# What Is Static Electricity?

11.1

Have you ever had your hair stand up after putting on, or taking off, a sweater (Figure 1(a))? Or have you perhaps noticed that a balloon placed near your head will attract your hair (Figure 1(b))? Why does this happen?

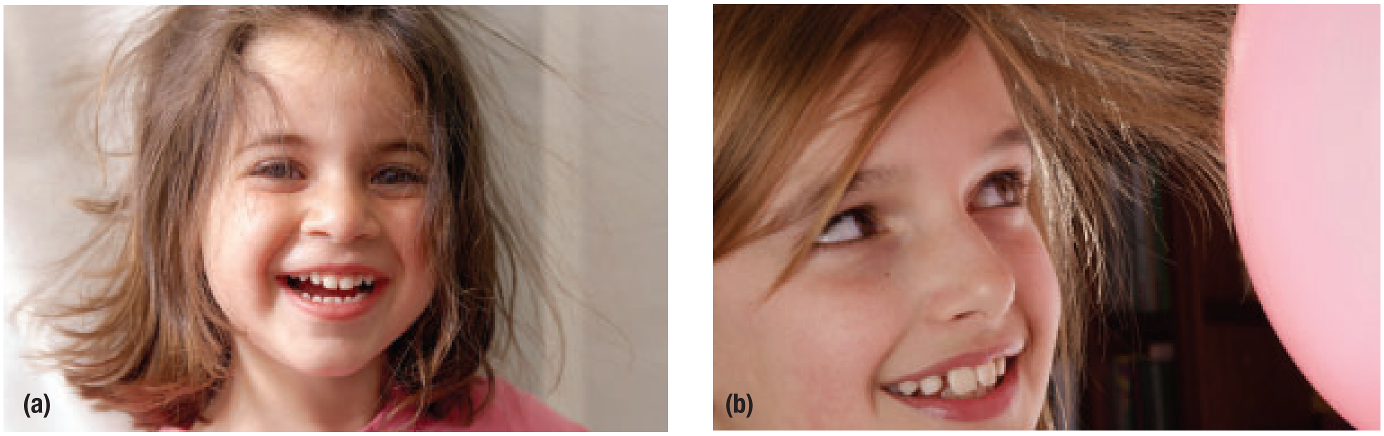


**Figure 1** (a) Have you ever removed a sweater and noticed that your hair stands straight up? (b) What causes this girl's hair to become attracted to a rubber balloon?

## Atomic Structure and Electric Charge

All matter is made up of atoms. Atoms contain smaller particles: protons, neutrons, and electrons. Some of these particles have an electric charge. Protons have a positive charge (+), electrons have a negative charge (–), and neutrons have no charge (0).

According to the Bohr-Rutherford model of the atom, protons and neutrons are located in the nucleus, or centre, of the atom and are held in place by very strong forces. Under normal circumstances, they cannot be removed from an atom. Electrons, however, can move in the space surrounding the nucleus and can be added to or removed from atoms (Figure 2). Table 1 summarizes the properties of the particles that make up an atom.

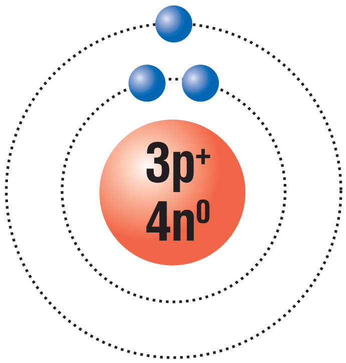


**Figure 2** A lithium atom. Electrons (blue) move in the space surrounding the nucleus of an atom and can be transferred from atom to atom. Electrons and protons carry the electric charges within an atom.

**Table 1** Properties of the Particles of an Atom

| Particle | Electric charge | Location | Particle symbol |
|---|---|---|---|
| proton | positive | nucleus | $p^+$ |
| neutron | no charge | nucleus | $n^0$ |
| electron | negative | outside nucleus | $e^-$ |

If an atom has the same number of protons and electrons, the positive and negative charges balance and the atom has no overall charge—it is neutral. If an atom does not have an equal number of protons and electrons, it has an **electric charge**. Recall from Chapter 7 that an atom that has an electric charge is called an ion. A negative ion is an atom that has picked up one or more electrons. A positive ion is an atom that has lost one or more electrons.

