SECTION 2

Electric Current and Electrical Energy

You might not realize that when you watch TV, use a computer, or even turn on a light bulb, you depend on moving charges for the electrical energy that you need.

What You Will Learn

- Describe electric current.
- Describe voltage and its relationship to electric current.
- Describe resistance and its relationship to electric current.
- Explain how a cell generates electrical energy.
- Describe how thermocouples and photocells generate electrical energy.

Vocabulary

electric current
voltage
resistance
cell
thermocouple
photocell

READING STRATEGY

Reading Organizer As you read this section, make a table comparing electric current, voltage, and resistance.

Electrical energy is the energy of electric charges. In most of the things that use electrical energy, the electric charges flow through wires. As you read on, you will learn more about how this flow of charges—called *electric current*—is made and how it is controlled in the things that you use every day.

Electric Current

An **electric current** is the rate at which charges pass a given point. The higher the current is, the greater the number of charges that pass the point each second. Electric current is expressed in units called *amperes* (AM PIRZ), which is often shortened to *amps*. The symbol for *ampere* is A. And in equations, the symbol for current is the letter *I*.

Reading Check **What is the unit of measurement for electric current?** (*See the Appendix for answers to Reading Checks.*)

Making Charges Move

When you flip the switch on a flashlight, the light comes on instantly. But do charges in the battery instantly reach the bulb? No, they don't. When you flip the switch, an electric field is set up in the wire at the speed of light. And the electric field causes the free electrons in the wire to move. The energy of each electron is transferred instantly to the next electron, as shown in **Figure 1**.

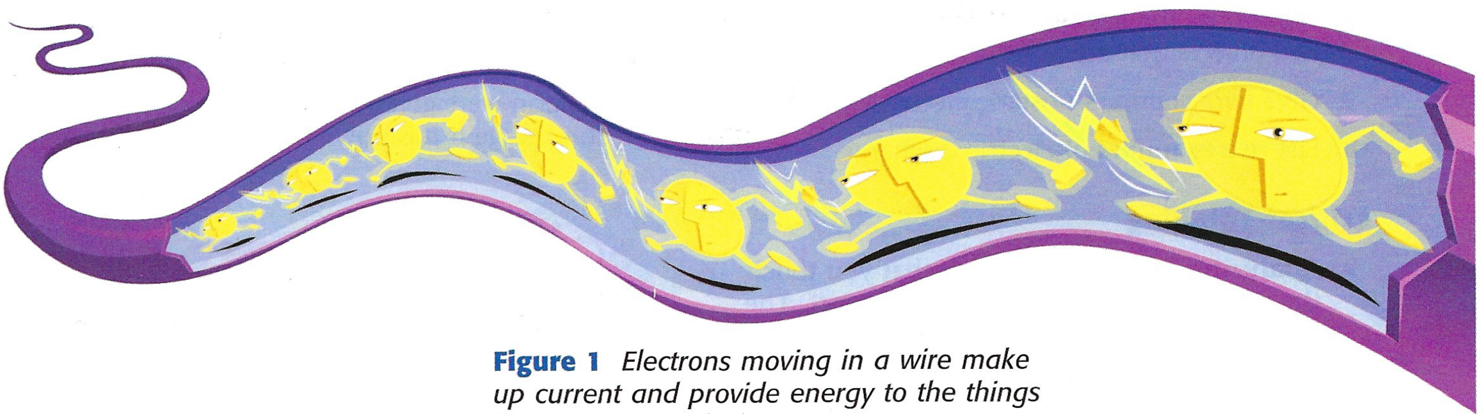


Figure 1 *Electrons moving in a wire make up current and provide energy to the things that you use each day.*

