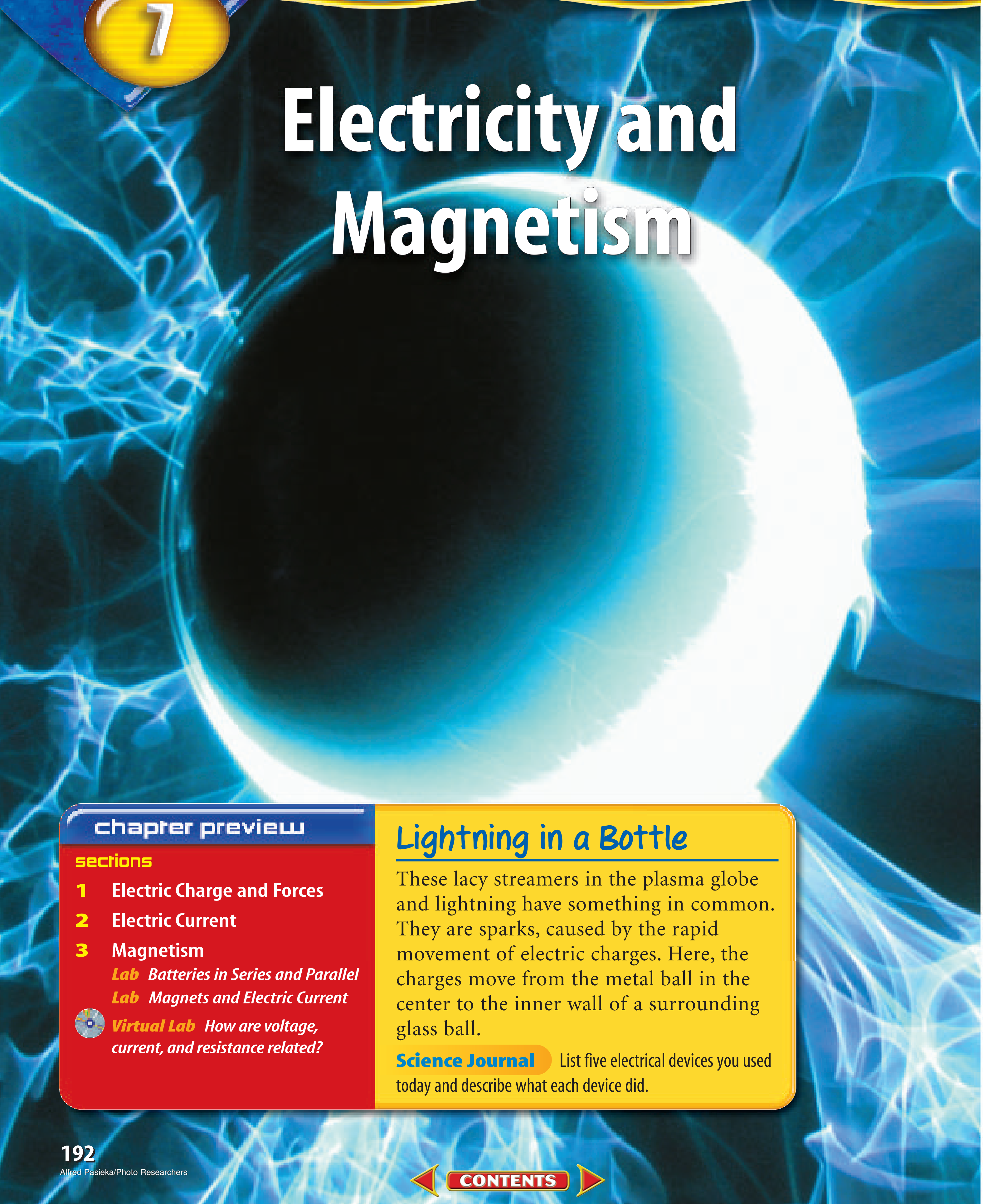
chapter 7

Electricity and Magnetism



chapter preview

sections

Lightning in a Bottle

These lacy streamers in the plasma globe and lightning have something in common. They are sparks, caused by the rapid movement of electric charges. Here, the charges move from the metal ball in the center to the inner wall of a surrounding glass ball.

Science Journal List five electrical devices you used today and describe what each device did.

Alfred Pasieka/Photo Researchers

Start-Up Activities

Launch LAB

Electric and Magnetic Forces

You exert a force on a skateboard when you give it a push. But forces can be exerted between objects even when they are not touching. When you throw a ball up into the air, Earth's gravity exerts a force on the ball that pulls it downward. Electric and magnetic forces also can be exerted on objects that are not in contact with each other.

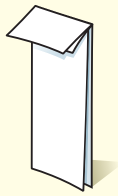
1. Inflate a rubber balloon and rub it against your hair or a piece of wool.
2. Bring the balloon close to a small bit of paper. Then bring the balloon close to a paper clip. Record your observations.
3. Bring a bar magnet close to a small bit of paper. Then bring the bar magnet close to a paper clip. Record your observations.
4. **Think Critically** Describe how the forces exerted by the balloon and the magnet were similar and how they were different. Compare the force exerted by the balloon and the force exerted by gravity on the paper. Compare the force exerted by the magnet and the force exerted by gravity on the paper clip.

FOLDABLES™ Study Organizer

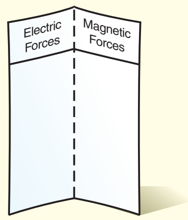
Electric and Magnetic Forces Make the following Foldable to help you understand the properties of electric forces and magnetic forces.

STEP 1 **Fold** a sheet of paper in half lengthwise.

STEP 2 **Fold** paper down about 2 cm from the top.



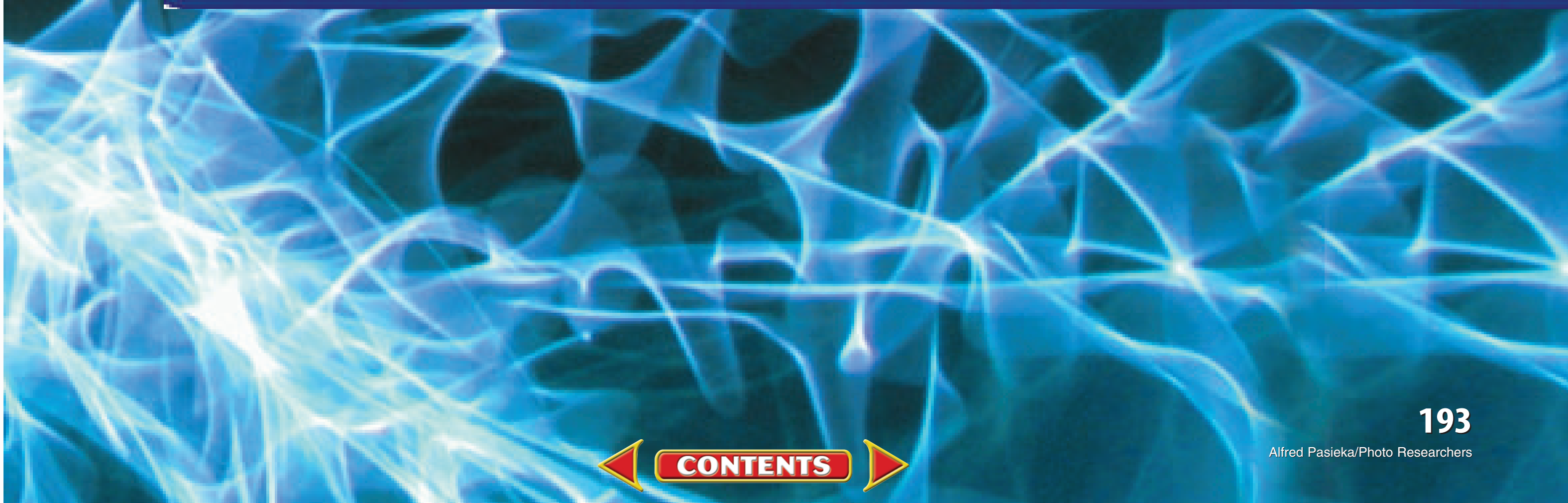
STEP 3 **Open and draw** lines along the horizontal fold. **Label** as shown.



Summarize in a Table As you read the chapter, summarize the properties of electric forces in the left column and properties of magnetic forces in the right column.

Science Online

Preview this chapter's content and activities at red.msscience.com



Alfred Pasieka/Photo Researchers

section 1

Electric Charge and Forces

as you read

What You'll Learn

- **Describe** how electric charges exert forces on each other.
- **Define** an electric field.
- **Explain** how objects can become electrically charged.
- **Describe** how lightning occurs.

Why It's Important

Most of the changes that occur around you and inside you are the result of forces between electric charges.

Review Vocabulary

atom: the smallest particle of an element; contains protons, neutrons, and electrons

New Vocabulary

- charging by contact
- charging by induction
- insulator
- conductor
- static charge
- electric discharge

Electric Charges

Does a clock radio wake you up in the morning? Do you use a toaster or a microwave oven to help make breakfast? All of these devices use electrical energy to operate. The source of this energy lies in the forces between the electric charges found in atoms.

Positive and Negative Charge The matter around you is made of atoms. Atoms are particles less than a billionth of a meter in size—much too small to be seen, even with tremendous magnification. Every atom contains electrons that move around a nucleus, as shown in **Figure 1.** The nucleus contains protons and neutrons. An atom has the same number of protons and electrons.

Protons and electrons have electric charge. Electrons have negative charge and protons have positive charge. The amount of positive charge on a proton equals the amount of negative charge on an electron. Neutrons have no electric charge.

Neutral and Charged Objects Because an atom has equal numbers of protons and electrons, it contains equal amounts of positive and negative charge. An object with equal amounts of positive and negative charge is electrically neutral. If an atom gains or loses electrons, it is electrically charged. An object is electrically charged if the amounts of positive and negative charge it contains are not equal.

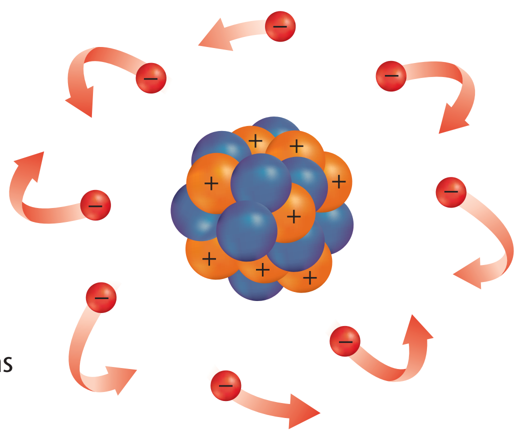


Figure 1 In an atom, negatively charged electrons move around a nucleus that contains neutrons and positively charged protons.

The Forces Between Charges

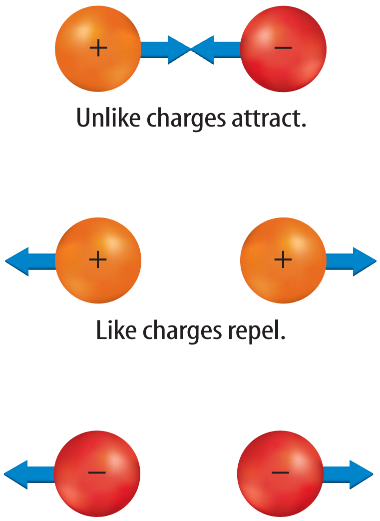


Figure 2 Electric charges exert forces on each other. The forces can be attractive or repulsive. **Describe** *how the forces change if the charges move closer together.*

When you drop a ball and it falls to the ground, the ball and Earth exert an attractive force on each other—the force of gravity. Just as two masses, such as Earth and the ball, exert forces on each other, two objects that are electrically charged exert forces on each other.

The force of gravity is always attractive. The forces exerted by charged objects on each other can be attractive or repulsive, as shown in **Figure 2.** If two objects are positively charged, they repel each other. If two objects are negatively charged, they also repel each other. If one object is positively charged and the other is negatively charged, they attract each other. In other words, like charges repel and unlike charges attract.

Electric Force Depends on Distance The electric force between two charged objects depends on the distance between the objects. The electric force decreases as the distance between the objects increases. For example, as two electrons move farther apart, the repulsive force between them decreases.

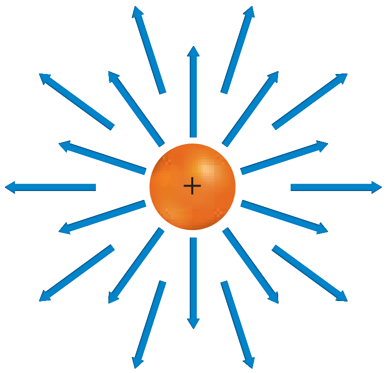
Electric Force Depends on Charge The electric force between two charged objects also depends on the amount of charge on each object. As the amount of charge on either object increases, the electric force between the objects also increases.

