SECTION 4

Electric Circuits

Think about a roller coaster. You start out nice and easy. Then, you roar around the track. A couple of exciting minutes later, you are right back where you started!

A roller-coaster car follows a fixed pathway. The ride's starting point and ending point are the same place. This kind of closed pathway is called a *circuit*.

What You Will Learn

- Name the three essential parts of a circuit.
- Compare series circuits with parallel circuits.
- Explain how fuses and circuit breakers protect your home against short circuits and circuit overloads.

Vocabulary

series circuit
parallel circuit

READING STRATEGY

Brainstorming The key idea of this section is electric circuits. Brainstorm words and phrases related to electric circuits.

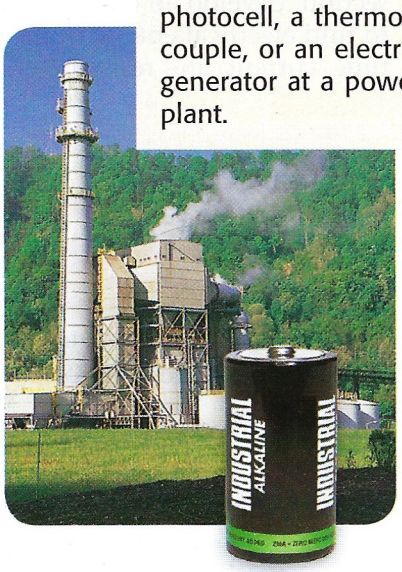
Parts of an Electric Circuit

Just like a roller coaster, an electric circuit always forms a loop—it begins and ends in the same place. Because a circuit forms a loop, a circuit is a closed path. So, an *electric circuit* is a complete, closed path through which electric charges flow.

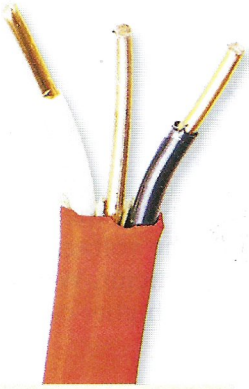
All circuits need three basic parts: an energy source, wires, and a load. Loads, such as a light bulb or a radio, are connected to the energy source by wires. Loads change electrical energy into other forms of energy. These other forms might include thermal energy, light energy, or mechanical energy. As loads change electrical energy into other forms, they offer some resistance to electric currents. **Figure 1** shows examples of the parts of a circuit.

Reading Check **What are the three parts of an electric circuit?**
(*See the Appendix for answers to Reading Checks.*)

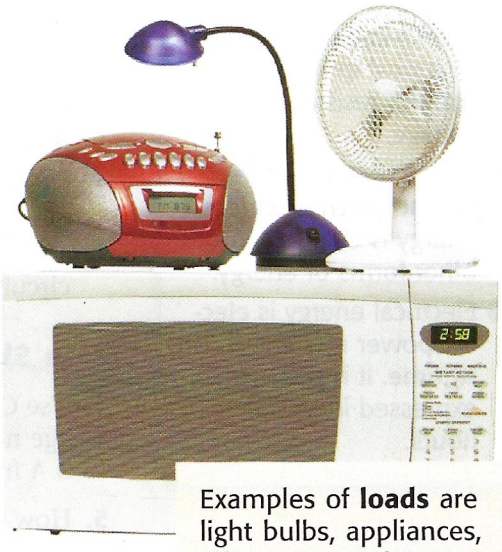
Figure 1 **Necessary Parts of a Circuit**



The **energy source** can be a battery, a photocell, a thermocouple, or an electric generator at a power plant.



Wires connect the other parts of a circuit. Wires are made of conducting materials that have low resistance, such as copper.

