12.1 Electricity at Home

Key Terms
direct current (DC)
alternating current (AC)
transformer
circuit breaker
fuse

If you get up in the middle of the night, you expect to see the glow of an alarm clock. You also expect to see street lights or lights from other buildings outside. To supply electricity day and night, the generators at the Adam Beck hydroelectric plant in Niagara Falls run all the time. When construction of the Adam Beck plant began in 1917, it was the largest construction project ever undertaken in North America. Over the next four years, water was diverted from the Niagara River, a canal was constructed, and two very large generators were built. As the demand for electricity grew, more generators were added. Then, in 1954, a second generating station, built under the city of Niagara Falls, was opened.

In 2006, the world's largest hard-rock-boring machine began boring a huge tunnel under the city, as shown in **Figure 12.1**. Grade 6 science students from Port Weller Public School in St. Catharines named the rock-boring machine that is being used "Big Becky." This name is a clever play on the name of the generating station. When completed, the tunnel will supply water to increase hydroelectric generating capacity.

Figure 12.1 These photographs show the new tunnel project and the hydroelectric plants at Niagara Falls. A huge tunnel, which is being bored through rock under the city of Niagara Falls, will increase the capacity of the Sir Adam Beck generating station to generate hydroelectric energy.

Generating and Distributing Electricity

To understand how electrical energy is generated and how it reaches your home, you need to understand the properties of two different kinds of electric current.

direct current (DC) current in which charged particles travel through a circuit in only one direction

alternating current (AC) current in which electrons move back and forth in a circuit

transformer an electrical device that changes the size of the potential difference of an alternating current

Direct Current and Alternating Current

The current from a cell is called **direct current (DC)**. As you learned in Chapter 11, in DC, charged particles in a circuit travel in only one direction. In a circuit containing a cell, electrons move from the negative terminal to the positive terminal.

Moving a magnet into and out of a coil of wire generates a current in the coil. The current moves in one direction when a pole of the magnet is inserted into the coil, and in the opposite direction when the magnet is removed from the coil. This kind of current is called **alternating current (AC)**. In AC, electrons move back and forth, but there is no net movement of electrons in either direction.

The Advantages of Alternating Current

Across the country, hundreds of kilometres of wire cables carry huge quantities of electrical energy. To transmit this energy, with a relatively low loss of energy as heat, requires a low current and a high potential difference. There is a potential difference of several hundred thousand volts between the ground and the wires on a transmission tower.

Study Toolkit

Making Inferences Why do you think electrical energy is transmitted over long distances, despite the costs of doing so?

Appliances and other devices in your home run on much lower voltage. An electric stove uses 220 to 240 V. Most other appliances in your home use 110 to 120 V. Thus, there is a need to change the potential difference. A simple electrical device called a **transformer** can change the potential difference of an alternating current. Transformers, however, do not work with direct current. This is one reason we use alternating current in our homes, businesses, and factories.

Many electronic devices, such as MP3 players and cellphones, use rechargeable batteries to supply DC. When you plug one of these devices into a wall outlet, a transformer reduces the potential difference from 110 V to the potential difference needed. Special circuits change the reduced AC output into DC to recharge the battery.

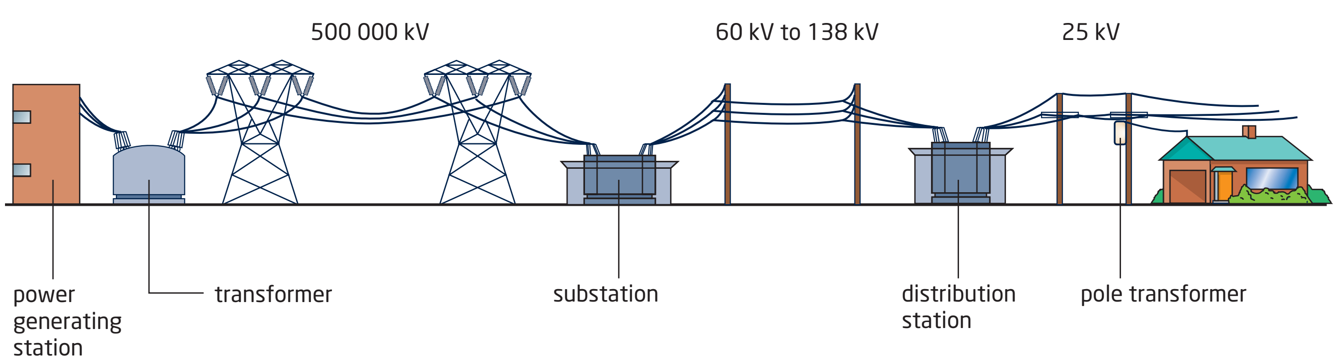

Figure 12.2 The electrical wires in your home are part of a circuit that includes power generation, transmission across the country, and distribution from substations.

