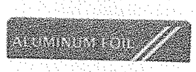
Inquiry **Skill Practice** **Follow a Procedure** 40 minutes

How can you build your own electroscope?

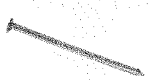
Have you noticed how a brush and your hair become less electrically charged on humid days when there is a lot of moisture in the air? That is because water molecules in the air carry away the electric charge instead of letting it build up on surfaces, such as your hair. You can use an electroscope to detect the presence of an electric charge. In this activity, you will follow a procedure to construct your own electroscope, electrically charge it, and observe the ways it discharges.

Materials

paper clip



aluminum foil



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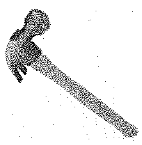
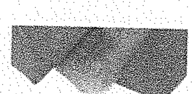


hammer



fabric samples

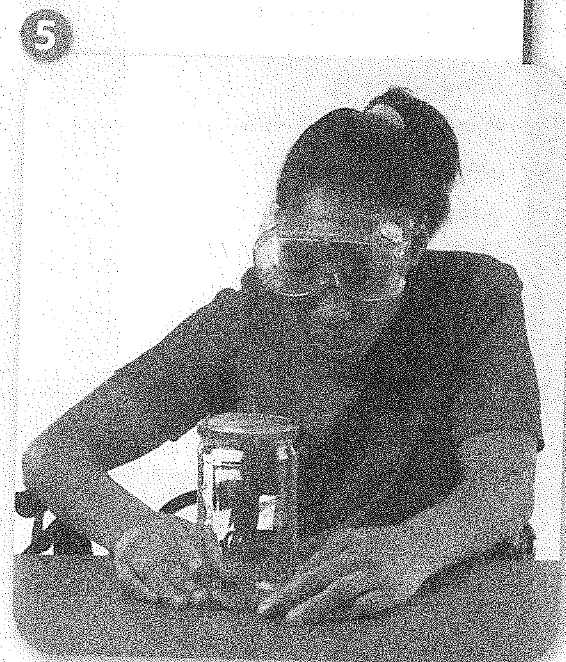
glass jar with metal lid

Also needed: assorted items to be electrically charged

Safety

Learn It

In order to construct and use a scientific device, you need to understand the properties of the materials to be used. Also, you need to know how and in what order to use the materials. To build a reliable device, you need to **follow a procedure.**

