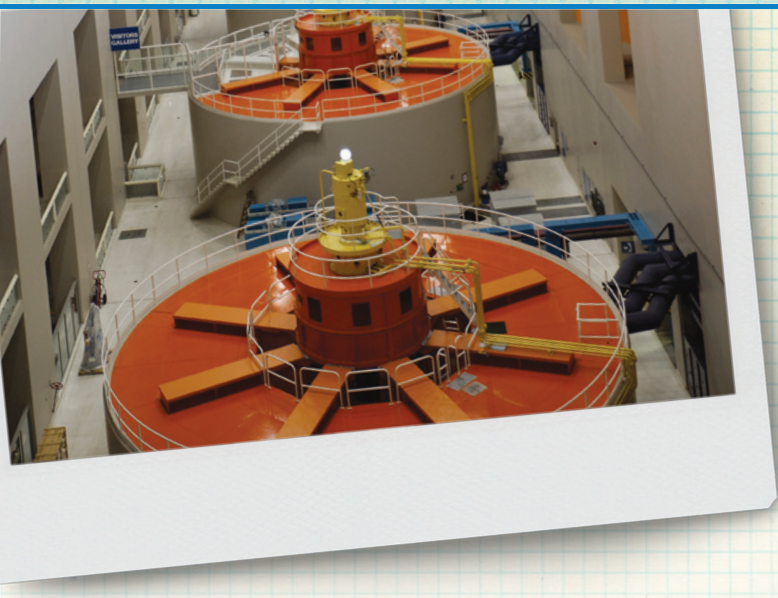
Lesson
94



8

Electricity and Magnetism

In the late 1700s a controversy arose about a dead frog's legs. Luigi Galvani found that touching the nerves of a dead frog's legs with two different metals could make the legs twitch. He concluded that animal tissue contains a force called "animal electricity," which Galvani thought flowed throughout the body. But another scientist, Alessandro Volta, thought that the contact between the two different metals produced the electricity. He called his force "metallic electricity."

Further research proved that both men were partly right and partly wrong. As with many other scientific discoveries, God allowed one man's ideas, though not completely right, to inspire another man to further research. The result of Volta's disagreement with Galvani's conclusions was the first battery using two different metals. Electricity became a force that could be controlled enough to do work.

187

Objectives

- Recognize God's use of man's curiosity
- Preview the chapter content

Introduction

God put man in charge of the earth to take care of it and to develop it. He gave man a natural curiosity and the ability to learn. No one learns everything at once, but everyone adds to his learning little by little. People, including scientists, learn from failures as well as successes. A mistake can help advance science when the weakness of one scientist's work inspires another scientist to try a different method or hypothesis.

Teach for Understanding

Provide time for the student to complete Looking Ahead, Activity Manual page 121. For part B, encourage the student to think of things he would like to learn about current electricity and electromagnets. He should write his answers in question form, such as, "Where are electromagnets used?"

Provide the answers for part A, and allow the student to check his work. After the chapter is finished, you may choose to have him look back at this page and check his understanding of the items he missed.

As time allows, discuss student questions from part B about current electricity and electromagnets. You may choose to provide trade books or other resources to help answer questions that are beyond the scope of this chapter.

Allow the student to leaf through the chapter, looking at the headings, pictures, captions, charts, etc., and discuss the things he thinks he will be learning about.

What is the chapter title? Electricity and Magnetism

What do you think is pictured in the photo? Answers will vary. The photo shows the top of two hydroelectric power generators.

Activity Manual

Preview, page 121

The Looking Ahead page is intended to assess the student's prior knowledge before beginning the chapter.

SCIENCE BACKGROUND

Luigi Galvani
Galvani's experiments furthered not only the study of electricity, but also the study of anatomy. Scientists concluded from his experiments that the messages of the nervous system were carried by an electrical current rather than through a conduit, like the blood.

Alessandro Volta
Volta built the voltaic pile, a simple wet-cell battery. Volta's original pile was made from zinc and silver discs alternated with pieces of cloth soaked in salt water.

Galvani and Volta controversy
Although the two scientists disagreed about electricity, they did not actually dislike each other. In fact, each highly respected the other. Volta was the man who developed the word *galvanization* to refer to administering electrical shocks.

TEACHER HELPS

Chapter preview
Other preview and prereading activities may include using a K-W-L chart, a probe, or an anticipation guide.

Diagrams
Diagrams from the Student Text are included on the Teacher's Toolkit CD.

Student Text pages 188–91
Activity Manual page 122

Objectives

- Explain what causes static electricity
- Identify the two things needed for an electric current to flow
- Describe the characteristics of conductors, resistors, and insulators

Vocabulary

static electricity	switch
current electricity	short circuit
circuit	insulator
conductor	resistor

Introduction

Play the game "Twenty Questions" after giving the clue.

I am not a mineral or an animal, and I am not alive or dead. I am both inside and outside your body and in outer space. I am invisible, tasteless, colorless, odorless, and likely to travel in circles. What am I? electricity

Teach for Understanding

Purpose for reading

What is lightning?

What is needed for electricity to be useful?

Discussion

What did the ancient Greeks observe about amber? It produced sparks when rubbed with fur.

Why was Thomas Edison's invention significant? because up to his time, electricity could not be controlled to be useful

What are some ways that electricity has changed the way we live? Accept reasonable answers.

Who gave man the ability to harness electricity? God

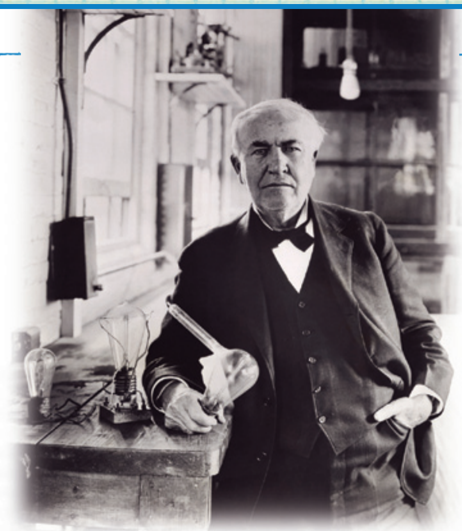
Identify the three types of electrical charges. neutral, positive, and negative

What kind of charge does an atom usually have? neutral

Electricity and magnetism—the two forces are inseparable. In many countries, it would be almost impossible to go through a day without using electricity and magnetism. Yet even complicated electrical equipment and electronics work because of the positive and negative charges that are part of tiny atoms.

Electricity

Man observed electricity long before he understood the parts of an atom. The ancient Greeks noticed that amber, fossilized tree sap, produced a spark when rubbed with fur. But only within the last 150 years has man been able to harness electricity for practical use. Thomas Edison revolutionized the use of electricity when he invented the electric light bulb in 1879. Finally, electricity could serve practical purposes. But even Edison could not have imagined all of the ways that electricity would change the way we live. The ability to harness electricity is a great gift from God. Using it wisely is being a good steward of God's gift.

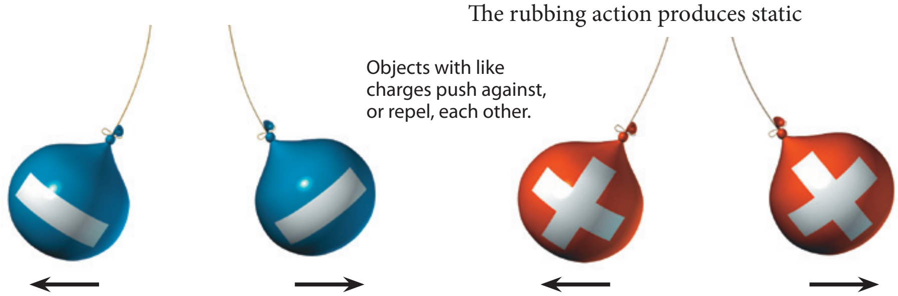


Thomas Edison

Static Electricity

Atoms, the building blocks of matter, generally have a neutral electrical charge, because the protons (+) and electrons (–) balance each other. However, an atom often gains or loses electrons, which causes it to have a temporary negative or positive charge.

Like atoms, objects normally have a neutral charge. However, rubbing two objects together may cause electrons to move from one object to the other. The rubbing action produces static



Objects with like charges push against, or repel, each other.

Like charges

188

SCIENCE BACKGROUND

Common lightning safety precautions

During a storm, the main principle to remember is to avoid contact with things that will attract or conduct electricity.

Stay inside a home or other large building when possible.

Avoid using a corded telephone. (Cellular phones are safe to use.)

Keep away from windows, and avoid contact with things inside a building that can conduct electricity, such as metal railings and water from metal pipes.

Avoid travel in an open vehicle such as a motorcycle, golf cart, or bicycle.

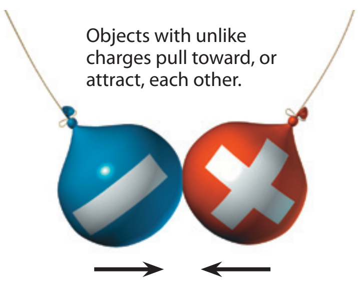
If outside, avoid wire fences, metal pipes, power lines, trees, water, open spaces, and high ground.

Franklin's kite

There is much debate about whether Franklin actually did this experiment or whether he just wrote about the fact that it could be done. Franklin did not keep detailed notes about his experiments, but we know he took precautions against electric shock. It is estimated that he did this experiment as a thunderstorm was just beginning in June 1752. He wrote a letter in October of that year describing how to do the experiment and later published an account of the experiment in the *Pennsylvania Gazette* without mentioning that he had done the experiment himself. Later Franklin told Joseph Priestly about it, and Priestly recorded the details of the experiment in his book, *The History and Present State of Electricity*, published in 1767. Franklin read the manuscript of Priestly's book.

electricity. **Static electricity** occurs when electrical charges build up on the surface of an object. One object gains extra electrons and has a negative charge. The other object loses electrons and has a positive charge. An object with a positive or negative charge has an electrical force that will repel or attract other charged objects. Charged objects with like charges repel each other. However, charged objects with unlike charges attract each other.

If you have ever walked across a carpet on a cold, dry day, you have probably experienced static electricity. As your shoes rub on the carpet, they collect charges. These charges build up on your body. When you reach for a doorknob, the electricity discharges, or jumps, from your hand to the doorknob. This discharge of electrons causes a spark and a shock. As the electrons flow from one object to the other, each object returns to a neutral state, having no charge at all. During a thunderstorm, charges build up in the clouds. When these charges discharge, they create the most dramatic kind of static electricity—lightning.



Unlike charges

SCIENCE & HISTORY

In the 1700s Benjamin Franklin began experimenting with electricity. He believed that lightning was a form of static electricity and that its electrical charges could be transferred to another object. During a thunderstorm, he flew a kite from a long length of wet twine. A thin metal wire and key were attached to the twine. He held onto a dry silk string attached to the key and observed that sparks flew from the key whenever he brought it near objects that were attached to the ground. He also found that the key could transfer electrical charges into a Leyden jar, a special container made to collect electricity. His kite experiment demonstrated that lighting is indeed a form of electricity.

Discussion

How do you determine the charge of an atom? Count the number of electrons and protons in the atom. If the atom has more electrons than protons, then it has a negative charge. If it has more protons than electrons, then it has a positive charge.

How do you represent positive and negative charges? positive charge (+) and negative charge (−)

Why would the loss of electrons possibly cause an object to have a positive charge? The loss of electrons may cause an object to have more protons than electrons, which will give it a positive charge.

What is often produced when you rub two objects together? static electricity

When does static electricity occur? when electrical charges build up on the surface of an object

When does an object have an electrical force? when it has a positive or negative charge

Describe what an electrical force does. attracts or repels other charged objects

Why would an object with a negative charge attract an object with a positive charge? Objects with unlike charges attract each other.

Give some examples of static electricity. Possible answers: lightning, static cling, static shock

Discuss *Science & History*.