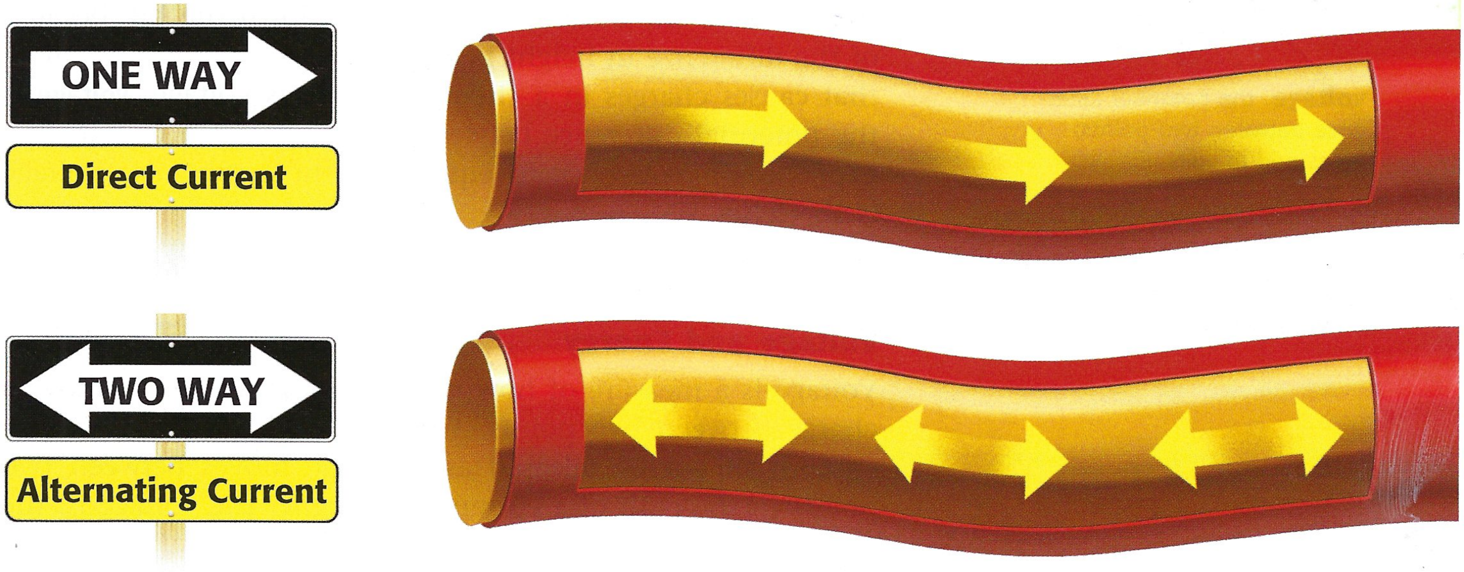


Figure 2 *Charges move in one direction in DC, but charges continually change direction in AC.*

Commanding Electrons to Move

This electric field is created so quickly that all electrons start moving through the wire at the same instant. Think of the electric field as a command to the electrons to charge ahead. The light comes on instantly because all of the electrons obey this command at the same time. So, the current that lights the bulb is established very quickly even though each electron moves quite slowly. In fact, a single electron may take more than an hour to travel 1 m through a wire.

electric current the rate at which charges pass through a given point; measured in amperes

AC and DC

There are two kinds of electric current—direct current (DC) and alternating current (AC). Look at **Figure 2.** In direct current, the charges always flow in the same direction. In alternating current, the charges continually shift from flowing in one direction to flowing in the reverse direction.

The electric current from the batteries used in a camera is DC. The electric current from outlets in your home is AC. In the United States, the alternating current changes directions 120 times each second, or has 60 cycles each second.

Both kinds of current can give you electrical energy. For example, if you connect a flashlight bulb to a battery, the light bulb will light. And you can light a household light bulb by putting it in a lamp and turning the lamp on.

Reading Check **What are two kinds of electric current?**

Voltage

If you are on a bike at the top of a hill, you know that you can roll down to the bottom. You can roll down the hill because of the difference in height between the two points. The "hill" that causes charges in a circuit to move is voltage. **Voltage** is the potential difference between two points in a circuit. It is expressed in volts (V). In equations, the symbol for voltage is the letter *V*.

voltage the potential difference between two points; measured in volts

Reading Check **What is the unit of measurement for voltage?**

Voltage and Energy

Voltage is a measure of how much work is needed to move a charge between two points. You can think of voltage as the amount of energy released as a charge moves between two points in the path of a current. The higher the voltage is, the more energy is released per charge.