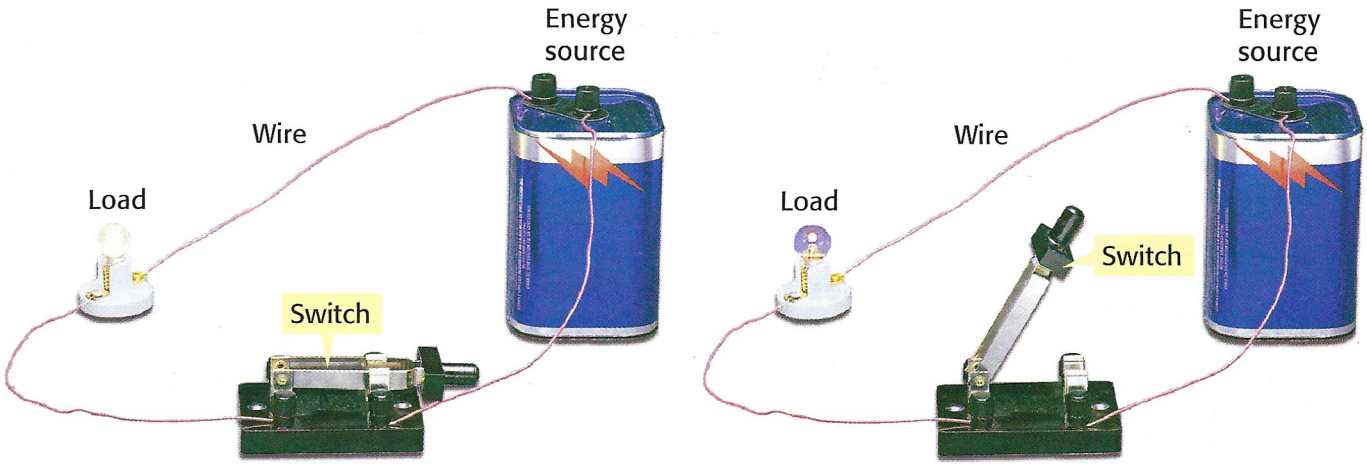


Examples of **loads** are light bulbs, appliances, televisions, and motors.

Figure 2 **Using a Switch**

When the **switch is closed,** the two pieces of conducting material touch, which allows the electric charges to flow through the circuit.

When the **switch is open,** the gap between the two pieces of conducting material prevents the electric charges from traveling through the circuit.



A Switch To Control a Circuit

Sometimes, a circuit also contains a switch, such as the one shown in **Figure 2.** A switch is used to open and close a circuit. Usually, a switch is made of two pieces of conducting material, one of which can be moved. For charges to flow through a circuit, the switch must be closed, or "turned on." If a switch is open, or "off," the loop of the circuit is broken. Charges cannot flow through a broken circuit. Light switches, power buttons on radios, and even the keys on calculators and computers open and close circuits.

Types of Circuits

Look around the room. Count the number of objects that use electrical energy. You might have found things, such as lights, a clock, and maybe a computer. All of the things you counted are loads in a large circuit. The circuit may connect more than one room in the building. In fact, most circuits have more than one load.

The loads in a circuit can be connected in different ways. As a result, circuits are often divided into two types. A circuit can be a series circuit or a parallel circuit. One of the main differences in these circuits is the way in which the loads are connected to one another. As you read about each type of circuit, look closely at how the loads are connected.

Reading Check **What are two types of electric circuits?**

CONNECTION TO Biology

WRITING SKILL **Nervous Impulses** Believe it or not, your body is controlled and monitored by electrical impulses. Research the electrical impulses that travel between your brain and the muscles and organs in your body. Then, in your **science journal,** write a one-page comparison of your nervous system and an electric circuit.

series circuit a circuit in which the parts are joined one after another such that the current in each part is the same

Series Circuits

A **series circuit** is a circuit in which all parts are connected in a single loop. There is only one path for charges to follow, so the charges moving through a series circuit must flow through each part of the circuit.

All of the loads in a series circuit share the same current. The four identical light bulbs in **Figure 3** are joined in series. Because the current in each bulb is the same, the lights glow with the same brightness. But if you add more light bulbs, the resistance of the whole circuit would go up and the current would drop. Therefore, all of the bulbs would be dimmer.

Reading Check **How are loads connected in a series circuit?**

Uses for Series Circuits

A series circuit has only one pathway for moving charges. If there is any break in the circuit, the charges will stop flowing. For example, if one light bulb in a series circuit burns out, there is a break in the circuit. None of the light bulbs in the circuit would light. Using series circuits would not be a very convenient way to wire your home. Imagine if your refrigerator and a lamp were in a series circuit together. Your refrigerator would run only when the lamp was on. And when the bulb burns out, the refrigerator would stop working!