**electric charge** a form of charge, either positive or negative, that exerts an electric force

## Positive, Negative, and Neutral Objects

Everyday objects such as combs, rulers, clothing, airplanes, and clouds are made up of billions and billions of atoms—each containing a number of positive and negative charges. For this reason, it is impossible to show individual atoms or their charged particles in diagrams of large objects.

In this unit, we will use charge symbols to represent charges. Each charge symbol represents a very large number of protons (+) or electrons (–). A "+" symbol will be used to represent a large number of protons (carrying positive charges) and a "–" symbol will be used to represent an equally large number of electrons (carrying negative charges). These symbols will be used to show the relative abundance and distribution of charges on an object (Figure 3). The overall electric charge of an object can be determined simply by comparing the number of positive and negative symbols drawn on the object.

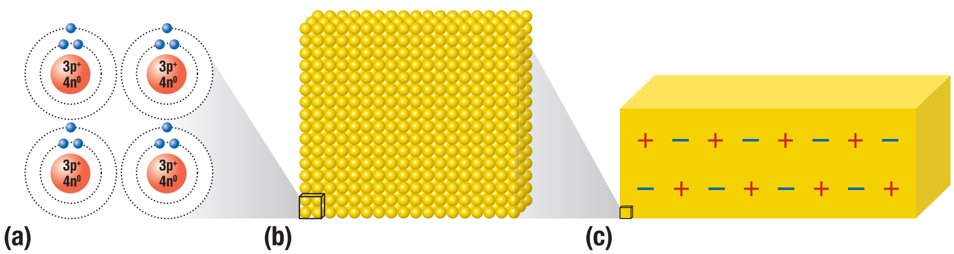


**Figure 3** (a) A Bohr–Rutherford diagram can be used to show the electrons and protons in an individual lithium atom. (b) Objects contain billions of individual atoms. (c) The "+" and "–" symbols on the object represent the relative numbers of protons and electrons and their distribution.

**neutral object** an object that has equal numbers of protons and electrons

**negatively charged object** an object that has more electrons than protons

**positively charged object** an object that has fewer electrons than protons

A **neutral object** is an object that has an equal number of protons and electrons (Figure 4(a)). A **negatively charged object** is an object that has more electrons than protons (Figure 4(b)). A **positively charged object** is an object that has fewer electrons than protons (Figure 4(c)).

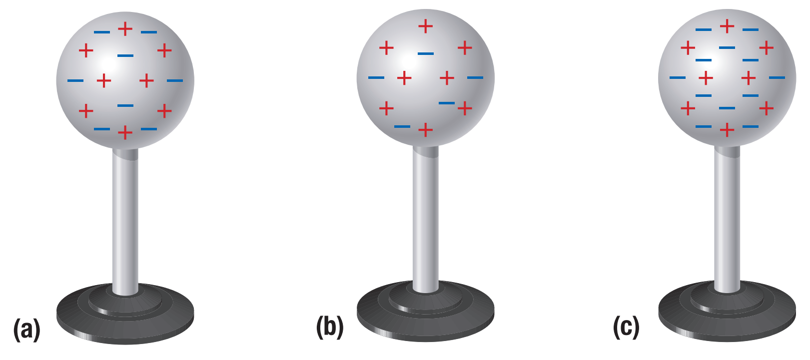


**Figure 4** (a) Neutral objects have equal numbers of protons and electrons. (b) Negatively charged objects have more electrons than protons. (c) Positively charged objects have fewer electrons than protons. (Note: Each charge symbol represents a very large number of protons (+) or electrons (–).)

Objects may also become charged when electrons are transferred to or from another object. For example, a neutral or positively charged object that gains electrons will become negatively charged if its total number of electrons is more than its total number of protons. Similarly, a neutral or negatively charged object that loses electrons will become positively charged if its total number of electrons is less than its total number of protons. Most of the objects and materials we interact with daily are electrically neutral.

When two neutral objects made of different materials come in contact, such as the hair and the rubber balloon in Figure 1, electrons can be transferred from one object to the other. Both objects become charged. In Figure 1, the balloon gains electrons and becomes negatively charged, and the hair loses electrons and becomes positively charged. Each hair on the girl's head becomes positively charged, which creates static electricity. **Static electricity** is an imbalance of electric charge on the surface of an object. The positive charges on the individual hairs react in such a way as to cause the hairs to move as far away from each other as they can. Static electricity produces what we call "static charges" because the charges are at rest on the surface of the object.