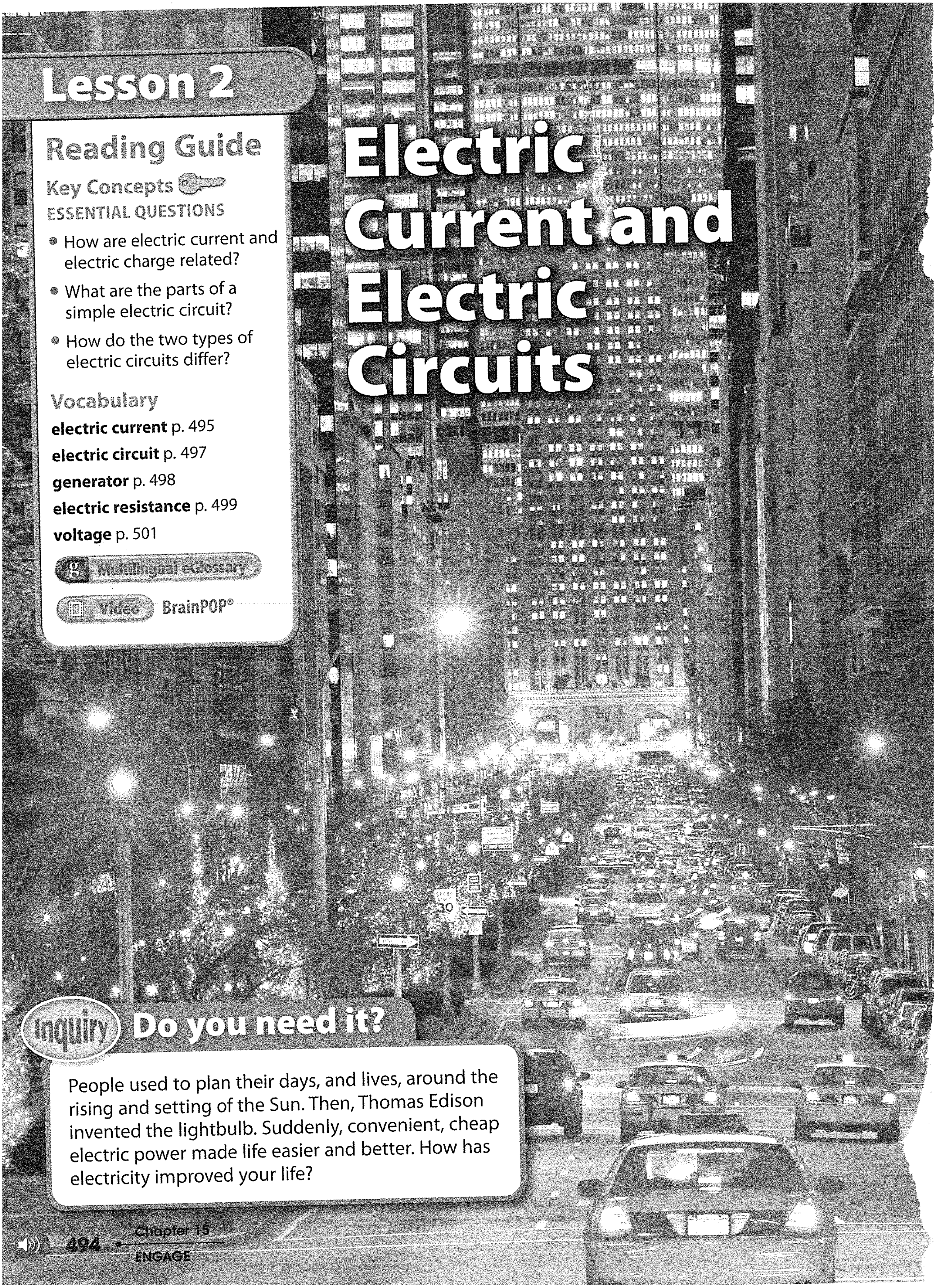


Try It

1. Read and complete a lab safety form.
2. Use a hammer and nail to poke a small hole in a jar lid.
3. Unfold a paper clip, and bend it into an L shape.
4. Push the long end of the paper clip L up through the hole in the lid. Bend the paper clip above the lid so it hangs through the lid without falling out.
5. Smooth the aluminum foil with your finger. Cut off a strip 4 cm by 1 cm. Fold the strip in half, and hang it from the paper clip below the lid.
6. Screw the lid on the jar.
7. Touch uncharged and charged objects to the paper clip. Record your observations of the hanging foil strip in your Science Journal.
8. Bring charged and uncharged objects near the paper clip, but do not touch it. Record your observations.

Apply It

9. **Explain** the importance of following a procedure.
10. **Classify** the components of your electroscope as conductors or insulators.
11. **Key Concept** Contrast the behavior of the foil to the ways the foil is charged.



Lesson 2

Electric Current and Electric Circuits

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

- How are electric current and electric charge related?
- What are the parts of a simple electric circuit?
- How do the two types of electric circuits differ?

Vocabulary

electric current p. 495

electric circuit p. 497

generator p. 498

electric resistance p. 499

voltage p. 501

g Multilingual eGlossary

Video BrainPOP®

Inquiry Do you need it?

People used to plan their days, and lives, around the rising and setting of the Sun. Then, Thomas Edison invented the lightbulb. Suddenly, convenient, cheap electric power made life easier and better. How has electricity improved your life?

Inquiry Launch Lab

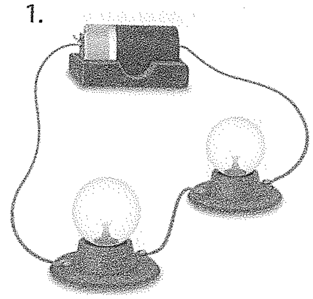
20 minutes

What are two ways to light two lightbulbs?

There are two ways to connect a battery and two lightbulbs so both bulbs light. Each way uses an electric conductor to create a path from the battery to each lightbulb and back to the battery.

1. Read and complete a lab safety form.
2. Examine the first diagram. Using **two lightbulbs in bases, one battery in a holder,** and **several wires,** construct the setup so both bulbs light.
3. Remove one bulb from its base. Observe the behavior of the other bulb. Record your observations in your Science Journal.
4. Examine the second diagram, and construct the setup. Both bulbs should be lit.
5. Unscrew one bulb from its base. Again, observe the behavior of the other bulb. Record your observations.

1.



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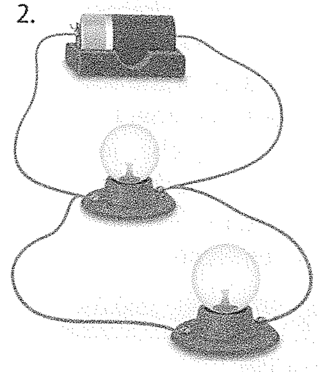


Think About This

1. Sketch each setup, and draw the path that connects the lightbulbs and the battery.
2. Describe how the brightness of the lightbulbs in each setup differs. Why do you think there is this difference?
3. **Key Concept** How do the two setups differ?

Electric Current—Moving Electrons

You read in Lesson 1 that electrons have the property of negative electric **charge.** Recall that negatively charged electrons are the tiny particles that move around the nuclei of atoms. Also, recall that many of the electrons of an electric conductor, such as a metal wire, easily move from atom to atom. When free electrons move in the same direction, an electric current is produced. *An* **electric current** *is the movement of electrically charged particles, such as electrons.*

Like all moving objects, moving electrons have kinetic energy. As electrons move from atom to atom, their kinetic energy transforms to other useful energy forms, such as light and thermal energy. Moving electrons, or an electric current, is one of the most common forms of energy. In this lesson, you will read about what causes electrons to move. You also will read about how their movement is controlled to make an electric current useful.

Key Concept Check How are electric current and electric charge related?

Science Use v Common Use

charge

Science Use a definite quantity of electricity

Common Use the price demanded for something

Two Types of Electric Current

An electric current, or the movement of electrons, carries energy near the speed of **light**. However, the negatively charged electrons themselves move more slowly.

REVIEW VOCABULARY
light
electromagnetic radiation you can see

Imagine a tube filled with marbles. Extra marbles pushed into one end of the tube cause other marbles to pop out the other end. The first marbles do not instantly move the length of the tube. Similarly, as electrons move into one end of a wire, other electrons leave the other end of the wire almost instantly. Each electron does not suddenly move the length of the wire.

