Section 20.1

1 FOCUS

Objectives

20.1.1 **Analyze** factors that affect the strength and direction of electric forces and fields.

20.1.2 **Describe** how electric forces and fields affect electric charges.

20.1.3 **Describe** how electric charges are transferred and **explain** why electric discharges occur.

Reading Focus

Build Vocabulary L2

Word-Part Analysis Ask students, **What word appears in most of the definitions?** *(Electric, electrical, electricity)* Explain that the root word for *electricity* comes from the Greek word for "amber," a substance that is easily charged. Ask, **What can be inferred from this?** *(Electricity deals with charges.)* Explain that the word *static* comes most recently from the Greek word *statikos,* which means "causing to stand." Point out to students that in static electricity, or static discharge, charges jump from one location to another. Thus, charges do move, so the term *static* is unfortunate.

Reading Strategy L2

a. The attraction or repulsion between electrically charged objects
b. Field strength depends on the net charge and distance from the charge.
c. Charge can be transferred by friction, contact, or induction.

2 INSTRUCT

Electric Charge

Build Reading Literacy L1

Outline Refer to page **156D** in **Chapter 6**, which provides the guidelines for an outline.

Have students create an outline of the section (pp. 600–603). Outlines should follow the head structure used in the section. Major headings are shown in green, and subheadings are shown in blue. Ask, **Based on your outline, what are the three ways static electric charges are transferred?** *(Friction, contact, and induction)*
Verbal, Logical

20.1 Electric Charge and Static Electricity

Reading Focus

Key Concepts

- What produces a net electric charge?
- What determines whether an electric force is attractive or repulsive?
- What determines the strength of an electric field?
- What are three ways in which charge is transferred?
- How does a static discharge occur?

Vocabulary

- electric charge
- electric force
- electric field
- static electricity
- law of conservation of charge
- induction

Reading Strategy

Identifying Main Ideas Copy the table below. As you read, write the main idea for each topic.

Topic	Main Idea
Electric Charge	An excess or shortage of electrons produces a net electric charge.
Electric Forces	a.________________
Electric Fields	b.________________
Static Electricity	c.________________

Think back to the last time a thunderstorm swept through your area. A bolt of lightning streaked across the sky, followed moments later by the crash of thunder. Have you ever wondered what causes lightning? Perhaps you've observed something similar on a smaller scale closer to home. When you take clothes out of a dryer, some of them can stick together, like the socks and towel in Figure 1. If you pull the clothes apart in a darkened room, you can see sparks that are like tiny bolts of lightning. This shouldn't be surprising once you realize that lightning and "static cling" have a similar cause—the movement of electric charges.

Figure 1 Electric charge is responsible for clothes that stick together when they are removed from a dryer.

Electric Charge

Recall that electrical energy is the energy associated with electric charges. But what exactly is electric charge? **Electric charge** is a property that causes subatomic particles such as protons and electrons to attract or repel each other. There are two types of electric charge, positive and negative. Protons have a positive charge and electrons have a negative charge. Electric charges move in a flash through a lightning bolt. Electric charges attract one another in clothes taken from the dryer. Although charged particles are too small to see, just about everything in your daily life is affected by charge in one way or another.

Section Resources

Print
- ***Laboratory Manual,*** Investigation 20B
- ***Reading and Study Workbook With Math Support,*** Section 20.1
- ***Transparencies,*** Chapter Pretest and Section 20.1

Technology
- ***Interactive Textbook,*** Section 20.1
- ***Presentation Pro CD-ROM,*** Chapter Pretest and Section 20.1

Figure 2 shows how charges are arranged in an atom. A cloud of negatively charged electrons surrounds the positively charged nucleus. The atom is neutral because it has an equal number of positive and negative charges. If an atom gains one or more electrons, it becomes a negatively charged ion. If an atom loses electrons, it becomes a positively charged ion. **An excess or shortage of electrons produces a net electric charge.**

The SI unit of electric charge is the coulomb (C). It takes about 6.24×10^{18} electrons to produce a single coulomb. A lightning bolt is about 10 to 20 coulombs of charge. In comparison, a flash camera uses the energy from 0.025 coulombs of charge to produce each flash.

