Section 2

Electric Current

Objectives

After this lesson, students will be able to

N.2.2.1 Explain how an electric current is produced.

N.2.2.2 Explain how conductors are different from insulators.

N.2.2.3 Describe what causes electric charges to flow in a circuit.

N.2.2.4 Explain how resistance affects current.

Target Reading Skill

Outlining Explain that using an outline format helps students organize information by main topic, subtopic, and details.

Answer

Electric Current

- I. Flow of Electric Charges
  - A. What Is Electric Current?
  - B. Current in a Circuit
- II. Conductors and Insulators
  - A. Conductors
  - B. Insulators
- III. Voltage
  - A. Charges Need Energy to Flow
  - B. Voltage
  - C. Voltage Sources
- IV. Resistance
  - A. Current Depends on Resistance
  - B. Factors That Determine Resistance
  - C. Path of Least Resistance

All in One Teaching Resources

- Transparency N17

Preteach

Build Background Knowledge

L2

A Current Through a Straw

Hold up a drinking straw and a straw-type coffee stirrer. Ask: **Is it easier to drink a milkshake through a narrow straw or a wide straw?** *(Through a wide straw)* Explain that a narrow straw is more resistant to the flow of the milkshake. Therefore, you have to suck harder to get the milkshake to flow through the straw. Tell students in this section they will learn about similar concepts involving the path of electric current.

Section 2

Electric Current

Reading Preview

Key Concepts

- How is an electric current produced?
- How are conductors different from insulators?
- What causes electric charges to flow in a circuit?
- How does resistance affect current?

Key Terms

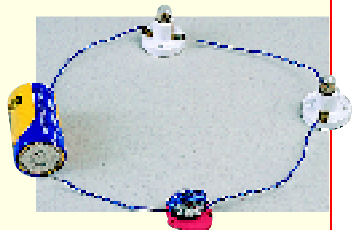
- electric current
- electric circuit
- conductor
- insulator
- voltage
- voltage source
- resistance

Target Reading Skill

Outlining As you read, make an outline about electric current. Use the red headings for the main ideas and the blue headings for the supporting ideas.

Lab zone Discover Activity

How Can Current Be Measured?

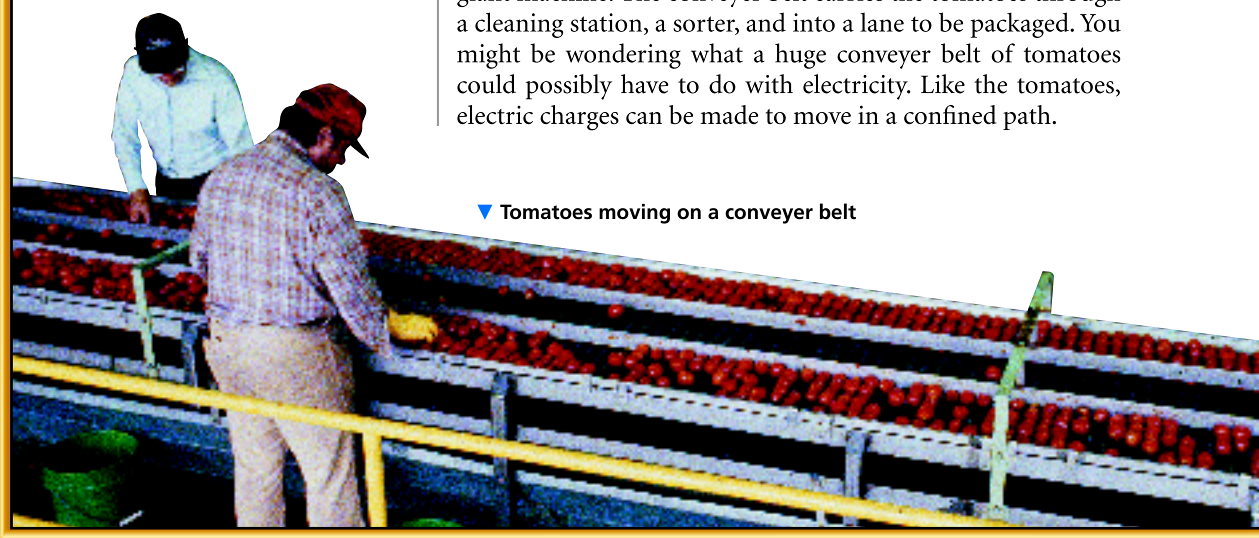


1. Obtain four pieces of wire with the insulation removed from both ends. Each piece should be about 25 cm long.
2. Wrap one of the wires four times around a compass as shown. You may use tape to keep the wire in place.
3. Build a circuit using the remaining wire, wrapped compass, two bulbs, and a D-cell as shown. Adjust the compass position so that the wire is aligned directly over the compass needle.
4. Make sure the compass is level. If it is not, place it on a piece of modeling clay so that the needle swings freely.
5. Observe the compass needle as you complete the circuit. Record the number of degrees the needle moves.
6. Repeat the activity using only one bulb, and again with no bulb. Record the number of degrees the needle moves.

Think It Over

Inferring Based on your observations of the compass, when did the compass needle move the most? How can you explain your observations?