Direct Current In the example above, marbles added continually to one end of the tube produce a steady stream of marbles flowing out the other end of the tube. Figure 6 shows that, in a similar way, electrons continually added to one end of a wire create a constant one-way flow of electrons. This is known as direct current. Some energy sources, including batteries, produce only direct current. Many portable devices, such as flashlights, operate using direct current.

Alternating Current If marbles are repeatedly added to one end of the tube and then to the other end, the marbles in the tube would move back and forth, never moving far from their original positions. An electric current that also continually reverses direction is known as an alternating current. Large generators in power plants supply homes and businesses with alternating current.

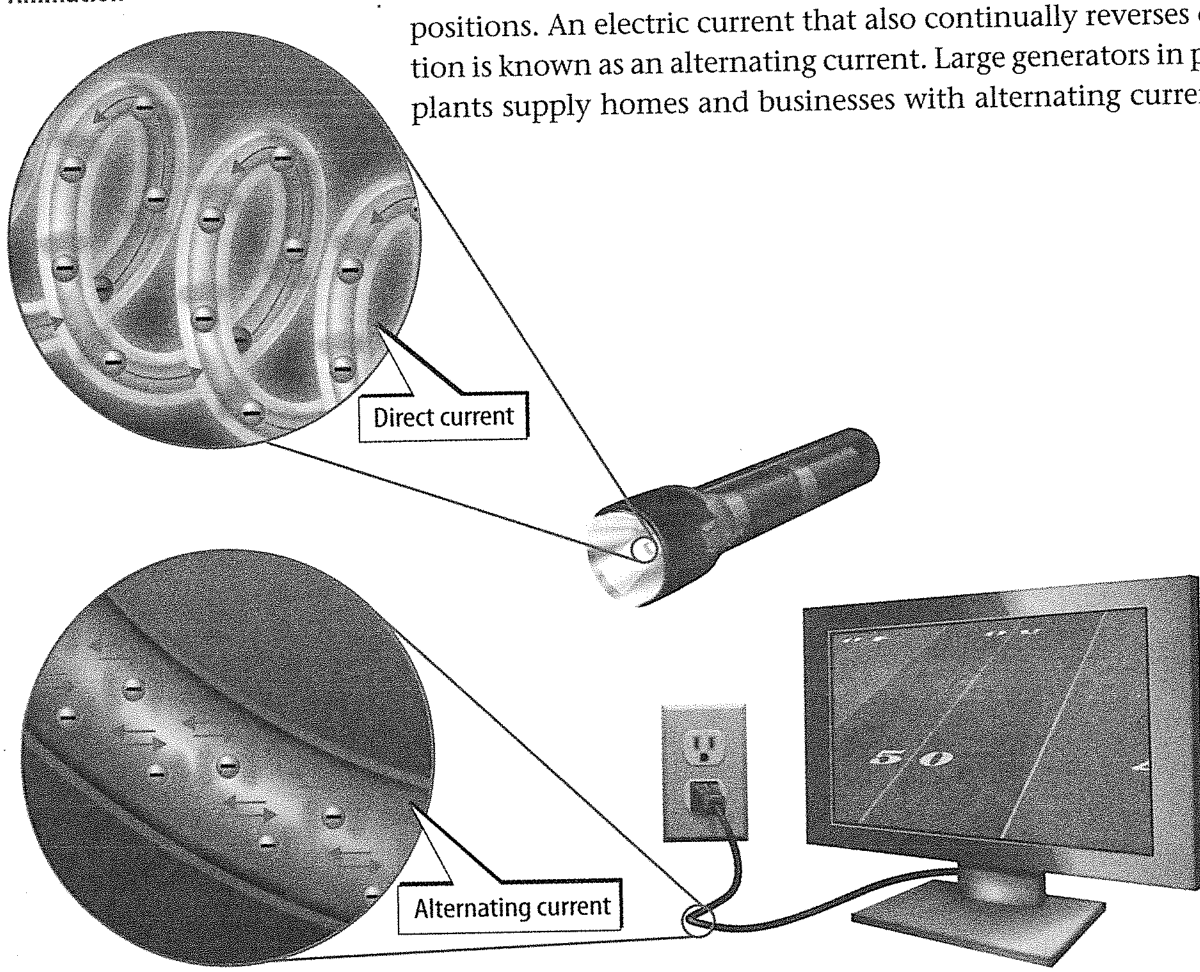


Figure 6 With direct current, electric charges continually flow from the negative side of the source to the positive side. The flow of electric charges of an alternating current changes direction many times per second.

Concepts in Motion
Animation

The Circuit—A Path for Electric Current

Electric circuits transform the energy of an electric current to useful forms of energy. *An* **electric circuit** *is a closed, or complete, path in which an electric current flows.* Electric circuits are all around you.

A Useful Circuit

Electric circuits are designed to transform electric energy to specific forms. For example, the electric circuits in a microwave oven transform electric energy to the radiant energy that cooks your food. **Figure 7** illustrates an electric circuit designed to transform the electric energy of a battery to the light energy emitted by a lightbulb. As shown, the circuit is complete, or closed, and the lightbulb is lit. If the circuit is broken, or open, at any point, the electric current stops and the lightbulb does not light.

