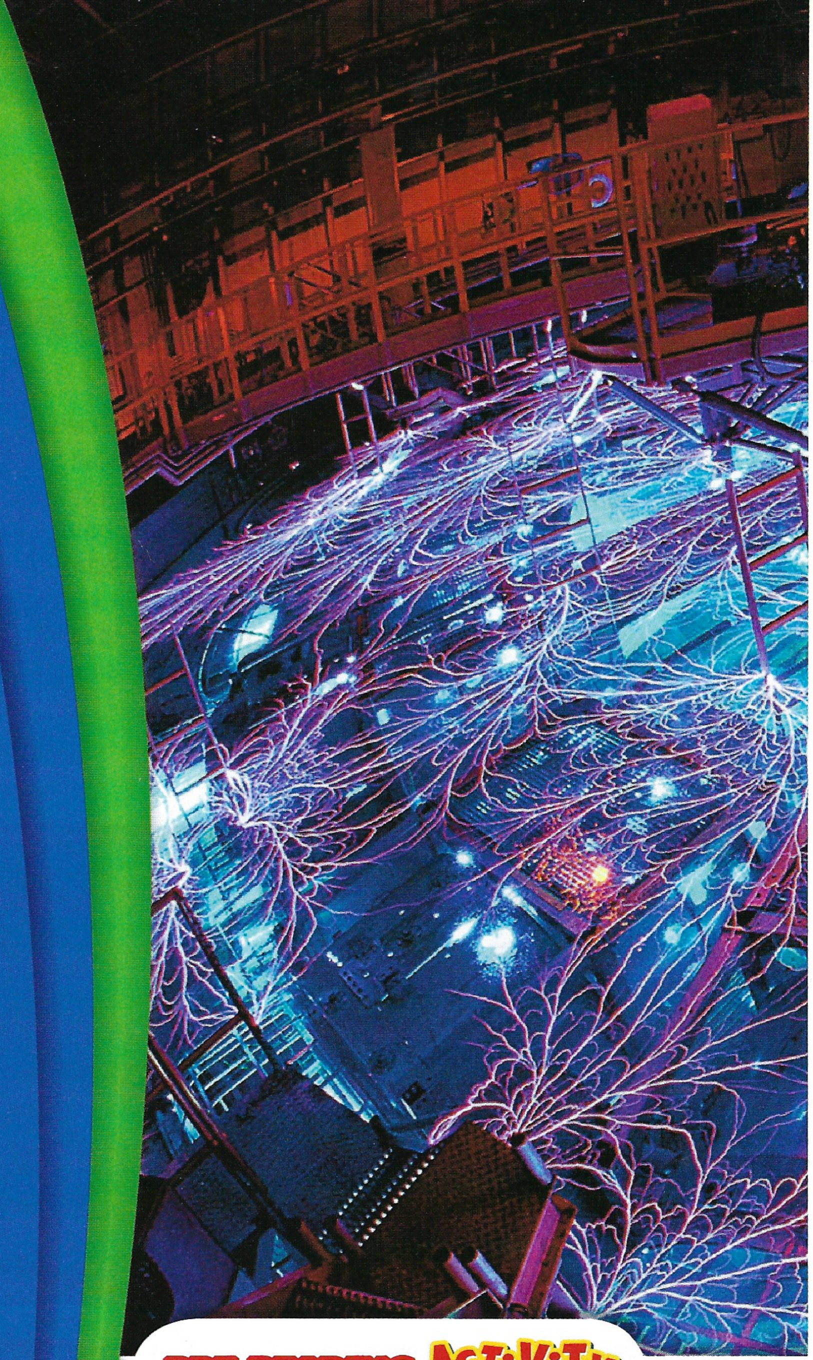
17

Introduction to Electricity

The Big Idea

Electrical energy is the energy of electric charges.

SECTION



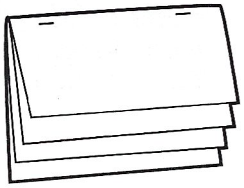
About the PHOTO

This incredible light display is not an indoor lightning storm, but it's close! When scientists at the Sandia National Laboratory fire this fusion device, a huge number of electrons move across the room and make giant sparks.

PRE-READING ACTIVITY

FOLDNOTES

Layered Book Before you read the chapter, create the FoldNote entitled "Layered Book" described in the **Study Skills** section of the Appendix. Label the tabs of the layered book with "Charge," "Current," "Voltage," and "Resistance." As you read the chapter, write information you learn about each category under the appropriate tab.