Thousands of tomatoes ride along a conveyer belt through a giant machine. The conveyer belt carries the tomatoes through a cleaning station, a sorter, and into a lane to be packaged. You might be wondering what a huge conveyer belt of tomatoes could possibly have to do with electricity. Like the tomatoes, electric charges can be made to move in a confined path.



▼ Tomatoes moving on a conveyer belt

Lab zone Discover Activity

Skills Focus Inferring L2

Materials 1 m bell wire, wire cutters and strippers, metric ruler, magnetic compass, electrical tape, 1 1.5-volt bulbs and sockets, D-cell and holder, modeling clay

Time 15 minutes

Tips Remove the insulation from the ends of the wire. Demonstrate how to connect the batteries and then how to rewire the circuit in Step 6 each time a bulb and socket are removed.

Expected Outcome The compass needle deflects more as bulbs and sockets are removed from the circuit.

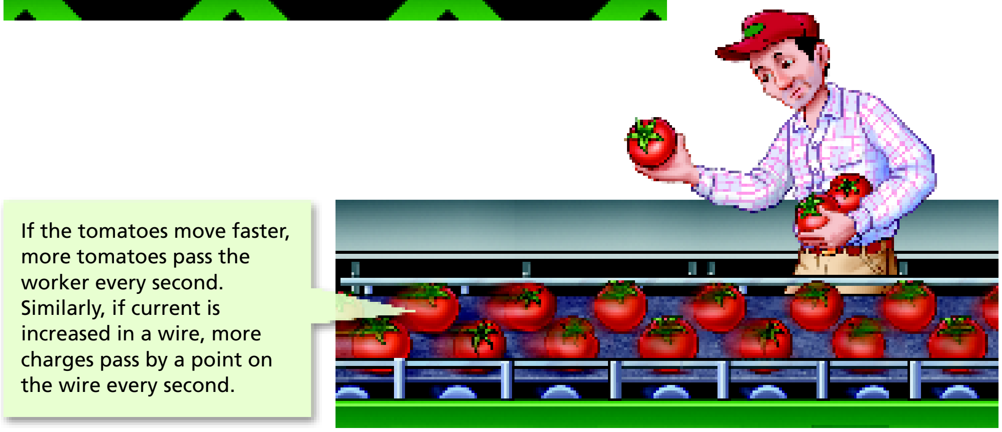
Think It Over Sample answer: The compass needle moved the most when no bulbs were present. Removing the bulbs may have increased the current.

Flow of Electric Charges

Lightning releases a large amount of electrical energy. However, the electric charge from lightning can't be used to power your TV, clock radio, video game, or kitchen lights because it only lasts for an instant. These electric devices need electric charges that flow continuously. They require electric current.

What Is Electric Current? Recall that static electric charges do not flow continuously. However, when electric charges are made to flow through a wire or similar material, they produce an electric current. **Electric current** is the continuous flow of electric charges through a material. The amount of charge that passes through the wire in a unit of time is the rate of electric current. The unit for the rate of current is the ampere, named for André Marie Ampère, an early investigator of electricity. The name of the unit is often shortened to *amp* or *A*. The number of amps describes the amount of charge flowing past a given point each second.

FIGURE 7
Representing an Electric Current
Tomatoes moving on a conveyer belt are similar to charges moving in a wire, or electric current.
Interpreting Photos *Which characteristics of electric current are represented in the illustrations?*



Instruct

Flow of Electric Charges

Teach Key Concepts L2

A Continuous Flow of Charges

Focus Explain that in static electricity, charges build up in an object, but the charges do not flow continuously. By contrast, an electric current is the continuous flow of electric charges through a material.

Teach Ask: **What is the rate of electric current?** *(The amount of charge that passes through a wire in a unit of time)* **What unit is used for rate of current?** *(The ampere, or amp)*

Apply Tell students that an electric current is flowing through two different wires, and the current through wire A has more amps that the current flowing through wire B. Ask: **What can you say about the electric charges flowing through each of the wires?** *(More charges are flowing past a given point per second in wire A than in wire B.)* **learning modality: verbal**

Independent Practice L2

All in One **Teaching Resources**

- Guided Reading and Study Worksheet: *Electric Current*

Student Edition on Audio CD

Differentiated Instruction

Less Proficient Readers L1

Identifying Supporting Ideas Have students listen to this section on the **Student Edition on Audio CD.** As they listen, they can identify supporting ideas and add them under the appropriate headings and subheadings in their section outlines. **learning modality: verbal**

Gifted and Talented L3

Communicating Have students find other real-world analogies to represent current and prepare a presentation to the class. Ask that they include a drawing or photograph to show to the class. **learning modality: verbal**

Monitor Progress L2

Writing Have students write a paragraph that explains how an electric current is like a conveyor belt.

Answer

Figure 7 An electric current consists of the continuous flow of charges through a material, similar to the flow of tomatoes on a conveyor belt.

Use Visuals: Figure 8

L2

An Unbroken Path

Focus Tell students that for an electric current to exist, charges must be able to flow from one place to another with no gaps in the path.

