Topic 4.6

What features make an electrical circuit practical and safe?

Key Concepts

- Practical wiring for a building has many different parallel circuits.
- Circuit breakers and fuses prevent fires by opening a circuit with too much current.
- Higher-voltage circuits, larger cords and cables, and grounding help make home circuits safe.

Key Skills

Numeracy

Key Terms

circuit breaker
fuse

Starting Point Activity

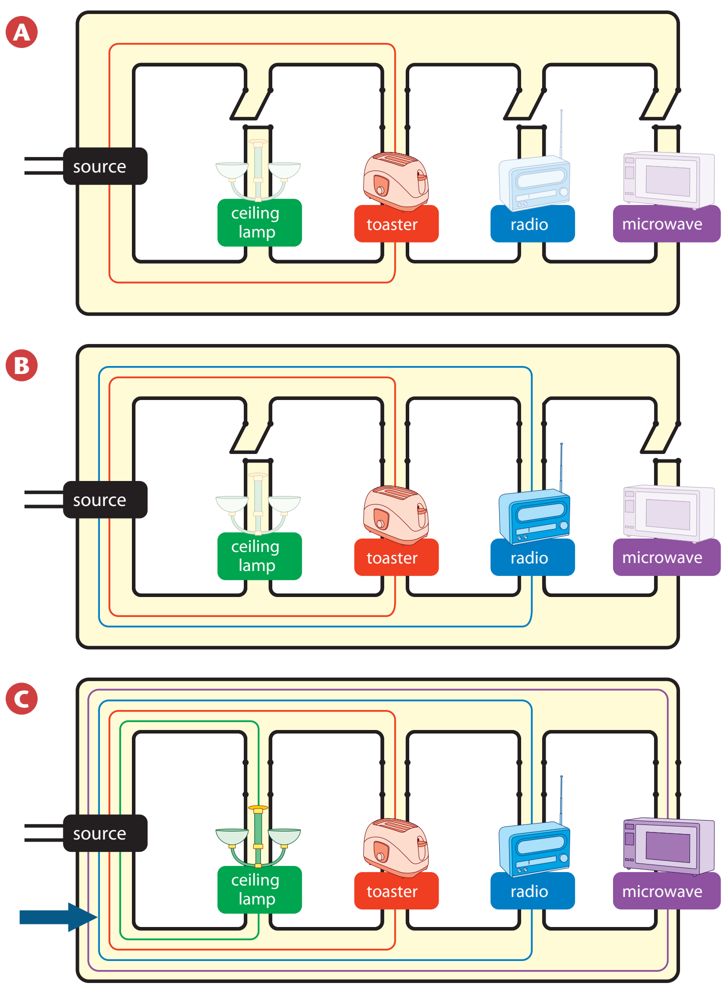
The picture shows a scene that could occur anywhere in the province. However, one thing that could *not* occur is the way the electrical devices are wired in this scene.

1. What kind of circuit connects all the devices in the picture?

2. Is this circuit practical? Explain why or why not. What would happen if homes were wired this way?

Practical wiring for a building has many different parallel circuits.

Examine the parallel circuit shown in **Figure 4.30**. As you know, current can flow around any closed conducting loop. So each device in a parallel circuit can be controlled by its own switch. For instance, in **Figure 4.30A**, when you turn on the switch for the toaster, it forms a closed loop so current can flow. Only the toaster is on. If you then turn on the radio, as in **Figure 4.30B**, you have formed a second closed loop that lets current flow. **Figure 4.30C** shows that when you turn on the ceiling lamp and the microwave oven, all of the appliances are turned on.