Figure 3 The balloon and the cat's fur can exert forces on each other, even without touching.

Roger Ressmeyer/CORBIS

Electric Field and Electric Forces

To slide a book across a table top, your hand has to touch the book to give it a push. However, electric charges can exert forces on each other even when they are not touching. **Figure 3** shows what happens when you rub a balloon on the cat's fur and then hold the balloon close to its fur. The balloon makes the fur stand on end. The balloon and the fur are exerting electric forces on each other, even though they are not touching.



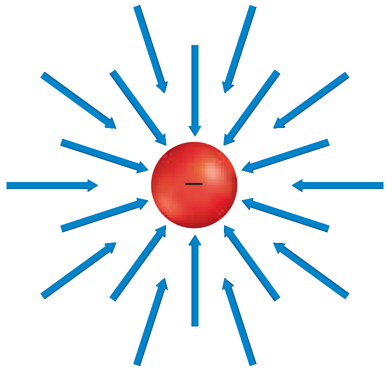


Figure 4 The electric field around a positive charge points away from the charge. The electric field around a negative charge points toward the charge.

Figure 5 Clothes that have been tumbling in a dryer become electrically charged by contact. Articles of clothing that have opposite charges stick together when they come out of the dryer.

Electric Field Surrounds a Charge How do electric charges exert forces on each other if they are not touching? An electric charge is surrounded by an electric field that exerts a force on other electric charges. Every proton and electron is surrounded by an electric field that exerts a force on every other proton and electron. The balloon you rubbed on the cat's fur becomes electrically charged, so it too is surrounded by an electric field. The electric field surrounding the balloon exerts the force on the fur that makes it stand up.

Describing the Electric Field The electric field surrounding an electric charge is invisible. A way to describe the electric field around a charge is shown in **Figure 4.** The electric field is represented by arrows that are related to the force the field exerts on a positive charge. There is an electric field at every point in space surrounding a charge. **Figure 4** shows the electric field at only a few points in the space surrounding the charges.

Making Objects Electrically Charged

When you rubbed a balloon on the cat's fur, it became electrically charged. The balloon no longer contained equal numbers of protons and electrons. The balloon became electrically charged because electric charges were transferred from the fur to the balloon.

Charging by Contact When you rubbed the balloon on the cat, the surface of the balloon came in contact with the surfaces of strands of fur. As atoms in the fur and in the balloon came close to each other, electrons were transferred from atoms in the fur to atoms in the balloon. This is an example of **charging by contact,** which is the transfer of electric charge between objects in contact.

Because the balloon gained electrons after rubbing, it had more electrons than protons and was negatively charged. Because the fur lost electrons, it had more protons than electrons and was positively charged. The amount of negative charge gained by the balloon equaled the amount of positive charge left on the fur.

Another example of charging by contact is shown in **Figure 5.** As clothes tumble in a clothes dryer, they rub against each other. Charging by contact occurs and electrons are transferred from one article of clothing to another. This can cause articles of clothing to stick to each other when you take them out of the dryer.

Aaron Haupt

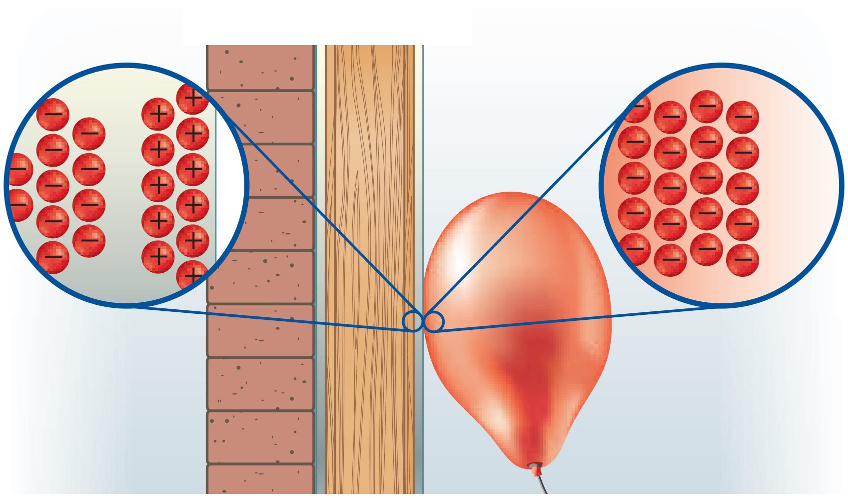


Figure 6 Charging by induction causes the charged balloon to push electrons away from the wall's surface. The surface of the wall becomes positively charged and attracts the negatively charged balloon.
Infer *whether a positively charged balloon would stick to the wall.*

Charging by Induction Have you ever rubbed a balloon on a sweater or your hair, and then stuck the balloon to a wall? The balloon became negatively charged after you rubbed it, but the wall was electrically neutral. **Figure 6** shows why the negatively charged balloon sticks to the wall. As the balloon is brought close to the wall, the electric field around the balloon repels the electrons in the wall. These electrons are pushed away from their atoms. This causes the region of the wall close to the balloon to become positively charged. The negatively charged balloon is attracted to this positively charged region, causing the balloon to stick to the wall.

In this case there is no electric charge transferred from one object and another. Instead, an electric field causes electrons to move from one region to another in an object. The rearrangement of electric charge due to the presence of an electric field is called **charging by induction.** As a result, one part of the object becomes positively charged and another part becomes negatively charged. However, the object remains electrically neutral.

Conductors and Insulators

In some materials electrons are held by atoms tightly enough that they are not able to move easily through the material. Materials in which electric charges do not move easily are **insulators.** Plastics, glass, rubber, and wood are examples of materials that are insulators.

In other materials, some electrons are held so loosely by atoms that they can move through the material easily. Materials in which electric charges can move easily are **conductors.** The best conductors are metals such as gold, silver, and copper. Because electrons can move easily in copper, it is widely used in electric wires.

Mini LAB

Observing Charging by Induction

Procedure

1. Turn on a **water faucet.** Adjust the flow so that the water stream is as slow as possible without producing drops.
2. Rub a **balloon** or a **comb** on your hair or on **wool cloth.**
3. Bring the charged end of the balloon or comb near the stream of water, and observe the result.

Analysis

1. Explain the behavior of the stream of water using the concept of charging by induction.
2. Infer how the distribution of charge on the water stream changed after it passed the charged area on the balloon or comb.

Try at Home

INTEGRATE History

Benjamin Franklin and Electricity American Benjamin Franklin lived from 1706 to 1790. He is best known as one of the country's Founders who played an important role in the formation of the United States Constitution. Franklin also was a scientist and was one of the first to prove that lightning was an electric discharge. In addition, he named the two types of electric charge—positive and negative—and produced a number of inventions, including the lightning rod and bifocal glasses.

Static Charge

If you walk across a carpet wearing shoes with rubber soles, charging by contact occurs. Electrons are transferred from the atoms in the carpet to the atoms on the soles of your shoes.

When charging by contact occurs, the amount of positive and negative charge on each object is no longer balanced. The object that loses electrons has more positive charge than negative charge. The object that gains electrons has more negative charge than positive charge. The imbalance of electric charge on an object is called a **static charge.**

Electric Discharge

When you walk across a carpet and then touch a metal doorknob, sometimes you might feel an electric shock. Perhaps you see a spark jump between your hand and the doorknob. The spark is an example of an electric discharge. An **electric discharge** is the movement of static charge from one place to another. The spark you saw was the result of a static charge moving between your hand and the doorknob.

Figure 7 shows why a spark occurs when you touch the doorknob. Electrons that are transferred from the carpet to your shoes spread over your skin. As you reach toward the metal doorknob, the electric field around your hand repels electrons in the doorknob. They move away, leaving the surface of the doorknob nearest your hand with a positive charge. If the attractive electric force on the excess electrons is strong enough, these electrons can be pulled from your hand toward the doorknob. This rapid movement of charge causes the spark you see and the shock you feel.

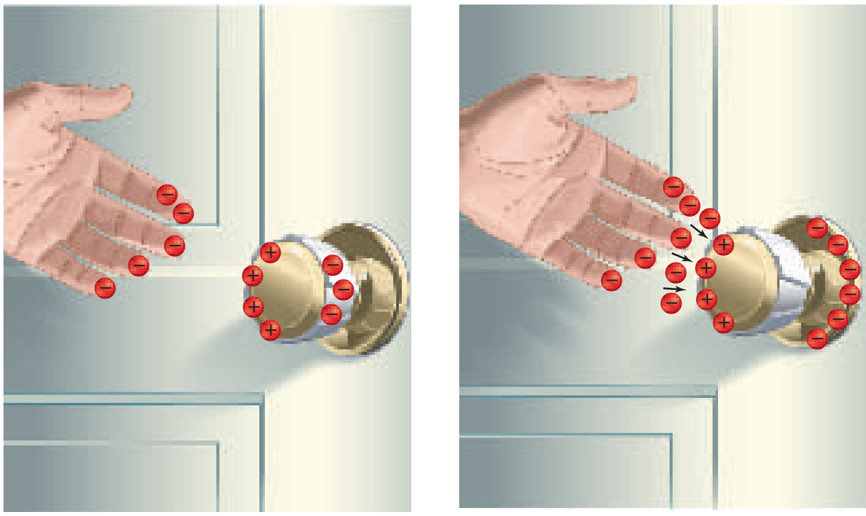


Figure 7 Charging by induction causes a spark to jump from your hand to the doorknob.

The excess negative charge on your hand repels electrons in the doorknob, leaving positive charges on the surface of the doorknob.

The attractive force between the charges on your hand and the doorknob can cause electrons to move to the doorknob.

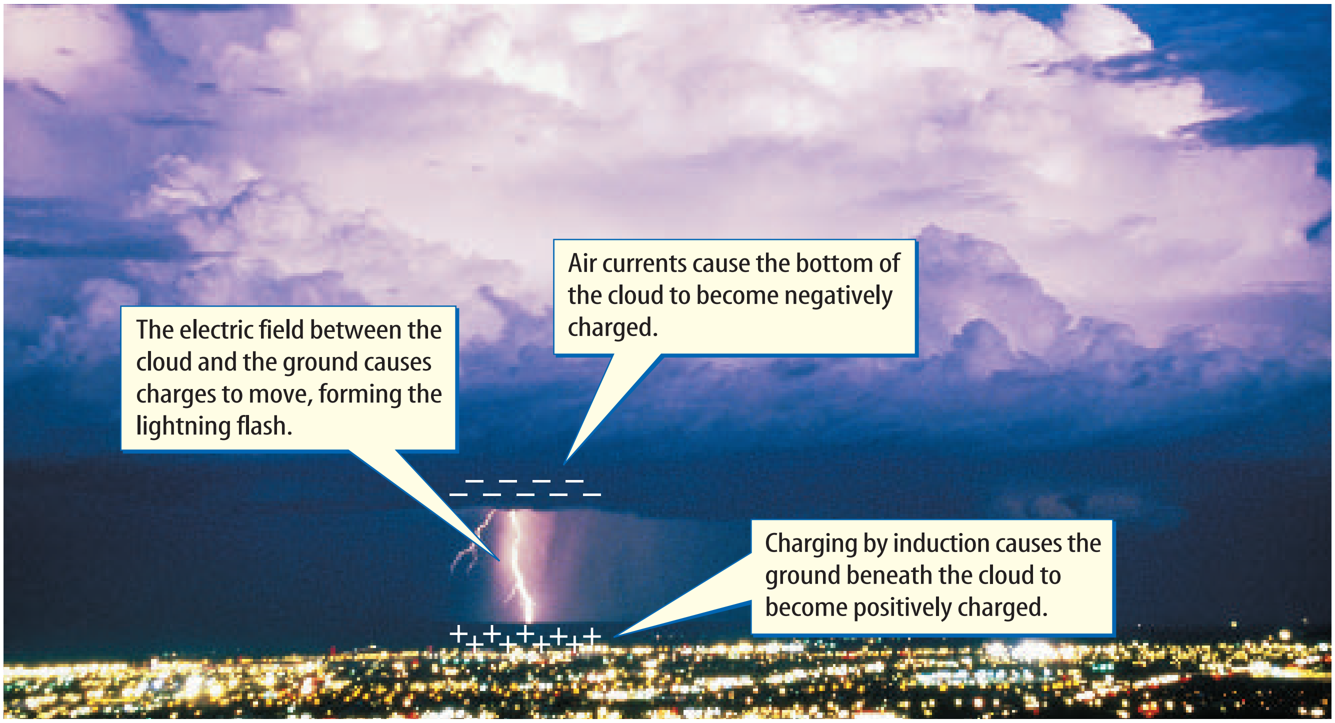


Figure 8 Lightning occurs when the static charge on a storm cloud causes charging by induction on the ground or another cloud.