From the Generating Plant to Your Meter

As shown in **Figure 12.2**, the electrical energy produced at a power plant begins with a source of energy, which is then used to spin the shaft of a generator. The source of energy may be moving water, wind, or steam produced by the burning of fossil fuels or the heat of nuclear reactions. Energy from the generator's shaft moves a magnet and a coil of wire relative to each other. This generates an electric field that causes electrons to move.

Electric current is generated at 20 000 V or less. Transformers increase the voltage to 115 000 V, 230 000 V, or 500 000 V before the current is sent to transmission lines, as shown in **Figure 12.3**. Transformers that increase potential difference are called step-up transformers. Various substations then use step-down transformers to distribute electricity to groups of users.

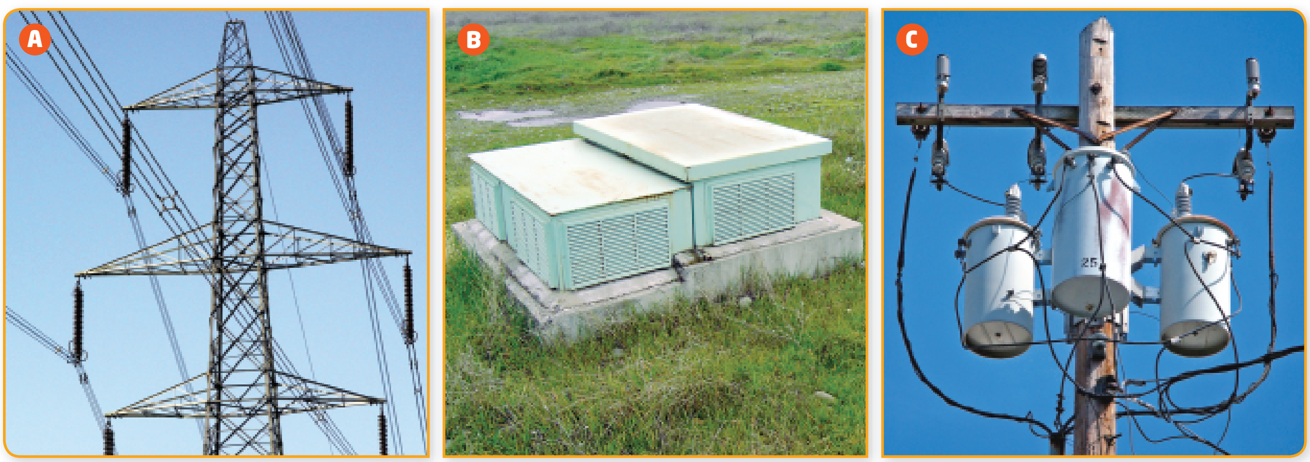

Figure 12.3 **A** The thin wires at the top of the tower are grounded to help protect the system from lightning strikes. The high voltage is between *adjacent* wires, not between the ends of a single wire. Insulators stop adjacent wires from touching. **B** Transformers step down the voltage before a line is connected to the meter at your home. In towns and cities, wiring is underground and step-down transformers are often inside green boxes. **C** In rural areas, cylindrical pole transformers are the norm.

Learning Check

1. What is the difference between direct current and alternating current?
2. A doorbell is connected to a 110 V supply, but it operates on only about 12 to 14 V. What kind of transformer does it have?
3. Refer to **Figure 12.3**. What are the two main advantages of supplying alternating current to homes and businesses?
4. Outline the sequence of events as electricity is sent from a generator to a device you used at home this morning. Explain how the electricity was generated, transmitted, and used.