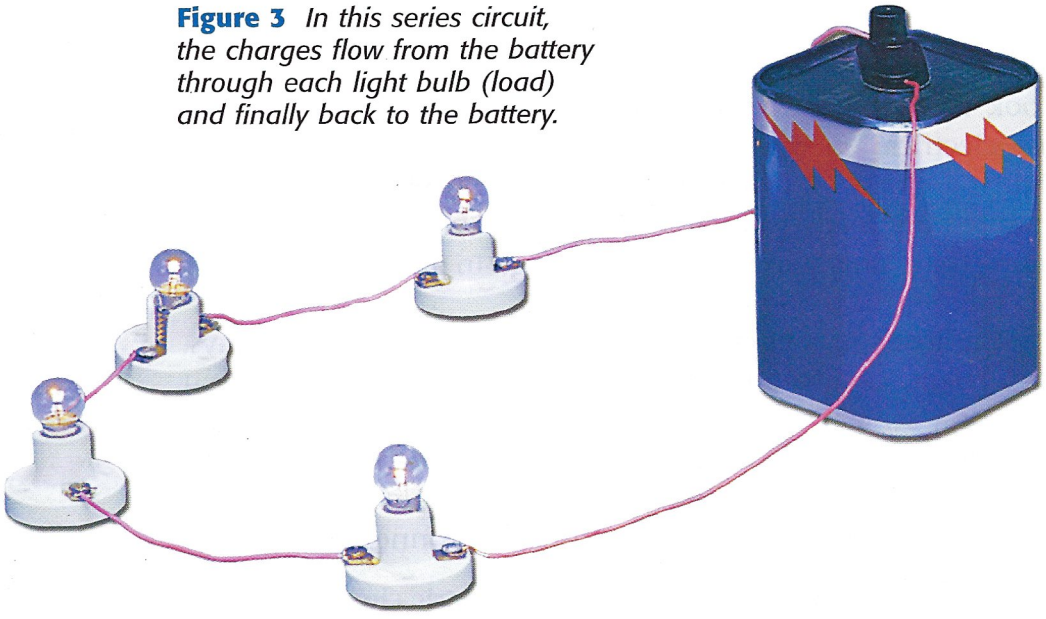
But series circuits are useful in some ways. For example, series circuits are useful in wiring burglar alarms. If any part of the circuit in a burglar alarm fails, there will be no current in the system. The lack of current signals that a problem exists, and the alarm will sound.

QUICK LAB

A Series of Circuits

1. Connect a **6 V battery** and **two flashlight bulbs** in a series circuit. Draw a picture of your circuit.
2. Add **another flashlight bulb** in series with the other two bulbs. How does the brightness of the light bulbs change?
3. Replace one of the light bulbs with a **burned-out light bulb.** What happens to the other lights in the circuit? Why?

Figure 3 *In this series circuit, the charges flow from the battery through each light bulb (load) and finally back to the battery.*



Parallel Circuits

Think about what would happen if all of the lights in your home were connected in series. If you needed to turn on a light in your room, all other lights in the house would have to be turned on, too! Instead of being wired in series, circuits in buildings are wired in parallel. A **parallel circuit** is a circuit in which loads are connected side by side. Charges in a parallel circuit have more than one path on which they can travel.

Unlike the loads in a series circuit, the loads in a parallel circuit do not have the same current. Instead, each load in a parallel circuit uses the same voltage. For example, each bulb in **Figure 4** uses the full voltage of the battery. As a result, each light bulb glows at full brightness no matter how many bulbs are connected in parallel. You can connect loads that need different currents to the same parallel circuit. For example, you can connect a hair dryer, which needs a high current to run, to the same circuit as a lamp, which needs less current.

Reading Check How are loads connected in a parallel circuit?

Uses for Parallel Circuits

In a parallel circuit, each branch of the circuit can work by itself. If one load is broken or missing, charges will still run through the other branches. So, the loads on those branches will keep working. In your home, each electrical outlet is usually on its own branch and has its own switch. Imagine if each time a light bulb went out your television or stereo stopped working. With parallel circuits, you can use one light or appliance at a time, even if another load fails.

parallel circuit a circuit in which the parts are joined in branches such that the potential difference across each part is the same

Quick Lab

A Parallel Lab

1. Connect a **6 V battery** and **two flashlight bulbs** in a parallel circuit. Draw a picture of your circuit.
2. Add **another flashlight bulb** in parallel with the other two bulbs. How does the brightness of the light bulbs change?
3. Replace one of the light bulbs with a **burned-out light bulb.** What happens to the other lights in the circuit? Why?