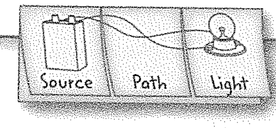
A Simple Circuit

Some electric circuits, such as those found in computers, are very complicated and have hundreds of parts. However, many common and useful circuits include only a few components. Simple circuits are found in flashlights, doorbells, and many kitchen appliances. All simple circuits contain: 1) a source of electric energy, such as a battery, 2) an electric device, such as a lightbulb, and 3) an electric conductor, such as wire. In addition to these basic components of all circuits, a switch is often included in a circuit. How do these basic components interact to make a useful electric current?

Key Concept Check What are the parts of a simple electric circuit?

FOLDABLES®

Create a horizontal three-tab book. Illustrate and label a simple electric circuit as shown. Use it to explain the components of a circuit.

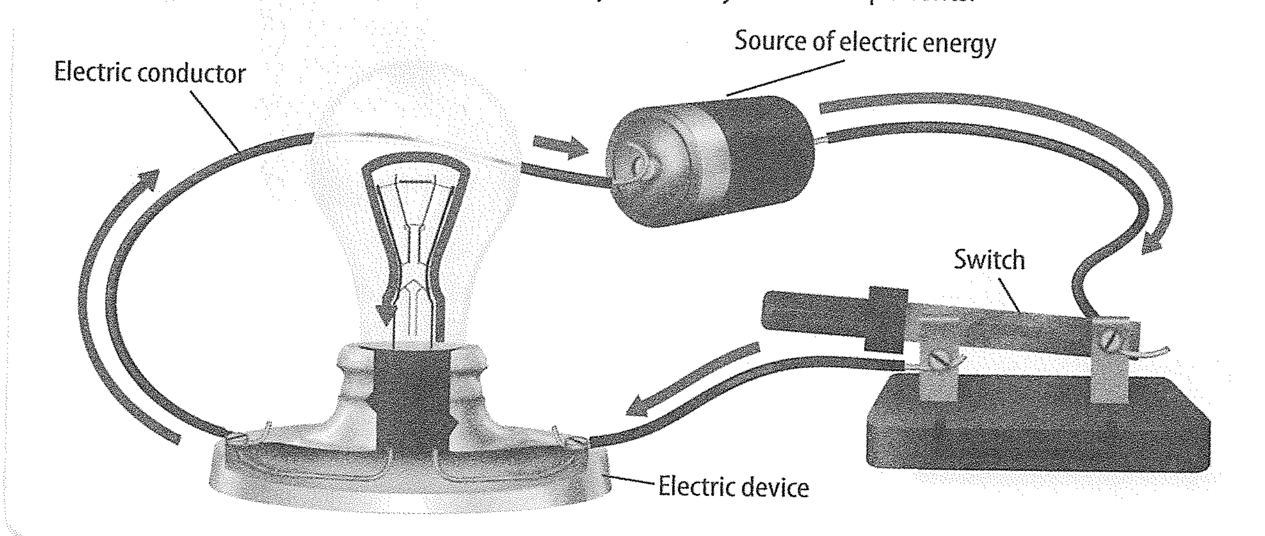


WORD ORIGIN

circuit
from Latin *circuire,* means "to go around"

Concepts in Motion
Animation

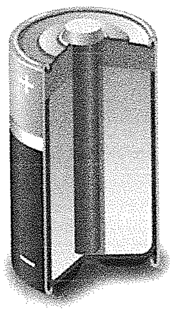
Figure 7 A practical electric circuit may have only a few components.



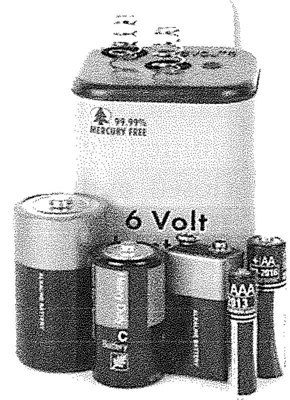
Sources of Electric Energy There are many uses of electric energy. Most uses require specific types of sources of electric energy. For example, a flashlight requires a small, portable source. Cities need sources that produce large amounts of electric energy that are nonpolluting. Figure 8 includes some of the technologies now being developed and improved to help meet the world's growing demand for electric energy.

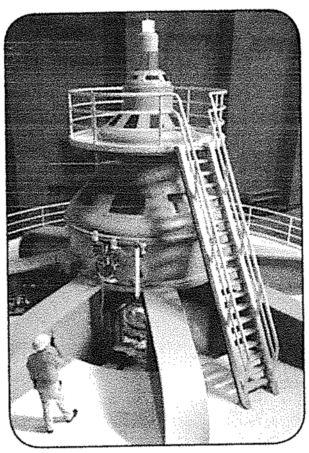
Figure 8 Many electric energy sources are being developed and improved.

Visual Check Why are fuel cells possibly a good source of electric energy?

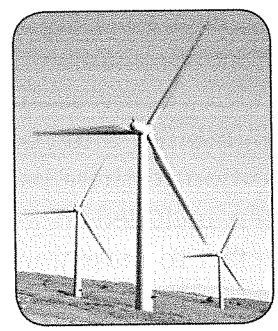


Batteries often are used when an electric energy source needs to be small and portable. A battery is simply a can of chemicals. Chemical reactions within a battery move electrons from one end of the battery (the positive terminal) to the other end (the negative terminal). Outside the battery, the electrons flow through a closed circuit from the negative terminal back to the positive terminal. As the chemical reactions continue, electrons keep moving through the battery and circuit.

