath.



**Using a handsaw**
Used for first cutting wood to approximate size.
There are two types: cross cut and rip.
A cross cut saw has finer teeth and is used for cutting across the grain.
A rip saw has larger teeth and is used for cutting parallel to the grain.

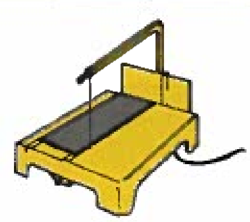


**Sawing wood accurately**
A tenon saw is used to make straight, accurate cuts in wood.
Always use a bench hook, held firmly in the vise.

**Coping saw**
Used to make curved cuts through wood and plastic.
Teeth point toward the handle; cuts on the pull stroke.

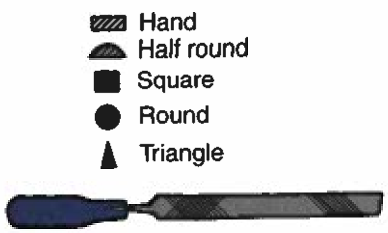
**Hacksaw**
Used to make straight cuts through metal and plastic.
Make sure at least three teeth are in contact with the material all the time.
Use small teeth for hard materials and large teeth for soft materials.
**Junior hacksaw**
Small and inexpensive.
Useful for cutting thin metals and light sections.

**Abrafile (rod saw)**
Used to make curved cuts through metal, plastic, and ceramics.
The blade is like a file and is held in a hacksaw frame.
The cutting edge is made of tungsten carbide particles bonded to a steel rod.

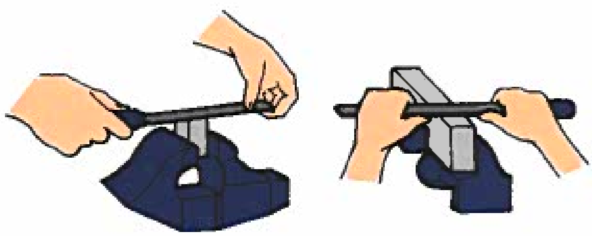


**Hot wire cutter (an alternative to sawing)**
Heated wire cuts straight and curved shapes in rigid foam plastic.
Must be used in a well-ventilated area as fumes are produced.

**Figure 5-3.** These tools are used for cutting operations.

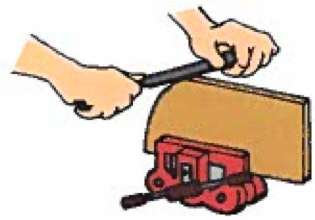



**Files**
Used to remove small particles of metal and plastic.
Double-cut files remove metal faster but make a rougher surface.
Single cut files produce a smooth surface.
Each shape is available in many sizes and degrees of coarseness.
Always use a file with a handle.

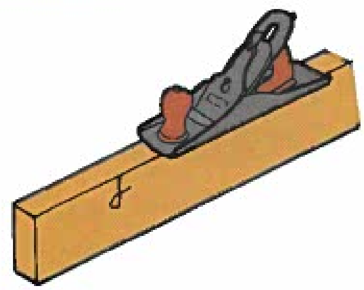


**Using a file**
For normal filing, hold the file at each end; it only cuts on the forward stroke (cross filing).
To produce a very smooth finish, push the file sideways (draw filing).

**Cleaning a file**
Small pieces of metal sometimes stick in the teeth of the file; this is known as *pinning*.
A special wire brush called a *file card* is used to clean the file.
Keeping the file clean is particularly important when filing plastic.



**Rasps**
Similar to coarse files.
Used for rough shaping free-form, sculptured shapes.



**Planes**
Used to remove a thin layer of wood (shaving).
A short plane, called a smoothing plane, is used on short pieces of wood.
A longer plane, called a jack plane, is used on longer pieces of wood.
Always plane in the direction of the grain.

**Surforms**
Are held like files and rasps but cut like planes.
Cut wood quickly but leave a rough surface.

**Figure 5-4.** Filing and planing tools are used to shape and smooth materials.

## Shearing and Chiseling

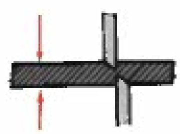
*Shearing* and *chiseling* are other techniques used to shape materials. These tasks require shears and chisels. Shears, also called *snips*, cut thin metals. Chisels are designed to cut wood or metal. See **Figure 5-5**.

Snips are designed for various kinds of cuts. A straight snips cuts straight lines and large curves. For cutting curves and intricate designs, an aviation snips or a hawk-billed snips is best.

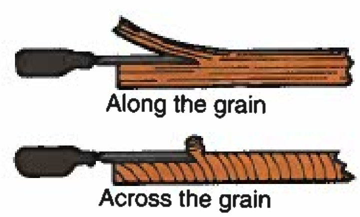
Chisels must be designed for the type of material on which they are to be used. Wood chisels have very sharp cutting edges so they will cut rather than tear the wood. Metal-cutting chisels have thicker, tougher cutting edges.

## Drilling

*Drilling* is a process used to make holes in wood, plastic, metal, and other materials. A drill cuts while turning. Twist drills for cutting metals are made of carbon steel, high-speed alloy steel, and titanium. Twist drills are also used to bore holes in woods and plastics. **Figure 5-6** shows some types of drills and how to use them.

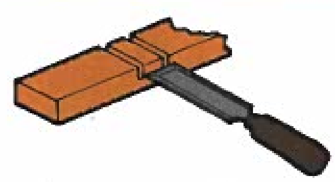


**Cutting action of shears (snips)**
Two blades are used like scissors to cut thin metal.



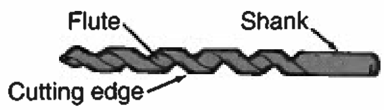

**Cutting action of wood chisel**
Chisel edge is straight and sharp.
Cutting action is like that of a wedge.
When chiseling along the grain, there is a greater possibilty the wood will split.

**Shearing technique**
Mainly used to cut tin plate, aluminum, and copper sheet.
To operate, use like scissors.
Alternatively one arm of the shears can be fastened in a vise while pressure is applied to the other arm.
Do not put the sheet all the way back into the shears.
Do not close the shears completely when cutting.



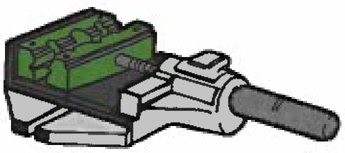
**Wood chiseling techniques**
Make sure wood is firmly clamped.
Keep both hands behind the cutting edge.
Never cut toward your body.
When cutting across the grain, first make two saw cuts at the limits of the groove, then chisel from both sides toward the center.

**Figure 5-5.** Shearing and chiseling tools are used to shape materials.

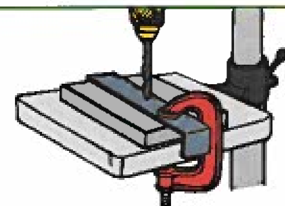



**Cutting action of drill**
Drills cut by rotating a cutting edge into a material.
A twist drill has a cutting edge, a spiral groove (the flute) to release the chips, and a straight shank to hold the drill in a chuck.

**Portable electric drill**
Clamp small pieces of material in a vise.
Center punch the location of the hole.
Place a small piece of wood on the underside to prevent splitting.
Do not bend the drill sideways or you will snap the drill bit.

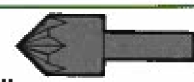


**Drilling technique**
Mark the point you want to drill.
Use a center punch on metal.
Never hand-hold work to drill; hold work in a vise or a clamp.
Place waste wood under the work to prevent damaging the bench after the drill has gone through; this also prevents the material from cracking away.
When drilling deep holes, remove the drill from the hole from time to time to avoid clogging and overheating.



**Drill press**
Remember that work is always held in a machine vise or clamp.
Always wear eye protection.
The speed can be adjusted: the larger the drill bit, the slower it should turn.
Place a piece of scrap wood under the workpiece to protect the table.

**Hand drill**
Concentrate on keeping the drill vertical.
Turn the handle at a steady speed, trying not to wobble the drill.



**Countersink drill**
Used to open out the end of a hole so that a flathead screw will fit flush with the surface.

**Holesaw**
Used to drill large holes in wood up to 3/4 in. (18 mm) thick.
Very useful for making discs or wheels.

**Figure 5-6.** Hand and electric tools for drilling holes and the techniques for using them.

# Bending and Forming

*Bending* and *forming* are two different processes. Bending sheet material is like folding paper along a straight, sharp crease. It is also quite easy to bend it along a gentle curve.

However, forming sheet material is more difficult. Forming changes the shape of sheet material into a more complex shape, such as a dome. It often involves using a mold or heating the material. Take a flat sheet of paper and try to form it into a dome. That is much harder than bending, isn't it? The sheet should bend and curve in many directions, but it tends to crease and buckle. See Figure 5-7.

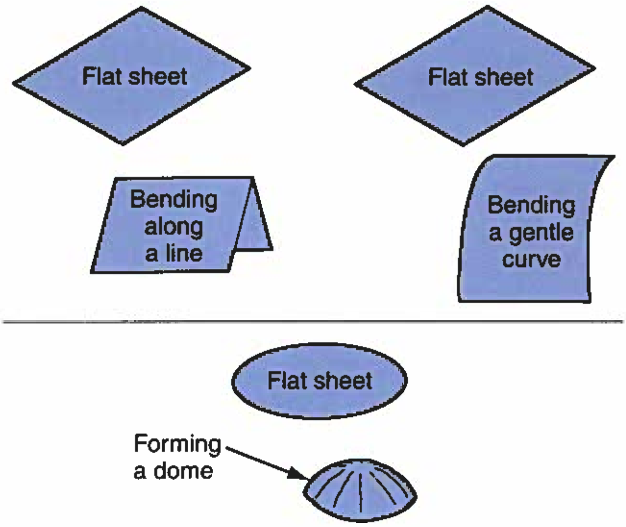



**Figure 5-7.** Sheet material bends or curves easily in one direction. Forming, or bending in several directions at the same time, is more difficult.

