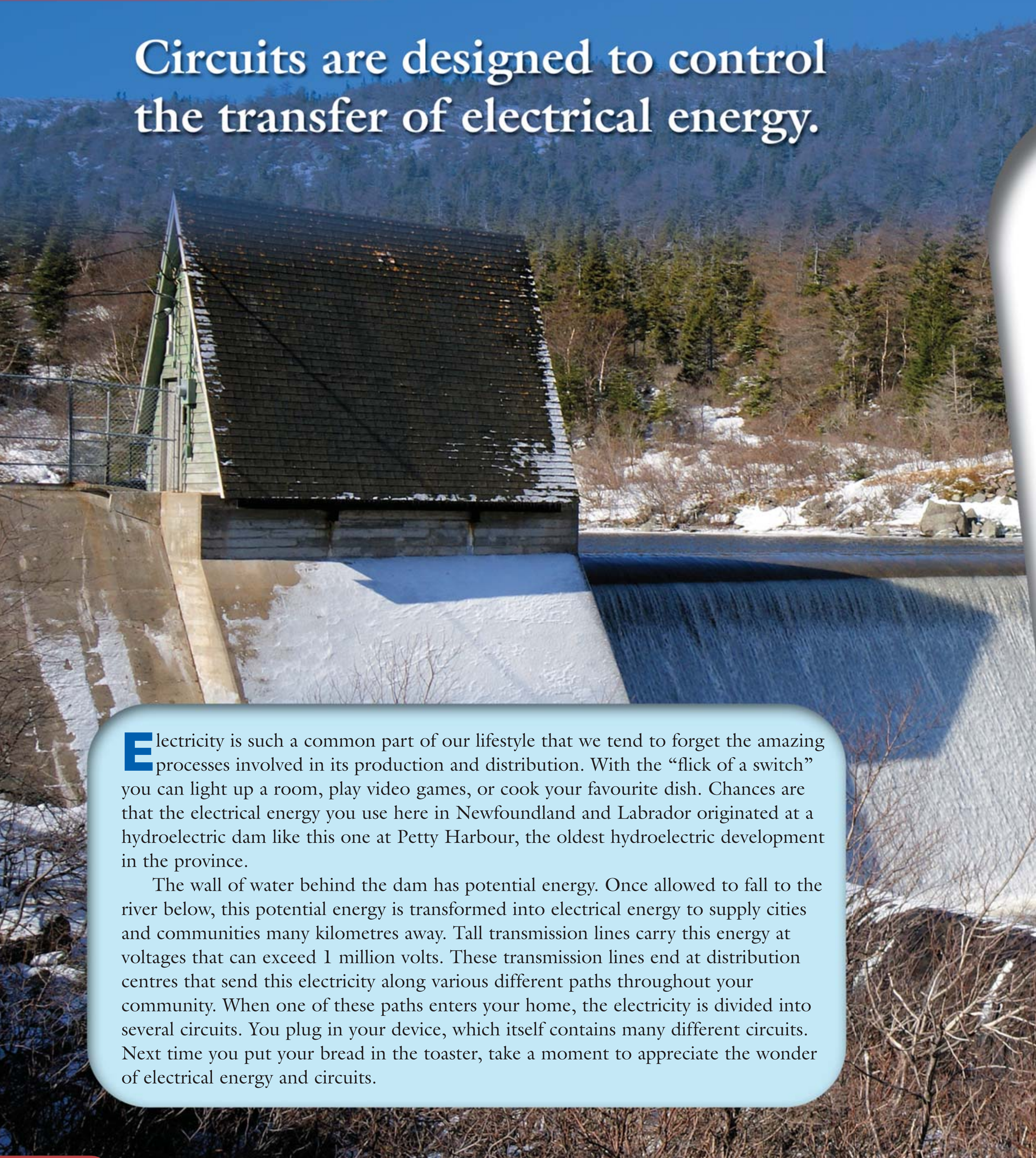
Chapter 9

Circuits are designed to control the transfer of electrical energy.



Electricity is such a common part of our lifestyle that we tend to forget the amazing processes involved in its production and distribution. With the "flick of a switch" you can light up a room, play video games, or cook your favourite dish. Chances are that the electrical energy you use here in Newfoundland and Labrador originated at a hydroelectric dam like this one at Petty Harbour, the oldest hydroelectric development in the province.

The wall of water behind the dam has potential energy. Once allowed to fall to the river below, this potential energy is transformed into electrical energy to supply cities and communities many kilometres away. Tall transmission lines carry this energy at voltages that can exceed 1 million volts. These transmission lines end at distribution centres that send this electricity along various different paths throughout your community. When one of these paths enters your home, the electricity is divided into several circuits. You plug in your device, which itself contains many different circuits. Next time you put your bread in the toaster, take a moment to appreciate the wonder of electrical energy and circuits.

What You Will learn

In this chapter, you will
- **differentiate** between series and parallel circuits in terms of current, voltage, and resistance
- **define** electrical energy and power
- **calculate** power using voltage and current
- **determine** energy consumption given the power rating of a device and duration of use
- **identify** ways to conserve electrical energy
- **describe** how electrical energy is produced

Why It Is Important

We use electrical energy in many devices that help make our lives easier and more comfortable. The cost to operate these devices is determined by the energy they consume.

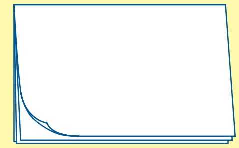
Skills You Will Use

In this chapter, you will
- **measure** current and voltage in both series and parallel circuits
- **model** series and parallel circuits
- **evaluate** energy consumption of common electric devices
- **evaluate** environmental problems associated with generating electrical energy

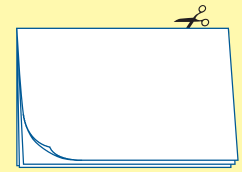
FOLDABLES™
Reading & Study Skills

Make the following Foldable and use it to take notes on what you learn in Chapter 9.

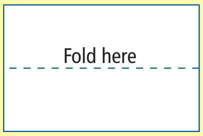
STEP 1 **Fold** three vertical sheets of paper in half horizontally.



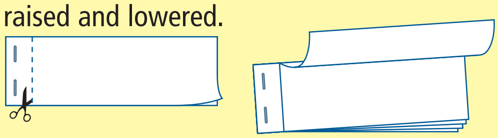
STEP 2 **Cut** along the fold lines, making six half sheets. (**Hint:** Use as many half sheets as necessary for additional pages in your book.)



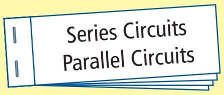
STEP 3 **Fold** each half sheet in half horizontally.



STEP 4 **Place** the folded sides of all sheets at the top and **staple** them together on the left side. About 2 cm from the stapled edge, **cut** the front page of each folded sheet to the top. These cuts form flaps that can be raised and lowered.



STEP 5 **Label** the six individual Flip Book Foldables with the six key points in the "What You Will Learn" section:
(1) series and parallel circuits
(2) electrical energy and power
(3) voltage and current
(4) energy consumption
(5) saving energy
(6) generating electrical energy



Record information, definitions, and examples beneath the tabs.

Define As you read the chapter, under the appropriate tabs define the terms and concepts needed to understand electrical energy.

9.1 Series and Parallel Circuits

In a series circuit, there is only one path for current to travel. The current is the same in each part of a series circuit. Each load in a series circuit uses a portion of the same source voltage. When a resistor is placed in series with other resistors, the total resistance of the circuit increases. In a parallel circuit, there is more than one path for current to travel. The voltage across each resistor in a parallel circuit is the same. Current entering a parallel circuit must divide among the possible paths. The current in each path depends on the resistance of that path. When you connect resistors in parallel, the total resistance decreases.

Key Terms

circuit breaker
fuse
grounding terminal
junction point
parallel circuit
series circuit

Lights are a part of many special celebrations. Some families use mini lights to decorate their homes in the winter. Cities sometimes use lights to decorate trees and buildings at night (Figure 9.1). Decorative lights are different from the light bulbs we use to light the rooms of our homes. They are smaller and less bright. Another difference can be the way they are connected together.

In your house, if a light bulb is removed or "burns out," the lights in the rest of the house stay lit (Figure 9.2). Some strings of decorative lights may be connected in such a way that if one of the bulbs is removed, the rest of the string of lights does not light. What accounts for this difference? The decorative lights and the house lights are on two different types of electric circuits.

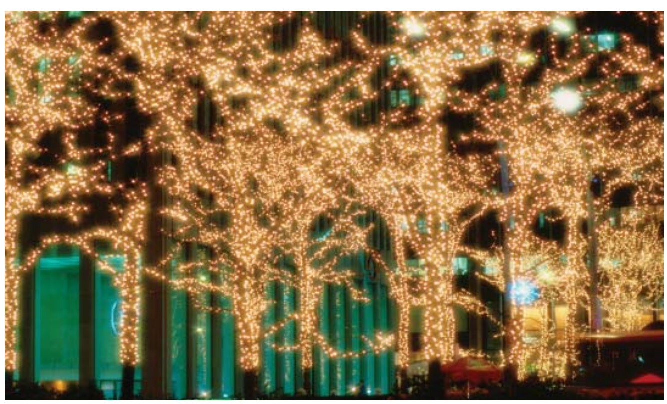


Figure 9.1 Some decorative lights are connected so that each light acts independently of the others. In other types, if one light is removed, none of the remaining lights will be lit.

Figure 9.2 The lights in your home are connected such that if someone turns off one light the rest of the lights stay lit.

Did You Know?

Thomas Edison did not invent the light bulb, but he did develop the first light bulb that could be used in homes. Edison realized that each light bulb should be able to be turned on or off without affecting the other light bulbs connected in the circuit. Since only part of the current goes to each bulb, Edison designed a high-resistance filament that required only a small current to produce large amounts of heat and light.

9-1A Turn Out the Lights

In this activity, you will construct two different circuits and compare the flow of electrons in each circuit.

Safety

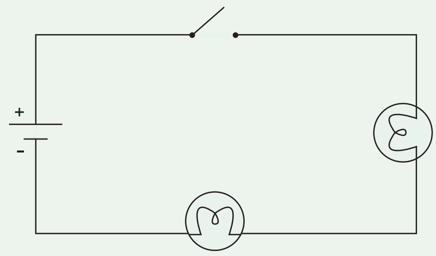
- Disconnect the circuit if any wires become hot.

Materials

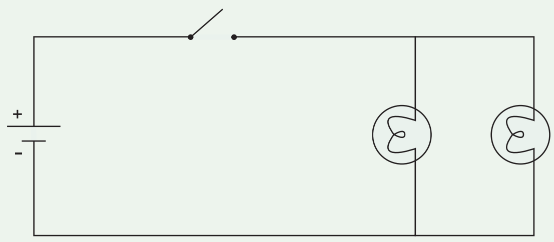
- 1.5 V cell
- two 2.0 V light bulbs
- switch
- connecting wires

What to Do

1. Using the materials provided, build circuit 1 as shown in the diagram.
2. Close the switch and observe the two light bulbs.
3. With the switch still closed, gently unscrew one of the light bulbs. Observe what happens to the remaining light bulb.
4. Replace the light bulb so that both bulbs are again lit. Gently unscrew the other light bulb. Again observe the remaining light bulb. Open the switch after you have made your observations.



Circuit 1



Circuit 2

5. Take circuit 1 apart. Build circuit 2 as shown in the diagram.
6. Close the switch and observe the two light bulbs.
7. With the switch still closed, gently unscrew one of the light bulbs. Observe what happens to the remaining light bulb.
8. Replace the light bulb so that both are again lit. Gently unscrew the other light bulb. Again observe the remaining light bulb. Open the switch after you have made your observations.
9. Clean up and put away the equipment you have used.

What Did You Find Out?

1. Imagine you are an electron leaving the negative terminal of the cell in circuit 1.
   (a) How many ways are there for you to travel through the circuit in order to arrive at the positive terminal?
   (b) How many light bulbs do you have to travel through?
2. In circuit 1, when one bulb is removed is the other bulb still lit? Why?
3. Imagine you are an electron leaving the negative terminal of the cell in circuit 2.
   (a) How many ways are there for you to travel through the circuit in order to arrive at the positive terminal?
   (b) In any one of these paths, how many light bulbs do you have to travel through?
4. In circuit 2, when one bulb is removed is the other bulb still lit? Why?

Charges with One Path to Follow

A simple waterslide at the local water park might consist of one set of stairs leading to a slide that travels down to a pool (Figure 9.3). Every person who climbs the stairs must travel down the same slide. If a person decides to stop either on the stairs or on the slide, the rest of the people using the slide must also stop because this person is blocking the only pathway.

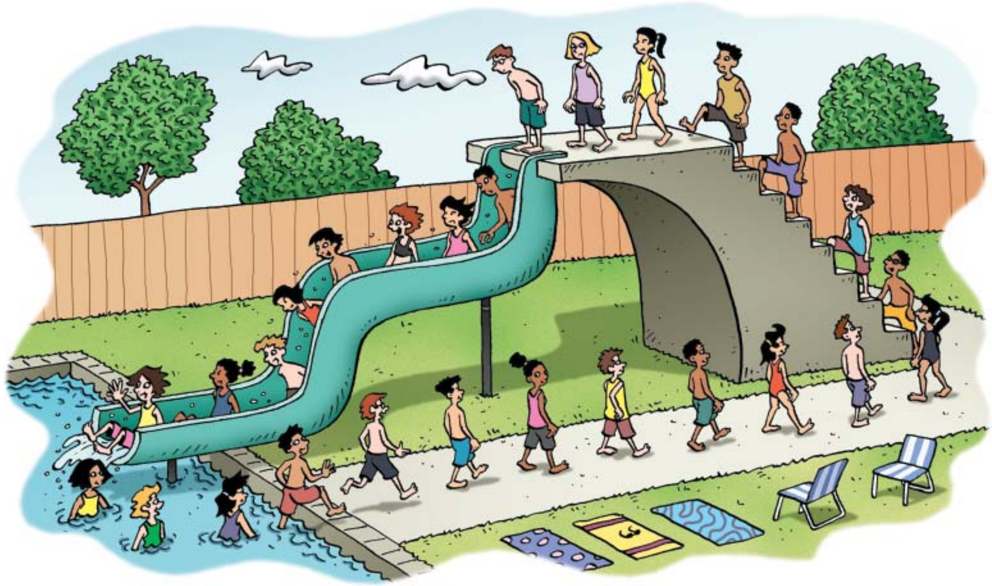


Figure 9.3 Everyone who uses this slide follows the same path.

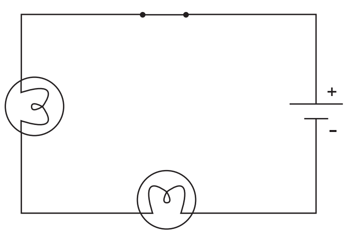


Figure 9.4 Electrons leaving the negative terminal of the battery in this circuit have only one path to return to the battery at the positive terminal.

Figure 9.4 is an electric circuit that is like the simple waterslide. A circuit that has only one path for current to travel is called a **series circuit**. In other words, electrons have only one pathway to travel through a series circuit. If the switch is opened, all electrons are blocked and the current stops.

9-1B Is the World Series a Series Circuit?

Think About It

A series circuit is a complete loop that has only one pathway. There are many physical examples of loops that have only one path. For example, running one lap on the school track is like a series circuit because it is one path that makes a complete loop. Another example is an assembly line in a factory where each worker adds another part to the frame of an automobile. In this activity, you will brainstorm other examples in your community and the world that represent a series circuit.

What to Do

1. Work with a partner or in a small group to list examples that represent series circuits in your home, your community, and the world.

What Did You Find Out?

1. Compare your list with another group's list. Which examples did you have in common?
2. Choose one of the examples that you have in common.
   (a) What travels through the circuit?
   (b) What energy causes the motion of the objects in the circuit?
   (c) If the circuit became broken or blocked, what would happen to the motion of the objects in the circuit?

Voltage and Current in a Series Circuit

The people on the waterslide represent the electrons that flow through the circuit. A person has more potential energy at the top of the stairs than at the bottom. Suppose the staircase has 12 steps. A person who slides from the top of the slide to the bottom will “lose” all 12 steps before returning to the bottom of the stairs.

In an electric circuit, the charge that leaves a 12 V battery “loses” all 12 V before it returns to the battery. These losses occur on loads such as light bulbs or resistors, which transform the electrical energy into other forms of energy. Each load in the series circuit loses a portion of the total voltage supplied to the electrons by the battery (Figure 9.5). The sum of the voltages lost on the loads equals the total voltage supplied by the battery.

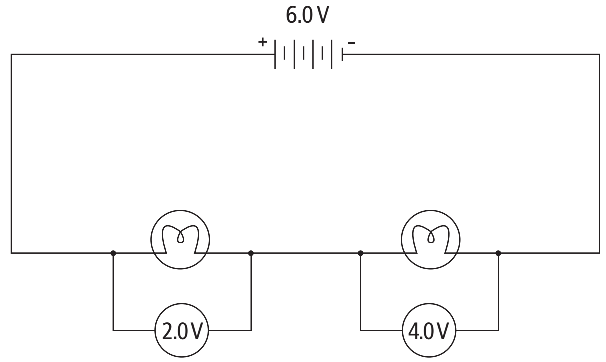


Figure 9.5 Each load in a series circuit loses a portion of the total voltage.

In an electric circuit, all of the electrons repel each other with the same action-at-a-distance force. Therefore, most of the electrons flowing in a circuit will remain fairly evenly spaced apart. Since there is only one path for the electrons to travel in the series circuit, the current in each part of a series circuit is equal (Figure 9.6). This is similar to a garden hose filled with water. The amount of water entering the garden hose must be the same as the amount of water leaving the same hose. All along the hose, therefore, the “current” of water is the same.

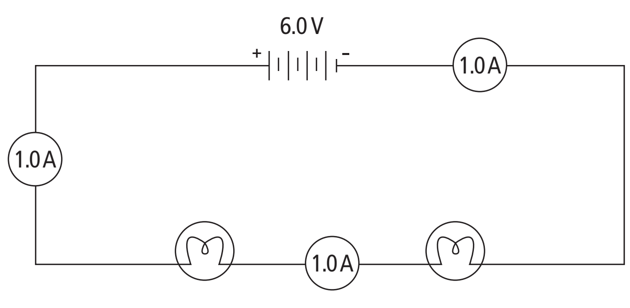
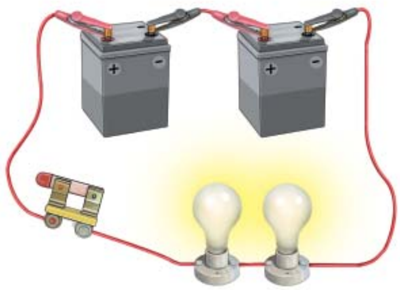


Figure 9.6 The current is the same throughout a series circuit.

Did You Know?

Cells can be connected in series to form a battery as shown in the diagram below. When cells are connected in series, the effective voltage of the circuit is increased to the sum of the voltages of the cells. If the resistance remains the same, doubling the voltage will double the current in the circuit as well (using Ohm’s Law, $V = IR$). The downside of connecting cells in series is that the battery’s lifespan is decreased.



Since there are two 1.5 V cells connected in series, the effective voltage of this battery is 3.0 V.

Suggested Activity

Find Out Activity 9-1D on page 298

Resistors in Series

Imagine if a waterslide contained a section where the water escaped and you had to slide across dry plastic. This section would have more resistance than the other parts of the slide, and therefore you would slow down. If all the people on this slide behaved like electrons and kept almost equal spacing, then everyone would slow down due to this resistance. Suppose there were another dry patch farther down the slide. This resistance would further slow down the person sliding across it and cause everyone to slow down even more. The total number of people reaching the bottom per minute would be less.

The same result occurs in an electric circuit when resistance is added. Resistors placed in series increase the total resistance of the circuit. When you place resistors in series, you increase the total resistance, and therefore the total current throughout the circuit decreases.

Reading Check

1. What do we call a circuit that has only one path?
2. What happens to the current in a series circuit when a switch is opened?
3. How does the total voltage lost on all loads compare to the total voltage supplied by the battery?
4. Why is the current at any two locations in a series circuit always the same?
5. If a resistor is added in series to an existing resistor, what happens to the total resistance?

Did You Know?