Lightning A spectacular example of an electric discharge is lightning. **Figure 8** shows how lightning is produced. During a storm, air currents in a storm cloud sometimes cause electrons to be transferred from the top to the bottom of the storm cloud. The electric field surrounding the bottom of the storm cloud repels electrons in the ground. This makes the ground positively charged. The resulting attractive electric forces cause charges to move between the cloud and the ground, producing a flash of lightning.

Air currents in a storm cloud can cause other parts of the storm cloud to become positively and negatively charged. As a result, lightning flashes often occur between one storm cloud and another, and also within a storm cloud.

INTEGRATE Health

Lightning Safety A lightning flash can be dangerous. On average, lightning strikes about 400 people a year in the United States, and causes about 80 deaths. You should always take lightning seriously, particularly if you are outside and a thunderstorm is in sight. You can help protect yourself by following the 30-30 rule. If the time between the lightning and the thunder is 30 seconds or less, the storm is dangerously close. Seek shelter in an enclosed building or a car, and avoid touching any metal surfaces. Wait 30 minutes after the last flash of lightning before leaving the shelter—even if the Sun comes out. One in ten lightning strikes occurs when no storm clouds are visible.

Science Online

Topic: Lightning
Visit red.msscience.com for Web links to information about different types of lightning that occur in Earth's atmosphere.

Activity Make a table listing different types of lightning in one column and a description of the lightning type in a second column.

Figure 9 A lightning rod provides a path to conduct the charge in a lightning strike into the ground.

Grounding A lightning flash can transfer an enormous amount of electrical energy. When lightning strikes trees in a forest, it can spark a forest fire. If lightning strikes a building, the building can be damaged or set on fire.

One way to protect buildings from the damaging effects of lightning is to attach a metal lightning rod to the top of the building. A thick wire is connected to the lightning rod, and the other end of the wire is connected to the ground.

When lightning strikes the lightning rod, the electric charges in the lightning flash flow through the connecting wire into the ground. Earth can be a conductor, and because Earth is so large, it can absorb large quantities of excess electric charge. The process of providing a path to drain excess charge into Earth is called grounding. Because the lightning rod in **Figure 9** is grounded, the excess charge in the lightning strike flows harmlessly into the ground without damaging the building.

section 1 review

Summary

Electric Charges and Forces

- Electrons are negatively charged and protons are positively charged.
- An electric charge is surrounded by an electric field that exerts a force on other charges.
- Like charges repel each other; unlike charges attract each other.

Making Objects Charged

- The transfer of electric charges between two objects that touch is charging by contact.
- Charging by induction occurs when an electric field rearranges the charges in an object.
- Static charge is an imbalance of electric charge on an object.

Lightning

- Lightning is an electric discharge between a storm cloud and the ground, or within or between storm clouds.
- Grounding can prevent damage caused to buildings by lightning strikes.

Self Check

1. **Explain** why an atom is electrically neutral.
2. **Describe** how a balloon becomes electrically charged after you rub the balloon on your hair.
3. **Predict** Suppose the air currents in a storm cloud caused the bottom of the cloud to become positively charged. Predict whether lightning could occur between the cloud and the ground. Explain your reasoning.
4. **Infer** When charging by contact occurs, how is the amount of positive charge on one object related to the amount of negative charge on the other object?
5. **Describe** how the electric force between two objects depends on the amount of charge on the objects and the distance between them.
6. **Think Critically** Sometimes just before a lightning strike occurs nearby, the hair on a person's head will stand up. Explain why this happens.

Applying Skills

7. **Sequence** Make an events-chain concept map that shows the sequence of events that occurs when a flash of lightning is produced.

Science Online red.msscience.com/self_check_quiz
CONTENTS

section 2

Electric Current

Electric Current

When you turn on a TV, images appear on the screen and sound comes out of the speakers. The TV produces light waves that carry energy to your eyes, and sound waves that carry energy to your ears. Where does this energy come from? You know that unless the TV is plugged into an electrical outlet, nothing happens when you turn it on. The electrical outlet provides electrical energy that the TV transforms into sound and light. This electrical energy becomes available only when an electric current flows in the TV.

What is an electric current? An **electric current** is the flow of electric charges. In some ways an electric current is like the flow of water in a pipe. In the pipe, water flows as water molecules move along the pipe. In a wire, there is an electric current when electrons in the wire move along the wire.

In a wire, the numbers of protons and electrons are equal and the wire is electrically neutral, as shown in **Figure 10.** When current flows in the wire, these electrons move along the wire. At the same time, electrons flow into one end of the wire and flow out of the other end. **Figure 10** shows that the number of electrons that flow out one end of the wire is equal to the number of electrons that flow into the other end. As a result, the wire remains electrically neutral.

The Unit for Current The amount of electric current in a wire is the amount of charge that flows into and out of the wire every second. The SI unit for current is the ampere, which has the symbol A. One ampere of electric current means an enormous number of electrons—about six billion billion—are flowing into and out of the wire every second.

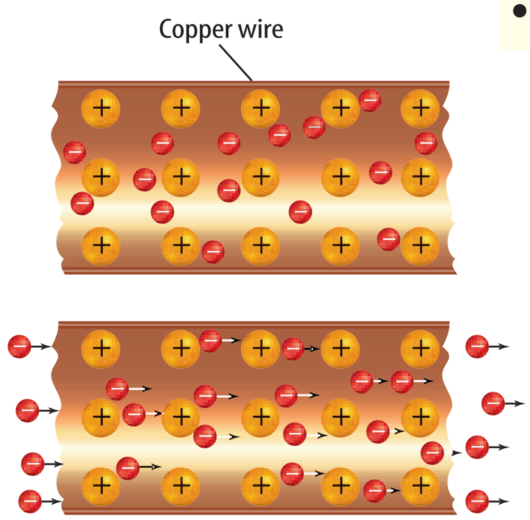


Figure 10 When a current flows in a wire, the same number of charges flow into and out of the wire. The wire remains electrically neutral.

as you read

What You'll Learn

- **Describe** how an electric current flows.
- **Explain** how electrical energy is transferred to a circuit.
- **Explain** how current, voltage, and resistance are related in a circuit.
- **Distinguish** between series and parallel circuits.

Why It's Important

Electrical appliances you use every day transform the electrical energy in an electric current into other useful forms of energy.

Review Vocabulary

kinetic energy: the energy an object has due to its motion

New Vocabulary

- electric current
- electric circuit
- electric resistance
- voltage
- series circuit
- parallel circuit

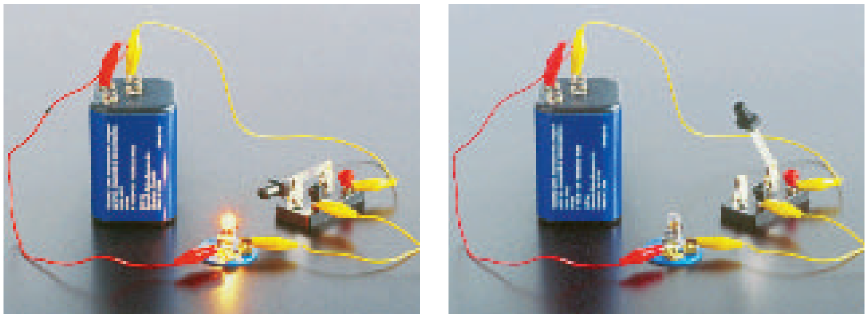


Figure 11 A battery, lightbulb, and connecting wires form a simple electric circuit. Current flows as long as the switch is closed. When the switch is open, current no longer flows.
Explain *whether current would flow if the lightbulb were disconnected.*

A Simple Electric Circuit

When a lightning flash occurs, electrical energy is transformed into heat, sound, and light in an instant. But to watch your favorite shows on TV, electrical energy must be transformed into light and sound for as long as your shows last. This means that an electric current must be kept flowing in your TV as you watch it.

Electric current will flow continually only if the charges can flow in a closed path. A closed path in which electric charges can flow is an **electric circuit.** A simple electric circuit is shown in **Figure 11.** Current will flow in this circuit as long as the conducting path between the battery, wires, and lightbulb is not broken. If the switch is open, current will not flow. Even with the switch closed, if one of the wires is disconnected or cut, or the filament wire in the lightbulb breaks, the path is no longer closed. Then current will no longer flow.

Science Online

Topic: Electric Shock
Visit red.msscience.com for Web links to information about the effects of electric current on the human body.

Activity Make a chart showing how the human body responds to different amounts of current that enter the body.

Making Electric Charges Flow

Water flows in a pipe when there is a force exerted on the water. For example, a pump can exert a force on water that pushes it through a pipe. A force must be exerted on electric charges to make them flow. Remember that a force is exerted on an electric charge by an electric field. To make electric charges flow in a circuit, there must be an electric field in the circuit that will move electrons in a single direction.

A Battery Makes Charges Flow The battery in **Figure 11** produces the electric field in the circuit that causes electrons to flow. When the battery is connected in a circuit, chemical reactions occur in the battery. These chemical reactions cause the negative terminal to become negatively charged, and the positive terminal to become positively charged. The negative and positive charges on the battery terminals produce the electric field in the circuit that causes electrons to flow. The battery makes electrons flow in the direction from the negative terminal toward the positive terminal.

Electric Resistance It can be slow going when you try to walk to class through a crowded corridor. To avoid collisions, you are constantly changing direction, slowing down, and speeding up. Even though you might change speed and direction many times, you keep moving toward your classroom. The flow of electrons in a circuit is similar. Electrons are constantly colliding with atoms and other electric charges as they flow. These collisions cause electrons to change direction, as shown in **Figure 12.** An electron flowing in a wire may be involved in trillions of collisions every second. However, between each collision, the electric field in the circuit keeps electrons accelerating in the direction current is flowing.

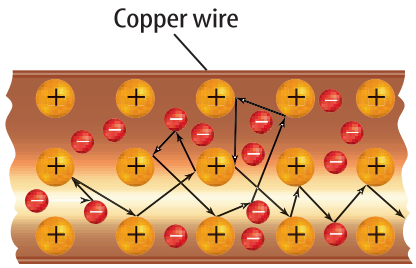


Figure 12 Collisions with atoms and other charges cause electrons in a wire to change direction many times each second.

Reading Check *Why do electrons constantly change direction as they flow in a circuit?*

The measure of how difficult it is for electrons to flow in an object is called the **electric resistance** of the object. The resistance of insulators is usually much higher than the resistance of conductors. The unit for electric resistance is the ohm, symbolized by Ω. An electric resistance of 20 ohms would be written as 20 Ω.

A Model for Electron Flow One way to picture how electrons flow in a circuit is to imagine a basketball bouncing down a flight of stairs, as shown in **Figure 13.** In this model the ball is like an electron moving through a circuit, and the steps are like the atoms it bumps into. When you drop the ball, it speeds up as gravity pulls it downward. When it hits a step, it changes direction. The ball also slows down as it bounces upward because the force of gravity continues to pull it downward. After the ball reaches the top of its bounce, it falls downward toward the next step and speeds up again. This process is repeated as the ball bounces from step to step.

Even though the ball changes direction after it hits each step, the overall motion of the ball is downward. In the same way, an electron in a circuit changes direction after each collision. However, its overall motion is in the direction of the current flow.

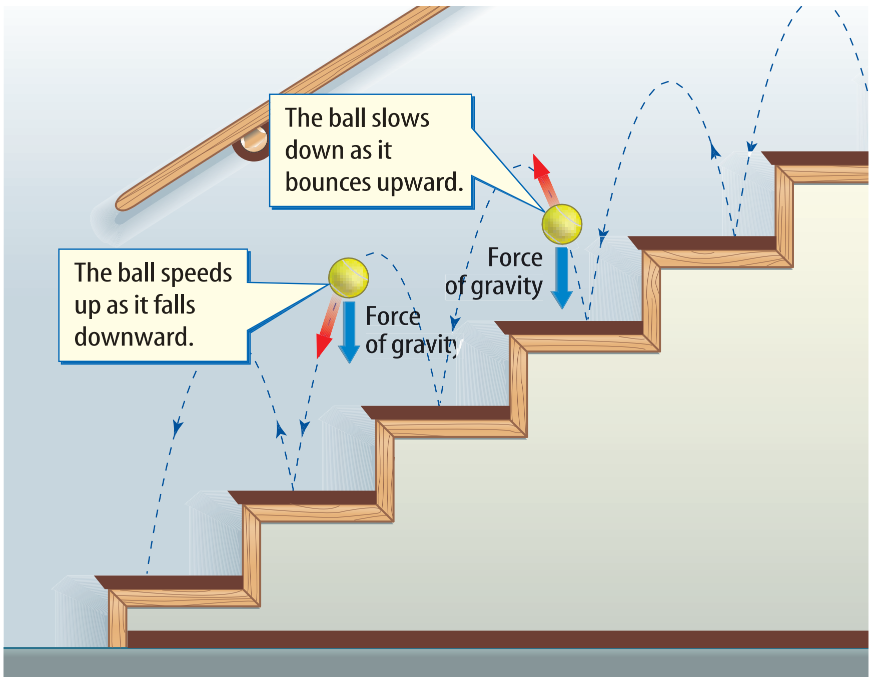


Figure 13 The motion of an electron flowing in an electric circuit is similar to the motion of a ball bouncing down the stairs. The force of gravity keeps the ball moving downward. An electric field keeps an electron moving in the direction of the current.