## *Wood*

Wood does not bend easily. One way to create a curved shape from wood is to cut the curve out of a thick, solid block as shown in **Figure 5-8A**. The problem is that the curved piece would break easily because of the short grain on the curved sections. The part made this way would be weak. But there is another way: laminating. This avoids the problem of short grain.

***Laminating*** is the process of gluing together several veneers (thin sheets of wood). See **Figure 5-8B**. These can be easily bent, glued, and held in a mold until the glue dries. The steps for laminating are:

1. Make a mold, as shown in **Figure 5-8C**. The two parts must fit together exactly.
2. Veneers vary in thickness. Calculate the number of veneers you will need to get the right thickness of laminate.
3. Clamp all of the veneers together without glue. If they don't bend easily, dampen the veneers and leave them clamped in the mold overnight. See **Figure 5-8D** and **Figure 5-8E**.
4. Completely cover the surfaces of the veneers with glue. Do not glue the outside surface of the top and bottom pieces or they will be permanently attached to the mold! Use a resin adhesive that becomes rigid when it sets. Avoid using contact cement or PVA, which remains rubbery. Once the glue has dried, the laminated wood will hold its shape. The glue keeps it from springing back to its old shape.
5. To prevent the veneers from sticking to the mold, wrap them in wax paper or a thin plastic sheet.
6. Use a thin rubber sheet between the mold and the veneers. This will take up any irregularities in the mold surface. It will also ensure even pressure over the entire surface of the mold.

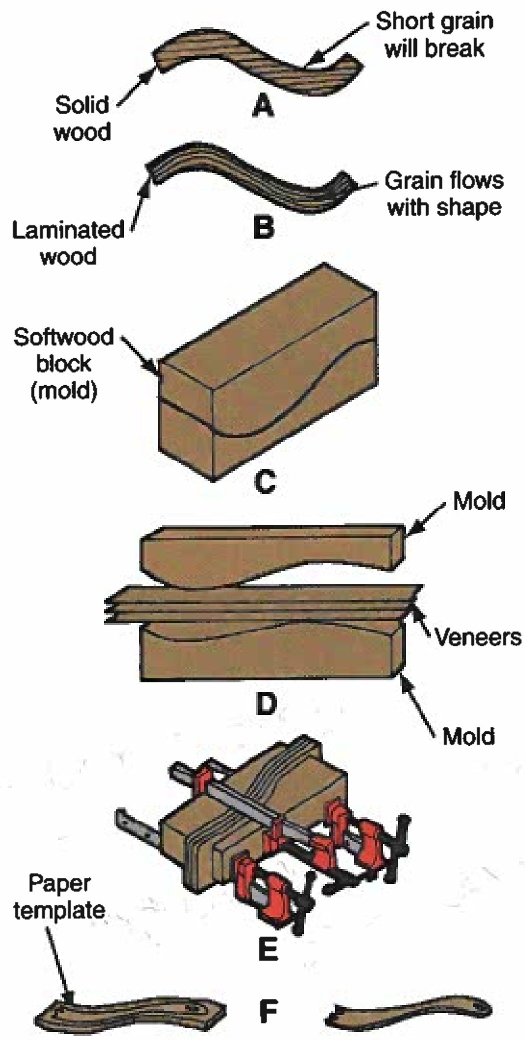



Figure 5-8. Laminating produces stronger parts than sawing the curved shapes out of solid wood.

7. Use bar clamps, Figure 5-8E, to squeeze the mold together until the glue is forced out along the edges of the veneer.
8. As shown in Figure 5-8F, make a template of the shape you want. Either glue it to the laminate or mark around it. Use the template as a pattern for cutting out the shape.

## Sheet Metal

Sheet metal can be bent and folded into three-dimensional objects. A pan is a good example. Before you begin to shape the metal, you must work out a *development*. A development is a pattern. It shows where the sheet metal must be cut and folded to make the object. See Figure 5-9A. Mark the development on the sheet metal. Then use shears to cut the shape.

To form straight bends, follow these steps:

1. Place the marked sheet metal into folding bars. The bend line should be touching the top edge of the bar.
2. Fasten the folding bars in a vise.
3. If the metal is wider than the vise jaws, add a C-clamp.

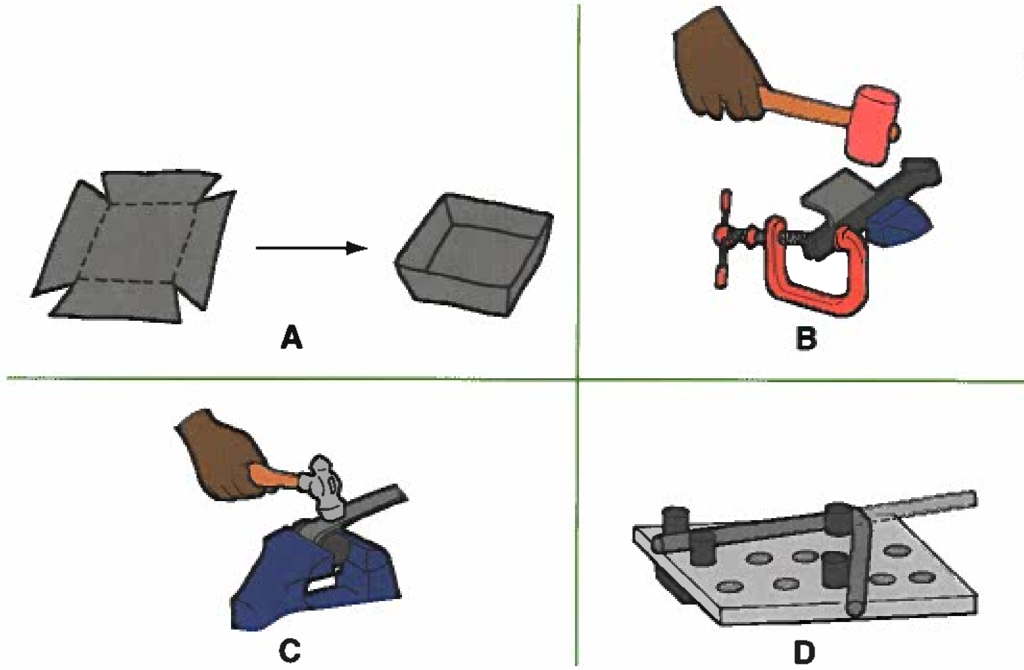



Figure 5-9. Procedures for bending metal.

4. Use a mallet with a rawhide or nylon head. Bend the metal over the bar, as shown in Figure 5-9B.

For some shapes, you may find a block of wood more useful than folding bars.

Lengths of mild steel not more than ¼″ (6 mm) thick can be bent fairly easily. Follow these steps to bend strip steel:

1. Clamp the metal vertically in a vise.
2. Hammer the metal from one side to bend it to the needed angle, as shown in Figure 5-9C.

A *jig* is a useful tool for bending metal. Small diameter rods can be bent on a peg jig, as shown in Figure 5-9D. Metal tubing can be bent using a similar jig.

## Plastics

Thermoplastics can be bent or formed when heated to between 300° and 400° F (150° and 200° C). Heat the plastic sheet or rod along the line of the bend. The narrower the heated line, the sharper the bend will be. Refer to Figure 5-10A.

Using a strip heater provides heat along a straight, narrow line for a sharp bend. To use the strip heater:

1. Place the sheet of plastic on the heater. The bend line must be exactly over the heat element.

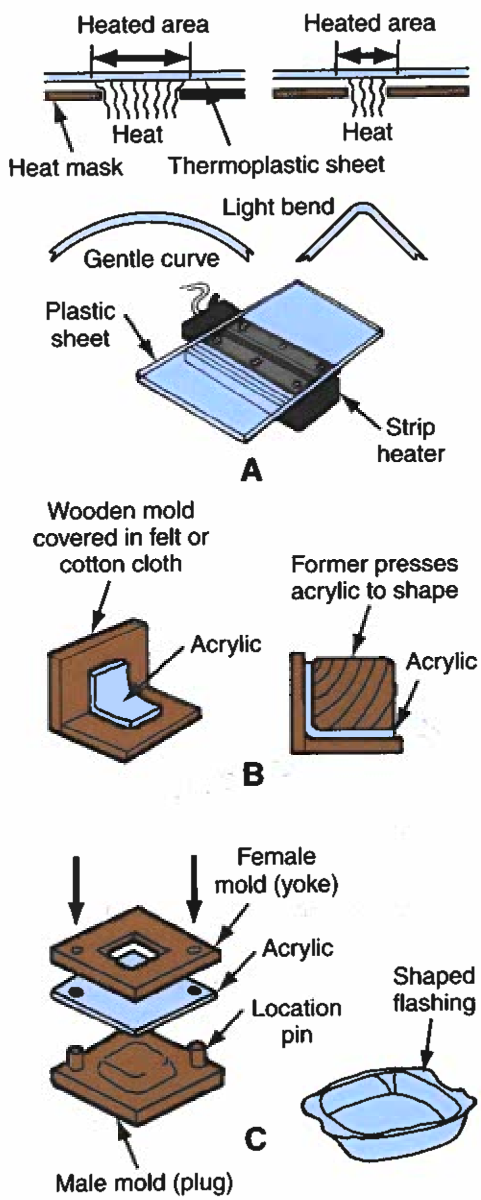



**Figure 5-10.** Processes for bending and forming thermoplastic sheet material.

2. For safety, wear gloves to protect your hands from the hot plastic.
3. Heat both sides of the sheet.
4. Bend the plastic to the required shape. For a 90° bend, press the plastic into a mold. See **Figure 5-10B**.
5. To produce a sharper bend, press a second mold into the corner, as shown in **Figure 5-10B**. Hold until cool.

