10.1 Exploring Static Charges

Key Terms
- electricity
- static charge (static electricity)
- charging by friction
- electrostatic series
- insulator
- conductor
- semiconductor
- ground

You have probably experienced static cling. It results from small charges and can be a minor nuisance, such as when clothes come out of a dryer stuck together, as shown in **Figure 10.1**. At other times, static cling can be useful. For example, it causes plastic wrap to stick to your lunch. However, charges can be dangerous. Lightning bolts are giant sparks caused by the build-up of large static charges. Static charges on the surfaces of objects must be reduced in many situations to protect people and equipment. For example, people who work with computers must reduce the net static charges on objects to avoid damaging sensitive circuits. In this section, you will learn how static charges are caused, how they can be used, and how they can be removed.

Charging by Friction

Electricity is a form of energy that results from the interaction of charged particles, such as electrons or protons. The word *static* means stationary, or not moving. Thus **static charge (static electricity)** refers to an electric charge that tends to stay on the surface of an object, rather than flowing away quickly. Static charges build up as different materials rub together, as in a clothes dryer. This process is called **charging by friction**. Rubbing a piece of wool cloth on a foam plate, rubbing a rubber balloon against a sweater, and combing your hair with a plastic comb are all examples of charging by friction.

When objects become charged by friction, one material has a stronger attraction to electrons (which are negatively charged) than another material, and therefore pulls electrons off the material that has the weaker attraction for them. As a result, both materials become charged due to an excess or a deficit (shortage) of electrons.

electricity a form of energy that results from the interaction of charged particles, such as electrons or protons

static charge (static electricity) an electric charge that tends to stay on the surface of an object, rather than flowing away quickly

charging by friction a process in which objects made from different materials rub against each other, producing a net static charge on each