The Speed of Electric Current Because the ball changes direction and slows down after each collision with a step, the time it takes the ball to reach the bottom of the stairs is much longer than if the ball had fallen without bouncing. In the same way, the electric resistance in a wire causes electrons to flow slowly. It may take several minutes for an electron in a circuit to travel one centimeter.

If electrons travel so slowly, why does a lightbulb light up the instant you flip a switch? When you flip the switch you close a circuit and an electric field travels through the circuit at the speed of light. The electric field causes electrons in the lightbulb to start flowing almost immediately after the switch is flipped. It is the electrons flowing in the lightbulb that cause it to glow.

Transferring Electrical Energy

As a ball bounces down a flight of stairs, it transfers energy to the stairs. Each time the ball collides with a step, some of the ball's kinetic energy is transferred to the step. Electrons flowing in a circuit also have kinetic energy. When a current flows in a material, the repeated collisions between electrons and atoms cause a continual transfer of kinetic energy to the material. The energy that flowing electrons transfer to the circuit also is called electrical energy. As electrons bump into atoms, electrical energy is converted into other forms of energy, such as heat energy and light.

For example, a lightbulb contains a filament that is a small coil of narrow wire, as shown in **Figure 14.** When current flows in the filament, electrical energy is converted into heat and light. The filament becomes hot and glows, giving off light that enables you to see in the dark.

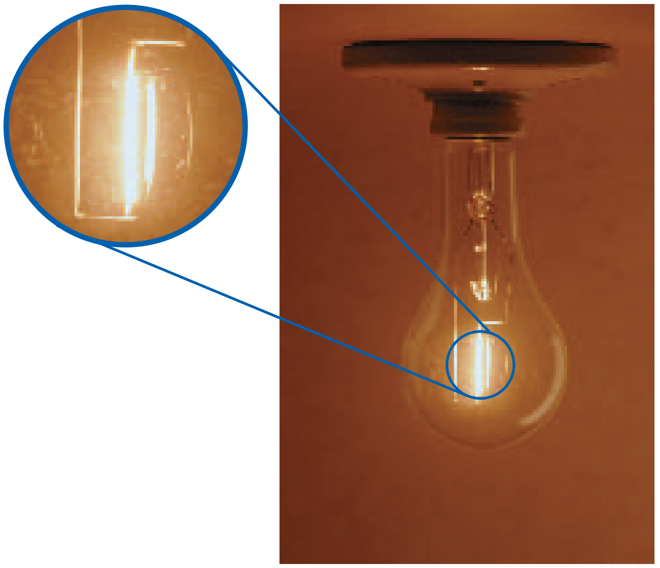


Figure 14 A lightbulb filament is a coil of thin wire. The electric resistance in the filament converts electrical energy into heat and light.

PhotoDisc

Electrical Energy and the Electric Field As electrons flow in a circuit, the electrical energy transferred to the circuit depends on the strength of the electric field. If the electric field becomes stronger, the electric force exerted on electrons increases as they move from one point to another in the circuit. This causes electrons to move faster between collisions. You might recall that the kinetic energy of an object increases as its speed increases. So the kinetic energy of flowing electrons increases as the electric field gets stronger. As a result, increasing the electric field causes more electrical energy to be transferred to the circuit.

Voltage

You might have seen signs on electrical equipment that read "Danger! High Voltage." What is voltage? Voltage is a measure of the electrical energy of electrons flowing in a circuit. When an electron flows between two points in a circuit, it transfers electrical energy. **Voltage** is a measure of the amount of electrical energy transferred by an electric charge as it moves from one point to another in a circuit. The voltage between two points in a circuit can be measured with a voltmeter. **Figure 15** shows how the voltage measured by a voltmeter depends on the location of the points in the circuit. The voltage between any two points in the circuit increases when the electric field in the circuit increases. The SI unit for voltage is the volt, which has the symbol V.

The voltage across the ends of this wire is small. Only a small amount of electrical energy is transferred to this wire.

The voltage across the connections to the lightbulb is large. A large amount of electrical energy is transferred to the lightbulb.

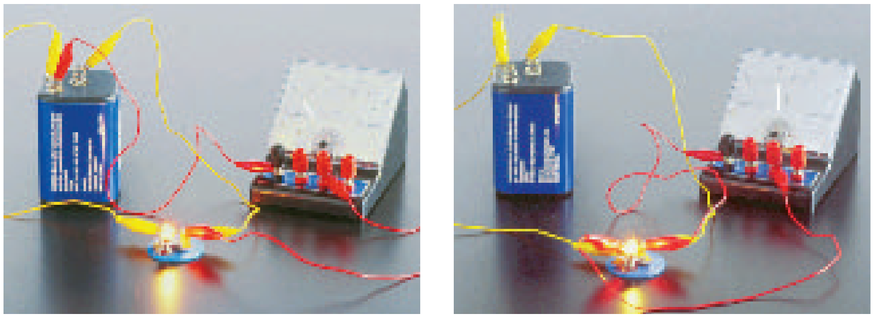


Figure 15 A voltmeter measures the voltage between different points in this electric circuit.
Determine *To which part of the circuit is most of the electrical energy transferred?*

A Battery Produces Electrical Energy When a current transfers electrical energy in a circuit, where does the electrical energy come from? The electric field in the circuit causes the flowing electrons to have electrical energy. If a battery is connected in the circuit, it is the chemical reactions in the battery that produce the electric field. As a result, in a battery chemical energy is transformed into electrical energy. This electrical energy then can be transformed into other forms of energy in the circuit. However, the battery is the source of the energy used by the devices connected in the circuit.

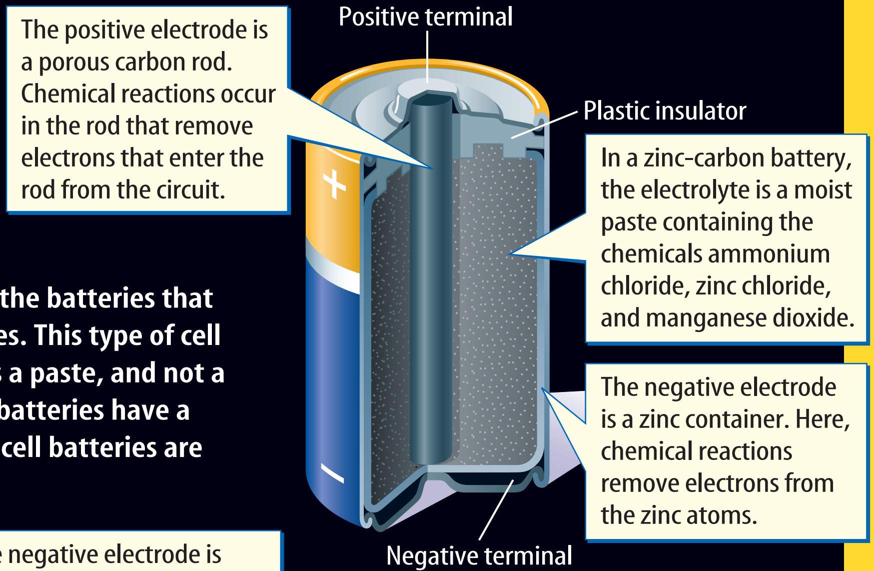
Reading Check *What form of energy is transformed into electrical energy in a battery?*

Battery Voltage The voltage between the positive and negative terminals of a battery is usually called the voltage of the battery. The battery voltage is related to the amount of electrical energy an electron would transfer to the circuit as it moved through the circuit all the way from the negative terminal to the positive terminal. This means that more electrical energy is transferred to the circuit as the voltage of the battery increases. **Figure 16** shows how the voltage produced by different types of batteries depends on the chemical reactions that occur in the battery.

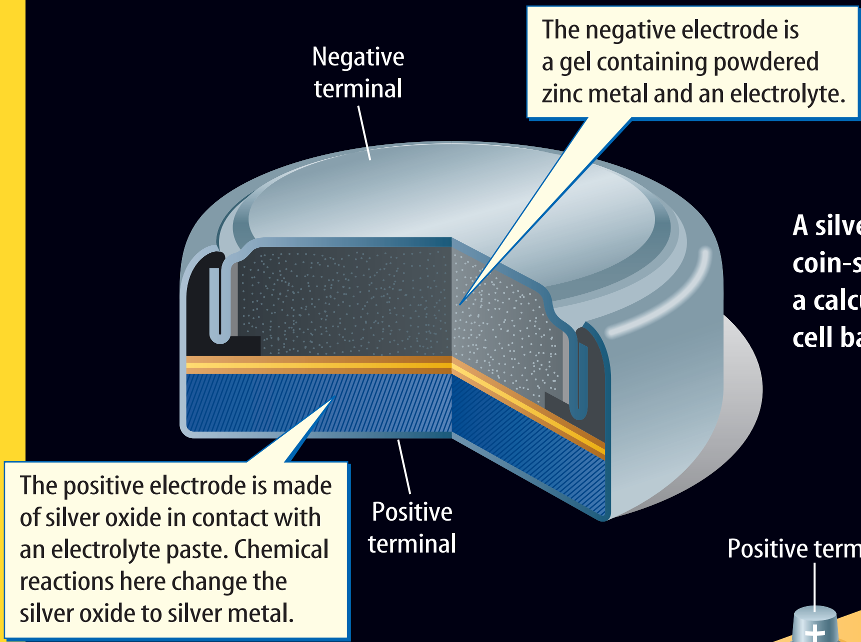
NATIONAL GEOGRAPHIC **VISUALIZING BATTERIES**

Figure 16

Many electrical devices use batteries to supply electrical energy. Every battery consists of one or more cells. The chemical reactions in a cell produce a voltage when the cell is connected in a circuit. Each cell has three parts—an electrolyte, a positive electrode, and a negative electrode. The electrolyte contains chemicals that cause chemical reactions to occur at the positive and negative electrodes. There are two types of cells—dry cells and wet cells.

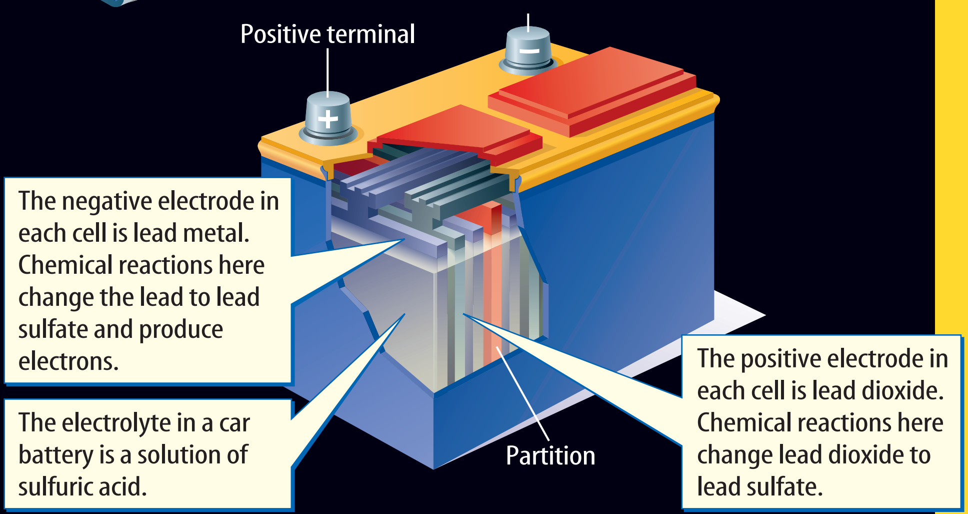


Dry-Cell Batteries Flashlight batteries and the batteries that run portable CD players are dry-cell batteries. This type of cell is called a dry cell because the electrolyte is a paste, and not a liquid. The cells commonly used in dry-cell batteries have a voltage of 1.5 V. The most inexpensive dry-cell batteries are zinc-carbon batteries, shown on the right.