**static electricity** an imbalance of electric charge on the surface of an object

## Detecting Static Electric Charges

Scientists can detect the presence of electric charges using an instrument called an electroscope.

One type of electroscope is a pith ball electroscope. A pith ball electroscope consists of a ball of pith (plant material) suspended from a stand by a thread (Figure 5). It can be used to test for the presence and type of electric charge on an object. This is done by bringing an object near the neutral pith ball. If the object is charged, the pith ball will be attracted to it. You will learn about another type of electroscope, the metal leaf electroscope, later on in this section.

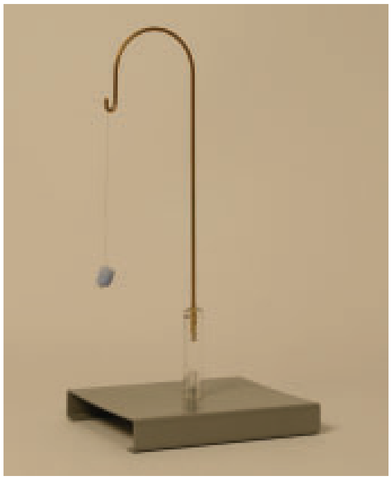

**Figure 5** A pith ball electroscope is a simple device that can be used to detect the presence of electric charges.

### TRY THIS POSITIVE AND NEGATIVE CHARGES

**SKILLS:** Hypothesizing, Observing

SKILLS HANDBOOK 3.B.3., 3.B.6.

In this activity, you will examine the interactions of objects that have been given an electrical charge. You will also examine the interactions of charged objects with a pith ball electroscope.

**Equipment and Materials:** acetate strips (2); ring clamp; retort stand; pith ball electroscope; thread; tape; vinyl strips (2); paper towels.

1. Use a piece of thread and tape to suspend and balance an acetate strip from a ring clamp (Figure 6). Rub the acetate strip at both ends with a paper towel. You can assume that the acetate has become positively charged.

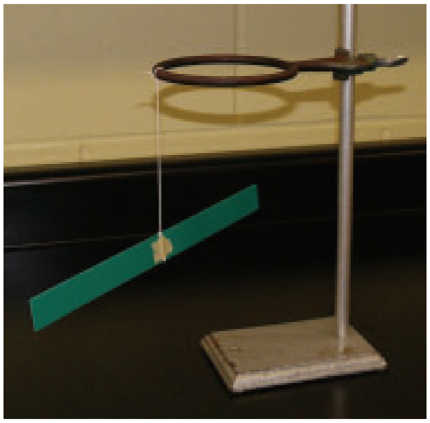

**Figure 6**

2. Rub a second acetate strip with a paper towel and bring the acetate strip toward the hanging acetate strip. Observe and record what happens.
3. Repeat steps 1 and 2 using two vinyl strips. Assume that the charge placed on the vinyl strip is negative.
4. Repeat steps 1 and 2, this time using one vinyl strip and one acetate strip.
5. Obtain a pith ball electroscope. Slowly bring a charged acetate strip up to the pith ball. Observe what happens before and after the pith ball contacts the acetate strip.
6. Gently roll the pith ball between your fingers to remove any charge from the pith ball. Then repeat step 5 with the electroscope and a charged vinyl strip.

A. Based on your observations, how do objects with similar charges behave? How do objects with different charges behave? T/I

B. How did the pith ball react to the positively and negatively charged strips? T/I C

C. Make a hypothesis to explain what happened to the pith ball after it made contact with a charged strip. How could you test your hypothesis? T/I C

In the Try This activity, you saw that two positively charged acetate strips repelled each other but were attracted to a charged vinyl strip. This means that the vinyl strip had a different type of electrical charge than the acetate strip—the vinyl strip was negatively charged. The activity shows us that two different types of electrical charge exist (positive and negative).