Teach Have students study Figure 8 and read the caption. Ask: **What is an electric circuit?** *(A complete, unbroken path through which electric charges flow)* **Why is a racetrack like an electric circuit?** *(Both a racetrack and an electric circuit form a complete path, or closed loop.)* Emphasize that a closed loop is a path from the beginning of the circuit, through the circuit, and back to the beginning of the circuit.

Apply Ask: **What are some other examples of closed loops?** *(Sample answer: A jogging track; a roller coaster.)* **learning modality: visual**

Conductors and Insulators

Teach Key Concepts

L2

Transfer of Charges Through Materials

Focus Tell students that electric charges do not flow through all materials equally well. Materials through which charges flow easily are called conductors, while materials through which charges do not flow easily are called insulators.

Teach Ask: **What is the difference between electrons in the atoms of conductors and the electrons in the atoms of insulators?** *(In a conductor, atoms contain electrons that are loosely bound and able to move through the conductor. In an insulator, the electrons are bound tightly to their atoms and do not flow easily.)* **What are some good conductors?** *(Metals, such as silver, copper, aluminum, and iron)* **What are some good insulators?** *(Rubber, glass, sand, plastic, and wood)*

Apply Show students an electric cord that is stripped at the end. Ask: **Which material is a conductor?** *(The inside metal part of the cord)* **Which is the insulator?** *(The outside covering of the cord)* **learning modality: visual**

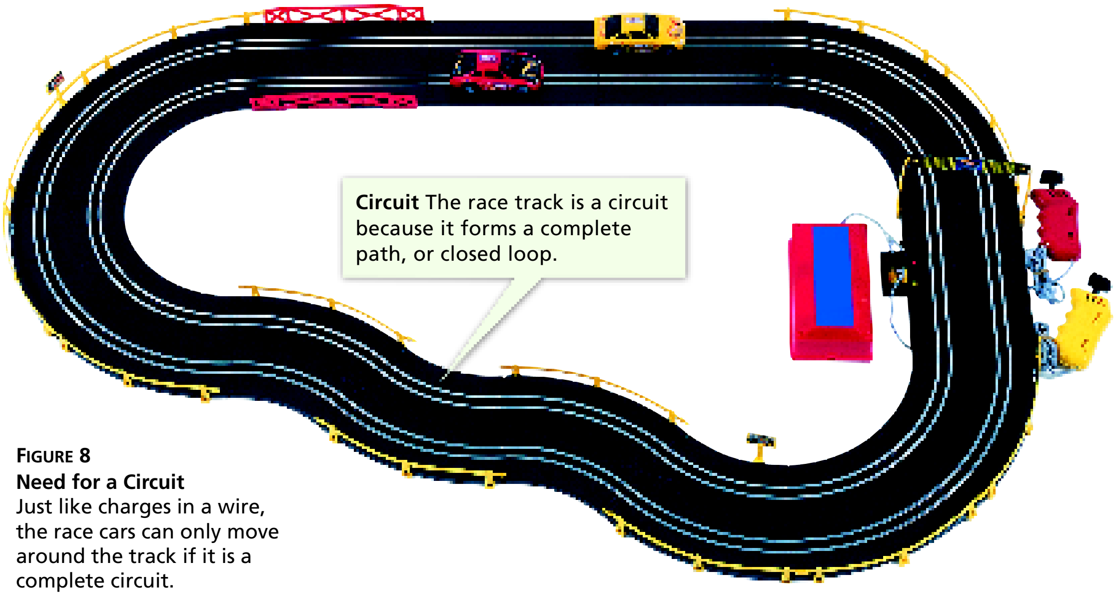


FIGURE 8
Need for a Circuit
Just like charges in a wire, the race cars can only move around the track if it is a complete circuit.

Current in a Circuit Electric current does not automatically exist in a material. Current requires a specific path to follow. **To produce electric current, charges must flow continuously from one place to another.** Current requires an electric circuit. An **electric circuit** is a complete, unbroken path through which electric charges can flow.

The cars on the racetrack in Figure 8 are like the charges in an electric circuit. If the racetrack forms a complete loop, the cars can move around the track continuously. However, if a piece of the racetrack is missing, the cars are unable to move around the loop. Similarly, if an electric circuit is complete, charges can flow continuously. If an electric circuit is broken, charges will not flow.

Electric circuits are all around you. All electrical devices, from toasters to radios to electric guitars and televisions, contain electric circuits. You will learn more about the characteristics of electric circuits in Section 4.

Reading Checkpoint **What is an electric circuit?**

Conductors and Insulators

Charges flow easily through a circuit made of metal wires. But would charges flow in wires made of plastic? The answer is no. Electric charges do not flow easily through every material. **A conductor transfers electric charge well. An insulator does not transfer electric charge well.** Figure 9 shows materials that are good conductors and materials that are insulators.

Conductors Metals, such as silver, copper, aluminum, and iron, are good conductors. A **conductor** is a material through which charge can flow easily. In a conductor, atoms contain electrons that are bound loosely. These electrons, called conduction electrons, are able to move throughout the conductor. As these electrons flow through a conductor, they form an electric current. Conductors are used to carry electric charge.