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circuit breaker a safety device that is placed in series with other circuits, which lead to appliances and outlets

fuse a safety device that is found in older buildings and some appliances; like a circuit breaker, it is placed in series with other circuits, which lead to appliances and outlets

The Meter and Distribution Panel

A box or pole transformer reduces the potential difference from 7200 V to 120 V. From the transformer, three wires go to your home. Two of the wires are "live" or "hot," and therefore insulated. They carry alternating current. The third wire is the ground. It is neutral and not insulated.

The wires from the street transformer are in series with a meter and a distribution panel. The meter registers the amount of electrical energy that is used in your home. By reading the meter, shown in **Figure 12.4A**, the utility company can determine how much to charge for your energy use and for a proportion of other costs, such as distribution, maintenance, and repair. Many apartment and condominium buildings have only one meter, so the cost of electricity is averaged among all the units.

After passing through the meter, the electrical supply is connected to a distribution panel. The distribution panel consists of circuit breakers, shown in **Figure 12.4B**, or fuses in older homes. **Circuit breakers** and **fuses** are safety devices that are placed in series with other circuits, which lead to the appliances and wall outlets in your home. A circuit may lead to a single appliance, such as an electric oven that operates at 240 V, or to several lights and wall outlets, which supply 120 V. As **Figure 12.5** shows, circuits with several lights and wall outlets are connected in parallel. The circuit breaker at the distribution panel is in series with the parallel connections.

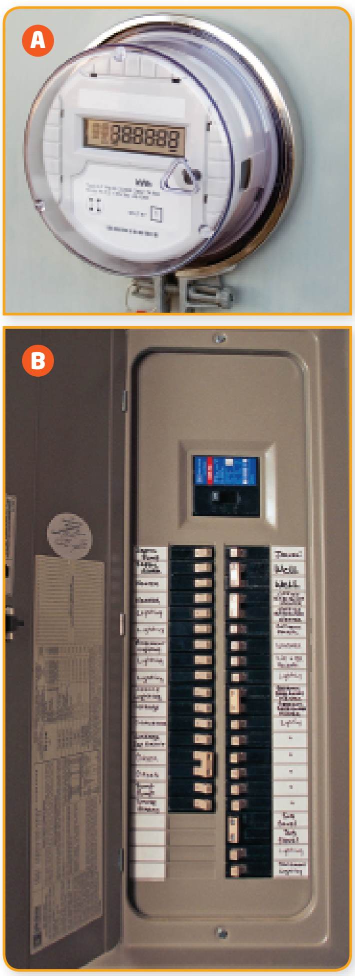

Figure 12.4 **A** All electrical energy use is metered. **B** In a typical home, the meter is in series with the wires from the street transformer and a distribution panel like the one shown here.

