CHAPTER 30

Mechanicals

Section 30.1
The Plumbing System

Section 30.2
The Electrical System

Section 30.3
HVAC Systems

Chapter Objectives

After completing this chapter, you will be able to:

- **Describe** or sketch a simple plumbing system.
- **List** the common materials used by a plumber.
- **Recognize** the various types of piping used for water supply and DWV systems.
- **Describe** the basic elements of an electrical system.
- **Identify** the three basic kinds of circuits.
- **Explain** how split-system air conditioners work and identify basic parts.

Discuss the Photo

Rough Wiring The electrician in the photo is installing rough wiring. *At what stage of construction do you think rough wiring is installed?*

Writing Activity: Gather Information

There are many different types of heating systems. Some examples include forced hot-air heating and radiant heating. Find out what type of heating system is used in your home. Locate reliable sources of information by contacting an HVAC professional. Write a brief description of the type of heating system in your home.

Jeff Greenberg/The Image Works

Chapter 30 Reading Guide

Before You Read Preview

The word *mechanical* will appear regularly throughout this chapter. Before reading the chapter, write down a definition of the word based on your knowledge. After you have finished reading the chapter carefully, rewrite your definition.

Content Vocabulary

- mechanicals
- fixture
- service main
- trap
- drain field
- circuit
- receptacle
- cell
- humidifier
- heat pump
- refrigerant
- infiltration
- air conditioning

Academic Vocabulary

You will find these words in your reading and on your tests. Use the academic vocabulary glossary to look up their definitions if necessary.

- rural
- circulates

Graphic Organizer

As you read, use a chart like the one shown to organize information about content vocabulary words and their definitions, adding rows as needed.

Content Vocabulary	Definition
fixture	any device that receives or drains water

Go to **glencoe.com** for this book's OLC for a downloadable version of this graphic organizer.

Academic Standards

Mathematics

Geometry: Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships (NCTM)

Measurement: Apply appropriate techniques, tools, and formulas to determine measurements (NCTM)

English Language Arts

Use information resources to gather information and create and communicate knowledge (NCTE 8)

Read texts to acquire new information (NCTE 1)

Science

Physical Science: Interactions of energy and matter (NSES)

Science and Technology: Abilities of technological design (NSES)

Earth and Space Science: Energy in the earth system (NSES)

Physical Science: Motions and forces (NSES)

Industry Standards

Mechanical and Electrical Safety

NCTE National Council of Teachers of English
NCTM National Council of Teachers of Mathematics
NSES National Science Education Standards

Section 30.1

The Plumbing System

Plumbing System Basics

What are some of the skills that a plumber must have?

The term **mechanicals** refers in general to plumbing, electrical, and heating/ventilating/air-conditioning (HVAC) systems. Mechanical systems should always installed by properly licensed subcontractors trained to do the work.

The various mechanical trades work at different times during the construction process. For example, plumbers are generally the first to arrive. They begin work during the rough framing stage to install rough drain lines. They return later to install finish plumbing. Because each trade requires multiple visits, their work must be carefully scheduled. The general contractor is responsible for coordinating the work of mechanical trades.

Each mechanical trade requires specialized tools and a great deal of knowledge. This chapter provides only a general introduction to mechanical systems.

The plumber installs the piping system for water and drainage, including all of the fixtures. In plumbing, a **fixture** is any device that receives or drains water. A bathtub is one example. The plumber must know the sizes of fixtures so that pipes will be in the correct location for each one.

Plumbers work with many different materials. Because of this, they must possess a wide variety of skills. These skills include woodworking, metalworking, welding, *brazing*, soldering, caulking, and pipe threading. Their hand tools include wrenches, reamers, drills, braces and bits, hammers, chisels, and saws. Plumbers also must be able to use power tools, such as portable drills and reciprocating saws. They also use oxyacetylene and propane torches for welding, brazing, and soldering, as shown in **Figure 30-1**.

As a house is being planned, the designer or architect determines the general location and type of fixtures. This information is shown on floor plans. However, the plumber determines the exact position of each fixture during installation. The plumber is also responsible for locating, sizing, and installing the pipes to serve those fixtures. Detailed specifications for installing plumbing systems are outlined in various publications, including the Uniform Plumbing Code (UPC), International Plumbing Code (IPC), and the International Residential Code (IRC). There may also be local codes that are suited to a particular town or region.

Figure 30-1 Water Supply Pipes

Soldering Pipes Plumbers work with many materials and with a wide variety of tools.

On the plans, individual fixtures are represented by standardized symbols. (A Plumbing Symbols table is in the **Ready Reference Appendix**.) The color, model number, and manufacturer of every fixture can be found on the plumbing fixture schedule.

Most plumbing installations must be checked by a plumbing inspector at two stages of construction: the rough-in stage and the finish stage. If the house has a concrete slab foundation, a plumbing inspection must also be performed prior to placing the concrete.

Understanding a Plumbing System

A plumbing system brings fresh water into the house and removes solid and liquid wastes. The two portions of the system are referred to as the supply side and the waste side. The waste side is also called the *drain/waste/vent (DWV) system*. A portion of a DWV system is shown in **Figure 30-2**.

A typical plumbing system consists of three basic types of pipes:

- *Supply pipes* are small-diameter pipes that distribute hot and cold water to fixtures. The pipes are usually made of copper. Normal operating pressures inside the house range from 40 psi to 80 psi.
- *Waste pipes* are large-diameter pipes made of plastic or cast iron. They convey liquid and solid wastes away from the house under atmospheric pressure only.
- *Vent pipes* are large-diameter plastic pipes. They encourage drainage and remove gases by balancing atmospheric pressure in the waste pipes.

A **service main** is a pipe that brings water to the house. It is sometimes called a *water service pipe* and is connected at the street to the municipal water system. Water pressure inside the service main can be considerably higher than pressure inside the house but is typically less than 160 psi.

A water meter connected to the service main records the amount of water used.

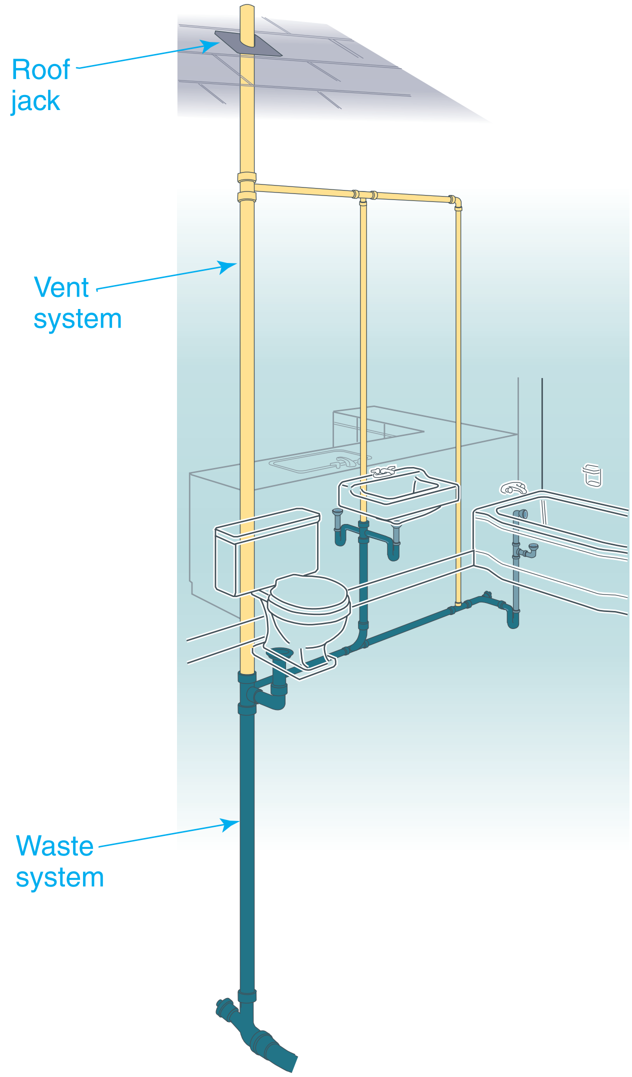


Figure 30-2 A Basic Waste System

Drain, Waste, Vent This schematic drawing shows the rough-in plumbing with the finished fixtures set in place. The plumbing is installed in a partition wall. A countertop sink is on one side, a lavatory sink is on the other side.

Waste flows out of the house by means of gravity to the public sewer or to a septic tank. Any horizontal lengths of waste pipe must be sloped so that they will drain properly.

An important component of the DWV system is a collection of traps. A **trap** is a curved section of drainpipe that is located beneath a fixture. It is sometimes called a *P-trap* due to its shape. A trap prevents gases

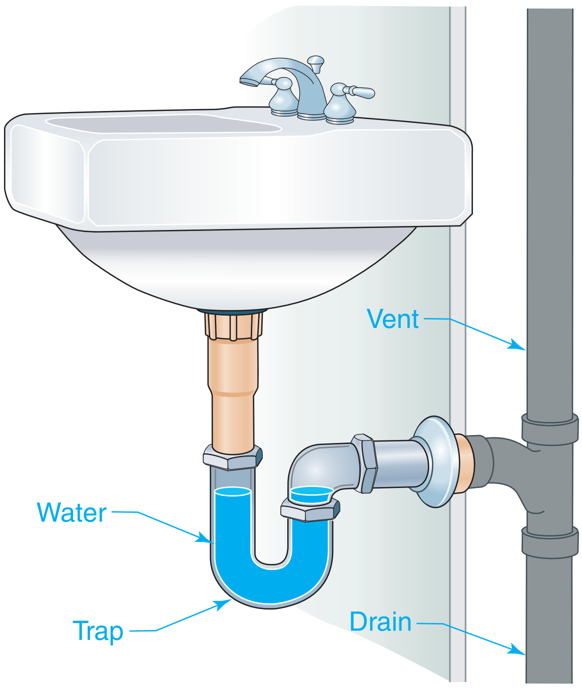


Figure 30-3 How a Trap Works
P-Trap A trap prevents gases from entering the house.

in the waste pipes from entering the house but does not block drainage. A small amount of water in the bottom of each trap serves as a gas plug, as shown in **Figure 30-3**.