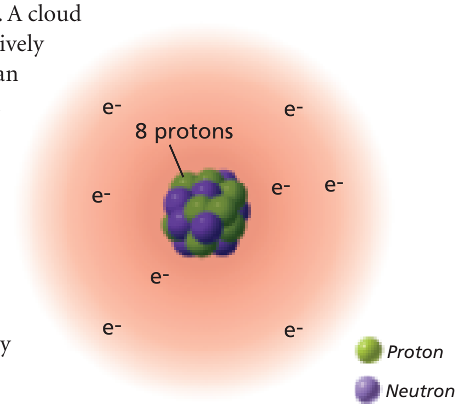

Figure 2 A neutral atom has equal numbers of protons and electrons.
Drawing Conclusions *What is the overall charge if the atom loses an electron?*

Electric Forces

Rub an inflated rubber balloon on your clean, dry hair. If it's a dry day, you can use the balloon to pick up bits of paper. The balloon attracts the paper because the balloon is negatively charged and the paper is positively charged. Now rub a second balloon on your hair and bring the two balloons close together. You can feel the balloons repel. The two balloons repel because they are negatively charged. **Like charges repel, and opposite charges attract.** The force of attraction or repulsion between electrically charged objects is **electric force.**

The French scientist Charles-Augustin de Coulomb (1736–1806) discovered that electric forces obey a law similar to the law of universal gravitation. The electric force between two objects is directly proportional to the net charge on each object and inversely proportional to the square of the distance between them. As you can see in Figure 3, doubling the net charge on one object doubles the electric force. If instead you double the distance between the objects, the electric force is one fourth as strong.

Inside an atom, electric forces are much stronger than gravitational forces. Electric forces form chemical bonds, which must be overcome in chemical changes. Electric forces also cause friction and other contact forces. But on a large scale, matter is mostly neutral and in that case, electric forces are close to zero.

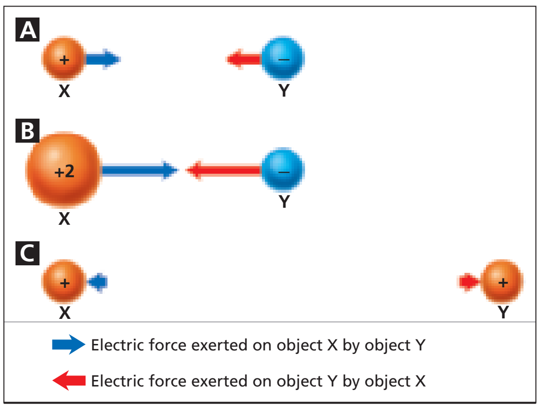

Figure 3 Electric force depends on charge and distance. **A** Opposite charges attract each other. **B** Doubling one charge doubles the force on both charges. **C** Like charges repel. Doubling the distance makes the force one fourth as great.

Reading Checkpoint *What is electric force?*

Build Science Skills L2

Using Models Have students apply what they know about force and mass to explain why negative charges are more mobile than positive charges. *(Positive charges are provided by protons, which are much more massive than electrons. Electrons, which carry negative charge, are less massive and therefore more easily moved.)*
Logical

Electric Forces

Teacher Demo

Electric Attraction and Repulsion L2

Purpose To show that attractive forces exist between unlike charges, and repelling forces exist between like charges.

Materials pith ball, thread, rubber or ebonite rod, fur

Procedure Attach the thread to the pith ball. Rub the fur against the rubber rod, and then touch this rod briefly to the pith ball. Bring the rod close to the pith ball. Next, move the fur near the pith ball.

Expected Outcome Friction causes the fur to become positively charged and the rod to become negatively charged. The rod then transfers negative charge to the pith ball. When the rod is brought close to the pith ball, the like charges exert a repelling force on each other, and the ball moves away from the rod. When the fur, which has an opposite charge to the rod, is brought close to the ball, the ball is attracted to the fur.
Visual

Customize for English Language Learners

Reinforce Vocabulary
Reinforce the vocabulary for this section by having English language learners construct a concept map. This will not only increase their familiarity with the terms, but will also help them understand how the various words, especially those that include the word *electric* or *electrical,* are related to each other.

Answer to . . .

Figure 2 *Net charge would be +1.*

Reading Checkpoint *An electric force is a force of repulsion or attraction between electrically charged objects.*

Electric Fields

Use Visuals L1

Figure 4 Stress that the directions of the electric fields for positive and negative charges are a matter of convention, much in the same way that the proton has charge that is called "positive." Emphasize that the field lines show the direction of the force on a positive "test" charge placed in the field. Ask, **In what direction is the force on a proton that is placed in each of these fields?** *(The force is outward [repulsive] in A and inward [attractive] in B.)*
Visual

Static Electricity and Charging

Address Misconceptions L2

Students may think that most or all of the atoms in an object charged by friction contribute to the object's net charge. Emphasize that only a small fraction of the atoms or molecules in a substance give up electrons. For instance, an acrylic rod that has been rubbed with fur may only have a net charge of 10^{-9} C. Explain that, while such a charge is produced by 10 billion electrons, there are about 10^{22} to 10^{24} atoms from which charges could be taken. In other words, only about one in a trillion atoms or molecules donate charges during charging by friction.
Logical