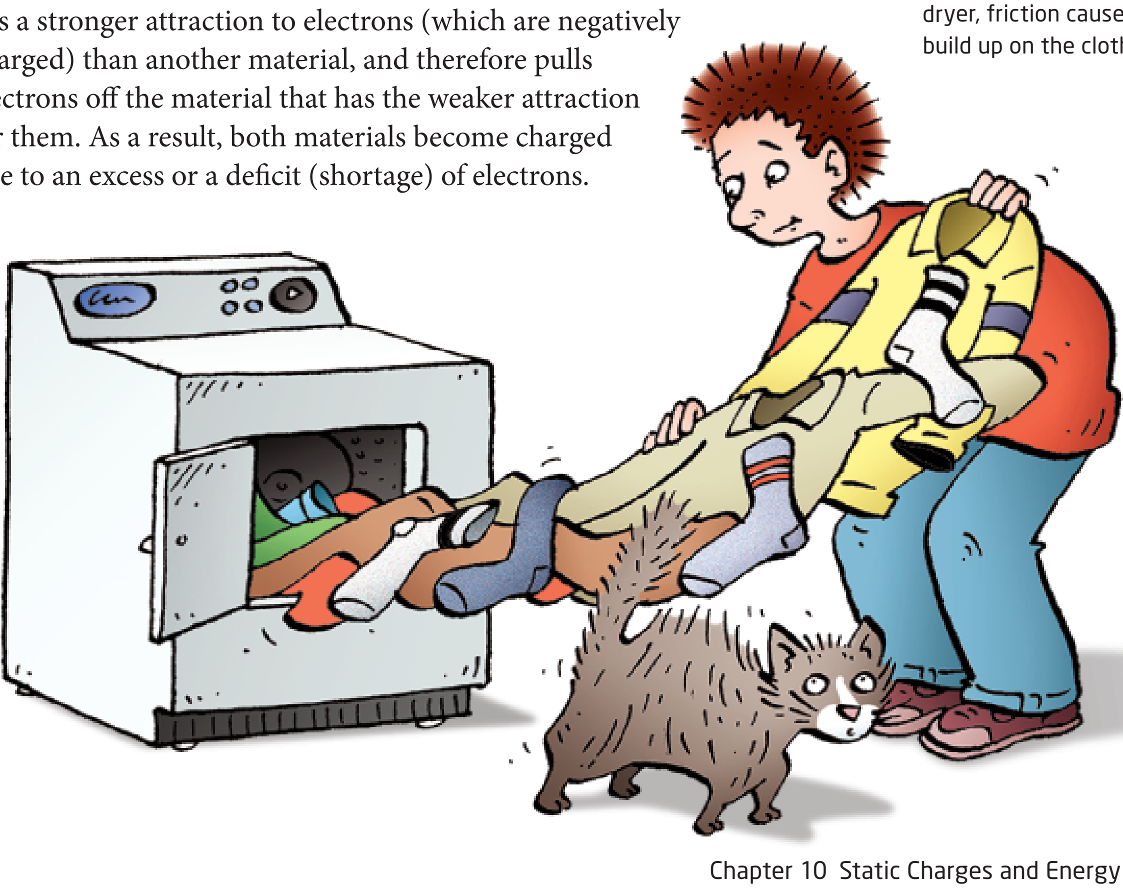

Figure 10.1 In an electric clothes dryer, friction causes charges to build up on the clothes.

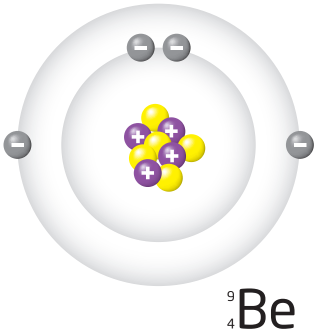

Figure 10.2 This is the Bohr-Rutherford model of a beryllium atom. In the Bohr-Rutherford model of an atom, electrons revolve around the nucleus in definite orbits.

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The Bohr-Rutherford Model of the Atom

In 1897, British physicist J. J. Thomson discovered some of the properties of a basic unit of matter that caused charge. Thomson named this particle the *electron*.

In the early 20th century, Danish physicist Niels Bohr and New Zealand physicist Ernest Rutherford developed the Bohr-Rutherford model of the atom. In this model, shown in **Figure 10.2**, atoms consist of three types of particles: protons, neutrons, and electrons. A central, relatively massive nucleus contains the protons and neutrons. Protons are positively charged. Neutrons, as their name suggests, are electrically neutral and so are not a source of static charge. Electrons move in the outer parts of the atom, relatively far from the nucleus. They are negatively charged. (For more on the structure of the atom, see Chapter 5.)

Causes of Electric Charges

Most objects are electrically neutral because they contain equal numbers of positively charged protons and negatively charged electrons. When two neutral objects made from different materials rub against each other, as shown in **Figure 10.3**, electrons from the atoms in one material can transfer to atoms in the other material. It is only electrons that transfer, because they have a small mass and are relatively far from the nucleus.

The Bohr-Rutherford model of the atom explains the following conclusions:

- Particles that carry electric charges can be neither created nor destroyed.
- Any net charge on a solid object, whether it is positive or negative, results from the transfer of electrons between this object and another object.
- Compared with a neutral object, an object with an excess of electrons (more electrons than protons) has a negative charge.
- Compared with a neutral object, an object with a deficit of electrons (fewer electrons than protons) has a positive charge.
- Different materials hold on to their electrons with different strengths.

Sense of scale

In **Figure 10.2**, + or – symbols indicate single charges. However, in most diagrams, such as **Figure 10.3**, + or – symbols indicate a very large number of charges that have either a net positive or net negative charge.

