

8.2 Electric Current

Current electricity is the flow of charged particles in a complete circuit. The unit for measuring electric current is the ampere (A), which is defined as one coulomb of charge passing a given point per second. An ammeter is a device used to measure current. To have a continuous flow of charge, the circuit must contain at least one source of voltage. In a circuit, electric potential energy is transformed into other forms of energy. Circuit diagrams are drawn to represent electric circuits.

Words to Know

amperes
circuit diagrams
current electricity
electric circuit
electric current
electric load

Did You Know?

A typical tiny computer chip contains more than a million circuits.

If you looked inside your computer or an old television or stereo, you would see many wires and components (Figure 8.7). All these wires and electronic components form pathways for transforming electrical energy into other forms of energy. A complete pathway that allows electrons to flow is called an **electric circuit**.



Figure 8.7 Inside a computer

8-2A Lighting It Up

Find Out ACTIVITY

In this activity, you will investigate ways to make a circuit using a battery, conducting wire, and a light bulb.

Safety

- If the wire becomes hot, disconnect it immediately.

Materials

- D cell
- 10 cm of insulated wire with both ends bare
- one 2.0 V flashlight bulb

What to Do

1. Using the flashlight bulb, wire, and battery, try to make the bulb light up. Once you are successful, disconnect the battery. Make a sketch of how these three materials were connected.
2. Rearrange the three materials and find a different way to make the bulb light up. Make a sketch of this second circuit.
3. Make a sketch that includes the three objects in such a way that the bulb will not light up. Then, using the materials, check if your sketch is correct.

What Did You Find Out?

1. Explain the difference between the sketches in steps 1 and 2 and the sketch in step 3.
2. Which of your sketches show a complete circuit?
3. Give an example of something in your home or community that represents a complete circuit.

Energy Around a Circuit

Any device that transforms electrical energy into other forms of energy is called an **electric load**. Some examples of a load are a light bulb, a buzzer, a heater, and a motor. Figure 8.8 illustrates a simple circuit containing a battery, conducting wires, and a buzzer. Chemical energy in the battery gives the electrons on the negative terminal electric potential energy. These electrons are attracted to the positive terminal of the battery. Since there is a pathway for them to travel, electrons leave the negative terminal and are pushed by the energy from the battery through the conducting wires to the buzzer. In the buzzer, the electrons' electric potential energy is transformed into sound energy. Electrons travel back to the battery through the complete circuit.

You can picture a waterslide (Figure 8.9) to help you think about an electric circuit.