Wells and Septic Systems

Houses, cities, and most towns are connected to a municipal water system. Water travels to the house from a centralized source. However, houses in **rural** areas and some small towns are not usually connected to a municipal water system. Instead, water is supplied by a water pump located near the house at the bottom of a narrow well. The well shaft is lined with pipe that is capped at the surface. Underground pipes lead from the pump to a tank located inside the house. Fresh water in the tank is kept under pressure and distributed by supply pipes as needed. In this system, each house in a neighborhood has an individual well.

Houses served by a well are not usually connected to a public sewer. Instead, wastes flow through the DWV system into a below-grade *septic system* on the property. A schematic drawing of this system is shown in **Figure 30-4**. The system collects solid waste in an underground tank and breaks it down with bacteria much like a municipal water treatment plant. The tank must be pumped out periodically to remove accumulated sludge. Liquid wastes in a septic system flow into a filtering area called a drain field. A **drain field** is a network of perforated pipes embedded in sand and gravel. The location of the drain field is determined primarily by soil conditions and grade. However, a well should always be located on the opposite or uphill side of the house from the drain field. It should be as far from the septic system as practical, but typically no less than 100 feet away.

Builder's Tip

VENT PIPES AT THE ROOF Vent pipes penetrate the roof and are sealed with flashing called a *roof jack*, as in Figure 30-2 on page 869. Beginning with the 2006 IRC, vent pipes must extend at least 6" above the roofing. In regions where snow is common, the pipe must extend at least 6" above the anticipated level of snow accumulation.

Plumbing Costs

Pipes are the least expensive portion of a plumbing system. Fixtures and their related parts are much more costly. A deluxe faucet, for example, can easily cost ten times as much as a modest faucet. When preparing cost estimates for the house, the contractor generally looks closely at plumbing system costs. One way to reduce overall costs is to use fixtures of lower quality. Arranging the fixtures efficiently can also reduce installation costs.

Framing Requirements

Supply pipes are relatively easy for the plumber to position. Their diameter is small and they are pressurized. This means they can be run in a way that avoids obstacles. However, waste pipes are not as easy to

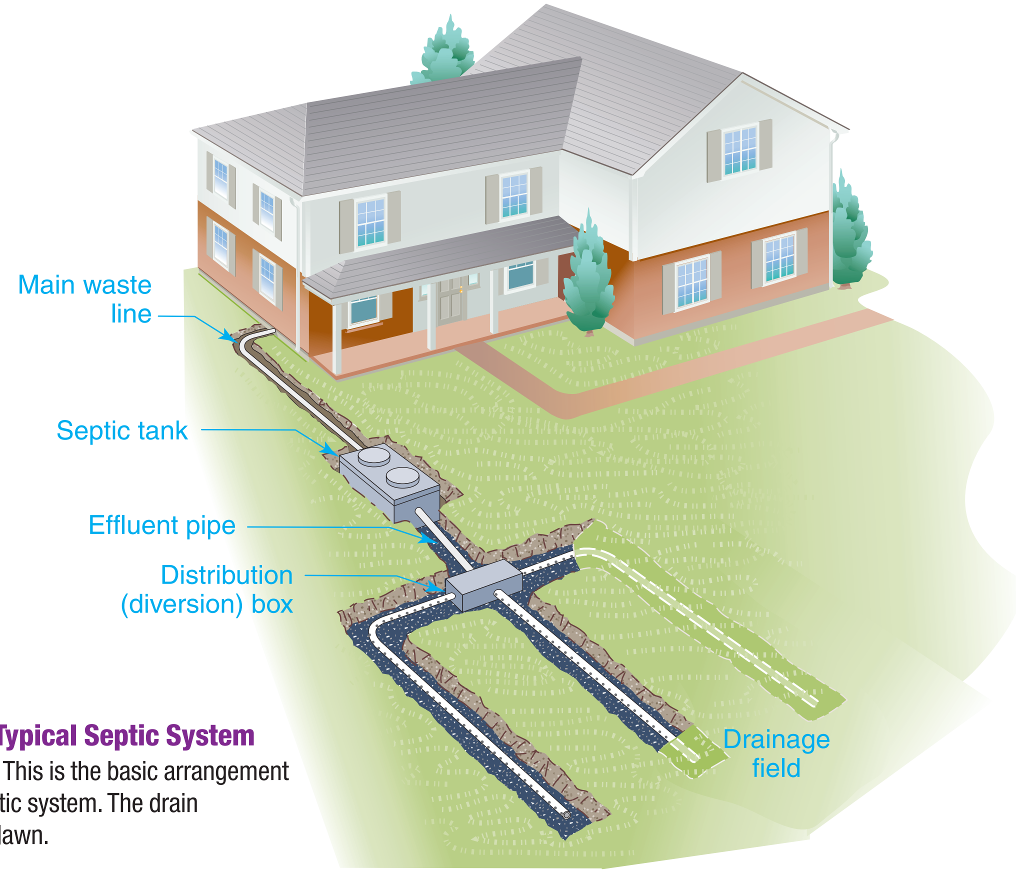


Figure 30-4 A Typical Septic System
On-Site Disposal This is the basic arrangement of a household septic system. The drain field is covered by lawn.

position. The pipes are large and must slope for proper drainage. When framing a house, carpenters should provide adequate space for drain and waste pipes. This is particularly important at bathtub and toilet locations.

Special framing is sometimes needed to support unusually heavy items such as large bathtubs. For details of this type of framing, see Section 16.4. Blocking may also be required to support heavy piping. This is usually considered the plumber's responsibility to install.

Cutting Floor Joists Plumbers often need to bore large holes through a series of joists in order to install waste pipes. However, building codes specify the limits for cutting holes and notches in joists and studs, as shown in **Figure 30-5**. The allowable size of holes and notches is based on the depth of

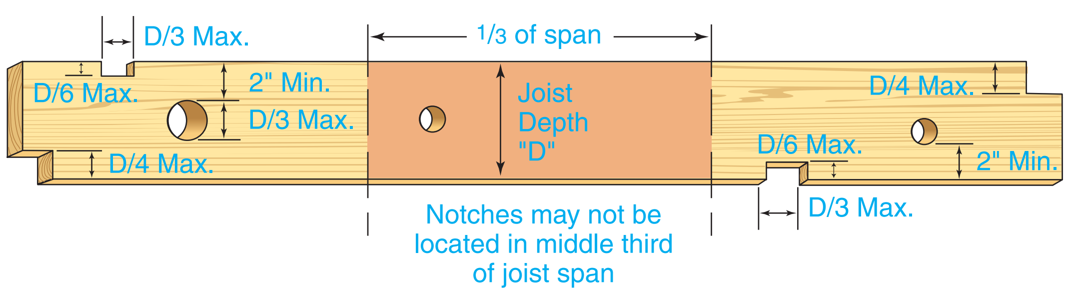


Figure 30-5 Holes and Notches in Wood Joists
Code Restrictions These are the maximum allowable sizes for notches and holes. Each hole or notch is sized based on the depth (D) of the joist.

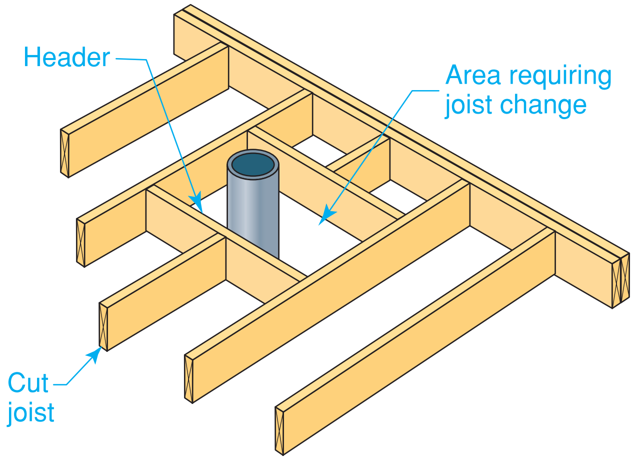


Figure 30-6 Supporting a Cut Joist
Always Provide Support Header joists are used to support joists that must be cut to make room for plumbing drain lines.

the joist. This means they can be larger as the size of the joist increases. It is generally best to avoid notching if at all possible.

If greater than allowable notching is unavoidable, joists must be reinforced by nailing a 2× scab to each side of the altered member, using 12d nails. A scab is a length of wood used to reinforce another piece. In extreme cases, an additional full-length joist, called a *sister*, must be nailed to the notched joist in order to maintain the strength of the floor system.

Sometimes a joist must be cut through completely. If this is necessary, the cut ends must be supported by headers, as shown in **Figure 30-6**. Proper planning during framing can usually eliminate the need to alter joists.

Basic Plumbing Materials

What is the purpose of soldering?

Pipes and tubing used in plumbing systems are made of several different materials and are joined in different ways. Most new supply systems have copper piping (sometimes called *copper tubing*), while most DWV pipes are now made of plastic.

Supply Piping

Copper pipes are joined with copper fittings that slide over the pipes. The fittings are then soldered to create a leak-free joint. Pipes come in 20' lengths. The main water distribution lines in a typical house are ¾" or 1" in diameter. Branch distribution lines lead to individual fixtures, as shown in **Figure 30-7**. They are typically ½" in diameter. Fittings come in many shapes and in each of the three common pipe diameters. Copper pipe also comes in three wall thicknesses:

- ***Type M*** Thin wall. This is most common in residential construction. These pipes are labeled using red ink.
- ***Type L*** Medium wall. These are labeled using blue ink.
- ***Type K*** Thick wall. These are used for underground water lines and are labeled using green ink.