Who demonstrated that lightning is static electricity? Benjamin Franklin

How did Benjamin Franklin show that lightning is static electricity? He flew a kite with a metal wire and key attached to it during a thunderstorm.

What did he observe happen when the key came near objects attached to the ground? sparks flew from the key

What is a Leyden jar? a special container made to collect electricity

SCIENCE MISCONCEPTIONS

Creating and losing electricity
Electricity cannot be created or lost. According to the Second Law of Thermodynamics, matter and energy can neither be created nor destroyed. They can only be converted into other forms of matter or energy. It only seems like electricity is lost as the electrical energy is converted into other forms of energy, such as heat and light.

LANGUAGE

Electron
The word *electron* comes from the Greek word for amber, *elektron*. Scientists used *elektron* to describe the part of the atom that carries a negative charge.

Which other words are similar to the word *electron*? Possible answers: electricity, electronics, electric, electrician

Circuit comes from a Latin word meaning "to go around."

Which other words have the prefix *circ-*? Possible answers: circle, circular, circulate, circulatory, circumference, circumnavigate, circumstance

Discussion

What is current electricity? the continuous flow of electrons around a circuit

Identify the two things needed to make current electricity. a circuit and a power source

What is a circuit? a continuous unbroken path through which electricity can flow

What is needed for electrical energy to be useful? a continuous flow of electrons

How does current electricity provide this continuous flow of electrons? The power source keeps the electrons moving, and the circuit provides a path for the electrons.

What do we call a material through which electricity flows easily? a conductor

Why do you think most electric wires are made of metals rather than of other materials? Possible answer: Most metals are good conductors.

Gold is one of the best conductors of electricity. Why do you think gold is not used to make electric wires? Possible answers: too expensive, too soft, too heavy

How can an electric current be turned off without removing the power source? with a switch

How does an open switch affect a circuit? It causes an open circuit, which does not provide a continuous path for electricity.

What happens if a switch is closed? It keeps the circuit closed so that electricity has a continuous path.

When does a short circuit occur? when electricity takes an unexpected path

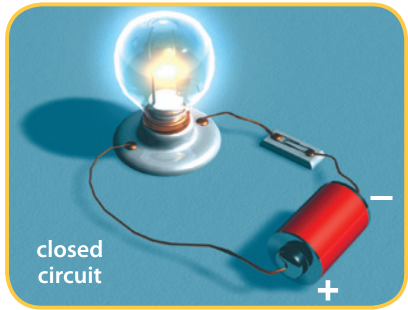
How are short circuits prevented in houses and appliances? Houses and appliances have built-in protection, such as circuit breakers or fuses.

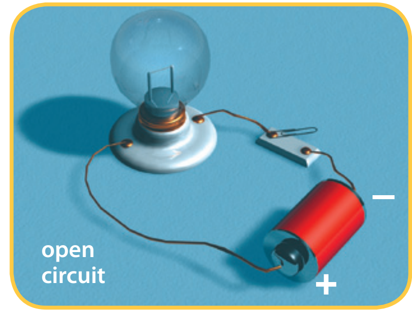
How are circuit breakers and fuses switches? They can open and close circuits.

How does a fuse work? A fuse has a thinner wire that breaks if too much electricity is flowing through the circuit. When it breaks, it opens the circuit.

What is the difference between a conductor and an insulator? A conductor allows electricity to flow through it easily. An insulator does not allow electricity to flow through it.

What are some good insulators? plastic, wood, glass





Current Electricity

Static electricity may jump from place to place, but its electrical force lasts for only a moment. In order for electrical energy to be useful, it must have a continuous flow of electrons. **Current electricity** is the flow of electrons around a circuit. The moving electrons produce electrical energy that can do work.

Two things are necessary to make current electricity. First, there must be a **circuit**, a continuous, unbroken path through which electricity can flow. Second, the circuit must have a power source that causes the electrons to start moving. The power source has an excess of electrons, so the extra electrons begin to flow away from it through the circuit because it contains fewer electrons. It is similar to the way water flows downhill due to the pull of gravity.

Conductors and switches

A **conductor** is a material that allows electricity to flow through it easily. Electrons in the atoms of conductors move freely from one atom to another. Most metals are good conductors because metals hold their electrons loosely.

Using a switch, we can turn most electrical appliances on and off without unplugging them. A **switch** is a conductor that can be moved to either bridge or not bridge the gap in a circuit. When the switch is closed, the circuit is complete, so electricity flows easily. This is a *closed circuit*. An open switch breaks the circuit, so the electrons cannot travel through a complete path. This is an *open circuit*.

Because electricity always flows through the easiest path, sometimes it may take an unexpected path. When this happens, a **short circuit** occurs. Short circuits can cause sparks and fires. To prevent short circuits, many electrical devices, and even house wiring, have fuses and circuit breakers that provide built-in protection. When too much electricity flows through a circuit, a fuse's thinner wire breaks and opens the circuit so electricity can no longer flow. A circuit breaker works in a similar way by popping a switch that opens the circuit. To close the circuit again, someone needs to either replace the fuse or switch the circuit breaker back to the *on* position.

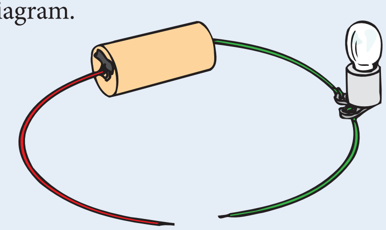
190

DIRECT A DEMONSTRATION

Identify materials as conductors or insulators

Materials: 3 pieces of insulated wire about 8 cm long, small light bulb in a socket, 6-volt battery, electrical tape, conductors to test (copper, iron, steel, aluminum, lead, or other metals), and insulators to test (paper, wood, plastic, rubber, glass, rock, or other organic materials)

Construct a circuit according to the diagram.



Show the objects you will be testing. Direct the student to list the items on his own paper and record his prediction of whether each item will act as a conductor or as an insulator.

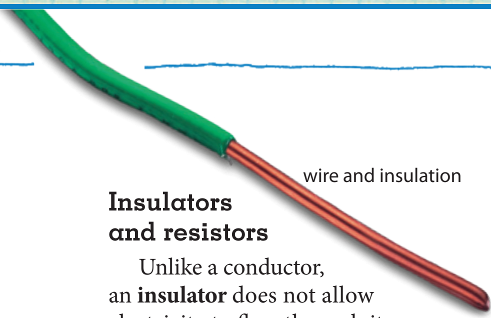
Place the first item between the wires to complete the circuit.

Did the light bulb glow? Is the item a conductor or an insulator? Was the prediction correct? Answers will vary depending on the item.

Repeat with the remaining objects.

What do all the items that were conductors have in common? They are made of metal.

What do all the items that were insulators have in common? They are made from materials other than metal.



Insulators and resistors

Unlike a conductor, an **insulator** does not allow electricity to flow through it. Plastic, wood, and glass are all good insulators. A wire that conducts electricity would be extremely dangerous without a coating of plastic insulation.

Sometimes we want electricity to flow but not flow easily. A **resistor** reduces the flow of electrons. As the electrons push harder to get through a resistor, friction causes the resistor to become hot. The resistor heats up, and it may begin to glow. The heating element in your toaster is a resistor. The metal wire, or filament, in a light bulb is also a resistor. The filament slows the flow of electrons, creating friction. This friction heats up the filament and causes it to glow and produce light.

QUICK CHECK

1. Why do some objects have a negative charge?
2. Identify two things that are needed to make current electricity.
3. Explain the difference between a conductor, an insulator, and a resistor.

Lewis Latimer

Lewis Latimer (1848–1928), the son of former slaves, helped develop electrical lighting. After serving in the Union army during the Civil War, Latimer worked as an office boy. He taught himself to be a draftsman, a person who draws detailed plans and sketches. While working for Thomas Edison's rival, Hiram Maxim, Latimer developed a light bulb filament that lasted longer and was cheaper than Edison's filament. (Edison's filament was the standard for light bulbs for many years.) Latimer supervised the installation of lighting systems in several large cities. Eventually Latimer went to work for Edison's company.

Although Latimer is credited with several inventions, he was also accomplished in many other areas. He wrote a book about electrical lighting, and he also wrote poetry. He played several instruments and taught himself to speak German and French. Latimer contributed greatly to the furtherance of the Industrial Revolution.

191

Discussion

What is meant when we say that a wire is live? Possible answer: The wire has electricity flowing through it.

Why would it be harmful for you to touch a bare live wire? Possible answers: Body fluids conduct electricity. Electric current is dangerous.

If a friend were receiving an electric shock, would a wooden stick or a metal rod work better to pull him away from the electric current? a wooden stick
Why? Metal conducts electricity and would pass the shock through your friend and on to you. Wood is an insulator.

Why are electric wires often covered in plastic? The plastic is an insulator and protects from electric shock.

What is the purpose of a resistor? to reduce the flow of electrons

What happens as a resistor reduces the flow of electrons? As the electrons push harder to get through a material, they create friction. This causes the material to get hot and glow. The electrical energy is changed into heat and light.

What common household items use resistors? Possible answers: toaster, incandescent light bulb, hair dryer, electric heater, coffeepot

Discuss the Lewis Latimer box.

When did Lewis Latimer live? 1848–1928

What did Lewis Latimer develop? a light bulb filament that lasted longer and was cheaper than Edison's light bulb filament

What were some of Latimer's other accomplishments? Possible answers: taught himself to be a draftsman; wrote a book about electrical lighting; wrote poetry; played several instruments; taught himself German and French

Answers

1. They have gained electrons.
2. a circuit and a power source
3. A conductor allows electricity to flow easily. An insulator prevents electricity from flowing. A resistor reduces the flow of electricity.

Activity Manual

Reinforcement, page 122

Lesson 96

Student Text pages 192–93
Activity Manual pages 123–24

Objectives
- Design and build an "unbreakable" circuit
- Experiment to test hypotheses

Materials
- one string of Christmas lights (preferably lights on a series circuit)
- See Student Text page

Introduction
Plug the Christmas lights into a wall socket.

What will happen if I remove one light bulb from the strand?

Remove one light bulb from the strand and plug the lights back into the wall socket.

When the bulb is lit, is it like an open or closed switch? a closed switch **Why?** because it completes the circuit

Is the light bulb a conductor or an insulator? It is a conductor because it acts like a closed switch.

What happened to the other lights on the strand? Did they all keep working?

Today you are going to try to build an unbreakable circuit, a circuit that keeps working even when one light bulb is missing.

Teach for Understanding
Purpose for reading
The student should read all the pages before beginning the activity.

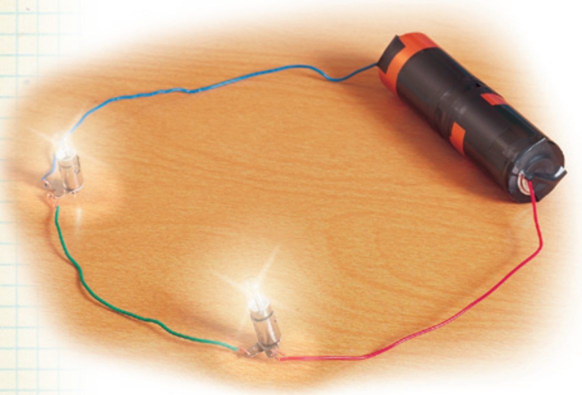
ACTIVITY

An "Unbreakable" Circuit

Process Skills
- Hypothesizing
- Predicting
- Experimenting
- Inferring
- Identifying and controlling variables

A circuit is an unbroken path of electricity. The picture shows the continuous flow of electricity from the battery, through two light bulbs, and then back to the battery. In this circuit, if one light bulb goes out, the second light bulb also goes out.

As an amateur electrician, you have the job of designing and building an "unbreakable" circuit. The key to this invention is the arrangement of the bulbs and battery in the circuit.