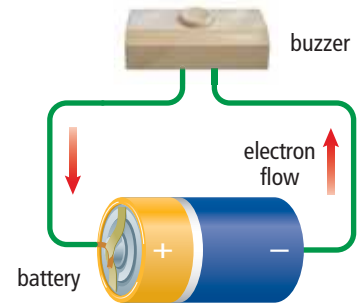
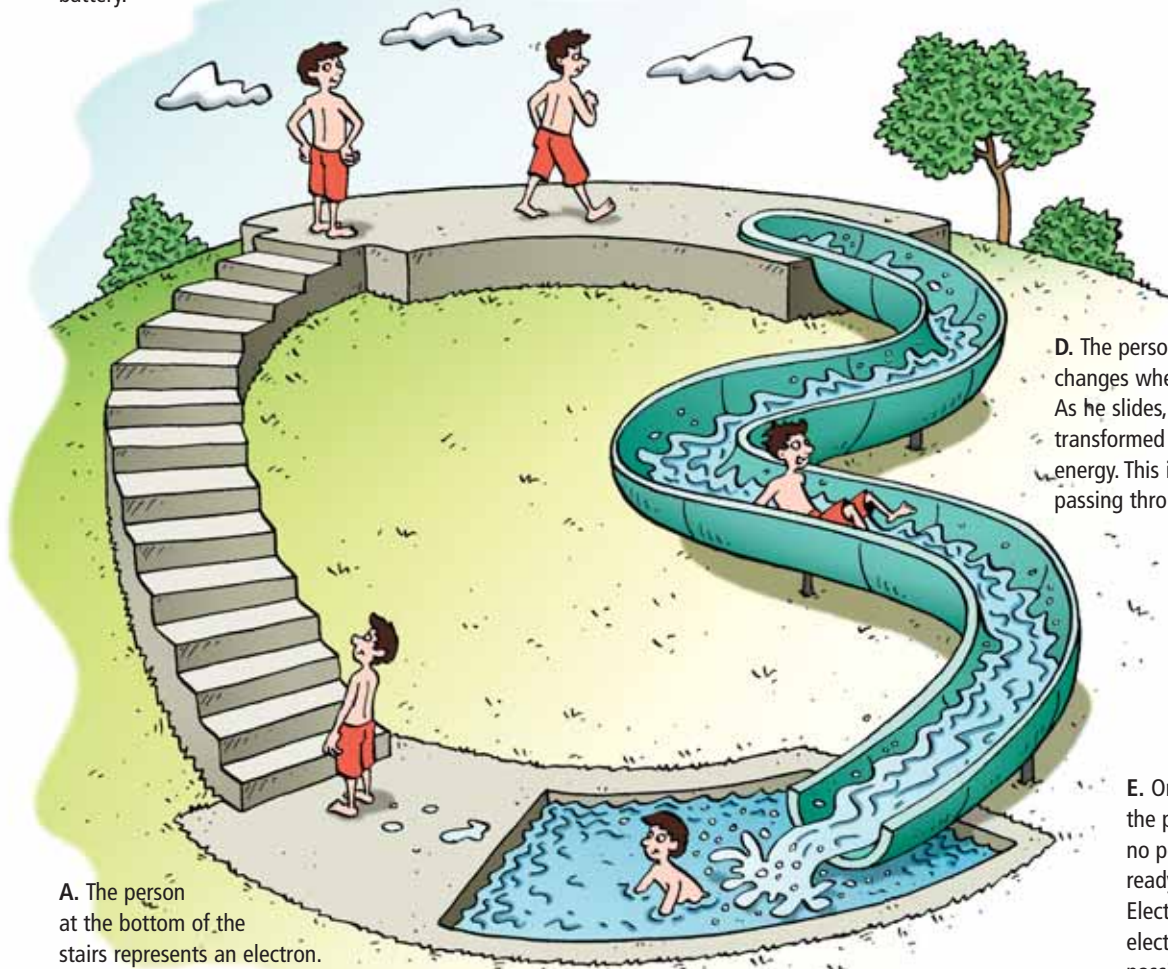


Figure 8.8 A battery provides the voltage that allows the electrons to travel through the circuit.

B. Once the person is at the top of the stairs, he has potential energy. The number of stairs he climbed represents the voltage of the battery.

C. As the person walks horizontally along the top platform, he is not changing his potential energy. This is similar to the electrons passing through the conducting wire.



A. The person at the bottom of the stairs represents an electron. The stairs are like the battery because they provide potential energy. In order for the person to gain potential energy, he must climb the stairs.

D. The person's potential energy changes when he descends the slide. As he slides, his potential energy is transformed into other forms of energy. This is like the electrons passing through the load.

E. Once the person stops in the pool at the bottom, he has no potential energy, and he is ready to climb the stairs again. Electrons in a circuit have zero electric potential energy after passing through the load.

Figure 8.9 One difference between the swimmer and the electron is that a single electron does not keep going around the circuit, whereas the swimmer may make many return trips down the slide!

Circuit Components and Diagrams

Even the most complex circuits are made of only four basic types of parts or components:

- *Source*: the source of electrical energy
- *Conductor*: the wire through which electric current flows
- *Load*: a device that transforms electrical energy into other forms of energy
- *Switch*: a device that can turn the circuit on or off by closing or opening the circuit

Suppose that you needed to have someone build an electrical circuit for you. You could describe what you needed using words, you could make an artist's sketch of the circuit, or you could take a photograph. Alternatively, you could make a circuit diagram. **Circuit diagrams** are diagrams that use symbols to represent the different components of the circuit. Figure 8.10 shows some common circuit symbols used in circuit diagrams.