Voltage and Electric Current

As long as there is a voltage between two points on a wire, charges will flow in the wire. The size of the current depends on the voltage. The greater the voltage is, the greater the current is. A greater current means that more charges move in the wire each second. A large current is needed to start a car. So, the battery in a car has a fairly high voltage of 12 V. **Figure 3** shows batteries that have a number of different voltages. If you have a device that uses direct current, one of these batteries might help.

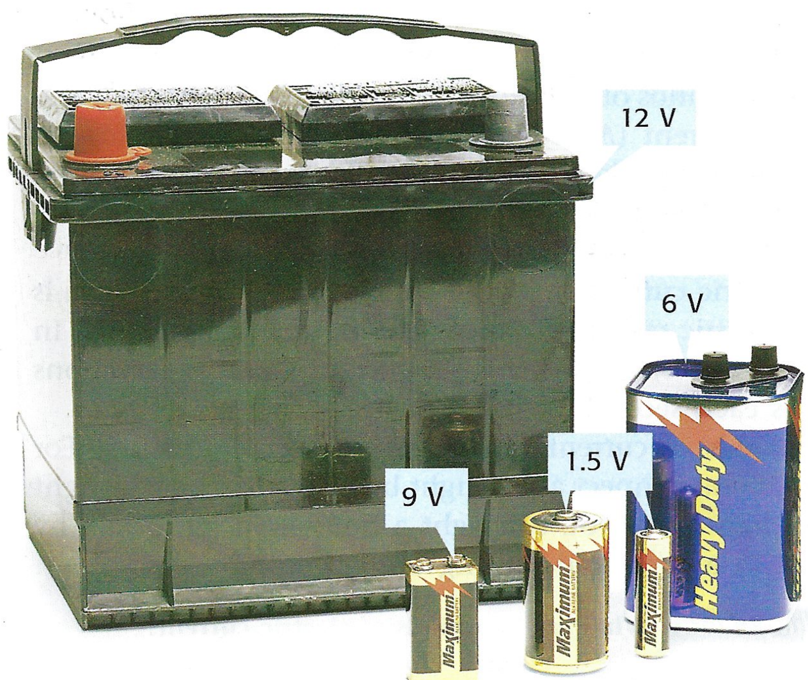


Figure 3 *Batteries are made with various voltages for use in many different devices.*

Figure 4 *An electric eel can create a voltage of more than 600 V!*

Varying Nature of Voltage

Things that run on batteries usually need a low voltage. For example, a portable radio might need only 3 V. Compare the voltage of such a radio with the voltage created by the eel in **Figure 4.** Most devices in your home use alternating current from an outlet. In the United States, electrical outlets usually supply AC at 120 V. So, most electrical devices, such as televisions, toasters, and alarm clocks, are made to run on 120 V.

CONNECTION TO Biology

Help for a Heart Pacemaker cells in the heart produce low electric currents at regular intervals to make the heart beat. During a heart attack, pacemaker cells do not work together, and the heart beats irregularly. Research how doctors sometimes "jump start" the heart during a heart attack. Make a poster to share your findings.

ACTIVITY

Resistance

Resistance is another factor that determines the amount of current in a wire. **Resistance** is the opposition to the flow of electric charge. Resistance is expressed in ohms (Ω, the Greek letter *omega*). In equations, the symbol for resistance is the letter *R*.

You can think of resistance as "electrical friction." The higher the resistance of a material is, the lower the current in the material is. So, if the voltage doesn't change, as resistance goes up, current goes down. An object's resistance depends on the object's material, thickness, length, and temperature.

resistance in physical science, the opposition presented to the current by a material or device