The joints between copper pipes and fittings are soldered (sweated) to seal the pipes and fittings together, as shown in **Figure 30-8**. Solder was once a combination of lead and tin. However, lead in water supply systems is now considered a health hazard. Lead-free solder has therefore been required since 1988.

Reading Check

Explain *What may occur if soldering is not done properly?*

Builder's Tip

COPPER PIPE DIMENSIONS The actual outside diameter of a copper pipe is always ⅛" larger than the standard size designation. For example, ½" pipe has an actual outside diameter of ⅝".

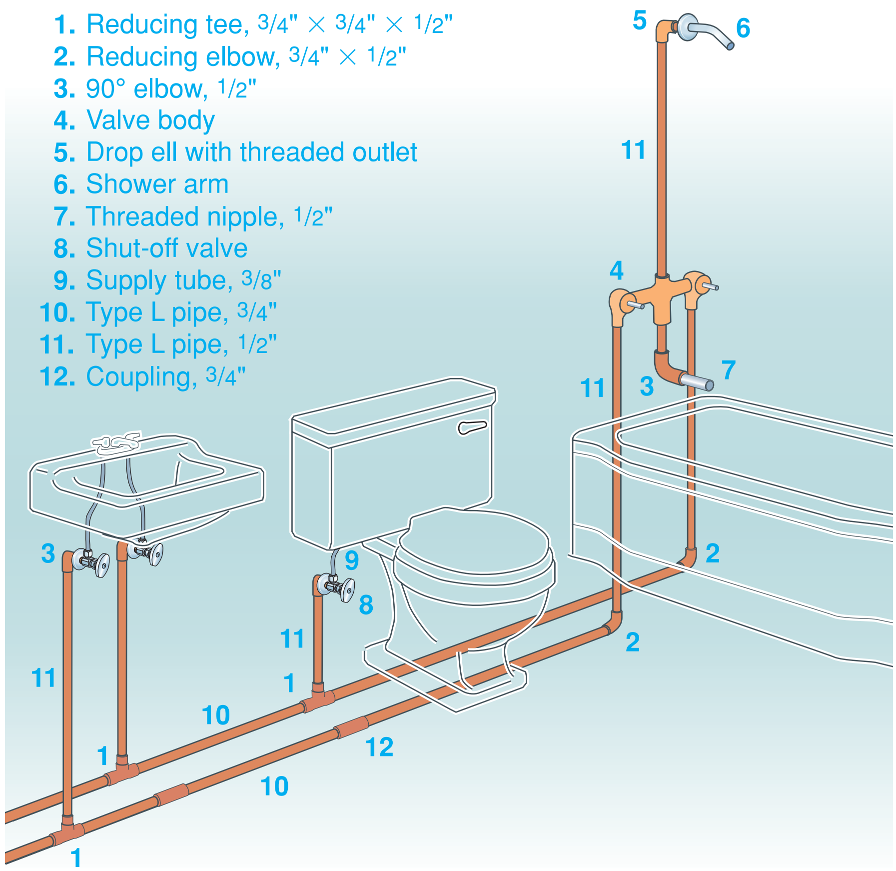


Figure 30-7 Water Distribution Piping

Common Fittings These are the fittings most often used for the water supply piping in a bathroom.

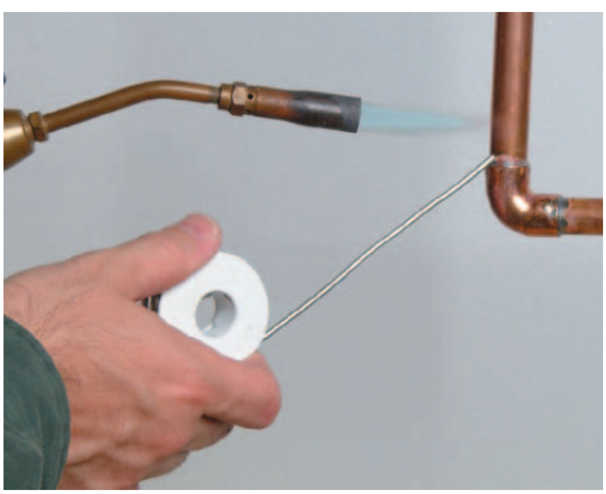


Figure 30-8 Lead-Free Solder

Water Supply Lead-free solder is a combination of tin, copper, and silver. Heat can be supplied by a propane torch.

Flexible copper tubing is much smaller in diameter than rigid copper piping. It comes in coils up to 100' long and is used to supply appliances that use water, such as dishwashers and refrigerator icemakers. It is connected by friction fittings instead of being soldered.

Various types of plastic pipe can now be used for water supply piping. Plastic supply pipe is lightweight, easy to handle, and resists fracture in freezing conditions. Connections between pipes and fittings are made with solvent welding or threaded fittings, or by using crimping rings. In the 2006 IRC, the following plastic supply piping was approved for use:

- chlorinated polyvinyl chloride (CPVC)
- cross-linked polyethylene (PEX)
- polyethylene (PE)
- polypropylene (PP)

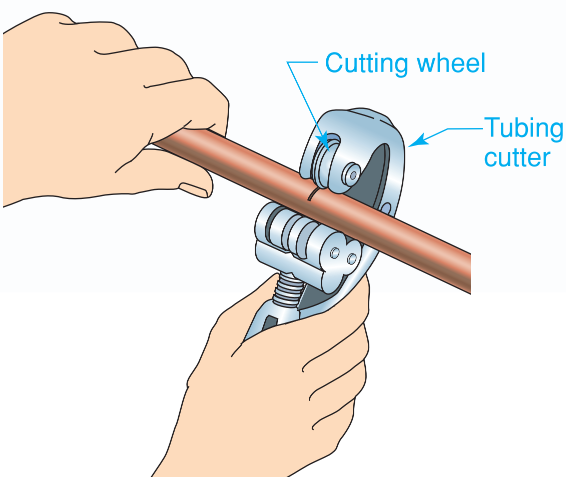
Always check for local code approval before using plastic supply pipe. Some materials may be approved only in limited areas or for limited uses. For example, they may be approved for use inside the house as distribution piping but not allowed under a concrete slab. As new products and installation techniques are developed, this area of construction will continue to change.

Soldering Copper Piping The basic technique for soldering copper pipe is described in the Step-by-Step Application below. The technique must be repeated for each joint in a supply system. When installing copper supply piping, it is often necessary to solder overhead. Protect your eyes and skin from molten drips of solder. Avoid standing directly under the fittings you are working on. When possible, assemble and solder joints on the floor, then lift the assembly into position. After the entire supply system has been assembled, it should be pressurized and checked for leaks. Faulty joints must be resoldered.

Step-by-Step Application

Soldering Copper Pipe The process of soldering copper pipe joints is one of the essential skills of a plumber.

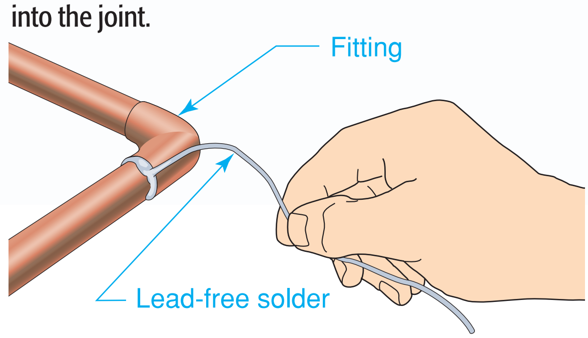
Step 1 Measure a length of pipe to fit the location, and cut it to length using a tubing cutter. Cut the pipe by rotating the tubing cutter repeatedly around the pipe. The cutter's wheel will gradually slice through the copper. Use the reamer on the back of the tubing cutter to smooth out any burrs left on the inside of the pipe. Test fit the pipe into the fitting.



Step 2 The outside surface of the pipe and the inside surface of the fitting must be shiny-clean where they meet. Use fine emery cloth or a wire pipe-cleaning brush to clean the surfaces.

Step 3 Flux is a special paste that helps to draw solder into the joint. Use a flux brush to coat the cleaned copper surfaces with flux. Assemble the joint and twist the pipe back and forth briefly to spread the flux evenly.

Step 4 Use a torch to heat the joint area evenly. Touch a length of lead-free solder to the area frequently. When the solder starts to melt, quickly turn off the torch and hold the tip of the solder against the joint. As the solder melts, capillary action will draw it into the joint.



Step 5 After the joint cools, wipe off surplus flux with a damp rag.

Go to **glencoe.com** for this book's OLC for additional step-by-step procedures, applications, and certification practice.

JOB SAFETY

SOLDERING SAFELY It is often necessary to solder fittings that are close to framing or sheathing. To prevent the wood from catching fire, always use a non-combustible shield to protect nearby wood.

Go to glencoe.com for this book's OLC for more on job safety.

DWV Piping

Cast-iron drainpipe (sometimes called *soil pipe*) is used for waste systems in high-quality construction. It is harder and more expensive to install than plastic drainpipe but muffles the sound of water rushing through the pipes. One type of cast-iron pipe has a flared fitting, called a *bell*, at one end of the pipe. The other end of the pipe is called the *spigot end*. The spigot end fits into the bell end. The joints are sealed using various methods. Another type of cast-iron pipe is called *hubless cast iron*. Each length of pipe is joined to another with polyethylene clamping rings.

The black plastic pipe used in DWV systems is acrylonitrile-butadiene-styrene (ABS). It is inexpensive, lightweight, and easy to cut. It is joined using a solvent cement.