A silver oxide battery is a button-shaped or coin-shaped battery, often used in a camera or a calculator. This type of battery also is a dry-cell battery, and usually has a voltage of 1.5 V.

Wet-Cell Batteries In a wet cell the electrolyte is a liquid. The most common wet-cell battery is a car battery. A 12-V car battery contains six wet cells connected in series. Each wet cell produces 2 V. Unlike the dry-cell batteries shown above, a wet-cell battery is rechargeable.



Ohm's Law The voltage, current, and resistance in a circuit are related. What happens if the voltage in a circuit is increased? As the voltage in a circuit increases, the electric field in the circuit increases and causes electrons to speed up more between collisions. As a result, the current in the circuit increases. Increasing the resistance in the circuit increases the number of collisions that occur every second as electrons flow. This makes it more difficult for electrons to flow in the circuit. As a result, increasing the resistance reduces the current.

The relationship between the voltage, current, and resistance in a circuit is known as Ohm's law. Ohm's law can be written as the following equation.

Ohm's Law

voltage (in volts) = **current** (in amperes) × **resistance** (in ohms)

$$V = IR$$

Applying Math — Solve a Simple Equation

FLASHLIGHT VOLTAGE When a flashlight is turned on, the current that flows in the flashlight circuit is 0.10 A. If the resistance of the circuit is 30.0 Ω, what is the voltage in the circuit?

Solution

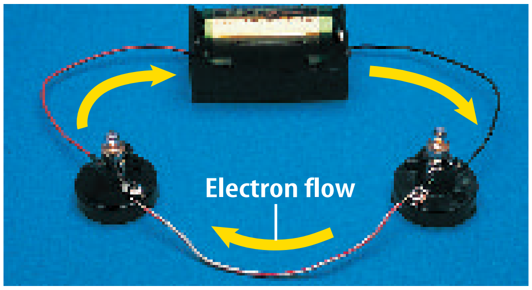
1. *This is what you know:*
   - current: $I = 0.10$ A
   - resistance: $R = 30.0\ \Omega$
2. *This is what you need to find:* voltage: $V = ?$V
3. *This is the procedure you need to use:* Substitute the known values for current and resistance into Ohm's law, and calculate the voltage:

   $V = IR = (0.10\ \text{A})(30.0\ \Omega) = 3.0\ \text{V}$
4. *Check your answer:* Divide your answer by the given resistance, 30.0 Ω. The result should be the given current, 0.10 A.

Practice Problems

1. When a portable radio is playing, the current in the radio is 0.3 A. If the resistance of the radio is 30.0 Ω, what is the voltage supplied by the radio battery?
2. The batteries in a portable CD player supply a voltage of 6 V. If the resistance in the CD player is 24 Ω, what is the current in the CD player when it's turned on?

Science Online — For more practice, visit red.msscience.com/math_practice



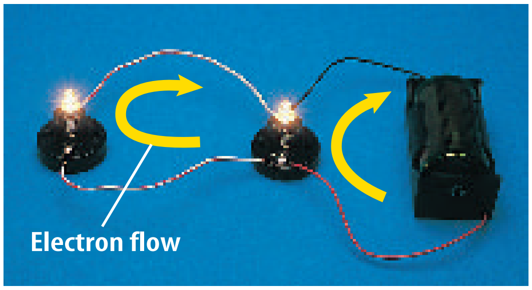


Figure 17 A series circuit (top) has only one path for current to follow. A parallel circuit (bottom) has more than one path for current to follow.

Series and Parallel Circuits

There usually are a number of devices and appliances connected to the circuits in your house. There are two ways that devices can be connected in a circuit. One way is a series circuit, shown in the upper part of **Figure 17,** and the other way is a parallel circuit, shown in the lower part of **Figure 17.**

In a **series circuit,** devices are connected so there is only one closed path for current to follow. However, if any part of this path is broken, current will no longer flow in the circuit.

In a **parallel circuit,** devices are connected so there is more than one closed path for current to follow. If the current flow is broken in one path, current will continue to flow in the other paths. The electric circuits in your house are parallel circuits. As a result, you can switch off a light in one room without turning off all the other lights in the house.

section 2 review

Summary

Electric Current

- An electric current is the flow of electric charges, such as electrons.
- Electric current will flow continually only in a closed path called an electric circuit.
- A battery produces an electric field in a circuit that causes electrons to flow.

Electric Resistance

- Electric resistance is a measure of how difficult it is for electrons to flow in a material.
- Electric resistance results from the collisions between electrons flowing in a current and the atoms and other charges in the circuit.

Electrical Energy and Voltage

- An electric current transfers electrical energy to a circuit.
- A battery transforms chemical energy into electrical energy.
- Voltage is a measure of the electrical energy transferred by an electron as it moves from one point to another in a circuit.

Self Check

1. **Describe** how the charge on a wire changes when an electric current flows in the wire.
2. **Explain** what causes electrons in an electric current to flow slowly in a circuit.
3. **Describe** the process that causes electrical energy to be transformed into heat and light energy as a current flows in a lightbulb.
4. **Determine** how the current in a circuit changes if the voltage in the circuit is decreased and the resistance remains the same.
5. **Think Critically** Two lightbulbs are connected in a series circuit. If the current flowing in one lightbulb is 0.5 A, what is the current flowing in the other lightbulb? Explain.

Applying Math

6. **Calculate Voltage** A hairdryer with a resistance of 10.0 Ω is plugged into an electrical outlet. If the current in the hairdryer is 11 A, what is the voltage?
7. **Calculate Resistance** What is the resistance of a loudspeaker connected to a 9.0-V battery if the current in the speaker is 0.3 A?

Science Online red.msscience.com/self_check_quiz

Español

section 3

Magnetism

Magnets

Did you use a magnet today? If you've watched TV, listened to a CD, dried your hair with a hairdryer, or used a computer, the answer is yes. Magnets are a part of all these devices and many others. Magnets can exert forces on objects that are made from, or contain, magnetic materials. Magnets also exert forces on other magnets. It is the forces exerted by magnets that make them so useful.

Magnetic Poles Every magnet has two ends or sides. Each of the ends or sides is a magnetic pole. There are two types of magnetic poles. One is a north pole and the other is a south pole. Every magnet has a north pole and a south pole. For example, one end of a bar magnet is a south pole and the other end is a north pole. For a magnet in the shape of a disc or a ring, one side is a north pole and the other side is a south pole.

Reading Check ***Where would the poles of a magnet shaped like a horseshoe be located?***

The Forces Between Magnetic Poles The magnetic poles of a magnet exert forces on the magnetic poles of other magnets, as shown in **Figure 18.** If two north poles or two south poles are moved toward each other, they repel. If the north pole of one magnet is brought toward the south pole of another magnet, the magnets attract each other. In other words, like poles repel and unlike poles attract. The magnetic forces between two magnets become stronger as the magnets move closer together, and weaker as they move farther apart.

as you read

What You'll Learn

- **Describe** how magnets exert forces on each other.
- **Explain** why some materials are magnetic.
- **Describe** how objects become temporary magnets.
- **Explain** how an electric generator produces electrical energy.

Why It's Important

Magnetism helps produce the electrical energy you obtain from electrical outlets.

Review Vocabulary

mechanical energy: the sum of the kinetic and potential energy of an object

New Vocabulary

- magnetic domain
- electromagnet
- electromagnetic induction

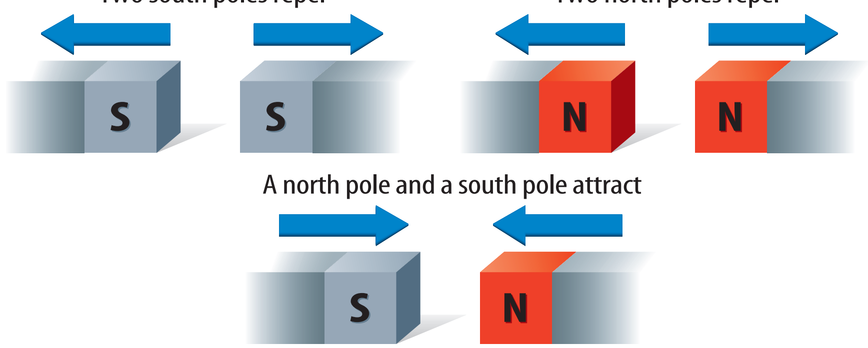
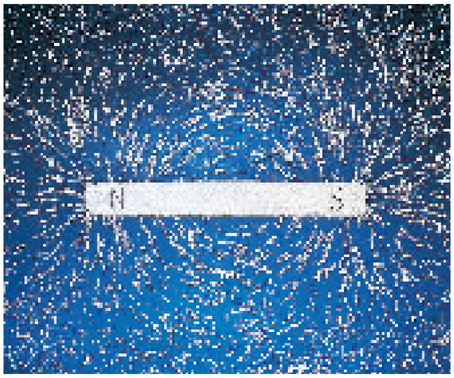
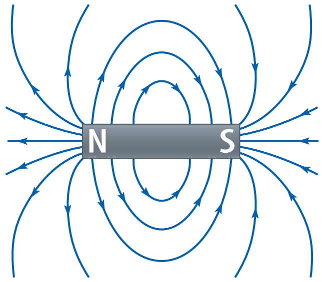


Figure 18 The magnetic forces between magnetic poles are attractive between unlike poles and repulsive between like poles.
Compare *the forces between magnetic poles to the forces between electric charges.*

Figure 19 Iron filings sprinkled around a magnetic bar show the magnetic field lines. Magnetic field lines always connect the north and south poles of a magnet.





Magnetic Field If you hold two like poles of two magnets near each other, you can feel them push each other apart, even though they are not touching. Recall that electric charges exert forces on each other even if they are not touching. This is because an electric charge is surrounded by an electric field that exerts a force on other electric charges. In a similar way, every magnet is surrounded by a magnetic field that exerts a force on other magnets.

The magnetic field around a bar magnet is shown in **Figure 19.** Iron filings sprinkled around a bar magnet line up to form a pattern of curved lines. These lines are called magnetic field lines. Magnetic field lines help show the direction of the magnetic field around a magnet.

Figure 19 shows that the magnetic field lines are closest together at the magnet's poles. At the poles of a bar magnet, the magnetic field is strongest. The magnetic field lines are closer together where the magnetic field is stronger.

Magnetic Materials

If you hold a magnet near a paper clip, the paper clip will stick to the magnet. However, a piece of aluminum foil will not stick to a magnet. Both the paper clip and the aluminum are metal. Why is one attracted to the magnet and not the other?

Only metals that contain the elements iron, nickel, cobalt, and a few other rare-earth elements are attracted to magnets. Materials that contain these elements are magnetic materials. Magnets also contain one or more of these metals. The steel paper clip contains iron and therefore is a magnetic material.

Why are some materials magnetic? Atoms of the elements that are magnetic, such as iron, nickel, and cobalt, are themselves tiny magnets. Each atom has a north pole and a south pole. Atoms of elements that are not magnetic, such as aluminum, are not magnets. As a result, objects that are made of these elements are not affected by a magnetic field.

INTEGRATE Earth Science

Earth's Magnetic Field Earth is surrounded by a magnetic field that is similar to the magnetic field around a bar magnet. Earth's magnetic poles are located near the geographic north pole and south pole. A compass uses Earth's magnetic field to help determine direction. Because a compass needle is a magnet, it rotates so it points toward Earth's magnetic poles. As a result, the north end of a compass needle points north.

Magnetic Domains In a magnetic material, forces that atoms exert on each other cause the magnetic fields surrounding atoms to line up. As a result, large numbers of atoms have their magnetic poles pointing in the same direction. A group of atoms that have their magnetic poles pointing in the same direction is called a **magnetic domain**. **Figure 20** shows how the atoms in a magnetic material form magnetic domains.