NOTE: Wooden molds must be covered with cotton or felt material. This prevents the wood grain from marking the plastic.

Forming plastic in a mold calls for a two-part mold. To form the plastic:

1. Heat the acrylic sheet in an oven until pliable.
2. Place it over the plug. Press the yoke down on top. See **Figure 5-10C**.
3. Allow the plastic to cool before separating the mold.

# Math Application

## Using Mixed Fractions to Calculate Material Needed

Before manufacturers begin shaping materials, they have to decide how much material will be needed for a given production run. For example, a manufacturer of metal nameplates must determine how many nameplates can be made per linear foot of metal. This often involves working with mixed fractions. A ***mixed fraction*** is a number that includes both a whole number and a fraction, such as $1\frac{1}{2}$.

To multiply a whole number by a mixed fraction, first change the mixed number to an improper fraction. To create an ***improper fraction***, multiply the whole number part of a mixed fraction by the denominator of the fraction and add the result to the numerator. Place this number over the denominator to complete the fraction. For example, to convert $3\frac{1}{2}$ to an improper fraction, multiply 3 by 2 and add the result to the 1: $3 \times 2 = 6$; $6 + 1 = 7$. The improper fraction is written as $\frac{7}{2}$.

After you have created the improper fractions, multiply the numerators. Then multiply the denominators. Reduce the result to lowest terms. Finally, divide the denominator into the numerator to reduce the fraction to a mixed fraction.

| | |
|---|---|
| Problem statement: | $50 \times 1\frac{3}{4}$ |
| Convert to improper fractions: | $\frac{50}{1} \times \frac{7}{4}$ |
| Multiply: | $\frac{50}{1} \times \frac{7}{4} = \frac{50 \times 7}{1 \times 4} = \frac{350}{4}$ |
| Divide: | $350 \div 4 = 87$, with a remainder of 2 |
| Reduce: | $87\frac{2}{4} = 87\frac{1}{2}$ |

For example, suppose the manufacturer has an order for 50 copper nameplates. Each nameplate will be $7\frac{1}{2}'' \times 1\frac{3}{4}''$. If the nameplates are blanked (stamped out) of a roll of copper that is exactly $7\frac{1}{2}''$ wide, what length of copper will be needed? (Note: The improper fraction for any whole number is that number over a denominator of 1.)

### Math Activity

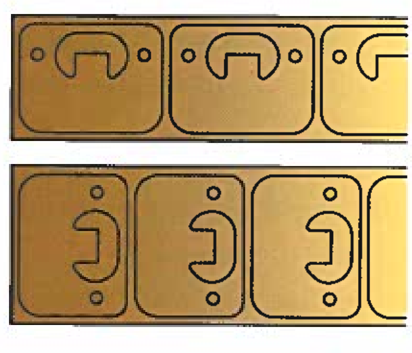
A door manufacturer needs 150 door strikes (Figure A) measuring $2\frac{1}{4}'' \times 1\frac{3}{4}''$. These will be blanked from a roll of brass, using the most economical cutting pattern. A space of $\frac{1}{8}''$ is needed between each piece. See Figure B for examples of cutting patterns. Determine the length of brass needed if the roll of brass is:

A. 2″ wide

B. $2\frac{1}{2}''$ wide

A

B



# Casting and Molding

Pouring liquid or plastic material into a mold to shape it is called *casting* and *molding*. Every time you make ice cubes you are casting. You are making a solid shape by pouring water into a tray. The liquid takes the shape of its container.

Casting is a method of making shapes that are almost impossible to produce by sawing, drilling, or filing. Three basic materials are used for casting and molding: metals, plastics, and ceramics. When the material is poured into the mold, the process is called *casting*. When the material is forced into the mold, it is called *molding*.

Metals become liquid when they are heated above their melting point. As they cool, they solidify. Plastics are available in a liquid form. These liquids set hard through chemical action.

Ceramics include materials such as silica (sand), clay, and concrete. Silica must be melted to make glass and other products. Clays and concrete are not melted. They are mixed with liquid and poured into a mold.

## *Metals*

Use the following steps to cast metal:

1. As shown in **Figure 5-11A**, make a pattern. A pattern is just like the finished product. Usually it is made of wood, but it could be made of some other easily worked material.

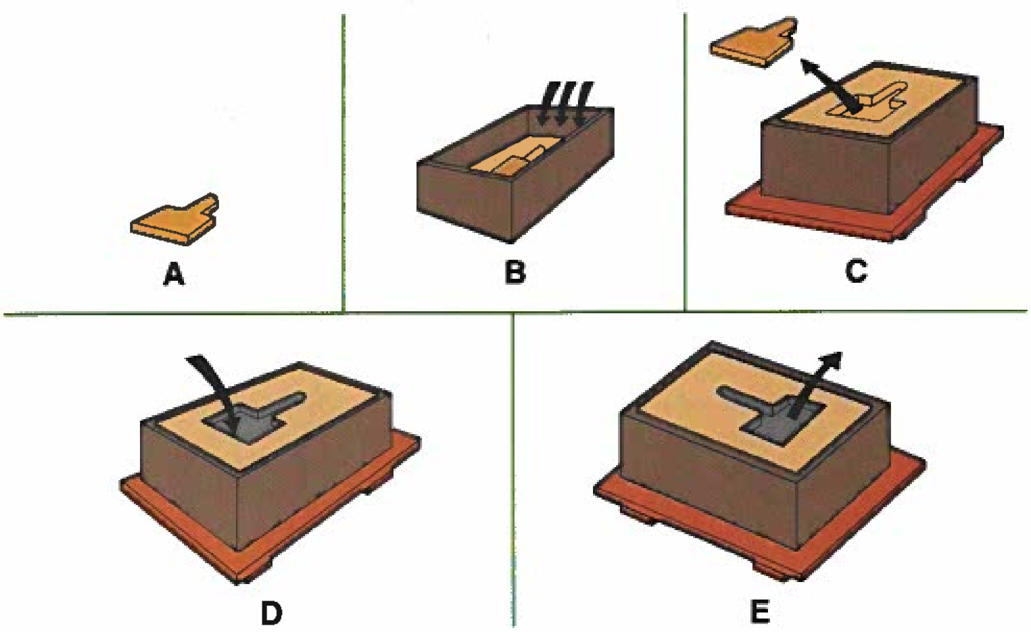



**Figure 5-11.** Process for casting metal.

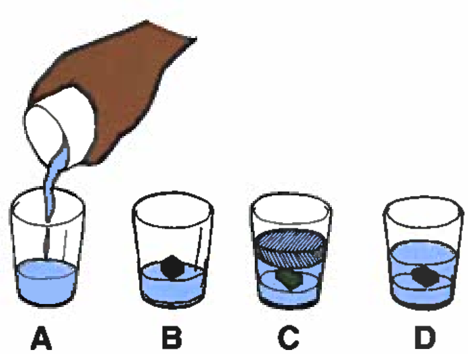
2. Place the pattern in a molding box on a flat surface. See Figure 5-11B.
3. Pack molding sand carefully around the pattern. Molding sand is made from high-quality silica sand mixed with a binder such as clay to hold it together.
4. Completely fill the molding box with molding sand. Tamp it tightly around and over the pattern.
5. Cover the box with another board and turn it over. Remove the board that was on the bottom.
6. Carefully remove the exposed pattern. See Figure 5-11C.
7. Pour molten metal into the cavity formed by the pattern, as shown in Figure 5-11D.
8. Allow the casting to cool and solidify. Then remove it. See Figure 5-11E.

### Plastics

Casting plastics has one big advantage over casting metal. The resins can be cast at room temperature. Small articles, such as paperweights, can be cast in plastic. If you wish, you can also embed decorative objects in them. Follow these steps:

1. Use a smooth mold. It will produce a smooth surface on the casting. Waxed drinking cups work well. Never use polystyrene (Styrofoam®) cups. The resin will dissolve them and may produce toxic gases.
2. Measure the amount of resin you will need. Add the recommended amount of catalyst (hardener). Mix thoroughly.
3. Pour a layer of the mixed resin into the mold and leave it to harden. This will form the top layer of the casting. See Figure 5-12A.
4. Place the decorative object (coin or stamp) face down on the hardened layer of resin. See Figure 5-12B.
5. Pour more resin around and over the object, as shown in Figure 5-12C. You can use clear resin throughout, or you can add pigment (color) to the last layer. This forms the base of the object.
6. When the resin has hardened, Figure 5-12D, remove the casting from the mold.
7. Smooth rough edges and surfaces with wet or dry sandpaper. Then polish the casting with a polishing paste.

**Figure 5-12.** Steps for embedding an object in plastic.



### Fiberglass-Reinforced Plastic

Fiberglass canoes, racecar bodies, and crash helmets may all be made from plastic resin reinforced with glass fiber. The reinforcing glass fiber makes the shells very tough. The thermosetting resin creates a smooth, hard surface. To make a fiberglass-reinforced product:

1. Paint on a release agent over the surface of the mold, as shown in **Figure 5-13**.
2. Mix polyester resin and a catalyst in the recommended proportions. (Color may be added to the resin.)
3. Brush on a gel coat of polyester resin.
4. Add a layer of fiberglass and coat it with more resin.
5. Use a roller to make each layer take up the exact shape of the mold. Be sure to remove air bubbles.
6. Add layers of resin and fiberglass to produce the required thickness.
7. Allow the assembly to cure (set hard), and then remove it from the mold.

# Joining Materials

There are many ways of joining materials. **Figure 5-14** lists some common choices for wood, metal, and plastic. You will notice that some methods, such as fastening with nuts and bolts, are good for all three. Others, such as soldering, may be used only for metal.