SECTION 1

Electric Charge and Static Electricity

What You Will Learn

- Describe how charged objects interact by using the law of electric charges.
- Describe three ways in which an object can become charged.
- Compare conductors with insulators.
- Give two examples of static electricity and electric discharge.

Vocabulary

law of electric charges
electric force
electric field
electrical conductor
electrical insulator
static electricity
electric discharge

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Have you ever reached out to open a door and received a shock from the doorknob? Why did that happen?

On dry days, you might get a shock when you open a door, put on a sweater, or touch another person. These shocks come from static electricity. To understand static electricity, you need to learn about atoms and charge.

Electric Charge

All matter is made up of very small particles called *atoms*. Atoms are made of even smaller particles called protons, neutrons, and electrons, which are shown in **Figure 1.** How do these particles differ? For one thing, protons and electrons are charged particles, and neutrons are not.

✓ *Reading Check* **What are the two types of charged particles in atoms?** (*See the Appendix for answers to Reading Checks.*)

Charges Exert Forces

Charge is a physical property. An object can have a positive charge, a negative charge, or no charge. Charge is best understood by learning how charged objects interact. Charged objects exert a force—a push or a pull—on other charged objects. The **law of electric charges** states that like charges repel, or push away, and opposite charges attract. **Figure 2** illustrates this law.

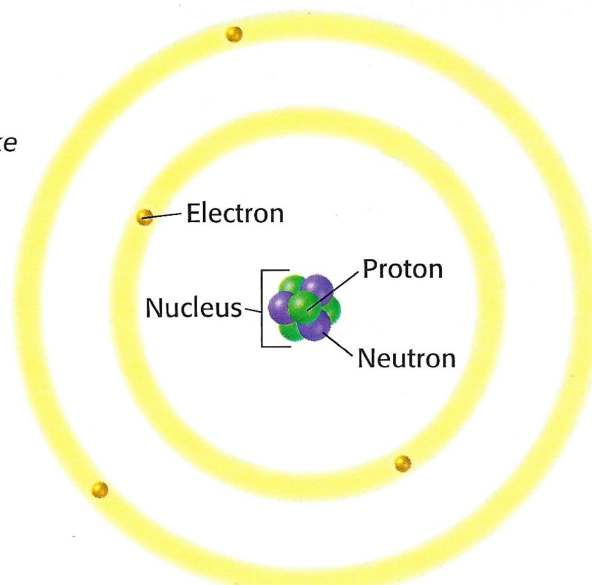


Figure 1 *Protons and neutrons make up the center of the atom, the nucleus. Electrons are found outside the nucleus.*