Suggested Activities

Find Out Activity 8-2C on page 285
Conduct an Investigation 8-2E on page 287

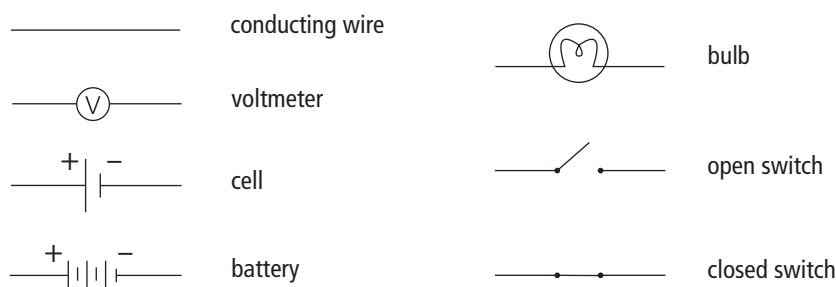


Figure 8.10 Circuit symbols help simplify complex circuits.

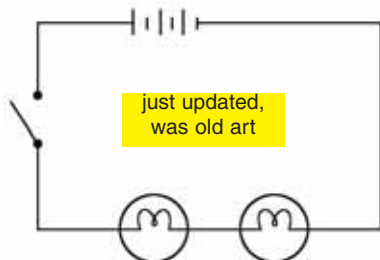


Figure 8.11 Drawing a circuit diagram is a quick and accurate way to model an electric circuit.

Circuit diagrams give an organized representation of the actual circuit. In order to make your circuit diagrams simple to read, be sure to meet the following criteria.

- Draw your diagrams using a ruler.
- Make all connecting wires and leads straight lines with 90° (right-angle) corners.
- If possible, do not let conductors cross over one another.
- Your finished drawing should be rectangular or square.

Figure 8.11 shows a sketch of a simple circuit and its circuit diagram. Check that the diagram meets all four of the criteria listed above.

Reading Check

1. What other forms of energy can electrical energy be converted into by a load?
2. What is an electric circuit?
3. Explain how electrons in a circuit are like people on a waterslide.
4. What are the four basic components of a circuit?
5. What is the purpose of a circuit diagram?

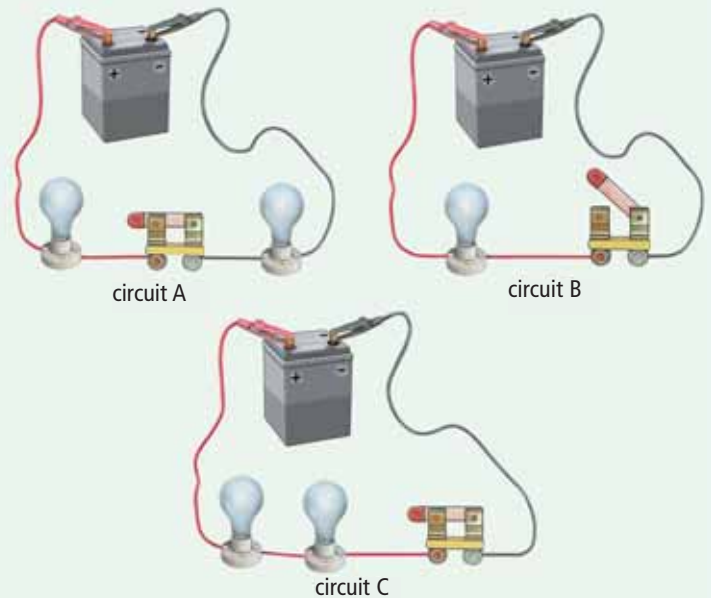
In a closed circuit, there can be no breaks in the path of electrons. An open circuit does not allow a flow of electrons because there is a break in the path. In this activity, you will draw and analyze circuit diagrams and decide which are open and which are closed.

What to Do

1. For each of the following circuit illustrations, draw its corresponding circuit diagram.

What Did You Find Out?

1. Which circuit(s) are closed circuits?
2. Which circuit(s) are open circuits?
3. In any of your closed circuits, identify the device that
 - (a) is the source of electric potential energy
 - (b) converts the electrical energy to other forms



Electrons Are So Pushy

In the circuits you have analyzed so far in this section, a battery supplies the energy to push electrons. Electrons are pushed from the negative terminal of the battery, along conducting wires through a load, for example a light bulb, and end up on the positive terminal of the battery. As soon as the battery is connected to the circuit, and the circuit is closed, electrons in every part of the circuit are pushing. That is why the light bulb goes on immediately.