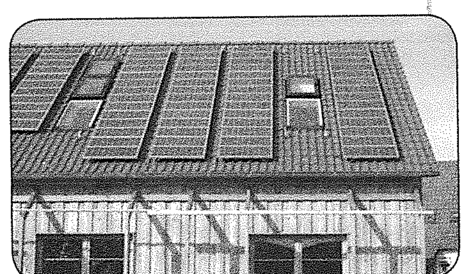


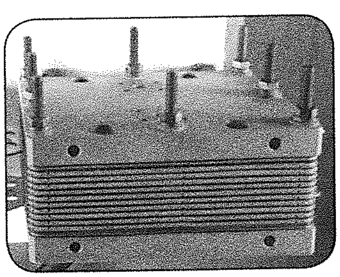


Generators *are machines that transform mechanical energy to electric energy*. Many power plants use fossil fuels or nuclear energy to power large generators. These fuels provide thermal energy to boil water into steam. The steam flows through and rotates a turbine that, in turn, rotates a generator. These types of turbine-powered generators provide most of the electric energy used in the United States. Other generators use wind or moving water for power. You will read more about generators in the next lesson.



Solar cells change sunlight into electric energy. Often cells are connected into solar panels to increase energy output. Simple solar cells power many small devices, such as calculators. Complicated systems have enabled humans to explore the solar system and beyond.





Fuel cells, like batteries, produce electric energy by a chemical reaction. But, unlike batteries, fuel cells need a constant flow of fuel, such as hydrogen gas. An advantage of using fuel cells as a source of electric energy is that they produce no pollution. Fuel cells have generated electric energy on space flights. Now, scientists and engineers are developing ways to use fuel cells in people's everyday lives.

Electric devices transform energy. An electric device is a part of a circuit designed to transform electric energy to a useful form of energy. For example, a lightbulb is designed to transform electric energy to light. Transformation of electric energy occurs wherever there is electric resistance in a circuit. **Electric resistance** *is a measure of how difficult it is for an electric current to flow in a material.* Electric devices with greater electric resistance transform greater amounts of electric energy. What causes a transformation of electric energy?

Think of an electric lightbulb. As electrons move in the high-resistance wire filament of the lightbulb, they collide with atoms of the filament. The atoms absorb some of the electrons' kinetic energy, then release the energy as light.

Electric Conductors and Electric Circuits An electric conductor, such as a wire, is used to complete the circuit by connecting the energy source to the electric device. Copper and aluminum make good wires for electric circuits because they are excellent conductors. A good conductor has little electric resistance.

Recall that an electric current easily flows through an electric conductor. However, even the best conductors, such as copper wire, resist an electric current a little. All conductors, including a device's power cord, have some electric resistance. Small amounts of electric energy in a circuit's conductors always transform to wasted thermal energy.

Reading Check Why are wires in an electric circuit often made of copper?

Inquiry MiniLab

20 minutes

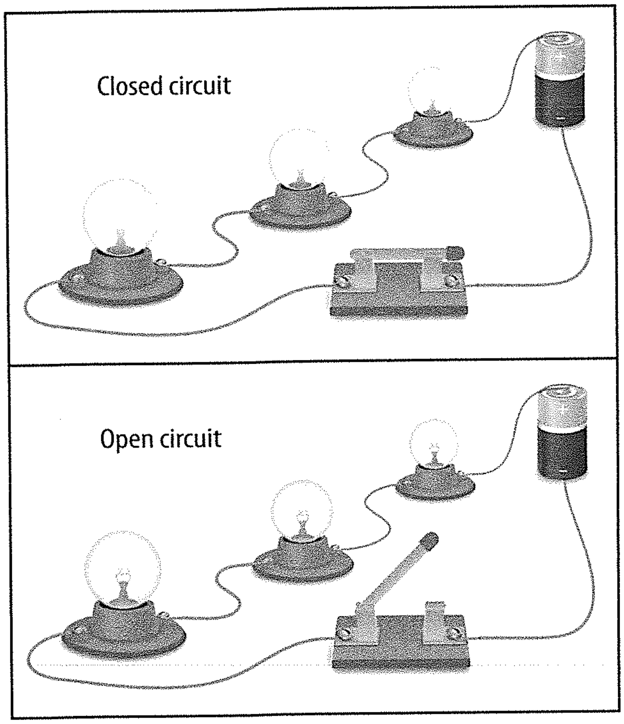
How can you determine whether a material is a conductor?

Conductors allow electrons to travel freely through them, while insulators prevent electrons from moving through them. Can you design a device that will determine whether a material is a conductor?

1. Read and complete a lab safety form.
2. Using a **battery, two wires,** and a **bulb in a screw base,** construct a circuit that lights the bulb.
3. Develop a plan to alter your circuit to test whether an item is a conductor. Record your ideas in your Science Journal.
4. Use your device to test **wood** and **aluminum foil.** Record your observations.
5. Select two other **items.** Predict and then test them. Record your observations.