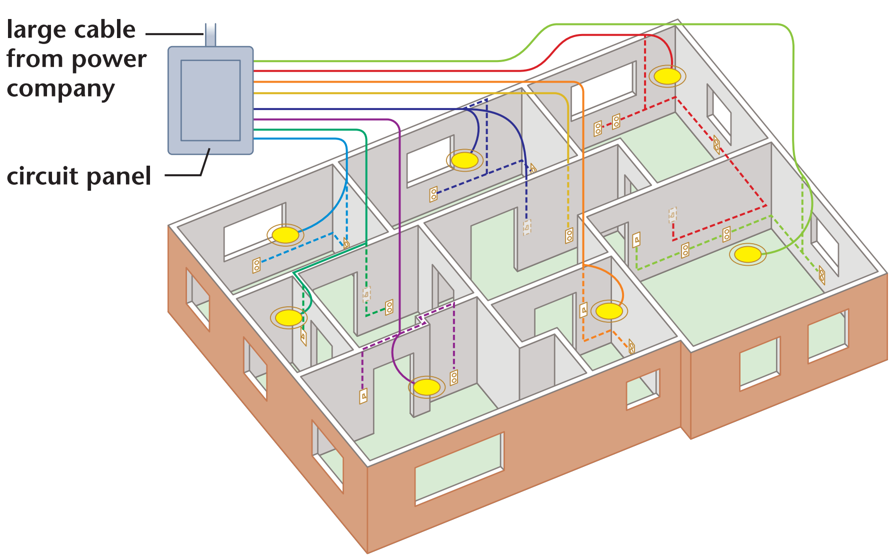


▶ **Figure 4.30** In this parallel circuit, each of the coloured lines represents the current flowing to a specific electrical device. Notice that all colours pass through the sections of the wire that are directly connected to the source. A large current like this can make a wire very hot.

Take a closer look at **Figure 4.30C**. Look at the place where the arrow in the picture is pointing. Notice that, when all appliances are on, all the current that is going to each appliance is passing through the conductor near the source. When large amounts of current flow through a wire, the wire can get very hot.

Now imagine that all the electrical devices in an entire home were connected to the same parallel circuit. The current flowing to each device also would be flowing through the wire conductors connected to the source. This large amount of current would make those wires extremely hot and would certainly start a fire. A parallel circuit with too many electrical devices connected to it is not practical, because it is not safe.

A house, apartment building, school, or any building must have many electrical outlets, because many electrical devices are used in it. So it is safer and more practical to install many separate parallel circuits in the building. Of course, all of the current flowing in all circuits in a building must be flowing in the conductors that lead into the building from a power company. Therefore, very large electrical cables are used to carry electrical energy from a power company to a building. Large cables are designed to carry a large current without becoming too hot. Inside the building, many different parallel circuits are connected to the large cables. This idea is shown in **Figure 4.31**.

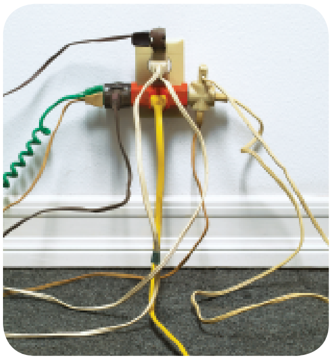


◀ **Figure 4.31** The box labelled "circuit panel" is the place in the building where large electrical cables connect the building to the electrical energy flowing from the power company. From the circuit panel, many smaller parallel circuits are wired throughout the building. Each colour in this diagram represents one small parallel circuit.

LEARNING CHECK

1. Refer to **Figure 4.30**. Describe how a switch controls the flow of electrical current through individual appliances.
2. Explain why a parallel circuit with too many electrical devices connected to it is not practical.
3. Explain what a circuit panel is.
4. Explain why a building must have many electrical outlets.

Circuit breakers and fuses prevent fires by opening a circuit with too much current.



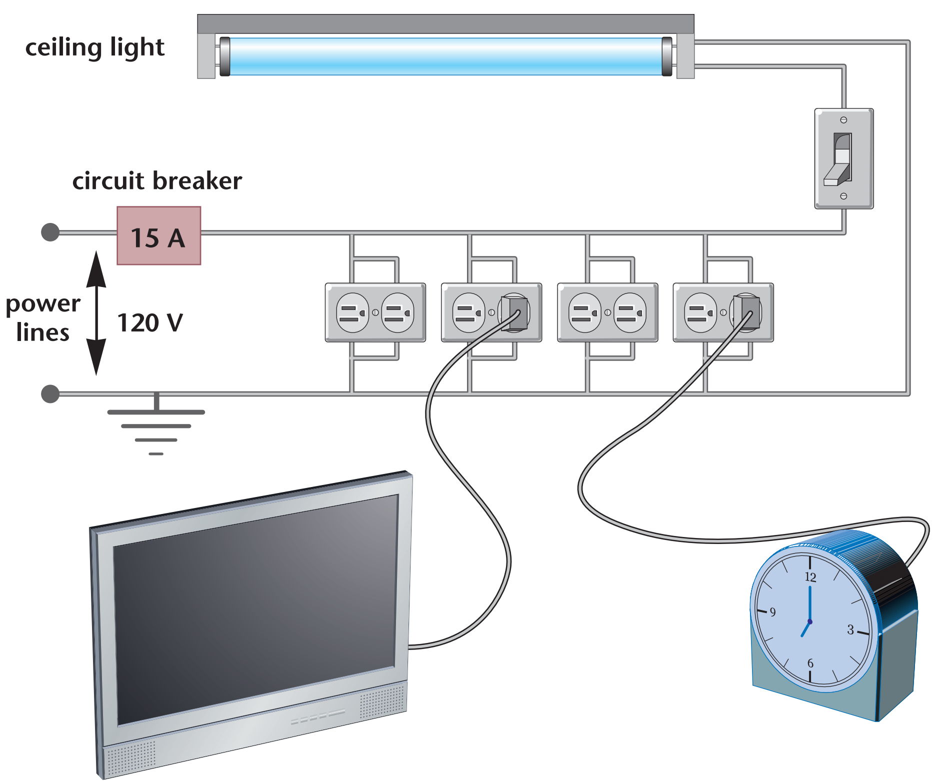
▲ **Figure 4.32** An outlet designed to connect two electrical devices to the source is now connecting many devices. If every device is turned on at the same time, they could draw a large amount of current.