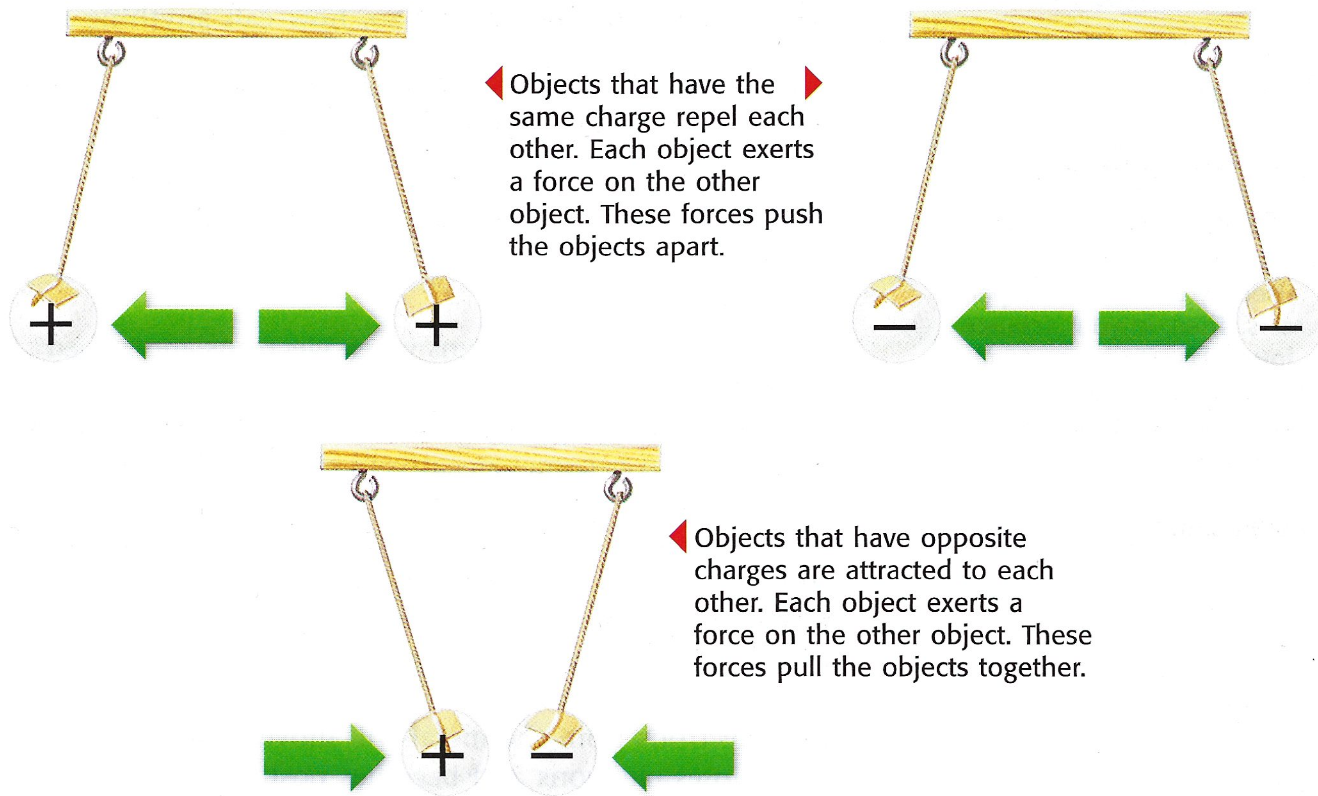


Figure 2 The Law of Electric Charges

Objects that have the same charge repel each other. Each object exerts a force on the other object. These forces push the objects apart.

Objects that have opposite charges are attracted to each other. Each object exerts a force on the other object. These forces pull the objects together.

The Force Between Protons and Electrons

Protons are positively charged. Electrons are negatively charged. Because protons and electrons have opposite charges, they are attracted to each other. Without this attraction, electrons could not be held in atoms.

The Electric Force and the Electric Field

The force between charged objects is an **electric force.** The size of the electric force depends on two things. The first thing is the amount of charge on each object. The greater the charge is, the greater the electric force is. The other thing that determines the size of the electric force is the distance between the charges. The closer together the charges are, the greater the electric force is.

Charged things are affected by electric force because charged things have an electric field around them. An **electric field** is the region around a charged object in which an electric force is exerted on another charged object. A charged object in the electric field of another charged object is attracted or repelled by the electric force acting on it.

law of electric charges the law that states that like charges repel and opposite charges attract

electric force the force of attraction or repulsion on a charged particle that is due to an electric field

electric field the space around a charged object in which another charged object experiences an electric force

Charge It!

Atoms have equal numbers of protons and electrons. Because an atom's positive and negative charges cancel each other out, atoms do not have a charge. So, how can anything made of atoms be charged? An object becomes positively charged when it loses electrons. An object becomes negatively charged when it gains electrons. Objects can become charged by friction, conduction, and induction, as shown in **Figure 3.**

✓ Reading Check **What are three ways of charging an object?**

Friction

Charging by *friction* happens when electrons are "wiped" from one object onto another. If you use a cloth to rub a plastic ruler, electrons move from the cloth to the ruler. The ruler gains electrons and becomes negatively charged. At the same time, the cloth loses electrons and becomes positively charged.