Sometimes, the largest voltages in a home are in the television set where 20 000 V is common. The electric stove in your kitchen is connected to 240 V but can take a current as large as 40 A.

More Than One Way to Go

A closed pathway that has several different paths is called a **parallel circuit**. Figure 9.7 shows a parallel electric circuit. Electrons leaving the battery have three possible ways of returning to the battery in this example. An electron can travel through bulb 1, bulb 2, or bulb 3 before returning to the battery.

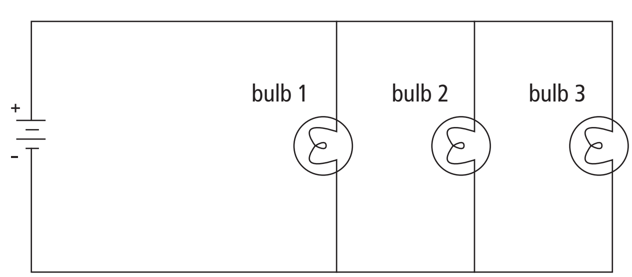


Figure 9.7 Electrons leaving the battery have three possible ways to return to the battery in this circuit.

A waterslide with more than one slide gives the rider different experiences than the single pathway waterslide (Figure 9.8). If someone decides to stop on one of the slides, the other pathways still operate. Even though there are different pathways down, everyone climbs the same stairs and everyone ends up in the same pool at the bottom of the slides.

Figure 9.8 People on this waterslide have three possible ways to reach the bottom of the slide.

9-1C More Things Are Parallel Than Lines

Think About It

A parallel circuit is a complete loop that has more than one pathway. If there is more than one way to travel between two locations, those different paths are called parallel. For example, in a busy mall there may be several escalators side by side that take you up to the next floor. Each of the escalators is parallel. In this activity, you will brainstorm situations that represent parallel paths.

What to Do

1. Work with a partner or in a small group to list examples that represent parallel paths in your home, your community, and the world.

What Did You Find Out?

1. Compare your list with another group's list. Which examples did you have in common?
2. Choose one of the examples that you have in common.
   (a) What travels through the circuit?
   (b) What energy causes the motion of the objects in the circuit?
   (c) If one pathway of the circuit became broken or blocked, what would happen to the motion of the rest of the objects in the circuit?

Voltage and Current in a Parallel Circuit

Suppose people climbed 50 stairs to reach the top of the waterslide. Regardless of which of the three slides the people travel down, they will end up in the same pool. They will "lose" all the potential energy they gained when they climbed the stairs by the time they reach the bottom. In an electric circuit, the battery supplies electric potential energy to the electrons through a potential difference. If the battery has a potential difference of 12 V, then the electrons will lose these 12 V of potential difference by the time they return to the battery. As you can see in Figure 9.9, the voltage on each of the light bulbs in parallel is the same. Loads that are in parallel have the same voltage.

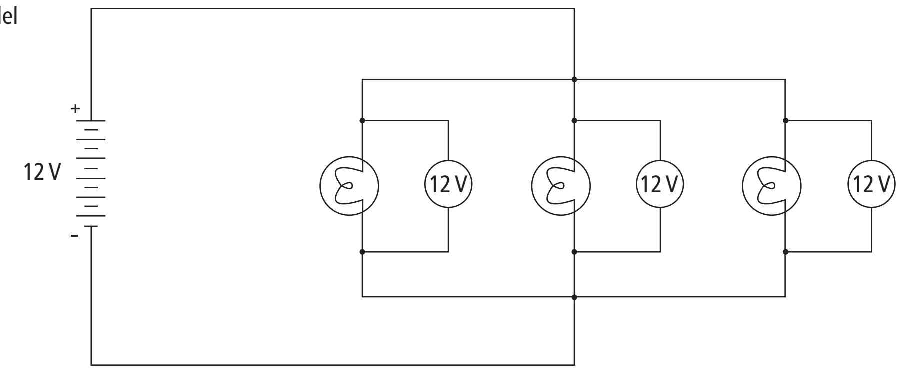
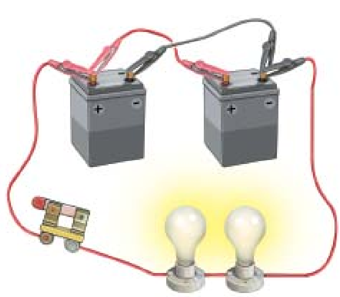


Figure 9.9 Each load in parallel must have the same voltage.

Did You Know?

When cells are connected in parallel as shown in the diagram below, the effective voltage of the circuit remains the same as the voltage in the individual cells. Why connect cells in parallel? By providing multiple energy sources for the circuit, the overall battery life is increased, so the circuit will operate for a longer period of time.



When cells are connected in parallel, the overall battery life is lengthened.

In a *series* circuit, the current is the same throughout the circuit. This is because there is only one path for the electrons to travel. In a *parallel* circuit, the current branches into different pathways that eventually rejoin. A portion of the electrons travels on each path. A pathway with less resistance will be able to have more electrons travel on it and therefore will have a greater current than a pathway with more resistance.

Figure 9.10 shows a battery connected to three different resistors connected in parallel. The total current leaving the battery divides into three possible pathways. The location where a circuit divides into multiple paths or where multiple paths combine is called a **junction point**. No current is created or destroyed by parallel paths. The current is only split up to travel different routes.

Loads of different resistance that are connected in parallel will have different currents. The total current entering a junction point must equal the sum of the current leaving the junction point.

Suggested Activity

Find Out Activity 9-1E on page 299

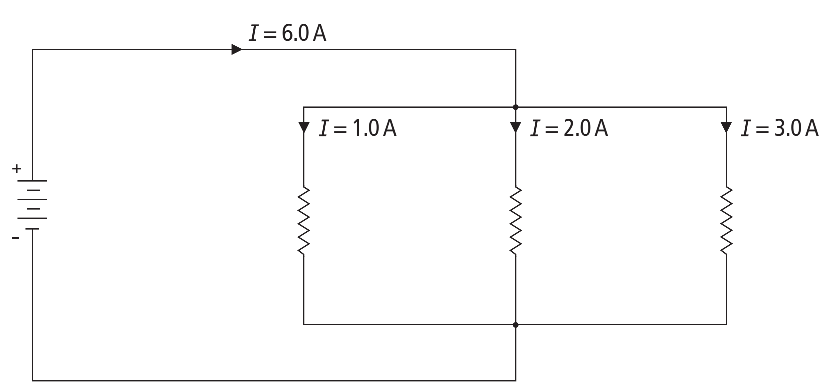


Figure 9.10 Current entering the junction point divides among the three possible paths.

Resistors in Parallel

Imagine that you are standing at the end of a long line in a grocery store. There is only one checkout open, and all customers must pass through the one checkout. This is like a series circuit since there is only one path. The cashier in this situation represents a resistor since the cashier slows down the customers. Suppose a second checkout is opened. Customers can now check out their groceries in either line. Even though the second cashier is also a resistor, the customers do not have to wait as long.

The same is true for electric circuits (Figure 9.11). When you place a resistor in parallel with another resistor, you create another pathway so the total resistance must decrease. Resistors placed in parallel will decrease the total resistance of the circuit. When the total resistance of the circuit decreases, the total current leaving the battery must therefore increase.

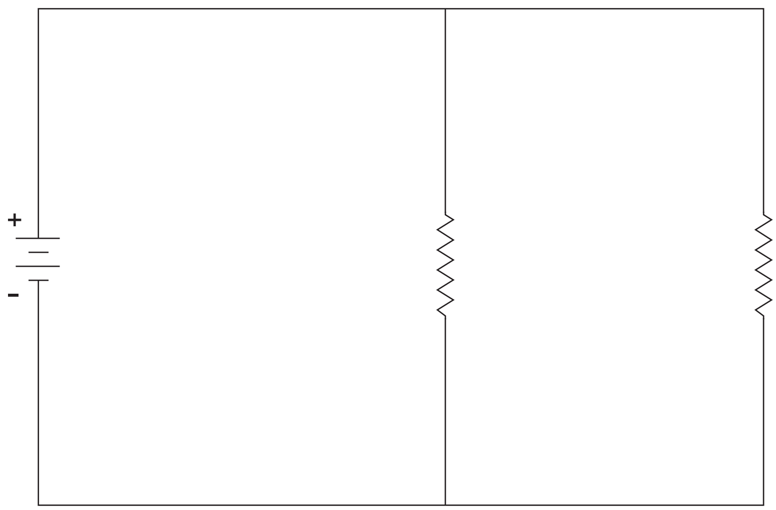


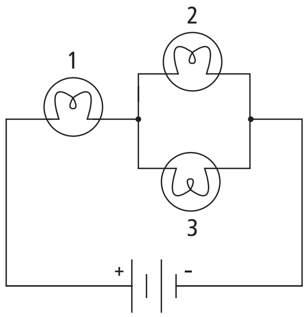
Figure 9.11 The total resistance of the circuit is decreased when resistors are placed in parallel.

Reading Check

1. What name is given to a circuit that contains more than one pathway?
2. Two loads are connected in parallel. Compare the voltage across each load.
3. Two loads are connected in parallel. Must the current through one load equal the current through the other load?
4. What name is given to a location in a circuit where the circuit branches into more pathways or where pathways rejoin?
5. How does current entering a junction point compare to current leaving that same junction point?
6. If you add a resistor in parallel to an existing resistor, what happens to the total resistance in the circuit?

Did You Know?

Most circuits are actually complex circuits made of some components in series, and others in parallel. When solving complex circuit problems, you need to use the rules for both series and parallel circuits and consider each piece of the circuit separately.



Bulbs 2 and 3 are in parallel, but they are both in series with bulb 1. What would happen if bulb 1 was removed?

Suggested Activity

Conduct an Investigation 9-1F on page 300

Explore More

The value of the total resistance of resistors connected in both series and parallel can be calculated. Find out how to calculate this total resistance. Begin your research at **www.discoveringscience9.ca**.

Explore More

Engineers can use the properties of series and parallel connections to change voltage, current, and resistance in circuits. For example, if too much voltage is dropped across a circuit component, a resistor can be added in series with the component to decrease the voltage. Find out more about the applications of series and parallel circuits, and how they can be used in practical applications. Begin your research at **www.discoveringscience9.ca**.

Series and Parallel Circuits

In this section, you have learned about the two types of electric circuits: series and parallel. Although both series and parallel circuits are built from the same basic electrical components, including cells, wire, and resistors, their properties and uses differ because of the way the components are connected. The similarities and differences between series and parallel circuits are summarized in Table 9.1 below.

Table 9.1 Series and Parallel Circuits

	Series Circuits	Parallel Circuits
Number of paths for electron flow	One	Multiple
Effect of removing a load from the circuit	Electrons cannot flow. (The circuit is broken.)	Electrons continue to flow through the remaining paths. (The circuit is not broken.)
Voltage (potential) drop	The sum of the voltage lost in the loads or resistors in the *entire* circuit equals the total voltage supplied by the battery.	The sum of the voltage lost in the loads or resistors in *each branch* of the circuit equals the total voltage supplied by the battery.
Current	• The current is the same throughout the circuit. • The current is dependent on the total resistance in the circuit.	• The total current entering or leaving a junction point is equal to the sum of the current in the individual paths. • The current in each of the paths is dependent on the total resistance in that path.
Resistance	• The total resistance of the circuit is increased when resistors or loads are added in series, since the total resistance is the sum of the resistances of each of the resistors or loads. • When the total resistance is increased, the overall current will decrease, since $V = IR$.	• The total resistance of the circuit is decreased when resistors or loads are placed in parallel. • When the total resistance is decreased, the overall current will increase, since $V = IR$.
Connecting cells to form a battery	• When cells are connected in series, the effective voltage is the sum of the voltages of each of the cells. • The maximum overall lifespan of the battery is the same as the lifespan of each of the individual cells.	• When cells are connected in parallel, the effective voltage is the same as the voltage of a single cell. • The maximum overall lifespan of the battery is the sum of the lifespan of each of the cells combined.

When considering whether to use a series or parallel connection, you need to ask some important questions. Should the rest of the circuit continue to function when one part does not? If one of your car headlights burns out, you will certainly want the other one to continue to provide light! But if a DVD player stops reading the DVD, is there any benefit to providing a picture and sound? Therefore, you will need to connect the lights in parallel. However, in some situations, there is no benefit to having components connected in parallel. If the disc reader on a DVD player stops functioning, it is not necessary for the video component to keep working. Therefore, these components can be connected in series.

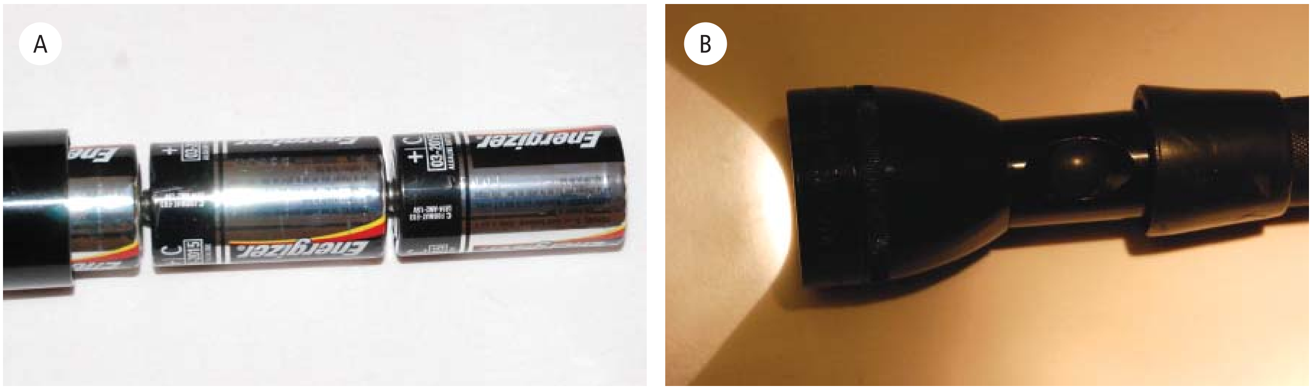


Figure 9.12 By connecting cells in series (A), more voltage is provided to the flashlight bulb, making it much brighter (B).

Take apart a flashlight, and you will notice that the cells are all connected in series (Figure 9.12). By connecting them in series, higher voltage and therefore a larger current is provided to the light bulb, resulting in a brighter light.

If the cells were connected in parallel, the light would be much dimmer, but the battery would last longer. The longer battery life for cells connected in parallel can be an important feature when access to the circuit to replace a battery or make repairs is difficult (Figure 9.13).

Figure 9.13 Cells connected in parallel have a much longer life span, reducing the amount of maintenance required. In addition, the circuit will continue to function when one cell is faulty. This is important for circuits in remote locations.

Protecting Household Circuits

The electric circuits in your home are a combination of series and parallel circuits. All of the electrical energy to your home is provided by one distribution line that goes through your electric meter and into the service panel (Figure 9.14).

Wires from the meter are connected in series to the main **circuit breaker**. The main circuit breaker acts as a switch and safety device that can cut off all power coming into your home. If the current exceeds a safe level, a bimetallic strip in the breaker heats up, bends, and opens the circuit. This is sometimes called "tripping" the breaker. Current stops flowing until the breaker cools and you reset it.

Older homes often have a fuse box instead of a breaker panel. A **fuse** contains a metallic conductor that melts when excessive current heats it up. This opens the circuit until the fuse is replaced. Fuses are rarely used in modern buildings, but they are common in electric stoves and automobile electrical systems.

The service panel contains additional circuit breakers or fuses for each of the circuits in your home. Each of these circuits provides power to one or more wall plugs, lights, or appliances connected in parallel. As additional loads are plugged into a circuit in parallel, the total resistance in the circuit decreases. As a result, the current in the circuit increases. The increased current in the wiring causes the wires to heat up. Before the wires become hot enough to start a fire, however, the circuit breaker or fuse in that circuit cuts off current to all of the loads in that circuit, which are in series with that circuit breaker. Because the other household circuits are in parallel, they will continue to operate (Figure 9.15).

Figure 9.14 The service panel, often found in the basement of a house, is the junction point from which a number of parallel circuits originate. Each circuit is protected by its own circuit breaker.

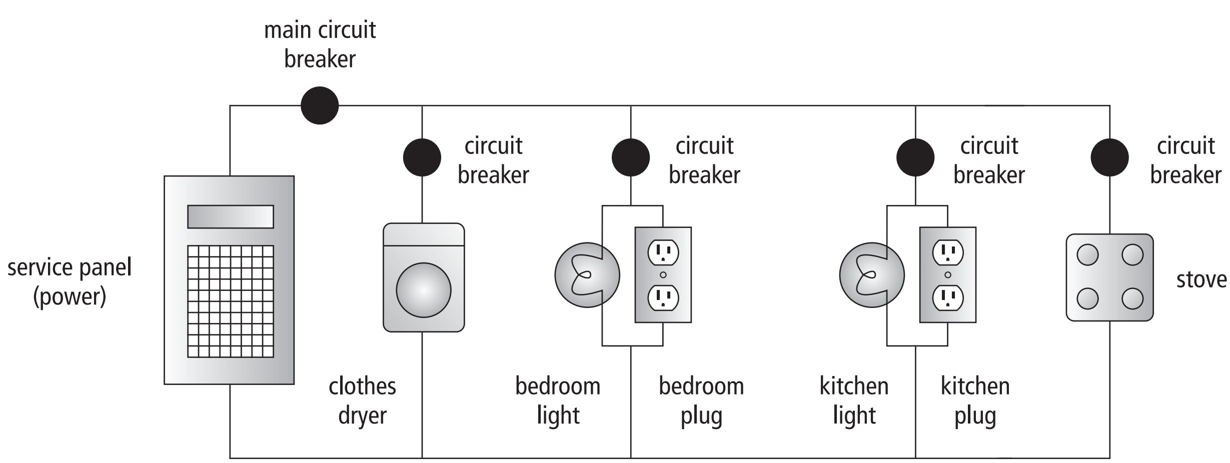


Figure 9.15 Since the kitchen plug circuit is in parallel with the other circuits, when that circuit breaker shuts off, the remaining circuits will continue to operate.

The circuit breakers, wall outlets, lights, and switches in each circuit are connected by cables that contain three wires. There are two wires that are usually insulated in black and white plastic, while the ground wire is either bare copper or covered with green insulation. The ground wire, as described in Chapter 7, provides a path for any excess current that has "leaked" onto metal components in the electric circuit. The three wires are connected to a wall outlet as shown in Figure 9.16.

Figure 9.16 Electrons flow into and out of a device through the two slots in a wall outlet. The round hole in a wall outlet is connected to a ground wire like the copper wire shown in this photo.

Suppose you were using an electric lawnmower and a "live" or "hot" loose wire inside the motor touched the metal frame. You could receive a dangerous electric shock. The round prong of a plug acts as a **grounding terminal**, connecting the lawnmower's metal frame to ground with negligible resistance. Therefore, the excess current will flow into the ground instead of giving you a shock.

Reading Check

1. Describe three differences between series and parallel circuits.
2. Describe the pros and cons of parallel and series connections of cells.
3. Describe a situation where a series connection of cells is used. Explain why.
4. Describe a situation where a parallel connection of cells is used. Explain why.
5. Explain the function of a circuit breaker and a fuse. How are they different?
6. What is a grounding terminal, and how does it protect us from electric shock?

9-1D A Series of Lights and Cells

Find Out ACTIVITY

In this activity, you will construct a series circuit. Using voltmeters and ammeters, you will measure and analyze the voltage and current in this circuit. What is the relationship between current and voltage in a series circuit? How do you think connecting cells in a series will affect current and voltage?

Safety

- If any wires become hot, disconnect the circuit.

Materials

- two 1.5 V cells
- two 1.5 V flashlight bulbs
- two ammeters
- voltmeter
- switch
- connecting wires

What to Do

1. Copy the following data table in your notebook twice, once for Part 1 and once for Part 2. Give the tables appropriate titles.

Current (mA)	Voltage (V)
Ammeter 1 =	Bulb 1 =
Ammeter 2 =	Bulb 2 =
	Battery =

Part 1

2. Construct the circuit shown in the diagram, using one 1.5 V cell as the source.
3. Close the switch and measure the current through each of the ammeters. Record these measurements in your data table.
4. Using your voltmeter, measure and record the voltage across each of the bulbs, and then across the power source.