**Figure 5-13.** Molding fiberglass on a form, such as this boat, is called a *lay-up*.

| | Mechanical | Chemical | Heat |
|---|---|---|---|
| Wood | Nails<br>Screws<br>Nuts and bolts<br>KD (knock-down) fasteners<br>Wedges<br>Hinges | Glues<br>Adhesives | |
| Metal | Rivets<br>Nuts/bolts/screws<br>KD fasteners<br>Hinges | Adhesives | Weld<br>Braze<br>Solder |
| Plastic | Rivets<br>Nuts/bolts/screws<br>KD fasteners<br>Hinges | Solvents<br>Cements | Weld |

**Figure 5-14.** Methods for joining wood, metal, and plastics.

# Mechanical Joining

*Mechanical joining* is the use of physical means to assemble parts. It can be done in one of two ways. One method is to use hardware such as nails, screws, or special fasteners. Another method is to shape the parts themselves so they interlock.

## Nails

Nails provide one of the easiest ways to join two pieces of wood. Nails hold the wood by friction between the wood fibers and the nail. See **Figure 5-15**. Nails can be shaped in many different ways. **Figure 5-16** shows several different types of nails. Remember these general points when using nails:

- Whenever possible, place one of the pieces to be nailed in a clamp or a vise. See **Figure 5-17A**.
- Always nail through the thinner piece into the thicker piece.
- Avoid bending the nail. Strike it squarely with the face of the hammer.
- When using finishing nails, drive the nail below the surface using a nail set, as shown in **Figure 5-17B**.
- Stagger the nails, as shown in **Figure 5-17C**. If you place them in a straight line, you may split the wood along the grain.
- To remove nails, use a claw hammer as shown in **Figure 5-17D**. Always use a block of waste wood to protect the surface of the wood.

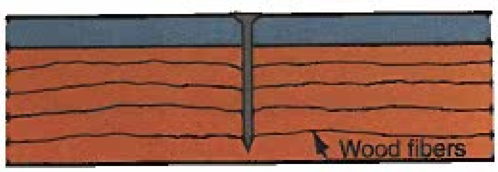



**Figure 5-15.** When a nail is forced into wood, the compression of the wood fibers and friction between the wood fibers and the nail hold the nail in place.

| Type of Nail | Uses |
|---|---|
| Common | Structural or other heavy work where head will be exposed. |
| Finishing | Finishing work where nail head should not be exposed. |
| Spiral | Building construction. Twisted shank causes nail to thread itself into wood, increasing its holding power. |
| Drywall | Fastening gypsum board to wood frames. |
| Concrete | Fastening to concrete. Nail is hardened to prevent bending. |
| Roofing | For wood, asphalt, and other roofing materials. Usually coated with zinc or galvanized to make them rust-resistant. |

**Figure 5-16.** Nails are made in many different shapes to serve special fastening purposes.


**Figure 5-20.** Common types of screw heads. What are the advantages and disadvantages of each?

Most screws are made of steel. They are very strong, but they can rust. Brass screws do not rust, but they are weaker than steel. Sheet metal screws, **Figure 5-21**, are used to join sheet metal, plastics, and particleboard. **Figure 5-22** shows the steps to fastening hardwood parts with a wood screw:

1. Hold the two pieces together. Drill a pilot hole the length of the screw.
2. In the top piece, drill a clearance hole. This is a hole the same diameter as the screw shank (unthreaded part of the screw below the head). Note that in softwood, the clearance hole is not usually necessary. Only a pilot hole is needed.
3. If you are using a flat head screw or oval head screw, countersink the hole.

NOTE: In softwood it is usually only necessary to drill a pilot hole.

Now you are ready to install the screw. The diameters of the most frequently used pilot holes and clearance holes are shown in **Figure 5-23**.

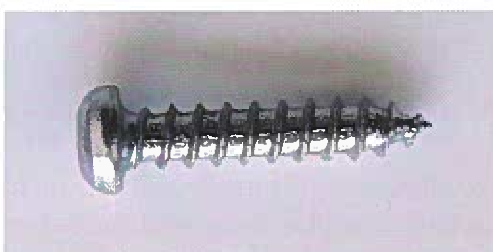


**Figure 5-21.** Sheet metal screws have threads that go all the way to the head.

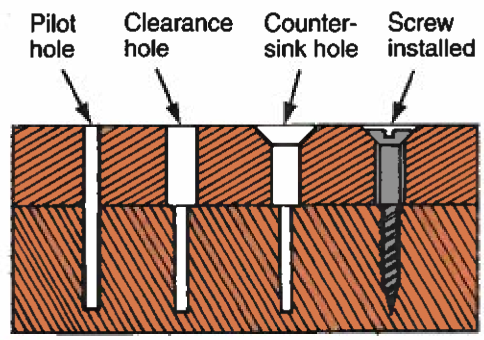



**Figure 5-22.** Special holes must be drilled when fastening hardwood with screws.

| Gauge No. of screw | Diameter of shank | Pilot hole | Clearance hole |
|---|---|---|---|
| 4 | 7/64 (3 mm) | 5/64 (2 mm) | 7/64 (3 mm) |
| 6 | 9/64 (4 mm) | 3/32 (3 mm) | 9/64 (4 mm) |
| 8 | 11/64 (5 mm) | 7/64 (3 mm) | 11/64 (5 mm) |
| 10 | 3/16 (5 mm) | 1/8 (4 mm) | 3/16 (5 mm) |
| 12 | 7/32 (6 mm) | 9/64 (4 mm) | 7/32 (6 mm) |

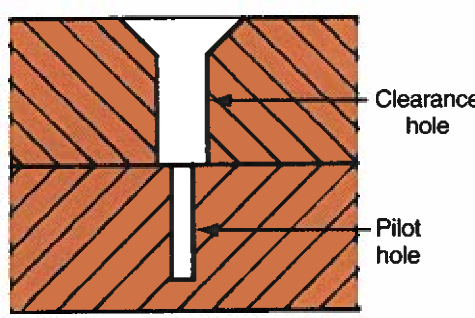



**Figure 5-23.** Pilot and clearance holes recommended for wood screws.

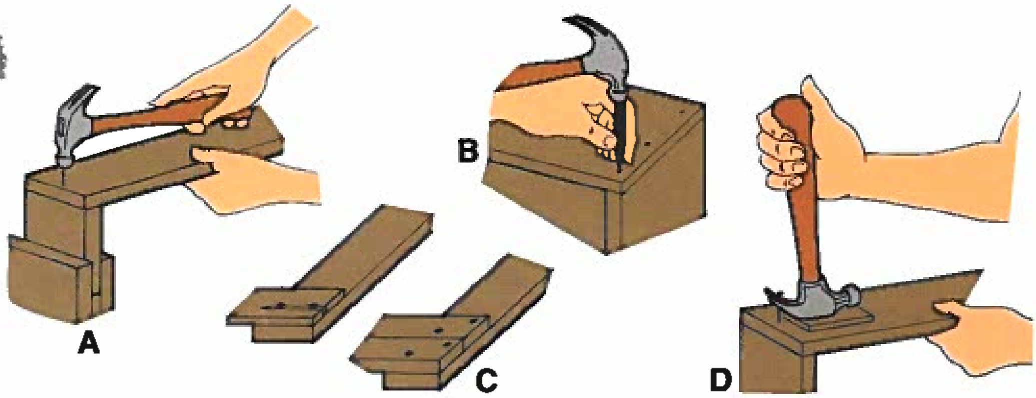



Figure 5-17. Techniques for assembly and disassembly using a hammer and nails.

## Screws

Screws have greater holding power than nails. See Figure 5-18. They also rely on friction for their strength. When two pieces of wood are held together, the head of the screw and the grip of the screw thread pull the two pieces together. Screws can be removed more easily than nails and without damaging the material.

Wood screws are used for fastening wood to wood and metal to wood (hinges to a door). They are also used for fastening all types of hardware to furniture. To choose the correct wood screw, you must decide on the:

- Shape of head and type of slot
- Length of screw
- Thickness or gauge
- Material

The three shapes of screw heads are shown in Figure 5-19. Flat head screws are used when the head of the screw must be flush with or below the surface of the wood. Oval head screws can also be used when the holding power of a flat head screw is needed. The screw head will show for decoration. Round head screws are used when the object that is being fastened by the screw is too thin to be countersunk.

The common head styles or types are shown in Figure 5-20. Screw lengths range from 1/4″ to 6″ (6 mm to 150 mm). The thickness of a wood screw is called its *gauge*. Gauge is expressed as a number. Screw gauges range from 0 to 24.

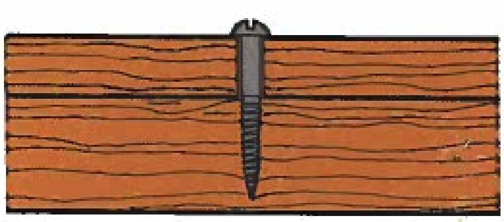


Figure 5-18. Wood fibers grip the threads of a screw. This gives the screw holding power.

Figure 5-19. Wood screws are named for the shapes of their heads. What types are shown in this photo?

The most common types of wood screws and screwdrivers used in the United States are straight slot (standard) and Phillips. In Canada the most common type is the Robertson (square). Use the largest screwdriver convenient for the work. More power can be applied to a long screwdriver than a short one. Also, there is less danger of it slipping out of the slot. The tip of the screwdriver must fit the slot correctly. See **Figure 5-24**.

## Nuts and Bolts

Nuts and bolts fasten metal, plastic, and sometimes wood parts together. They are quite different from wood screws. Bolt threads do not depend on gripping the fibers of the material. Bolts go completely through a drilled clearance hole. This is a hole large enough for the bolt to be pushed through. A nut threads onto the bolt end. Tightening the nut squeezes the parts together and holds them. Sometimes, threads are cut into the hole in the second piece of material, as shown in **Figure 5-25**. This takes the place of the nut.