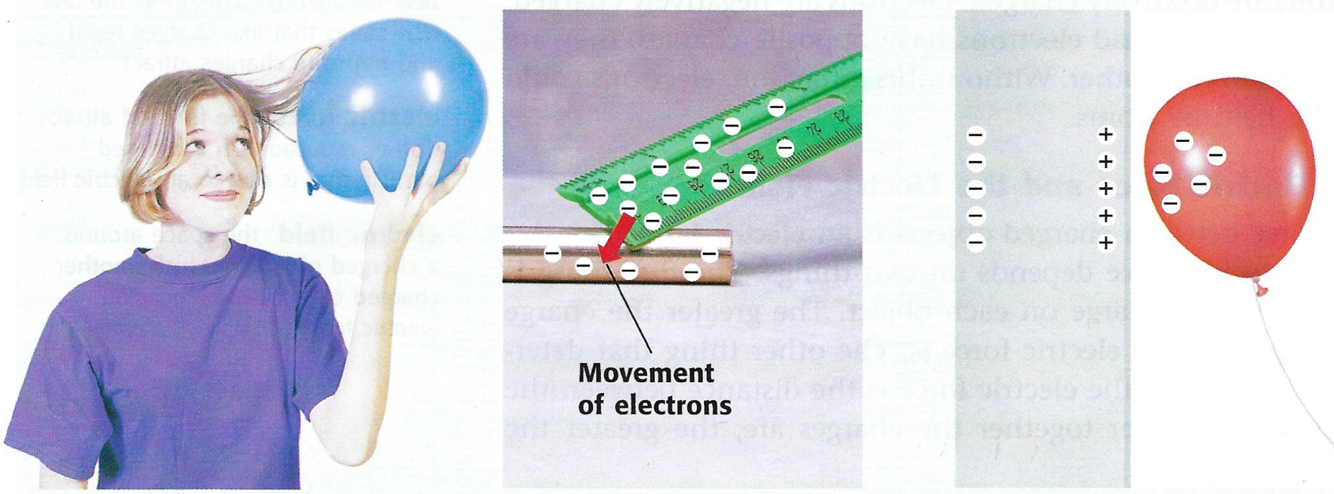
Conduction

Charging by *conduction* happens when electrons move from one object to another by direct contact. Suppose you touch an uncharged piece of metal with a positively charged glass rod. Electrons from the metal will move to the glass rod. The metal loses electrons and becomes positively charged.

CONNECTION TO Environmental Science

WRITING SKILL **Painting Cars** Research how charge and electric force are used by car makers to paint cars. Then, in your **science journal,** write a one-page report describing the process and explaining how the use of charge to paint cars helps protect the environment.

Figure 3 **Three Ways to Charge an Object**



Friction

The friction of rubbing a balloon on your hair causes electrons to move from your hair to the balloon. Your hair and the balloon become oppositely charged and attract each other.

Conduction

When a negatively charged plastic ruler touches an uncharged metal rod, the electrons in the ruler travel to the rod. The rod becomes negatively charged by conduction.

Induction

A negatively charged balloon makes a small section of a metal beam have a positive charge through induction. Electrons in the metal are repelled by and move away from the balloon.

Induction

Charging by *induction* happens when charges in an uncharged metal object are rearranged without direct contact with a charged object. Suppose you hold a metal object near a positively charged object. The electrons in the metal are attracted to and move toward the positively charged object. This movement causes (or induces) an area of negative charge on the surface of the metal.

Conservation of Charge

When you charge something by any method, no charges are created or destroyed. The numbers of electrons and protons stay the same. Electrons simply move from one atom to another, which makes areas that have different charges. Because charges are not created or destroyed, charge is said to be conserved.

Detecting Charge

You can use a device called an *electroscope* to see if something is charged. An electroscope is a glass flask that has a metal rod in its rubber stopper. Two metal leaves are attached to the bottom of the rod. When the electroscope is not charged, the leaves hang straight down. When the electroscope is charged, the leaves repel each other, or spread apart.

Figure 4 shows a negatively charged ruler touching the rod of an electroscope. Electrons move from the ruler to the electroscope. The leaves become negatively charged and repel each other. If something that is positively charged touches the neutral rod, electrons move off the electroscope. Then, the leaves become positively charged and repel each other. An electroscope can show that an object is charged. However, it cannot show whether the charge is positive or negative.