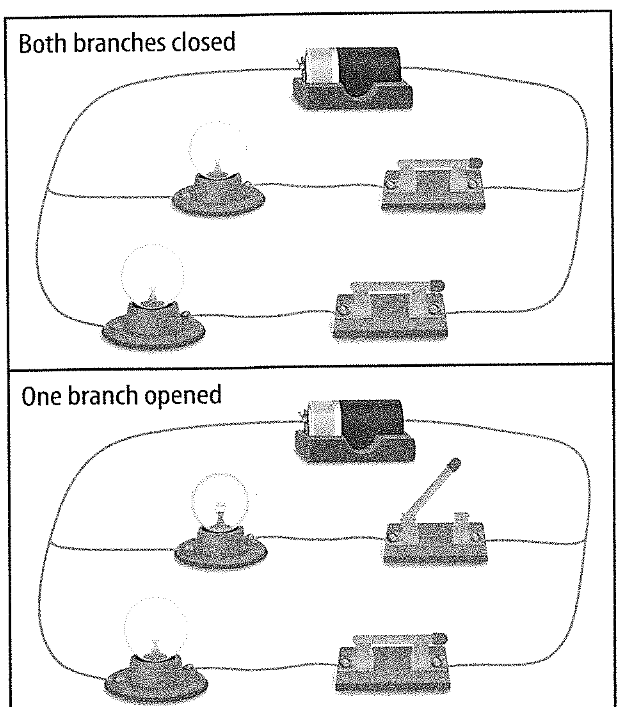
Analyze and Conclude

1. Compare the materials which you found to be conductors.
2. Classify all the materials found in your device.
3. **Key Concept** Explain how your device works.



▲ **Figure 9** In a series circuit, all components are connected in a single loop.

Figure 10 In a parallel circuit, opening one branch does not affect devices in the other branches. ▼



Concepts in Motion Animation

Series and Parallel Circuits

An electric circuit can have more than one device. For example, a string of holiday lights is a circuit that has many lightbulbs, or devices. Recall the circuits you built in the Launch Lab at the beginning of this lesson. With some holiday lights, if you remove one of the bulbs from its socket, all of the lightbulbs go out!

Now, think of the electric lights in the rooms of your home. These lights are devices connected in an electric circuit, too. However, if you remove the lightbulb from the lamp in your room, what happens to the light in the kitchen? Nothing. It remains lit.

How can you explain this difference in the two circuits? The answer is that there are two types of electric circuits.

Series Circuit In the example at the top of this page, the string of holiday lights is a series circuit. A series circuit is an electric circuit that has only one path through which an electric current can flow. In other words, all of the devices in a series circuit are connected end to end. As shown at the top of Figure 9, the same electric current flows through all the lightbulbs in the string. Breaking, or opening, a series circuit causes the electric current to stop flowing through the entire circuit.

Parallel Circuit A different type of circuit connects the devices in your home. Houses do not use series circuits. Instead, they use parallel circuits. A parallel circuit is an electric circuit where each device connects to the electric source with a separate path, or branch. The bottom of Figure 10 shows two lightbulbs connected to a battery as a parallel circuit. If any one of the branches is opened, the other lightbulbs still have a complete path in which current flows.

Key Concept Check How do the two types of electric circuits differ?

Voltage and Electric Energy

You may know the term *voltage*. For example, your home has 120-V outlets. To understand what this means, you must first know how to count electrons. But, there are so many electrons in a circuit! It is impossible to count them individually. Therefore, just as we quickly count eggs by the dozen, we count electrons by the coulomb (KEW lahm). One coulomb of electrons is a huge quantity—approximately 6,000,000,000,000,000,000 electrons!

WORD ORIGIN

voltage
from *Alessandro Volta*, (1745-1827), Italian physicist

Voltage of an Entire Circuit

Recall that all parts of an electric circuit have electric resistance. Therefore, energy is required to move electrons through a circuit. *The* **voltage** *of an electric circuit is the amount of energy used to move one coulomb of electrons through the circuit.*

Think of two identical lightbulbs. One is powered by a 3-V battery. The other is powered by a 6-V battery. The 6-V lightbulb is lit brighter than 3-V lightbulb. But why?

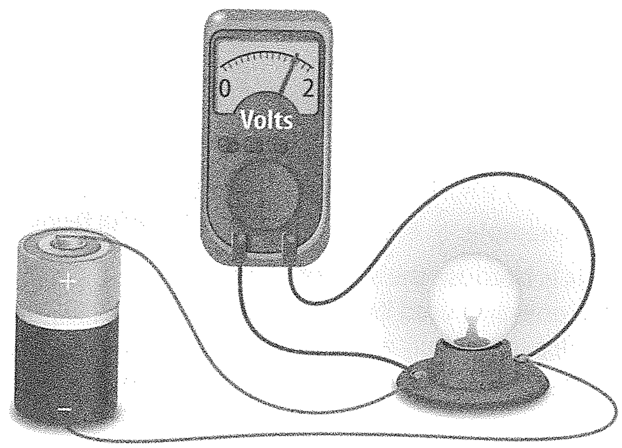
The definition of voltage tells you that the 6-V battery uses twice as much energy than the 3-V battery as it moves electrons through a circuit. Thus, the 6-V circuit transforms twice the electric energy to light.

Voltage of Part of a Circuit

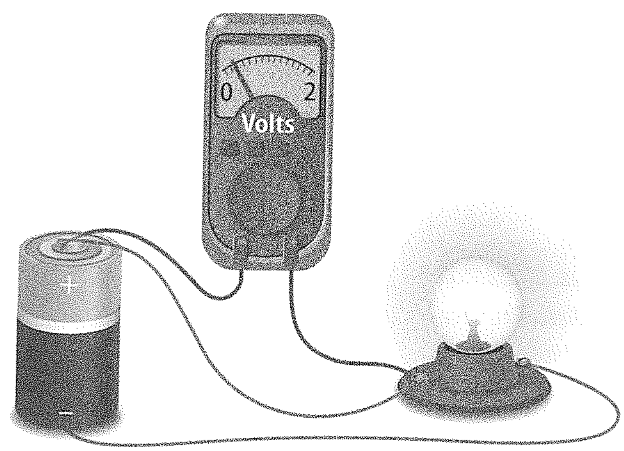
You also can measure the voltage of part of a circuit. The voltage measured across a part of a circuit tells you how much energy is used by moving electrons through that part of the circuit. **Figure 11** shows the voltages across a lightbulb and a wire in the same circuit. The higher voltage across the lightbulb tells you that the lightbulb transforms more electric energy than the wire.