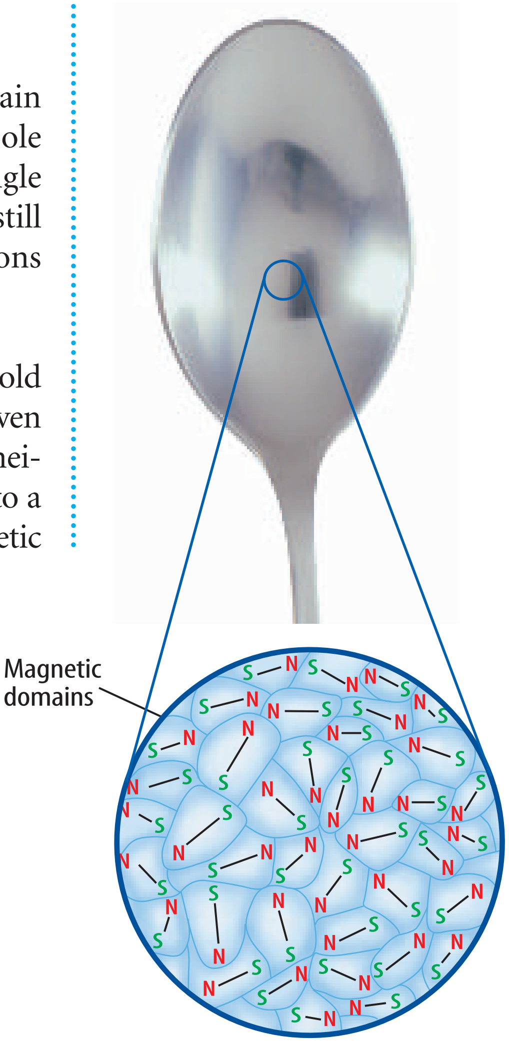
Reading Check *What are magnetic domains?*

The magnetic fields of all the atoms in a magnetic domain add together. As a result, each magnetic domain has a north pole and a south pole and is surrounded by a magnetic field. A single magnetic domain may contain trillions of atoms, but it is still too small to see. Even a small piece of iron may contain billions of magnetic domains.

Domains Line Up in Permanent Magnets If you hold one paper clip against another paper clip, nothing happens. Even though they both are made of magnetic material, iron, they neither attract nor repel each other. Why do the paper clips stick to a bar magnet, but not to each other? In a paper clip the magnetic domains are oriented in random directions, as shown in **Figure 21.** As a result, the magnetic fields around each domain cancel out. The paper clip is not surrounded by a magnetic field.

Figure 21 shows that in a permanent magnet, such as a bar magnet, most of the domains are oriented in a single direction. As a result, the magnetic fields around the domains don't cancel out. Instead these magnetic fields add together to form a stronger magnetic field. The magnetic field that surrounds the magnet is the combination of the magnetic fields around the magnetic domains.

Figure 20 This spoon is made of a magnetic alloy. The spoon is not a magnet because the magnetic poles of the magnetic domains point in random directions.
Explain *why the spoon is not surrounded by a magnetic field.*



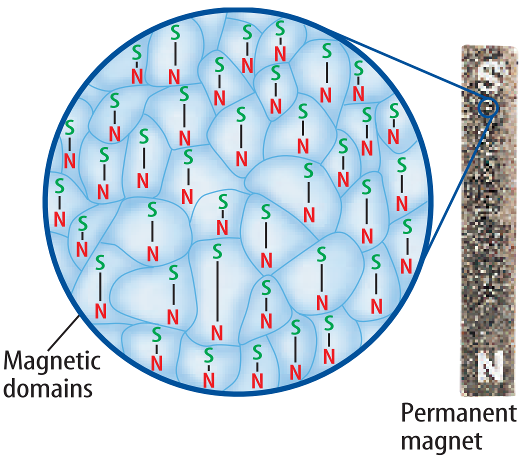


Figure 21 In a permanent magnet, most of the poles of the magnetic domains point in the same direction.
Explain *why the magnet is surrounded by a magnetic field.*

(t)PhotoDisc, (b)Mark Burnett
CONTENTS

The poles of the magnetic domains in the paper clip point in random directions when there is no magnet nearby.

The force exerted by the magnet on the domains causes them to point toward the nearby magnetic pole.

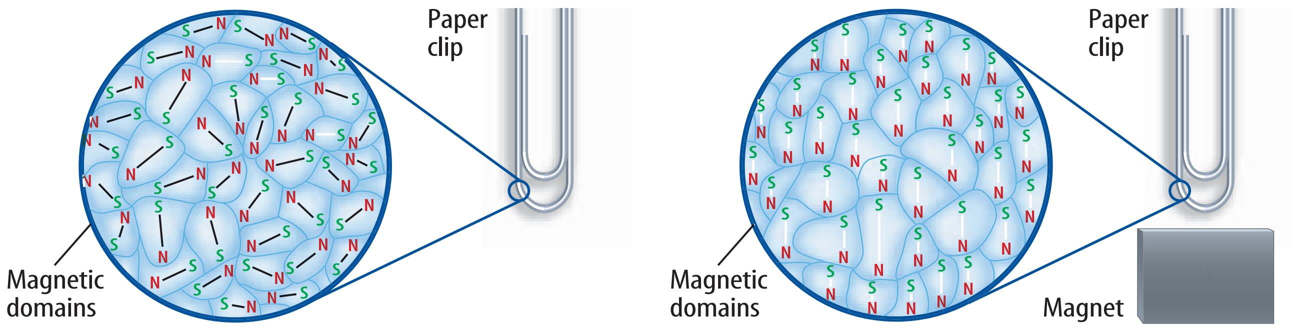


Figure 22 A paper clip that contains iron becomes a temporary magnet when a permanent magnet is nearby.

Why are magnetic materials attracted to a magnet?

A paper clip is not a magnet, but it contains magnetic domains that are small magnets. Usually these domains point in all directions. However, when a permanent magnet comes close to the paper clip, the magnetic field of the magnet exerts forces on the magnetic domains of the paper clip. These forces cause the magnetic poles of the domains to line up and point in a single direction when a permanent magnet is nearby, as shown in **Figure 22.** The nearby pole of the permanent magnet is always next to the opposite poles of the magnetic domains. This causes the paper clip to be attracted to the magnet.

Because the domains are lined up, their magnetic fields no longer cancel out. As long as the paper clip is attached to the magnet, it is a temporary magnet with a north pole and a south pole.

Electromagnetism

Even though they might seem to be different, electricity and magnetism are related. In the early 1800s it was discovered that a wire carrying an electric current is surrounded by a magnetic field. Not only is a current-carrying wire surrounded by a magnetic field, but so is any electric charge in motion. The connection between electricity and magnetism often is called electromagnetism.

Electromagnets The magnetic field produced by a current-carrying wire can be made much stronger by wrapping the wire around an iron core. A current-carrying wire wrapped around an iron core is an **electromagnet.** Just like a bar magnet, one end of an electromagnet is a north magnetic pole and the other end is a south magnetic pole, as **Figure 23** shows. However, if the direction of current flow in the wire coil of an electromagnet is reversed, then the north and south poles switch places.

Mini LAB

Observing Magnetic Force on a Wire

Procedure

1. Connect one end of a **50-cm piece of 22-gauge wire** to one terminal of a **D-cell battery.**
2. Form the wire into a loop and place one pole of a **bar magnet** about 2 cm from the loop.
3. Touch the free end of the wire to the other terminal of the battery. Record your observations.
4. Repeat step 3 with the connections to the battery terminals reversed. Record your observations.

Analysis

1. Explain how your observations show that a current in the wire produces a magnetic field.
2. Infer how the magnetic field around the wire depends on the direction of current in the wire.

Using Electromagnets The strength of the magnetic field produced by an electromagnet depends on the amount of current flowing in the wire coil. Increasing the amount of current increases the magnetic field strength. However, the magnetic field disappears if no current flows in the coil. As a result, an electromagnet is a temporary magnet whose magnetic properties can be controlled. Because of this, electromagnets are used in many devices, including doorbells, telephones, CD players, and computers.

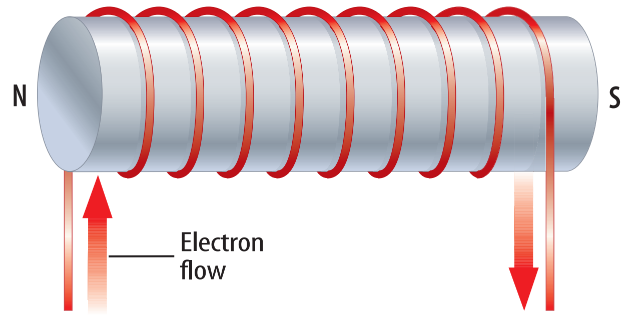


Figure 23 An electromagnet has north and south magnetic poles, and can be attracted or repelled by a permanent magnet. **Describe** *how the magnetic field around the electromagnet changes if the current in the coil is decreased.*

Generating Electric Current

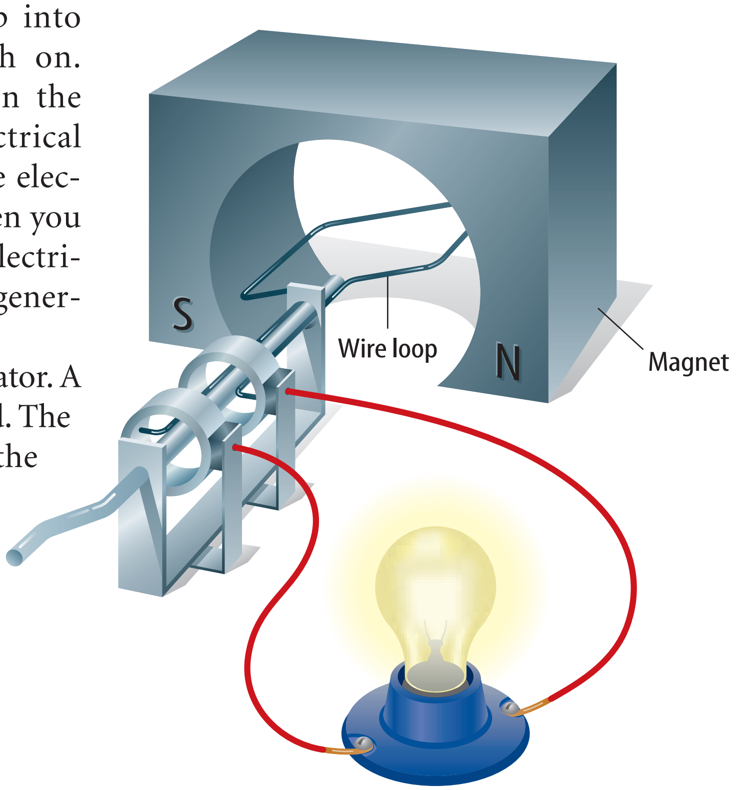
If an electric current produces a magnetic field, can a magnetic field be used to produce an electric current? The answer is yes. If a magnet is moved through a wire loop that is part of a circuit, an electric current flows in the circuit. The current flows only as long as the magnet is moving. A current also flows in the circuit if it is the wire loop that moves and the magnet that is at rest. The production of an electric current by moving a magnet and a loop relative to each other is called **electromagnetic induction.**

Remember that a battery produces an electric field in a circuit that causes electrons to flow. Electromagnetic induction also produces an electric field in a circuit that causes electrons to flow.

Electric Generators You plug a lamp into an electrical outlet and turn the switch on. Immediately, an electric current flows in the lamp, causing the lightbulb to glow. Electrical energy is supplied to the lamp through the electric field created in the lamp. However, when you plug a device into an electrical outlet, the electrical energy used is produced by an electric generator instead of a battery.

Figure 24 shows a simple electrical generator. A loop of wire is rotated within a magnetic field. The motion of the wire loop with respect to the magnetic field produces an electrical field in the wire. This electrical field causes a current to flow. Current continues to flow as long as the wire loop is kept rotating. To keep the wire loop rotating, mechanical energy must be continually supplied to the generator. As a result, a generator converts mechanical energy into electrical energy.

Figure 24 When the wire loop rotates in the magnetic field of the permanent magnet, an electric current flows in the lightbulb.



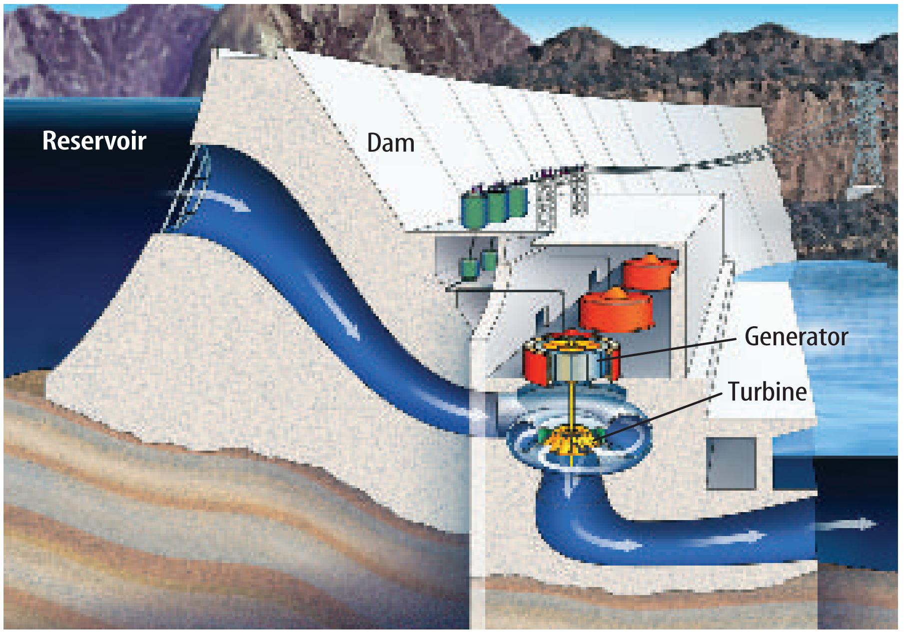


Figure 25 In a hydroelectric plant, the kinetic energy of falling water is converted into electrical energy by a generator.