This concept is similar to water in a hose connected to a tap, as shown in Figure 8.12. If the hose is already filled with water, as soon as you turn on the tap, water flows from the other end of the hose. The electrons leaving the negative terminal push the electrons ahead of them, just like water leaving the tap pushes on the water in front. You may remember from Chapter 7 that electrons do not need to touch in order to push other electrons. Electrons apply an action-at-a-distance force.



Figure 8.12 Electrons are pushed through a circuit in a similar way to how water is pushed through a hose.

Current Electricity and Static Electricity

Recall from Chapter 7 that static electricity is charge that remains stationary on an insulator. The charge in a battery is *not* an example of static electricity, even though the charge remains very nearly fixed on the battery terminals when the battery is not connected to a closed circuit. Once a battery is connected to a complete circuit, charge will flow continuously through the circuit. The continuous flow of charge in a complete circuit is called **current electricity**.

Did You Know?

On average, electrons travel only about 0.5 mm/s in a circuit.

Current: The Measure of Flow

You might have used the term “current” to describe the flow of water. How does the current in the Fraser River compare to the current in a small stream? Even though the water in the stream might move faster, the total volume of water in the Fraser River passing a point every second would be greater (Figure 8.13).

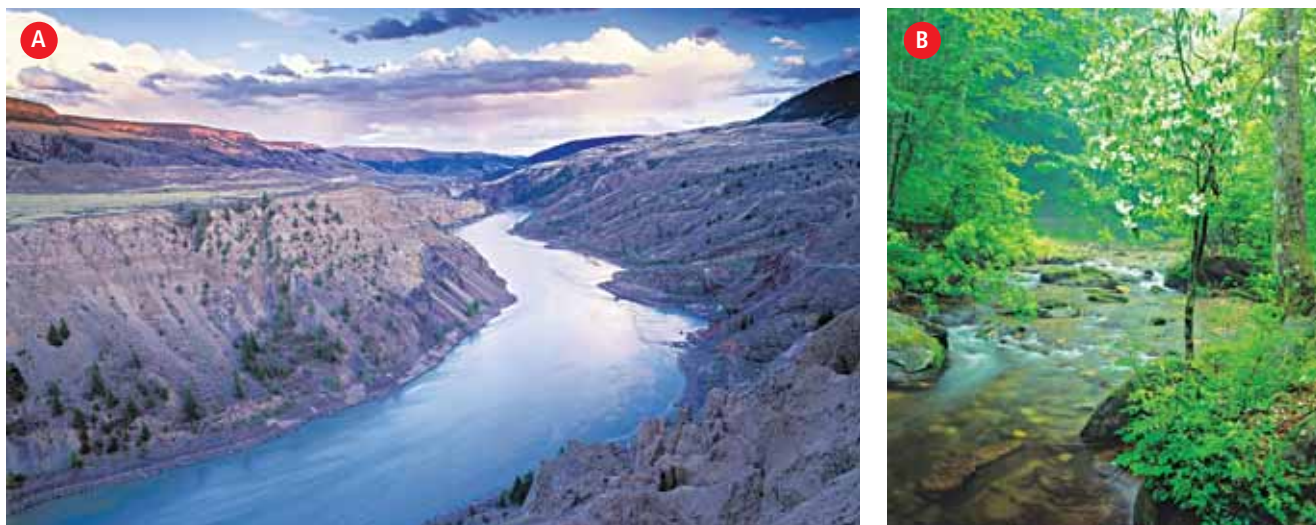


Figure 8.13 The volume of water flowing in the Fraser River (A) is greater than that of a stream (B). Therefore the river is said to have more current.