Washers are often used under the bolt head and the nut. This protects the surfaces by distributing the load over a larger area. Lock washers prevent nuts from accidentally loosening due to vibration. Joints fastened with nuts and bolts can be taken apart and reassembled.

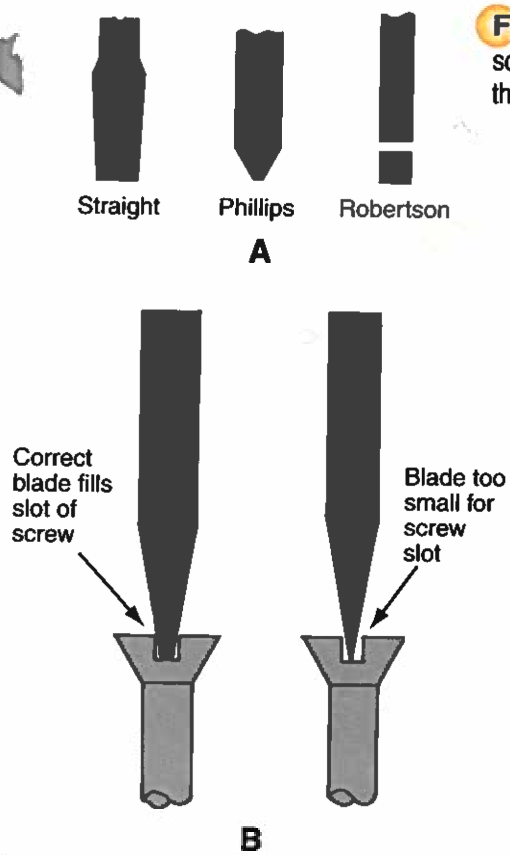



**Figure 5-24.** A—Three common types of screwdrivers. B—The screwdriver tip must fit the slot in a straight screw head.

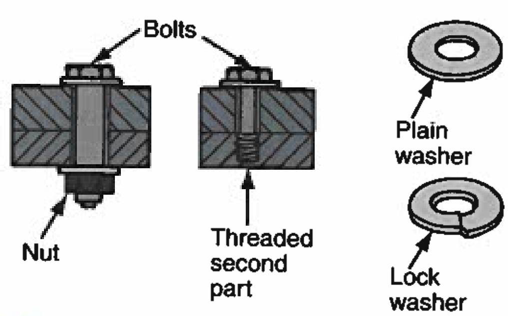



**Figure 5-25.** Two methods of fastening metal parts with bolts. Washers are used to protect the material from the bolt and nut when they are tightened.

To choose the right nut and bolt, you need to decide on the following items:

- Length
- Diameter
- Shape of head
- Thread series. Some are coarse; others are fine. Some have standard threads, and others have metric threads.
- Material

Some of the choices are shown in **Figure 5-26**. Can you name any of the types shown?

Most nuts and bolts are tightened using a wrench. Machine screws are tightened with screwdrivers or Allen keys. A combination wrench is shown in **Figure 5-27**. It has one open end and one box end. The box wrench is usually preferred because it does not slip. Sometimes there is not enough room for a box end. Use an open end when clearance is a problem.

An adjustable wrench fits a range of nut sizes. As **Figure 5-28** shows, always pull on the wrench handle. Pushing can be dangerous. If the wrench should slip, you could injure your knuckles.

**Figure 5-26.** Nuts and bolts are made in many different shapes and sizes.


**Figure 5-27.** A combination wrench contains both an open-ended wrench and a socket wrench.

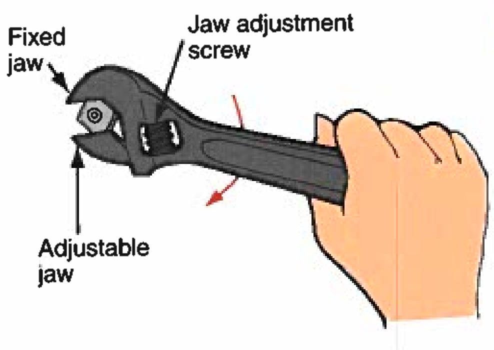



**Figure 5-28.** When using an adjustable wrench, always pull against the fixed jaw.

## Rivets

Like nuts and bolts, rivets squeeze two or more pieces of metal or plastic together. They are either solid or pop type.

Solid rivets are usually made of mild steel. They may have round or flat heads. The four steps for installing a round head rivet are shown in **Figure 5-29**.

To use solid rivets, you must be able to reach both sides of the rivet. When this is not possible, pop rivets can be placed from one side only. They are made of a hollow aluminum head with a steel pin through it. Use the following procedure to install a pop rivet:

1. Drill a hole in the parts large enough to receive the pop rivet.
2. Push the pop rivet through the hole.
3. Slip the rivet gun over the pin.
4. Squeeze the handle to pull the pin back. This creates the rivet head on the back (concealed) side.
5. Continue squeezing until the pin breaks off. See **Figure 5-30**.

## Knockdown (KD) Fasteners

Some furniture is designed for "do-it-yourself" assembly and is purchased in a flat pack. This requires special fasteners that are strong and easy to use. The fasteners require no special tools or skills. Known as "knockdown" or KD fasteners, they can be taken apart and reassembled as needed. The three most common types are shown in **Figure 5-31**.

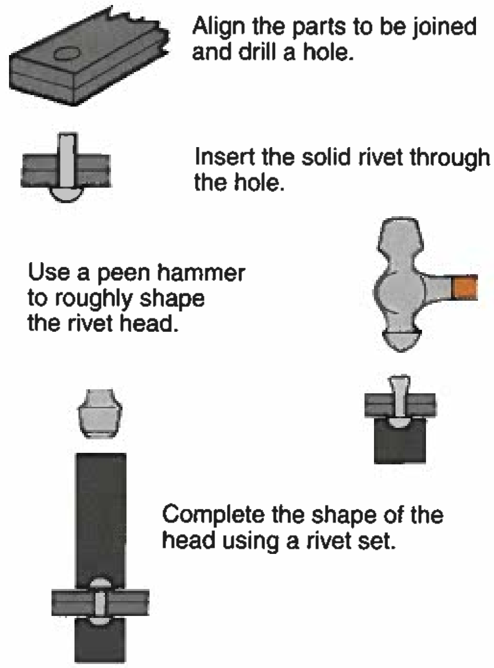



**Figure 5-29.** Steps to fasten sheet metal using solid rivets.

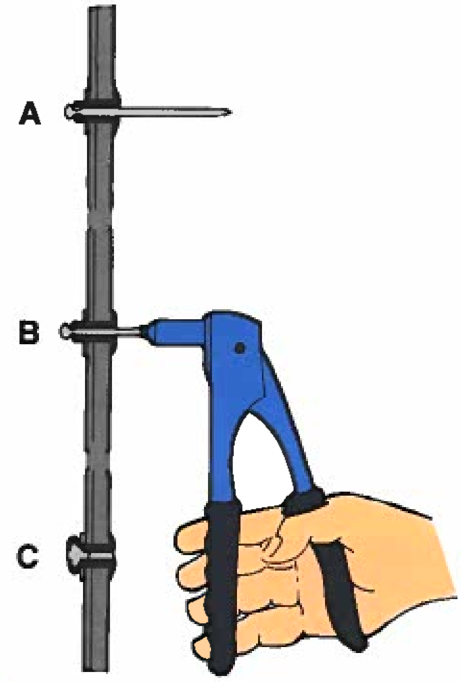



**Figure 5-30.** Using a pop riveter. A—Insert rivet in predrilled hole. B—Slip the tool over the pin and squeeze. C—Pin breaks off when its sleeve has expanded on the blind side of the rivet.

## Movable Mechanical Joints

Some joints are made so that the joined parts can move. Think of how a door is joined to its frame. A hinge is used. The knife switch in **Figure 5-32** is another example of a movable joint. Both are pin hinges. They can only move back and forth. We say that they "move through one plane only."

A second type of movable joint is the ball and socket joint. This type of joint allows movement in more than one plane. See **Figure 5-33**. The joystick of a video game uses a ball and socket joint. A camera tripod uses a lockable ball and socket. It can move in three different directions. The drive shaft of a car uses a universal joint. It permits the joint to move up and down or left and right as the shaft spins.