Did you ever wonder why a light goes on the instant you flip the switch? How do the electrons get to your lamp from the electric company so fast? The answer is that electrons are not sent to your house when you flip a switch. They are already present inside the conductors that make up the circuit. When you flip the switch, electrons at one end of the wire are pulled, while those at the other end are pushed. The result is a continuous flow of electrons through all parts of the circuit as soon as the circuit is completed.

Insulators A material through which charges cannot flow easily is called an **insulator**. The electrons in an insulator are bound tightly to their atoms and do not move easily. Rubber, glass, sand, plastic, and wood are good insulators. Insulators are used to stop the flow of charges.

The rubber coating on an appliance cord is an example of an insulator. A cord carries charges from an electrical outlet to an appliance. So why don't you get a shock when you touch a cord? The inner wire is the conductor for the current. The rubber coating around the wire is an insulator. The cord allows charge to continue to flow to the appliance, but stops it from flowing into your hand and shocking you.

Reading Checkpoint **Why don't you get a shock from touching an extension cord?**

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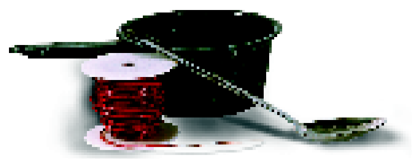
Conductors



Insulators

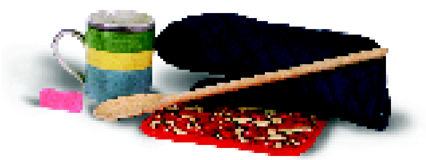


FIGURE 9
Conductors and Insulators
Charges easily move through conductors. In contrast, charges do not move easily through insulators. Classifying *In which category do metals belong?*

Address Misconceptions L1

Metals Aren't the Only Conductors

Focus Many students may think that metals are the only good conductors. Tell them that although many metals are good conductors, other materials conduct electric current as well.

Teach Explain that good conductors also include various liquids and gases. Tell students that they will learn later that charges flow easily through liquids and pastes in batteries.

Apply Turn on a fluorescent light. Explain that a fluorescent light bulb contains a gas through which charges flow freely. Ask: **If charges flow freely through the gas in this bulb, how would you classify the gas?** *(As a conductor, because a conductor is a material through which charges can easily flow)*
learning modality: verbal

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Students can review electric currents in an online interactivity.

Monitor Progress L2

Oral Presentation Call on students at random to give one example of a conductor and one example of an insulator and to describe the difference between them.

Answers

Figure 9 Metals are good conductors.

Reading Checkpoint A complete, unbroken path through which electric charges can flow

Reading Checkpoint The coating on the cord is an insulator, which keeps charges from flowing into your body.

Voltage

Teach Key Concepts

L2

Potential Difference in a Circuit

Focus Explain to students that current is present in an electric circuit because there is a difference in electrical potential energy between two places in the circuit.

Teach Ask: **What causes a current in an electric circuit?** *(Voltage)* Tell students that the terms *voltage* and *potential difference* are two terms for the same concept. Explain that for current to flow, there must be a force that causes it to flow. That force is voltage. Ask: **What maintains voltage in an electric circuit?** *(A voltage source)* **What are two examples of a voltage source?** *(Batteries and generators)*

Apply Use the analogy shown in Figure 10 to clarify concepts related to voltage. Ask: **What is the roller coaster motor like in an electric circuit?** *(A voltage source)* **What happens when the car reaches the top of the hill?** *(It moves down the hill.)* **Why does it move down the hill?** *(Potential energy at the top of the hill is higher than at the bottom of the hill.)* **What does this difference in potential energy represent in an electric circuit?** *(Voltage, or difference in electrical potential energy)* **learning modality: visual**

Help Students Read

Identifying Supporting Evidence Refer to the Content Refresher in this chapter, which provides the guidelines for identifying supporting evidence.

Have students read the subsection related to voltage. Ask: **What is the hypothesis for this subsection?** *(Sample answer: Voltage causes current in an electric circuit.)* Write the hypothesis on the board, leaving enough room around it to add supporting evidence. This will be the center of a graphic organizer. As students read, have them call out the supporting evidence for the hypothesis. Ask: **What is one piece of evidence that supports this hypothesis?** *(Sample answer: Charges in an electric circuit flow because of a difference in electrical potential energy.)* Write the supporting evidence on the board, drawing "spokes" from each piece of evidence to the hypothesis.

Lab zone Try This Activity

Down the Tubes

Use water to model voltage.

1. Set up a funnel, tubing, beaker, and ring stand as shown.

2. Have a partner start a stopwatch as you pour 200 mL of water into the funnel.
3. Stop the stopwatch when all of the water has flowed into the beaker.
4. Repeat steps 2 and 3 setting the funnel at different heights.

Making Models How did your model represent voltage? How did changing the height affect the model's "voltage"?

Voltage

Imagine you are on a roller coaster at an amusement park. Strapped in your seat, you wait anxiously as your car climbs to the top of the hill. Then, whoosh! Your car speeds down the steel track. Believe it or not, electric charges flow in much the same way as your roller coaster car moves on the track.