Use Visuals L1

Figure 5 Stress that friction usually separates charges on a pair of electrically neutral objects, whereas charging by contact moves some of the net charge on a charged object to another object. Ask, **What would happen if electrons were conveyed by contact to an object with a positive charge?** *(The electrons would reduce the overall positive charge of the object.)* Ask, **What would happen if the positive and negative charges were equal?** *(The object would become electrically neutral.)*
Visual

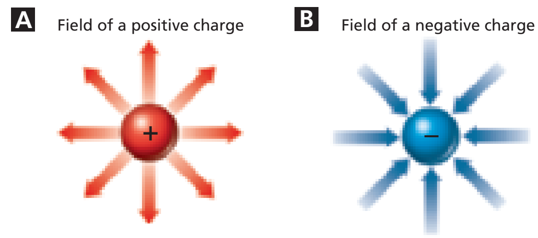

Figure 4 The strength of an electric field depends on the amount of charge that produces the field and on the distance from the charge. **A** The electric field around a positive charge points outward. **B** The electric field around a negative charge points inward.

Electric Fields

The effect an electric charge has on other charges in the space around it is the charge's **electric field.** Figure 4 shows the fields of positive and negative charges. **The strength of an electric field depends on the amount of charge that produces the field and on the distance from the charge.** The lines representing the field are closer together near the charge, where the field is stronger.

An electric field exerts forces on any charged object placed in the field. The force depends on the net charge in the object and on the strength and direction of the field at the object's position. The more net charge an object has, the greater is the force on it. The direction of each field line shows the direction of the force on a positive charge.

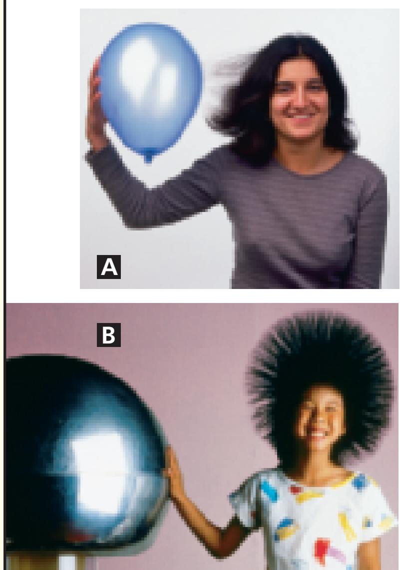

Figure 5 Charge can be transferred by friction and by contact. **A** Friction transferred electrons from the hair to the balloon. The balloon then attracts the hair because opposite charges attract. **B** A Van de Graaff generator has charged the metal sphere. Touching the sphere transfers charge. The hairs repel each other because like charges repel.

Static Electricity and Charging

Static electricity is the study of the behavior of electric charges, including how charge is transferred between objects. There are several ways that a net charge can build up on an object or move from one object to another. **Charge can be transferred by friction, by contact, and by induction.** Keep in mind that whenever there is a charge transfer, the total charge is the same before and after the transfer occurs. This is the **law of conservation of charge**—the total charge in an isolated system is constant.

Charging by Friction The balloon in Figure 5A attracts hair because opposite charges attract. But how do balloons and hair pick up a net charge? Rubbing a balloon on your hair is an example of charging by friction. Electrons move from your hair to the balloon because atoms in rubber have a greater attraction for electrons than atoms in hair. The balloon picks up a net negative charge. Because your hair loses electrons, it becomes positively charged. Even simple everyday activities like walking across a carpet can build up charge this way.

Charging by Contact Why do the girl's hairs repel each other in Figure 5B? In this case, charge is transferred by contact. A Van de Graaff generator has charged the metal sphere. When the girl touches the sphere, she acquires a charge large enough to make her hairs stand on end. The sphere is still charged, but its net charge is reduced.

Facts and Figures

Electrical Force and Gravitational Force
Electrical forces are much stronger than the gravitational forces that operate among particles in an atom. For instance, an electron and a proton in a hydrogen atom are 5.3×10^{-11} m apart, on average. The mass of the electron is 9.11×10^{-31} kg and the mass of the proton is 1.67×10^{-27} kg, while both have a charge with magnitude 1.60×10^{-19} C. The gravitational force of attraction between the two particles is 3.6×10^{-47} N, while the electrical force of attraction is 8.2×10^{-8} N, or about 2×10^{39} times greater than the gravitational attraction between them.

Charging by Induction Suppose you reach for a doorknob after walking across a carpet. You have picked up extra electrons from the carpet, so your hand is negatively charged. The net negative charge in your hand repels electrons in the metal doorknob. Figure 6 shows that electrons move to the base of the doorknob, leaving a net positive charge in the part of the doorknob closest to the hand. Overall, the doorknob is still neutral, but charge has moved within it. This is **induction,** a transfer of charge without contact between materials.