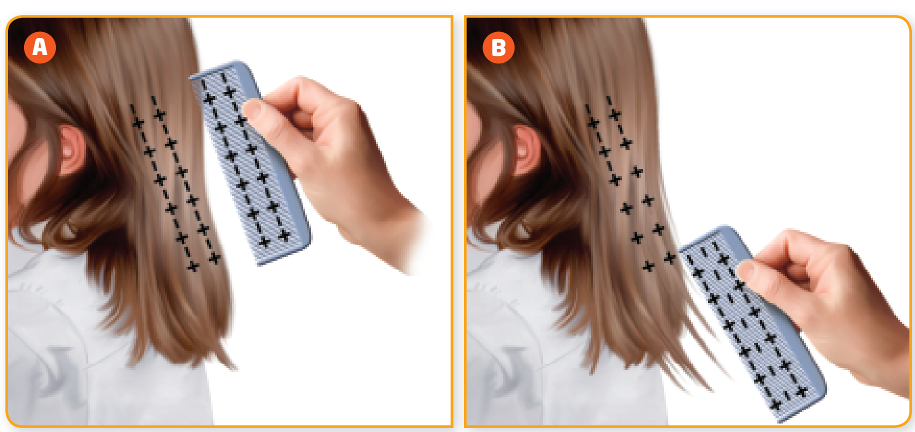


Figure 10.3 Look carefully at the + and - symbols. **A** Before combing, both the girl's hair and the plastic comb are neutral. **B** After combing, the girl's hair is positively charged, and the comb is negatively charged.

An Electrostatic Series

An **electrostatic series**, like **Table 10.1**, is a list of materials that have been arranged according to their ability to hold on to electrons. An electrostatic series is based on data from experiments. Scientists determine whether the charges on two materials, after they are rubbed together, are positive or negative. The material with atoms that have a stronger hold on electrons ends up with a negative charge. The other material, whose atoms have a weaker hold on electrons, loses its electrons to the first material and becomes positively charged. In **Table 10.1**, materials that are closer to the bottom of the list become negatively charged after being rubbed with materials that are closer to the top of the list, which become positively charged.

electrostatic series a list of materials that have been arranged according to their ability to hold on to electrons

Table 10.1 Electrostatic Series of Some Common Materials

Material	Strength of Hold on Electrons
Glass	Weak
Human hair	
Nylon	
Wool	
Fur	
Silk	
Cotton	
Lucite (a clear plastic)	
Rubber balloon	
Polyester	
Foam	
Grocery bags (low density polyethylene)	↓
Ebonite (a hard form of rubber)	Strong

- Different sources often list the materials in a different order, because the surface layer on a material can slightly change its properties. If you rub together two materials that are far apart in an electrostatic series, however, you can accurately predict the charge on each that will result.
- Different animals have fur with slightly different characteristics. For example, rabbit fur holds on to electrons more strongly than cat fur.

Note that cotton holds on to its electrons more strongly than nylon. Thus, when nylon socks and cotton shirts are dried together in a clothes dryer, the nylon socks become positively charged and the cotton shirts become negatively charged. This difference in charge is what causes "static cling."

When an object is said to have a positive charge, it means that the object has a net positive charge. An object with a net positive charge has many more protons than electrons. Likewise, an object with a net negative charge has many more electrons than protons.

Sense of Value

Conductors can also be ordered by their conductivity. The following metals are listed in order, from greater to lesser conductivity: silver, copper, gold, aluminum, chromium, molybdenum, tungsten, zinc.

Suggested Investigation

Plan Your Own Investigation 10-A, Comparing Conductivity, on page 429

Learning Check

1. When you comb your hair with a plastic comb, which object, the hair or the comb, holds on to its electrons more tightly? What is the charge on this object?
2. If you comb your hair vigorously, how is the amount of charge on your hair and the comb affected? Why?
3. If leather is rubbed with polyester, the polyester becomes negatively charged. Would you place leather above or below polyester in an electrostatic series? Refer to **Table 10.1**.
4. In the winter, removing a wool hat can give your hair a static charge. Use **Table 10.1** to predict the type of charge on your hair.

Study Toolkit

Word Families Why do you think several words in this chapter have *conduct* as their base?