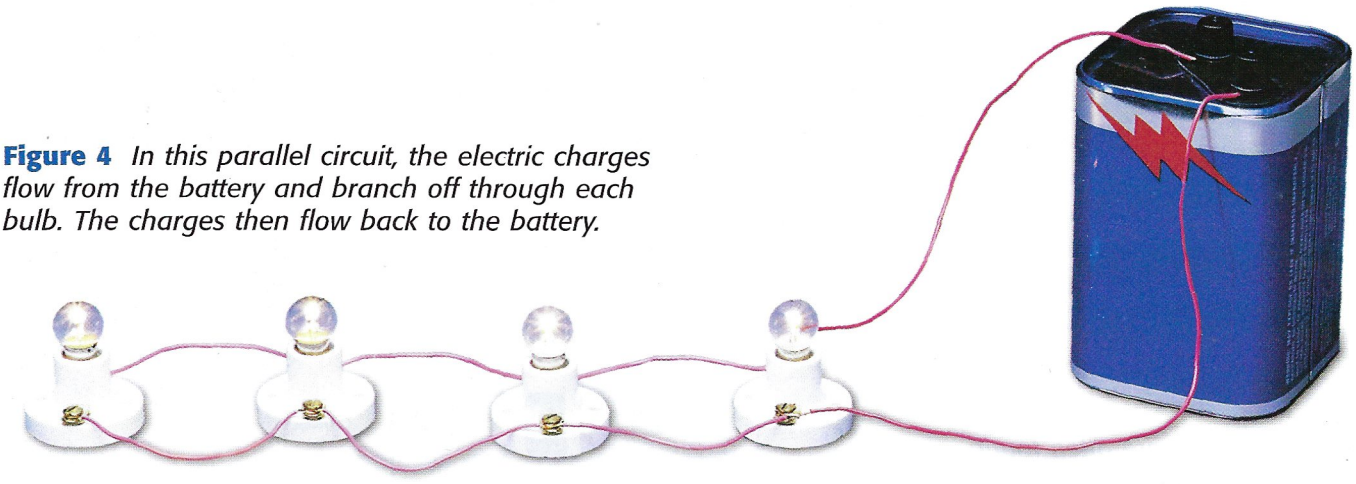


Figure 4 *In this parallel circuit, the electric charges flow from the battery and branch off through each bulb. The charges then flow back to the battery.*

Household Circuit Safety

In every home, several circuits connect all of the lights, appliances, and outlets. The circuits branch out from a breaker box or a fuse box that acts as the "electrical headquarters" for the building. Each branch receives a standard voltage, which is 120 V in the United States.

Circuit Failure

Broken wires or water can cause a short circuit. In a short circuit, charges do not go through one or more loads in the circuit. The resistance decreases, so the current increases. The wires can heat up, and the circuit could fail. The wires might even get hot enough to start a fire. Circuits also may fail if they are overloaded. When too many loads are in a circuit, the current increases, and a fire might start. Safety features, such as fuses and circuit breakers, help prevent electrical fires.

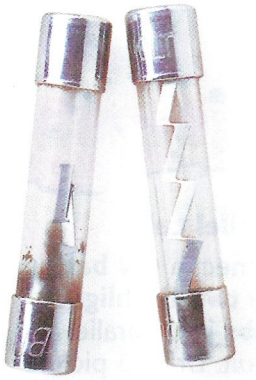


Figure 5 *The blown fuse on the left must be replaced with a new fuse, such as the one on the right.*

Fuses

A fuse has a thin strip of metal. The charges in the circuit flow through this strip. If the current is too high, the metal strip melts, as shown in **Figure 5.** As a result, the circuit is broken, and charges stop flowing.

Circuit Breakers

A circuit breaker is a switch that automatically opens if the current is too high. A strip of metal in the breaker warms up, bends, and opens the switch, which opens the circuit. Charges stop flowing. Open circuit breakers can be closed by flipping a switch after the problem has been fixed.

A ground fault circuit interrupter (GFCI), shown in **Figure 6,** acts as a small circuit breaker. If the current in one side of an outlet differs even slightly from the current in the other side, the GFCI opens the circuit and the charges stop flowing. To close the circuit, you must push the reset button.