Materials
colored pencil
2 C- or D-cell batteries
10 wires approximately 6–10 cm long
2 light bulbs in their own sockets
electrical tape
Activity Manual

Problem
How can you set up a circuit with two light bulbs so that you can unscrew one while keeping the other lit?

Procedures
1. List the materials that you will use.
2. Predict a solution to the problem.
3. Draw a sketch of your circuit to use as your hypothesis. Use the colored pencil to trace the path of the electricity in your sketch.

192

TEACHER HELPS

Reading ahead
For this discovery activity, do not let the student read ahead in the Student Text about series and parallel circuits.

To determine if your Christmas lights have series or parallel circuits, remove one light bulb and plug the strand of lights into the wall. If the other light bulbs remain lit, your strand has parallel circuits. If part or the entire strand of lights does not light when you plug it in, your strand has series circuits. Some strands have two or three series circuits connected together, so only part of the strand may not work when a bulb is missing.

Wire
Insulated wire, 18–25 gauge, will work best.

Number of circuits
Remind the students that they are not limited to one circuit. They can attach more than one or two wires to a light bulb or battery.

Working in groups
If some groups are unsuccessful and time permits, allow groups to share information.

4. Tape the two batteries together with electrical tape. The negative end (–) of one battery should be taped to the positive end (+) of the other.
5. Build the circuit.
6. To test your circuit, unscrew one bulb. If you discovered the "unbreakable" circuit, the other bulb will remain lit.
7. If you were unsuccessful, think of some reasons your circuit did not work. Adjust your circuit and retest. Keep adjusting and testing your circuit as time permits.

Conclusions

- What arrangement produced an "unbreakable" circuit?
- What things could you do to improve your circuit?

Follow-up

- Make a circuit where one bulb burns brighter than the others.
- Add more bulbs to your circuit. Observe what happens.

193

SCIENCE PROCESS SKILLS

Experimenting

How do you test a hypothesis? by experimenting

What do you need in order to experiment? materials and necessary conditions for testing your hypothesis

As a scientist, would you stop if one experiment did not prove your hypothesis? probably not

What would you do? Possible answer: Rethink your hypothesis and try again.

Why is experimenting important to scientific discovery? Answers will vary, but elicit that without experimentation, ideas are simply people's opinions rather than proven facts.

Procedure

Give each group 15–20 minutes to create an unbreakable circuit.

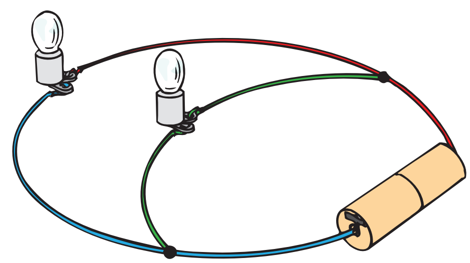
Provide more direction to those who are not having success, or show them a working circuit to build.

The following are questions to ask a struggling group.

What does each bulb need to have to remain lit? a complete circuit and a power source

Trace the path of electricity around the circuit of the student's diagrams. Does each have a complete path?

To solve the problem, the student will design a type of parallel circuit, such as the one below.



Conclusions

Did your results support your hypothesis? Were you able to build an "unbreakable" circuit"?

Allow the student to examine successful circuits.

Why did one bulb remain lit when the other one was disconnected? Conclude that the lit bulb has a complete circuit.

How did using a diagram help determine whether the electricity would flow or not? Answers will vary.

Use the questions in the Science Process Skills to discuss experimenting.

Activity Manual

Activity, pages 123–24

Assessment

Rubric

Select the prepared rubric, or design a rubric to include your chosen criteria.

Student Text pages 194–97
Activity Manual pages 125–28

Objectives
- Differentiate between parallel circuits and series circuits
- Distinguish among the three basic units of electrical measurement: volt, ampere, and watt
- Explain how a battery works

Materials
- electric power bill for your location (optional)

Vocabulary

series circuit	ampere
parallel circuit	electric cell
volt	electrolyte
watt	battery

Introduction

Have you ever experienced the power in your house going out because a car hit a utility pole down the street?

When a utility pole is hit and the power goes out, it usually affects the power for more than that pole only. Often several houses and buildings near the pole also lose power, because that pole is connected to one power line that services a group of houses, buildings, and streetlights.

What do you think would happen to the power going to the houses of your neighbors if a branch fell on the line that goes from the street to your house? Elicit that nothing would happen to their power.

The power in our neighborhoods uses different types of circuits.

Today we will learn about two types of circuits and how they work.

Teach for Understanding

Purpose for reading

What is the difference between a parallel circuit and a series circuit?

What are the parts of a battery?

Discussion

How many paths does a series circuit have? one

How is a light bulb attached to a series circuit similar to a switch? The light bulb closes the circuit and completes the path. When the bulb burns out, the circuit breaks.

What happens to the light bulbs on a parallel circuit when one bulb burns out? The other bulbs stay lit, because the burned out bulb breaks only its own circuit. The electricity has a complete circuit through the other bulbs.

Kinds of Circuits

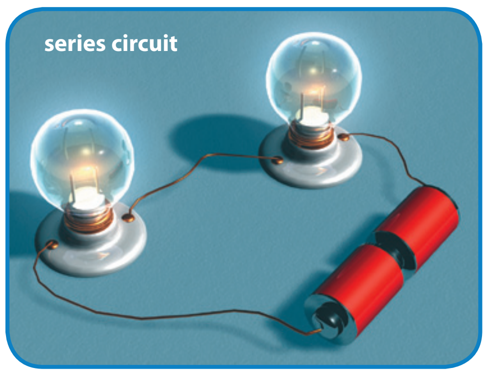
Series circuits

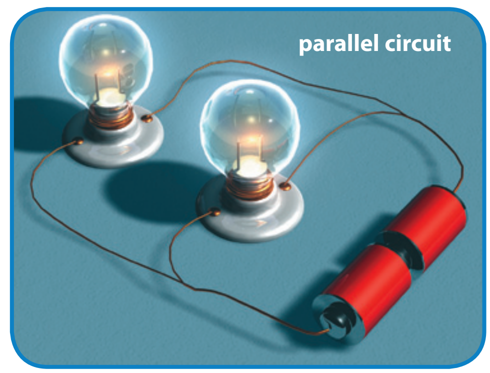
Have you ever seen a half-lit Christmas tree? Before the invention of the "unbreakable" circuit, all of the Christmas lights on a strand were arranged on one circuit. If one light bulb broke or burned out, the circuit broke, and the entire strand of lights stopped working. To relight the strand, a person would have to test each light bulb until he found and replaced the broken or burned-out bulb, or he would have to replace the whole strand of lights.

A **series circuit** has only one path, or one circuit, for the electricity to travel. If the path has a break at any point, the current cannot complete the circuit. A light bulb attached to a circuit acts like a switch. It closes the circuit, completing the path. However, when the filament in a bulb burns out, the circuit opens and breaks the path of the electricity.

Parallel circuits

Unlike a series circuit, a **parallel circuit** has multiple paths for the electricity to flow. On a parallel circuit, each bulb has its own circuit. If a bulb burns out, it breaks only the one circuit and does not affect the other circuits. All of the bulbs except the broken bulb will light because the electricity can complete its path.





194

SCIENCE BACKGROUND

House circuits
A house has many main circuits. Usually the circuits of a house are arranged so the appliances that use a large amount of power, such as a refrigerator, washing machine, and water heater, are on separate circuits.

TEACHER HELPS

Practice reading a schematic
Kinds of Circuits is a page located on the Teacher's Toolkit CD that may be used to help students practice reading schematic drawings before doing Activity Manual page 126. Answers for the page are 1-C, 2-A, 3-D, and 4-B.

electric meters

Measuring Electricity

If you look at the label on a small electrical appliance you will find information about how the appliance uses electricity. One piece of information that the label shows is how many volts the appliance requires. A **volt** is the measurement of the amount of electrical push, or force, in a circuit. The wiring in a typical house in the United States carries 115–120 volts of electrical force.

An appliance label also indicates how many watts the appliance uses. A **watt** is the measurement of power, or how fast work is done. For example, a 100-watt light bulb uses more power than a 60-watt light bulb. A hair dryer might use 1000 watts of power, but a mixer may use only 200 watts. The electric meter on a house measures the amount of power being used in the house. Power is measured in kilowatts (1 kW = 1000 watts).

Another unit of measure for electricity is the ampere. An **ampere** is the unit used to measure how much current flows through a given part of a circuit in one second. In most houses, circuit breakers are designed to allow 15 or 20 amperes of current to pass through a circuit safely. If more electrical current than the circuit can safely handle passes through the circuit, the circuit breaker will open.

The three basic units of measurement—volts, watts, and amperes—are related to each other. If you know two of the measurements, you can use this relationship to find the other measurement. Suppose a small appliance uses 240 watts at the normal household voltage of 120. To find the amperes needed, you divide the number of watts by the number of volts.

watts ÷ volts = amperes
240 W ÷ 120 V = 2 amps

DIRECT AN ACTIVITY

Identifying how electricity is used

Materials: several small appliances

Allow the student to examine the unplugged appliances to find out how many amperes and how many watts each of the appliances uses. The numbers should be written on labels or engraved directly on the appliances.

MATH

Using a formula

Display a formula that shows the relationship between the units of electrical measurement (current × voltage = power, or amps × volts = watts.)

If there are 10 amps and 10 volts, how many watts of power are there? 100

If there are 5 volts and 20 watts, how many amps are there? 4

Continue with other examples.

Discussion

What units of measurement are used to measure electricity? volt, ampere, and watt

What is a volt? a measurement of the amount of electrical push, or force, in a circuit

How many volts is most wiring in a house in the United States? 115–120 volts

Which unit measures power, or how fast work is done? watt

Does a 100-watt light bulb use more or less power than a 60-watt light bulb? more

What unit of power does the electric meter on a house show? kilowatts

How many watts is a kilowatt? 1000 watts

The electric meters in the photos are examples of meters found on houses and businesses. Both meters measure the amount of power used in kilowatts. What is different between the two? One is digital and one is analog (has dials).

Display the back of the power bill that explains how to read a meter. Discuss the information.

What is an ampere? the unit used to measure the amount of electric current flowing through any given part of the circuit in one second

How many amperes do most house circuit breakers allow to pass safely? 15 or 20

If a circuit has too many watts being required of it, it will cause too much electricity to flow through the circuit. The amperes will exceed the circuit breaker's capacity and cause it to open, thus breaking the circuit.

What is the relationship between amperes, watts, and volts? the number of watts divided by the number of volts equals the number of amperes

What does *amps* mean? It is an abbreviation for amperes.

Suppose you knew the number of volts and amps but not the number of watts. How would you write the equation to find the number of watts? volts × amps = watts

Discussion

What is needed to make an electric cell? two different metals and an electrolyte

What is an electrolyte? a liquid or paste substance that conducts electricity

How does an electric cell produce an electrical current? The chemical reaction between the metals and the electrolyte frees the electrons to travel around the circuit.

How does the electricity flow from an electric cell? It flows from the negative terminal through the wire, through the electrolyte, enters the cell again through the positive terminal, and then flows back to the negative terminal, continuing the current as long as the chemical reaction continues.

How many electric cells are contained in a battery? at least one, but there are usually more

What are two advantages of a wet-cell battery? It can produce a large amount of current for a relatively short time period, and it is rechargeable.

Why do some cars have wet-cell batteries? to supply the quick, powerful charge needed to start the engine

What are some disadvantages of wet-cell batteries? They must remain upright and are not very portable. The electrolyte used in wet-cell batteries is usually corrosive or poisonous and is not sealed.