## The Law of Electric Charges

**electric force** the force exerted by an object with an electric charge; can be a force of attraction or a force of repulsion

A charged object exerts an **electric force**, which can be either an attractive force (pulling together) or a repulsive force (pushing apart). This is summarized in the Law of Electric Charges, which states that

- objects that have like charges repel each other (Figure 7(a))
- objects that have opposite charges attract each other (Figure 7(b))

**LEARNING TIP**

**Opposites Attract**
To remember the Law of Electric Charges, remember that "opposites attract." Opposite charges attract and like charges repel. You can observe this in magnets: opposite poles of two magnets will attract and like poles of two magnets will repel.

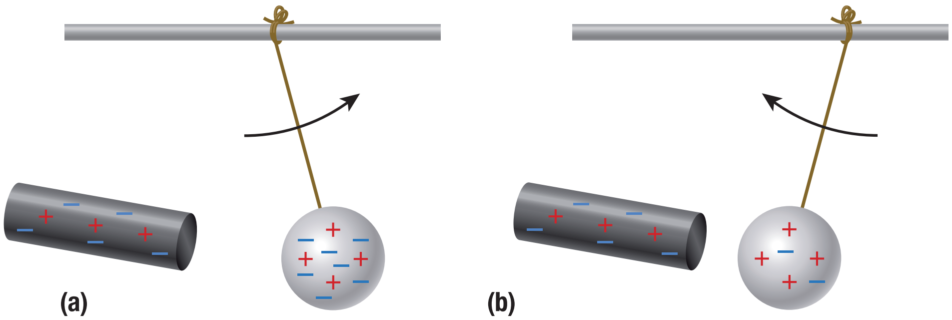


**Figure 7** (a) Both objects are negatively charged and repel each other. This causes the pith ball to move away from the metal rod. (b) When the pith ball and the metal rod are oppositely charged, they are attracted to each other and the pith ball moves toward the rod.

The strength of the electric force is related to both the amount of charge on each object and the distance between the charged objects. Electric force increases with increasing electrical charges and decreases with increasing distance.

### Attraction of Neutral Objects to Charged Objects

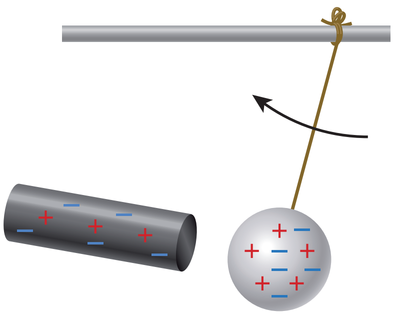

**Figure 8** The side of the pith ball facing the negatively charged metal rod now has a local positive charge and is attracted to the metal rod. The force of attraction is greater than the force of repulsion because of the differences in distances between the charges.

A neutral object has an equal number of positive and negative electric charges, which means that when two neutral objects are brought together, they are neither attracted nor repelled from one another. What happens when a charged object is brought toward a neutral object? When a charged object is brought near a neutral object, it causes (induces) the electrons to shift in position. The induced movement of electrons in a neutral object by a nearby charged object is called an **induced charge separation**. The movement of electrons occurs according to the Law of Electric Charges. If the charged object is positively charged, it will induce electrons in the neutral object to move toward it. If the charged object is negatively charged, if will induce electrons in the neutral object to move away from it (Figure 8). After the electrons shift position, the side of the neutral object closest to the charged object will be attracted to the charged object. This force of attraction can cause a neutral object to move toward a charged object. Although there is a shift in the positions of the electrons in the neutral object, it does not gain or lose any electrons. Once the charged object is moved away from the neutral object, the electrons return to their original positions.

**induced charge separation** a shift in the position of electrons in a neutral object that occurs when a charged object is brought near it

## TRY THIS CHARGING OBJECTS

**SKILLS:** Hypothesizing, Observing

SKILLS HANDBOOK 3.B.3., 3.B.6.

In this activity, you will examine the interactions of charged objects and neutral objects and use neutral objects to detect an electrical charge.

**Equipment and Materials:** wool; wooden stick; Petri dish; acetate strip; copper pipe; 10 paper circles (from a hole punch); balloon; paper towel.

1. Use a piece of wool to rub and charge a wooden stick. Then bring the wooden stick close to the paper circles (Figure 9). Record your observations.