Anti-static Sheets

Clothes are made from many different materials, such as cotton, wool, and nylon. These materials hold on to their electrons with different strengths. A clothes dryer generates static charges on the different materials when they tumble and rub against each other as the dryer drum rotates. In other words, charging by friction occurs. An anti-static sheet is a small piece of cloth that contains a waxy compound. Hot air from the dryer vaporizes the waxy compound, which then coats the clothes. This causes the clothes to behave as if they were made from the same material, so no static charges build up.

insulator a material in which electrons cannot move easily from one atom to another

conductor a material in which electrons can move easily between atoms

semiconductor a material in which electrons can move fairly well between atoms

Insulators and Conductors

Each material listed in the electrostatic series shown in **Table 10.1** is a non-metal and an **insulator**. An electrical insulator is a material in which electrons cannot move easily from one atom to another. Metals and other materials in which electrons can move easily between atoms are classified as electrical **conductors**. There are some non-metals, such as silicon, in which electrons can move fairly well. These non-metals are called **semiconductors**. The degree to which electrons move between atoms is different in all materials, so different materials have different conductivities.

Because different materials have different conductivities, they can be used for different applications. For example, copper and aluminum are conductors that are used in wire. Another conductor, mercury, is used in switches. Insulators, which include wood, rubber, and plastic, are used to make the coverings and connectors for wires, wall socket protectors, and screwdriver handles.

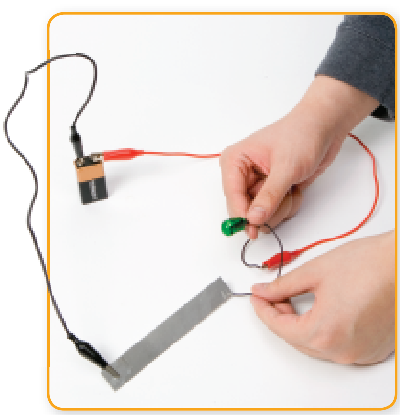


Figure 10.4 The light on a conductivity tester glows brightly if the material being tested is a good conductor.

Using a Conductivity Tester

You can use a conductivity tester to distinguish between an insulator and a conductor. A conductivity tester consists of a battery that is connected to a light and two contact points. When the contact points touch a material that conducts electricity, as shown in **Figure 10.4**, electrons flow through the light and the light goes on.

Water: Insulator and Conductor

You may have noticed that static charges are more common during the winter when the air is dry. Dry air is a good insulator, but moist air is a fair conductor. In the summer, static charges tend to be reduced by the transfer of electrons to or from water molecules in the moist air.

Pure water is a good insulator, but water is such a good solvent that it is rarely pure, even when it falls as rain. Water from a faucet contains dissolved substances that make it a fairly good conductor. This is why you should never use an electrical device, such as a radio plugged into an outlet, in a bathroom. If the radio fell into the bathtub while you were bathing, an electric current would flow through the water and you could be electrocuted. Similarly, a stream of water can be a conductor. If a stream of water from a garden hose hit an electrical device plugged into an outlet outside, the water would become a conductor. The person holding the hose could be electrocuted. With these facts in mind, look at **Figure 10.5**.

Figure 10.5 Firefighters spray mist on a fire that might involve live electrical equipment operating on very high voltage.

Learning Check

5. Refer to **Table 10.1**. Which types of materials are good insulators and good conductors? Give two examples of each type.
6. Explain how a conductivity tester works.
7. Your friend says that every material must be either a good insulator or a good conductor. Is your friend correct? Write a sentence to explain why you agree or disagree.
8. Refer to **Figure 10.5**. Why could a steady stream of water electrocute a firefighter? Why do you think the mist is safer?

Grounding: Removing Static Charges

The simplest way to remove the net static charge on an object is to put it in contact with what is called a **ground**. A ground has a very large number of charges. It can supply electrons to a positively charged object and can remove electrons from a negatively charged object. The object becomes neutral. The ground, which had been neutral, remains neutral. A conductor is grounded if electrons are free to flow between the conductor and Earth.