Look at *Wet-cell Battery*. What are two metals that can be used in a battery? zinc and carbon

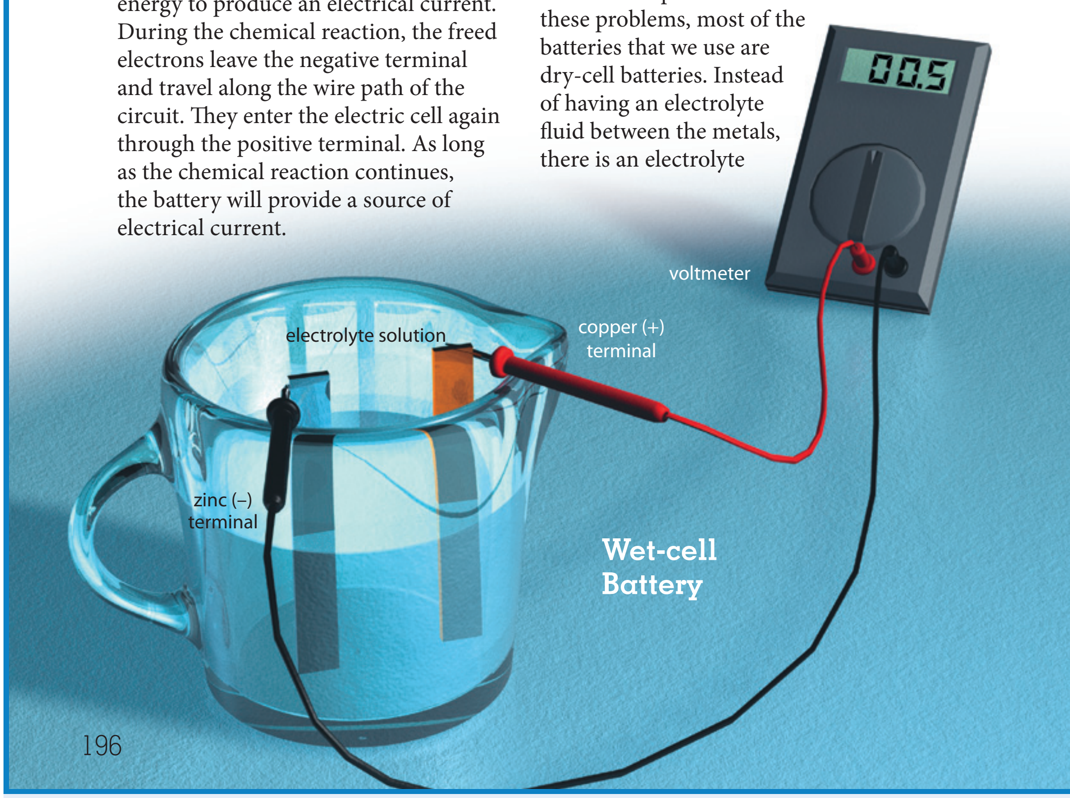
Batteries

Around 1800, scientists discovered that they could use two different metals and a solution to produce an electric current. The device they invented was called an **electric cell**. A wire connected the two metals, and the metals were in contact with an **electrolyte** (ih LEK truh LYTE), a liquid or paste substance that conducts electricity. Scientists found that the chemical reaction between the metals and an electrolyte, such as an acid, allowed electrons to move to complete a circuit.

An electric cell uses chemical energy to produce an electrical current. During the chemical reaction, the freed electrons leave the negative terminal and travel along the wire path of the circuit. They enter the electric cell again through the positive terminal. As long as the chemical reaction continues, the battery will provide a source of electrical current.

A **battery** contains one or more electric cells. The first batteries were wet-cell batteries. A wet-cell battery has the advantage of producing a large amount of current for a relatively short period of time. Wet cells are also rechargeable. Perhaps you have seen someone check the fluid in a car battery. A car battery is a wet-cell battery that provides the quick, powerful charge needed to start an engine.

Wet-cell batteries, however, have some disadvantages. They must remain upright and are not very portable. The electrolyte used in the battery is usually corrosive or poisonous. Because of these problems, most of the batteries that we use are dry-cell batteries. Instead of having an electrolyte fluid between the metals, there is an electrolyte



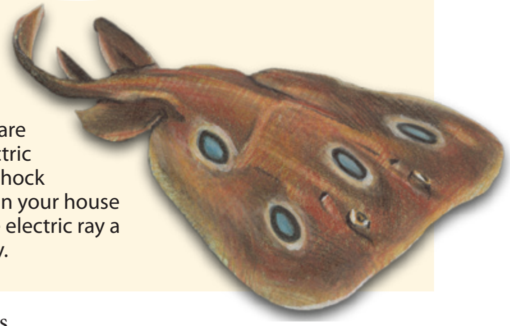
Wet-cell Battery

196

SCIENCE BACKGROUND

Wet cells and dry cells
The terms *wet cell* and *dry cell* refer to the type of electrolyte that is used in the battery. While all wet-cell batteries are rechargeable to some extent, only certain dry cells are rechargeable. Rechargeable batteries contain electrodes and an electrolyte that can be reconstituted.

CREATION CORNER



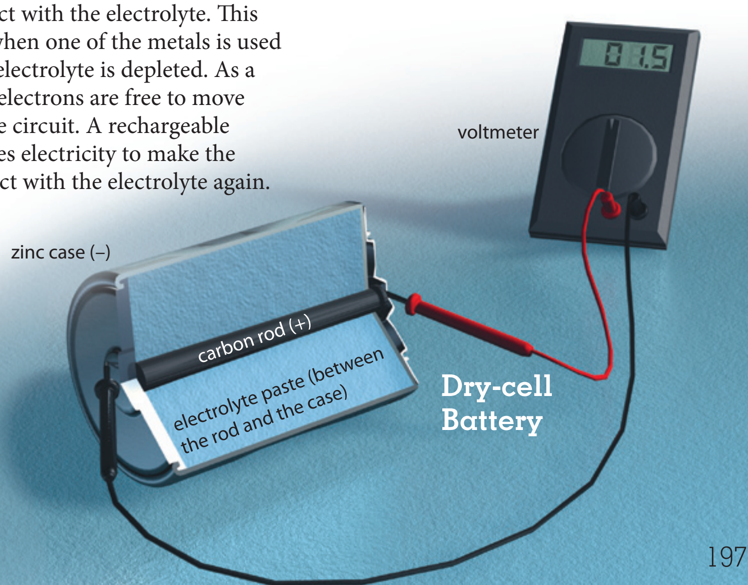
Did you know that some batteries swim in the ocean? God has designed the electric ray with organs that work similarly to batteries. These organs can store electricity and are connected like parallel circuits. An electric ray can electrocute a large fish with a shock as powerful as 200 volts! Most outlets in your house carry only 110 volts. God has given the electric ray a powerful charge to use to capture prey.

paste. This improvement made batteries safer and easier to use. Dry-cell batteries can be used in any position and in most locations. They are sealed and less likely to expose a person to the corrosive or poisonous electrolyte. Scientists continue to experiment with metal and electrolyte combinations to try to make batteries that last longer.

In a "dead" battery, the metals no longer react with the electrolyte. This happens when one of the metals is used up or the electrolyte is depleted. As a result, no electrons are free to move around the circuit. A rechargeable battery uses electricity to make the metals react with the electrolyte again.

QUICK CHECK

1. What is the difference between a series circuit and a parallel circuit?
2. What are three units used to measure electricity? What does each of them measure?
3. What is needed to produce an electric cell?



Dry-cell Battery

DIRECT A DEMONSTRATION

Demonstrate making a battery

Materials: small piece of copper, 2 plastic cups, 20 mL vinegar, 10 mL salt, 20–30 mL water, 5–10 cm strip of aluminum foil, 5–10 cm strip of paper towel, voltmeter

Copper and aluminum should react when an electrolyte is between them.

Soak the copper in vinegar while setting up the demonstration.

Mix the salt and water together.

Fold the paper towel into a square and immerse it in the salt water.

Fold the piece of foil into a small square.

Make a battery cell by sandwiching the wet paper towel between the copper and foil.

Set the voltmeter for DC (direct current). Using the voltmeter, place the red lead (+) on the copper and the black lead (–) on the aluminum foil.

Direct the student to observe how much electricity the battery generates.

What was the liquid electrolyte? salt water

Which two metals reacted with each other? copper and aluminum

What change occurred to the piece of copper? It may have dark blotches of corrosion on it.

If the voltmeter does not register that any electricity has been produced, check to see if the leads are touching the desired objects. If needed, touch the black lead to the copper and the red lead to the aluminum foil.

Discussion

How is the electrolyte of a dry-cell battery different from that of a wet-cell battery? A dry-cell battery uses a paste instead of a fluid.

What are three advantages of a dry-cell battery? It can be used in any position. It can be used in most locations. It is sealed and is less likely to expose a person to the corrosive or poisonous electrolyte.

What happens when one of the metals in a battery is used up or when the electrolyte is depleted? No electrons are freed to move around the circuit, and the battery is "dead."

What kind of battery uses electricity to make the metals react with the electrolyte again? a rechargeable battery

Discuss *Creation Corner*.

How is an electric ray similar to a battery? It has organs that can store electricity and are connected like a parallel circuit.

How did God design for the electric ray to use its stored electricity? to capture prey

Is the electric ray's shock greater than or less than a household circuit? greater than

Answers

1. A series circuit has one path. A parallel circuit has many paths.
2. A volt is a measurement of the amount of electrical push, or force. The watt is a measurement of the power, or how fast work is done. An ampere is a measurement of the amount of electric current flowing through any given part of the circuit in one second.
3. An electric cell needs two different metals and an electrolyte.

Activity Manual

Reinforcement, page 125

Expansion, page 126

This page allows the student to practice reading schematic drawings of electrical circuits.

Review, pages 127–28

These pages review Lessons 95 and 97.

Assessment

Quiz 8-A

The quiz may be given any time after completion of this lesson.

Student Text pages 198–200
Activity Manual page 129

Objectives

- Describe what happens to magnets at their poles
- Explain the relationship between magnetism and electricity
- Identify and describe the parts of a generator
- Explain how a generator works

Vocabulary

magnet
magnetism
magnetic field
electromagnet
generator

Materials

- voltmeter (or current detector if voltmeter is not available)
- batteries with different voltages (1.5, 6, 9)
- black paper

Introduction

Prior to class, wrap black paper around each of the batteries to hide the labels. Display the voltmeter and attach it to one of the batteries.

How many volts did this battery have?

Remove the black paper and compare the number identified by the voltmeter with the number written on the battery. Repeat this test for each battery.

How do you think the voltmeter got its name? *Meter* means "to measure," so a voltmeter measures the number of volts.

How does a voltmeter detect current? The magnetic field produced by electricity attracts the magnet in the compass.

Purpose for reading

How are electricity and magnetism similar?

What are the parts of a generator?

Discussion

What is a magnet? any material that has the ability to attract iron

What other materials will a magnet attract? Possible answers: nickel, cobalt

Magnetism

A **magnet** is any material that has the ability to attract iron. In addition to attracting iron, magnets also attract objects made from nickel and cobalt. Magnets can be natural or manmade. Even though magnets come in many shapes and sizes, every magnet has two poles, a north pole and a south pole.

Magnetic Attraction

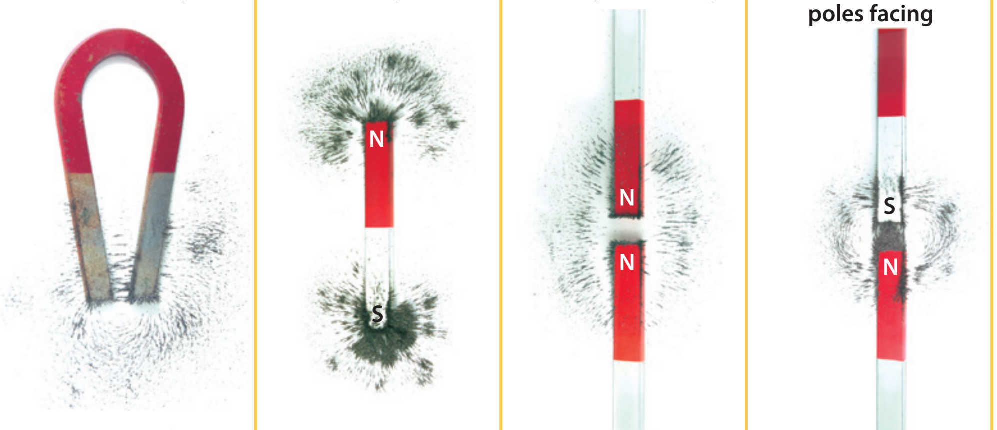
Another name for magnetic force is **magnetism**. By sprinkling iron filings in the **magnetic field**, the area of magnetic force, we can see that the magnetic force is strongest at the poles of a magnet. The middle of a magnet has the weakest magnetic force.