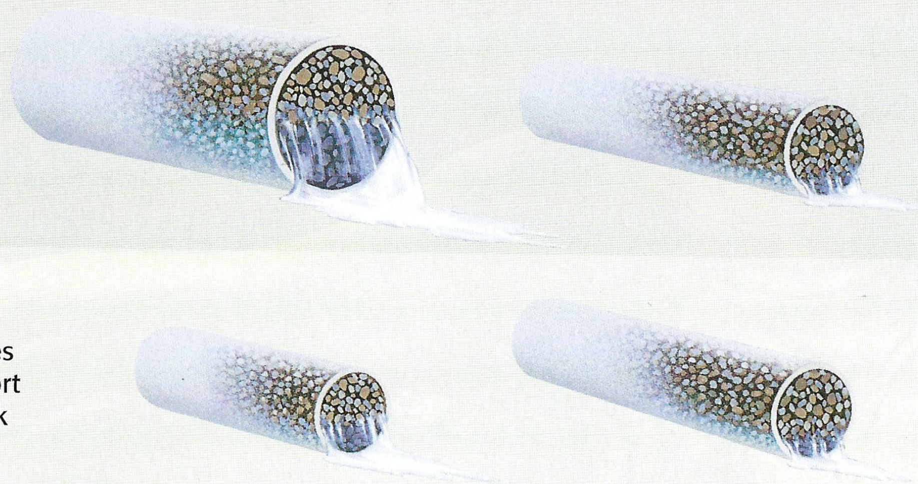
Resistance and Material

Good conductors, such as copper, have low resistance. Poor conductors, such as iron, have higher resistance. The resistance of insulators is so high that electric charges cannot flow in them. Materials with low resistance, such as copper, are used to make wires. But materials with high resistance are also helpful. For example, the high resistance of the filament in a light bulb causes the light bulb to heat up and give off light.

Figure 5 **A Model of Resistance**

A thick pipe has less resistance than a thin pipe does because there are more spaces between pieces of gravel in a thick pipe for water to flow through.

A short pipe has less resistance than a long pipe does because the water in a short pipe does not have to work its way around as many pieces of gravel.



Resistance, Thickness, and Length

To understand how the thickness and length of a wire affect the wire's resistance, look at the model in **Figure 5.** The pipe filled with gravel represents a wire. The water flowing through the pipe represents electric charges.

Resistance and Temperature

Resistance also depends on temperature. In general, the resistance of metals increases as temperature rises. The atoms vibrate faster at higher temperatures and get in the way of the flowing electric charges. If you cool certain materials to a very low temperature, resistance will drop to 0 Ω. Materials in this state are called *superconductors.* A small superconductor is shown in **Figure 6.** Very little energy is wasted when electric charges move in a superconductor. However, a large amount of energy is needed to cool them. Scientists are studying how superconductors can be used to store and transmit energy.