Charges Need Energy to Flow The roller coaster cars need energy to give you an exciting ride, but they have no energy when you first climb aboard. A motor provides energy to move a chain attached to the cars. The moving chain pulls the cars to the top of the hill. As they climb, the cars gain potential energy. Potential energy is the energy an object has as a result of its position, or height. The higher up the hill the chain carries the cars, the more potential energy the cars gain. Then, after reaching the hilltop, the cars rush down the hill. As they do, they move from a place of high potential energy—the hilltop—to a place of low potential energy—the bottom of the hill. It is the difference in potential energy between the hilltop and the bottom of the hill that allows the cars to speed down the hill.

In a similar way, charges in an electric circuit flow because of a difference in electrical potential energy. Think of the charges that make up the electric current as being like the roller coaster cars. The circuit is like the steel track. An energy source, such as a battery, is like the roller coaster motor. The battery provides the potential energy difference for the circuit. However, its potential energy is not related to height, as in the roller coaster. Instead it is related to the charges inside the battery.

Voltage Just as the roller coaster creates a difference in potential energy between two places, so does an electric circuit. The difference in electrical potential energy between two places in a circuit is called **voltage,** or potential difference. The unit of measure of voltage is the volt (V). **Voltage causes a current in an electric circuit.** You can think of voltage as the amount of force pushing an electric current.

Voltage Sources At the amusement park, if there were no way of pulling the roller coaster cars to the top of the first hill, there would be no ride. Recall that the ride has a source of energy, a motor. The motor moves the chain that takes the cars to the top of the hill. Once the cars reach the top of any hill, they gain a high potential energy.

Lab zone Try This Activity

Skills Focus Making Models L1

Materials 2-mL beakers, funnel, ring stand, clear tubing of various lengths and widths, stopwatch

Time 15 minutes

Tips Have students work in pairs. Keep paper towels handy to clean up spills.

Expected Outcome The height of the tubing represents voltage or potential difference. The higher the funnel, the more potential energy the water has, or the higher the model's "voltage."

Extend Challenge students to find out what happens if they increase or decrease resistance by using tubing of different lengths and widths. **learning modality: kinesthetic**

An electric circuit also requires a source of energy, such as a battery, to maintain a voltage. A **voltage source** is a device that creates a potential difference in an electric circuit. Batteries and generators are examples of voltage sources. A voltage source has two terminals. The voltage between the terminals causes charges to move around the circuit.

Reading Checkpoint **What does a voltage source do?**

FIGURE 10
Voltage
Voltage in a circuit is similar to the difference in potential energy on a roller coaster. **Interpreting Diagrams** *From where do the cars get their energy?*

Lab zone Build Inquiry L2

Modeling Potential Difference

Materials plastic bottle with small hole in bottom and cap removed, flexible plastic tubing, basin, modeling clay

Time 15 minutes

Focus Tell students they can design and build a model that can represent what happens as voltage, or potential difference, increases.

Teach Divide the class into groups and provide each group with a set of materials. Challenge each group to design a model using the given materials and water that will show what happens as voltage increases. Give groups time to plan their models.

Apply Check student plans, and then allow them to test their models. A sample model might be to insert tubing through the bottom of the bottle, seal around the tubing with modeling clay, and fill the bottle with water. When the end of the plastic tube is at the same height as the top of the water bottle, no water flows, because there is no potential difference. As the bottle is raised or the end of the tubing is lowered, the water flows faster and faster—higher and higher potential difference. **learning modality: kinesthetic**

Monitor Progress L2

Writing Ask students to write a paragraph explaining why voltage is needed for current to flow.

Answers

Figure 10 The motor provides energy to the roller coaster cars.

Reading Checkpoint A voltage source creates a potential difference in an electric circuit.

Resistance

Teach Key Concepts

L2

The Difficulty of Flowing

Focus Explain that charges have more difficulty flowing through some materials than others.

Teach Ask: **What is resistance?** *(The measure of how difficult it is for charges to flow through a material.)* Write the term *Resistance* on the board, and ask: **What are the four factors that determine the resistance of any object?** *(The material, the length of the material, the diameter of the material, and the temperature of the material)* Write each factor on the board, and question students about the details of each.

Apply Ask: **If there is more resistance in a circuit, is there more or less current for a given voltage?** *(Less)* **Do longer wires have more or less resistance?** *(More)* **Therefore, does a longer wire have more or less current than a shorter wire, if the voltage is the same in both wires?** *(The longer wire has less current because it has more resistance.)* **learning modality: verbal**

All in One Teaching Resources

- Transparency N18

Lab zone Teacher Demo

L1

The Path of Least Resistance

Materials latex glove, push pin, scissors, sink or basin

Time 10 minutes

Focus Tell students that you will model with water a path of least resistance.

Teach Fill the glove with water until the water is about 4–6 cm from the top of the wrist. Then tie the wrist. Hold the glove over the sink or basin with the fingers pointed upward, and put a single pinhole in one finger of the glove. Then snip the tip off a different finger. Ask students to predict what will happen if you turn the glove back over. Allow students to observe the water flowing out of the fingers of the glove.