Suggested Activity

Find Out Activity 8-2D on page 286

Scientists think about electric current as charge flowing in a conductor. **Electric current** is defined as the amount of charge passing a point in a conductor every second. Electric current is measured in **amperes (A)**. This unit is named in honour of the French physicist André-Marie Ampère who studied the relationship between electricity and magnetism (Figure 8.14). Small currents are measured in milliamperes (mA); $1.0 \text{ A} = 1000 \text{ mA}$. An **ammeter** is a device used to measure the current in a circuit. An ammeter symbol on a circuit diagram looks like this: $\text{---} \textcircled{\text{A}} \text{---}$



Figure 8.14 André-Marie Ampère (1775–1836)

Conventional Current

In 1747, Benjamin Franklin wrote about charged objects as being electrified “positively” and “negatively,” meaning that the positively charged objects contained more electric fluid (a greater, or positive amount) than the negatively charged objects (a lesser, or negative amount). This suggests that whenever electricity flows, it moves from positive to negative. Notice that a flow of charge from positive to negative is the opposite of the idea that we use today. For historical reasons, Franklin’s idea is named *conventional current*. The concept of conventional current is still used to describe and calculate potential difference in a circuit. The concept of electron flow to describe current was not accepted by scientists until the late 1800s, after the discovery of the electron.

Reading Check

1. From which terminal of a battery are electrons pushed?
2. When a battery is connected to a circuit, all the electrons throughout the circuit immediately start to move. How is this possible considering that most of the electrons in the circuit are far from the battery?
3. Why is the charge in a battery not an example of static electricity?
4. What is the difference between static electricity and current electricity?
5. Define electric current.
6. What are the units of electric current?
7. What is the purpose of an ammeter?
8. How is electron flow different from conventional current?

Explore More

The design of a computer chip that contains millions of electric circuits is an example of nanotechnology. Nanotechnology is technology on a very small scale, usually of one micron or less. Find out more about nanotechnology and electrical components. Start your search at www.bcscience9.ca.



8-2C Pushing Electrons

Find Out ACTIVITY

When a battery is connected to a circuit, electrons in the conductor “push” or repel the other electrons nearby. The force between electrons is an action-at-a-distance force. In this activity, you will make a model for the motion of electrons in an electric circuit.

Materials

- 6 plastic drinking straws
- 3 bar magnets

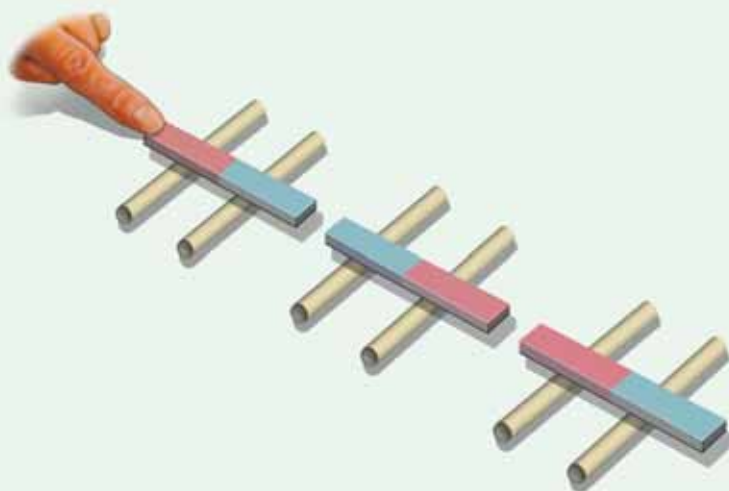
What to Do

1. Using the straws as rollers, line up the magnets as shown in the illustration. Make sure the north and south ends of the magnets are oriented as shown.

2. Carefully push the end magnet and observe the motion of the other two magnets.

What Did You Find Out?

1. In a short paragraph, explain how this model demonstrates the motion of electrons in a circuit.
2. Your finger provided the “push” to start the magnets moving. In an electric circuit, what device “pushes” the electrons through the circuit?
3. Suppose the magnets of this model were replaced with wooden blocks the same size as the magnets. Why would the wooden block model not be as useful a model as the magnet model?



Carefully observe what happens to the magnets.

In this activity, you will construct a circuit from a circuit diagram and use an ammeter to correctly measure current. If you need to convert the units for the current, remember that $1.0 \text{ A} = 1000 \text{ mA}$.

Safety



- Make sure that the positive terminal of the ammeter is connected to the positive terminal of the battery, and the negative terminal of the ammeter is connected to the negative terminal of the battery.
- Never connect an ammeter directly across the terminals of a battery.
- There must be a load, like a light bulb, in the circuit to limit the flow of electrons.
- If the wires get hot, disconnect them immediately.