Magnets and static electricity act in somewhat similar ways. Both can attract and repel other objects. With static electricity, objects that have different charges attract each other. In the same way, the opposite ends, or poles, of magnets attract each other. The south pole of one magnet will be attracted to the north pole of another magnet. However, two south poles will repel each other.

Electricity and Magnetism

Electricity and magnetism are related. A flow of electricity can produce a magnet, and a magnet can produce electricity. In 1820 the Danish scientist Hans Christian Oersted (UR sted) discovered that current traveling through a wire produces a weak magnetic field in the wire. Then in 1831 American scientist Joseph Henry and British scientist Michael Faraday made similar discoveries. Although they did not work together, both discovered that moving a magnet around or through a loop of wire produces electricity in

horseshoe magnet | bar magnet | north poles facing | north and south poles facing



198

Make a current detector

A current detector does not measure the number of volts, but it can detect electricity.

Use 2–3 m of 25-gauge insulated wire and a compass.

Leave a length of 10 cm on both ends of the wire. Coil the remaining wire around a compass at least 40 times so that the coil forms an X with the compass needle.

When the ends of the wire are attached to the poles of a battery, the compass needle should move.

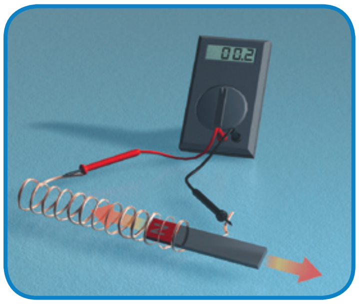
SCIENCE BACKGROUND

Detecting current

A voltmeter, galvanometer, and homemade current detector each detect current using a coil of wire and a pivoting needle. The coil has a magnetic field when electricity flows through it that causes the needle to move.

Poles of a magnet

Every magnet has two poles, a north pole and a south pole. The location of the poles depends on the shape of the magnet. A bar magnet has its poles on either end of the magnet. A horseshoe magnet has poles at the ends of the magnet. Donut magnets and disc-shaped magnets have one pole on the top of the magnet and the other pole on the bottom.

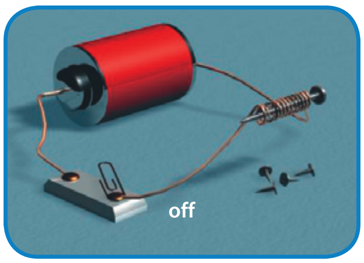


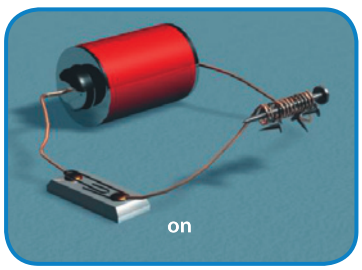
the wire. They also found that moving a wire between the north and south poles of two magnets produces electricity in the wire. However, a wire resting between two magnets does not produce electricity. Either the wire or the magnet must be moving. Modern machines, such as generators, use this principle to make electricity.

Electromagnets

The magnetic field of an electrical wire in your home is too weak to do work. Coiling a current-carrying wire increases the strength of the magnetic field. In 1825 William Sturgeon discovered that adding a metal core to a coil of wire increases the magnetism even more. An **electromagnet** is a coil of wire with a core attached to an electrical source. When electricity travels through the coil of wire, the core acts like a magnet. The core has both north and south poles. However, if no electricity travels through the coil of wire, the core is not magnetized. An electromagnet with an iron core can lift a piece of iron twenty times heavier than the magnet's iron core. When it has a larger core, the magnet is able to do even more work. The shape of the core and the distance between the poles also affect the strength of the electromagnet.

An electromagnet has several advantages over other magnets. It is made from inexpensive, common materials. Since electromagnets can turn on and off, they can power machines. The strength of an electromagnet can be increased or decreased by increasing or decreasing the number of coils. An electromagnet is much stronger than a natural magnet. Electromagnets attached to cranes at scrap yards are powerful enough to lift whole cars. Doorbells, microphones, radio speakers, and even the particle accelerators used to study atoms all use electromagnets.





199

DIRECT A DEMONSTRATION

Demonstrate magnetic fields

Materials: one blank overhead transparency, two bar magnets, one horseshoe magnet, iron filings

If iron filings are not available, a substitute can be made by cutting small pieces from steel wool.

To see the magnetic field of a bar magnet, place the magnet under a sheet of overhead transparency. Sprinkle iron filings on the transparency. Observe the shape of the magnetic field. Repeat the demonstration with the horseshoe magnet.

This demonstration can also be done with two magnets. Place two bar magnets under an overhead transparency with opposite poles facing each other but not touching. Sprinkle the iron filings onto the transparency. Repeat with like poles facing each other.

Discussion

What is magnetism? magnetic force

How many poles does every magnet have? two **What are these poles called?** north pole and south pole

What is the magnetic field of a magnet? the area of magnetic force, or the area in which a magnet can attract things

How can we demonstrate that a magnetic field is strongest at a magnet's poles? When iron filings are sprinkled around the magnet, we can see that more iron filings go to the poles than to the center of the magnet.

What is the relationship between magnetism and electricity? Electricity can produce magnetism, and magnetism can produce electricity.

What do magnets and static electricity have in common? Both can attract and repel other objects.

Who discovered that an electrified wire has a magnetic field? Hans Christian Oersted

Which men discovered how to make electricity in a wire by using a magnet? Joseph Henry and Michael Faraday

Describe how a magnet produces electricity. Possible answers: moving a magnet around or through a loop of wire; moving a wire between magnets

How can you increase the magnetic field of a current-carrying wire? coil the wire

What is an electromagnet? a coil of wire with a core attached to an electrical source

Who discovered the electromagnet? William Sturgeon

Which part of an electromagnet acts like a magnet? the core

Will the core work like a magnet if electricity is not traveling through the wire? no

What are two ways to change the strength of an electromagnet? Possible answers: change the number of coils; change the core

What are three advantages of an electromagnet? inexpensive; can turn on and off; strength can be increased or decreased

Identify two common uses of an electromagnet. Possible answers: doorbell, microphone, radio speaker, particle accelerators

Discussion

What is a generator? a machine that converts motion into electrical energy

Describe how small, fuel-powered generators work. The engine burns the fuel and causes the shaft to turn. That causes the magnet to rotate in the coil of wire, generating an electric current that can be used to power appliances.

What do most electric power plants use to power generators? turbines

What makes the blades on the turbine move? water, wind, or steam

How do the turbine-powered generators work? As the blades on the turbine turn, a shaft turns a magnet inside a coil of wire.

Is it possible to generate electricity by moving the coil of wire instead of the magnet? yes **Explain.** Electricity will be generated if either the wire or the magnet is moving.

Why do most power plants have a moving magnet and a stationary coil? It takes less energy to spin the magnet than it does to rotate the heavy coil around the magnet.

According to the Second Law of Thermodynamics, matter (energy) is neither created nor destroyed. Energy simply changes form. Generators change motion into electrical energy. A motor does the opposite. It converts electrical energy into motion, such as that of a mixer or fan.

Discuss the path of electricity from the power plant to the house.

Answers

1. Possible answers: Moving a magnet around or through a loop of wire produces electricity in the wire. Moving a wire between the north and south poles of two magnets produces electricity in the wire.
2. An electromagnet is a coil of wire with a core attached to an electrical source.
3. A generator is a machine that converts motion into electrical energy.

Activity Manual

Review, page 129

This page reviews Lesson 98.

Assessment

Quiz 8-B

The quiz may be given any time after completion of this lesson.

Generators

The movement of a magnet within a coil of wire or of a coil of wire within a magnet causes an electrical current. This principle is used by a **generator**, a machine that converts motion into electrical energy.

Some generators are very small. You may even have used one to supply electricity during power outages. These smaller generators are often portable and run on gasoline or some other type of fuel. The engine burns the fuel and causes a shaft, or long pole, to turn. The shaft has a magnet attached to the end of it which turns with the shaft. As the magnet rotates in a coil of wire, it causes an electrical current that may be used to power appliances or other machines.

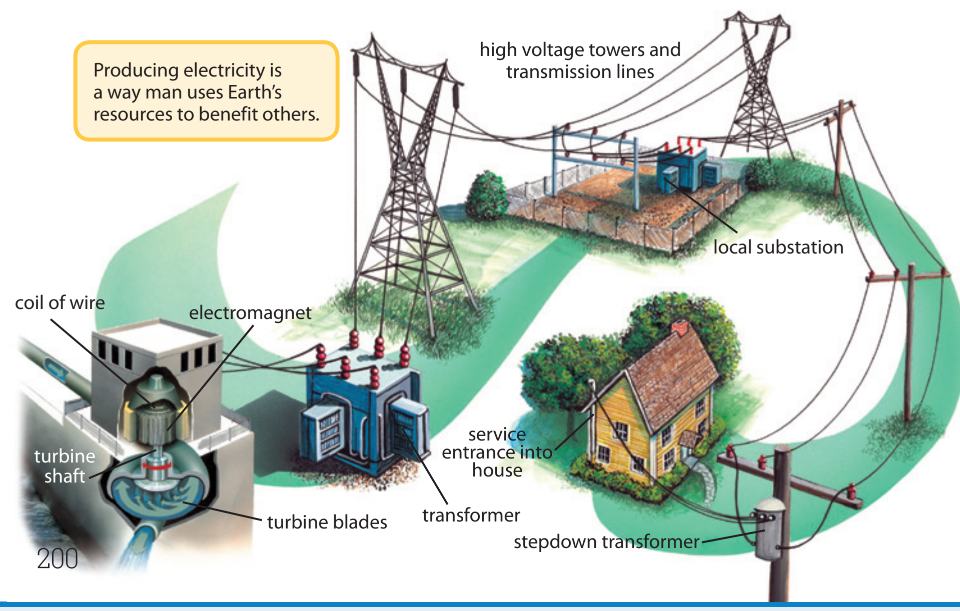
Most electric power plants use turbines to power generators. The turbine has blades that are moved by water, wind, or steam. As the blades turn, a shaft turns a magnet within a coil of wire. The spinning magnet creates an electric current in the coil of wire.

Another way to generate electricity is to attach the shaft of the turbine to the coil of wire. The moving turbine rotates the coil around the magnet or spins the coil in a magnetic field. However, spinning the heavy coil around the magnet requires more energy than rotating the magnet requires. For this reason, most electrical power plants have stationary coils and moving magnets.

QUICK CHECK

1. How can you produce an electric current with a magnet and a coil of wire?
2. What is an electromagnet?
3. What is a generator?

Producing electricity is a way man uses Earth's resources to benefit others.



200

TEACHER HELPS

Discussing the diagram Although the Student Text does not elaborate on all the parts of the path of electricity from power plant to house, help the student identify parts of the system that he is familiar with. The electrical energy coming from the power generating station has a very high current level. If it was sent directly out through the wires, the resistance as it traveled through miles of transmission lines would cause much of it to be lost as it was converted to heat. To prevent this, the power is "stepped up" at the first transformer to levels around 110,000 volts. Increasing the voltage reduces the amperes. At substations near the end of the line, step-down transformers reduce the voltage and increase the amperage. The final step-down transformers, often mounted on poles or sitting on the ground, reduce the voltage to the appropriate level for household use.