Apply Ask: **Which path offered the least resistance? Why?** *(The path through the finger with the larger hole offered the path of least resistance, because the water could flow out of that hole more quickly.)* **learning modality: visual**

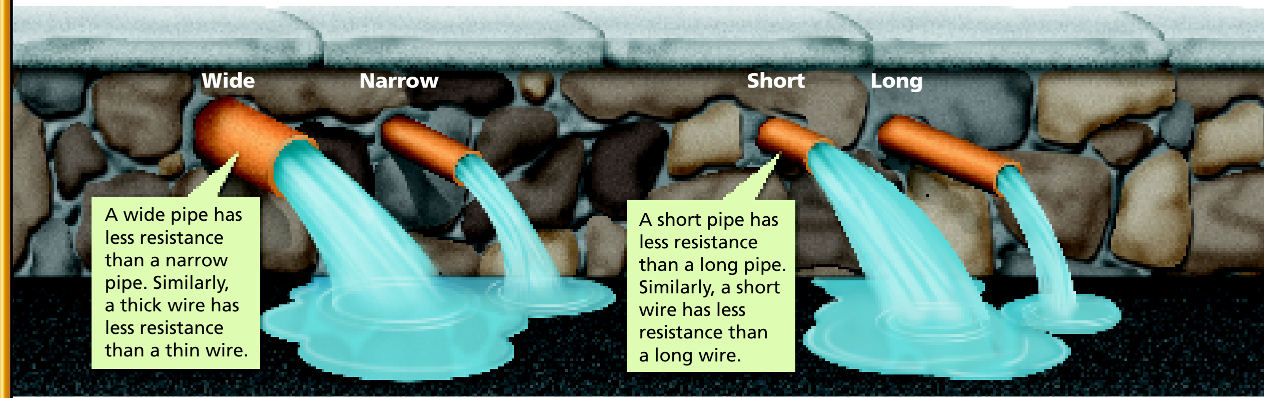


FIGURE 11
Resistance
Two factors that affect the resistance of water flowing in a pipe are diameter and length. The diameter and length of a wire also affect resistance in a circuit.
Inferring *If you reduce the resistance in a circuit, will there be more or less current?*

Resistance

In the example of the roller coaster, you only learned how the height difference, or "voltage," affected the cars' speed. But other factors affect how fast the cars move. For instance, if the roller coaster cars have rusty wheels, their speed will decrease because the wheels do not turn as well. Current in a circuit works in a similar way.

Current Depends on Resistance The amount of current that exists in a circuit depends on more than just the voltage. Current also depends on the resistance of the material. **Resistance** is the measure of how difficult it is for charges to flow through a material. **The greater the resistance, the less current there is for a given voltage.** The unit of measure of resistance is the ohm (Ω). The ohm is named for Georg Ohm, a German physicist who investigated resistance.

Factors That Determine Resistance There are four factors that determine the resistance of a wire, or any object. The first factor is the material from which the wire is made. Some materials, such as insulators, have electrons that are tightly held to their atoms. Insulators have a high resistance because it is difficult for charges to move. Other materials, such as conductors, have electrons that are loosely held to their atoms. Conductors have a low resistance because charges can move through them easily.

The second factor is length. Long wires have more resistance than short wires. The resistance of current in a wire can be compared to the resistance of water flowing through a pipe. Suppose water is being released from a reservoir held by a dam. As shown in Figure 11, less water flows from the reservoir through the long pipe than through the short pipe. The water in the long pipe slows down because it bumps into more of the pipe's inner wall.

Diameter is the third factor. In Figure 11, the pipe with the small diameter has less water flowing through it than the pipe with the large diameter. In the small-diameter pipe, there is less area through which the water can flow. Similarly, thin wires have more resistance than thick wires.

The fourth factor that determines the resistance of a wire is the temperature of the wire. The electrical resistance of most materials increases as temperature increases. As the temperature of most materials decreases, resistance decreases as well.

Path of Least Resistance Perhaps you have heard it said that someone is taking the "path of least resistance." This means that the person is doing something in the easiest way possible. In a similar way, if electric charge can flow through either of two paths, more of the charge will flow through the path with lower resistance.

Have you seen a bird perched on an uninsulated electric fence? The bird doesn't get hurt because charges flow through the path of least resistance. Since the bird's body offers more resistance than the wire, charges flow directly through the wire without harming the bird.

FIGURE 12
Which Path?
Charges flow through the wire, not the bird, because the wire offers less resistance.

Reading Checkpoint **What is the "path of least resistance"?**

Section 2 Assessment

Target Reading Skill Outlining Use your outline to help you answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** What happens when an electric current is produced?
   b. **Comparing and Contrasting** Contrast electric current and static electricity.
   c. **Relating Cause and Effect** Explain why electric current cannot exist if an electric circuit is broken.
2. a. **Defining** Define *conductor* and *insulator*.
   b. **Listing** List materials that make good conductors. List materials that are insulators.
   c. **Applying Concepts** If a copper wire in a working electric circuit is replaced by a piece of rubber tubing, will there be a current in the circuit? Explain.
3. a. **Listing** What are two examples of voltage sources?
   b. **Explaining** How does voltage cause electrons to flow in a circuit?
   c. **Predicting** The electrical potential energy at one point in a circuit is greater than the electrical potential energy at another point. Will there be a current between the two points? Explain.
4. a. **Reviewing** What is resistance?
   b. **Summarizing** What are four factors that determine resistance?