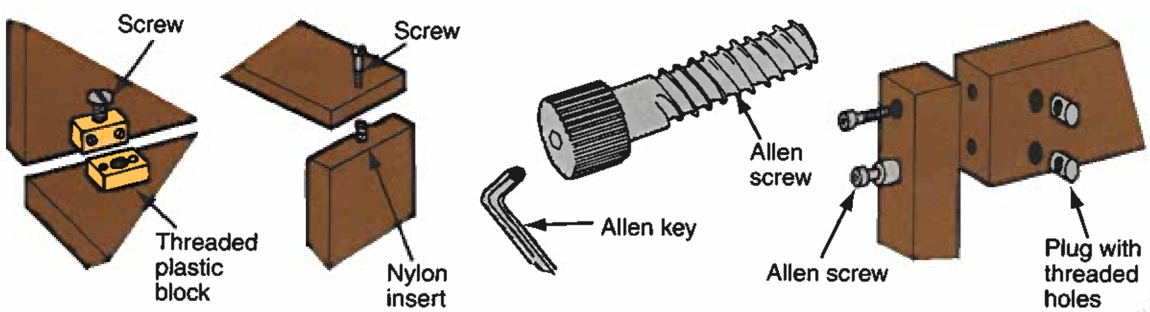



**Figure 5-31.** Knockdown furniture uses one of three basic fasteners.

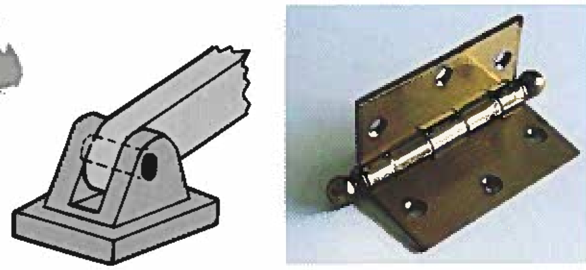



**Figure 5-32.** Pin hinges allow movement in one plane only.

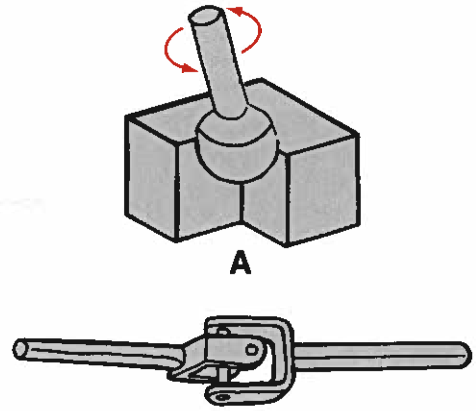



**Figure 5-33.** A—A ball and socket joint. B—A universal joint can move up and down as well as side to side.

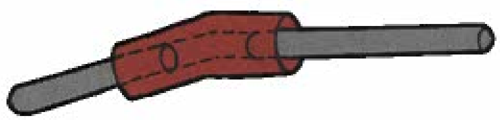


**Figure 5-34.** A flexible joint can move in any direction.

A third type of movable joint is the integral or living hinge. It consists of a flexible material such as polypropylene. See **Figure 5-34**. The material itself acts as a hinge wherever it is folded.

### Wood Joints

The strength of a wood joint depends on two things:

- The way the wood parts meet at the joint to provide mechanical interlocking. See **Figure 5-35**.
- The amount of surface area of the joint to be glued.

Wood joints can be grouped by type, as shown in **Figure 5-36**. One group is used on frames. The other group is used to make boxes. Frame joints are found on chairs, windows, doors, and similar products. Box joints are used to construct items such as cabinets, drawers, and storage boxes. **Figure 5-37** shows eight different joints for constructing frames or boxes.

## Chemical Joining

Mechanical joints are often strengthened by *chemical joining*. Where would we be without adhesives? Furniture would disintegrate, books and shoes would fall apart, and we couldn't cap our teeth. Imagine life without stamps, tape, or Post-it® notes. Glues, adhesives, solvents, and cements are all methods of chemical joining.

Glues and adhesives are used to join woods and metals. Glues were once made from natural materials. These included animal bones, hides, and milk. They are rarely used today. Although we still use the term *glue*, it is more correct to use the term *adhesive*.

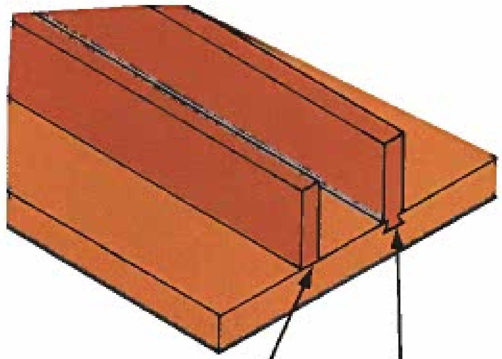



**Figure 5-35.** An interlocking joint is strong because one part fits into the other.

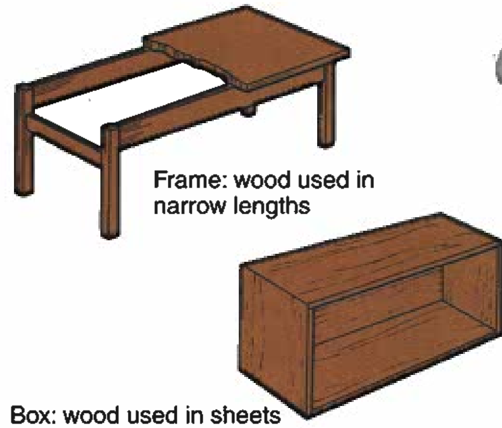
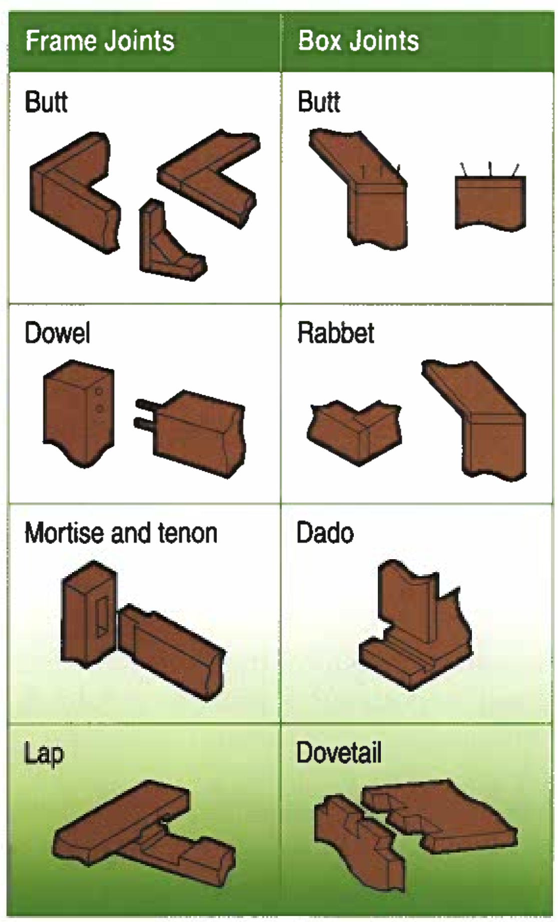



**Figure 5-36.** Two basic kinds of wood construction for making furniture are frame and box construction.

**Figure 5-37.** Each type of joint has advantages and disadvantages. Which of these joints has the greatest mechanical strength? Which has the largest gluing surface?



Adhesives come from petroleum products. These adhesives are of two types: thermoplastic and thermoset. One common thermoplastic adhesive is liquid white glue. Also known as *polyvinyl acetate*, it is commonly used in wood joints.

Thermoplastic adhesives harden by loss of water or solvent. They may be softened by heat and are not waterproof. Thermoset adhesives include various types of resins. Heat will not soften them, and they are waterproof.

## How Glues and Adhesives Work

To act as an adhesive, the molecules that make up the glue must form strong links to one another, and the glue must stick to both surfaces being joined. This ensures that they cannot be separated when the two surfaces are pulled apart. An adhesive must flow easily to coat both surfaces and have a natural attraction, or ***adhesion***, between its molecules. Adhesion is also increased when the glue hardens and tiny air bubbles get trapped. This causes a suction that has to be overcome if the surfaces are to be separated.

## How Solvents and Cements Work

Solvents and cements are used to join plastics. A pure solvent softens the areas to be joined, while cements dissolve a small amount of the plastic. They penetrate deeper into the two surfaces because the solvent evaporates much more slowly. However, cement provides a stronger joint than a pure solvent.

Solvents and cements work on the principle of ***cohesion***. In cohesion, the materials being joined become fluid. Then the molecules of each piece mix together. There is no foreign material in the joint. Fluid edges flow together and fuse. Cementing of thermoplastics is an example of cohesion fastening.

**Figure 5-38** shows uses for different solvents, adhesives, and glues. For safety and good results, follow these general rules:

- Make sure the surfaces are clean and dry. Remove grease, paint, varnish, or other coatings.
- Carefully read the instructions and cautions.
- Secure a good fit between the two surfaces.
- Work in a well-ventilated area, especially when using solvents and cements.
- Clamp the joint until the adhesive or solvent dries.

| Class | Type | Uses | Comments |
|---|---|---|---|
| Glues | Animal | Interior woodwork | Difficult to use<br>Must be used hot<br>Not waterproof or heat proof |
| | Casein | Interior woodwork | White powder mixed with water<br>Sets in six hours<br>Heat and water resistant |
| Adhesives | Polyvinyl acetate (PVA-white glue) | Wood, leather, paper | White liquid ready to use<br>Hardens in under one hour<br>Not waterproof |
| | Plastic resins (urea and phenol) | Wood | Urea: powder mixed with water<br>Phenol: ready to use<br>Hardens in approximately 2–6 hours<br>Urea is water resistant: Phenol is waterproof<br>Good strength |
| | Epoxy resin | Wood and metal | Two parts are mixed together<br>Hardens in 12–24 hours<br>Waterproof<br>Very high strength |
| | Contact cement | Plastic laminates | Ready-to-use liquid<br>Apply to both surfaces and let dry to touch<br>Used in situations where clamps cannot be applied |
| | Cyano acrylate (Superglue™ or Krazy Glue™) | Nonporous materials such as glass and ceramics | Ready to use liquid<br>Hardens almost immediately<br>Water resistant |
| Solvents | Pure solvent (methylene chloride and ethylene dichloride) | Acrylics | Colorless liquid, ready to use<br>Bonds almost immediately<br>Waterproof |
| | Solvent cement | Acrylics | Colorless, viscous liquid<br>Sets in 12–24 hours<br>Waterproof |
| SAFETY NOTE: Use solvents and cements in well-ventilated areas | | | |

**Figure 5-38.** Glues, adhesives, and solvents are designed for specific applications.

## Solvent-Joining Acrylic Sheet

Low-viscosity solvent travels through a joint area by capillary action. This is a force that causes a liquid to rise through a solid. Properly done, solvent joining yields strong, perfectly transparent joints. It will not work at all if the parts do not fit together perfectly. To join acrylic parts using a solvent:

1. After removing the protective paper from the acrylic, hold the two pieces of acrylic in a jig, as shown in **Figure 5-39**.
2. Apply solvent along the entire joint. Work from the inside of the joint where possible. Use a hypodermic syringe or needle or an applicator bottle with a nozzle to apply the solvent.
3. Allow the joint to dry thoroughly (24 to 48 hours).
4. Remove the part from the jig.