Materials

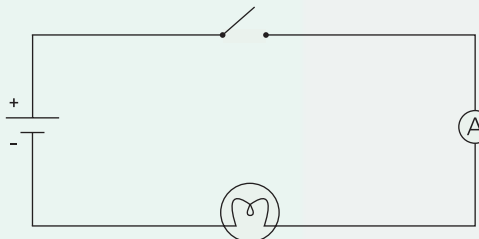
- 1.5 V cell
- various flashlight bulbs (1.5 V, 3.0 V, 6.0 V)
- connecting wires
- knife switch
- ammeter

What to Do

1. Copy the following table into your notebook. Give your table a title.

Bulb Type (V)	Measured Current (mA)

2. Using one of the light bulbs, connect the circuit as shown in the circuit diagram below.



In step 2, connect the circuit but leave the switch open.

Science Skills

Go to Science Skill 11 for information on using an ammeter.

3. Close the switch briefly and measure the current. Open the switch. Record the measurement in your data table.
4. Repeat step 3 with the remaining light bulbs.

What Did You Find Out?

1. (a) Which circuit had the largest current?
(b) Which circuit had the smallest current?
2. Why is it important to connect the positive lead of the ammeter to the positive side of the battery?
3. What is the purpose of the switch in this circuit?
4. When you measure an unknown current, you should start with the meter set to a large current scale and then decrease the scale. Explain the purpose of starting with a higher setting.

SkillCheck

- Communicating
- Modelling
- Explaining systems
- Working co-operatively

Criteria

- Your circuit needs to represent:
 - battery
 - electrical load
 - conducting wires
 - electrons
- You must show how energy is transformed by passing through the load.
- Electrons need to flow through your circuit for at least a minute or two.
- Your props are limited to a few small objects, such as tennis balls or bean bags.

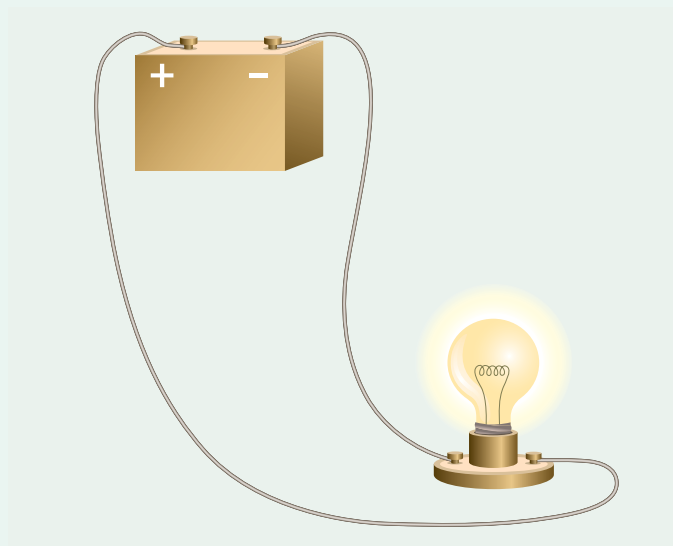
Using models to explain an idea or concept is a key skill in science. In this activity, you will make a human model of an electric circuit.

Problem

How can you design and build a human model of an electric circuit?

Design and Construct

1. Meet together with group members and make a group flowchart or other drawing of what happens in an electric circuit. Include as much detail as possible.
2. Discuss how the group could model the circuit. Be sure to include everyone's ideas and input.
3. Decide whether you will need any simple props.
4. Practise your presentation and refine your model.
5. Perform your presentation for other groups.



Make a human model to represent electrons flowing in an electric circuit.

Evaluate

1. How did your group show the change in potential energy in different parts of the circuit?
2. How did your group show how energy was transformed?
3. What was the most difficult part about making a human model of an electrical circuit?
4. In what ways was your model an inaccurate representation of an electric circuit?
5. How could you refine your model based on ideas from other groups' presentations?

Science Watch

The Faraday Cage

Most commercial airplanes avoid turbulent thunderstorms by flying over them or around them. But even with these precautions, it is estimated that every commercial airplane in Canada is hit by lightning at least once a year. How is it that the passengers and equipment on these planes avoid being damaged by this huge voltage? The answer to this was already known in 1836, long before planes were even invented.