Power Plants The electrical energy you obtain from an electrical outlet is produced by generators in electric power plants. In these generators electromagnets are rotated past wire coils. To rotate the magnets, power plants use mechanical energy in the form of the kinetic energy of moving steam or moving water into electrical energy.

In some power plants fossil fuels are burned to heat water and produce steam that is used to spin generators. In hydroelectric power plants, the flow of water from behind a dam provides the mechanical energy that is transformed into electrical energy, as shown in **Figure 25.**

section 3 review

Summary

Magnets

- All magnets have a north pole and a south pole.
- Like magnetic poles repel each other and unlike magnetic poles attract each other.
- A magnet is surrounded by a magnetic field that exerts a force on other magnets.

Magnetic Materials

- Individual atoms are magnets in magnetic materials such as iron, cobalt, and nickel.
- Magnetic domains contain atoms with their north or south magnetic poles pointing in the same direction.
- The magnetic domains in a permanent magnet have their magnetic poles aligned.

Electromagnetism

- An electric current is surrounded by a magnetic field.
- An electric current can be produced by the relative motion of a magnet and a wire loop.

Self Check

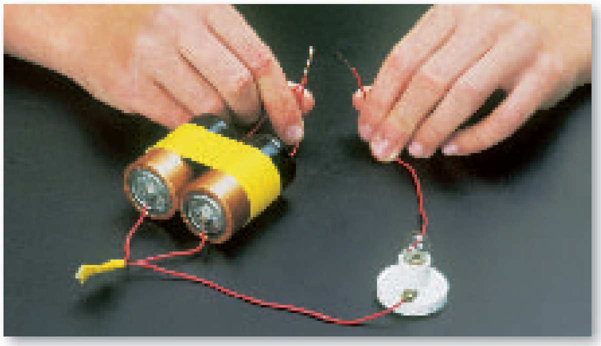
1. **Compare and contrast** a permanent magnet and a temporary magnet made from a magnetic material.
2. **Explain** why an object made from aluminum will not stick to a magnet.
3. **Compare and contrast** an electric generator and a battery.
4. **Identify** the circumstances that would cause an aluminum wire to be attracted or repelled by a magnet.
5. **Compare and contrast** an electromagnet and a permanent magnet.
6. **Think Critically** The north pole of one magnet is attracted only to the south pole of another magnet. However, a paper clip will stick to either the north pole or the south pole of a bar magnet. Explain.

Applying Math

7. **Solve a Simple Equation** A certain power plant generates enough electrical energy to supply 100,000 homes. How many of these power plants would be needed to generate enough energy for 2,000,000 homes?

Batteries in Series and Parallel

Many battery-powered devices use more than one battery to supply electrical energy. Why are these batteries usually connected so that a positive terminal is in contact with a negative terminal?



Real-World Question

How does the way that batteries are connected affect the voltage they provide?

Goals

- **Infer** how the voltage produced by two batteries in a circuit depends on how they are connected.

Materials

1.5-V lightbulbs (2)
1.5-V batteries (3)
minibulb sockets (2)
10-cm long pieces of insulated wire (8)
tape

Safety Precautions

Procedure

1. Make a brightness tester by connecting one battery to a lightbulb. Disconnect one wire after you've made the lightbulb light.
2. Tape two batteries together in series so that the positive terminal of one battery touches the negative terminal of the other battery.
3. Connect the batteries to a lightbulb. Close the circuit in the brightness tester and compare the brightness of the lightbulbs. Record your observations.
4. Tape two batteries together in parallel side-by-side with positive terminals on one end and negative terminals on the other end.
5. Tape a wire to each battery terminal. Twist together the ends of the wires connected to both negative terminals. Do the same for the wires connected to the positive terminals.
6. Repeat step 3.

Conclude and Apply

1. **Infer** If the brightness of a lightbulb increases as the current in a circuit increases, in which circuit was the current the largest?
2. **Apply** Ohm's law to determine in which circuit the voltage was the largest.
3. **Compare** the voltage provided by two batteries in series and in parallel.

Communicating Your Data

Compare your conclusions with those of other students in your class. **For more help, refer to the Science Skill Handbook.**

Matt Meadows

LAB

Magnets and Electric Current

Goals

- **Observe** the effects of a bar magnet on a compass.
- **Observe** the effects of a current-carrying wire on a compass.
- **Observe** how the relative motion of a magnet and a wire coil affects a compass.

Materials

bar magnet
compass
D-cell batteries (2)
3-m length of insulated wire
50-cm length of insulated wire
tape

Safety Precautions

Real-World Question

Have you ever used a compass? The needle in a compass is a small bar magnet with a north pole and a south pole. Because a compass needle is a magnet, other magnets and magnetic fields can cause a compass needle to move. As a result, a compass can be used to detect the presence of a magnetic field. An electric current flowing in a wire is surrounded by a magnetic field. How does an electric current affect a compass needle?

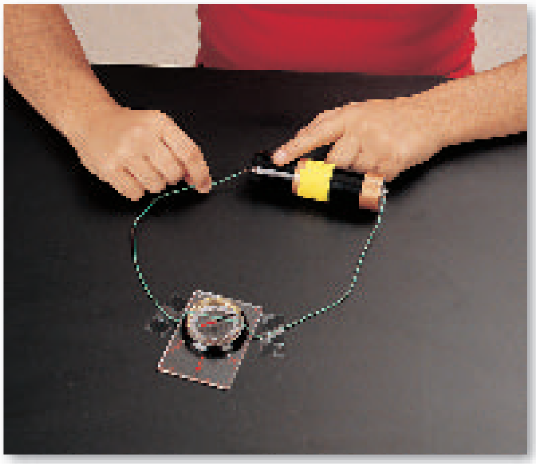
Procedure

1. Make a data table similar to the one below.

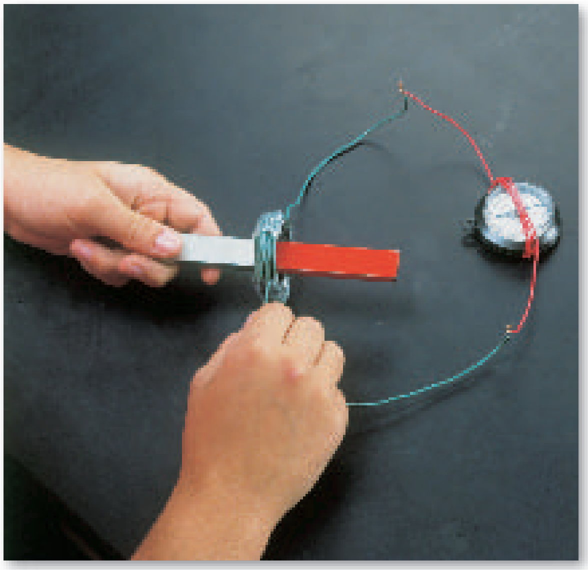
Effects of Magnets and Current on a Compass

Situation	Effect on Compass
Bar magnet nearby	
Current-carrying wire nearby	Do not write in this book.
Magnet moves in coil	
Coil moves past magnet	

2. Place a compass on the table top. Place one pole of a bar magnet next to the compass. Record your observations.
3. Make a battery pack by taping two D-cell batteries together so the negative terminal of one battery is in contact with the positive terminal of the other battery.
4. Tape one end of the 50-cm wire to the exposed positive terminal of the battery pack.



Matt Meadows



5. Place the wire on top of the compass and position the wire so it lines up with the compass needle. Touch the free end of the wire to the other terminal of the battery pack for a few seconds. Record your observations.
6. Wrap the long piece of wire around three fingers about 25 times so there is about 3 cm of wire left at each end. Tape the coil so it doesn't unravel.
7. Wrap the 50-cm wire around the compass several times so there is about 3 cm of wire left at each end. Connect the ends of the wire from the compass with the ends of the wire from the coil.
8. Hold the bar magnet in the center of the coil. Keeping the coil stationary, move the magnet quickly back and forth. Record your observations.
9. Hold the bar magnet in the center of the coil. Keeping the magnet stationary, move the coil quickly back and forth. Record your observations.

Analyze Your Data

1. **Describe** how the bar magnet affected the compass when the magnet was placed next to it.
2. **Describe** how the compass was affected when an electric current flowed in the wire that had been placed on top of the compass.
3. **Compare** how the compass was affected when the magnet was moved inside the stationary wire coil and when the wire coil was moved past the stationary magnet.

Conclude and Apply

1. **Compare** the effect of the bar magnet on the compass and the effect of the current-carrying wire on the compass.
2. **Infer** why the current-carrying wire had the effect on the compass that you observed.
3. **Infer** whether a current flowed in the wire coil when the coil and the magnet were moving relative to each other. Which observations support your conclusion?

Communicating Your Data

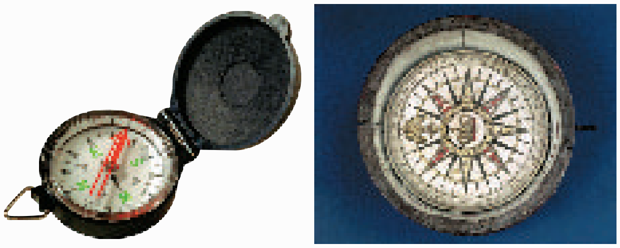
Compare your observations with those of other students in your class. Which actions caused the compass needle to move the most?

Which way to go?

The first record of boats large enough to carry trade goods is around 3500 B.C. The first navigators sailed close to shore and navigated by land characteristics that they could see by day. Sailing at night was impossible. Eventually, sailors learned to find their way by using the position of the Sun and stars. Using their knowledge of the heavens and the ocean currents, Vikings and Polynesians traveled remarkable distances, far from the sight of land. But what happened on cloudy nights?

Kissing Rocks

The Chinese had discovered the solution more than 2,000 years ago. They found interesting rocks that they called *tzhu shih*—loving stones, because they liked to "kiss." These rocks contained magnetite, a mineral containing magnetic iron oxide.



The compass on the right was used by sailors during the 18th century. The compass on the left is a modern compass.

The Chinese realized that they could use the magnetite to magnetize iron needles. When the needles floated in water, they always pointed north and south. They had made the first compass!

Earth's Magnetic Field

Earth's iron core produces a magnetic field similar to the field of a huge bar magnet. A compass needle rotates until its north and south poles point toward Earth's opposite magnetic poles, which are close to the geographic north and south poles. So whether it was clear or cloudy, the compass allowed sailors to travel great distances and to return home safely!

A modern GPS receiver uses a system of satellites to determine its position on Earth's surface.

The World Opens Up

Between the 13th and 19th centuries, there were many improvements to the compass. The ability to travel the seas opened trade between distant cultures. Goods and customs were exchanged, leading to the development of new ideas and tools. Knowing which way to go in rain or shine opened up the world.

Brainstorm **Imagine that you are an early sailor before the invention of the compass. What would limit your knowledge of the world? How far could you travel by boat? What kinds of trips might you take? How would the compass change your lifestyle and your culture?**

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Reviewing Main Ideas

Section 1 Electric Charge and Forces

1. Positive and negative charges are surrounded by an electric field that exerts forces on other charges.
2. Two positive or two negative charges repel each other; a positive and a negative charge attract each other.
3. Charges can be transferred from one object to another. Charges in an object can be rearranged by an electric field.