The current that flows through a wire conductor can become very high, even if the parallel circuit has just a few outlets connected together. For example, people sometimes use a gadget like the one in **Figure 4.32**. It converts a double outlet into an outlet that has more places to plug in additional pieces of equipment. People do this for convenience. But connecting too many electrical devices to one outlet is a safety hazard, because it increases the amount of current in the circuit.

Circuit Breakers

A safety device called a **circuit breaker** will prevent any circuit from carrying too much current and starting a fire. Refer to **Figure 4.33**. A circuit breaker has a strip made of two metals. When the metals get too hot, they bend and cause a switch to open. This open switch prevents current from flowing through the entire circuit. When a circuit breaker opens the switch, you can close it by going to the breaker panel and pushing the switch back in place. However, you need to turn off some of the electrical devices that caused the large current to flow, or the circuit breaker will break (open) the circuit again.

▶ **Figure 4.33** Every switch in a circuit panel controls one parallel circuit. Circuit breakers are always located beside the source. When they break the circuit, no current flows to any of the pathways. The circuit breaker in the diagram will open the circuit when the current goes above 15 A.



Fuses

Many years ago, fuses were used in homes instead of circuit breakers. Some very old buildings still have a fuse box with fuses instead of circuit breakers. A **fuse**, shown in **Figure 4.34**, has a small wire that will melt and break apart when the current gets too high. This has the same effect as opening a breaker switch. Both fuses and breaker switches stop the current from flowing when the wire becomes too hot. However, when a fuse "blows out," it has to be replaced with a new one.

circuit breaker: a safety device that opens a circuit if the current gets too high; it can be reset

fuse: an older safety device that opens a circuit if the current gets too high. it must be replaced.

◀ **Figure 4.34** Before circuit breakers were invented, everyone used fuses similar to these.

A Each fuse has a label on it that shows the amount of current that would cause the fuse wire to melt.

B Fuses are still used today in many applications. For example, electrical systems in cars use fuses like this one.

LEARNING CHECK

1. Refer to **Figure 4.32**. Explain why connecting too many electrical devices to one outlet is a safety hazard.
2. Use a Venn diagram to compare a circuit breaker with a fuse.
3. Use a flowchart or other graphic organizer to outline the steps you would follow to reset a circuit breaker in your home.

Numeracy Focus

Activity 4.12

MAKE AND BREAK THE CIRCUIT

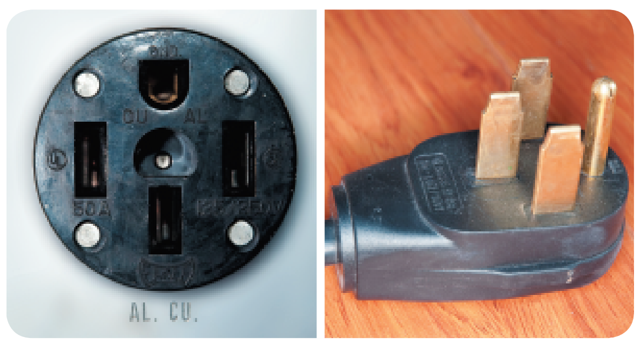
Most circuit breakers in homes are designed to open if the current becomes greater than 15 A. The chart contains common home appliances and the current they use. List all the combinations of devices that could be on and working at the same time. Then list all the combinations of devices that would make the circuit breaker open the switch.

Device	Approximate Current (A)
coffee maker	10
microwave oven	6.25
clothes iron	15
laptop computer	0.4
toaster	6.5
toaster oven	10
refrigerator	6
ceiling fan	1.5
dishwasher	20
clock radio	0.1

Higher-voltage circuits, larger cords and cables, and grounding help make home circuits safe.