Reading Check **What are two safety devices used in circuits?**

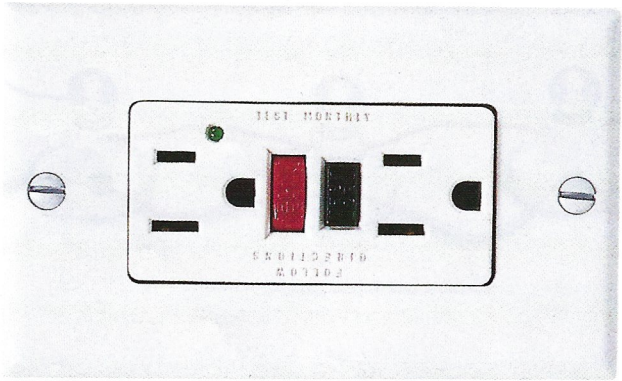


Figure 6 *GFCIs are often found on outlets in bathrooms and kitchens to protect you from electric shock.*

Electrical Safety Tips

You use electrical devices every day. So, remembering that using electrical energy can be hazardous is important. Warning signs, such as the one in **Figure 7,** can help you avoid electrical dangers. To stay safe while you use electrical energy, follow these tips:

- Make sure the insulation on cords is not worn.
- Do not overload circuits by plugging in too many electrical devices.
- Do not use electrical devices while your hands are wet or while you are standing in water.
- Never put objects other than a plug into an electrical outlet.

Figure 7 *Obeying signs that warn of high voltage can keep you safe from electrical dangers.*

SECTION Review

Summary

- Circuits consist of an energy source, a load, wires, and, in some cases, a switch.
- All parts of a series circuit are connected in a single loop. The loads in a parallel circuit are on separate branches.
- Circuits fail through a short circuit or an overload. Fuses or circuit breakers protect against circuit failure.
- It is important to follow safety tips when using electrical energy.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *series circuit* and *parallel circuit.*

Understanding Key Ideas

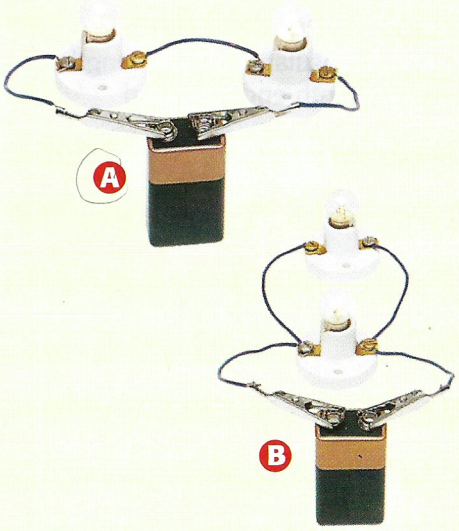
2. Which part of a circuit changes electrical energy into another form of energy?
   - **a.** energy source
   - **b.** wire
   - **c.** switch
   - **d.** load
3. Name and describe the three essential parts of a circuit.
4. How do fuses and circuit breakers protect your home against electrical fires?

Critical Thinking

5. **Forming Hypotheses** Suppose that you turn on the heater in your room and all of the lights in your room go out. Propose a reason why the lights went out.
6. **Applying Concepts** Will a fuse work successfully if it is connected in parallel with the device it is supposed to protect? Explain your answer.

Interpreting Graphics

7. Look at the circuits below. Identify each circuit as a parallel circuit or a series circuit.



Chapter Review

USING KEY TERMS

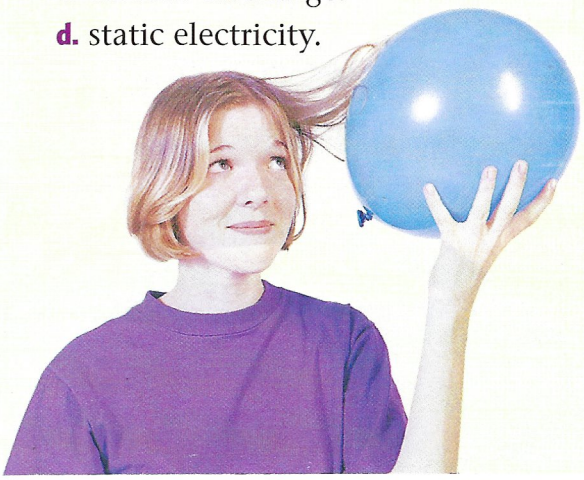
The statements below are false. For each statement, replace the underlined term to make a true statement.