The sum of the voltages across all the parts of an electric circuit equals the voltage of the energy source. This means that all the parts of an electric circuit transform all the energy produced by the energy source.

Figure 11 Portions of an electric circuit with higher voltage readings transform more of the battery's energy.



Higher voltage across lightbulb



Lower voltage across wire

Visual Check Which part of the circuit is transforming most of the battery's energy into some other form?

Math Skills

Using Fractions

Imagine a 9-V battery and two lightbulbs in a series circuit. The voltage across one lightbulb is 6 V. The second lightbulb reads 3 V. What part of the circuit's total energy is used by each lightbulb?

Divide the voltage reading across one of the lightbulbs by the voltage across the entire circuit (across the battery).

First bulb: $\frac{6\text{ V}}{9\text{ V}} = \frac{2}{3}$

Second bulb: $\frac{3\text{ V}}{9\text{ V}} = \frac{1}{3}$.

If you add the fractions together, they equal one.

For example: $\frac{2}{3} + \frac{1}{3} = 1$

This is because the sum of the energies used by each device in a circuit equals the total energy in the circuit.

Practice

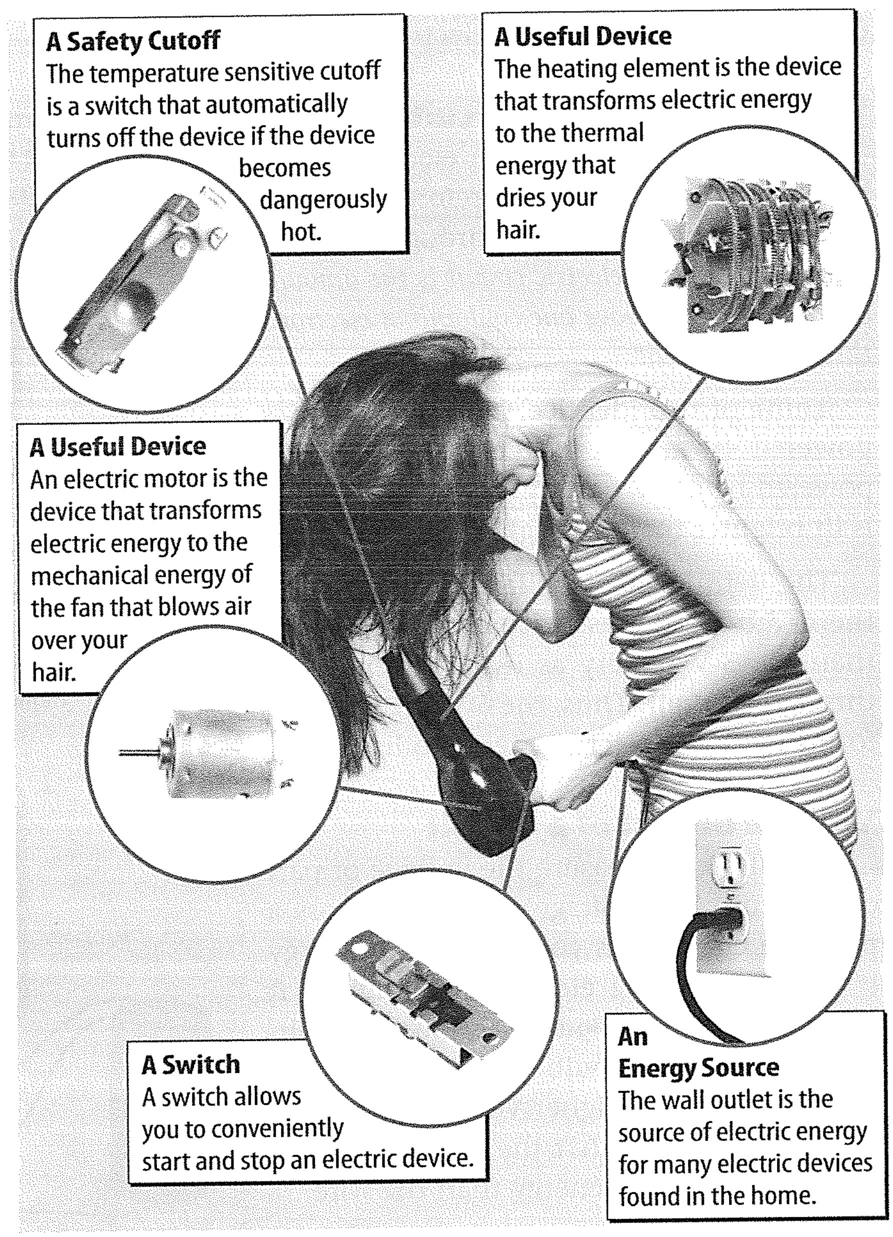
A 12-V battery powers a series circuit that contains two lightbulbs. The voltage across one of the lightbulbs is 8 V. What fractional part of the circuit's total energy is transformed in the second lightbulb?