White plastic pipe is made from polyvinyl chloride (PVC). It has considerably lower thermal expansion characteristics than ABS. This makes it particularly suitable for long pipe runs. It is sometimes joined using a solvent-type primer followed by PVC cement. One-step primer-cements are also available.

Before connecting ABS or PVC pipe to a fitting, cut the pipe square with a fine-tooth saw. Plumbers use saws intended specifically for cutting plastic because they result in a clean, square cut. However, a hacksaw will also work. Be sure to remove any burrs from the end of the pipe after cutting it. Any leaks discovered in ABS or PVC fittings during testing generally require the fitting to be cut out and replaced.

Section 30.1 Assessment

After You Read: Self-Check

1. What does the abbreviation HVAC stand for?
2. At what stages must a plumbing inspector check a plumbing system while it is being installed?
3. What is a trap and what is its purpose?
4. How can joists be reinforced after notching?

Academic Integration: Mathematics

5. **Pipe Length** What is the length of piping needed to connect two offset pipes when the offset angles are both 45° and form an isosceles right triangle whose base and altitude are both 15"?

   Math Concept The length of the sides of a right triangle are related according to the Pythagorean Formula, $a^2 + b^2 = c^2$.

   Step 1: Plug the known values into the formula: $15^2 + 15^2 = c^2$

   Step 2: Solve for c, the unknown value: $\sqrt{15^2 + 15^2} = c$

Go to glencoe.com for this book's OLC to check your answers.

The Electrical System

Electrical System Basics

How does electricity use affect the environment?

The general scheme of a home's wiring is shown in the wiring plan portion of the floor plans, such as those shown in **Figure 30-9**. The wiring plans use symbols to indicate the type of electrical devices to install at each location. (An Electrical Symbols table is in the **Ready Reference Appendix**.) However, the location of wires, as well as the exact placement of switches and receptacle outlets, is the electrician's responsibility.

The wiring plans should consider present and future needs of the homeowner. This is increasingly important due to the home use of computers and other electrical equipment once found only in office buildings, shown in **Figure 30-10**. Specialized wiring is often added during this phase. This includes cable for television or Ethernet cable for high-speed

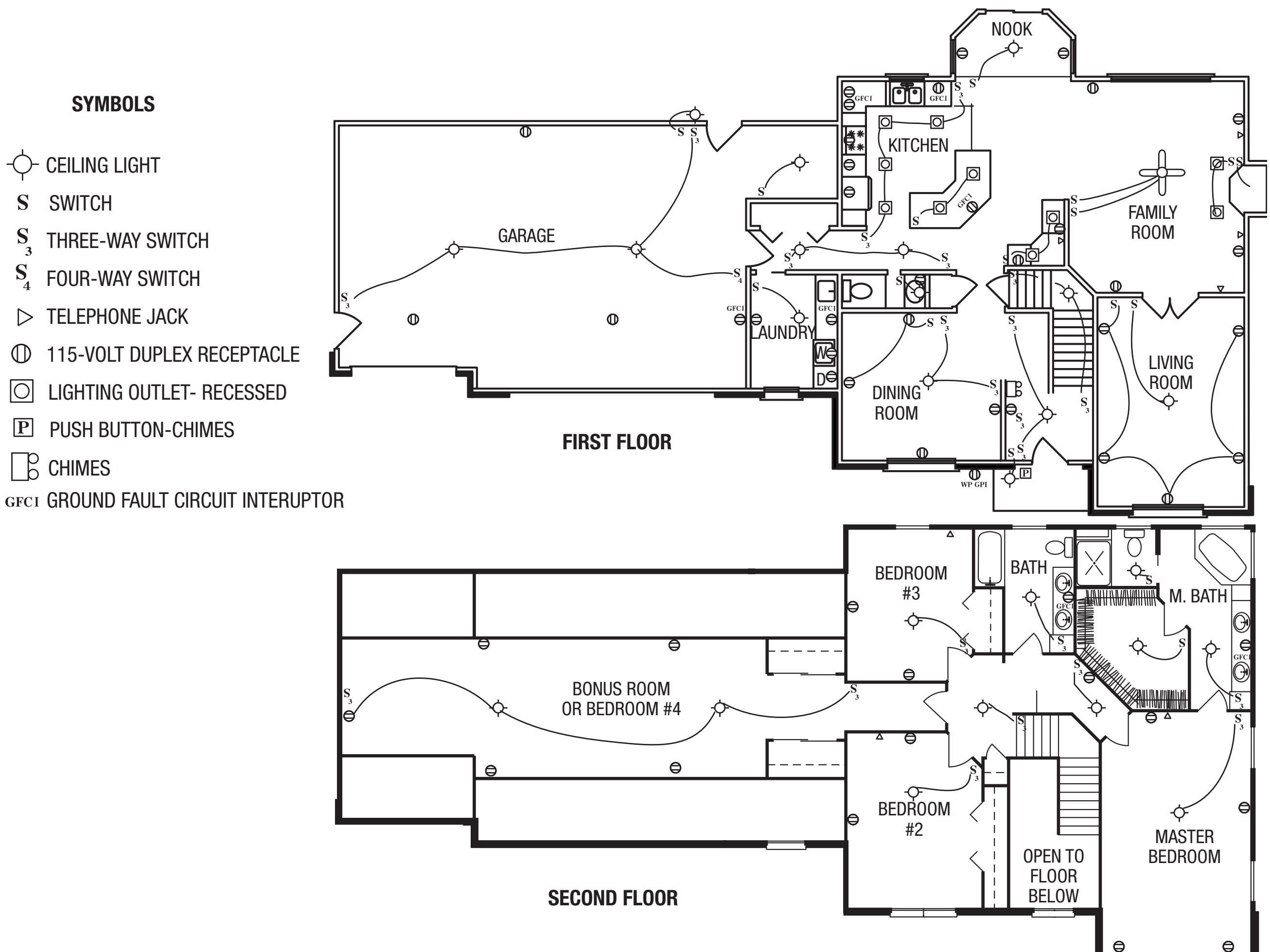


Figure 30-9 Wiring Plan

Power Arrangement The electrician uses an electrical plan as a guide when installing the various components of an electrical system. *Why is it important for all electricians to know how to read electrical symbols?*

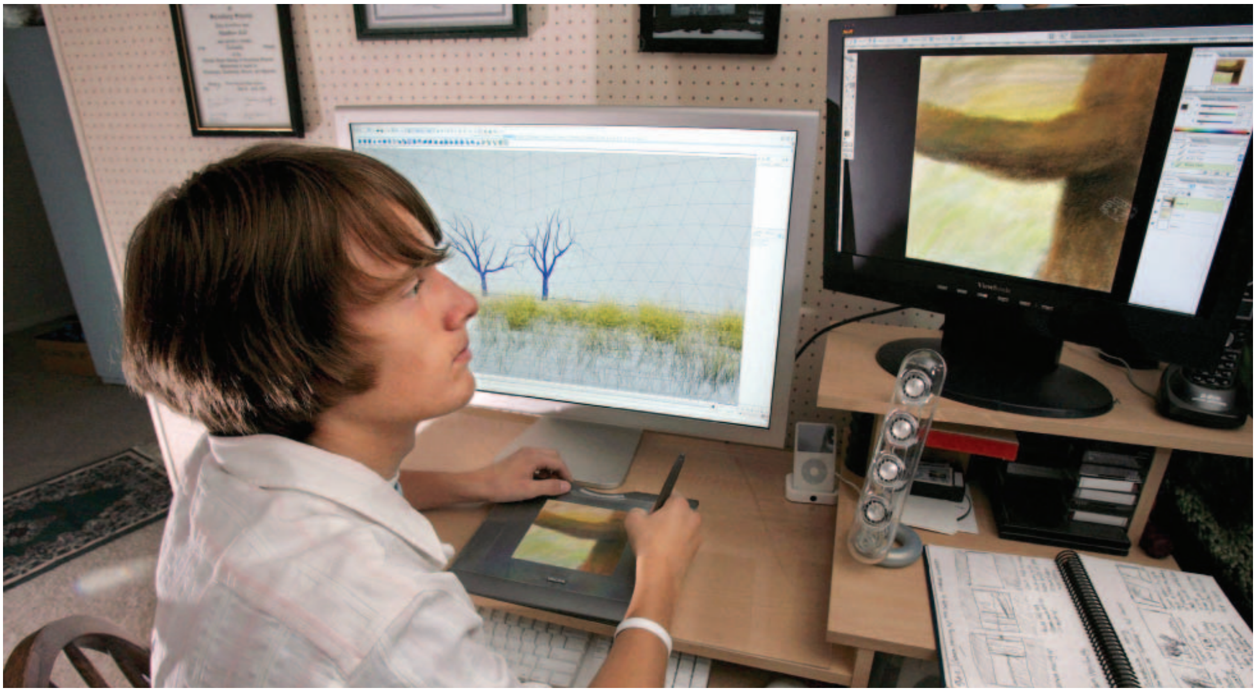


Figure 30-10 Home Office

Technology at Home Many people now work partly or entirely at home. Wiring for a home office must allow for equipment such as computers, fax machines, scanners, and printers.

Internet access. Additional wiring may serve phone, audio, intercom, and other systems. Electricians install the general electrical system. Other contractors may be called on to install specialized wiring.

Understanding an Electrical System

All power comes into a building through the service entrance wires. These may be overhead wires or an underground cable called a *lateral*. A schematic drawing of this system is shown in **Figure 30-11** on page 878. New houses are generally supplied with 200-ampere service. As explained in Chapter 6, an *ampere* (amp) is a measure of electrical current. The service entrance wires run first to the watt-hour meter. This records how much electricity is used within the house. In newer homes, digital watt-hour meters are installed to make recording usage easier.