Some electrical appliances use so much current that they must have their own circuit. The most common example in the home is the electric stove. However, an electric water heater, an air conditioner, or an electric clothes dryer might also have its own circuit. Even if one of these appliances was connected to its own 120 V circuit, it would require so much current that it would still make the conductor dangerously hot. Therefore, electricians create a circuit that provides a potential difference of 240 V instead of 120 V.

By doubling the potential difference from 120 V to 240 V, a circuit uses half as much current and still provides the same amount of energy. To prevent people from plugging an appliance into the wrong outlet, outlets that provide 240 V are different from those that provide 120 V. **Figure 4.35** shows what a 240 V outlet looks like and the kind of plug that fits it.



▸ **Figure 4.35** The plug for an electric stove usually is very large and has three flat prongs and one curved prong. The cord is also very large. The large size of the cord and prongs allows them to safely carry a large amount of current without becoming too hot.

Safety with Larger Cables

You might have seen electrical wiring that is inside the walls of a home. These cables are much larger than a typical electrical cord on an appliance. Their size allows them to carry more current than is usually needed for a single appliance, without becoming too hot. The cables leading from the power company into your home are even larger.

Safety with Grounding

Grounding of some wires is also a safety feature. Of the two wires for every parallel circuit, one is grounded at the source. Recall that grounding means that the wire is attached to some type of conductor buried in the ground. Any excess current will go to the ground. Accidentally touching a grounded wire would not cause a shock. The wire in a circuit that is not grounded is called the hot wire. You would get a dangerous shock if you touched it.

Safety with Outlets

Figure 4.36 shows three types of outlets commonly found in homes and other buildings. You may have seen two-hole outlets like the one in **Figure 4.36A** in very old buildings. Three-hole outlets like the one in **Figure 4.36B** are required by law in newer homes. The third hole is for a different type of grounding that is not connected to either of the two wires in the electrical circuit. The third prong on the plug is connected to metal parts of the lamp or appliance. When plugged in, these metal parts are grounded. If, for any reason, the hot wire inside the appliance became frayed or damaged and touched a metal part of the appliance, all of the metal would be "hot." If you touched any metal part of the appliance, you would get a serious shock. The third prong prevents this type of shock from occurring.

Figure 4.36C is a ground fault interrupter or GFI. It is a special safety device that is installed in bathrooms and other locations near water faucets. If water splashes on an appliance like a hair dryer or radio and on you, it can create a conductor that includes your body. Current leaves the circuit and passes through you and goes to the ground that you are standing on. Such a shock can be fatal. The GFI measures the current leaving one end of the circuit and current entering the other. If these currents are not the same, the GFI immediately opens the circuit and stops any more current from flowing. A normal circuit breaker would also open the circuit when current gets too high, but it would not act soon enough. You could still get a fatal shock. The GFI responds more quickly than a circuit breaker or fuse. GFIs save lives.

◄ **Figure 4.36** Types of outlets found in many homes

A Two-hole outlets like this are found in very old buildings. Newer buildings are designed with three-hole outlets.

B In three-hole outlets, the third hole is for a grounding wire that safely channels current back into the ground.

C This type of outlet is called a ground fault interrupter, or GFI outlet. It is very sensitive and is commonly found in bathrooms or other locations that are within 2 m of water. A GFI outlet opens a circuit if there is any difference between current leaving one hole and entering the other.

LEARNING CHECK

1. Refer to **Figure 4.35**. Explain why a 240 V outlet has a different shape than a 120 V outlet.
2. Use a t-chart with the headings "Method" and "Where It Is Used" to summarize the three methods used to make home circuits safe.
3. Refer to **Figure 4.36**. Explain, in terms of your personal safety, why it is important that all of the electrical outlets in a bathroom are protected by a ground fault interrupter (GFI).

Numeracy Focus

Activity 4.13

DELIVERING ELECTRICAL ENERGY TO YOUR HOME

Exposure to high voltages can stop your heart. Large currents also can heat body tissues very quickly, causing severe burns.

Perhaps you have seen a fenced area like the one in the photo, with warning signs about the danger. This type of site is called an electrical substation. The electrical current that flows into your home passes through a number of substations on its way from where it is first generated at a power plant. Along the way, the voltage is increased and decreased several times.

Suppose a power company wanted to transmit 1.0 MW (megawatts) of power over 100 km of power lines. Power represents the amount of energy that is transmitted or changed to another form of energy every second. What would be the advantage of transmitting the power at 500 000 V instead of 20 000 V?

A power company would want ways to minimize the loss of power between the generating plant and its customers. Since a current passing through a wire causes heating, the most significant losses would occur due to heating of the transmission lines.