Science Skills

Go to Science Skill 7 to learn more about how to use an ammeter and a voltmeter.

Part 2

5. Add another 1.5 V cell to your circuit, connecting the two 1.5 V cells together in series, positive to negative.
6. Repeat steps 3 to 4.
7. Clean up and put away the equipment you have used.

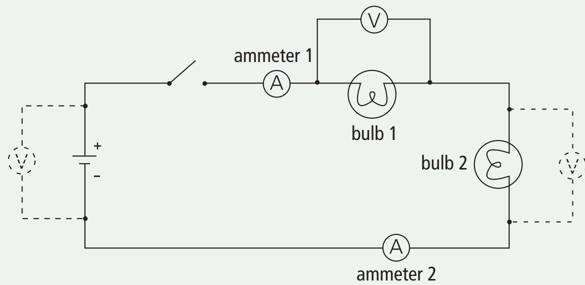
What Did You Find Out?

Part 1

1. Compare the current in ammeters 1 and 2.
2. Compare the voltage across the two bulbs.
3. Add the voltage of the bulbs together. Compare the total voltage lost on the two bulbs to the battery voltage.
4. What is the relationship between the number of bulbs in a series circuit and the current? How could you test your theory?

Part 2

5. Compare the currents and voltages measured in Part 1 with those measured in Part 2.
6. What is the relationship between current and voltage in a series circuit?
7. Use the relationship between current and voltage when cells are connected in series to explain how series connections of cells could be useful.



In Part 1, use one 1.5 V cell. In Part 2, use two 1.5 V cells, connected together positive to negative.

9-1E Parallel Lights and Cells

Find Out ACTIVITY

In this activity, you will construct a parallel circuit. Using voltmeters and ammeters, you will measure and analyze the voltage and current in this circuit. What is the relationship between current and voltage in different parts of a parallel circuit? How do you think connecting cells in parallel will affect current and voltage?

Safety

- If any wires become hot, disconnect the circuit.

Materials

- two 1.5 V cells
- three 1.5 V flashlight bulbs
- three ammeters
- voltmeter
- switch
- connecting wires

What to Do

1. Copy the following data table in your notebook twice, once for Part 1 and once for Part 2. Give the tables appropriate titles.

Current (mA)	Voltage (V)
Ammeter 1 =	Bulb 1 =
Ammeter 2 =	Bulb 2 =
Ammeter 3 =	Bulb 3 =
	Battery =

Part 1

2. Construct the circuit shown in the diagram, using one 1.5 V cell as the source.
3. Close the switch and measure the current through each of the ammeters. Record these measurements in your data table.
4. Using your voltmeter, measure and record the voltage across each of the bulbs, and then across the power source.

Part 2

7. Add another 1.5 V cell to your circuit, connecting the cell in parallel, as shown in red in the diagram below.
8. Repeat steps 3 and 4.
9. Clean up and put away the equipment you have used.

What Did You Find Out?

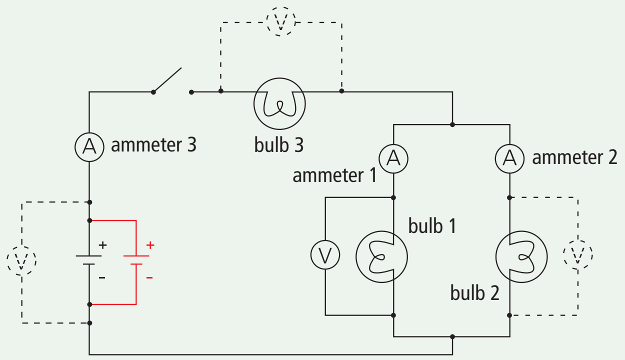
Part 1

1. Compare the voltage across the three bulbs.
2. Compare the current through each bulb, as measured by the three ammeters.
3. Add the current in ammeter 1 and ammeter 2. Compare this to the current leaving the cell and through bulb 3 (ammeter 3).
4. What is the relationship between the number of bulbs in a parallel circuit and the current? How could you test your theory?
5. What is the relationship between current and voltage in different parts of a parallel circuit?

Part 2

6. Compare the currents and voltages measured in Part 1 with those measured in Part 2.
7. a) Describe the effect on voltage and current of connecting cells in parallel.

   b) Given this effect, how can parallel connections of cells be used?



In Part 1, use one 1.5 V cell. In Part 2, use two 1.5 V cells connected in parallel, as shown in red.

9-1F Resistors in Series and Parallel

SkillCheck
- Observing
- Measuring
- Explaining systems
- Evaluating information

Resistors slow down the flow of charge and change electrical energy into other forms of energy. By connecting resistors in different configurations, you can control both current and energy in the circuit. In this investigation, you will build both series and parallel circuits involving resistors. By measuring the current and voltage, you can use Ohm's law to calculate resistance.

Safety

- If any components become hot, open the switch immediately.
- If a power supply is being used instead of batteries, be sure to turn off the power supply while constructing the circuit.

Materials

- 6.0 V lantern battery or power supply
- 3 resistors of different sizes (100 Ω–500 Ω)
- ammeter
- voltmeter
- switch
- connecting wires

Science Skills

Go to Science Skill 7 to learn more about how to use an ammeter and a voltmeter.

Question

How does the total resistance of a circuit change when resistors are connected in series and in parallel?

Procedure

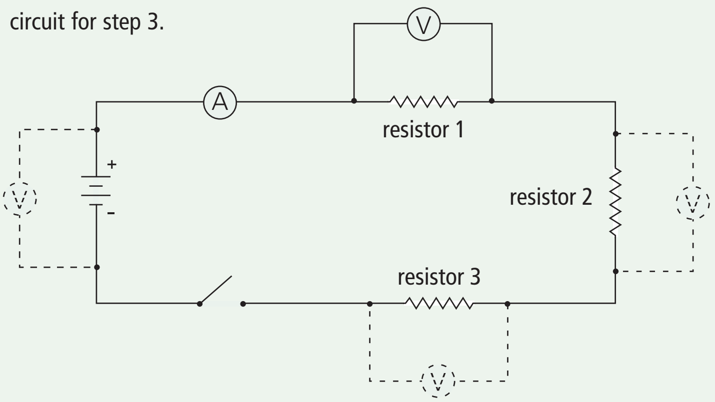
Part 1 Resistors in Series

1. Copy the following data table in your notebook. Give your table a title.

Resistance (Ω)	Voltage (V)	Current (A)
Resistor 1 =	Voltage across resistor 1 =	Total current leaving the battery =
Resistor 2 =	Voltage across resistor 2 =	
Resistor 3 =	Voltage across resistor 3 =	
	Voltage across battery =	

2. Using the resistor colour code, determine the resistance of each resistor. Record these values in your data table.
3. Construct the circuit shown in the diagram.

Construct this circuit for step 3.



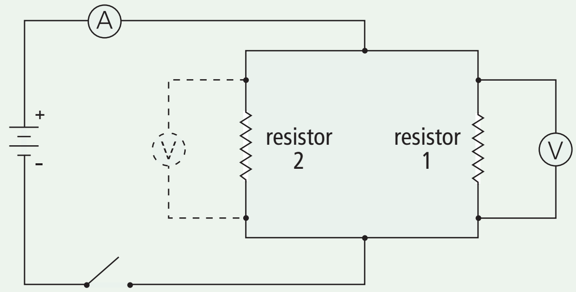
4. Close the switch, and measure the current through the ammeter. Record this current in your data table. If your ammeter is measuring milliamperes (mA), be sure to convert this to amperes (A).
5. Measure the voltage across resistor 1. Record this in your data table.
6. Move your voltmeter, and measure the voltage across the remaining resistors and the battery. Record each measurement in your data table.
7. Open the switch, and disassemble your circuit.

Part 2 Resistors in Parallel

8. Copy the following data table in your notebook. Give your table a title.

Resistance (Ω)	Voltage (V)	Current (A)
Resistor 1 =	Voltage across resistor 1 =	Total current leaving the battery =
Resistor 2 =	Voltage across resistor 2 =	
	Voltage across battery =	

9. Using the resistor colour code, determine the resistance of any two of your three resistors. Record these values in your data table.
10. Construct the circuit shown in the diagram below, using the two resistors you have recorded.



Construct this circuit for step 10.

11. Close the switch, and measure the current through the ammeter. Record this current in your data table.
12. Measure the voltage across resistor 1. Record this in your data table.
13. Move your voltmeter, and measure the voltage across resistor 2 and the battery. Record each measurement in your data table.
14. After you have taken all measurements, open the switch.
15. Clean up and put away the equipment you have used.

Analyze

Part 1

1. Use Ohm's law ($R = \frac{V}{I}$) to calculate the total resistance of your series circuit. (Use the battery voltage and the current leaving the battery.)
2. Compare the total resistance calculated in question 1 to the individual resistors used in the circuit. Is the total resistance greater than or less than the individual resistors?
3. Compare the voltage across each resistor. Does each resistor lose the same amount of voltage?
4. Add the voltages on each of the three resistors. Compare the total voltage lost on the three resistors to the battery voltage.

Part 2

5. Use Ohm's law to calculate the total resistance of your parallel circuit. (Use the battery voltage and the current leaving the battery.)
6. Compare the total resistance calculated in question 5 to the individual resistors used in the circuit. Is the total resistance greater than or less than the individual resistors?
7. Compare the voltage across each resistor. Does each resistor lose the same amount of voltage?

Conclude and Apply

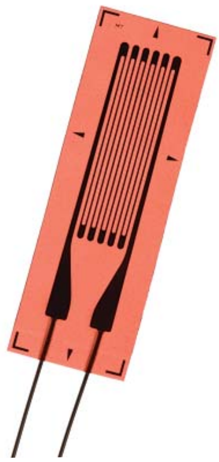
1. Write a short paragraph that states the relationships of the following terms in a series circuit: total resistance, individual resistors, total voltage, voltage across each resistor.
2. Write a short paragraph that states the relationships of the following terms in a parallel circuit: total resistance, individual resistors, total voltage, and voltage across each resistor.

The Robotic Cockroach

Engineers are closely studying one of nature's most successful species in order to design and build better robots. Is that successful species human? No, it is the common cockroach.

Early robots were designed to have human characteristics, for example two legs. These early robots were slow and worked well only on smooth surfaces. Scientists now realize that arthropods (insects, spiders, crustaceans), for their size, possess greater strength, balance, agility, and speed than humans. The problem with a six-legged robot is co-ordinating each leg to produce the desired motion, even over rough terrain. The solution? Modern robots use a strain gauge to detect the pressure and motion of individual legs.

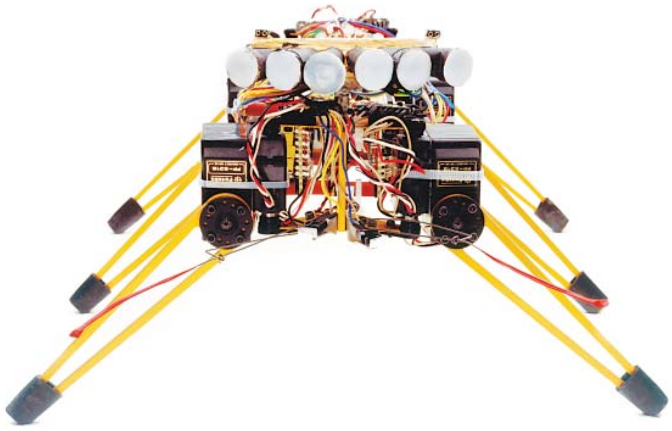
A strain gauge is a device used to measure the bend in an object. Invented in 1938, the most common strain gauge consists of a thin metallic foil or flexible semiconductor. Bending or deforming the foil causes its electrical resistance to change. This change in resistance can be used to detect pressure or motion.



A common application of a strain gauge is in an electronic bathroom scale. A strain gauge attached to a beam is bent when you step on the scale. The change in resistance due to the bend is then used to electronically calculate your weight or mass.

The idea of placing electronic strain gauges on the exterior of the robot was based on an insect design. Insects and spiders have biological strain gauges attached to their exoskeleton. These sense organs are located mostly near the joints and tips of the legs. The biological strain gauges in insects are as sensitive to motion as the receptors in the human ear are to sound. Strain gauges in insects regulate their walking movement. Robotic engineers are trying to closely copy what occurs in nature.

Recently designed six-legged robots are both quick and mobile. These robots can travel up to five body-lengths per second and can continue in a forward motion even when encountering small obstacles. Robots with such speed and balance could be useful for exploring dangerous areas such as toxic waste sites or active volcanoes and could function well on difficult terrain, such as that of the Moon or Mars.



Questions

1. Make a list of the advantages and disadvantages of a six-legged robot as compared to a two-legged robot.
2. (a) What electric property changes when a strain gauge is deformed?
   (b) What effect would this have on an electric circuit?
3. Engineers have studied insects to design better robots. Describe another technology that has been designed by studying nature.

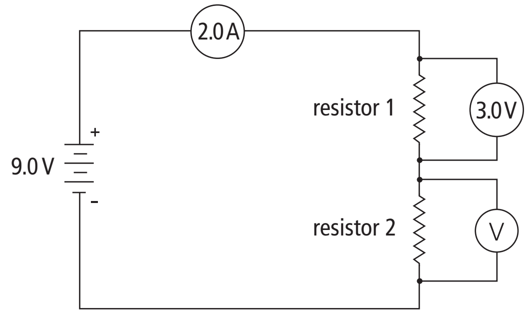
Check Your Understanding

Checking Concepts

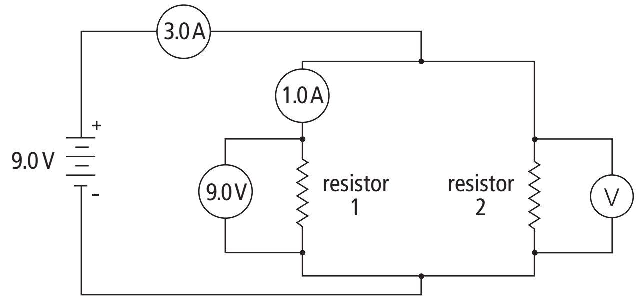
1. How is a parallel circuit different from a series circuit?
2. In a series circuit, how does the voltage supplied by the battery compare to the voltages on each load?
3. Two resistors are connected in parallel to a battery. What must be the voltage across these two resistors?
4. Is the current in one branch of a parallel circuit more than, less than, or equal to the total current entering the junction point of the circuit?
5. How does a circuit breaker protect against electric shock?
6. What is a grounding terminal? How does it work?

Understanding Key Ideas

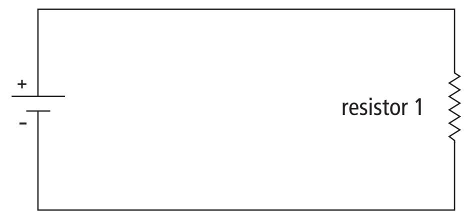
7. For the following circuit, find:
   (a) the current through resistor 2
   (b) the voltage across resistor 2



8. For the following circuit, find:
   (a) the current through resistor 2
   (b) the voltage across resistor 2

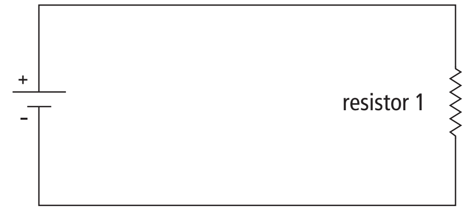


9. You are given the following circuit.



A second resistor is now added in series with resistor 1.
(a) Draw the new circuit diagram.
(b) Comparing your new circuit to the original, describe the changes in:
  (i) total resistance
  (ii) current leaving the cell
  (iii) voltage across resistor 1

10. You are given the following circuit.



A second resistor is now added in parallel with resistor 1.
(a) Draw the new circuit diagram.
(b) Comparing your new circuit to the original, describe the changes in:
  (i) total resistance
  (ii) current leaving the cell
  (iii) voltage across resistor 1

Pause and Reflect

Are the lights in your school connected in series or in parallel? Justify your answer using facts about series and parallel circuits.

9.2 The Power of Electricity

Electrical power is the rate at which electric potential energy is being transformed. One joule (J) of electric potential energy transformed in one second is one watt (W) of power. Electrical power can be calculated by multiplying voltage and current ($P = VI$). The amount of electrical energy used by a device is its power consumption multiplied by the length of time the device is turned on ($E = Pt$). Because the joule is a very small amount of electrical energy, the kilowatt-hour (kW·h) is used for devices that consume larger amounts of energy.

Key Terms

electrical energy
electrical power
joule
kilowatt-hour
power
power rating
watt

Imagine two cars at the bottom of a very steep hill on a racetrack (Figure 9.17). One car is a well-kept race car whereas the other is an older automobile in a poor state of repair. The old automobile and the race car have exactly the same mass. When the vehicles reach the top of the hill, they will have both gained the same amount of potential energy since they are at the same height. On this particular day, the drivers have a race to the top of the hill. As you might expect, the race car reaches the top of the hill before the old automobile. Both vehicles converted the same amount of energy to reach the top of the hill. What gives the race car the ability to do this work faster?

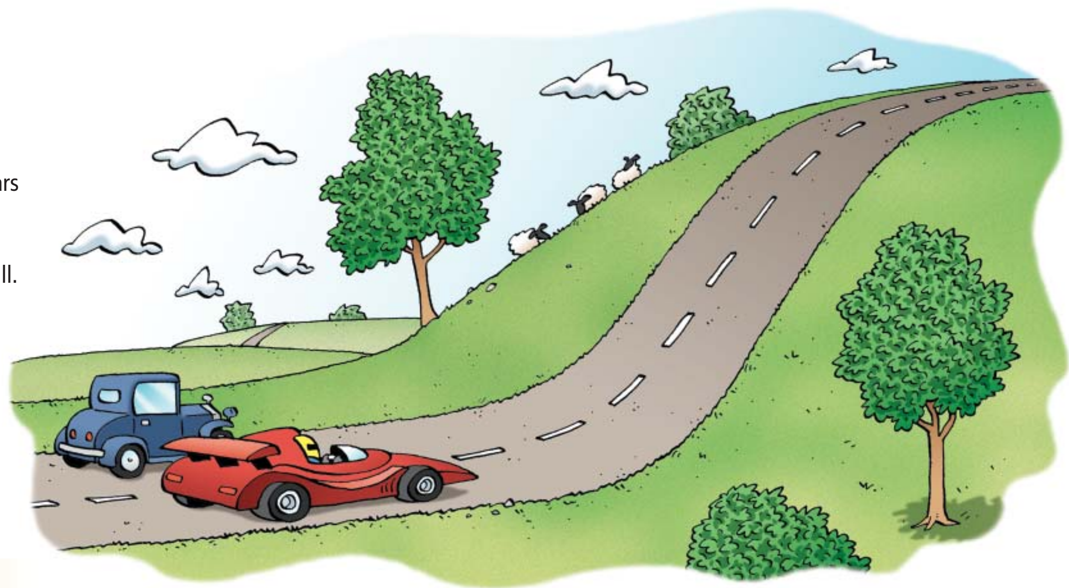


Figure 9.17 Both cars will convert the same amount of energy to reach the top of the hill.

In this section, you will investigate one form of energy, **electrical energy**, and the rate at which it is transferred. Electrical energy, like all other forms of energy, is the ability to do work. In an electric circuit, batteries supply charge with electric potential energy. You can picture this process as the batteries "pushing" the charge "uphill." Once at the top of the "hill," the electrical energy gets transformed into other forms of energy by loads in the circuit such as resistors and light bulbs. A load that can transform the energy quickly is like the race car in the example above.

Did You Know?

The amount of electrical energy used to dry your hair with a hair dryer is the same amount of energy needed to lift an average student 1.5 km into the air.

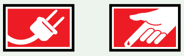
9-2A Energy Transformation in Resistors

Find Out ACTIVITY

Teacher Demonstration

In this teacher demonstration, you will compare the rate of energy transfer for three different resistors.

Safety



- Avoid touching resistors while current passes through them and immediately afterward. They can get hot enough to burn you.
- Do not use the power supply to generate voltages greater than 6.0 V.
- Be careful taping the resistor to the glass bulb of the thermometer.