Michael Faraday (1791–1867) was a brilliant chemist and physicist. During his studies of electricity, Faraday realized that excess charges were spread evenly

over a conducting surface. Faraday hypothesized that if an object were totally enclosed by conducting material, any excess charge placed on the surface would not have an effect on the object inside. Every point on the conducting surface would be at the same electric potential and therefore there would be no potential difference (voltage) inside the enclosure.

To test his hypothesis, Faraday built a room covered with metal foil. A large Van de Graaff generator was used to apply a “lightning bolt” to the room. Inside the room, Faraday held an electroscope to detect static charge. As Faraday had predicted, the large voltage applied to the exterior of the room had no effect on objects inside the room. An enclosure of conducting material is now called a Faraday cage.

Since airplanes have a complete outer covering of conducting metal, they act as a Faraday cage. The charge from a lightning strike spreads evenly over the surface without creating voltage inside the aircraft. Sensitive instruments onboard the plane are protected by their own separate Faraday cage.

An automobile can also act as a Faraday cage, and therefore it is a relatively safe place to be during a thunderstorm. During a thunderstorm, you can turn the motor off and remain in the car without touching any of its metal parts until the storm has passed.

Faraday cages can even be used as clothing, allowing trained electricians to safely work near high voltage transmission cables without turning off the power. These workers wear a suit of heavy fabric that contains about 25 percent conducting metal fibres. This suit directs almost all the current around the body rather than through it.

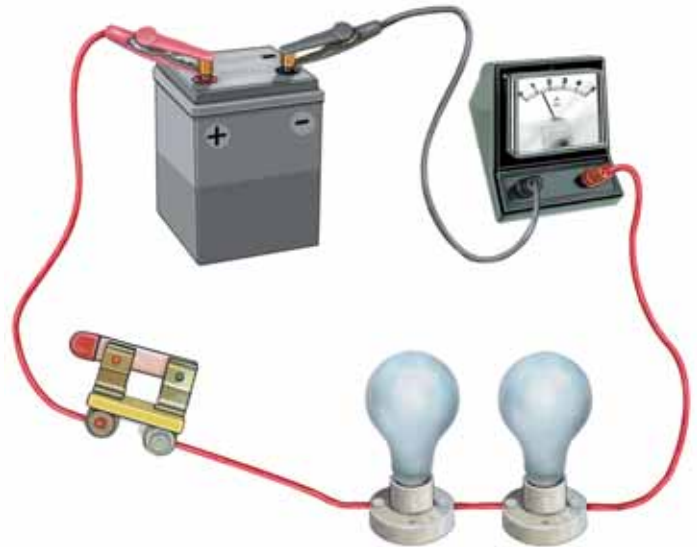


Check Your Understanding

Checking Concepts

1. What is the function of the battery in an electric circuit?
2. What is the function of the load in an electric circuit?
3. What are three different examples of loads?
4. Draw and label each of the following circuit symbols:
 - (a) conducting wire
 - (b) cell
 - (c) battery
 - (d) light bulb
 - (e) open switch
 - (f) closed switch
 - (g) voltmeter
 - (h) ammeter
5. What is the amount of charge passing a given point every second called?
6. State the correct units of electric current.
7. What device is used to measure electric current?

12. Explain how two conductors could have different current even though the electrons in each conductor are travelling at the same speed.
13. Draw a circuit diagram for the circuit shown.



Understanding Key Ideas

8. What is the difference between electron flow and conventional current?
9. Explain the difference between static electricity and current electricity.
10. A circuit contains a 3.0 V battery and a light bulb. Suppose the battery were replaced by a 6.0 V battery. Would the electrical energy transformed in the light bulb increase or decrease? Use the example of a waterslide to explain your answer.
11. Explain how electrons are “pushed” through a conductor without having to touch other electrons.

Pause and Reflect

In this chapter, a waterslide was used as an analogy, or a comparison, for the energy transfer in an electric circuit. In that analogy, the stairs represented the battery, the person represented the charges, and the slide represented the loss of electrical energy on a load. What other analogy can you develop for an electric circuit? In your description, identify the battery, the load, and the charge.