Earth is only a fair conductor. However, Earth's capacity to absorb or supply electrons is so great that Earth remains neutral when electrons are transferred between it and a charged object.

You can ground many kinds of charged objects by touching them. This is because your fingers conduct electrons. Your body can receive or supply enough electrons to neutralize the charge on those objects. You feel only a small shock or no shock at all. **Figure 10.6** shows the symbol for a ground.

ground an object that can supply a very large number of electrons to, or can remove a very large number of electrons from, a charged object, thus neutralizing the object

Figure 10.6 This symbol for a ground indicates a material that can discharge a conductor.

Shocking Results

When a relatively large number of electrons flow rapidly through your hand, you feel a shock. What happens if you walk on a carpet while wearing socks in the winter, when the air is dry? If you touch a metal doorknob, you may experience a shock, as shown in **Figure 10.7**. This happens because your body has an electric charge. One way to eliminate the shock is to rub your hand over the doorframe, if it is wood, before touching the doorknob. Wood is an insulator. Therefore, few electrons can transfer at any one point of contact between your hand and the doorframe. Rubbing your hand over the wood doorframe transfers relatively few electrons at each point you touch. The charge is slowly reduced, and you do not feel a shock. The flow of electrons is shown in **Figure 10.7C**. How would these diagrams change if you had a positive charge when you approached the door?

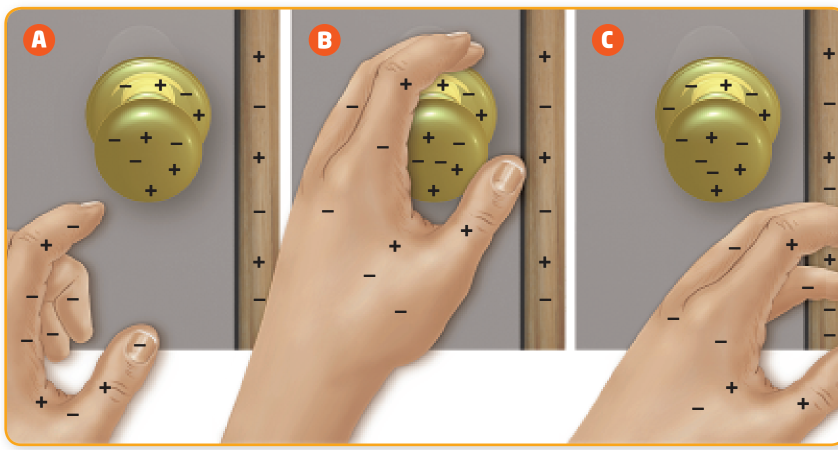


Figure 10.7 **A** The hand has a negative charge (a surplus of electrons). **B** If the hand touches the metal doorknob, there is a rapid transfer of electrons, and a shock is felt. **C** If the hand touches the wooden doorframe, there is a slower transfer of electrons, and no shock is felt.

In many situations, static charges are a serious hazard, and people or equipment must be grounded. For example, electrical equipment can be easily damaged by static charges. Many computer hard drives have lost data or been damaged when they were touched by someone with a static charge. People who assemble electronic equipment and work on computer circuit boards must be grounded, as shown in **Figure 10.8**.

Figure 10.8 Both the people and the electrical equipment are grounded to eliminate the risk of a rapid transfer of electrons to the sensitive equipment.

Grounded for Good

Static electricity can be generated by friction in many ways. When the discharge could result in a spark that would be dangerous, precautions must be taken to reduce the build-up of charges. For example, sparks from an electrostatic discharge have caused explosions at grain elevators, flour mills, and coal mines. Surgeons use electrical equipment and sometimes insert devices, such as pacemakers, that could be damaged by sparks. Some of the gases that are used for anesthesia are explosive, and thus sparks must be avoided. In an operating room, insulating materials, such as rubber footwear and wool blankets or clothing, are not allowed. Clothing worn by surgeons and nurses is made using fibres that conduct well, and the operating room is kept at relatively high humidity.