Materials

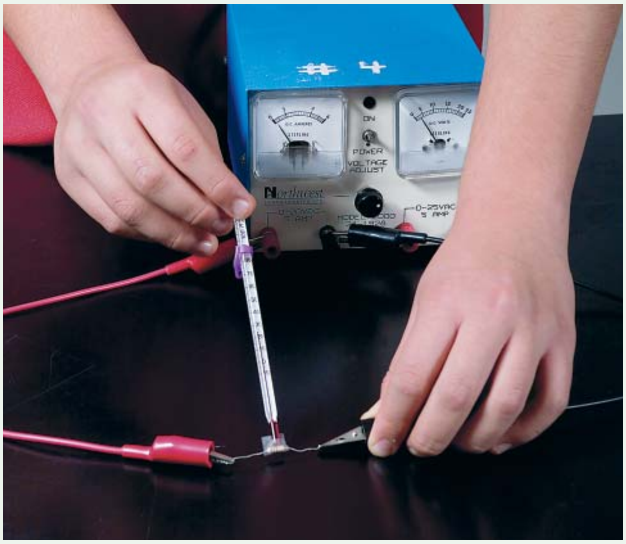
- 3 power supplies
- 3 resistors of different sizes (50 Ω–100 Ω)
- 3 thermometers
- clear adhesive tape
- stopwatch
- connecting wires

What to Do

1. Predict how the size of a resistor affects the amount of heat generated in a circuit. Record your prediction.
2. Copy the following data table in your notebook. Give your data table a title.

	Resistor 1 ______ Ω	Resistor 2 ______ Ω	Resistor 3 ______ Ω
Initial temperature of thermometer (°C)			
Time to increase thermometer temperature by 5.0°C (s)			

3. Using the colour code, determine the resistance of each resistor. Record this value in your data table.
4. Use the adhesive tape to attach each resistor to the bulb of a thermometer. Use one resistor per thermometer, as shown.
5. Note and record the temperature indicated by each thermometer.
6. Connect each resistor to an individual power supply using the connecting wires.
7. Set the power supplies to 6.0 V and start the stopwatch.
8. Record the time for each thermometer to increase its temperature by 5.0°C.
9. Clean up and put away the equipment you have used.



What Did You Find Out?

1. What form of energy is being produced by the resistors?
2. Compare the amount of resistance of the resistors to how quickly each transformed the electrical energy from the power supply.
3. Which of these resistors had the greatest amount of current? Explain your answer.
4. Based on your observations in this experiment, explain the relationship between current and the rate at which energy is transformed by the resistor.

A Matter of Time and Energy

It is obvious that a race car could get to the top of the hill in a much shorter time than an old automobile (Figure 9.18). This is because the race car has more power. **Power** is defined as the rate of change in energy. Power is also the rate at which work is done or energy is transformed. The unit for measuring energy is the **joule** (J), named for the British scientist James Prescott Joule (1818–1889). One joule (J) of energy transformed in one second (s) is called one **watt** (W) of power, in honour of Scottish inventor James Watt (1736–1819).

By the time they reach the top of the hill, both cars have gained the same change in energy since they had the same mass and climbed the same hill. Because the race car could transform its energy faster, it has more power.

Did You Know?

A typical compact fluorescent light (CFL) bulb costs more than an incandescent light bulb, but uses 75% less electrical energy and lasts longer. One CFL bulb can save you several times its cost in electricity.

A 13 W CFL bulb produces as much light as a 60 W incandescent bulb (shown in Figure 9.19).

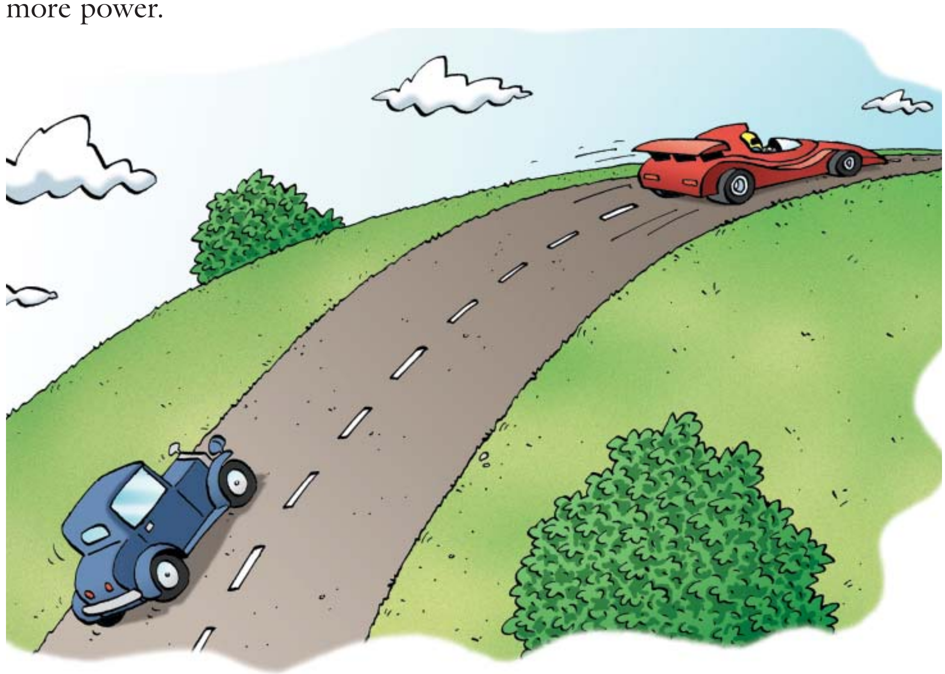


Figure 9.18 The rate of energy transformation is faster in the race car than in the old automobile.

Electrical power is the rate of change in electrical energy. An electrical load changes electrical energy to other forms. The amount of electrical energy changed or transformed on a load per second is the power rating of the load. For example, a 60 W light bulb uses 60 J of electrical energy every second and produces 60 J of heat and light energy (Figure 9.19).

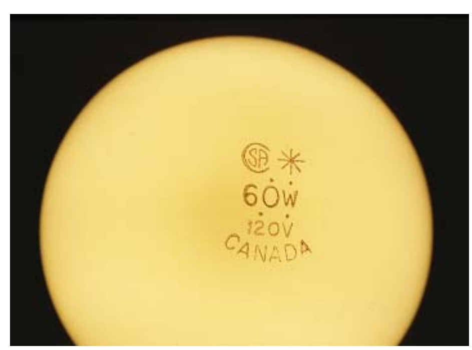


Figure 9.19 A 60 W light bulb converts 60 J of electrical energy into 60 J of light and heat every second.

Energy Consumption

To relate electrical power to energy consumption, it is more common to talk about voltage and current rather than energy and time. Power consumption is directly related to voltage, current, and time. That is, the higher the current and voltage and the longer the device is operated, the greater the power consumption. Batteries and household electricity provide a constant voltage, but each electrical device is designed to operate with a specific current. The current is usually listed on the back of the device (Figure 9.20).

Did You Know?

The Bay d'Espoir Generating Facility is the largest hydroelectric plant on the island of Newfoundland, producing an average of 2657 GWh annually.

Figure 9.20 This portable DVD player has an adapter so that it can be plugged into a wall outlet or operated on battery power. This adapter supplies the device with a voltage of 9.5 V and a current of 2.0 A.

Understanding energy consumption relationships can be very useful, particularly if you are faced with a long road trip and a limited supply of batteries. If a portable DVD player uses 2.2 amperes of current and an MP3 player only uses 1.1 amperes with the same voltage, the MP3 player will be able to provide you with twice as many hours of entertainment on the same number of batteries.

Power Ratings

You may have noticed that many electrical devices are labelled with their power rating (Figure 9.21). A **power rating** is a measurement of how much electrical energy an electrical device consumes for every second it is in use. You may remember that the definition of power is the rate of change in energy. In other words, 1.0 W is the transfer of 1.0 J of energy every second. This means a 1500 W hair dryer uses 1500 J of electrical energy each second.

Figure 9.21 Light bulbs, hair dryers, and kitchen appliances are labelled with their power ratings.

Suggested Activity

Conduct an Investigation 9-2C on page 311

Calculating Energy Consumption

By using the power rating and the amount of time, you can calculate the amount of electrical energy a particular device consumes. Power (P) is defined as energy transferred (E) per time interval (t). Therefore,

$$P = \frac{E}{t}$$

Since $P = \frac{E}{t}$, to get energy, multiply both sides of this equation by t.

$$Pt = \frac{E}{\not{t}}$$ In this equation, the t's cancel.

Therefore the electrical energy consumed can be calculated by

$E = Pt$ where energy (J) = power (W) × time (s)

The following is an example of how you can use this formula to calculate electrical energy consumption.

Read the question:

How much electrical energy is consumed by a 1200 W hair dryer if it is used for 5.0 min?

Science Skills

Go to Science Skill 9 to learn more about using scientific notation, such as 3.6×10^5.

Use the formula:

Before you begin, make sure your time is in seconds.
5.0 min = 5 × 60 s = 300 s.

$$\begin{aligned} E &= Pt \\ &= (1200\ \text{W})(300\ \text{s}) \\ &= 360\ 000\ \text{Ws} \\ &= 3.6 \times 10^5\ \text{J} \end{aligned}$$

State your answer:

A 1200 W hair dryer consumes 3.6×10^5 J of electrical energy if it is used for 5.0 min.

Practice Problems

Try the following energy consumption problems. Show each step in your solution.

1. How much electrical energy is consumed by a 60 W light bulb if it is left on for 25 min?
2. A 1600 W kettle is turned on for 3.0 min. How much electrical energy does the kettle use in this time?
3. How much electrical energy is consumed by a 100 W light bulb left on for 4.0 h?

Answers

1. 9.0×10^4 J
2. 2.9×10^5 J
3. 1.4×10^6 J

A Larger Unit for Energy

As you can see in the example on the previous page, a 1200 W hair dryer used for only 5.0 min consumes 360 000 J of energy. Could you imagine how many joules of electrical energy are consumed by all the electric devices in your home in one day? In terms of electrical energy, the joule is a very small amount.

$$1.0 \text{ joule} = 1.0 \text{ watt} \times 1.0 \text{ second}$$

You can also use a larger unit of electrical energy. To increase this measurement, power is measured in kilowatts (kW) and time is measured in hours (h). There are 1000 W in 1 kW and 3600 s in 1 h. A **kilowatt-hour** (kW·h) is the product of power in kilowatts and time in hours.

$$1.0 \text{ kilowatt-hour} = 1.0 \text{ kilowatt} \times 1.0 \text{ hour}$$

or

$$1.0 \text{ kW·h} = 1.0 \text{ kW} \times 1.0 \text{ h}$$

Energy labels on electric appliances show energy consumption in kilowatt-hours rather than joules.

Did You Know?

Over 75% of the electrical energy produced in Newfoundland and Labrador is exported.

Paying for Electricity

The power company that supplies electricity to your home keeps track of the electrical energy you consume. Your home probably has a meter similar to the one in Figure 9.22 that monitors your energy consumption. Every time you turn on a load, such as a light bulb, current passes through the meter and turns the dials. An employee of the power company visits your home and reads this meter to determine how much energy has been consumed since the last bill. These meters represent the energy consumed in kilowatt-hours. When you receive your electricity bill, you are charged for each kilowatt-hour of electrical energy you have used.

Figure 9.22 The electricity meter in your home may be similar to this one. The middle disk turns, showing the rate at which electrical energy is being used within the home.

For example, suppose a family uses 1500 kW·h of electrical energy in a given month. If the power company charges 10 cents for every kW·h of energy, how much is the electric bill for the month?

$$\text{cost of energy used} = \frac{\$0.10}{1 \text{ kW•h}} \times 1500 \text{ kW·h} = \$150.00$$

The family will owe the electric company $150.00 for the electrical energy it used.

internet connect

To find out more about reading a home electricity meter, go to **www.discoveringscience9.ca**.

9-2B The Cost of Electricity

Think About It

In this activity, you will use the power rating and time of use to calculate the energy consumption and cost of operating specific devices.

What to Do

1. Copy the following data table in your notebook. Give your data table a title.

Appliance	Power (W)	Time of Use Each Day (h)	Energy (kW•h)	Cost (cents)	Cost (dollars)
Television	200	2.0			
Stereo	80	1.5			
Kitchen stove	12 000	2.0			
Microwave	1 400	0.5			
Bedroom light	100	4.0			

2. Calculate the energy consumed, in kilowatt-hours, by each of the appliances. Be sure to change the power in watts to kilowatts.
3. Using the cost of electricity as 9.6 cents per kilowatt-hour, calculate the daily cost of each appliance in cents and in dollars.

What Did You Find Out?

1. Which appliance had the greatest daily cost?
2. Considering all the electrical devices in your home, state which ones you think would have the greatest daily cost.

Explore More

Hydroelectric dams are usually located great distances from the cities and communities they serve. Therefore, electrical energy must be transmitted through many kilometres of power lines. The power company transmits this energy at extremely high voltages. Find out the risks and benefits of transmitting electricity at high voltage. Begin your research at **www.discoveringscience9.ca**.

Electrical Surges

Surges of electric charge are brief increases in voltage to tens of thousands of volts and can occur through household wiring, telephone lines, and coaxial cable. Electrical surges can be caused by lightning, by turning on or off large electrical appliances, or by a local power company transferring large amounts of energy into or out of the power grid. An electrical surge protector absorbs some of the electrical surge and then diverts the rest to the ground (Figure 9.23).

Figure 9.23 An electrical surge protector

Reading Check

1. Define power.
2. How are power (P), voltage (V), and current (I) related?
3. What does a power rating of 40 W mean in terms of energy and time?
4. What is the formula that relates energy consumption (E) to power (P) and time (t)?
5. What unit of energy is commonly used when dealing with large quantities of energy?

9-2C A Current View of Power

Conduct an INVESTIGATION

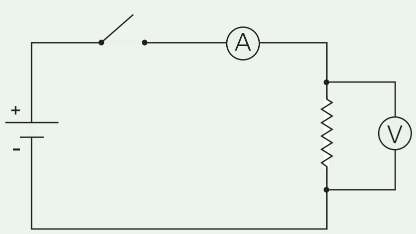
Inquiry Focus

SkillCheck
- Predicting
- Measuring
- Controlling variables
- Evaluating information

Safety

- If any of the resistors or wires become hot, open the switch immediately.

Materials
- 3 resistors of different sizes (100 Ω–1000 Ω)
- 1.5 V cell
- ammeter
- voltmeter
- switch
- connecting wires



Science Skills
Go to Science Skill 7 to learn more about using an ammeter and a voltmeter.

The light bulbs you use in your home are resistors that change electrical energy into both heat and light energy. A 60 W light bulb has a different resistance than a 100 W light bulb. In this activity, you will measure the voltage and current of a circuit in order to calculate the power of different resistors.

Question
What is the relationship of resistance, current, and power?

Procedure

Part 1 Measuring Voltage and Current
1. Copy the following data table in your notebook. Give your data table a title.

Resistance (Ω)	Voltage (V)	Current (A)	Power (W)
1			
2			
3			

2. Using the colour code, determine the value of each resistor. Record these values in your data table.
3. Using one resistor, set up the circuit shown in the diagram.
4. Close the switch and measure the current and voltage for your first resistor. Record these values in your data table. If your ammeter is measuring in milliamperes, be sure to convert the current to amperes.
5. Open the switch, and replace resistor 1 with resistor 2. Repeat step 4.
6. Open the switch, and replace resistor 2 with your final resistor. Repeat step 4.
7. Clean up and put away the equipment you have used.

Part 2 Calculating Power
8. You can calculate the power of an electrical device by multiplying voltage and current. In other words, electrical power (P) is the product of voltage (V) and current (I): $P = VI$. Using the equation $P = VI$, calculate the power for each resistor.

Analyze
1. Compare the voltage across each of your three resistors.
2. Compare the current through each resistor.
3. Which resistor had the greatest power?
4. In one or two sentences, relate power, resistance, and current.

Conclude and Apply
1. Given what you have learned in this investigation, would a 60 W or 100 W light bulb have more resistance? Explain your answer.

Career Connect

Industrial Electrician

The opportunity to work on a variety of different projects and equipment is the most rewarding part of Tim Sacrey's job as an industrial electrician. Tim knows he will learn something new each day he goes to work at the Churchill Falls Generating Station. The station is one of the world's largest underground power stations. It has a generating capacity of 5428 megawatts of electricity.

Q. How is an industrial electrician different from other types of electricians?

A. When most people think of an electrician, they think of a construction or residential electrician who installs lights, receptacles, and other devices in houses or other buildings. Industrial electricians are different. We work in an industrial environment such as a factory, a mine, or, in my case, an electrical utility company. We do install new electrical equipment, but we also maintain, repair, and troubleshoot this equipment once it is in service.

Q. What is a typical job for an industrial electrician?

A. The kinds of jobs I work on vary from day to day. Some of our jobs are big projects that take weeks to complete; others take only a few hours. Often I am troubleshooting electrical control circuits if a pump, motor, or generator will not start. We also maintain and repair all the heating and lighting for the buildings on our site. Sometimes I make sure it is safe for workers in other trades to work on a piece of equipment. This involves using my voltmeter to make sure there is no voltage on the equipment that could result in an electrical shock.

Q. What training did you need to become an electrician?

A. To become an electrician, I first had to complete a nine-month pre-employment course. This is when you learn about safety and the basics of electrical theory. When I completed the pre-employment course, I was registered as an electrical apprentice and went to work to gain experience as an electrician and learn the trade from more experienced electricians. After every year of work, I returned to school to complete an eight-week block of training. I completed three of these blocks and then wrote the inter-provincial journeyman exam, which I had to pass to become a qualified journeyman electrician.

Q. What is the most challenging part of your job?

A. The most challenging part of my job is keeping up with the ever-changing technology. Every day, new equipment is being developed and installed and it is up to workers like me to learn how the new equipment works and how to repair and maintain it.

Q. What do you need to know about circuits, current, and voltage to do your job?

A. Most of the work I do is based on the theory of circuits, current, and voltage. When an electrical device or piece of equipment isn't working properly, I use my electrical multimeter to test the control circuit for voltage and current, and this helps me find the problem. This is what we call troubleshooting the circuit.

Tim Sacrey

Questions

1. How is an industrial electrician different from a residential electrician?
2. How does an industrial electrician help keep other workers safe?
3. What training do you need to become an electrician?

Checking Concepts

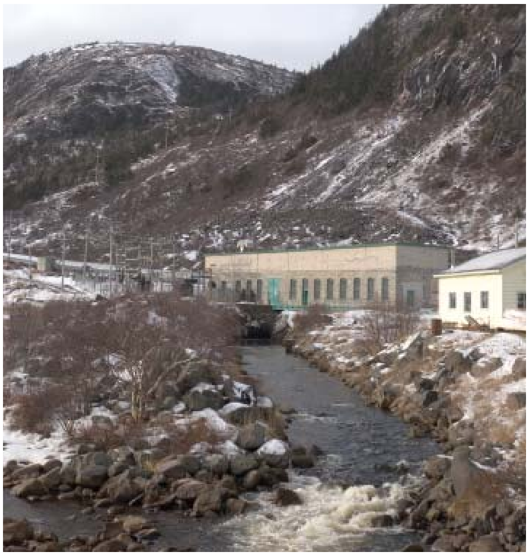
1. What is electrical energy?
2. What do we call the rate at which energy is transformed?
3. State one unit for energy and one unit for power.
4. What is another name for joules per second?
5. In which unit are large amounts of electrical energy measured?
6. How many joules is 1 kW•h equal to?
7. What three factors determine electrical energy consumption?

Understanding Key Ideas

8. Two identical batteries are connected to different circuits. Explain how it is possible for the batteries to supply different amounts of power.
9. How much electrical energy, in joules, does a 40 W light bulb consume in 15 min?
10. (a) A 1600 W hair dryer is used for 15 min. How much electrical energy, in kW•h, did the hair dryer consume during this time?
    (b) If the cost of electricity is 9.6 cents/kW•h, how much did it cost to use the hair dryer?
11. In a set amount of time, a battery supplies 25 J of energy to an electric circuit that includes two different loads. One of the loads produces 10 J of heat energy during this time interval. How much heat energy is produced by the second load in this time? Explain your answer.