**SAFETY:** Work with solvents only in a well-ventilated area!

Dipping is a second method of joining acrylic sheet material, as shown in **Figure 5-40**:

1. Set up a tray of solvent. The tray must be larger than the plastic pieces.
2. Ensure that the tray is sitting level.
3. Dip only the very edge of each plastic part into the solvent.
4. Use finishing nails in the bottom of the tray to keep the acrylic off the bottom.
5. Place the two pieces to be joined together and allow them to dry thoroughly (24 to 48 hours).

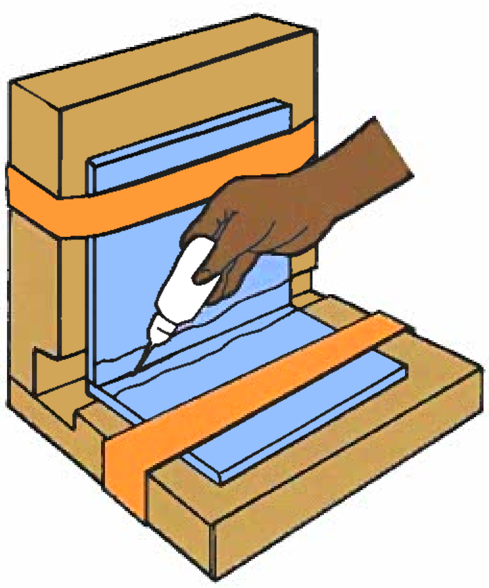


**Figure 5-39.** Apply the solvent to the inside edges of the parts where possible.

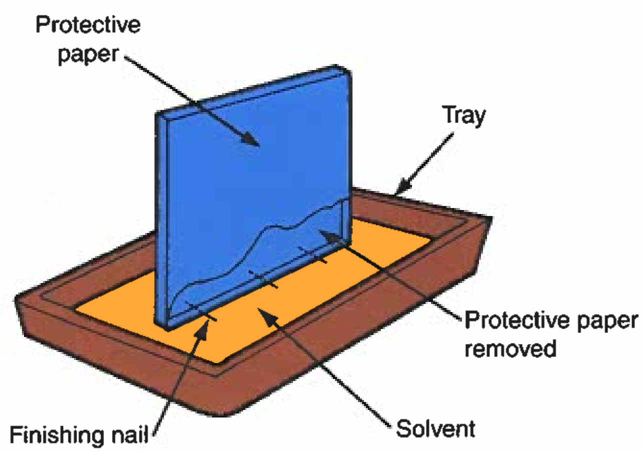



**Figure 5-40.** Dipping is a method for solvent joining. Note that the protective paper has been removed from the acrylic to allow for softening of the material.

# Heat Joining

*Heat joining* is used mostly on metals. It is also used to some exten on plastics. Two types of heat joining are used on metals:

- Welding
- Brazing and soldering

Welding brings metals to their melting point. When they melt, the metals flow together. When they cool, they solidify, becoming one piece. The joint is as strong as the original metal. Welding may also be used to join plastics. This is possible with some thermoplastics such as PVC. A hot air torch heats the two parts of the joint. Heat fuses them.

Brazing and soldering work differently than welding. The heat melts the metal being used to join the parts. It does not melt the metal in the parts themselves. Brazing uses a brass alloy to join the parts. The alloy melts at 1650° F (900° C).

A mixture of tin and lead has traditionally been used in solder. However, it is being phased out because even a small amount of lead can be harmful to health. People who continue to use tin and lead solder should be sure to wash their hands after working with it. However, the best plan is to avoid lead solder entirely.

There are many different varieties of lead-free solder. One of the most popular contains 96.5% tin, 3% silver, and 0.5% copper. It is a little more costly due to its silver content. It melts at approximately 425° F, a slightly higher temperature than traditional lead solder. A high-wattage soldering iron with temperature adjustment is helpful.

To solder tinplate, copper, brass, and mild steel using lead-free solder:

1. Select a high-wattage soldering iron with temperature adjustment and several sizes of replaceable tips.
2. Choose a tip that makes the right contact with the joint to be connected. It should not be too big or too small.
3. Set the temperature at about 700° F (370° C).
4. If needed, clean the tip using a wet sponge.
5. Apply lead-free solder to the soldering iron, being sure to keep the tip wet with solder at all times. See **Figure 5-41**.
6. Allow the joint to cool slowly before moving it.

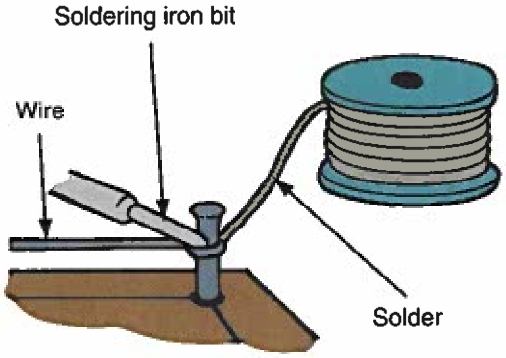



**Figure 5-41.** Heat the parts to be soldered before applying the solder.

# Finishing Materials

When a product is completed, its surface is usually finished. *Finishing* changes the surface by treating it or placing a coating on it. Finishing is done for several reasons:

- Protect the surfaces from damage caused by the environment
- Prevent corrosion, including rust
- Improve the appearance by covering the surface or treating it to bring out the natural beauty of the material

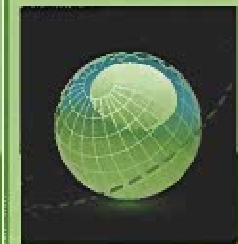
## Converted Surface Finishes

When the surface is treated to beautify or protect, it is called a *converted surface*. The material is chemically altered to change the way it reacts to elements in the environment. The reaction of the chemical and the atoms on the product's surface provide the protective coating.

Some converted coatings are natural. Aluminum develops an oxide covering if exposed to the open air. This covering resists the natural elements.

## Surface Coatings

Materials applied to a surface are called *coatings*. The most common coatings are paints, enamels, shellac, varnish, lacquer, vinyl, silicone, and epoxy. For centuries, machinery and tools have been coated with oil and grease. Paint, varnish, and enamel are widely used to protect ships, trains, cars, and bridges. Heating ducts, and sometimes nails, are galvanized (coated with zinc). Food cans are plated with tin. Many decorative objects are electroplated. A coating of nickel, chromium, copper, silver, or gold is applied to their surface.



## Think **Green**

### Eco-Friendly Paints

Most people today are aware that some paints are more environmentally friendly, or "eco-friendly," than others. What you may not know is that paint companies use different definitions of the term "eco-friendly." Some paints are made of all-natural products. Others have low levels of volatile organic compounds, and still others are completely free of volatile organic compounds. ***Volatile organic compounds (VOCs)*** are chemicals in paint that are released as the paint dries. They often account for the strong smell of a freshly painted surface, and they can cause health problems such as dizziness and headaches.

The most eco-friendly paints are those that are free of all toxins, solvents, and odors. Tour a local home improvement center or go online to see the different "eco-friendly" paints that are available. Find out exactly what characteristics make the paint eco-friendly. Which paint would you choose?

The first step in finishing is to prepare the surfaces. They should be clean and smooth. Surfaces can be made smooth using abrasive papers or abrasive cloths, which are made in a wide range of grades and coarseness. Abrasive materials and their uses are described in Figure 5-42.

You should follow these three general rules when using an abrasive:

- Clean inside surfaces before assembling the project.
- Begin with a coarse abrasive. Then gradually work up to a fine grade.
- Support the abrasive whenever possible, as shown in Figure 5-43. A wood or cork block can be used for wood and plastic. Files can be used for holding abrasive papers while finishing metals. See Figure 5-44.

Figure 5-45 lists several different finishes. Some are for wood. Others are best used on plastics or metal. Finishes can be applied by wiping, brushing, rolling, dipping, and spraying.

You can apply stain and oil to wood by wiping with a cloth. Brushes work well with most finishes. They are best with liquid plastic and paint. A roller works well for painting large surfaces. Items with many curves and parts can sometimes be dipped.

Paint can be sprayed onto most shapes and materials. Aerosol spray cans are fast and easy to use on small areas. Spray guns use compressed air. They produce a high quality finish for larger surfaces. Paint dries when the solvent it contains, either water or an organic solvent, evaporates.

| Material | Abrasive | Comments |
|---|---|---|
| Wood | *Sandpaper* was once the general name given to all abrasive papers used for smoothing wood. Today, the industry calls them coated abrasives. | |
| | Flint paper | Crushed flint or quartz used as the abrasive<br>Wears out quickly<br>Cuts slowly<br>Normally used in grades coarse to extra fine (50–320 grit) |
| | Garnet paper | Uses garnet as the abrasive<br>More durable than flint paper<br>Normally used in grades coarse to extra fine (50–320 grit) |
| Metal | Emery cloth | Uses emery a natural abrasive<br>Dull black in color<br>Normally used in grades coarse, medium, and fine (3–3/0)<br>Oil may be added to the fine grade to give a mirror finish |
| Wood and Metal | Aluminum oxide | An artificial abrasive<br>Gray-brown in color<br>Tough, durable, and resistant to wear<br>Normally used in grades coarse, medium, and fine (40–180 grit)<br>Used on steel and other hard materials |
| Wood, metal, and plastic | Silicon carbide paper (wet-and-dry paper) | An artificial abrasive<br>Available in three common grades: coarse (50), medium (100), very fine (400)<br>Paper is best used wet<br>Creates a smooth, matte finish |