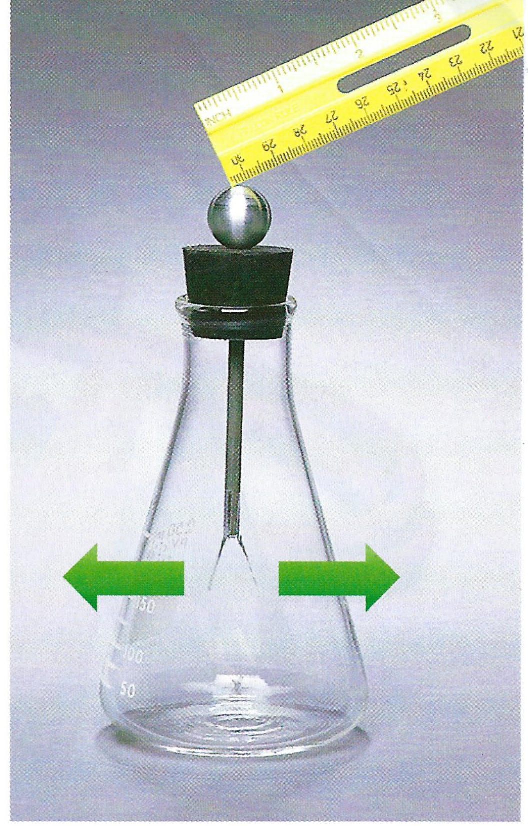


Figure 4 *When an electroscope is charged, the metal leaves have the same charge and repel each other.*

Reading Check **What can you do with an electroscope?**

Quick Lab

Detecting Charge

1. Use **scissors** to cut **two strips of aluminum foil** that are 1 cm × 4 cm each.
2. Bend a **paper clip** to make a hook. (The clip will look like an upside-down question mark.)
3. Push the end of the hook through the middle of an **index card,** and tape the hook so that it hangs straight down from the card.
4. Lay the two foil strips on top of one another, and hang them on the hook by gently pushing the hook through them.
5. Lay the card over the top of a **glass jar.**
6. Bring **various charged objects** near the top of the paper-clip hook, and observe what happens. Explain your observations.

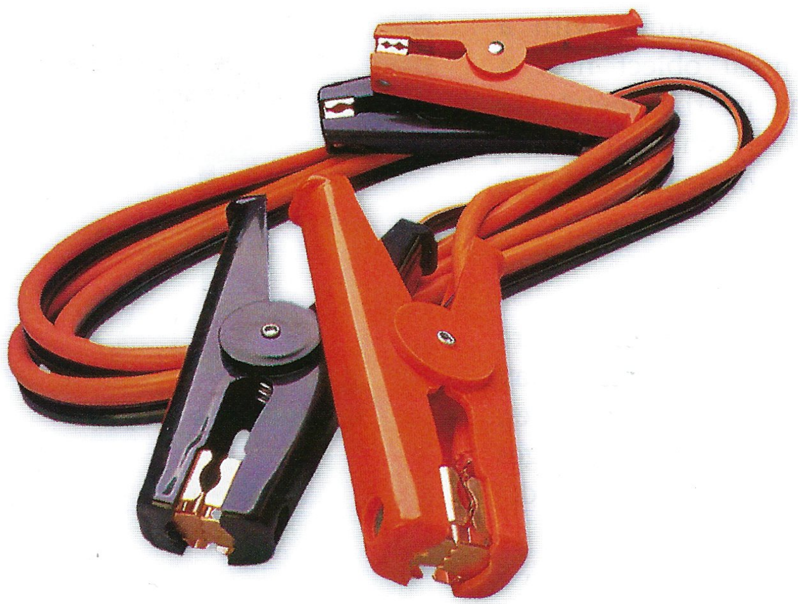


Figure 5 *These jumper cables are made of metal, which carries electric charges, and plastic, which keeps the charges away from your hands.*

Moving Charges

Look at **Figure 5.** Have you ever noticed that electrical cords are often made from metal and plastic? Different materials are used because electric charges move through some materials more easily than they move through others. Most materials are either conductors or insulators based on how easily charges move in them.

Conductors

An **electrical conductor** is a material in which charges can move easily. Most metals are good conductors because some of their electrons are free to move. Conductors are used to make wires. For example, a lamp cord has metal wire and metal prongs. Copper, aluminum, and mercury are good conductors.

Insulators

An **electrical insulator** is a material in which charges cannot move easily. Insulators do not conduct charges very well because their electrons cannot flow freely. The electrons are tightly held in the atoms of the insulator. The insulating material in a lamp cord stops charges from leaving the wire and protects you from electric shock. Plastic, rubber, glass, wood, and air are good insulators.

electrical conductor a material in which charges can move freely

electrical insulator a material in which charges cannot move freely

static electricity electric charge at rest; generally produced by friction or induction

Static Electricity

After you take your clothes out of the dryer, they sometimes are stuck together. They stick together because of static electricity. **Static electricity** is the electric charge at rest on an object.