EXPLORATION

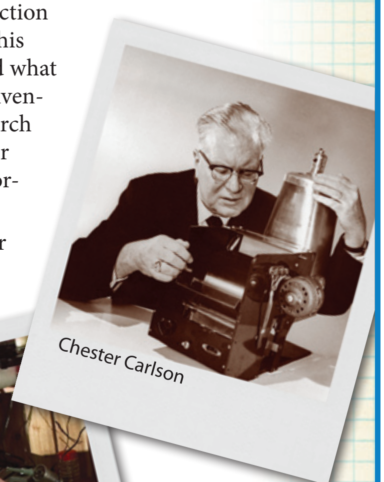
Famous Inventors

A whole new door of opportunity for inventors opened when people learned how to use magnetism and electricity to power devices. Men such as Thomas Edison became famous for the hundreds of devices that they invented and patented. A person can obtain a patent by registering his or her invention with the government so that no one else can claim credit for the invention.

Imagine that you are at an awards ceremony honoring one of the people who invented a device that furthered the use of electricity and magnetism. You have been asked to introduce the guest of honor.

What to do

1. Choose an inventor from the list your teacher provides.
2. Research the person that you choose. Your introduction should include the following: the inventor's name, his country, when he lived, his family background, and what invention he is famous for. Also include how the invention improved people's lives, how it furthered research and use of electricity and magnetism, and any other inventions credited to the honoree. Record the information you find in your Activity Manual.
3. Prepare a one-to-two minute speech honoring your chosen inventor.


Chester Carlson


Wilson Greatbatch


Bessie Blount Griffin

201

Objectives

- Research an inventor
- Present a speech honoring an inventor

Materials

- *Famous Inventors and Discoveries* (IA), for display

Introduction

Have you ever heard your pastor introduce a missionary, evangelist, or other speaker? Answers will vary.

Why would a pastor introduce a special speaker? Possible answers: to help the audience get to know the speaker; to get the audience interested in listening

What types of details might a pastor include in his introduction? Possible answers: where the person has been; important things that the person has done; the length of time that the person has been involved in the ministry; a brief family background; awards earned; special positions held

The Bible tells us that it is appropriate to honor those who deserve honor. Giving an introduction is a way of acknowledging a person who has earned honor (Rom. 13:7).

Teach for Understanding

Purpose for reading

The student should read the pages before beginning the exploration.

What to do

Display *Famous Inventors and Discoveries*. Guide the student in choosing a person to research. Encourage the student to consult a variety of resources. Remind him to complete his Activity Manual page during his research. Explain your requirements and due date for his speech.

Assessment

Rubrics

Select the prepared rubric, or design a rubric to include your chosen criteria.

TEACHER HELPS

Speaking tips
Encourage the student to practice eye contact and clarity as he speaks.

For some students, public speaking is a frightening experience. Although the student should do adequate and accurate research, a lighthearted approach to the speech may ease some students' fears.

Suggest that the student prepare a note card with the basic information for his speech. Encourage the student to refer to the card, but discourage his reading it word for word.

Student Text pages 202–3
Activity Manual pages 131–32

Objectives
- Identify ways to increase a wire's magnetism
- Predict ways to strengthen an electromagnet
- Experiment to test predictions

Materials
- electromagnet from an old appliance or photo of an electromagnet
- See Student Text page

Introduction
Display the electromagnet or photo. Allow the student to examine it.

What is on the outside of the electromagnet? wire

What is produced around a wire that has electricity flowing through it? a weak magnetic field

What is the advantage of coiling the wire? to increase the magnetic field

An electromagnet is made of more than coiled wire. It also has a core and a power source. Changing variables of any of the parts can affect the magnetic strength.

Today you will build an electromagnet and experiment with ways to increase its strength.

Teach for Understanding
Purpose for reading
The student should read all the pages before beginning the activity.

Procedure
The student should complete step 1 (Test 1) before formulating his hypothesis. His hypothesis explains what he thinks will make that electromagnet stronger. His first electromagnet (step 1) may not be strong enough to attract one staple.

After recording his hypothesis, the student should build an electromagnet that matches his hypothesis. The results from testing this electromagnet should be recorded as Test 2.

ACTIVITY

Build an Electromagnet

Electromagnets are a vital part of our everyday lives. From the doorbell on your house to the mega magnet at the junkyard, magnetism and electricity provide many useful tools for our daily lives. In this activity you will build an electromagnet. It is your job to determine how to make the magnet stronger.

Process Skills
- Hypothesizing
- Predicting
- Experimenting
- Observing
- Inferring
- Identifying and controlling variables
- Recording data

Problem
How can you make an electromagnet stronger?

Procedure
Note: Disconnect your electromagnet from the battery after each test.

Materials
- 2–3 meters of insulated wire
- 1 large metal paper clip (straightened)
- electrical tape
- 2 D-cell (1.5-volt) batteries or 1 six-volt battery
- 1 bar of staples (separated into individual staples)
- various materials such as different-sized nails, wooden pencils, plastic rods, additional batteries and wire
- Activity Manual

1. Remove 5 centimeters of insulation from the ends of each piece of wire. Wrap the longest piece of wire 5 times around the straightened paper clip. Attach the ends of the wire to the battery. See how many staples your electromagnet (bare tip of the paper clip) attracts. Record the results in your Activity Manual.
2. Write a hypothesis about an electromagnet and the number of staples it can pick up. You may change the object used as the core of the electromagnet, or you may change the amount of times the wire is wrapped around the core.
3. Build your electromagnet and test it. Record the result in your Activity Manual.
4. If your electromagnet was not stronger than the first one, choose one variable to change. Explain the adjustment you make. Retest your electromagnet and record the test results.

202

TEACHER HELPS

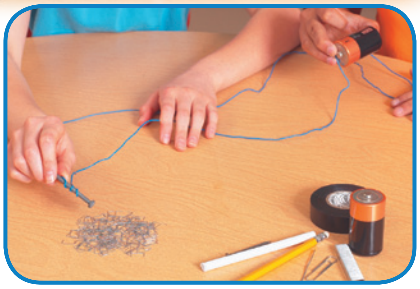
Electromagnet for display
Many small appliances, such as hairdryers, contain an electromagnet. Plan ahead to acquire one for display.

Batteries
Use fresh batteries. Avoid using more than a 6-volt battery. A stronger battery may cause the wires to get hot.

Staples
Staples are easily separated by discharging them through a stapler.

Magnetized staples
A strong electromagnet easily magnetizes the staples. Once magnetized, the staples will clump together. This clumping is not a problem unless you are trying to test a weak electromagnet using the magnetized staples. To test a weak electromagnet, use staples that are not magnetized. Heating or dropping magnetized staples on a hard surface will weaken the magnetic field.

Optional core materials
Provide students with optional core materials such as a thick iron nail about 8–10 cm (3–4 in.) in length, a thinner iron nail about the same length, wooden pencils, and plastic rods. Provide additional batteries and wire for students to experiment with if they choose.



5. If your electromagnet was stronger, keep trying to increase the strength until it can pick up 50 or more staples. Remember to change only one variable at a time. Use the chart to record your information.

Conclusions

- Do your results support your hypothesis?
- Can you see any direct relationship between the changes you made and the strength of the electromagnet? For example, how many more staples could an additional battery pick up?

Follow-up

- Change other variables to try to strengthen your electromagnet.

203

SCIENCE PROCESS SKILLS

Predicting

If your electromagnet did not pick up the number of staples in your hypothesis, how did you determine what to do to increase its strength? Answers will vary, but elicit that the student knows that some actions, such as increasing the number of coils, will increase the strength of the electromagnet.

Could you predict the result of changing the core? Answers will vary, but elicit that unless the student had tried a different core or had additional knowledge outside of the Student Text, he would not have any basis for predicting.

Predicting is based on knowledge and past experiences.

After trying different cores, could you predict how one of those cores and how additional coils would affect the electromagnet? yes **Why?** because the prediction would be based on knowledge and experience

Procedure

To test the electromagnet, the student should touch an end of the core to the staples. Encourage the student to wrap the wire tightly against the core. Batteries may be taped together.

Use the following questions to help the student think of ideas to try.

Did the information about electromagnets in the Student Text give any ideas for increasing the strength of an electromagnet?

How many times did you coil the wire?

Would a wooden or plastic core work? Why or why not?

Do you think it makes a difference if the wires are wrapped smoothly and evenly or wrinkled and criss-crossed?

Could you increase the size of the core?

Is there a way that you could increase the voltage or amount of electricity?

Use the questions in the Science Process Skills to discuss predicting.

Conclusions

Provide time for the student to evaluate his hypothesis and answer the questions.

Did your results support your hypothesis?

What changes did you make that made your electromagnet stronger? Possible answers: use a bigger core; increase the number of coils; increase the amount of electricity

How many staples did your strongest electromagnet pick up?

What generalization can you make about the features that strengthen an electromagnet? An electromagnet with the greatest number of coils, largest size of core, and highest voltage of electricity will be the strongest electromagnet.

Activity Manual

Activity, pages 131–32

Assessment

Rubrics

Select the prepared rubric, or design a rubric to include your chosen criteria.

Lesson 101

Student Text pages 204–5
Activity Manual page 133

Objectives

- Explain how electromagnets are used in maglev trains
- Identify some ways a maglev train may benefit the environment and transportation

Vocabulary

maglev

Introduction

In the 1890s the fastest way to travel was by the train called *Empire State Express*. The engineer, Charles Hogan, took the steam engine along a 36-mile straightaway, reaching a speed of 112.5 mi/h, the fastest a human had gone up to that time.

Do you think the engine could go that fast while pulling a load? probably not

What happened in Kitty Hawk, North Carolina, in the early 1900s? Orville and Wilbur Wright flew the first airplane.

How has airplane travel progressed? Possible answer: from the first plane in North Carolina to the passenger plane to the stealth fighter

As highways and airports become busier, people look for more efficient ways of traveling that have little impact on the environment.

Teach for Understanding

Purpose for reading

What kind of train floats above its track?

How does this type of train work?

Discussion

What kind of train can float above a track? a maglev train

What does *maglev* stand for? magnetic levitation

Can a maglev train use a conventional train track? no **What kind of magnets are on its guideway?** electromagnets

How do the electromagnets on the guide rails work? The guide rails are lined with metal coils connected to a power supply. An electric current flows through those coils, making them electromagnets.

The train itself also has magnets. What are two uses for those magnets? to stabilize the train and to propel it forward

TECHNOLOGY

Magnetic Levitation

When you think of trains, what comes to your mind? Perhaps you see smoke billowing from a smokestack or hear the loud clacking of wheels turning on a track. Maybe you think of a caboose or of an engineer up front blowing the whistle. Perhaps you can feel the vibrations of a subway rushing into an underground station. Or maybe you picture a train quietly whooshing by, floating above a specially designed track.

Floating above a track! What kind of a train would do that? Magnetic levitation trains, or **maglev** trains, do exactly that. The maglev train does not use a conventional track. Instead, electromagnets propel it along a guideway. Because the train does not touch the track, it runs very quietly.

The maglev train works by using guide rails lined with metal coils that are connected to a power supply. An electric current flows through the coils, thus creating an electromagnet. There are also magnets located on various parts of the train cars. These magnets have many uses. Some of the magnets stabilize the train so that it will not tip over. Other magnets propel the train forward. The magnetized coil in the guideway repels the magnets on the bottom of the train, causing the train to rise, or levitate, about ten millimeters off the track. The train floats above the track on this cushion of air.

Opposite magnetic principles can be used to propel the train. One train uses a traveling magnetic field's repulsion to push the train forward. Other trains use the magnetic attraction to pull the train along. Some trains even use a combination of the two principles.