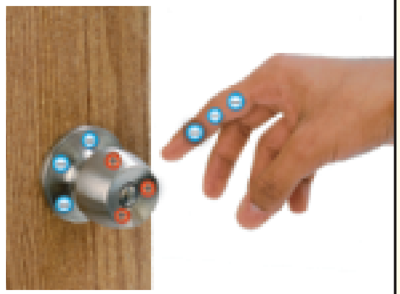

Figure 6 Induction occurs when charge is transferred without contact between materials. Negative charges in the hand induce charges to move within the metal doorknob. **Predicting** *What would happen if the hand had a net positive charge?*

Static Discharge

Why do you get a shock from a doorknob? The spark you feel is a static discharge. **Static discharge occurs when a pathway through which charges can move forms suddenly.** Charges will not travel through air from your hand to the doorknob. But air becomes charged suddenly when the gap between your finger and the doorknob is small. This air provides a path for electrons to flow from your hand to the doorknob. If the room is dark, you can even see this spark.

Lightning is a more dramatic discharge. Charge can build up in a storm cloud from friction between moving air masses. Negative charge in the lower part of the cloud induces a positive charge in the ground below the cloud. As the amount of charge in the cloud increases, the force of attraction between charges in the cloud and charges in the ground increases. Eventually the air becomes charged, forming a pathway for electrons to travel from the cloud to the ground.

Go Online PLANETDIARY

For: Activity on thunder and lightning
Visit: PHSchool.com
Web Code: ccc-2201

Section 20.1 Assessment

Reviewing Concepts

1. How is a net electric charge produced?
2. What determines whether charges attract or repel?
3. Name two factors that affect the strength of an electric field.
4. List three methods of charge transfer.
5. Explain how static discharge occurs.
6. How does electric force depend on the amount of charge and the distance between charges?
7. What is the law of conservation of charge?

Critical Thinking

8. **Forming Hypotheses** Why does plastic food wrap cling better to some materials than to others?
9. **Inferring** When a glass rod is rubbed with neutral silk, the glass becomes positively charged. What charge does the silk now have? Explain.
10. **Relating Cause and Effect** Many lightning strikes occur within a cloud, rather than between clouds and the ground. Explain why. (*Hint:* Assume a cloud has no net charge.)

Writing in Science

Explanatory Paragraph Write a paragraph explaining the series of events that may cause you to receive a shock from a metal doorknob on a dry winter day. (*Hint:* Use a flowchart to organize your ideas before writing your paragraph.)

Section 20.1 Assessment

1. An excess or shortage of electrons produces a net electric charge.
2. If charges are alike, they will repel. Opposite charges will attract.
3. Net charge and distance from the charge
4. Friction, contact, induction
5. A pathway through which charges can move forms suddenly.
6. Electric force increases proportionally with charge, while the force is inversely proportional to the square of the distance.
7. The total charge in a system is constant, so that the total charge before charges are transferred is the same as after.
8. The plastic attracts electrons more strongly than some materials and less strongly than others.
9. The charge on the silk must be negative because charge is conserved.
10. If the cloud is neutral, some areas will have a net positive charge, and others a net negative charge. Within the clouds, an area with negative charge buildup discharges to an area with positive charge buildup.

Static Discharge

Build Science Skills L2

Relating Cause and Effect Have students write a short paragraph describing lightning. Be sure students suggest a reason why excess electrons in a cloud induce a positive charge in the ground. Have students discuss the electric forces in static discharge. *(Friction between water droplets separates charges. Tell students that convection currents within a cloud move positive charges to the top of the cloud and negative charges to the bottom. Through induction, the electric force from the negatively charged region of the cloud repels nearby negative charges on Earth's surface. This leaves a positive charge on the ground. Lightning is the discharge between the oppositely charged regions—either cloud-to-ground or cloud-to-cloud.)*
Logical

3 ASSESS

Evaluate Understanding L2

Ask students to write a paragraph describing interactions between charges. The paragraph should indicate the two kinds of charges, the forces between the charges, and the ways (friction, contact, and induction) that charges are transferred to and from surfaces.

Reteach L1

Have students use Figure 3 to summarize the way electric forces act between charges.

Writing in Science

Paragraphs should start by describing a buildup of charge on the person, for example by friction with the carpet. When the hand nears the doorknob, charge moves within the metal doorknob by induction. When the hand gets very close, the air suddenly becomes charged. Electrons then flow rapidly either to or from the doorknob, depending on whether the hand has a net negative or positive charge.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 20.1.

Answer to . . .

Figure 6 *Electrons in the doorknob would move close to the hand. The base of the doorknob would be positively charged.*