A moving vehicle produces friction between the rubber tires and the highway surface, as well as dust and the air. Each of these sources of friction can generate static charges on the vehicle, which is not grounded because of the insulating properties of the rubber tires. To guard against a spark that could cause an explosion, a fuel tanker truck is always grounded before the fuel is transferred, as in **Figure 10.9**. Also, some trucks have chains that touch the road and keep the truck grounded.

Figure 10.9 This fuel truck must be grounded before it can be fuelled.

Section 10.1 Review

Section Summary

- Static charge (static electricity) is an electric charge that tends to stay on an object's surface.
- Friction can cause a static charge when objects made from different materials rub together.
- Protons are positively charged, and electrons are negatively charged.
- Any net charge on a solid object results from the transfer of electrons between it and another object.
- An object with more electrons than protons has a negative charge. An object with fewer electrons than protons has a positive charge. An object with equal numbers of electrons and protons is neutral.
- An electrostatic series describes how strongly different materials hold on to their electrons.
- In electrical insulators, such as most non-metals, electrons cannot move easily between atoms.
- In electrical conductors, such as metals, electrons can move easily from one atom to another.
- A ground is connected to Earth and can supply a very large number of electrons to, or can remove a very large number of electrons from, a charged object.

Review Questions

K/U **1.** Use the Bohr-Rutherford model of the atom to explain how an insulator differs from a conductor.

C **2.** Draw two sketches of the same balloon with charges indicating that the balloon is (a) negative and (b) positive.

K/U **3.** If you want to avoid charge build-up on your hair, should you use a plastic comb or an aluminum comb? See **Figure 10.3**.

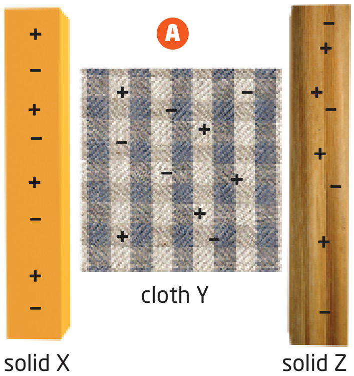
K/U **4.** Nylon socks and a silk blouse are tumbled in a clothes dryer. Use the electrostatic series to predict the type of charge on each.

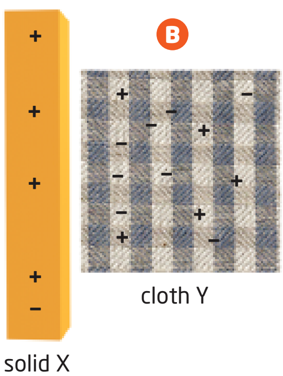
K/U **5.** List two materials that are electrical conductors and two materials that are insulators. For each material, give an example of how its electrical properties are useful.

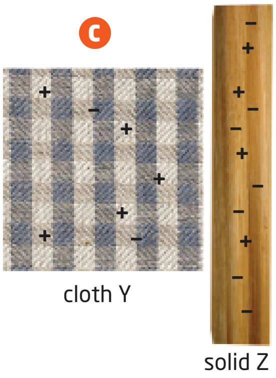
T/I **6. a.** Diagram **A** on the right shows the initial charges on two solid objects (X and Z) and a cloth (Y) made from different materials. What type of net charge is on each?

b. In diagram **B**, solid X has been rubbed with the cloth. Which material has the greater hold on electrons?

c. In diagram **C**, solid Z has been rubbed with the cloth. Rank the three materials, from greatest to least, according to their ability to hold on to electrons.







T/I **7.** Rainwater contains dissolved substances that allow it to conduct electricity. Why would you not be electrocuted if you walked under an electric transmission line during a rainstorm?

A **8.** Why is the flooring in an operating room made of a conducting material? Should the floor be waxed?