A maglev train can move at very high speeds. It floats on a cushion of air, so there is no friction with the track to slow it down. Also, its aerodynamic design reduces wind resistance. These factors and others allow maglev trains to go much faster than regular trains. They have been recorded going more than 500 km/h (310 mi/h)!

Maglev train cars are designed to carry large amounts of freight as well as passengers. The idea is that tractor trailers will be able to be parked, fully loaded, in one of the cars and then be taken to another city. Then the truck could be driven just a short distance to its destination. This will help to reduce the amount of traffic on roads in

204

SCIENCE BACKGROUND

Maglev technology
Two types of maglev technology are being used and further developed. One form is electromagnetic suspension (EMS) in which electromagnets on the train body are attracted to the iron rails. The attractive upward force lifts the train. This system is used in Germany and China. The electrodynamic suspension (EDS) uses repulsive forces from currents in the guideways. The Japanese trains operate with EDS. EDS trains usually levitate at higher heights and are able to reach faster speeds than EMS trains. Another difference is that EDS trains use wheels until they reach a lift-off speed. EMS trains do not have wheels. A third design, inductrack, is a new type of EDS technology. Maglev technology might even be used someday for space travel. The StarTram Maglev System is in development and would use electric energy and electromagnets instead of rockets.

Maglev systems
The EDS maglev system was invented and designed in 1966 by American scientists Dr. James Powell and Dr. Gordon Danby. Both Germany and Japan interviewed them while building and developing their systems. Dr. Powell and Dr. Danby have continued developing their ideas and have now created a second generation Maglev 2000 system which has several improvements over the first generation Japanese and German systems. The second generation maglev is able to use (with modifications) existing conventional railroad track. The new design is expected to be cheaper to build.

the future. Carrying trucks on trains would also save gasoline. And, by using maglev trains, a tractor trailer could travel across the country from New York to California in a few hours rather than days.

Maglev trains are very energy efficient. They also work quietly and do not emit pollution. The trains have no moving parts, so there is less maintenance to do. There are no wheels to break down or axles to fix. This makes the cost of maintaining the trains relatively low. The guideways also do not need much maintenance because there is no contact between the train and its surface. However, because of the guideways, the trains can be expensive to build. The trains can run only on the guideways built specifically for them. They cannot use railroads previously built for other trains unless modifications are made to those tracks.

Maglev technology has been worked on and dreamed about since the early 1900s. In the 1960s, two American scientists developed the first practical system of maglev trains. However, maglev trains are not yet in use in the United States. They are being developed and used in China, Germany, Japan, and South Korea. Someday maglev trains may be more popular than airplanes for long-distance, high-speed travel.

205

Discussion

What does it mean to levitate? Possible answers: to rise, to hover, to float

How does a maglev train levitate? Electromagnets in the guideway repel the magnets on the bottom of the train.

What principle of magnetic attraction does the train use? Like poles of magnets repel each other.

How high does a maglev train levitate? about 10 mm

Different trains levitate at different heights.

Share the Science Background information about Maglev technology from page 222 as time allows.

How does the train move forward? Magnets attract or repel to move the train.

What three things does a maglev train need to operate? a power source, metal coils in the guideway, and magnets attached to the train

What do you think happens if the power, or electricity, goes out? Answers will vary, but elicit the idea that some trains have an emergency battery-power supply.

Trains that operate on an EMS system have battery-power supplies in case of power failures. EDS trains utilize super-cooled, superconducting magnets that can conduct electricity even after the power supply has been shut off. Their wheels also help the train come to a safe stop.

What factors help the maglev train to go faster than regular trains? no friction because it floats; its aerodynamic design reduces wind resistance

How would maglev trains affect the freight industry? reduce the time for a truck to drive to its destination; reduce the amount of traffic on crowded roads, reduce the amount of fuel (gasoline) used

What are some benefits of maglev trains? energy efficient; work quietly and do not emit pollution; less maintenance; cost of maintaining would be relatively low

What are some disadvantages? The guideways are expensive to build. They cannot use existing railroad track unless modifications are made to those tracks.

Who developed the first practical system of maglev trains? two American scientists

Activity Manual

Technology, page 133

TEACHER HELPS

Height of levitation

The height of 10 millimeters, or 1 centimeter, mentioned in the lesson is the levitation height of an EMS train. The speed referenced in the student text refers to an EDS train's speed.

DIRECT A DEMONSTRATION

Demonstrate magnetic levitation

Materials: shoebox, masking tape, 12 disc-shaped magnets

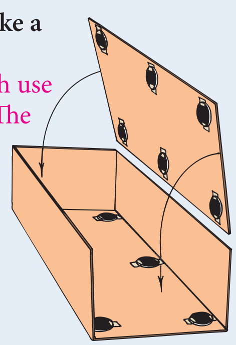
Prepare the shoebox before the lesson.

Cut one short side from the bottom of the shoebox. Trim all the sides from the lid so that it will lay inside the bottom of the box without touching the sides. Tape 3 magnets along both long edges of the bottom of the box. Tape 6 magnets in matching positions on the underside of the lid. Place the lid, magnet side down, gently on the bottom of the box. Adjust the magnets as needed until each pair repels.

Why does the lid not touch the bottom of the box? The magnets are repelling each other, causing the lid to float.

What is it called when something floats? levitation

How is this model like a maglev train? Possible answer: Both use magnets to levitate. The sides of the box act as guiderails.



Student Text pages 206–9
Activity Manual page 134

Objectives

- Explain the difference between electricity and electronics
- Identify the benefits of an integrated circuit
- Identify some of the parts of a computer

Vocabulary

electronic device	semiconductor
electrical signal	CPU
binary number system	ROM
integrated circuit	RAM

Introduction

Electronic devices use electricity to communicate information.

What are your favorite electronic devices?

What are some electronic devices that you would find at home?

How would you describe life without electronics?

Teach for Understanding

Purpose for reading

Why was the invention of the integrated circuit important?

Does a computer have intelligence? Explain your answer.

Discussion

How are electrical devices and electronic devices similar? Both use current electricity and both can do work.

What can an electronic device do that an electrical device cannot? transfer information

Define an electrical signal. an electric current that carries information

What is the name of the code that integrated circuits use to communicate information? binary system

How does the binary system work? The binary system uses open and closed circuits to communicate the numbers 0 and 1.

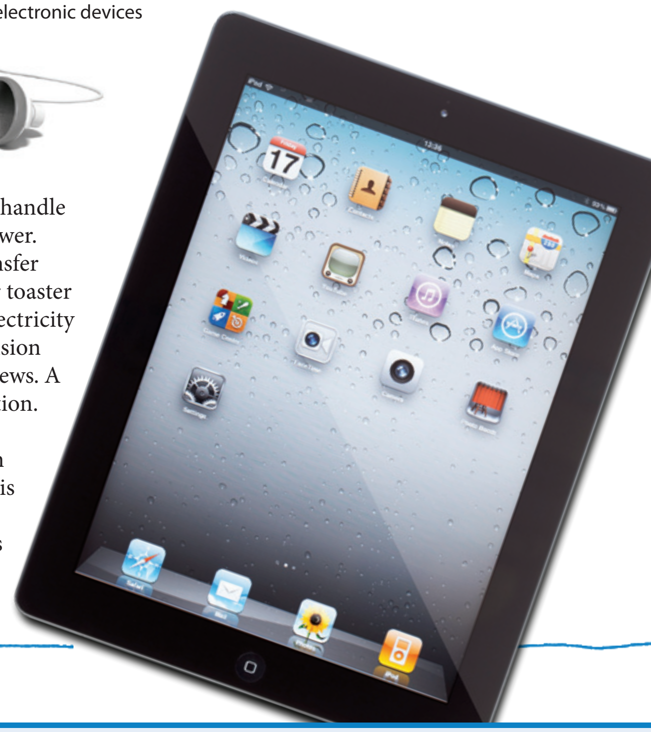
Electronics

For one moment, imagine life without electronics. There would be no computers, radios, televisions, digital watches, or even cell phones. Each of these objects is an **electronic device** that uses electricity to communicate information.

Although not identical, electronic devices are similar to electrical devices. Both use current electricity, and both can do work. Electrical devices handle the transfer of electricity for power. Electronic devices, though, transfer information. For example, your toaster is an electrical device. It uses electricity to produce heat. But your television can communicate the evening news. A toaster cannot transfer information.

To carry information, the current must vary, or change, in some way. An **electrical signal** is an electric current that carries information. Television stations use electronic devices with electrical signals to broadcast programs. Sound, motion, pictures, letters, and words are communicated to your television set by electronic signals.

Electronic devices use a code in much the same way as a telegraph operator uses Morse code. Instead of dots and dashes, many electronic devices use a code called the binary system. The **binary number system** uses open and closed circuits to communicate the number 0 and the number 1. An open circuit means 0, and a closed circuit mean 1. Using this code, electronic devices can communicate almost any type of information.



electronic devices

206

SCIENCE BACKGROUND

Technical terms
An integrated circuit has four main parts. The terms *switch*, *resistor*, *insulator*, and *conductor* are used to describe the functions of the parts. The technical names for the parts of an integrated circuit are diode, transistor, resistor, and capacitor. For this lesson the function of the parts is more important than the actual terms.

Silicon
The parts of most integrated circuits are made from silicon. The location of the impurities in the silicon determines when the silicon acts like a diode, transistor, resistor, or capacitor. By varying where the impurities are located and putting them in a pattern, scientists can determine where each resistor, transistor, and capacitor is placed. Adding impurities to silicon is called *doping*.

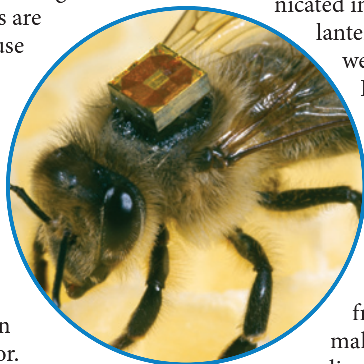
SCIENTIST

Jack Kilby and Robert Noyce
The integrated circuit was independently developed by two men, Jack Kilby and Robert Noyce. In 1959 both men applied for and received patents for miniaturized electronic circuits. One of the first organizations to use the new computer chips was the US Air Force.

Jack Kilby also invented the portable calculator in 1967. In 1968 Robert Noyce started Intel, a company that led the way in microprocessors.

Integrated Circuits

Today most electronic devices use computer chips to process information quickly. A computer chip, or microchip, is really an **integrated circuit** (IC), a very small circuit with all of its components in a single unit. Integrated circuits are called *microchips* because they are manufactured on chips of silicon. Each microchip can have over a billion components, including switches, resistors, insulators, and conductors.



Silicon, a major ingredient of sand, is an excellent semiconductor. A **semiconductor** is a material that can work as a conductor or as an insulator. It acts somewhat like a switch. Under some conditions, a semiconductor conducts electricity and keeps the circuit closed. Under other conditions, it does not conduct electricity and causes an open circuit. At other times, silicon acts like a resistor.

Do you remember Paul Revere's light signal? The lights Paul Revere saw in the Old North Church communicated information. If one lantern was lit, the British were coming by land. If two lanterns were lit, the British were attacking by sea. More information could have been communicated through a sequence of blocking the light from a lantern or by making the flame brighter or dimmer. In a similar way, integrated circuits signal information by varying the amount of electricity by opening and closing circuits in sequence.

Integrated circuits have many benefits that other circuits do not have. They are small in size, inexpensive to produce, and durable. To make an IC durable, a piece of plastic or ceramic insulates the whole chip.

Microchips can be used for many purposes. For example, scientists and beekeepers have put microchips on bees to help them monitor the insects' behavior. They can track the bees entering and leaving the hive and see how long it takes for a specific bee to return to the hive.

SCIENCE & HISTORY

To compete in the space race, the United States of America needed faster, smaller computers. Some early computers were as big as a warehouse! The invention of the microchip solved these problems. The computer that sits on your desk, resides in your cell phone, or rests in the palm of your hand is probably more powerful than the computer that sent the first men into space.