From the meter, the wires run to a master distribution panel, called the *service panel*. The panel is usually located in the basement or in a utility area. At the top of the service panel is a master switch. It is used to cut off all electricity in the house. This would be done in an emergency or when various parts of the wiring system are being worked on.

Smaller wires lead from the service panel to points throughout the house. The wires are organized into circuits. A **circuit** is a cable or group of cables that supplies electricity to a specific area or appliance. It can be connected or disconnected without affecting any other circuit. Each circuit is connected to an individual device called a *circuit breaker*. Circuit breakers are located inside the service panel below the master switch. A circuit breaker is like a fast-acting switch. It shuts off power in a circuit if it detects overloads that might lead to a fire. The circuit breaker can also be turned off manually if maintenance work must be performed on the circuit.

A house could easily have as many as 25 or more separate circuits. There are three basic kinds of circuits: appliance circuits, general-purpose circuits, and special-purpose circuits.

David Hassman/Syracuse Newspapers/The Image Works

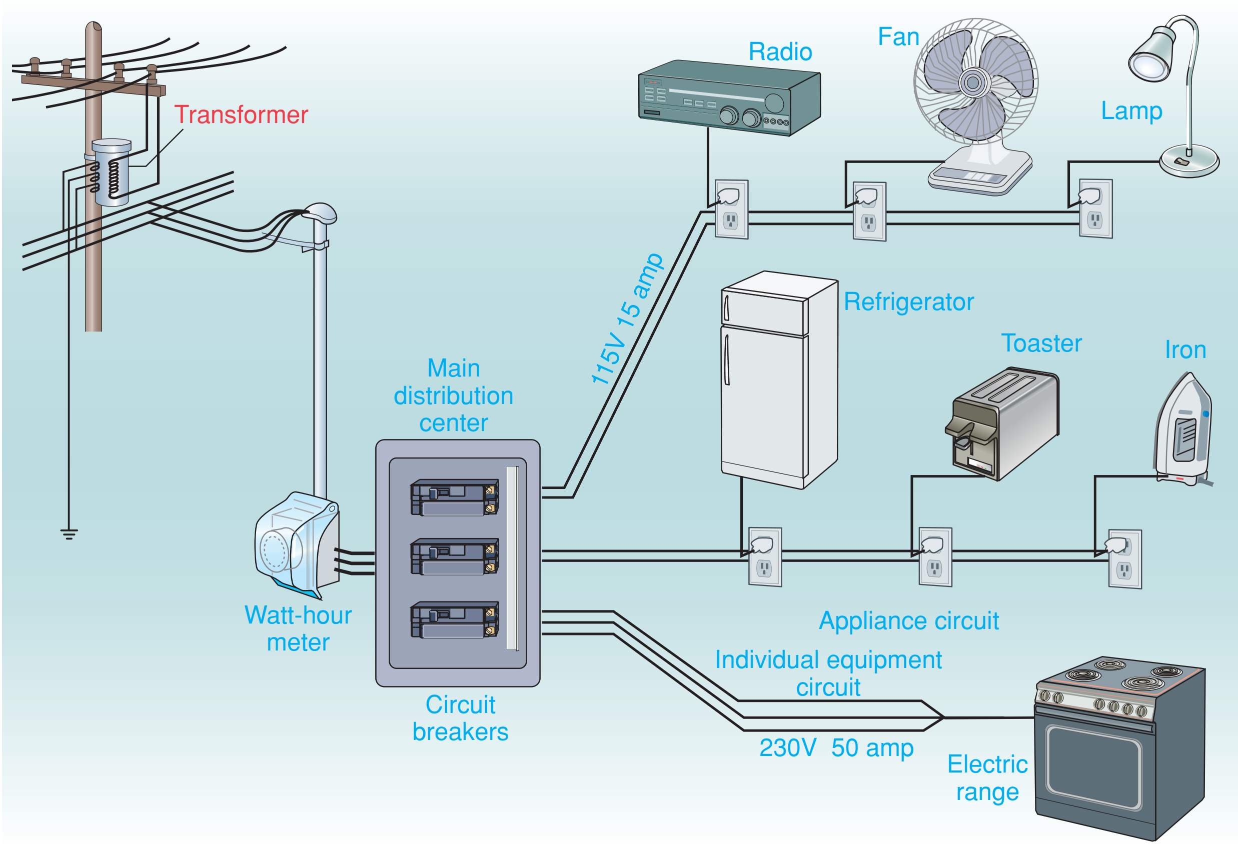


Figure 30-11 A Basic Electrical System

Distributing Power This drawing illustrates how electricity is distributed to the house and to the circuits inside.

- A small *appliance circuit* is wired with No. 12 wire and is connected to a 20-ampere circuit breaker. At least two small appliance circuits are needed in the kitchen. An appliance circuit might also be added in a basement to provide electricity for shop tools.
- A *general-purpose circuit* is wired with No. 14 wire and connected to a 15-ampere circuit breaker. It also may use No. 12 wire and a 20-amp circuit breaker. These circuits lead to lighting and to all receptacles.
- A *special-purpose circuit* supplies the needs of stoves, air conditioners, furnaces, and other appliances that use large amounts of electricity. It often serves a single appliance. This circuit uses thicker wire than other circuits and is connected to a 30-ampere or greater circuit breaker.

Electrical Materials & Systems

What are common types of wire?

Electrical materials include wires and outlet boxes.

Wires

Several different kinds of wire and wiring systems are allowed by electrical codes. Electrical wires are referred to as *conductors*. This distinguishes them from standard utility wire. Conductors are usually made of copper, although in some cases aluminum is allowed. Several common types of wires are shown in **Figure 30-12**.

- *Nonmetallic sheathed cable wiring (NMC)* is the most common, the simplest to install, and the least expensive. The cable consists of two or three insulated copper conductors and one bare copper conductor within a thermoplastic covering. All wires within a given cable are always the same size.

- *Armored cable* is used in exposed locations where mechanical damage might be expected. It is also used where local codes do not allow NMC. This hollow cable, commonly called *BX,* has a flexible metal exterior. Individual insulated conductors are contained within the cable.
- *Rigid metal* or *plastic conduit* is used in exposed locations and sometimes underground. Like BX cable, it protects the conductors inside. Metal conduit can be bent around corners, using a special tool called a *conduit bender*. Plastic conduit is joined with solvent and plastic fittings.

Reading Check

Summarize *Why are electrical wires referred to as conductors?*

Outlet Boxes

Wiring leads from the service panel to various types and sizes of metal or plastic *outlet boxes,* shown in **Figure 30-13**. Outlet boxes provide a convenient location for joining wire. They also prevent dust and debris from collecting on the connectors. They limit damage from short circuits and other wiring faults that could cause fires. They provide a solid mounting surface for switches, receptacles, and other devices.

Wiring enters a box through pre-scored holes called *knockouts*. Where wires enter, they must be held securely by cable clamps or by some other method. This prevents the wires from pulling away from receptacles. A **receptacle** has a combination of slots and grounding holes sized to accept the prongs of an electrical plug. Each box must be nailed securely to the framing. The electrician must position each box so that its front edge will be flush with the final wall covering.

An outlet box is required wherever wiring will be connected to a device, such as a switch, a ceiling light, or a receptacle. An outlet box is also required wherever lengths of wiring are spliced together. Wiring must never be spliced outside a box.

Wiring a House

Wiring is done in two stages: the rough-in stage and the finish stage. The rough-in wiring is done after the exterior of the house has been completed but before the insulation

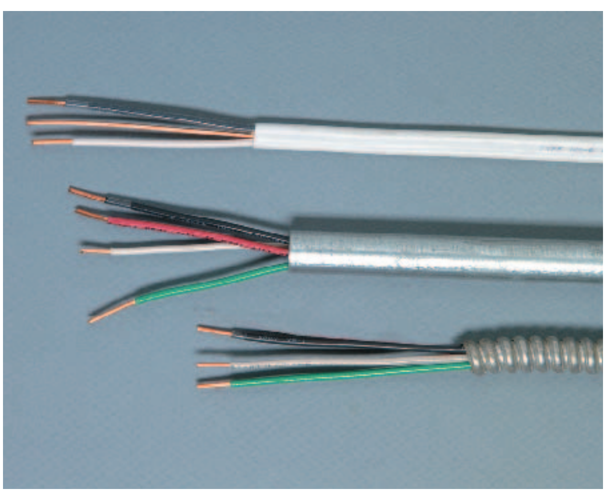


Figure 30-12 Common Wire Types
Basic Types Three kinds of wiring are used between the circuit breakers and the outlet (junction) boxes: Nonmetallic sheathed cable (top); conduit (middle); and armored cable (bottom).

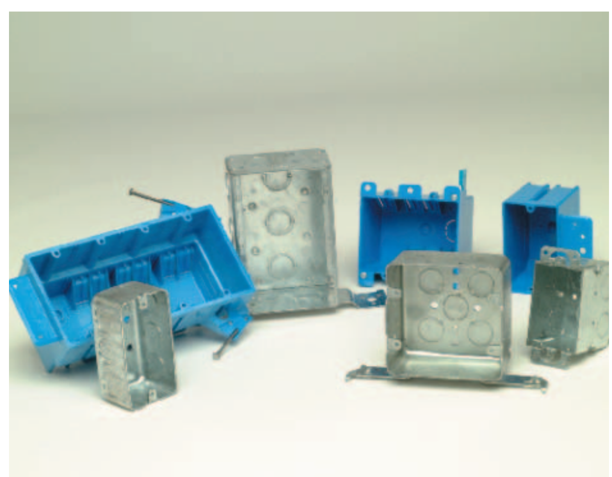


Figure 30-13 Outlet Boxes
Metal and Plastic Outlet boxes are available in a wide variety of sizes. Electrical codes determine the number and size of wires that can enter a particular size of box.