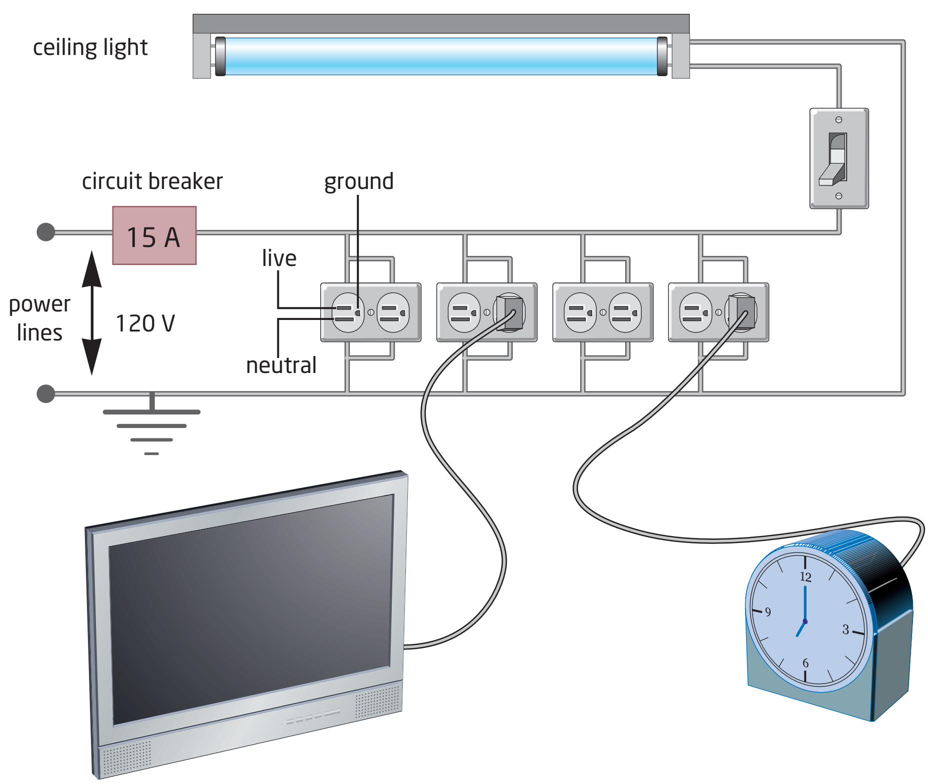

Figure 12.5 Most of the circuits in your home are series-parallel combinations. A circuit breaker or fuse at the distribution panel is always connected in series. Lights and wall outlets in each room, such as the kitchen, are connected in parallel.

Characteristics of Alternating Current

The electricity that is supplied to your home from the street transformer consists of two "live" or "hot" wires and a neutral ground wire. When an electrician wires an appliance that needs 240 V, the two live wires and the ground wire are used. Each live wire provides a potential difference of 120 V. When the potential difference in one wire is +120 V, however, the potential difference in the second wire is −120 V. Thus, the potential difference between the two wires is 240 V. Lights and wall outlets, which operate at 120 V, use only one of the two live wires, as well as the ground.

The current through a toaster (**Figure 12.6**) switches direction as the potential difference alternates. Electrons in direct current move very slowly, at about 0.01 cm/s. Electrons in alternating current do not flow in one direction along the wires at all. They only move back and forth. Many electrical devices that you use at home, such as a kettle, hair dryer, and toaster, convert electrical energy into heat.

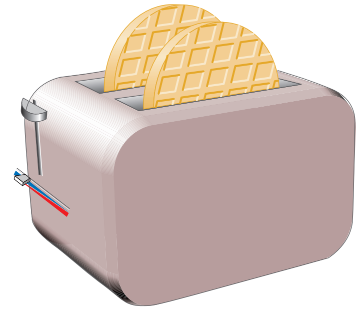

Figure 12.6 Many appliances make use of the heat that is generated by an alternating current.

An Analogy for Alternating Current

The analogy shown in **Figure 12.7** may help you understand how electrons in alternating current convert electrical energy into heat. Imagine an exercise bicycle. In this analogy, the pedals represent a source of electrical energy, and the tire represents electrons in a circuit. If you cranked the pedals in one direction, representing a direct current source, the tire would move in one direction. If the tire rubbed against an object, friction would make the tire very hot.

Suggested Investigation

Technology Investigation 12-A, Designing a Staircase Circuit, on page 513.

Now imagine that you turn the pedals first in one direction and then in the opposite direction, analogous to an alternating current. The tire moves back and forth. Again, if the tire rubbed against an object, the tire would become very hot.

Similarly, the electric field that is generated by alternating current generators changes direction. The electric field travels through a circuit at almost the speed of light, exerting a force on electrons in the circuit. The electrons have no net movement through an alternating current circuit because the direction of the field is always changing.

Although the electrons in AC do not always flow in one direction, the energy they carry is equivalent to the energy of a DC source that has the same current and potential difference.