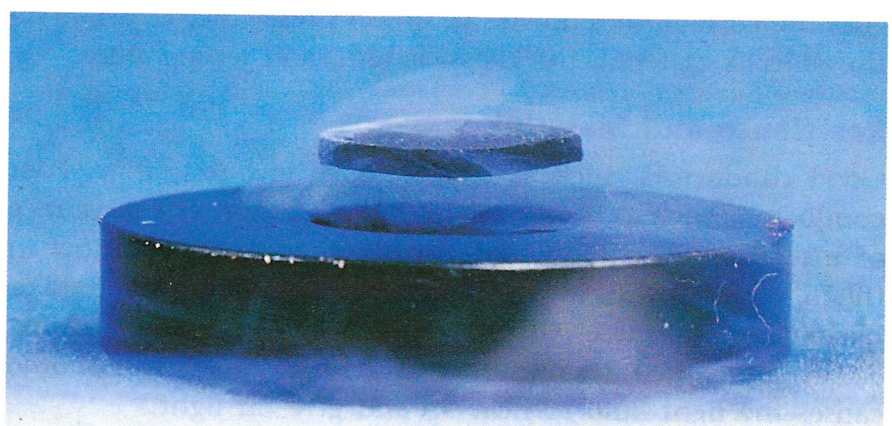
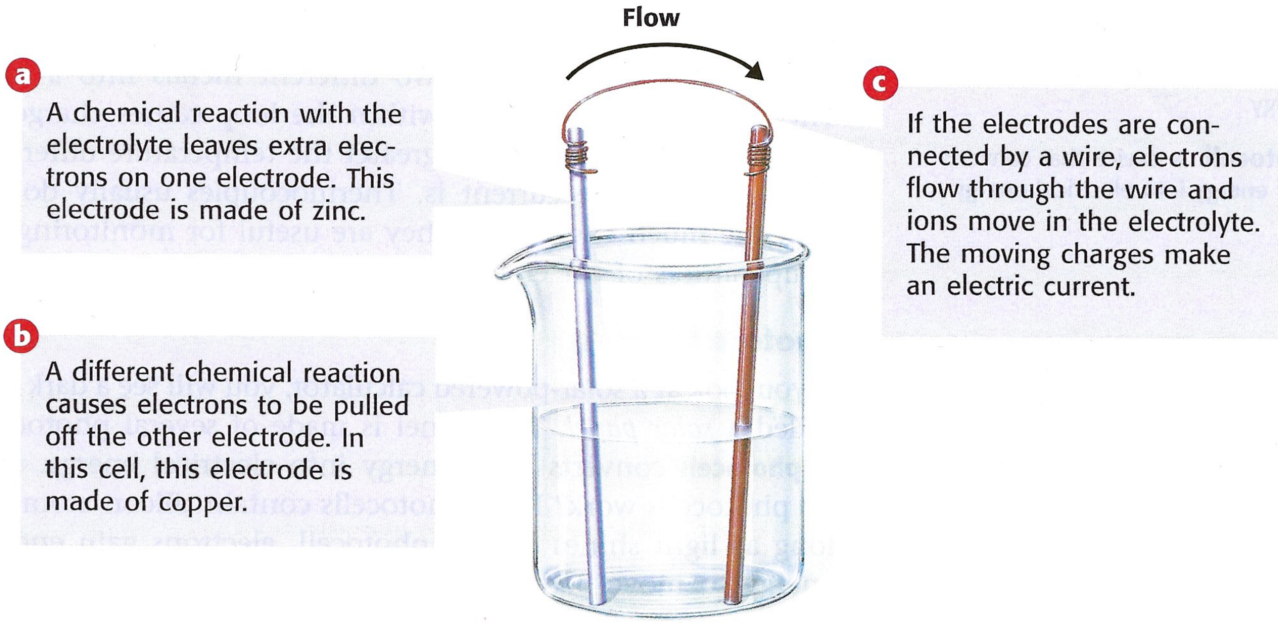


Figure 6 *One interesting property of superconductors is that they repel magnets. The superconductor in this photo is repelling the magnet so strongly that the magnet is floating.*

Figure 7 **How a Cell Works**



Generating Electrical Energy

You know that energy cannot be created or destroyed. It can only be changed into other kinds of energy. Many things change different kinds of energy into electrical energy. For example, generators convert mechanical energy into electrical energy. **Cells** change chemical or radiant energy into electrical energy. Batteries are made of one or more cells.

cell in electricity, a device that produces an electric current by converting chemical or radiant energy into electrical energy

Parts of a Cell

A cell, such as the one in **Figure 7,** contains a mixture of chemicals called an *electrolyte* (ee LEK troh LIET). Electrolytes allow charges to flow. Every cell also has a pair of electrodes made from conducting materials. An *electrode* (ee LEK TROHD) is the part of a cell through which charges enter or exit. Chemical changes between the electrolyte and the electrodes convert chemical energy into electrical energy.

Kinds of Cells

Two kinds of cells are wet cells and dry cells. Wet cells, such as the one in **Figure 7,** have liquid electrolytes. A car battery is made of several wet cells that use sulfuric acid as the electrolyte. You can make your own wet cell by poking strips of zinc and copper into a lemon. When the metal strips are connected, enough electrical energy is generated to run a small clock, as shown in **Figure 8.** Dry cells work in a similar way. But the electrolytes in dry cells are solid or pastelike. The cells used in small radios and flashlights are types of dry cells.

Figure 8 *This cell uses the juice of a lemon as an electrolyte and uses strips of zinc and copper as electrodes.*

Reading Check What are two kinds of cells?

thermocouple a device that converts thermal energy into electrical energy

photocell a device that converts light energy into electrical energy

Thermocouples

Thermal energy can be converted into electrical energy by a **thermocouple.** A simple thermocouple, shown in **Figure 9,** is made by joining wires of two different metals into a loop. The temperature difference within the loop causes charges to flow through the loop. The greater the temperature difference is, the greater the current is. Thermocouples usually do not generate much energy. But they are useful for monitoring the temperatures of car engines, furnaces, and ovens.