Section 2 Electric Current

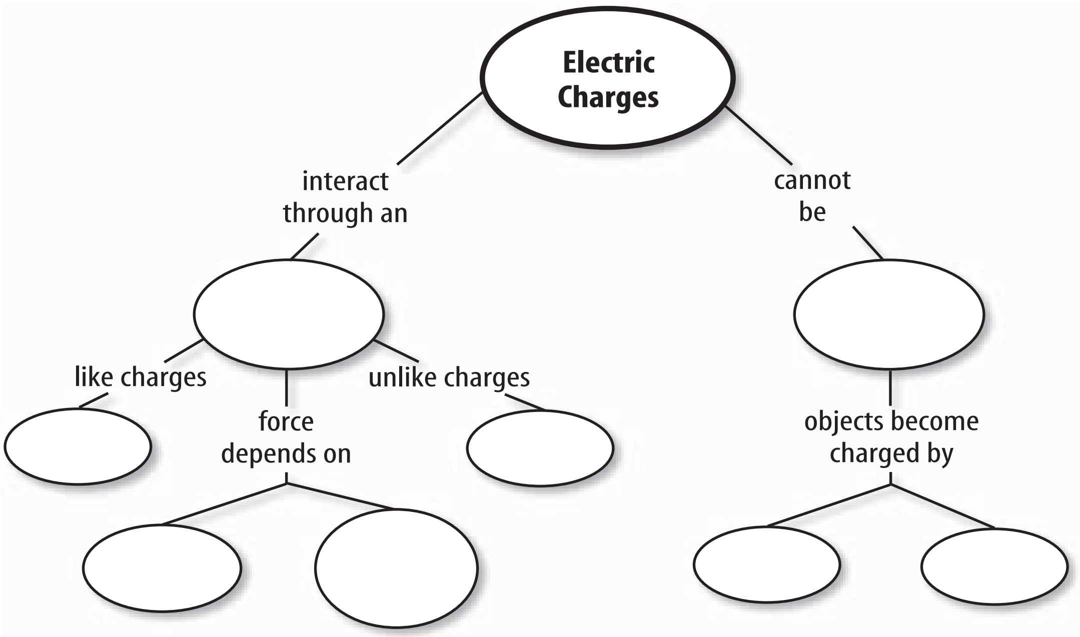
1. An electric current is the flow of electric charges. A current will flow continually in a closed path called an electric circuit.
2. An electric field in a circuit causes charges to flow and transfer electrical energy.
3. Resistance is a measure of how difficult it is for electrons to flow in a material.
4. Voltage is a measure of the energy transferred by an electron as it flows in a circuit.

Section 3 Magnetism

1. A magnet has a north pole and a south pole and is surrounded by a magnetic field.
2. Like magnetic poles repel each other and unlike poles attract each other.
3. Some materials are magnetic because their atoms behave like magnets.
4. An electric current is surrounded by a magnetic field. Moving a wire loop and a magnet past each other produces a current.

Visualizing Main Ideas

Copy and complete the following concept map on electric current.



chapter 7 Review

Using Vocabulary

charging by contact p. 196
charging by induction p. 197
conductor p. 197
electric circuit p. 202
electric current p. 201
electric discharge p. 198
electric resistance p. 203
electromagnet p. 212
electromagnetic induction p. 213
insulator p. 197
magnetic domain p. 211
parallel circuit p. 208
series circuit p. 208
static charge p. 198
voltage p. 205

Complete each statement using a word(s) from the vocabulary list above.

1. A(n) _________ is a closed path that electric current can follow.
2. In a(n) _________, electric charges can move easily.
3. A(n) _________ has more than one path for electric current to follow.
4. An object that does not contain equal amounts of positive charge and negative charge has a(n) _________.
5. A(n) _________ is the flow of electric charges.
6. _________ is a measure of the energy electrons transfer to a circuit as they flow.
7. A(n) _________ is made of a current-carrying wire wrapped around an iron core.
8. A measure of how difficult it is for current to flow in an object is its _________.

Checking Concepts

Choose the word or phrase that best answers the question.

9. Which of the following causes current to flow in a wire?
   A) electric field
   B) electric circuit
   C) electric resistance
   D) magnetic domains
10. Which of the following energy conversions occurs inside a battery?
    A) electrical to chemical
    B) chemical to electrical
    C) thermal to electrical
    D) thermal to chemical
11. How does the electric force between two electrons change as they get farther apart?
    A) The force stays the same.
    B) The force increases.
    C) The force decreases.
    D) The force switches direction.
12. Every electric charge is surrounded by which of the following?
    A) electric field
    B) electric resistance
    C) electric current
    D) magnetic domains
13. Which of the following is true about a permanent magnet?
    A) Its domains are lined up.
    B) It contains an iron core.
    C) Its domains are randomly oriented.
    D) It contains a current-carrying wire.
14. What does a simple generator rotate in a magnetic field to produce current?
    A) a battery
    B) a wire loop
    C) a magnet
    D) domains
15. Increasing the voltage in a circuit increases which of the following in the circuit?
    A) the electric resistance
    B) the energy transferred to the circuit
    C) the static charge
    D) the number of charges
16. Which of the following does NOT describe the magnetic force between two magnets?
    A) Like poles repel.
    B) Like poles attract.
    C) It decreases as the magnets move apart.
    D) Unlike poles attract.

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CONTENTS

Thinking Critically

17. **Compare** the force of gravity to the forces between electric charges.

18. **Explain** why an electron can push another electron even though both electrons are not touching.

19. **Explain** why a charged balloon does not attract a person's hair if the balloon is far from the person's head.

20. **Determine** how the total charge on a doorknob changes when the doorknob is charged by an electric field.

Use the table below to answer questions 21–23.

Effect of Battery Voltage on Current

Battery	Battery Voltage (V)	Current in Circuit (A)
A	2	0.2
B	4	0.4
C	6	0.6
D	10	1.0

21. **Make a Graph** The table above shows the current measured in a circuit when different batteries are connected in the circuit. For each battery, plot the current on the vertical axis and the battery voltage on the horizontal axis. Describe the shape of the plotted line.

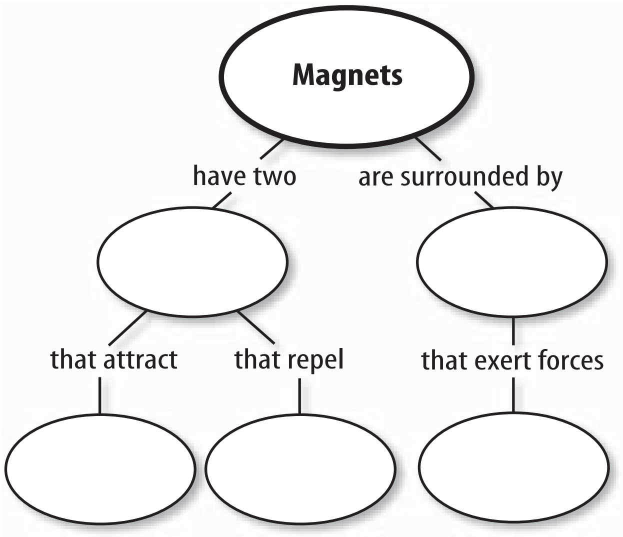
22. **Infer** from your graph the current in the circuit if the battery voltage is 8 V.

23. **Predict** from the table above the current in the circuit if the battery voltage is 12 V.

24. **Explain** why even though aluminum and iron are both metals, aluminum is not a magnetic material, but iron is.

25. **Predict** whether a generator that is designed to rotate a permanent magnet around a wire loop that doesn't move, will produce electric current.

26. **Concept Map** Copy and complete the following concept map on magnets.



Performance Activities

27. Determine the number of hours in a week that you and your family spend using certain electrical appliances. Choose three appliances. Put paper and a pencil by each one so that each person can write down the amount of time they are used. Which appliance is used the most?

Applying Math

28. **Lightbulb** A 100-W lightbulb is connected into a circuit in which the voltage is 110 V. What is the current in the lightbulb?

29. **Battery** The voltage of a battery in a circuit is increased from 3 V to 4.5 V. If the resistance in the circuit is 5 Ω, calculate the percentage change in the current.

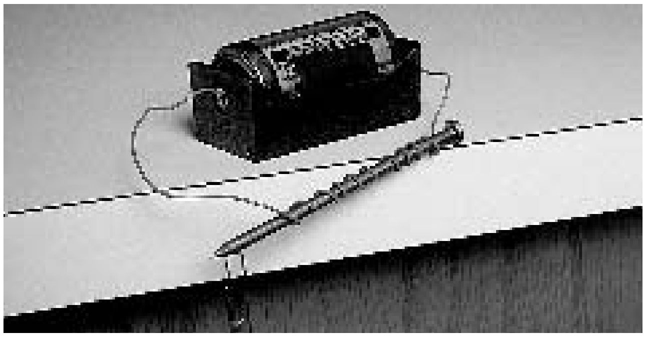
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which of the following materials is a good electrical conductor?

A. aluminum **C.** rubber
B. plastic **D.** wood

Use the figure below to answer questions 2 and 3.



2. What happens if you switch the ends of the wire coil from one battery terminal to the other?

A. Current does not flow through the coil.
B. The electromagnet repels the paper clip.
C. The magnetic poles of the electromagnet are reversed.
D. The magnetic field decreases.

3. The strength of the magnetic field produced by the electromagnet depends on which of the following?

A. The number of domains in the nail.
B. The amount of current in the coil.
C. The number of charges in the coil.
D. The size of the battery.

4. Which of the following describes an object that is negatively charged?

A. It has more neutrons than protons.
B. It has more protons than electrons.
C. It has more protons than neutrons.
D. It has more electrons than protons.

5. How does the amount of positive charge on a proton compare with the amount of negative charge on an electron?

A. The proton has more positive charge.
B. The electron has more negative charge.
C. The amounts are equal.
D. Both particles have no charge.

6. After electrons are transferred from object A to object B, which of the following is true?

A. A and B attract each other.
B. A and B repel each other.
C. A and B exert no force on each other.
D. B has more charge than A.

Use the table below to answer questions 7 and 8.

Current and Voltage in Circuits		
Circuit Number	Voltage (volts)	Current (amps)
1	6	0.1
2	9	0.05
3	12	0.075
4	15	0.25

7. Which circuits have the same resistance?

A. Circuits 1 and 2
B. Circuits 3 and 4
C. Circuits 1 and 4
D. Circuits 2 and 3

8. What is the resistance of circuit 4?

A. 60 Ω **C.** 6.25 Ω
B. 90 Ω **D.** 0.9 Ω

9. Electrical energy is converted into thermal energy in a circuit when which of the following occurs?

A. Electrons are transferred.
B. Electrons collide with atoms.
C. The voltage is decreased.
D. The voltage is increased.

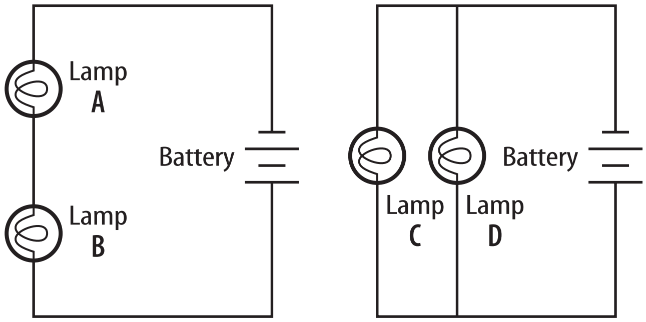
Doug Martin

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

10. What is the continuous flow of electric charge in a material called?

Use the illustration below to answer questions 11 and 12.



11. The illustrations above show two electrical circuits. Which of these is a parallel circuit? Which is a series circuit?

12. If lamp A burns out, will lamp B continue to shine? If lamp C burns out, will lamp D continue to shine?

13. Explain whether two charged objects must touch each other for a static discharge to occur.

14. Why does the temperature of a wire increase when current flows through it?

15. A student makes a simple circuit consisting of a conducting wire connected to a battery and a lamp. What are two ways the student can increase the current in the circuit?

16. Explain why a current stops flowing in a lightbulb when the filament breaks.

17. A simple electric circuit contains a battery connected to a lightbulb. If the resistance of the connecting wires increases, how does the current flowing through the lightbulb filament change?

Part 3 Open Ended

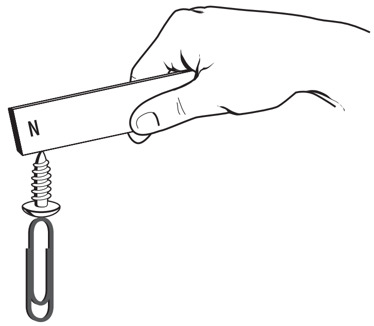
Record your answers on a sheet of paper.

18. Explain why a balloon can stick to a wall if you first rub the balloon against your hair.

19. When two objects rub against each other, such as your shoes against a carpet, why is it usually electrons that move from one object to the other and not protons?

20. Describe how a battery can create a current in a conducting wire.

Use the illustration below to answer questions 21 and 22.



21. The magnet in the illustration above attracts the screw and paper clip. Describe why the screw is able to attract the paper clip and keep it from falling.

22. If the magnet were removed, would the screw still attract the paper clip and keep it from falling?

Test-Taking Tip

Organize Discussion Points For essay questions, spend a few minutes listing and organizing the main points that you plan to discuss. Be sure to do all of this work on your scratch paper, not on the answer sheet.