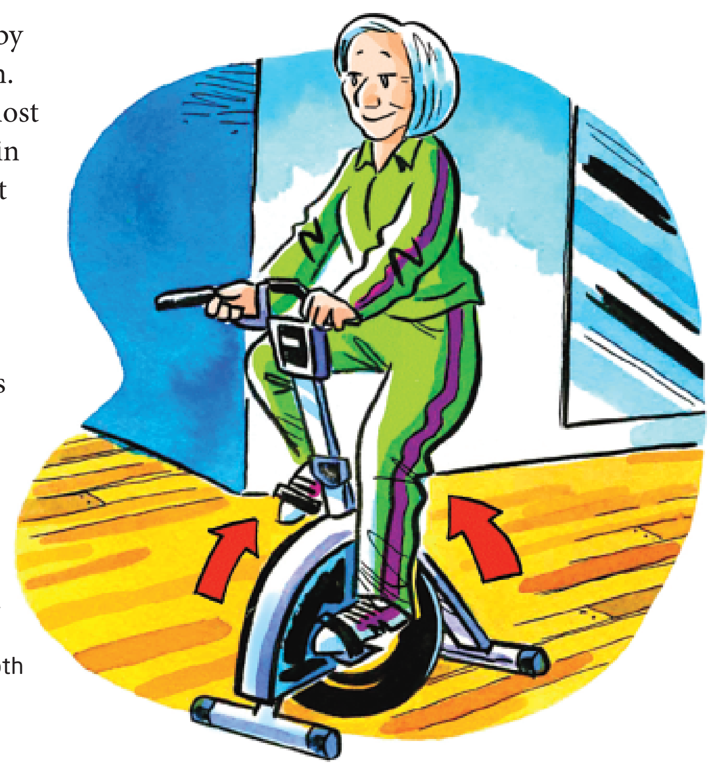

Figure 12.7 The tire can rotate in one direction, analogous to direct current. It can also turn back and forth, analogous to alternating current. In both cases, the tire has energy.

Electrical Safety in the Home

Elecricity can be dangerous if used incorrectly. The combination of potential difference and current is the significant hazard. You can easily generate a potential difference of thousands of volts between you and the ground by scuffing your feet across a carpet while wearing socks. Because the current is very small, you experience only a small shock if you touch a doorknob. A wall outlet at 120 V can be lethal, however, because it can supply a large current. Your home has several features that help to protect you from a large current. **Table 12.1** summarizes some important safety devices.

Table 12.1 Electrical Safety Equipment in the Home

Device	Safety Purpose	How It Works	Example
Circuit breaker	Limits the amount of current to a set value; prevents overheating in wires and possible resulting fires	Main circuit breaker is in series with meter and with parallel connections to other breakers; when a current is too large, a part of the circuit breaker is heated, and then bends and breaks contact with another part, opening the circuit; the circuit breaker must then be reset	
Fuse	Limits the amount of current to a set value; prevents overheating in wires and possible resulting fires	Contains a metal conductor that melts at a temperature corresponding to a set amount of current, which creates an open circuit and stops the current; must be replaced	
Ground fault circuit interrupter	Replaces wall outlet when it is within 2 m of water source	Contains a circuit breaker that trips if there is any difference in current between the right (hot) slot and the left (neutral) slot	
Wall outlet and plug	Prevents shock resulting from faulty appliances	Outlet contains three slots, including a round one that is grounded; plug's round prong is electrically connected to appliance's metal frame; if a loose wire is connected to the frame, it sets up a large current that trips a circuit breaker connected to the outlet	
Surge protector	Prevents damage to circuits in electronic devices during power surges caused by lightning	Current above a pre-set maximum causes resistance of part of the surge protector to drop rapidly, diverting the current to ground	
Power bar with switch	Allows all appliances connected to the power bar to be turned off with one switch	Each outlet on the power bar is connected in parallel; the switch is in series with the wall outlet	

Section 12.1 Review

Section Summary

- Electrical energy is always generated from another source of energy.
- In direct current, charged particles travel through a circuit in only one direction. In alternating current, electrons move back and forth in a circuit.
- Alternating current is generated when a magnet and a coil of wire are moved relative to each other.
- Alternating current can be transmitted at high potential difference over long distances, with only a small loss of electrical energy.
- Transformers can increase (step up) or decrease (step down) potential difference, but they only work with alternating current.
- Circuit breakers and fuses are safety devices that limit the current to appliances and wall outlets in your home.

Review Questions

K/U **1.** Explain why it is not accurate to speak of electrons flowing in an alternating current.

K/U **2.** A microwave oven requires 3000 V to operate. How could this potential difference be obtained if the microwave oven is plugged into a 120 V wall outlet?

A **3.** Older transmission lines are made from copper cable. What advantages does copper have compared with aluminum? Why is aluminum used to make transmission lines today?

T/I **4.** What advantage does a circuit breaker have, compared with a fuse? Refer to **Table 12.1**.

T/I **5.** Describe at least two different situations that could result in a large current in a household circuit.

T/I **6.** Why is it not safe to plug an appliance with a three-prong plug into an extension cord with a two-slot socket?

C **7.** Research electrical hazards in a home. Prepare a safety sheet that could be given to parents of school-age children.

T/I **8.** Why can birds stand safely on a 230 000 V transmission line, as shown on the right, whereas someone who is trimming a tree and touches the same line will be electrocuted?

This bird is unharmed as it perches on the live transmission line.