Writing in Science

Analogies An analogy can help people understand new information by comparing it to something familiar. Write a paragraph that compares an electric circuit to skiing down a slope and riding the chairlift to the top.

Monitor Progress L2

Answers
Figure 11 More current
Reading Checkpoint The path with lower resistance.

Assess

Reviewing Key Concepts

1. a. A continuous flow of charges travels through a material. **b.** An electric current is a continuous flow of charge. Although charges build up on an object in static electricity, the charges do not flow. **c.** A continuous flow of charge cannot occur because the path is no longer complete.
2. a. A conductor is a material through which charges can flow easily. An insulator is a material through which charges cannot flow easily **b.** Sample answer: Silver, copper, aluminum, and iron are examples of good conductors. Rubber, sand, plastic, glass, and wood are examples of good insulators. **c.** There will be no current because rubber is an insulator.
3. a. Sample answer: Batteries and generators **b.** Voltage can be thought of as the amount of force pushing an electric current. **c.** Yes. A difference in electrical potential energy in a circuit causes charges to flow in the circuit, resulting in a current.
4. a. Resistance is the measure of how difficult it is for charges to flow through a material. **b.** Four factors that determine resistance are the material, the length of the material, the diameter of the material, and the temperature of the material.

Reteach L1

Have students create a concept map using the terms *electric current, electrical potential, voltage, resistance, ohms, amperes*, and *volts*.

Performance Assessment L2

Skills Check Ask each student to write two questions each about electric currents, conductors and insulators, voltage, and resistance. Then, divide the class into groups and have group members ask each other to answer their questions.

All in One Teaching Resources
- Section Summary: *Electric Current*
- Review and Reinforce: *Electric Current*
- Enrich: *Electric Current*

Lab zone Chapter Project

Keep Students on Track By this point in the project, students should have begun to construct their alarm circuits. Each student should have designed a detector switch that closes when an event occurs. Talk to each student, and try to provide any materials they might need to complete the building of their circuits.

Writing in Science

Writing Mode Analysis
Scoring Rubric
4 Exceeds criteria; develops the analogy accurately and interestingly
3 Meets criteria
2 Meets some criteria; fails to fully develop the analogy
1 Fails to develop the analogy in an accurate way

Lab zone Skills Lab

L2

Constructing a Dimmer Switch

Prepare for Inquiry

Key Concept

The brightness of a bulb is controlled by the amount of current flowing in the circuit, which in turn depends on the voltage and the resistance in the circuit.

Skills Objectives

After this lab, students will be able to:

- predict how the brightness of the bulb will change
- observe the change in brightness of the bulb

Prep Time 10 minutes

Class Time 30 minutes

Advance Planning

Cut the copper wire and the rubber tubing to the same length as the pencil lead.

Alternative Materials

Any nonconductor, such as wood or plastic, can be substituted for the rubber tubing.

Safety

Caution students to be careful not to break the flashlight bulb. Review the safety guidelines in Appendix A.

All in One Teaching Resources

- Lab Worksheet: *Constructing a Dimmer Switch*

Guide Inquiry

Invitation

Ask students to think about sitting in a movie theater just as the show is about to begin. Ask: **When people are arriving, are the lights on or off?** *(On)* **During the show, are the lights on or off?** *(Off)* **Do the lights all go off suddenly?** *(No. They gradually get dimmer.)*

Lab zone Skills Lab

Constructing a Dimmer Switch

Problem

What materials can be used to make a dimmer switch?

Skills Focus

predicting, observing

Materials

- D-cell
- masking tape
- flashlight bulb in a socket
- thick lead from mechanical pencil
- uninsulated copper wire, the same length as the pencil lead
- rubber tubing, the same length as the pencil lead
- 1 wire, 10–15 cm long
- 2 wires, 20–30 cm long
- 2 alligator clips