Pause and Reflect

Throughout Newfoundland and Labrador, there are stations where electrical energy is generated from other forms of energy such as at the Petty Harbour Hydroelectric Generating Station on the eastern coast of the island of Newfoundland and the Holyrood Thermal Electric Generating Station in Conception Bay. Why are such stations often referred to as *power* stations?



9.3 Electrical Energy in the Home

Electrical energy is converted into sound, light, and heat by electrical devices in your home. Not all of the electrical energy is converted into a useful form. The percentage of energy converted into a useful form compared to the total amount of energy consumed is called efficiency. Efficiency can be calculated by dividing the useful energy output by the total energy input and multiplying by 100 to convert efficiency to a percentage. Electrical energy can be conserved by turning off devices when they are not in use, changing the way things are done to use less electrical energy, and choosing more energy efficient devices.

Key Terms

efficiency
EnerGuide

Figure 9.24 All three devices will be able to reheat your lunch. Which would you choose?

When it comes to reheating your lunch, which device would you choose (Figure 9.24)? All of the electrical devices shown will be able to do the job, but which is the most practical? An oven takes a long time to heat up, yet it could warm up not only your lunch, but enough to feed your entire family. The microwave oven will be able to reheat your lunch the fastest, but it can only heat one lunch at a time. What about a lamp? It's not designed to reheat a lunch, but it can be done—early models of the Easy Bake™ Oven toy used a 100 W light bulb to bake small cakes. How could you choose which device to use?

In this section, you will investigate energy efficiency; that is, how much of the energy consumed is converted into a useful form. Once you have a better understanding of efficiency and energy conversions, you can make more informed choices about how you use electrical energy and steps you can take to conserve it.

Did You Know?

The amount of energy a person uses on a low-activity 24 h day is about the same as the energy that a 100 W light bulb uses when it is on for 24 h. People, of course, obtain their energy from food.

9-3A Putting Energy Conversions to Good Use

Find Out ACTIVITY

Teacher Demonstration

In this activity, you will investigate electrical energy conversions to determine which conversions are "useful."

Safety

- Avoid touching the light bulb, as it will become hot.

Materials

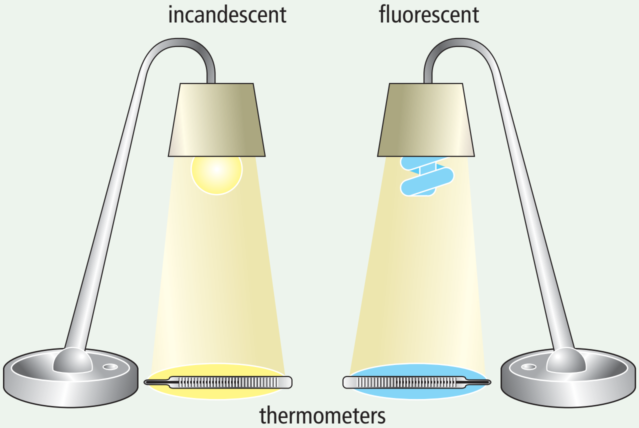
- incandescent light bulb (60 W)
- compact fluorescent light bulb (13 W)
- 2 desktop lamps
- 2 thermometers
- ruler

What to Do

1. Copy the following data table in your notebook. Give your data table a title.

	Incandescent Light Bulb	Compact Fluorescent Light Bulb
Power Rating		
Initial Temperature (°C)		
Final Temperature (°C)		
Brightness		

2. Set up the apparatus as shown. Secure each thermometer in place on your working surface with a small piece of tape. The two light bulbs must both be 10 cm away from the thermometers.



3. Record the initial temperature on the two thermometers.
4. Turn on both lights.
5. Record your observations about the brightness of the bulbs.
6. After 10 minutes, turn off the lights and record the final temperatures.

What Did You Find Out?

1. Describe the energy conversions that are taking place in the light bulbs.
2. From your observations, which of the two light bulbs
   (a) uses less energy per second?
   (b) produces more light?
   (c) produces more heat?
3. What is the relationship between energy, heat, and light for each of the bulbs? Why do you think this is the case?

Energy Conversions

Electrical energy can be converted into a number of different forms, including light, heat, and sound. An electric lawnmower converts electrical energy into mechanical energy, heat, and sound (Figure 9.25). How much of the electrical energy provided to the lawnmower is converted into useful energy and how much is wasted? Since a lawnmower is designed to cut the grass, the only energy output considered "useful" is the mechanical energy turning the mower blades. The heat and sound are both considered "waste."

Figure 9.25 A lawnmower converts electrical energy into mechanical energy, heat, and sound.

Energy Efficiency

Efficiency is the percentage of energy input that is converted to a useful form. If electrical devices were perfect, all of the electric energy they took in (input energy) would be converted into useful output energy. No real device, however, is a perfectly efficient energy converter. Some input energy is always converted into waste heat. As you discovered in Find Out Activity 9-3A, different types of electrical lighting provide a good example of differences in efficiency.

Electrical lighting in many homes is still largely provided by incandescent light bulbs (Figure 9.26A). As current passes through a thin metal wire, or filament, coiled inside the bulb, the filament becomes so hot that it glows. Incandescent bulbs are only about five percent efficient at converting electrical energy to light. That is, about 95 percent of the input energy is converted to waste heat. Although incandescent bulbs are much less expensive to purchase than the more energy-efficient alternatives, they do not last as long.

Halogen bulbs (Figure 9.26B) are filled with a high-pressure gas containing traces of iodine, which helps preserve their filaments. These bulbs operate at very high temperatures, but their filaments glow brighter and last longer than those of traditional bulbs. Although halogen bulbs are about 15 percent efficient, they still waste a large amount of energy as heat and can be a fire hazard. Halogen bulbs last two to six times longer than traditional incandescent bulbs. They are best used in situations where bright, focused light is needed such as in headlights or spotlights.

At present, the most common replacement for the incandescent light bulb is a compact fluorescent light bulb (CFL) (Figure 9.26C). CFLs were developed from the more traditional fluorescent tubes that you see mounted on the ceilings in a school or office building (Figure 9.26D). CFLs and fluorescent tubes contain a gas such as mercury vapour. When current passes through the vapour, it emits energy that affects a white material on the inside of the glass, causing it to glow. They operate at relatively low temperatures, so they waste very little energy as heat. CFLs are more expensive than incandescent bulbs, but they last much longer and are three to four times more efficient at generating light. Over time, a CFL is less expensive than a traditional incandescent light bulb that produces the same intensity of light. One disadvantage of CFLs is that they contain a small amount of mercury, which is highly toxic, so these bulbs must be disposed of properly. Some retailers are now accepting used CFLs for recycling.

Light emitting diodes (LEDs) (Figure 9.26E) have long been used to produce the numbers on digital displays. More recently, they have been put to use in traffic lights and holiday lights, but researchers are still working on producing LEDs that will be able to provide room lighting. LEDs are constructed from semiconductor chips similar to those used in computers. They do not need a filament or a glass bulb, and do not get hot during operation. A whole string of LED lights consumes the same amount of energy as a single bulb in a similar string of incandescent bulbs.

Did You Know?

When most people are buying light bulbs, they think of "watts" as a measure of brightness. But a watt is a measure of power, not brightness. Light output is measured in "lumens." A 60 W incandescent light bulb and a 13 W CFL both produce about 860 lumens of light.

Figure 9.26 Replacing incandescent light bulbs (A) with more efficient alternatives such as halogen bulbs (B), compact fluorescent bulbs (C), traditional fluorescent bulbs (D), or light emitting diodes (E) can significantly reduce energy requirements and operating costs for electrical lighting.

Reading Check

1. List three forms of energy that result from the conversion of electrical energy.
2. Define efficiency.
3. What is the difference between "useful" energy and "waste" energy?
4. List four different light bulb technologies. Which is the most energy efficient? Which is the most common?

Calculating Efficiency

Efficiency can be expressed quantitatively by using the following mathematical relationship.

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

Read the question:

How efficient is an incandescent light bulb if it uses 6.48×10^5 J to provide 3.39×10^4 J of light energy?

Use the formula:

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

$$= \frac{3.39 \times 10^4 \text{ J}}{6.48 \times 10^5 \text{ J}} \times 100\%$$

$$= 5.23\%$$

State your answer:

The light bulb is 5.23% efficient.

Practice Problems

Try the following efficiency problems. Show each step of your solution.

1. A kettle used 198 kJ of electrical energy to boil 500 mL of water. If 168 kJ were used in boiling the water, what is the efficiency of the kettle?
2. A microwave oven was used to heat the same quantity of water as in question #1. The microwave used 336 kJ of electrical energy to boil the water. Calculate the microwave's efficiency.
3. A stove-top element is determined to be 21.0% efficient. How much electrical energy would be used (energy input) to boil 500 mL of water?

Answers

1. 84.8%
2. 50.0%
3. 800 kJ

Calculating Energy Input or Output

To find the efficiency of electrical devices, it is often necessary to calculate energy inputs or outputs. On page 308, you learned the formula for power $\left(P = \frac{E}{t}\right)$. To determine the electrical energy input of a device, this formula can be manipulated to solve for energy.

Read the question:

A 1000 W electric kettle takes 4.00 min to boil some water. If it takes 1.96×10^5 J (196 000 J) of energy to heat the water, what is the efficiency of the kettle?

Use the formula:

Before you begin, make sure your time is in seconds.

4.00 min = 4 × 60 s = 240 s

Calculate the energy input.

$$\begin{aligned} E &= Pt \\ &= (1000\ \text{W})(240\ \text{s}) \\ &= 240\ 000\ \text{J} \end{aligned}$$

$$\begin{aligned} \text{efficiency} &= \frac{\text{useful energy output}}{\text{total energy input}} \times 100\% \\ &= \frac{196\ 000\ \text{J}}{240\ 000\ \text{J}} \\ &= 81.7\% \end{aligned}$$

State your answer:

The kettle is 81.7% efficient.

Practice Problems

Try the following efficiency problems. Show each step of your solution.

1. An older model Easy Bake™ Oven uses a 100 W light bulb to bake small cakes. If it takes 15 minutes to bake a cake, which requires 45 000 J of energy to bake, what is the heating efficiency of the light bulb? Where does the "wasted energy" go?
2. Determine the efficiency of an electric beverage warmer if it uses 100 W of power over a one hour period to provide enough energy to keep your hot chocolate warm (72 000 J).
3. How efficient is a coffee maker if it takes 5 minutes and 1000 W of power to make a pot of coffee, using 28 000 J of electrical energy to heat the water?

Answers

1. 50%
2. 20%
3. 9.3%

Explore More

The electrical devices in your home have two costs. The first is the purchase price, and the second is the cost of operating them. Over the lifetime of an electrical appliance, the cost of operating it is usually larger than the cost of buying it. Find out more about calculating the "second price tag." Begin your research at **www.discoveringscience9.ca**

Making Energy-Conscious Choices

Now that you know more about efficiency and electrical energy conversions, you are better able to make energy-conscious choices when buying new appliances or electronic devices. Most people, though, have very little idea of how much energy a particular appliance uses in their home, and how much (or how little) of the energy consumed is actually converted into a usable form. In Canada, all major appliances and room air conditioners must meet minimum efficiency standards and must display an **EnerGuide label** (Figure 9.27).

Figure 9.27 An EnerGuide label details how much energy an appliance uses in a year and compares its energy consumption with other appliances in the same category. An indicator arrow on the left side of the EnerGuide scale means a more energy-efficient model.

An EnerGuide label tells you how much energy an appliance uses in a typical year of use. Consumers should use the EnerGuide label to help them make an informed choice when they purchase an appliance. Products that use 10 to 50 percent less energy compared with a standard product in the same category earn an Energy Star rating (Figure 9.28).

Figure 9.28 The Energy Star® logo is found on only the most energy-efficient devices in a category. Unlike the EnerGuide label, Energy Star® logos may be found on office equipment, consumer electronics, windows, and lighting, in addition to appliances and air conditioning units.

Doing Your Part

Choosing energy-efficient devices will definitely decrease the amount of electrical energy you and your family consume. But far more important than simply using different appliances is taking a closer look at your home and your energy consumption habits. Small improvements and changes in behaviour can lead to significant energy savings over the long term.

On average, 60 percent of Canadians' total energy cost is spent on heating and cooling their homes. How can that be reduced? Figure 9.29 illustrates the most common sources of air leaking into and out of a house. On a cold day, if you open your clothes dryer door, you'll quickly feel how much air is moving in and out of the house from the dryer vent alone! By improving the home's overall insulation and by sealing windows, doors, and air ducts, it is estimated that the average homeowner could save 20 percent on overall heating costs. Other ways to decrease heating costs include installing a programmable thermostat with a built-in timer to lower the heat at night or when you are away, and of course, to put on a sweater instead of turning up the thermostat!

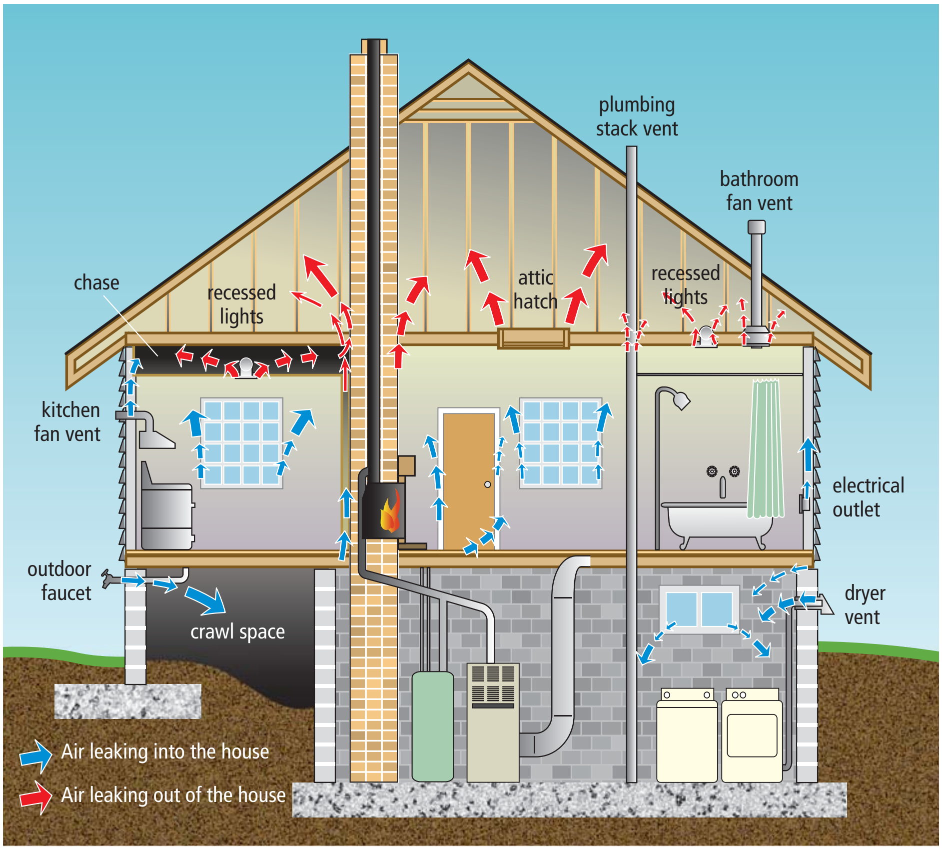


Figure 9.29 Holes hidden in attics, crawlspaces, and basements can be sealed with caulking, spray foam, or weather stripping to reduce heat loss.

Did You Know?

Less energy is consumed when a light is turned on and off than when it is left on all the time. This is also true for electronics and computer equipment. Enable your computer's energy-savings features, and shut down instead of choosing "sleep mode." Some electronics, including televisions, continue to use electricity even when they are turned off.

Other behaviours that can reduce electrical energy consumption include limiting the use of electrical appliances. For example, you could air dry your clothes when the weather is suitable. During the winter, when the clothes dryer must be used, sort loads into heavy, medium, and lightweight items, since lightweight items will dry faster. Do consecutive loads since the dryer will already be warm, and don't forget to clean the lint filter. A clogged lint filter not only is a fire hazard, but can increase energy use by up to 30 percent.

Reading Check

1. What is the formula for efficiency?
2. How could you find out how much energy is used by an appliance in your home?
3. What are three sources of heat loss in a house?
4. How can sorting your laundry help to conserve energy?

Conserving Electricity

Turning out the lights is an important way to conserve energy at home, but there are many more ways. Find as many as you can.

What to Do

1. Research ways of conserving electrical energy at home. You can check the Internet, obtain literature from your local power company, or use the library. Find ways to conserve electrical energy that involve each of the following categories:
   (a) cooking
   (b) laundry
   (c) refrigerator or freezer
   (d) water heater
   (e) crafts and recreation
2. Bring your lists to class and combine all lists.

What Did You Find Out?

1. How many means of conservation did your class find to save electrical energy at home?
2. Which do you think will have the biggest impact?

Extension

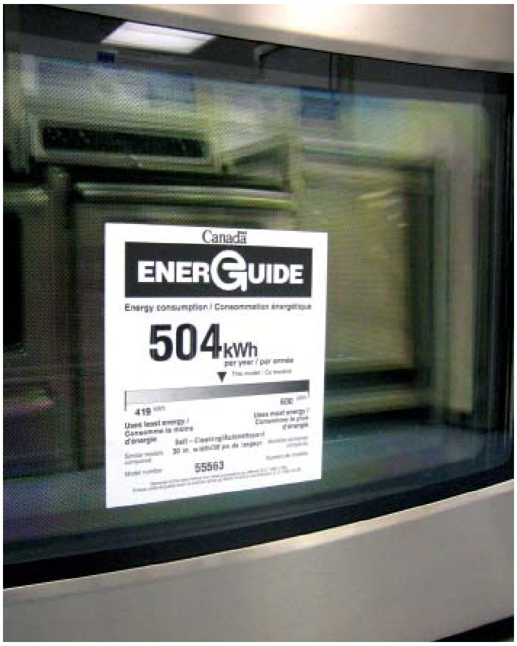
Most major power companies offer electric power-consumption calculation tools on their Internet sites to help you find out where your family's power consumption dollars are going. Many power company sites also offer energy conservation suggestions. Find out more about saving money by conserving energy. Begin your research at **www.discoveringscience9.ca**

Checking Concepts

1. List the energy conversions that take place when an incandescent light bulb is lit.
2. What is efficiency? How is it calculated?
3. What information does an EnerGuide label contain?
4. What does having an Energy Star® logo mean?
5. Which light bulb technology involves heating a wire filament hot enough to make it glow?
6. What is the environmental drawback of using CFLs?

Understanding Key Ideas

7. A clothes dryer converts electrical energy to a number of different energy types. Which are useful, and which would be considered waste? Explain.
8. List three forms of energy that can be produced from the conversion of electrical energy. Include an example of a device that uses this form of energy.
9. For each of incandescent, halogen, compact fluorescent, and light emitting diode technology, provide a positive and a negative point about its use.
10. Calculate the efficiency of an electric hair dryer if it uses 47 500 J to produce 22 000 J of useful heat.
11. A 100 W incandescent light bulb produces 2.45×10^4 J of useful light energy over a 3.0 h period. What is the efficiency of the light bulb?
12. Given the EnerGuide label for the electric stove below, describe how its energy efficiency compares to other stoves.



13. There are a number of home improvements and behavioural changes that can help conserve electrical energy. For each of the following household tasks, list one home improvement and one behavioural change that could be made to save energy:
(a) washing and drying clothes
(b) bathing/showering
(c) home lighting
(d) recreation (watching television, playing computer games)

Pause and Reflect

You've learned a lot about energy efficiency and making wise decisions about energy use and conservation. What else could you do to make a difference in your community? How could you and some of your classmates help your school save energy and save money?

9.4 Electricity and the Environment

Most of the electrical energy in Canada is produced by converting mechanical energy into electrical energy at a generating station. The mechanical energy of moving water, wind, or steam is used to turn a turbine; the turbine is connected to an electrical generator, which creates electric current by rotating a wire conductor within a magnet. Electrical energy is transmitted at high voltage and low current over transmission wires and is converted to household voltages at transformers. Electrical energy may be generated using a variety of natural resources, depending on availability, properties, and both economic and environmental costs.