Review
- Math Practice
- Personal Tutor

A Practical Electric Circuit

Recall that a simple circuit can function with only a few basic parts—a lightbulb can be lit with just a battery and a couple of wires. However, most useful circuits include additional components to make them more useful and safer. Figure 12 illustrates and describes some electric components of a hair dryer you might not be familiar with.

Figure 12 Useful electric circuits are simple circuits with a couple extra parts.



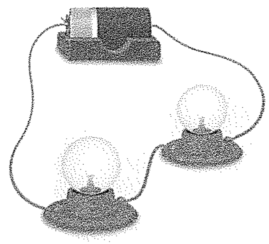
Visual Check What is the function of a safety cutoff?

Lesson 2 Review

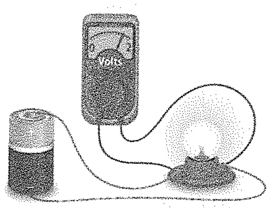
Assessment Online Quiz

Inquiry Virtual Lab

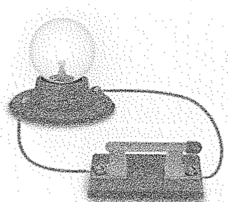
Visual Summary



A series circuit is one of two types of electric circuit.



Voltage is related to the amount of electric energy transformed in a circuit.



A switch makes a simple circuit useful.

FOLDABLES

Use your lesson Foldables to review the lesson. Save your Foldables for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

3. A battery in an electric circuit produces an electric current.

4. Every magnet has one magnetic pole.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

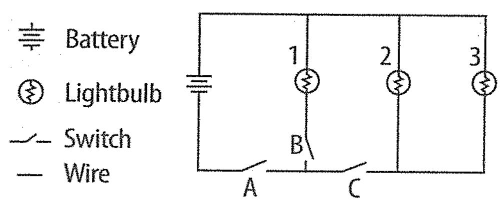
1. **Distinguish** between electric resistance and voltage.
2. **Make up** a sentence using the terms *electric circuit* and *electric current.*

Understand Key Concepts

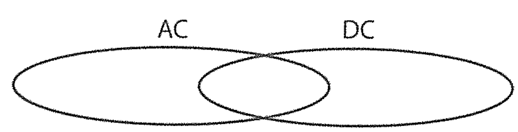
3. **Summarize** how the two types of electric circuits differ.
4. **List** the basic parts of a simple circuit.
5. An electric current is the movement of
   A. atoms.
   B. charged particles.
   C. neutral particles.
   D. neutrons.

Interpret Graphics

6. **Determine** In the circuit below, which switch will turn off only lights 2 and 3?



7. **Compare and Contrast** Copy and fill in the graphic organizer below. Compare and contrast the two types of electric current.



Critical Thinking

8. **Contrast** How might the circuits of a 6-V flashlight and a 1.5-V flashlight differ? Explain your reasoning.

Math Skills

Review

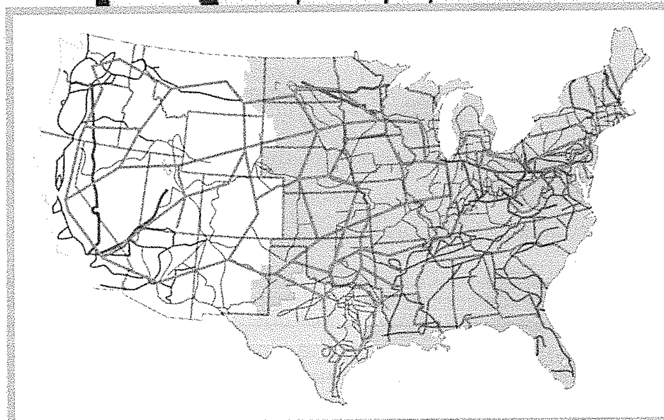
Math Practice

9. A string of ten holiday lights connected as a series circuit is plugged into to a 120-V outlet. All the lightbulbs are identical and are lit. What is the voltage across each bulb?

SCIENCE & SOCIETY

A Smart Grid?

Electric Energy for the Future



The North American power grid is a system of interconnected electric transmission wires that reaches across the continent. This network of transmission wires includes smaller, regional grids in the eastern United States, the western United States, and Texas. The grid is the electric super highway that delivers electric energy to all our communities.

The grid, shown as red lines on the map, is aging quickly. Many transmission wires are too small to carry all the electric energy people demand. Parts of the grid often are overloaded. As electric current becomes too great in one part of the grid, that part shuts down to prevent damage to generators and transmission wires. The electric current then shifts to other transmission wires that become overloaded, too. This type of cascading overload can cause power failures and blackouts over large areas of the country. One solution to our electric distribution problem is to build a smart grid, shown as green lines on the map.

Computers at distribution centers throughout the grid would constantly analyze electric energy needs across the country. The system could route electric power from where it is produced, anywhere in the country, to where it is needed.

Also, consumers would have smart meters at their homes. Each smart meter would be connected to a personal computer to allow homeowners to see how much energy each of their household's electrical devices uses. They quickly could see where they unwisely use electric energy. People could adjust their use of electric energy to save money and decrease their demands on the grid.

It's Your Turn

RESEARCH AND REPORT Many experts agree that we must soon build a smart grid for electric energy distribution. Research why a smart grid is necessary for the development of alternative energy sources.