To find the amount of power lost to heat, or the energy lost to heat every second, you can use a formula: $P = I^2R$. (P is the symbol for power, I is the symbol for current, and R is the symbol for resistance.) For typical copper conductors that are used in high voltage lines, the resistance of 100 km of wire is about 100 Ω.

What To Do

1. Use the formula $I = \frac{P}{V}$ to find the current in the transmission lines, when 1.0 MW of power is transmitted at 500 000 V. Note that 1.0 MW is 1 000 000 W or 1.0×10^6 W. The value 500 000 V also can be written as 5.0×10^5 V.
2. Use your answer for step 1 and the formula $P = I^2R$ to find the amount of power that is lost to heat in 100 km of transmission lines, when 1.0 MW of power are transmitted at 500 000 V.
3. Find the percent of power lost to heat when 1.0 MW of power is transmitted at 500 000 V. To do this, use the formula

$$\text{percent power lost} = \frac{\text{power lost to heat} \times 100\%}{\text{total power transmitted}}.$$

4. Find the current in the transmission lines when 1.0 MW of power are transmitted at 20 000 V.
5. Use your answer for step 4 and the formula $P = I^2R$ to find the amount of power that is lost to heat in 100 km of transmission lines, when 1.0 MW of power are transmitted at 20 000 V.
6. Find the percent of power lost to heat when 1.0 MW of power are transmitted at 20 000 V.

What Did You Find Out?

1. Write a paragraph that explains why power companies transmit power at very high voltages when transmitting power over long distances.

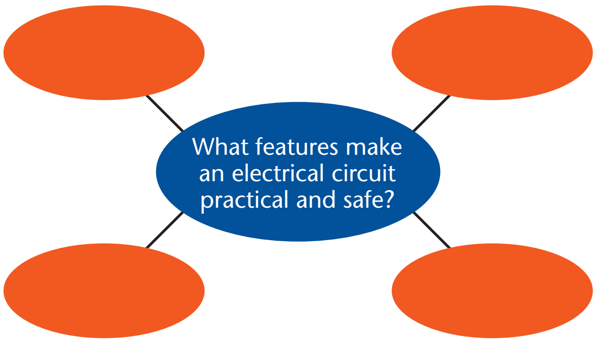
Topic 4.6 Review

Key Concept Summary

- Practical wiring for a building has many different parallel circuits.
- Circuit breakers and fuses prevent fires by opening a circuit with too much current.
- Higher-voltage circuits, larger cords and cables, and grounding help make home circuits safe.

Review the Key Concepts

1. Answer the question that is the title of this topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words.



2. K/U Use words or diagrams to show how a) a circuit breaker and b) a fuse work to prevent electrical fires.

3. T/I Look at the graph on this page.

a) In your notebook, draw a circuit diagram that includes a source with a potential difference of 120 V and that has two loads—the toaster and the iron—wired in a parallel circuit.

b) Calculate the total amount of current in this circuit if both the toaster and the iron were turned on. Show your work. (Hint: When you have loads in parallel, you can find the total current in the circuit by adding up the current drawn by each device.)

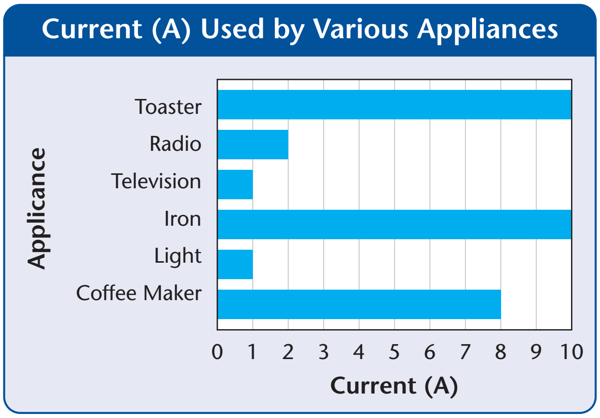
c) Predict what would happen if this circuit were protected by a 15 A circuit breaker.

4. T/I Refer to the graph on this page.

a) In your notebook, draw a circuit diagram that includes a source with a potential difference of 120 V and that has four loads—the radio, television, and two lights—wired in a parallel circuit.

b) Calculate the total amount of current in this circuit if all four appliances were turned on. Show your work.

c) Predict what would happen if this circuit were protected by a 15 A circuit breaker.



5. A You are helping your neighbour Freda construct a wooden fence around her garden. Freda is using an electric drill to screw the boards to the frame. You notice the drill has a damaged plug and is missing the ground wire prong. You ask Freda why she removed the ground wire prong. She answers that an old extension cord had only a two-prong outlet, so she cut off the ground wire prong. Explain to Freda why this was not a good idea.