Key Terms

fuel cell
generator
hydroelectric
non-renewable
nuclear energy
renewable
thermal energy
transformer
turbine

Imagine depending on battery-powered flashlights to light a sports field for a night game (Figure 9.30). Not likely? Batteries are fine for portable power, but they cannot supply the quantities of electrical energy required for outdoor lighting equipment, heavy appliances, and large industrial machinery.

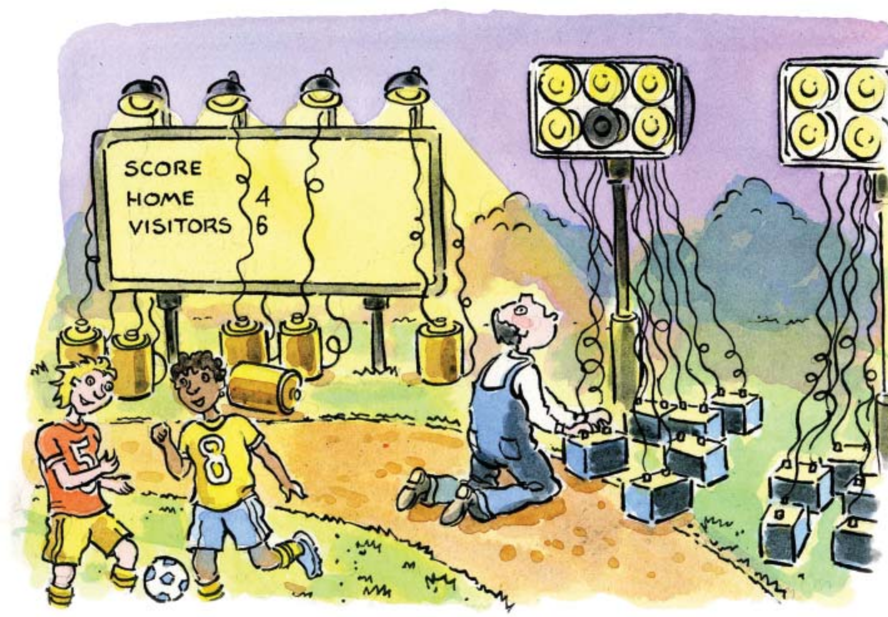


Figure 9.30 Cells and batteries are a reasonable solution for portable electrical energy, but are not practical for some uses.

Most of Canada's electrical energy comes from the conversion of mechanical energy. Mechanical energy is associated with any system with moving parts—for example, a rotating windmill, moving waters of rivers or tides, or the moving steam generated in thermal, nuclear, or geothermal power plants. A device that converts mechanical energy into electrical energy is called a **generator**. The operation of a generator depends on the fact that electricity and magnetism are related.

9-4A Generating an Electric Current

Find Out ACTIVITY

Using a magnet and a coil of wire to produce an electric current is the basic principle of electric generators. In this activity, you will build a simple generator and investigate the factors that affect the current produced.

Materials

- 5 m insulated copper wire (about 26 gauge)
- cardboard tube
- galvanometer or ammeter
- powerful bar magnet

What to Do

1. Make a table with two columns: "Description of Magnet or Coil Movement" and "Ammeter Reading". Give your table a title.
2. Leaving about 15 cm for a lead at the end of the wire, make a coil of about 25 turns by wrapping the wire around the cardboard tube. Remove the tube from the coil.
3. Strip the insulation off each end of the wire, and connect the wire to the ammeter.
4. While closely monitoring the meter, insert one end of the bar magnet into the coil of wire and then pull it out. Record any movement on the meter needle that you observe.
5. Next, record the effect on the meter needle when you
   (a) vary the speed with which you move the magnet inside the coil of wire.
   (b) vary the speed with which you move the magnet over the outside of the coil.
   (c) move the coil over the magnet while the magnet remains still.
   (d) move the magnet outside the coil in different directions (e.g., parallel to the coil, perpendicular to the coil).

What Did You Find Out

1. Describe how electricity and magnetism are related.
2. How does the magnet's speed affect the electric current produced?
3. How does the position of the coil or magnet affect the electric current produced?
4. What combination of conditions generates the largest current?

Magnetism to Electricity

Experiments such as the one you have just done show that electric currents can be produced using a magnet. Michael Faraday and John Henry made this discovery in 1831. Working independently, they found that a voltage developed in wires that were moved at an angle to a nearby magnet. The same thing happened when the magnet moved at an angle to a stationary wire. If the motion stopped, or if the magnet and wire moved parallel to each other, no voltage developed. Faraday and Henry extended their experiments by connecting the wire to a load. Now an electric current flowed in the circuit, but only as long as either the wire, or the magnet, or both were moving (Figure 9.31).

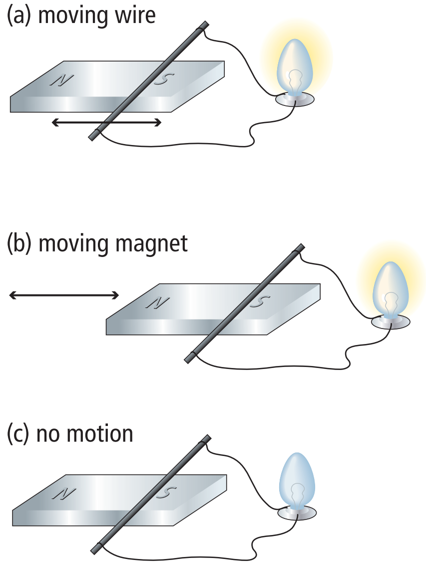


Figure 9.31 If either the wire (a) or the magnet (b) is moved, current flows through the circuit connected to the wire. If both the wire and the magnet are stationary, no current flows (c).

Today, we say that a voltage is "induced" in a wire when there is relative motion between the wire and a nearby magnet. When the wire is connected to an electric circuit, an "induced current" flows. This connection between magnetism and electricity was used to develop generators and other electrical technology long before scientific theories were developed to explain the relationship.

What's in a Generator?

A common form of generator has a coil of wire that rotates inside a stationary field magnet (Figure 9.32). Electric current produced by this type of generator is called alternating current (AC) because it changes direction, or alternates. Cells and batteries produce direct current (DC), in which electrons travel in only one direction.

Did You Know?

Generators that produce alternating current are also called "alternators." Car electrical systems use an alternator to generate AC for the motor's ignition system and to provide electrical energy for a car's accessories, including the stereo and heating fans.

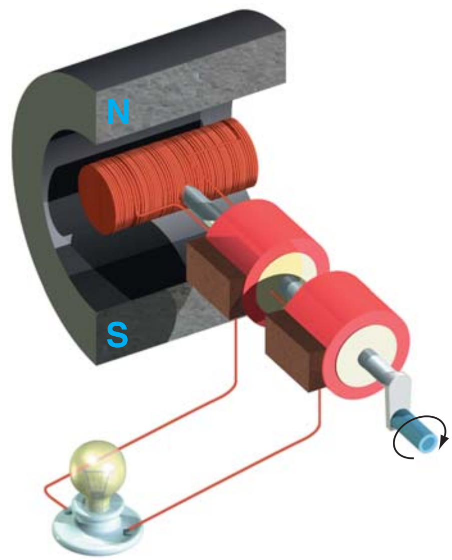


Figure 9.32 In this generator, electric current is produced when a coil of wire is rotated inside a magnet.

Generating and Transmitting Electrical Energy

To produce electric current using a generator, some form of energy input is required to turn the coil of wire within the magnet. In Canada, that energy is often supplied by the mechanical energy of steam or falling water. The steam or falling water moves over a **turbine**, a cylinder outfitted with paddles or blades (Figure 9.33). As the steam or water pushes the blades, the cylinder turns, moving the coil of wire within the magnet of a generator.

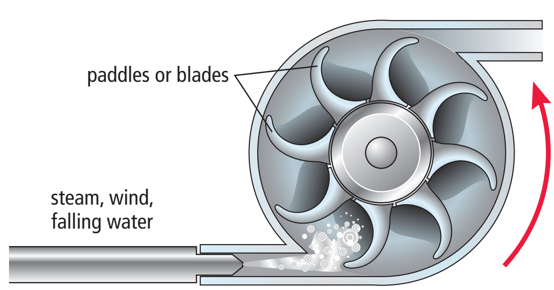
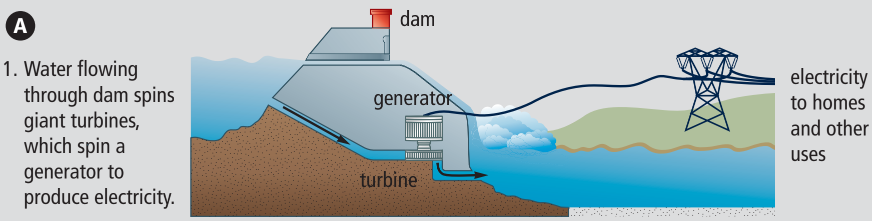


Figure 9.33 The turbine rotates as a result of moving steam, wind, or water, which in turn moves the coil of wire within the magnet of the generator, creating an electric current.

Three types of generating stations in which mechanical energy is used to generate electrical energy are shown in Figure 9.34.

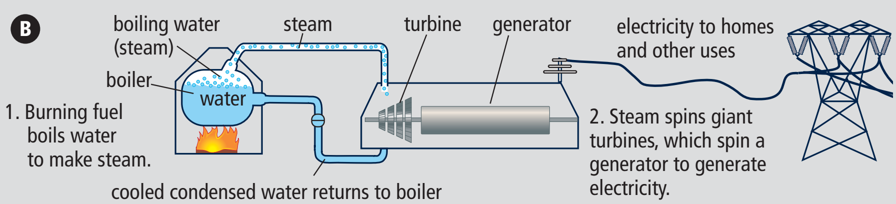
- **hydroelectric** – uses the energy of falling or flowing water to spin a turbine
- **thermal energy** – uses the heat produced from the burning of fossil fuels, including coal, gas, and diesel, to boil water. The resulting steam is used to spin a turbine.
- **nuclear energy** – uses the heat released from a nuclear reaction to boil water. The resulting steam is used to spin a turbine.

Hydroelectric generating station



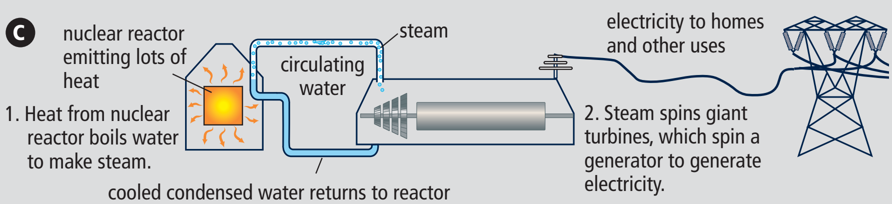
Advantage: once constructed, very little maintenance and no greenhouse gas emissions
Disadvantage: requires significant construction and may damage surrounding ecosystems

Thermal generating station



Advantage: infrastructure is in place to provide fuel for thermal plants
Disadvantage: produces greenhouse gas emissions

Nuclear generating station



Advantage: no greenhouse gas emissions
Disadvantage: spent fuel rods remain radioactive for thousands of years

Figure 9.34 All three generating stations use turbines and generators to produce electrical energy. The only difference is the source of mechanical energy.

Before leaving the generating station, **transformers** are used to "step up" the voltage. A transformer is a simple electrical device that changes voltage. You learned in Section 9.2 that electrical power (P) is directly related to both voltage (V) and current (I). When there is a constant level of power, increasing, or "stepping up," the voltage at the generating station will cause a decrease in the current. Some power is always lost due to resistance in the wire, but this can be minimized by transmitting the electricity at a low current.

Did You Know?

You learned on page 311 that the equation for power is $P = IV$. You also learned on page 273 that voltage, current, and resistance are related according to the equation $V = IR$. If you substitute the second equation in place of V in the first equation, you get $P = I^2R$. This equation calculates power loss due to resistance. By increasing the voltage and reducing the current, the power loss due to resistance is decreased.

Electrical energy is generated at 20 000 V or less, and transformers are used to increase the voltage to up to 500 kV (500 000 V) before it is fed to transmission lines which may carry electrical energy to customers hundreds of kilometres away (Figure 9.35).

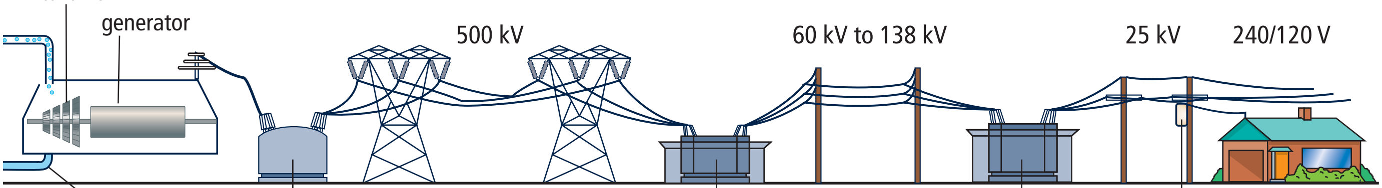


Figure 9.35 Turbines and generators at the generating station produce electrical energy. The voltage is stepped up at the generating station using transformers. Close to the customer, transformers at sub-stations, distribution stations, and in local neighbourhoods step the voltage down.

On the outskirts of a city or town you may see a large substation, with smaller substations located closer to homes, offices, and factories. Each substation uses transformers, called step-down transformers, to reduce voltage. From the substation, electricity is distributed to smaller groups of users. On your street, the final step-down transformer is a green box or a pole transformer, which reduces the voltage to 120 V and 240 V for household use (Figure 9.36).

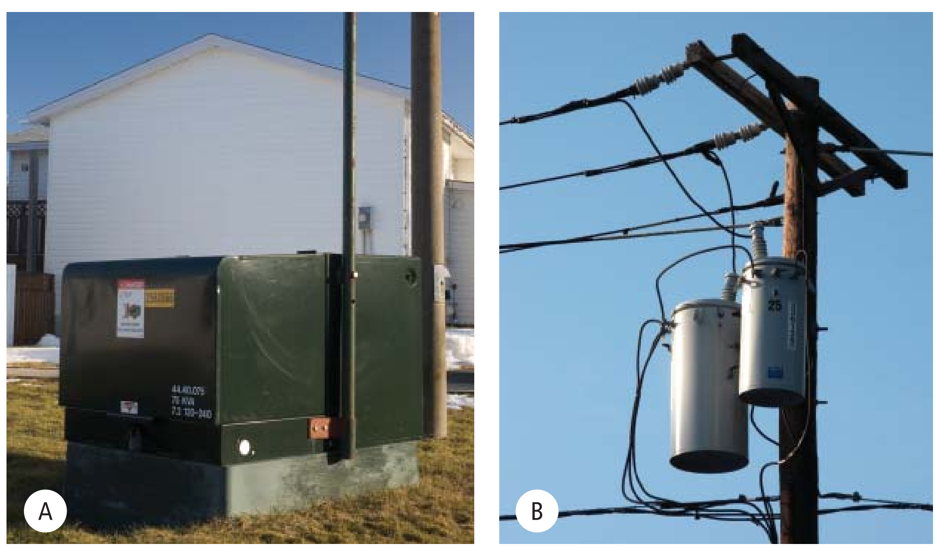


Figure 9.36 Transformers step down the voltage before a line is connected to the meter at your home. Transformers are located either inside a green box (A), or on the power pole (B).

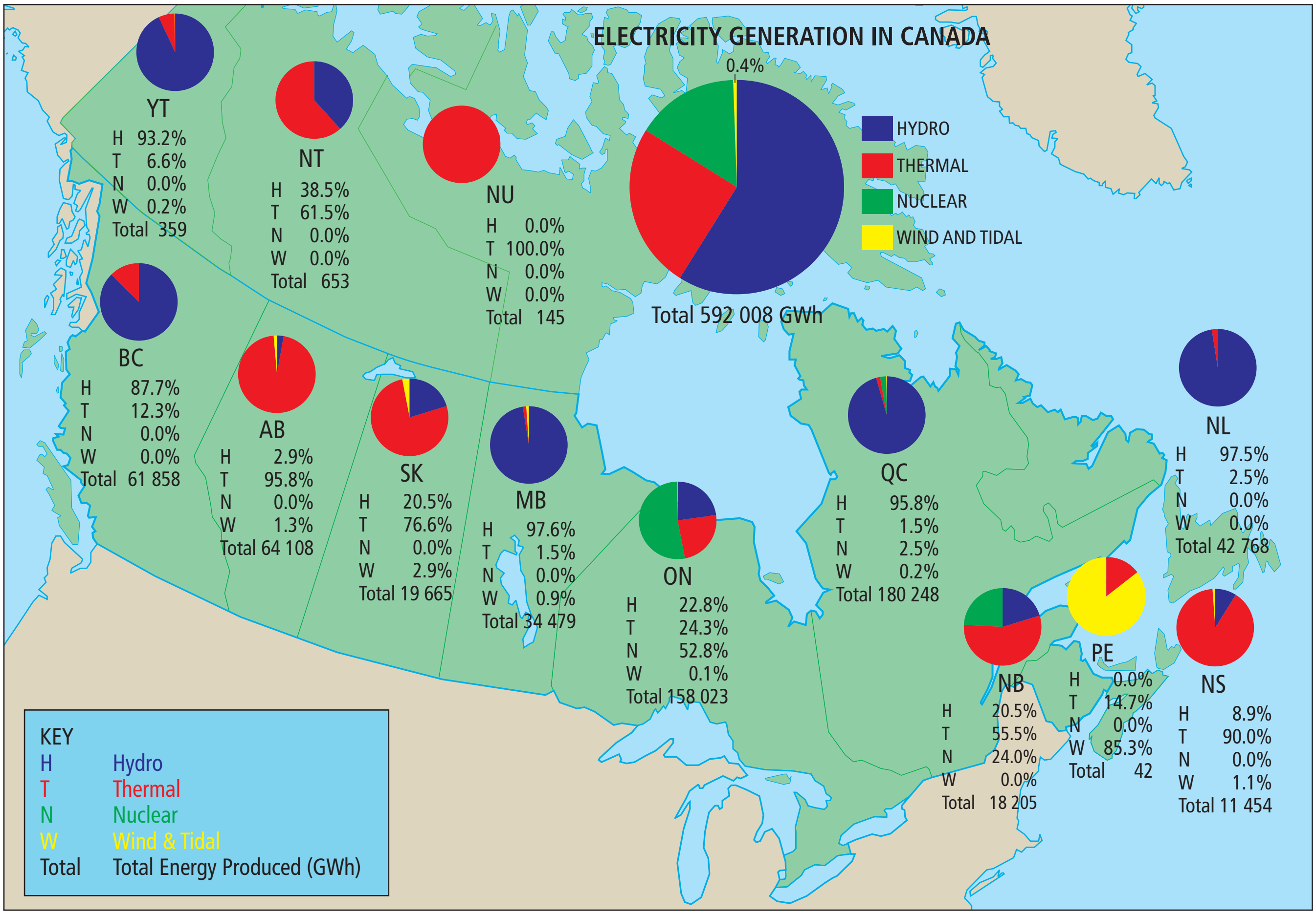
Reading Check

1. How are electricity and magnetism related?
2. How does a generator work?
3. List three types of electrical generating stations.
4. What is a transformer, and where could it be used?
5. Why is electrical energy transmitted at high voltage and low current?

Electricity Production and the Environment

Over 98 percent of Canada's electrical energy is produced by hydroelectric, thermal (using coal, natural gas, or heavy fuel oils), or nuclear generating plants. In some remote areas, gasoline-powered generators or gasoline turbines produce electrical energy. In addition to these more conventional methods of generating electrical energy, wind and tidal generating plants are now becoming more common. The map below shows the amount of electrical energy produced by the different methods in each of the provinces (Figure 9.37).

Note that in 2006, the most recent year for which statistics are available from Statistics Canada, Newfoundland and Labrador produced 390 kW of electricity through wind power. However, when converted to a percentage of the total electricity produced in the province, wind energy production is reported as 0.0%. While this province has the highest potential for wind energy production in Canada, the greatest hurdle is the cost associated with developing and exporting the electricity produced. Numerous pilot projects and test sites have been established since 2006 and the province continues to investigate how best to capitalize on this renewable resource.