Arnold & Brown; David R. Frazier Photolibrary, Inc.

has been installed. The electrician installs the service panel and breakers, as shown in **Figure 30-14**. Then cables are routed from the panel into outlet boxes throughout the house. This is sometimes referred to as *pulling the cables.*

Inside each outlet box, the outer sheathing of the cable is stripped off to expose individual conductors. The conductors are left exposed until the finish wiring stage, as shown in **Figure 30-15**.

After the rough-in wiring is completed and has been approved by a building inspector, insulation and wall finishes can be installed. After the interior of the house has been painted, the electrician returns to complete the finish wiring. All switches, receptacles, and lighting fixtures are connected at this stage, both inside and outside the house. The electrician connects conductors

Builder's Tip

ARC-FAULT INTERRUPTERS One study of house fires indicated that over 40,000 homes each year catch fire due to problems with wiring. A relatively new device reduces fire hazards so it is now required in houses. It is called an *arc-fault circuit interrupter (AFCI)*. When the device senses conditions that would cause arcing or sparking in a wire, it cuts power to that circuit. This is different than a ground-fault circuit interrupter (GFCI). A GFCI is designed to protect people from electric shocks. An AFCI is designed to protect against fire hazard. Eventually, devices that combine both functions will be available.

Figure 30-14 Service Panel

Distribution Center Circuit breakers are located in the main service panel. Never work on the panel unless you are absolutely certain that power is not being supplied to it.

by holding their bare ends together and then twisting on a threaded cap called a *wire nut* or *wire connector.*

When the finish wiring is completed, the electrician tests it. Outlet covers must then be attached over all switches and receptacles. The inspector then returns to check and approve, or *final,* the installation.

Reading Check

Explain *When is rough-in wiring done?*

JOB SAFETY

DANGEROUS CURRENT In cases of electric shock, current is what kills. A person can die from as little as one-tenth the amount of current needed to light a light bulb. Always follow all safety precautions when dealing with electricity.

Go to **glencoe.com** for this book's OLC for more on job safety.

A

B

Figure 30-15 Wiring a Switch

Basic Steps A. During the rough-in stage, boxes are positioned and cable is run into them. The wires are left exposed until later. The V-shaped mark on the stud indicates which side of the stud the box should be attached to. Once interior finishes are complete, the electrician will return to install and test the switch. **B**. In this photo, the drywall was left off to show how wires are secured to the stud.

Section 30.2 Assessment

After You Read: Self-Check

1. What is an ampere?
2. What is the purpose of a circuit breaker?
3. What is a receptacle?
4. During the rough-in phase, what happens to cable after it is routed to the outlet boxes?

Academic Integration: Science

5. **Circuit Breaker** What size circuit breaker is needed for a dishwasher with a 115 volt circuit that carries a resistance of 8 ohms?

   Math Concept Voltage (E) is the force that causes electricity to flow through a conductor. We measure the resistance to that force in ohms (R). We measure the rate of electron flow through a conductor in amperes, or amps, (I). These three are related according to the formula $E = IR$, or $I = E \div R$.

   Step 1: Plug the known values into the formula. $I = 115 \div 8$

   Step 2: Solve for I, the unknown value.

Go to glencoe.com for this book's OLC to check your answers.

Section 30.3 HVAC Systems

Heating Systems

What are the different types of heating systems?

Without effective temperature control, houses in many areas would be either too hot or too cold. Because temperature control systems can be costly to operate, a great deal of research is under way to make them more energy efficient. This means getting more energy from less fuel. New HVAC systems are far more efficient than older systems. Thermostats that control the systems are also more efficient, such as the digital thermostat shown in **Figure 30-16**. They can be programmed to allow temperatures in a house to drop at night, or when the house is not occupied. The thermostat will automatically increase temperatures to a comfortable level when necessary.

There are many types of heating systems. Some are combined with air-conditioning and ventilation systems. Heating systems are categorized primarily by the way the heat is distributed, not by the fuel they use. Various fuels can supply the heating energy needed.

Reading Check

State *Why should homeowners maintain up-to-date HVAC systems in their home?*

Figure 30-16 Electronic Thermostat
Programmable Electronic thermostats can be set to change temperatures on an hourly or daily basis. They are sometimes called *set-back thermostats*.

Forced Hot-Air Heating

A forced hot-air heating system consists of a furnace, ducts, and registers. The system is popular because it responds quickly to changes in outdoor temperatures. It can be used in many types of houses. The ducts and registers can also be used to distribute cool air created by a central air conditioner.

Fuel is burned inside the furnace. A blower **circulates** the warm air to the rooms through *supply ducts.* The ducts may be made of sheet metal, flexible insulated tubes, or rigid fiberglass insulation. *Supply registers* are located along the outside walls of the house. There is usually a *return-air register* in each room. It is usually located across the room from the supply registers. As air within the room cools, it sinks to the floor and flows into the return-air register. Return registers and ducts carry cooled room air back to the furnace. There, it is reheated and recirculated, as shown in **Figure 30-17**.

Heated air is filtered through replaceable or washable filters, sometimes called *media filters.* It is important for the homeowner to remove them for inspection on a regular basis during the heating season. Clogged filters dramatically reduce the effectiveness of the system and make it less efficient. As an alternative to media filters, electronic air cleaners can be installed in some heating systems. They are very effective at removing pollen, fine dust,

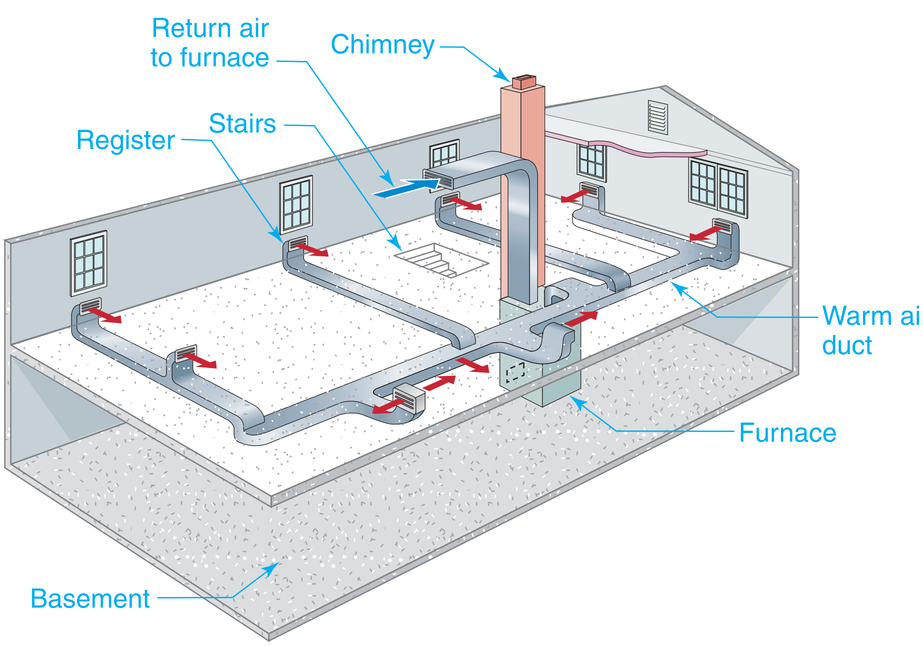


Figure 30-17 Forced Hot-Air System
Circulating Warmed Air Some forced hot-air systems have a cold-air return in each room (except the bathroom and the kitchen).

and other irritants that normally pass through standard filters. The part within an electronic air cleaner that actually removes contaminants is called a **cell**. Cells should be cleaned on a regular basis and can be reused.

A humidifier is another device that can be added to a hot-air system. A **humidifier** adds moisture to the air inside the house and counteracts the drying effects of hot air. Water is constantly fed to the humidifier by way of copper tubing. The tubing is connected to the main water supply.

In houses with a slab foundation, heating equipment and duct work are usually installed in the attic. However, cylindrical ducts may be installed in the slab as a *perimeter loop system*, as shown in **Figure 30-18**. If this is done, the ducts must be positioned within the foundation formwork before the concrete is placed.

Heat Pumps A **heat pump** is a device that can heat and cool a house. Heat pumps are energy-efficient because they do not burn fuel to make heat. Instead, they rely on electricity to pump refrigerant through a closed-loop system. **Refrigerant** is a material that absorbs heat as it becomes a gas and gives up heat as it becomes a liquid. The heat pump itself, such as the one shown in **Figure 30-19**, is located outside the house. It contains a compressor and a fan. Pipes containing the refrigerant connect the heat pump to a unit inside the house. This unit contains evaporator coils and a blower. The blower sends heated or cooled air through the house using a standard duct system.