**Figure 5-42.** Coated abrasives prepare the surfaces of a material for finishing.


**Figure 5-43.** Always sand wood along the grain, or you will see the scratches made by the abrasive.

**Figure 5-44.** One way to use emery cloth on metals is to wrap the cloth around a file.

| Material | Type | Comments |
|---|---|---|
| Wood | Liquid plastic (urethane) | Provides a clear coating<br>Apply with a brush<br>Gives a hard, water resistant, and long-lasting coating |
| | Stain | Changes the color of wood<br>Cheaper wood can be stained to resemble the color of more expensive woods<br>Applied with brush or cloth<br>Another clear, protective finish must be applied later |
| | Paint | Two types: latex (water-based) and oil (linseed oil or synthetic)<br>The surface must be primed with a primer coat<br>Read and follow the manufacturer's directions |
| | Plastic laminate | Provides a decorative, durable surface<br>The laminate is glued to a flat surface using contact cement |
| | Creosote and pressure treatment | Wood is immersed in a creosote or a preservative is forced into the wood under pressure<br>Exterior use only |
| | Oil | Teak oil is preferred, as linseed oil requires preparation<br>Used on handmade furniture |
| Metal | Paint | Surface must be completely free of oil and grease<br>First apply a primer coat, then an undercoat, and finally a top coat |
| | Plastic coating | Metal is heated and dipped into fine particles of PVC that soften under the heat to form a smooth coating<br>Useful for tool handles |
| | Enameling | A thin layer of glass is fused onto a metal surface<br>For decorative work, copper is the metal used |
| Plastic | Polish | Surfaces are polished using very fine silicone-carbide paper followed by using a buffing attachment on a power drill<br>Buff with light pressure to prevent melting the plastic |
| | Dye | Dip transparent plastic in a strong dye for a few minutes to give a tinted effect |

**Figure 5-45.** Finishes are applied for various purposes. What criteria would you use to select a finish?

## End Note

Tools are used to shape and form materials into finished products. *When designing and making a product, you must know how to select* and use both hand and machine tools safely. In addition to shaping and forming materials, you may need to join materials either temporarily or permanently. Materials can be joined using mechanical devices, chemicals, or heat. Finishing involves processing or coating the surface of the product.

As new materials and technologies are developed, new processes are developed for working with them. Manufacturers are looking for replacements for harmful chemicals used in the past and present, such as chromium and cadmium. A partial answer may lie in nanotechnology. For example, nanotechnology is now being applied to finishing processes. A nanocrystalline cobalt and phosphorus compound has been developed to replace chromium coatings in some cases. Other products and processes are also under development to reduce carbon emissions and the use of hazardous chemicals.

## Summary

- Working safely with hand and power tools requires careful planning and attention to detail.
- To create a product, materials are first marked out. Then they are shaped using one of several processes. Examples include sawing, filing, planing, shearing, chiseling, drilling, bending, forming, casting, and molding.
- Materials can be joined using mechanical fasteners or other mechanical methods, chemicals, or heat.
- Materials are finished to protect their surfaces or to improve their appearance.

## Reading Target

### Summarizing Information

Copy the following graphic organizer onto a separate sheet of paper. For each chapter section (topic) listed in the left column, write a short, one-paragraph summary of the topic in the right column.

| Chapter Section (Topic) | Summary |
|---|---|
| Learning to Work Safely | |
| Shaping Materials | |
| Joining Materials | |
| Finishing Materials | |

# Test Your Knowledge

Write your answers to these review questions on a separate sheet of paper.

1. In addition to following general safety rules, how can you help ensure your own safety when you work with tools and materials?
2. Explain how hazard identification and risk identification can help you work safely with tools and materials.
3. What tools are needed to mark a piece of wood to length?
4. Which tool is used to make straight cuts through metal and plastic?
5. To make the edge of a piece of metal smooth and flat, which tool should you use?
6. Which tool is used to make a wood surface smooth?
7. Which tool cuts aluminum and copper sheet?
8. How would you go about cutting a round hole in a piece of wood, metal, or plastic?
9. Describe the process of lamination.
10. What is the purpose of a strip heater?
11. In which process is liquid metal or plastic poured into a mold?
12. Describe the difference between mechanical, chemical, and heat joining. Give examples of each.
13. Why is a finish applied to the surface of a material?
14. Describe ways in which a finish can be applied to a material.
15. List three general rules to follow when using an abrasive to prepare surfaces for finishing.

# Critical Thinking

1. A friend tells you that he has been trying to smooth the surface of the wooden table he is making, but he can't get the scratches out of the surface. What might be causing the scratches, and how can this be fixed?
2. List what you consider to be the five most dangerous activities in the technology room. What could you do to reduce the dangers?
3. When you develop a new product, you have to take into consideration all of the processes needed to convert the materials into the final product. This includes any processes needed during the design, development, manufacture, and servicing of the product. What steps should you take to ensure that someone unfamiliar with your product could reproduce these processes accurately?

# Apply Your Knowledge

1. Use one of the design processes described in Chapter 2 to design and make a simple game for a young child.
2. List five objects you use at school every day. Describe how the parts of each object are joined.
3. Choose five objects, each with a different type of finish. Make a chart to show (a) the material, (b) the finish, and (c) the reason why that finish has been used.
4. List at least three tools you have in your home. State the material and process for which each is designed.
5. Research one career related to the information you have studied in this chapter. Create a report that states the following:
   - The occupation you selected
   - The education requirements to enter this occupation
   - The possibilities for promotion to a higher level
   - What someone with this career does on a daily basis
   - The earning potential for someone with this career

   You might find this information on the Internet or in your library. If possible, interview a person who already works in this field to answer the five points. Finally, state why you might or might not be interested in pursuing this occupation when you finish school.

# STEM Applications

1. **ENGINEERING** Design and make an ergonomically correct chair using measurements of students in your class. Your design should do all of the following:
   - Have a seat and back.
   - Support a person weighing at least 200 pounds.
   - Be comfortable to sit in.
   - Be aesthetically pleasing.
2. **MATH** Choose a wood table or desk in your home or school. Measure the item carefully. Determine the type(s) of wood and other materials you would need to build it. On the Internet or in a local home improvement store, find out what standard lengths and sizes are available in this type of wood. On paper, carefully plan how to build the table with the least amount of scrap. Then make a materials list including how much of

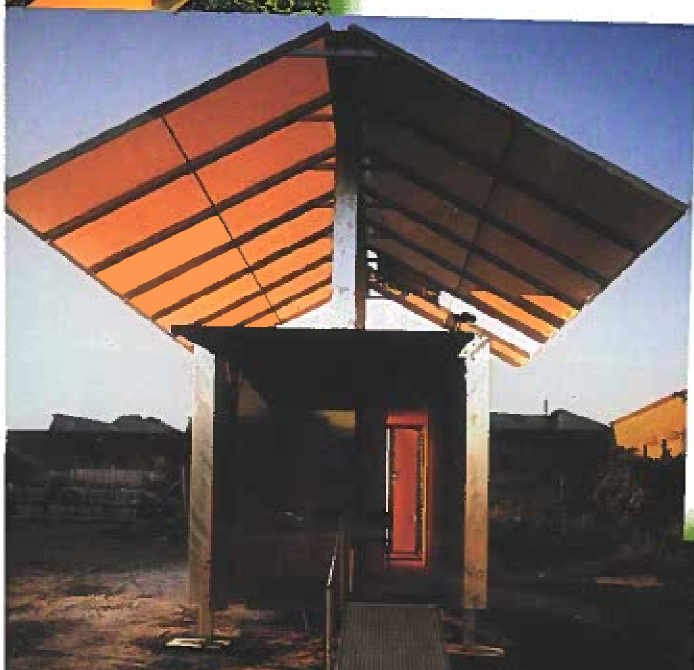
CHAPTER 6

# Structures

## Better by Design

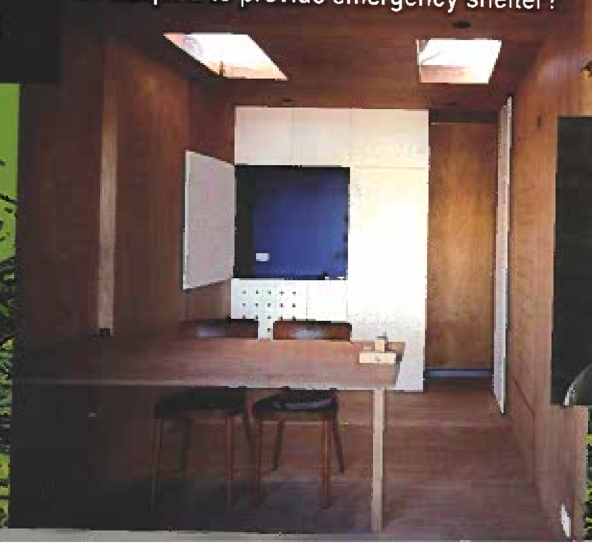
### Sean Godsell designs emergency shelters

Earthquakes, floods, and hurricanes leave thousands of people needing short-term relief housing immediately. Architects around the world are tackling this problem. Some have designed inflatable concrete tents. Others have designed homes built from recycled wood pallets. Sean Godsell, an Australian architect, has designed the *Future Shack*. Made from a mass-produced, inexpensive, and durable shipping container, it has a parasol roof made from recycled plastic that packs into the container when closed and collects rainwater when open. Also packed inside the container during shipping are solar panels to generate electricity, water storage tanks, and telescoping legs to support it on uneven terrain. *Future Shack* can easily be shipped and transported by road or rail.



A shipping container provides the basis for a self-contained refugee housing unit.

The interior of the Future Shack unfolds to provide basic items such as a table and sink. What other mass-produced products could be adapted to provide emergency shelter?



*"Architects have the power, if we trust them, to transform our lives."*
*—Sean Godsell*