Source: Statistics Canada *Electric Power Generation, Transmission and Distribution–2006* (11-12)

Figure 9.37 The percentage of energy generated for each province by source, and the total amount of electrical energy produced. The annual values for the amount of electrical energy produced is given in GW·h (gigawatt hours). A GW·h is a huge amount of energy: 3.6×10^{12} J.

9-4B Seek the Source

Think About It

In this activity, you will contrast the most common sources of electrical energy in Canada.

What to Do

1. Use the map in Figure 9.37 on the previous page to create a bar graph for each of the following points:
   - total electrical energy production
   - percentage of electricity from thermal sources (which include gasoline powered generators)
   - percentage of electricity from hydroelectric sources
   - percentage of electricity from nuclear sources
   - percentage of electricity from wind and tidal sources

What Did You Find Out?

1. How does the total electrical energy production in Newfoundland and Labrador compare to that in other provinces? What percentage of Canada's electrical energy is produced in Newfoundland and Labrador? How does that compare with the percentage of Canada's population living in Newfoundland and Labrador? Explain any discrepancies.
2. Which source of energy is responsible for most of the electrical energy produced in Newfoundland and Labrador? How does the electrical energy production in other provinces from this source compare to that of Newfoundland and Labrador? Explain.
3. Rank the sources of electricity in Canada from most widely used to least widely used.
4. Why do you think Newfoundland and Labrador, Alberta, and Ontario produce most of their electrical energy in different ways?

Other Electrical Energy Alternatives

The map in Figure 9.37 shows the electrical energy generation mix as captured by Statistics Canada in 2006. What will the numbers look like in the future as older generating stations are closed, new ones are built, and new forms of electrical energy generation become more widespread? In planning for the future, scientists and engineers are working to ensure that new technologies developed for electrical energy generation limit environmental impact, are economically feasible, and are moving to more renewable sources of energy. **Renewable** energy sources are those that can renew or replace themselves. Hydroelectricity is an example of a renewable energy source because the water flowing through a hydroelectric generating station is not used up in the process (Figure 9.38). Other renewable energy sources include wind, solar, biomass, and geothermal.

Figure 9.38 Over 90 percent of the electrical energy generated in Newfoundland and Labrador is at hydroelectric generating plants, like this one at Petty Harbour.

Non-renewable energy sources cannot be replaced within a human lifetime. Fossil fuels and nuclear energy are examples of non-renewable energy sources because eventually the supply of these materials will be gone (Figure 9.39).

As demand for electrical energy continues to grow, using renewable energy sources will become more important since the supply of non-renewable energy sources is limited. In deciding which energy sources are appropriate for electrical energy in your province, a number of factors need to be considered, including availability, environmental impact, cost, and the properties of the materials used. Although renewable energy sources are not depleted, there are sometimes significant environmental and other risks associated with their use.

Figure 9.39 The Holyrood Generating Station burns heavy fuel oil, a non-renewable energy source.

Wind Energy

Wind energy produces electrical energy using turbines in a similar fashion to hydroelectric power generation. The major difference is that wind turbines can be either configured together in a "wind farm" that supplies electrical energy to a utility company for distribution, or they can be set up to supply energy directly to an individual home or farm (Figure 9.40). A single large-scale wind turbine produces enough energy to power hundreds of homes, while a smaller turbine might be used to power a single house or farm.

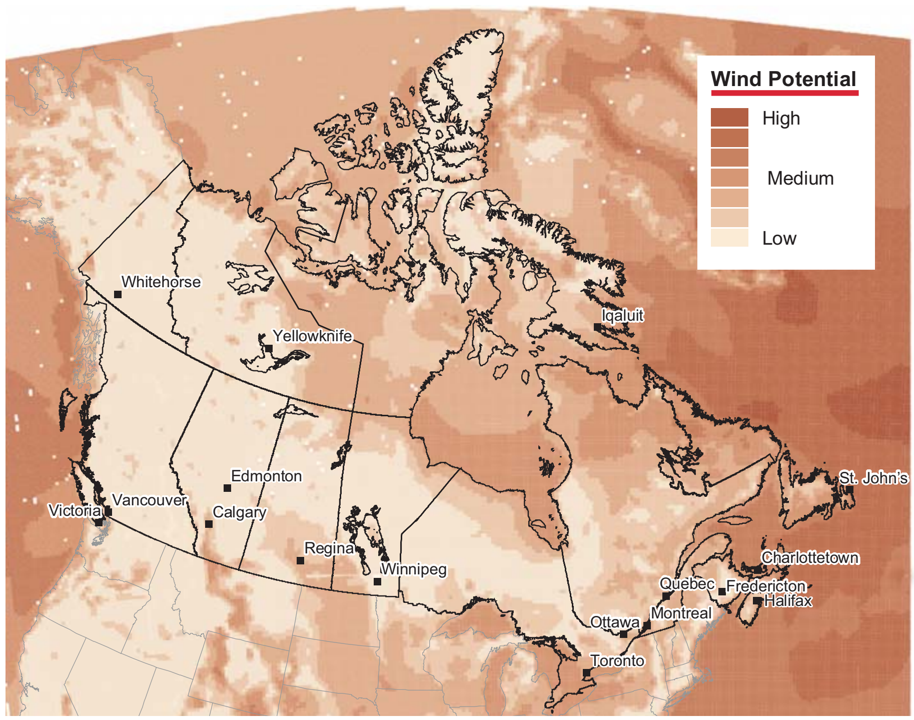
Figure 9.40 (A) A wind farm with large-scale turbines can provide enough energy for thousands of homes and businesses. (B) A smaller turbine is sufficient for an individual house or farm.

Explore More

An innovative project was launched in 2004 in Ramea, off the southwest coast of the island of Newfoundland. The project will assess the potential of an integrated energy source, using wind, diesel, and hydrogen, to provide electricity to remote locations. Find out more about this and other experimental projects on integrating energy sources. Start your search at **www.discoveringscience9.ca**.

Wind energy is the fastest-growing form of renewable energy in the world. It is considered a clean and sustainable energy source as it requires no fuel, and produces no greenhouse gases. The potential for wind power in Canada is significant; it is estimated that 20 percent of Canada's energy demand could be met with wind power. With its extensive coastline, many of Canada's regions are suitable for the installation of wind turbines (Figure 9.41).

Figure 9.41 Not all regions in Canada are suitable for harnessing wind energy. Wind turbines begin producing electricity when the wind speed is about 13 km/h, and must be shut down for safety reasons when wind speeds reach 90 km/h or more.



Source: Statistics Canada *Human Activity and the Environment - Annual Statistics 2004* (13)

The province of Newfoundland and Labrador embarked on its first large-scale wind projects in 2007 (Figure 9.42). Located at St. Lawrence, on the Burin Peninsula, and Fermeuse, south of St. John's, these wind farms are projected to provide 200 000 MW of energy per year. This will provide electrical energy to 14 000 homes and replace 300 000 barrels of oil that would have been burned at the Holyrood thermal generating plant. Emissions at the Holyrood plant will be reduced by almost 15 percent.

What happens on a windless day? Wind generators must be used together with other electric energy sources or storage devices. For example, wind-generated electrical energy could charge storage batteries, pump water into a reservoir for generating hydroelectric energy on a small scale, or split water molecules into hydrogen and oxygen gas for use as fuel for fuel cells.

Figure 9.42 Wind farms like this one at Fermeuse reduce the need for energy from non-renewable sources.

Solar Energy

Solar cells convert sunlight into electrical energy. You or your family may have a calculator, wristwatch, or garden lights that make use of solar cells. Modern parking meter machines, emergency highway telephones and movable traffic signals also use solar cells.

The amount of solar energy that reaches a solar cell depends on its position on the Earth, seasonal factors such as day length, and weather conditions. In Canada, the amount of sunlight available is limited because we are so far north of the equator. The low efficiency of solar cells, at less than 30 percent, also limits the amount of energy that can be collected. Relying on solar energy to provide electrical power for the typical home is not practical. Although the fuel is free, solar cell technology remains expensive and requires a backup system for nighttime use and for cloudy days.

When other electrical energy sources are not readily available, however, solar cells are a viable alternative. Solar cells are commonly used in remote locations where connecting to existing transmission lines would be expensive or impossible, like cottages, remote villages, and satellites. Solar cells are also becoming a more reasonably-priced alternative power source for portable electronic devices like laptop computers (Figure 9.43).

Figure 9.43 Solar bags contain solar cells designed to charge the batteries in laptops, cell phones, and MP3 players.

Fuel Cells

A **fuel cell** is like a battery, as it produces an electric current using two electrodes and it contains an electrolyte. Unlike a battery, a fuel cell's chemical components are not consumed over time, nor stored inside the cell. There are six different types of fuel cells, each categorized by the fuel and electrolyte used. Commonly used fuels include hydrogen, natural gas, formic acid, and methanol. The environmental impact of using fuel cells depends on the fuel used and how that fuel is obtained. If renewable resources such as hydroelectric or solar power are used to produce hydrogen fuel, the impact is less than if natural gas, a fossil fuel, is used. In addition to fuel, these cells use platinum or other expensive components. Current research to either reduce the amount of expensive components or find more cost-effective alternatives is in progress.

Although the fuel cell industry is small, Canada is considered to be a world leader, with over 50 percent of fuel-cell powered vehicles worldwide employing Canadian technology. Most of the research and development in fuel cells is taking place in British Columbia. Fuel cell vehicles, which include both cars and buses, continue to be one area of focus. Since the first fuel cell bus was produced in 1993, significant improvements in using hydrogen for mass transit have been made. Recently, BC Transit purchased 20 buses for their hydrogen fuel cell demonstration fleet program, to be operated in Whistler before, during, and after the 2010 Olympic Games (Figure 9.44).

Image courtesy of BC Transit

Figure 9.44 This latest generation bus uses a hybrid fuel cell/battery with an electric drive that is being tested for its fuel efficiency over standard diesel buses.

Fuel cell cars are also in development. The major challenge facing developers of fuel cell vehicles is the lack of refuelling stations. British Columbia, recognizing this limitation, is developing the "Hydrogen

Highway" to provide refuelling stations for hydrogen-powered vehicles as well as to showcase fuel cell technology.

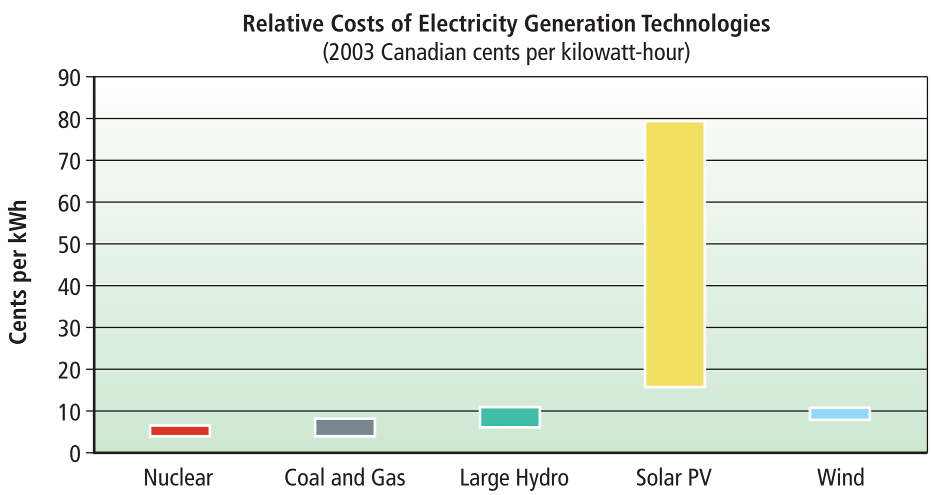
Other fuel cell technology in the demonstration phase includes stationary applications that could provide electrical energy for a car wash or backup lighting. "Micro applications" could include radio communication and lighting for mobile operations (Figure 9.45).

The final decision as to which energy source or combination of sources should be developed is not an easy one. Numerous hydroelectric and thermal generating stations are currently in operation in Nefoundland and Labrador, employing many people. By shifting energy production away from thermal generation, jobs will be lost. The dependability of the energy source must also be considered. For example, both solar and wind energy require a backup power source. Finally, the cost of generating electrical energy using a particular source, including environmental and safety costs, must be addressed. As shown in Figure 9.46, the most expensive commercially available electrical energy source is solar energy. However, long-term environmental costs and waste disposal costs are not included in this assessment.

Explore More

Many believe that hydrogen is the fuel of the future. Finding and developing cost-effective and environmentally friendly sources of hydrogen continues to be an area of research. Find out more about hydrogen as a fuel. Start your search at **www.discoveringscience9.ca**.

Figure 9.45 This micro hybrid hydrogen storage device, used to power a cell phone, is a prototype that was shown at the International Hydrogen and Fuel Cell Expo in Tokyo, Japan in 2007.



Source: Canadian Energy Research Institute, *Relative Costs of Electricity Generation Technologies* (2006: 3)

Figure 9.46 Each bar in this graph represents a range of costs for a particular energy source. Solar energy is the most expensive electrical power generation source per KW·h.

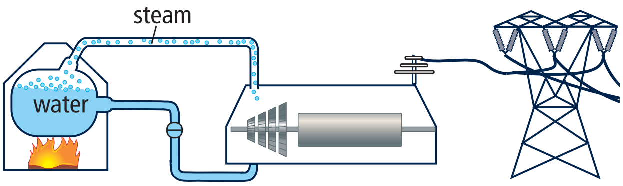
Reading Check

1. Why is hydroelectric power generation so common in Newfoundland and Labrador, but almost non-existent in Alberta?
2. What is the difference between non-renewable and renewable energy sources? Provide an example of each type that is currently in use in Newfoundland and Labrador.
3. List three examples of alternative sources of electrical energy.
4. List three limitations in developing alternative sources of electrical energy.

Check Your Understanding

Checking Concepts

1. How is electrical energy generated at a thermal generating station?
2. How does electrical energy generation differ between hydroelectric, nuclear, thermal, and wind generating stations?
3. What are the essential components in a generator?
4. What is a transformer used for?
5. What voltage of electrical energy is delivered for household use?
6. What type of generating station is the second-highest producer of electrical energy in Newfoundland and Labrador?
7. List two renewable energy sources.
8. List two non-renewable energy sources.
9. How efficient are solar cells?
10. (a) What kind of generating station is shown in the following diagram?



    (b) What kind of materials provide the fuel for this type of generating station?
    (c) What is one advantage and one disadvantage of this type of generating station?

Understanding Key Ideas

11. Describe the steps involved in the generation and transfer of electrical energy from a generating station to the home.
12. How does a generator produce an electric current?
13. Explain why electrical energy is transmitted at high voltage and low current over large distances.
14. Which of the following might be appropriate as an electrical energy source to supply a remote fishing village in Newfoundland and Labrador? Explain your answer.
    (a) solar energy
    (b) wind energy
    (c) hydroelectric power

Pause and Reflect

Many of the alternative electrical energy sources in development are more efficient and more environmentally friendly than traditional sources, but they cost more. Do you think people are prepared to pay more for electrical energy?

Chapter 9 Chapter Review

Prepare Your Own Summary

In this chapter, you investigated how circuits are designed to control the transfer of electrical energy. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 8 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Series and Parallel Circuits
2. Power
3. Energy Efficiency
4. Producing Electrical Energy

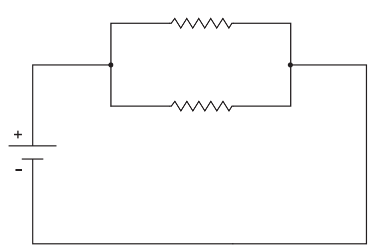
Checking Concepts

1. In terms of the number of pathways, what is the difference between a series circuit and a parallel circuit?
2. Two resistors are connected in series. How does the current through the second resistor compare to the current through the first resistor?
3. A 6.0 V battery is connected to three resistors connected in series. What is the total voltage lost on the three resistors?
4. Complete each of the following sentences in your notebook, using "increases," "does not change," or "decreases."
   (a) Adding a resistor in series ___________ the total resistance of the circuit.
   (b) Adding a resistor in parallel __________ the total resistance of the circuit.
5. Two resistors are connected in parallel. How does the voltage on one resistor compare to the voltage on the second resistor?
6. (a) A current entering a junction point branches into two pathways. Describe the relationship between the current entering the junction point and the total current in the two pathways that leave the junction point.
   (b) If the two pathways have different resistances, will the current in each pathway be the same?
7. (a) State the definition of power.
   (b) What unit is used to measure power?
8. What information would you need to calculate the electrical energy consumed by a device?
9. (a) What two units are used for measuring electrical energy?
   (b) Which unit is larger?
10. What is the definition of power in terms of energy and time?
11. Explain what is meant by "useful energy" and "waste energy."
12. Distinguish between renewable and non-renewable energy sources.

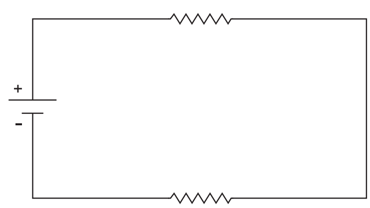
Understanding Key Ideas

13. A battery and two light bulbs are all connected in series.
    (a) What happens to the second light bulb if the first one "burns out"?
    (b) Would the result be the same if the bulbs were connected in parallel? Explain.
14. Give a non-electric example of a real life situation that represents:
    (a) a series circuit
    (b) a parallel circuit
15. For each circuit below, state if the resistors are connected in series or parallel. Give a reason for your answer.

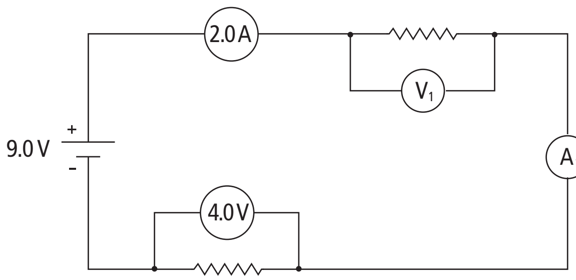
A



B

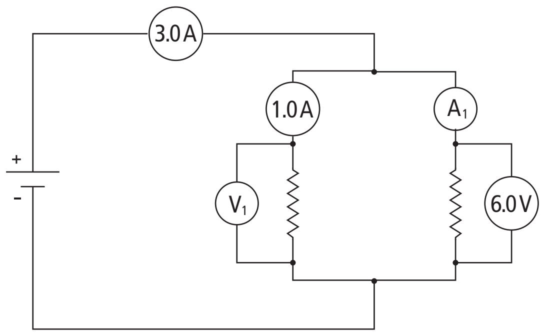


16. In the circuit shown below, what would be the readings on the voltmeter V_1, and the ammeter A_1?



17. A battery is connected to a resistor and the current leaving the battery is measured. What would happen to the current leaving the same battery if another resistor is
(a) connected in series with the original resistor? Explain your answer.
(b) connected in parallel with the original resistor? Explain your answer.

18. In the circuit shown below, what would be the reading on the voltmeter V_1 and the ammeter A_1?



19. List the following device usages in order of highest consumption of energy to lowest consumption of energy.

Device	Power Rating	Time
Hair dryer	600 W	15 min
Light bulb	60 W	4 h
Microwave oven	700 W	5 min

20. If the electric company charges 9.6 cents for every kW·h of energy, calculate how much it costs for each of the following:
(a) 5.0 kW stove used for 2.0 h
(b) 200 W water heater used for 8.0 h

21. Sarah sits down in front of her computer to complete a homework assignment. Describe the useful energy output of the computer. Is there any energy wasted by the computer?

22. What do you think would be the most efficient form of lighting to use for
(a) the keypad numbers on a cell phone?
(b) a headlight on a schoolbus?
(c) overhead lighting in the school hallway?
(d) a lamp in your bedroom?

23. What is the efficiency of a 1500 W microwave that produces 1.80×10^5 J of useful heat energy in 15 minutes?

24. Why are transformers necessary?

25. What energy sources could be used as a practical alternative to fossil fuel for powering a car? What sources would not be practical? Explain.

26. Which type of energy generation do you think has the least negative impact on the environment? Explain.

Pause and Reflect

A battery supplies 6.0 W of power when connected to two resistors in series. The same two resistors are then connected in parallel to the same battery. The battery now supplies 24 W of power. Why is there a difference in power?