The ability of the system to heat and cool relies on the fact that the refrigerant absorbs heat or gives off heat as it changes back and

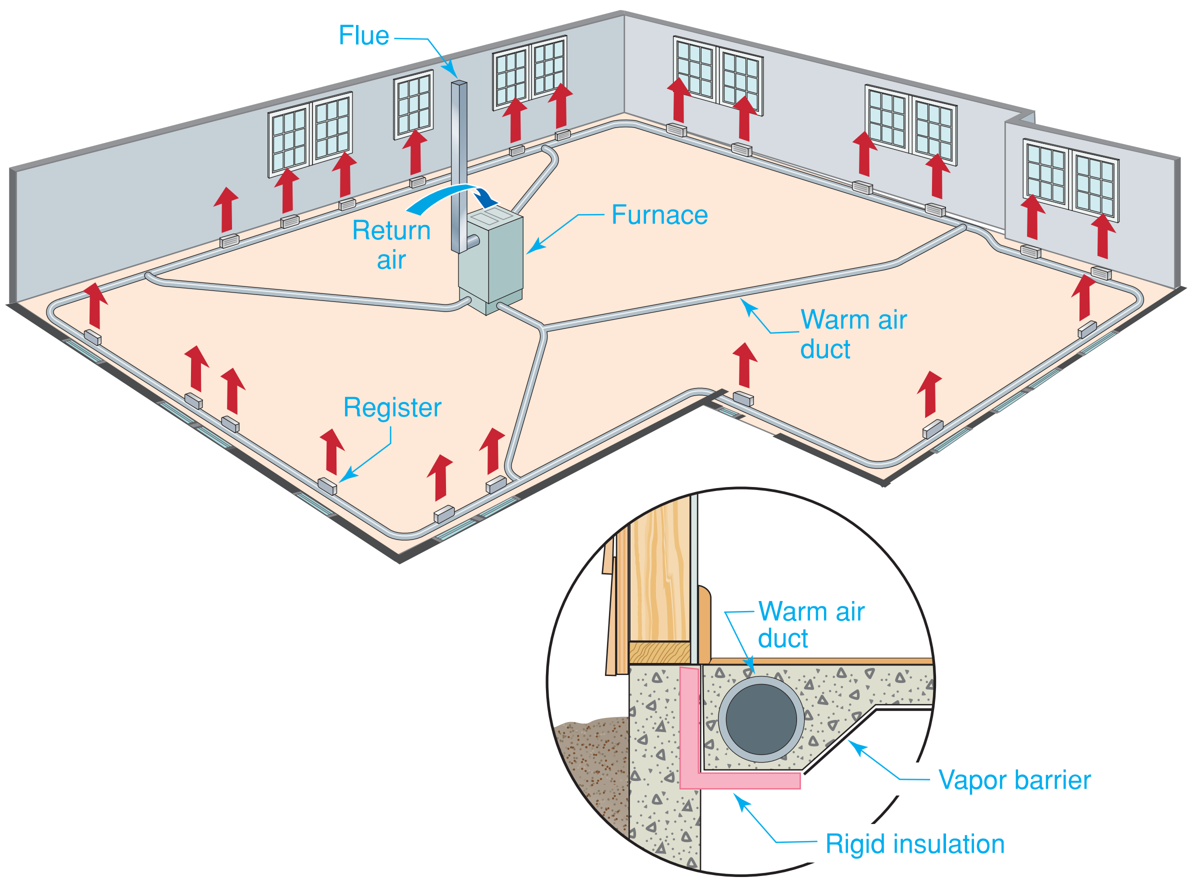


Figure 30-18 Perimeter Loop System

Suitable for Slabs Perimeter loop hot-air systems are sometimes used in houses that are built on a concrete slab.

forth from a liquid to a gas. In the summer, refrigerant is pumped through the system so that it absorbs excess heat from the house and releases it in the heat pump outdoors. In the winter, the process is reversed. The refrigerant is pumped through the system so that it extracts heat from outdoor air and releases it indoors. This is why heat pump systems are not suited to climates with cold winters. When the outdoor temperature drops below about 45° F, the system becomes less efficient.

Hydronic Heating

Hydronic heating systems, or hot-water systems, consist of a boiler, pipes, and room-heating units (convectors or radiators). Hot water generated in the boiler is pumped through copper pipes to the *convectors* or *radiators*. Heat then radiates into the room.

REGIONAL CONCERNS

Heating & Fuel Climate and the type of heating fuel used vary from region to region. These factors affect the type of heating system that is most common. In the northeastern United States, for example, oil is the most common heating fuel. In much of the Northwest, it is common to heat with electricity. This is because the climate is relatively mild and electricity is fairly inexpensive (compared to oil) due to plentiful hydroelectric resources. In still other parts of the country, natural gas is preferred. In regions with consistently clear skies, solar-assisted heating systems are a workable option.

Go to **glencoe.com** for this book's OLC for more information about regional concerns.

Figure 30-19 Heat Pump

Double Duty A heat pump such as this one is part of a system that can heat and cool a house.

M Stock/Alamy

Boilers are made of steel or cast iron. When fuel is burned inside the boiler, this generates heat that is transferred to pipes containing water, as shown in **Figure 30-20**. A pump circulates this water to the room-heating units. As the water cools, it is returned to the boiler and heated again. Boilers can be designed to use various fuels, including electricity, coal, natural gas, or oil. Boilers designed for remote areas can even use wood as the basic fuel.

One problem with any system based on a boiler is that corrosion can shorten boiler life. Boilers should be inspected at the beginning of each heating season.

Convectors usually consist of tubes with fins. They are enclosed in a housing that has openings at the top and bottom. Hot water circulates through the tubes. The fins maximize the transfer of heat to the surrounding air. Convectors usually run along the baseboards and are often placed under windows. Low-profile convectors can be placed in locations that would otherwise not be suitable.

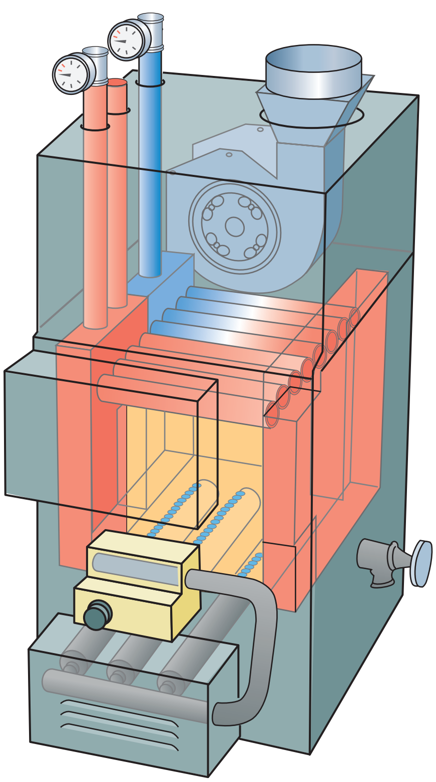


Figure 30-20 Hot-Water Boiler
Cutaway View Boilers heat water and circulate it through pipes to heat the house. Heat is extracted from the water as it flows through convectors or radiators.

Science: Air Density

Hot Air/Cool Air Forced hot-air heating systems utilize return-air registers to circulate air from a room in a home to the furnace. The return-air registers are located on the floor of the room because as the air cools it sinks to the floor. Explain why cool air sinks and hot air rises.

Starting Hint Find out about the difference in density between hot and cold air.

Radiant Heating

In *radiant heating* systems, heating coils, tubes, or cables are buried within ceilings, floors, or walls. No registers or ducts are required. This makes the system very quiet. Rather than heating air, as in a forced-air or hydronic system, a radiant system heats a material. This material then radiates the heat directly into the room. Many people find this type of heat very comfortable. There are two basic types of radiant systems: electric and hydronic.

Electric Systems Many types and designs of electric radiant heating systems are available. In one system, electric heating cable is laid back and forth across the ceiling surface. It is then covered with plaster or a second layer of drywall. As the cover material heats up, it radiates warmth to the room. Radiant panel units can also be placed directly on the finished surface of the ceiling. A thermostat located in each room generally controls heat levels.

Hydronic Systems In a radiant hot-water system, water heated in a boiler is circulated through continuous coils of polyethylene tubing. The tubing is embedded in a concrete floor, as shown in **Figure 30-21**. As the heated water circulates, it conducts its heat to the masonry. The floor then radiates heat to the room.

Figure 30-21 Preparing for Radiant Heat

Heat in the Slab In a radiant floor heating system, concrete is poured over a network of hot water distribution tubing. The red material is epoxy-coated rebar.

Heat Recovery Ventilation

Fresh air leaks into a house through cracks around windows, doors, and framing in a process called **infiltration**. This air must be heated in cold weather. However, heated air leaks out as easily as cold air leaks in. Builders reduce air infiltration by building "tight" houses. This means that there are few gaps in the house that can let in cold air. Of course, this also means that fresh air cannot get in. Moisture and indoor pollutants such as formaldehyde, tobacco fumes, and combustion byproducts can build to unhealthy levels in a tight house.

One solution is to install a device called a *heat recovery ventilator (HRV)*. Heat recovery ventilators are sometimes called air-to-air heat exchangers or energy recovery ventilators. A cutaway view of an HRV is shown in **Figure 30-22** on page 888.

An HRV removes the heat from stale indoor air before exhausting the air outdoors. That heat is transferred to fresh air drawn into the house. To accomplish this, a fan within the HRV pulls in fresh air from outdoors through a duct. A second fan removes stale air from inside the house through a separate duct. Both sets of ducts meet at the HRV. There, heat is transferred from one air stream to the other. Each air stream is kept separate. By using heat from the outgoing air to warm the incoming air, less energy is required to raise the temperature of the incoming air.

Cooling Systems

What factors affect how easily a house can be cooled?

In some areas, cooling a house is far more necessary than heating it. Energy efficiency is just as important when a house is being cooled as when it is being heated. Two types

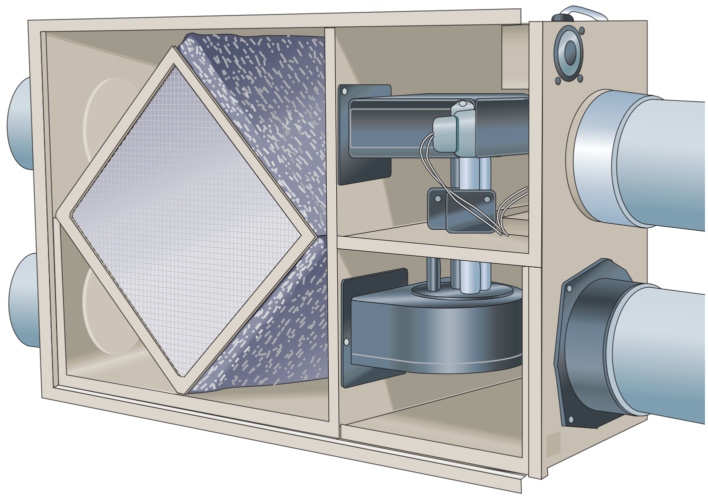


Figure 30-22 Heat Recovery Ventilator
Energy Saver An HRV brings in fresh air and exhausts stale air. *What happens to the incoming fresh air?*

of systems—central air conditioning and whole-house ventilation—can be used to cool a house.