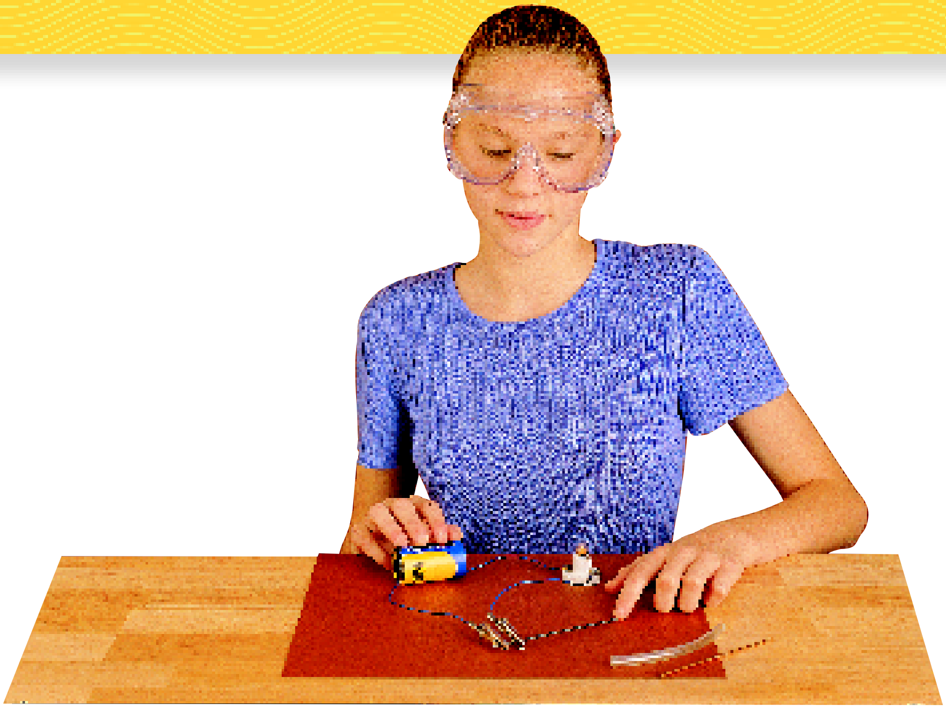
Procedure

1. To make a device that can dim a light bulb, construct the circuit shown in the photo on the opposite page. To begin, attach wires to the ends of the D-cell.
2. Connect the other end of one of the wires to the bulb in a socket. Attach a wire with an alligator clip to the other side of the socket.
3. Attach an alligator clip to the other wire.
4. The pencil lead will serve as a resistor that can be varied—a variable resistor. Attach one alligator clip firmly to the tip of the pencil lead. Be sure the clip makes good contact with the lead. (*Note*: Pencil "lead" is actually graphite, a form of the element carbon.)
5. Predict how the brightness of the bulb will change as you slide the other alligator clip back and forth along the lead. Test your prediction.

Introduce the Procedure

Have students read through the entire procedure, and then answer any questions they have. Explain that pencil lead is not made of lead but graphite, a form of carbon.

Tell students that the drawing part of a pencil is called lead because people use to draw on paper with the metal lead before pencils were invented.



6. What will happen to the brightness of the bulb if you replace the lead with a piece of uninsulated copper wire? Adapt your pencil-lead investigation to test the copper wire.
7. Predict what will happen to the brightness of the bulb if you replace the pencil lead with a piece of rubber tubing. Adapt your pencil-lead investigation to test the rubber tubing.

Analyze and Conclude

1. **Controlling Variables** What variable did you manipulate by sliding the alligator clip along the pencil lead in Step 5?
2. **Observing** What happened to the brightness of the bulb when you slid the alligator clip along the pencil lead?
3. **Predicting** Explain your reasoning in making predictions about the brightness of the bulb in Steps 6 and 7. Were your predictions supported by your observations?
4. **Interpreting Data** Do you think that pencil lead has more or less resistance than copper? Do you think it has more or less resistance than rubber? Use your observations to explain your answers.
5. **Drawing Conclusions** Which material tested in this lab would make the best dimmer switch? Explain your answer.
6. **Communicating** Suppose you want to sell your dimmer switch to the owner of a theater. Write a product information sheet that describes your device and explains how it works.

More to Explore

The volume controls on some car radios and television sets contain resistors that can be varied, called rheostats. The sliding volume controls on a sound mixing board are rheostats as well. Homes and theaters may use rheostats to adjust lighting. Where else in your house would rheostats be useful? (*Hint*: Look for applications where you want to adjust a device gradually rather than just turn it on or off.)

Troubleshooting the Experiment

- Poor contact between alligator clips and the pencil lead can be improved by buffing the lead with sandpaper.
- To make a quantitative comparison of bulb brightness, students could use small pieces of paper through which they view the bulb. They can compare the brightness by how many pieces of paper they can see the bulb through. This procedure works best in a darkened room.

Expected Outcome

As students include more pencil lead in the circuit, the total resistance increases and current decreases, and so the bulb becomes dimmer. When students move the clips close together—making the circuit contain less graphite—the total resistance decreases and the bulb becomes brighter. Students will observe that the copper wire conducts well and the rubber tubing doesn't conduct at all.

Analyze and Conclude

1. Resistance. The amount of resistance increased as the length of pencil lead increased.

2. The bulb became dimmer as the length of lead in the circuit increased.

3. Sample answer: I reasoned that the brightness would increase in Step 6 because copper is an excellent conductor. I reasoned that the bulb would not light in Step 7 because rubber is an excellent insulator. My observations supported my predictions.

4. Sample answer: My tests showed that pencil lead has more resistance than copper and that rubber has such a high resistance that it did not conduct electric current at all.

5. Sample answer: Pencil lead. Copper wire would have to be very long to offer enough resistance, and rubber would not conduct enough.

6. Students' product information sheets should describe the dimmer device and explain how it works. Students also may explain how a dimmer switch could help a theater owner create pleasant, low-light conditions while trailers are being shown and moviegoers are moving in and out of their seats. A dimmer switch might also save money for the owner by decreasing their theaters' use of electricity.

Extend Inquiry

More to Explore Students' should find that variable resistors are common and useful in household devices such as electric dryers, exercise treadmills, ceiling fans, and variable-speed tools.