When something is *static,* it is not moving. The charges of static electricity do not move away from the object that they are in. So, the object keeps its charge. Your clothes are charged by friction as they rub against each other inside a dryer. As the clothes tumble, negative charges are lost by some clothes and build up on other clothes. When the dryer stops, the transfer of charges also stops. And because clothing is an insulator, the built-up electric charges stay on each piece of clothing. The result of this buildup of charges is static cling.

Electric Discharge

Charges that build up as static electricity on an object eventually leave the object. The loss of static electricity as charges move off an object is called **electric discharge.** Sometimes, electric discharge happens slowly. For example, clothes stuck together by static electricity will eventually separate on their own. Over time, their electric charges move to water molecules in the air.

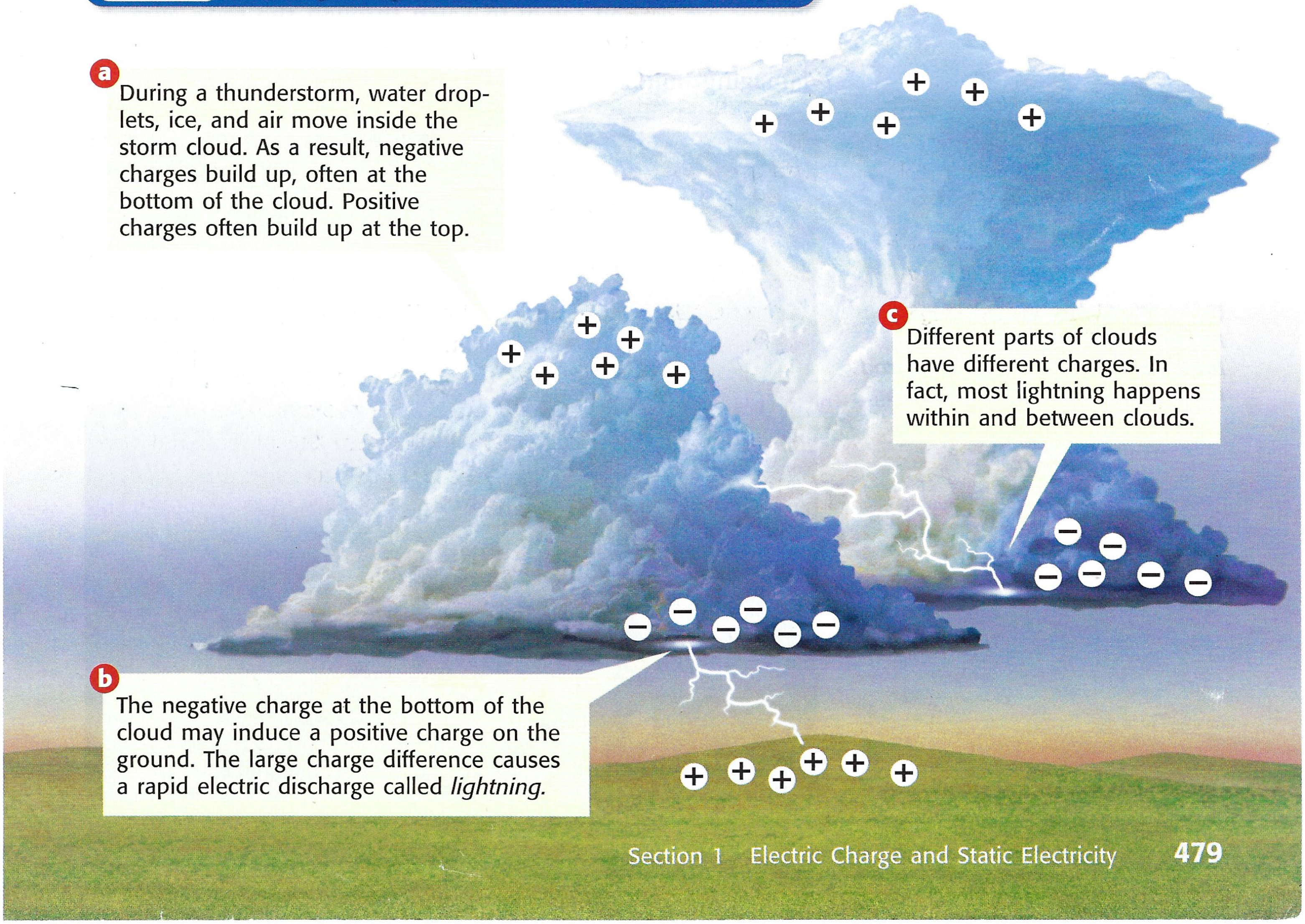
electric discharge the release of electricity stored in a source

Sometimes, electric discharge happens quickly. It may happen with a flash of light, a shock, or a crackling noise. For example, when you wear rubber-soled shoes and walk on carpet, negative charges build up on your body. When you reach out for a metal doorknob, the negative charges on your body can jump to the doorknob. The electric discharge happens quickly, and you feel a small shock.