Central Air Conditioning

Air conditioning is a process of extracting heat from air and then releasing the heat outside the house. It relies on the same principles used by heat pumps. Small air-conditioning units can be placed in a window to cool a room. All the devices needed are contained in the unit. However, cooling an entire house calls for a central air-conditioning system. These units are sometimes called split systems because part is located outdoors and part is located indoors, as shown in **Figure 30-23**.

There are three basic elements in a split system:

- ***Refrigerant Coils*** These coils of copper tubing hold a liquid refrigerant. The condenser coil is located outside the house. The evaporator coil is located inside the house. The coils are connected by additional tubing to form a closed loop.
- ***Air Handler*** This unit contains the evaporator coil. It also contains a blower to move air through an insulated duct system.
- ***Compressor*** This unit contains the condenser coil. It includes a fan but does not include ductwork.

Here is how the system works:

1. The system is turned on when a thermostat indicates the temperature in a room has risen to a preset level.
2. The air handler draws in warmed house air through ducts and blows it over the evaporator coils. Refrigerant in the coils absorbs heat from the air. The cooled air is then distributed to the house.
3. As the refrigerant absorbs heat, it turns into a gas. The gas travels to the condenser coil outside the house, where it gives up its heat. The fan helps this process by circulating air over the condenser coil.
4. As the vapor cools, it condenses back to a liquid and returns to the evaporator coils. The process then repeats.

Whole-House Ventilation

If ventilation is desirable but a central air-conditioning system is not justified, a house can sometimes be cooled using a centralized

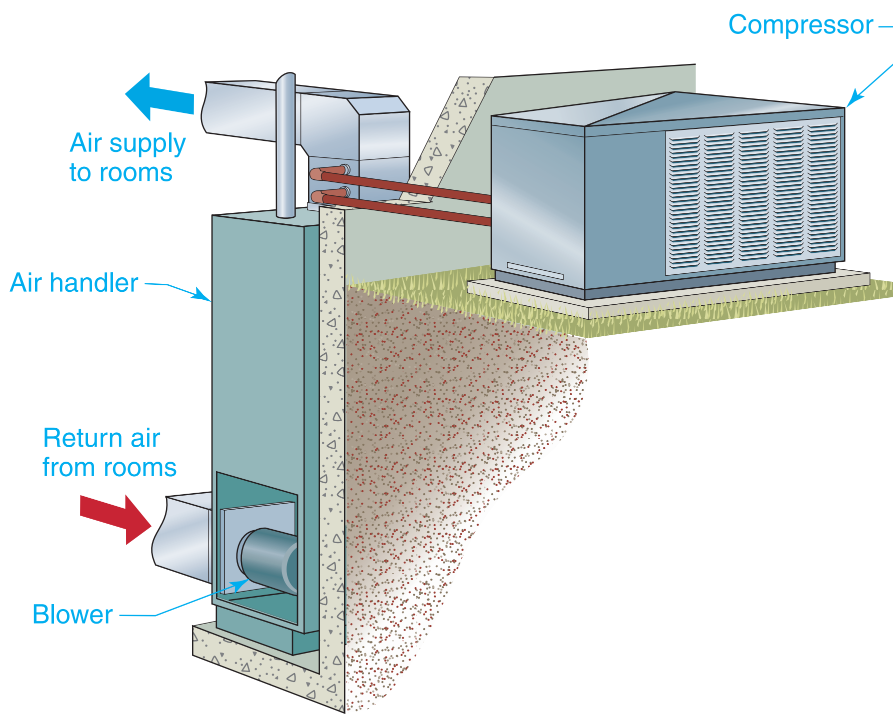


Figure 30-23 A Central Air-Conditioning System
Same Ducts Central air conditioning can use the same ductwork as the central heating system.

fan. This powerful enclosed fan is mounted in the highest ceiling in the house, which is often above a stairwell. The fan draws relatively cool air into the house through open windows while exhausting hot air into the attic. Attic vents exhaust the heat outside. The system requires no ducts.

Some whole-house ventilating fans are designed to be mounted on top of ceiling joists. This eliminates the need to cut joists for installation. However, the unit should be mounted on rubber pads. This limits any noise and vibration that might otherwise be transmitted through the framing. Some fans have variable speed controls.

Section 30.3 Assessment

After You Read: Self-Check

1. Name four types of boiler fuel.
2. In a forced-air system, what happens after heated air is delivered to a room?
3. Describe the purpose of fins on a convector.
4. Describe the interaction of the air handler and the evaporator coils in a split-system air conditioner.

Academic Integration: Science

5. **From Liquid to Gas** Central air-conditioning systems, or split systems, are used in many homes. These systems use refrigerant coils that hold a liquid refrigerant. Refrigerant is a material that changes from a liquid to a gas. Explain how a refrigerant is converted to a gas.

Go to **glencoe.com** for this book's OLC to check your answers.

CHAPTER 30

Review and Assessment

Chapter Summary

Section 30.1

A basic plumbing system consists of a supply side and a DWV side. Supply pipes are pressurized, while DWV pipes are not. Traps are simple devices that prevent sewer gases from entering the house.

Section 30.2

An electrical system consists of wires, called conductors, which lead from circuit breakers in a service panel to individual outlet boxes. Each set of wires connected to a circuit breaker is called a circuit and leads to a particular portion of the house.

Section 30.3

Heating systems are classified according to how they distribute heat, rather than by what fuel they use to create it. Air-conditioning systems are sometimes incorporated with forced-air heating systems so that they can use the same ducts.

Review Content Vocabulary and Academic Vocabulary

1. Use each of these content vocabulary and academic vocabulary words in a sentence or diagram.

Content Vocabulary

- mechanicals (p. 868)
- fixture (p. 868)
- service main (p. 869)
- trap (p. 869)
- drain field (p. 870)
- circuit (p. 877)
- receptacle (p. 879)
- cell (p. 884)
- humidifier (p. 884)
- heat pump (p. 884)
- refrigerant (p. 884)
- infiltration (p. 887)
- air conditioning (p. 888)

Academic Vocabulary

- rural (p. 870)
- circulates (p. 883)

Speak Like a Pro

Technical Terms

2. Work with a classmate to define the following terms used in the chapter: *supply pipes* (p. 869), *waste pipes* (p. 869), *vent pipes* (p. 869), *septic system* (p. 870), *copper tubing* (p. 872), *service panel* (p. 877), *circuit breaker* (p. 877), *appliance circuit* (p. 878), *general-purpose circuit* (p. 878), *special-purpose circuit* (p. 878), *conductors* (p. 878), *outlet boxes* (p. 879), *knockouts* (p. 879), *pulling the cables* (p. 880), *wire nut* (p. 881), *wire connector* (p. 881), *final* (p. 881), *supply ducts* (p. 883), *supply registers* (p. 883), *return-air register* (p. 883), *media filters* (p. 883) *hydronic heating* (p. 885), *convectors* (p. 885), *radiators* (p. 885), *radiant heating* (p. 886).

Review Key Concepts

3. List the components of plumbing system.

4. Name the tools and materials used in basic plumbing.

5. Describe the various types of piping used for water supply and DWV systems.

6. List the components that make up an electrical system.

7. Describe the three basic kinds of circuits.

8. Identify the basic parts of a split-system air conditioner and describe how it works.

Critical Thinking

9. **Discuss** Explain the difference between supply pipes and waste pipes. Why should you not interchange supply and waste pipe materials?

Academic and Workplace Applications

STEM Engineering

10. **Electrical Circuitry** Could both of the following be run on the same 115 volt circuit?
    - An oven that has 16.5 ohms of resistance and runs on 12.25 amps.
    - A saw that runs on a 15 amp circuit and has 7 ohms of resistance.

    Starting Hint Voltage (E), ohms (R), and amps (I) are related according to the formula $E = IR$.

    Step 1: Use the formula to determine the voltage requirement of the oven and the saw.

    Step 2: Compare the results to the voltage of the circuit.

STEM Science

11. **Water and Aquifers** Most houses in rural areas are not connected to a municipal water system. Instead, water is supplied by a water pump located near the bottom of a deep but narrow well. Wells often draw water from an underground aquifer. Use the Internet or your school library to find out more about aquifers. Write a few sentences describing what an aquifer is. Identify some types of rocks that make good aquifers.

21st Century Skills

12. **Interpersonal Communication** Assume that you are a journeyman HVAC professional in the eastern United States. Your firm has just hired an individual from Washington state. Your supervisor has asked you to work with the new employee for a few weeks. Each day you notice that the employee is having a hard time adjusting to the differences in procedure and installation of HVAC units. The individual continues to refer to the electricity-based HVAC systems he is used to installing in the Northwest. Write a short paragraph explaining how you would deal with this situation. Explain why different heating fuels are used in the East and in the Northwest. Describe the interpersonal tactics you could use to help the new employee. How can you remain professional and courteous while informing the employee of the differences?

Standardized TEST Practice

CERTIFICATION PREP

Short Response

Directions Write one or two sentences in response to the following questions.

13. How are waste materials broken down in a septic system?

14. What is the purpose of a watt-hour meter?

15. Why is it important to maintain clean filters in a forced hot-air heating system?

TEST-TAKING TIP

Use complete sentences when answering short-answer questions. A complete sentence contains both a subject and a predicate (verb phrase).

*These questions will help you practice for national certification assessment.