Photocells

If you look at a solar-powered calculator, you will see a dark strip called a *solar panel*. This panel is made of several photocells. A **photocell** converts light energy into electrical energy. How do photocells work? Most photocells contain silicon atoms. As long as light shines on the photocell, electrons gain enough energy to move between atoms. The electrons are then able to move through a wire to provide electrical energy to power a device, such as a calculator.

In larger panels, photocells can provide energy to buildings and cars. Large panels of photocells are even used on satellites. By changing light energy from the sun into electrical energy, the photocells provide energy to the many devices on the satellite to keep the devices working.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5ELEW.**

✓ Reading Check **What device converts light energy into electrical energy?**

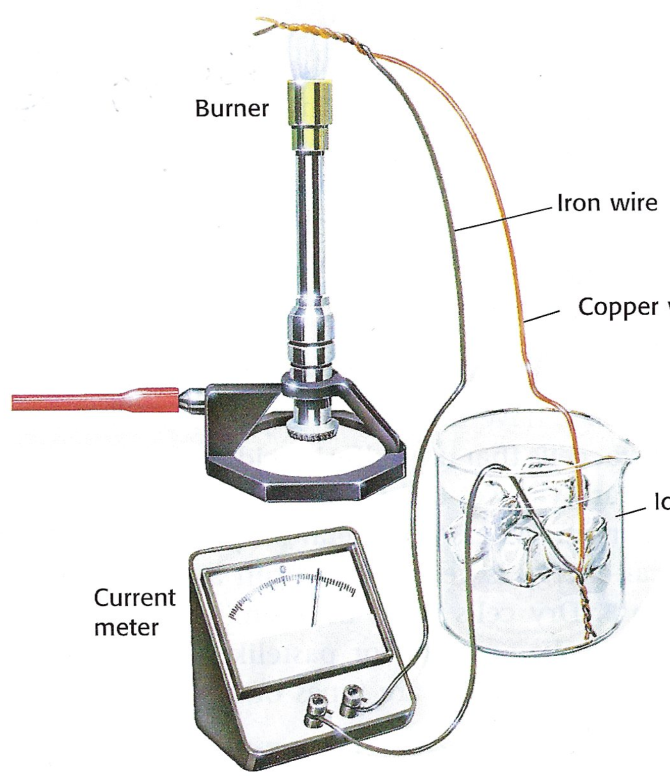


Figure 9 *In a simple thermocouple, one section of the loop is heated and one section is cooled.*

SECTION Review

Summary

- Electric current is the rate at which charges pass a given point.
- An electric current can be made when there is a potential difference between two points.
- As voltage, or potential difference increases, current increases.
- An object's resistance varies depending on the object's material, thickness, length, and temperature. As resistance increases, current decreases.
- Cells and batteries convert chemical energy or radiant energy into electrical energy.
- Thermocouples and photocells are devices used to generate electrical energy.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

voltage	electric current
resistance	cell

1. The rate at which charges pass a point is a(n) ___.

2. The opposition to the flow of charge is ___.

3. Another term for *potential difference* is ___.

4. A device that changes chemical energy into electrical energy is a(n) ___.

Understanding Key Ideas

5. Which of the following factors affects the resistance of an object?

a. thickness of the object
b. length of the object
c. temperature of the object
d. All of the above

6. Name the parts of a cell, and explain how they work together to produce an electric current.

7. Compare alternating current with direct current.

8. How do the currents produced by a 1.5 V flashlight cell and a 12 V car battery compare if the resistance is the same?

9. How does increasing the resistance affect the current?

Critical Thinking

10. Making Comparisons A friend is having trouble studying the types of cells in this section. Explain to your friend how the terms *photocell* and *thermocouple* hold clues that can help him or her remember the type of energy taken in by each device.

11. Making Inferences Why do you think some calculators that contain photocells also contain batteries?

12. Applying Concepts Which wire would have the lowest resistance: a long, thin iron wire at a high temperature or a short, thick copper wire at a low temperature?

Interpreting Graphics

13. The wires shown below are made of copper and have the same temperature. Which wire should have the lower resistance? Explain your answer.