One of the most dramatic examples of electric discharge is lightning. How does lightning form through a buildup of static electricity? **Figure 6** shows the answer.

Reading Check What is electric discharge?

Figure 6 How Lightning Forms



Lightning Dangers

Lightning usually strikes the highest point in a charged area because that point provides the shortest path for the charges to reach the ground. Anything that sticks up or out in an area can provide a path for lightning. Trees and people in open areas are at risk of being struck by lightning. For this reason, it is particularly dangerous to be at the beach or on a golf course during a lightning storm. Even standing under a tree during a storm is dangerous. The charges from lightning striking a tree can jump to your body.

Reading Check **Why is it dangerous to be outside in an open area during a storm?**

CONNECTION TO Social Studies

Benjamin Franklin In addition to being a statesman, Benjamin Franklin was a scientist. Research Franklin's discovery that lightning is a form of electricity. Make a poster describing the procedures that he used, the terms that he coined, and the inventions related to electricity that he designed. **ACTIVITY**

Lightning Rods

A lightning rod is a pointed rod connected to the ground by a wire. Lightning rods are often mounted so that they are the tallest point on a building, as shown in **Figure 7.** Objects, such as a lightning rod, that are joined to Earth by a conductor, such as a wire, are *grounded.* Any object that is grounded provides a path for electric charges to move to Earth. Because Earth is so large, it can give up or absorb charges without being damaged. When lightning strikes a lightning rod, the electric charges are carried safely to Earth through the rod's wire. By directing the charge to Earth, the rods prevent lightning from damaging buildings.

Figure 7 *Lightning strikes the lightning rod rather than the building, because the lightning rod is the tallest point on the building.*

SECTION Review

Summary

- The law of electric charges states that like charges repel and opposite charges attract.
- The size of the electric force between two objects depends on the size of the charges exerting the force and the distance between the objects.
- Charged objects exert a force on each other and can cause each other to move.
- Objects become charged when they gain or lose electrons.
- Objects may become charged by friction, conduction, or induction.
- Charges are not created or destroyed and are said to be conserved.
- Charges move easily in conductors but do not move easily in insulators.
- Static electricity is the buildup of electric charges on an object. It is lost through electric discharge.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *static electricity* and *electric discharge*
2. *electric force* and *electric field*
3. *electrical conductor* and *electrical insulator*

Understanding Key Ideas

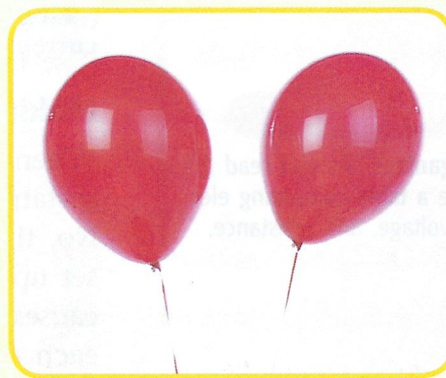
4. Which of the following is an insulator?
   a. copper
   b. rubber
   c. aluminum
   d. iron
5. Compare the three methods of charging.
6. What does the law of electric charges say about two objects that are positively charged?
7. Give two examples of static electricity.
8. List two examples of electric discharge.

Critical Thinking

9. **Analyzing Processes** Imagine that you touch the top of an electroscope with an object. The metal leaves spread apart. Can you determine whether the charge is positive or negative? Explain your answer.
10. **Applying Concepts** Why is it important to touch a charged object to the metal rod of an electroscope and not to the rubber stopper?

Interpreting Graphics

The photograph below shows two charged balloons. Use the photograph below to answer the questions that follow.



11. Do the balloons have the same charge or opposite charges? Explain your answer.
12. How would the photograph look if each balloon were given the charge opposite to the charge it has now? Explain your answer.

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