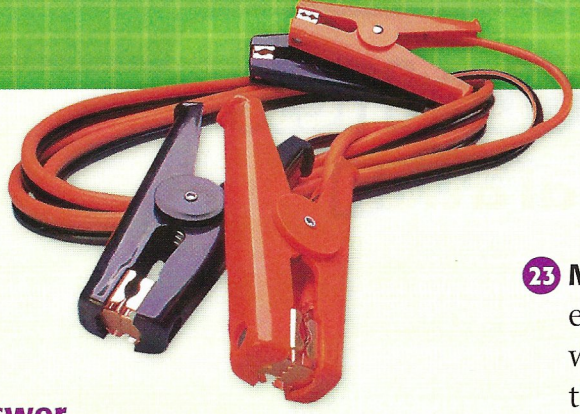
1. Charges flow easily in an <u>electrical insulator</u>.
2. Lightning is a form of <u>static electricity</u>.
3. A <u>thermocouple</u> converts chemical energy into electrical energy.
4. <u>Voltage</u> is the opposition to the current by a material.
5. <u>Electric force</u> is the rate at which electrical energy is converted into other forms of energy.
6. Each load in a <u>parallel circuit</u> has the same current.

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Two objects repel each other. What charges might the objects have?
   - **a.** positive and positive
   - **b.** positive and negative
   - **c.** negative and negative
   - **d.** Both (a) and (c)
8. Which device converts chemical energy into electrical energy?
   - **a.** lightning rod
   - **b.** cell
   - **c.** light bulb
   - **d.** switch
9. Which of the following wires has the lowest resistance?
   - **a.** a short, thick copper wire at 25°C
   - **b.** a long, thick copper wire at 35°C
   - **c.** a long, thin copper wire at 35°C
   - **d.** a short, thick iron wire at 25°C
10. An object becomes charged when the atoms in the object gain or lose
    - **a.** protons.
    - **b.** neutrons.
    - **c.** electrons.
    - **d.** All of the above
11. Which of the following devices does NOT protect you from electrical fires?
    - **a.** electric meter
    - **b.** circuit breaker
    - **c.** fuse
    - **d.** ground fault circuit interrupter
12. For a cell to produce a current, the electrodes of the cell must
    - **a.** have a potential difference.
    - **b.** be in a liquid.
    - **c.** be exposed to light.
    - **d.** be at two different temperatures.
13. The outlets in your home provide
    - **a.** direct current.
    - **b.** alternating current.
    - **c.** electric discharge.
    - **d.** static electricity.





Short Answer

14. Describe how a switch controls a circuit.

15. Name the two factors that affect the strength of electric force, and explain how they affect electric force.

16. Describe how direct current differs from alternating current.

Math Skills

17. What voltage is needed to produce a 6 A current in an object that has a resistance of 3 Ω?

18. Find the current produced when a voltage of 60 V is applied to a resistance of 15 Ω.

19. What is the resistance of an object if a voltage of 40 V produces a current of 5 A?

20. A light bulb is rated at 150 W. How much current is in the bulb if 120 V is applied to the bulb?

21. How much electrical energy does a 60 W light bulb use if it is used for 1,000 hours?

CRITICAL THINKING

22. **Concept Mapping** Use the following terms to create a concept map: *electric current, battery, charges, photocell, thermocouple, circuit, parallel circuit,* and *series circuit.*

23. **Making Inferences** Suppose your science classroom was rewired over the weekend. On Monday, you notice that the lights in the room must be on for the fish-tank bubbler to work. And if you want to use the computer, you must turn on the overhead projector. Describe what mistake the electrician made when working on the circuits in your classroom.

24. **Applying Concepts** You can make a cell by using an apple, a strip of copper, and a strip of silver. Explain how you would construct the cell, and identify the parts of the cell. What type of cell did you make? Explain your answer.

25. **Applying Concepts** Your friend shows you a magic trick. First, she rubs a plastic pipe on a piece of wool. Then, she holds the pipe close to an empty soda can that is lying on its side. When the pipe is close to the can, the can rolls toward the pipe. Explain how this trick works.

INTERPRETING GRAPHICS

26. Classify the objects in the photograph below as electrical conductors or electrical insulators.