Discussion

What is an integrated circuit? a very small circuit with all of its components in a single unit

Why are integrated circuits sometimes called microchips? because they are manufactured on chips of silicon

How many components can a single microchip have? over a billion **What are some of those components?** switches, resistors, insulators, and conductors

What is a semiconductor? a material that can work as a conductor or as an insulator; It can also act as resistor.

How does the integrated circuit communicate information? by varying the amount of electricity going through the circuit by opening and closing the circuits in sequence

What are some benefits of using integrated circuits? Possible answers: They are small in size, inexpensive to produce, and durable.

Microchips are in computers and many other electronic devices. What is another use for microchips? Possible answer: to monitor the behavior of honeybees

Why do you think scientists would want to monitor bees entering and leaving the hive? Possible answers: to study how long it takes the bees to return; to find out what is killing off so many colonies of honeybees; to count the number of bees, to use the data in studying the effects of pesticides and insecticides on bee health

RFID microchips such as the one pictured are used to monitor insect behavior. The microchip records the individual bee's tag number each time it enters or exits, providing data about its condition and travel frequency.

Discuss *Science & History*.

How big were some of the early computers? as big as warehouses

What is amazing about the size of computers today? Even small modern computers are probably more powerful than the computer that sent the first men into space.

DIRECT AN ACTIVITY

Identify electronic devices

Materials: *Electronics Everywhere* (IA)

This page may be used to help the student recognize which devices in his home are electric and which are electronic.

DIRECT AN ACTIVITY

Explore binary code combinations

Materials: 6 coins

Direct the student to use coins to show the numerous combinations available using a binary code.

Pretend that each coin is a circuit. Heads represents a closed circuit. Tails represents an open circuit.

The student should see how many combinations of open and closed circuits (heads and tails of each coin) he can make in five minutes and write each combination on paper.

For example, one combination would be having the first circuit closed (heads) and the other circuits open (tails).

Write this combination as follows: h t t t t t.

Without repeating any combination, there are sixty-four possible combinations.

Discussion

What is a computer? an electronic device that can communicate information and is able to save, process, and retrieve that information

Does a computer have one integrated circuit? No, it has many of them connected together.

Name three examples of integrated circuits found in a computer. CPU, ROM, and RAM

What does *CPU* stand for? central processing unit

What does the CPU do? It processes the information.

What is ROM? the read-only memory; the built-in memory and programs

What are programs? sets of instructions that tell the computer what to do

How is ROM like your long-term memory? ROM remembers facts for a long time.

What does *RAM* stand for? random access memory

What is RAM? temporary memory storage

Which can be changed, ROM or RAM? RAM

Which part of the computer's memory is lost when the computer is turned off? RAM

Can a computer save information to RAM or ROM? no **Why not?** ROM cannot be changed, and RAM is lost when the computer turns off. A computer can save information to data storage devices.

What are some data storage devices? Possible answers: hard drive, CD-ROM, DVD, flash memory drive

Which kind of storage device is a permanent part of the computer? hard drive

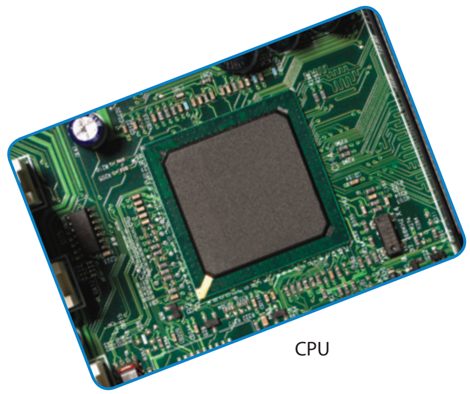
What are some input devices of a computer? Possible answers: keyboard, mouse, modem, scanner

What are some output devices? Possible answers: monitors, printers

Computer Parts

The electronic device called a computer uses many, many integrated circuits connected together. A computer can communicate information and save, process, and retrieve that information. The CPU, ROM, and RAM are examples of integrated circuits in a computer.

hard drive



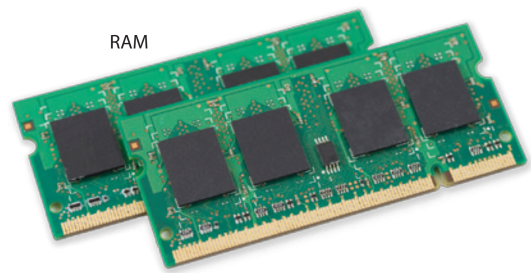
CPU

The **CPU (central processing unit)** acts like the brain of the computer. It is the part of the computer that processes the information. The CPU is part of the motherboard, or main circuit board for the computer.

ROM (read-only memory) is built-in memory and programs, sets of instructions that tell the computer what to do. ROM cannot be deleted or changed by the CPU. ROM can remember information for a long time. It is somewhat similar to your long-term memory. For example, when someone asks your name, you can easily recall it. It is part of your long-term memory.

RAM (random access memory) stores information temporarily. The CPU can change information stored in RAM. Information stored in RAM is not remembered forever. It is lost when you turn the computer off.

RAM



SCIENCE BACKGROUND

Computer parts
The hard drive is only one part of a computer. A computer actually has three main categories of parts: input devices, output devices, and a system unit.

Input devices, such as the keyboard and mouse, take your message and translate it into computer language. Then the computer can save, process, and retrieve that information.

An output device, such as a computer monitor, translates the information from computer language to a language that you can read.

The CPU, RAM, and ROM are part of the system unit. This part of the computer does the actual saving, processing, and retrieving of data. The hard drive is a type of secondary, or permanent, storage.

HISTORY

First computer
Credit for inventing the first computer is given to Charles Babbage. Although his computer in 1884 was a mechanical device and not an electronic device, many of the principles he used are still used for modern computers.

The computer cannot save information in RAM or ROM. The CPU can save information only to data storage devices. A hard drive, CD-ROM, DVD, and flash memory drive are examples of data storage devices. A hard drive, sometimes called the hard disk, is a permanent part of the computer. The other devices are called removeable storage.

Computers receive information through input devices such as a keyboard, mouse, modem, or scanner. They give information through output devices such as monitors and printers.

Computer "Intelligence"

A computer "knows" only two things, open and closed circuits. An open circuit can mean no, or 0, while a closed circuit can mean yes, or 1. By sequencing the open and closed circuits, a computer can represent information using the binary number system.

A computer can solve problems so fast that it seems like it is actually thinking. But it is not. A computer only seems to have intelligence. It can only do what the programmer and designer have told it to do. It can recall facts quickly and accurately, but it does not understand the facts. A programmer could tell the computer that $2 \times 2 = 4$, and the computer would process this fact. But it would not know why two times two equals four. A programmer could also tell the computer that $2 \times 2 = 5$. The computer would not know that this is incorrect unless it was programmed with that information.

Computers can process billions of computations in seconds. But computers can do only what they have been programmed to do. As amazing as the computer is, the human brain is far more amazing. The brain is a living organ. It is the center of emotions, able to think and sense. The storage capacity of the brain appears to be unlimited. Your brain will never be too full to store more information. The brain has an estimated one hundred billion nerve cells, which constantly send and receive information by electrical messages. Yet God created the human brain with about 75 percent of it being watery fluid. That much fluid would short circuit any microprocessor! Though there still is much we do not understand about the brain, we can praise God that we are fearfully and wonderfully made (Ps. 139:14).

QUICK CHECK

1. How does an integrated circuit signal information?
2. What are some benefits of integrated circuits?
3. How much information does a computer really know?

Discussion

How much does a computer really know? It knows two things—open and closed circuits.

What information does an open circuit communicate? no or 0 **A closed circuit?** 1 or yes

Does a computer really think and understand? No; it knows only what the programmer and designer tell it. It does not understand facts.

What has God given us that is more amazing than a computer? our brain

What is the storage capacity of the brain? It appears to be unlimited.

What is unique about the brain that would cause a computer to quit working? God created the brain with about 75% of it being watery fluid.

Answers

1. It varies the amount of electricity by opening and closing circuits in sequence.
2. small, inexpensive to produce, and durable
3. open and closed circuits; what it is programmed to know

Activity Manual

Review, page 134

This page reviews Lesson 102.

Assessment

Quiz 8-C

The quiz may be given any time after completion of this lesson.

DIRECT AN ACTIVITY

Practicing life without electronics
Encourage the student to try going without using any electronic devices for a day. He can record his experiences in a journal.

The student should record the electronic devices he regularly uses and their purposes in his life. Then he can make journal entries about frustrations, humorous experiences, and how often he was successful at avoiding electronics. Have him include the things he did as a replacement for not using the devices.

Afterward, discuss lessons learned, such as how much time can be wasted using certain technology. You may choose to also have the student list ways in which electronic devices can be used to aid spiritual growth.

Student Text page 210
Activity Manual pages 135–36

Objectives
- Recall concepts and terms from Chapter 8
- Apply knowledge to everyday situations

Introduction
Material for the Chapter 8 Test will be taken from Student Text page 210 and Activity Manual pages 127–29 and 134–36. You may review any or all of the material during the lesson. Questions similar to Solve the Problem or the ones in Thinking It Through, Activity Manual pages 135–36, may appear on the test.

You may choose to review Chapter 8 by playing "Complete the Circuit" or a game from the Game Bank on the Teacher's Toolkit CD.

Teach for Understanding
Diving Deep into Science
Information on this page reflects the vocabulary and concepts the student should know for the test.

Solve the Problem
In order to solve the problem, the student must apply material he has learned. The student should attempt the problem independently. The answer for this Solve the Problem is based on the material on Student Text page 195. Answers will vary and may be discussed.

Activity Manual
Review, pages 135–36
These pages require written respones to application questions.

Lesson 104

Objective
- Demonstrate knowledge of concepts taught in Chapter 8

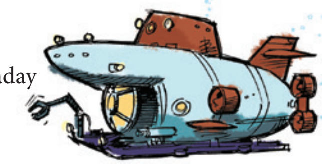
Assessment
Tests, Chapter 8

DIVING DEEP INTO SCIENCE

Words to Know

circuit	parallel circuit	magnetic field
conductor	volt	electromagnet
switch	watt	maglev
short circuit	ampere	electrical signal
insulator	electric cell	binary number system
resistor	electrolyte	integrated circuit
series circuit	magnet	semiconductor

Key Ideas
Difference between current electricity and static electricity
Illustrate parallel circuits and series circuits
How a battery works
Relationship between electricity and magnetism
Significant contribution of Hans Christian Oersted
Significant contributions of Joseph Henry and Michael Faraday
Significant contribution of William Sturgeon
How an electromagnet works
How a generator works
Differences between electrical devices and electronic devices
Parts of a computer



Solve the Problem
Every morning in her bedroom your sister uses a blow dryer and hot curlers to get ready for school. When her 750-watt blow dryer stopped working, she replaced it with one that uses 1500 watts. The next morning she plugged in the blow dryer. As soon as she turned it on, the electricity in her room went out. What might have happened, and why did it happen? Can you think of a way to prevent it from occurring again?

Accept any answer that demonstrates that additional wattage results in more amperes being used. This could cause a circuit to overload and the circuit breaker to trip. The circuit in her room could not handle the additional 750 watts. She will need to unplug some electrical devices on that circuit or find another circuit that has fewer amperes being used.

210

Review Game
Complete the Circuit
Divide the class into teams of four members each. Tell the teams that they can choose to be a parallel or a series circuit. If they choose a series circuit, all four members must answer a question correctly. If the team completes the series circuit, they receive three points. If the team chooses a parallel circuit, the team may miss one question and still complete the circuit. However, the team will receive only one point. If the team cannot complete the circuit it chooses, then the team has "short circuited" and receives no points. A team may choose a different circuit each time it completes a circuit or "short circuits." Alternate questions between teams.