Unit Summary

7 Static charge is produced by electron transfer.

- Static charge is electric charge that is held in one place. (7.1)
- An atom or material becomes charged when electrons transfer into it or out of it. (7.1)
- Insulators keep charges in one place, whereas conductors allow charges to move more easily. (7.1)
- Like charges repel. Opposite charges attract. Neutral objects are attracted to charged objects. (7.2)
- Electric force is a force at a distance. Electric force can be increased by increasing the amount of charge on objects and by decreasing the distance between charged objects. (7.2)

8 Ohm's law describes the relationship of current, voltage, and resistance.

- Unlike charges gain electric potential energy when they are moved farther apart. (8.1)
- Voltage (potential difference) is the change in potential energy per coulomb of charge. (8.1)
- Electrical energy depends on the amount of charge and the voltage. (8.1)
- Current electricity is the continuous flow of charge in a complete circuit. (8.2)
- Ohm's law states that the electrical resistance of a circuit is the ratio of the voltage to the current. (8.3)

9 Circuits are designed to control the transfer of electrical energy.

- The current is the same in each part of a series circuit, and each load uses a portion of the same voltage. (9.1)
- The current in each part of a parallel circuit depends on the resistance of that path. (9.1)
- When resistors are placed in series, the total resistance of the circuit increases. When resistors are placed in parallel, the total resistance decreases. (9.1)
- Power consumption multiplied by time of use equals the amount of electrical energy used by a device. (9.2)
- Electrical energy can be conserved by changing habits or by using more energy-efficient devices. (9.3)
- Electrical energy is generated in a variety of ways, each with its own benefits and risks. (9.4)

Key Terms

- acetate
- action-at-a-distance forces
- atoms
- charging by conduction
- charging by induction
- conductors
- contact forces
- coulomb
- electric force
- electrons
- force
- grounding
- insulators
- laws of static charge
- neutral
- protons
- static charge
- Van de Graaff generator

Key Terms

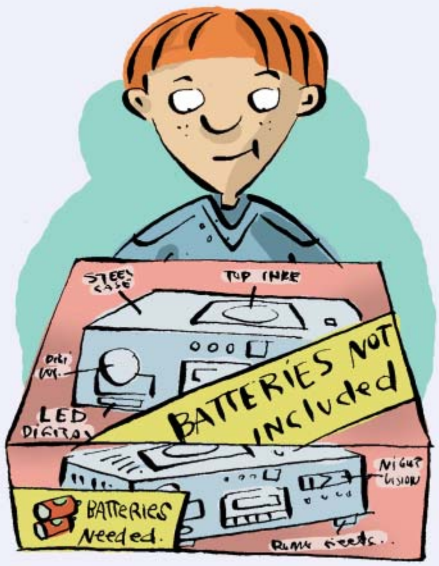
- amperes
- battery
- circuit diagrams
- current electricity
- electrical resistance
- electric circuit
- electric current
- electric load
- electric potential energy
- electrochemical cells
- electrodes
- electrolyte
- energy
- ohm
- Ohm's law
- potential difference
- resistance
- resistor
- volt
- voltage

Key Terms

- circuit breaker
- efficiency
- electrical energy
- electrical power
- EnerGuide
- fuel cell
- fuse
- generator
- grounding terminal
- hydroelectric
- joule
- junction point
- kilowatt-hour
- non-renewable
- nuclear energy
- parallel circuit
- power
- power rating
- renewable
- series circuit
- thermal energy
- transformer
- turbine
- watt

Finding the Best Battery

As you remove your new electronic device from its packing, you read “Batteries Not Included.” The store stocks three different brands of the battery size you need. Which brand will produce the most electrical energy?



Problem

In this project, you will work in groups to determine which brand of battery supplies the most electrical energy.

Safety

- If any wires become hot, disconnect the circuit immediately.

Suggested Materials

- 3 brands of one battery type, such as C, D, AA, or AAA
- identical bulbs
- voltmeters
- ammeters
- stopwatches
- connecting wires
- switches

Criteria

- Draw a circuit diagram for your set-up.
- Construct a circuit from a circuit diagram.
- Collect data for voltage, current, and time.
- Calculate power.
- Graph your data.

Procedure

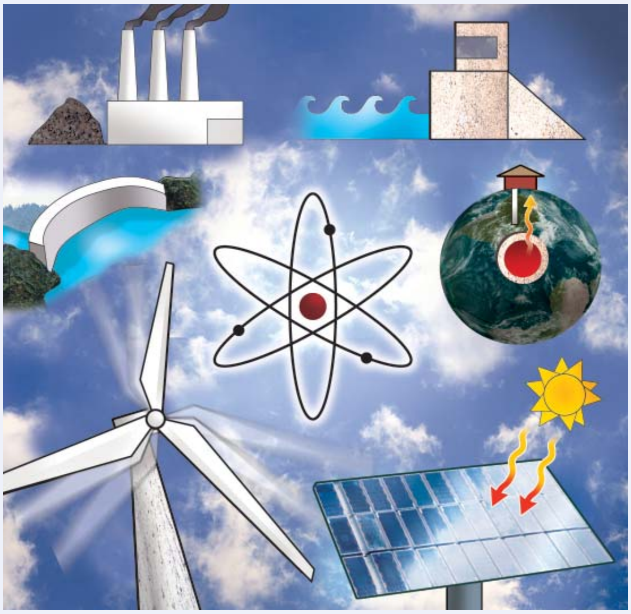
1. With your group, design a circuit that has one battery connected to two or three bulbs in parallel. Include an ammeter to measure the current leaving the battery, a voltmeter to measure the voltage across the battery, and a switch.
2. Draw a circuit diagram for your group’s design. Have your teacher approve your circuit design.
3. Create a data table to record your data for each brand of battery.
4. Have each member of the group construct the approved circuit using one of the three batteries. Close the switch and measure the initial voltage and current. Record these values for time = 0.
5. At consistent time intervals, record the voltage and current. Continue these measurements until the bulbs are no longer lit.
6. Disconnect your circuit. Clean up and put away the equipment you have used.
7. For each set of data, calculate the power provided by the battery ($P = VI$).

Report Out

1. Construct a graph of power vs. time. Plot your data for each brand of battery on the same graph. For each battery, connect your data points with a smooth line.
2. The area below the graph line is proportional to the energy produced by the battery ($E = Pt$). Analyze your graph, and state which brand of battery produced the most energy.

Generating Electrical Energy

In this investigation, you will choose a source of energy and research the methods used to convert the energy source into electricity.



Background

Over the last 100 years, Newfoundland and Labrador has continually increased its dependence on electricity. Growth in population, technology, and industry has put a strain on our ability to safely generate enough affordable electricity. Scientists have been researching different methods of generating electrical energy to find methods that are safe and affordable. The most common forms of generating electricity include the following.

Energy Source	Description
Hydroelectric	Dams are built on rivers to convert gravitational potential energy into electricity. Currently, over 90 percent of Newfoundland and Labrador's electricity is hydroelectric.
Thermal	Coal or natural gas is burned to convert thermal energy into electricity.
Geothermal	Earth's heat is used to produce electricity.
Nuclear	Nuclear reactors convert nuclear energy into electricity.
Wind	Air movement is converted into electricity by windmills.
Wave/tidal	The motion of the ocean is used to produce electricity.
Solar	Solar panels are used to convert the Sun's energy to electricity.

Find Out More

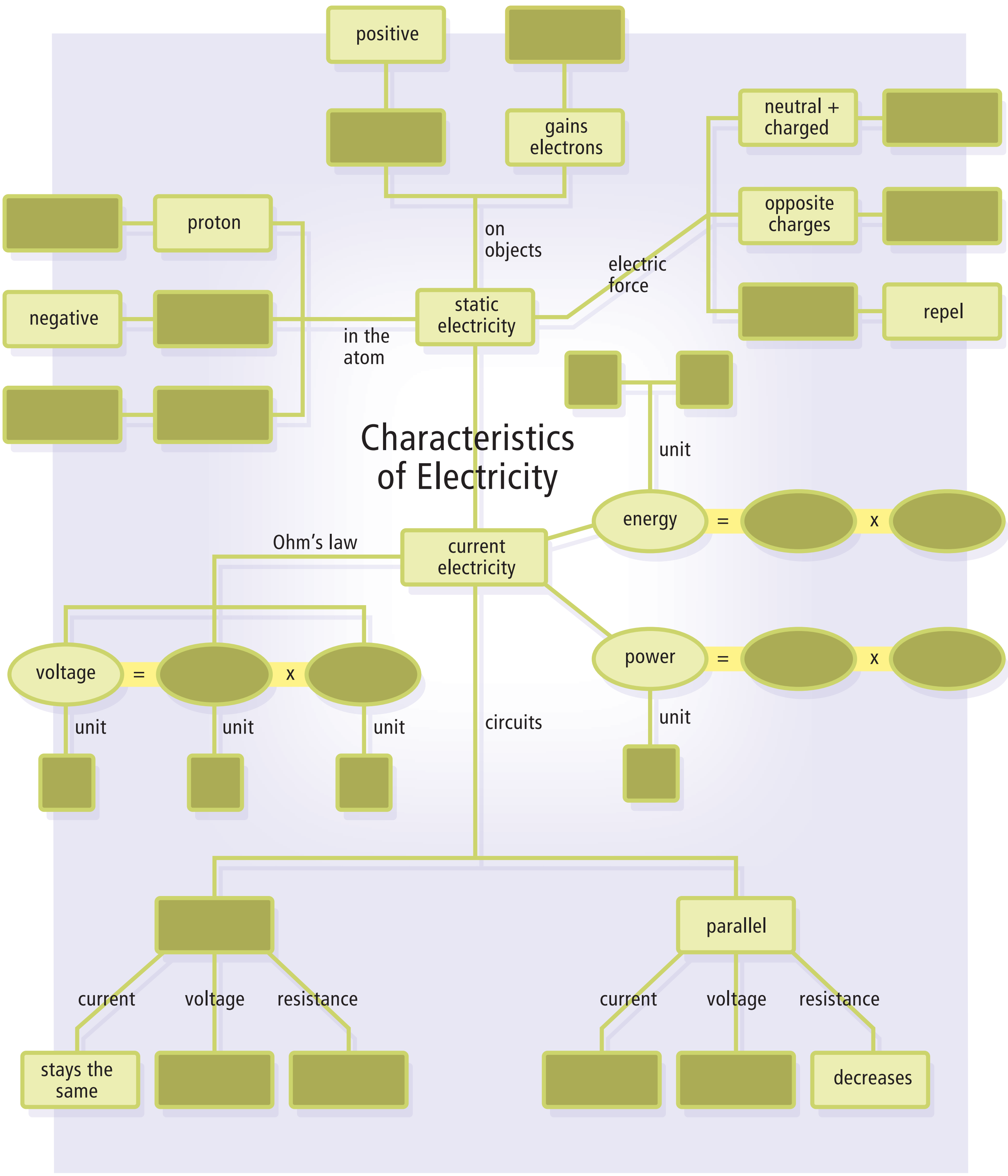
Choose one source of energy from the table. Use the Internet, encyclopedias, books, or other sources to research how the energy source is converted into electricity. You can start your search at **www.discoveringscience9.ca**.

Report Out

1. Create a poster to display the results of your research. Your poster could include information about:
   - method(s) used to convert your energy source to electricity
   - effects on the environment
   - cost
   - dependability
2. Take part in a "town hall" debate in which you promote your source of energy to a small community on the coast of Newfoundland and Labrador that will soon be expanding and needs a new energy source.

Visualizing Key Ideas

1. Copy the concept map about the characteristics of electricity into your notebook. Complete the map.



Using Key Terms

2. In your notebook, state whether the following statements are true or false. If a statement is false, rewrite it to make it true.
   (a) If an object is neutral, it has no positive and negative charges.
   (b) Grounding an object is allowing charge to flow into Earth.
   (c) An insulator does not allow charge to move easily.
   (d) The load in a circuit converts electrical energy into other forms of energy.
   (e) Resistors slow down the flow of current.
   (f) In a series circuit, the potential difference of the source is equal to the potential difference across each load.
   (g) In a parallel circuit, the current entering the junction point equals the current leaving the junction point.
   (h) Most devices have 100 percent efficiency.
   (i) Hydroelectric energy is an example of a renewable energy source.

Checking Concepts

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3. (a) What is the name of the device used for detecting static charge?
   (b) How does this device indicate the presence of a static charge?
4. What two names are given to oppositely charged objects?
5. (a) Which two parts of the atom have a charge?
   (b) What is the charge on each of these parts?
6. What is the charge on an object after it is grounded?
7. What particle is transferred when a neutral object is charged?
8. (a) Give two examples of materials that are electrical conductors.
   (b) Give two examples of materials that are electrical insulators.
9. State the three laws of static charge.

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10. Define voltage in terms of electric potential energy and charge.
11. What is the difference between kinetic energy and potential energy?
12. State what each of the following meters is designed to measure:
    (a) voltmeter
    (b) ammeter
    (c) ohmmeter
13. What is the difference between static electricity and current electricity?
14. Contrast conventional current and electron flow.
15. What happens to the electrical energy when a charge passes through a resistor?
16. State Ohm's law in terms of voltage, current, and resistance.
17. Describe the purpose of the coloured bands on a resistor.

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18. What is the difference between a series circuit and a parallel circuit?
19. Use the words "same," "different," "increases," and "decreases" to complete the following table.

	Series	Parallel
Current in every part of the circuit		
Voltage across different size resistors in the circuit		
Total resistance when a resistor is added		

20. In any complete series circuit, how does the voltage supplied by the battery compare to the sum of the voltages lost on each resistor?
21. If 4.0 A of current enters the junction point of a parallel circuit, how much total current must leave that junction point?
22. What factors affect electrical energy cost?

23. Two light bulbs, a 60 W bulb and a 100 W bulb, are left on for the same amount of time. Which bulb consumes more energy?
24. What information is presented on an EnerGuide label?
25. What is a transformer?

Understanding Key Ideas

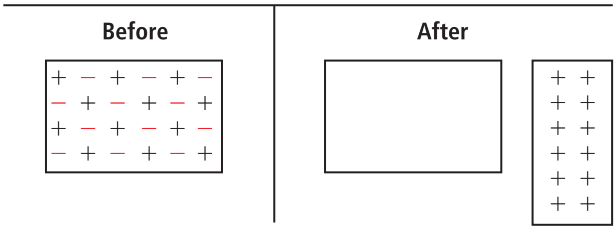
26. Explain the cause of lightning.
27. Explain why a charged balloon sticks to the wall.
28. Explain how you can use a charged rod and an electroscope to determine whether an object is a conductor.
29. Suppose that you rub a piece of plastic on your sweater and it gains a charge. Describe how you could use a negatively charged acetate strip to determine the charge on this piece of plastic.
30. Two charged objects are placed 10 cm apart. Describe two ways of increasing the electric force between these two charged objects.
31. Explain, using the motion of electrons, the difference between charging by conduction and charging by induction.
32. Describe two ways to increase the current in a circuit.
33. When a battery is connected to a complete circuit, electrons flow throughout the circuit instantaneously. Explain.
34. A resistor is connected to a battery and a 4.0 A current leaves the battery. The resistor is now replaced by a new resistor with half the resistance. How much current will now leave the battery?
35. Explain why household wiring is constructed in parallel instead of in series.
36. How does a generator produce electrical energy?
37. Describe three ways that you could (or already do) conserve energy in your home.
38. Two identical light bulbs are connected to a battery in a series circuit.
    (a) What will happen to the brightness of the second bulb if the first bulb is unscrewed?
    (b) Would this result be the same if the bulbs were connected in parallel? Explain.
39. A string of 12 identical holiday lights is connected in series. If this string is plugged into a 120 V source, what is the voltage across each light?

Thinking Critically

40. A charged object is brought near a pile of puffed rice cereal. Some pieces of the cereal are attracted to the charged object, but as soon as they contact the charged object they fly off in all directions. Explain this observation.
41. You are caught in a thunderstorm while playing golf. Your caddy suggests that you either keep playing or stand under a tree. Do you think these are good ideas? Give reasons for your answer.
42. Two wires can be placed across the terminals of a battery. One wire has a high resistance, whereas the other has a low resistance. Which will produce heat energy at a faster rate? Explain.
43. Your teacher tells you that the Sun is the ultimate source for energy that is stored in fossil fuels. Do you agree? Explain.

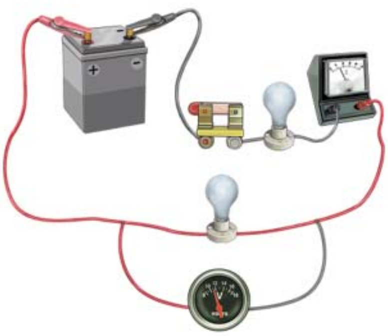
Developing Skills

44. Copy the following diagram into your notebook. Place positive (+) and negative (−) signs in the blank object to demonstrate the induced charge distribution.



45. Draw a circuit diagram for each of the following circuits.

A



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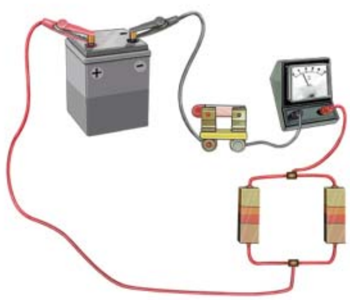
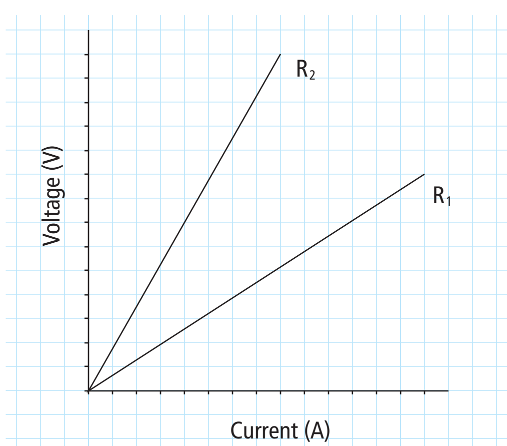


46. A 2.0 A current flows through a 220 Ω resistor. What is the voltage across this resistor?

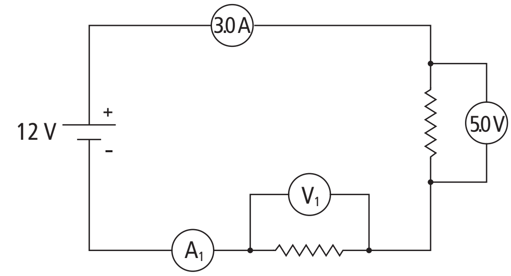
47. A circuit takes 0.45 A of current from a 9.0 V battery. What is the resistance of this circuit?

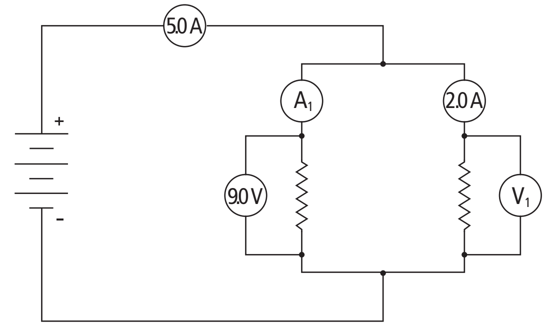
48. A 18 MΩ resistor is connected to 120 kV high-power lines. What is the current, in milliamperes (mA) through this resistor?

49. Two different resistors, R_1 and R_2, are connected to various batteries, and the current is measured. The data for each resistor are plotted on the graph below. Which resistor has the largest resistance? Explain.



50. Determine the voltage V_1 and the current A_1 in each of the following circuits.





51. Calculate the efficiency of a CD player that uses 80 kJ of energy and produces 30 kJ of waste heat energy. What assumption do you need to make to complete this calculation?

52. A 1400 W toaster oven is used for 30 min.
(a) Find the amount of energy consumed by this toaster oven. Give your answer in:
(i) joules (J)
(ii) kilowatt hours (kW·h)
(b) If the electric company charges 10 cents for every kW·h of energy, how much did it cost to operate the toaster oven in (a)?

Pause and Reflect

In less than 300 years, our understanding of electricity has progressed from creating a static charge by friction to the design of powerful computers. What have you learned in this unit that has helped you better understand the importance of electricity in your life?