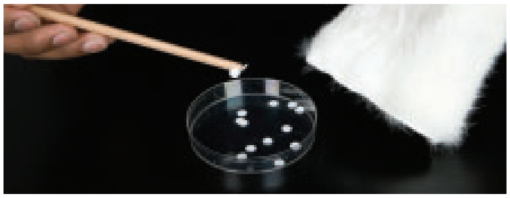

Figure 9

2. Blow up the balloon and rub it against your hair. Bring the rubbed surface of the balloon close to the paper circles. Record your observations.
3. Repeat step 1 using paper towel and the acetate strip, and wool and the copper pipe.

A. Based on your observations, what general conclusion can you make regarding neutral objects and charged objects? T/I

B. Did the paper circles behave in an identical manner with all the charged objects? Suggest an explanation for your answer. T/I C

C. Did the behaviour of the paper circles allow you to tell what kind of charge (positive or negative) was on the object? T/I

D. Suggest a method you might be able to use to measure the amount of charge on an object. T/I C

## Using a Metal Leaf Electroscope to Detect Electric Charge

A metal leaf electroscope is more sensitive to electric charge than a pith ball electroscope and is more commonly used to detect electric charge. It consists of a vertical rod, which has two thin pieces of metal foil (often gold) known as "the leaves". The charge to be tested is applied to a metal terminal attached to the top of the vertical rod (Figure 10(a)). When the metal terminal is touched with a charged object, electrons are transferred to (or from) the leaves of the electroscope. The leaves receive the same charge, which causes them to repel each other and spread apart.

A metal leaf electroscope can also be charged without touching it to a charged object. For example, if a negatively charged object is brought near the electroscope terminal, the electrons in the terminal are repelled by the electrons in the negatively charged object and move down onto the leaves. This causes a separation of charge in the electroscope-the terminal becomes positively charged, and the leaves become negatively charged. The negatively charged leaves repel each other and spread apart (Figure 10(b)). When the charged object is moved away from the electroscope, the electrons and the leaves return to their original positions (Figure 10(c)).

### WRITING TIP

**Connecting to the Main Idea**

Conclude your persuasive text by connecting the main idea and key points. For example, for a persuasive text on a metal leaf electroscope, you might conclude by saying a metal leaf electroscope is a valuable tool to tell if a charge on an object is positive or negative because of the way the "leaves" move.

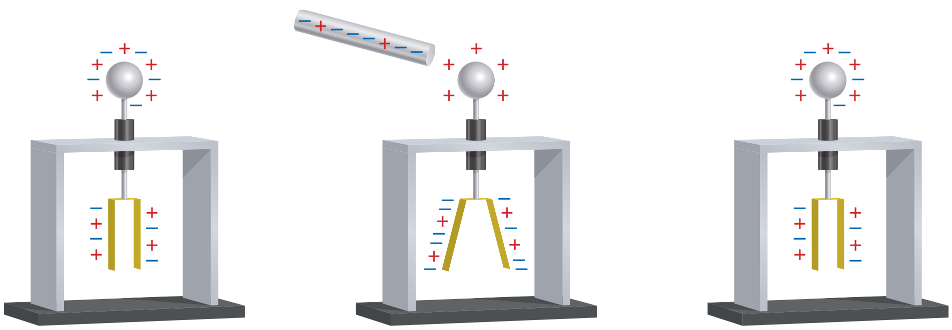


**Figure 10** A metal leaf electroscope (a) is used to detect electric charge. When a negatively charged object is brought near the electroscope electrons are transferred into the leaves, which causes them to repel and spread apart (b) until the charged object is removed (c).

## Using Static Charges

Scientists and engineers can use the properties of static charges in many useful ways in a branch of science called electrostatics. Electrostatics is the branch of science that deals with static charges and static electricity.

### Electrostatic Paint Sprayers

If you have ever used a can of spray paint, you know that some of the paint can miss the target and spray into the air or onto surrounding objects. This can be messy and wasteful. In addition, solvent-based paints are damaging to the environment and to human health. Many industries use electrostatic paint sprayers to reduce the amount of wasted paint. Electrostatic paint sprayers use the properties of static charges to more efficiently paint objects. The paint is given a charge as it leaves the nozzle of the sprayer, and the object to be painted is given the opposite charge (Figure 11). The charged paint particles are attracted to the object, which minimizes the amount of wasted paint and ensures that the object receives an even coat of paint. Electrostatic paint sprayers are especially useful for painting curved objects (Figure 12).

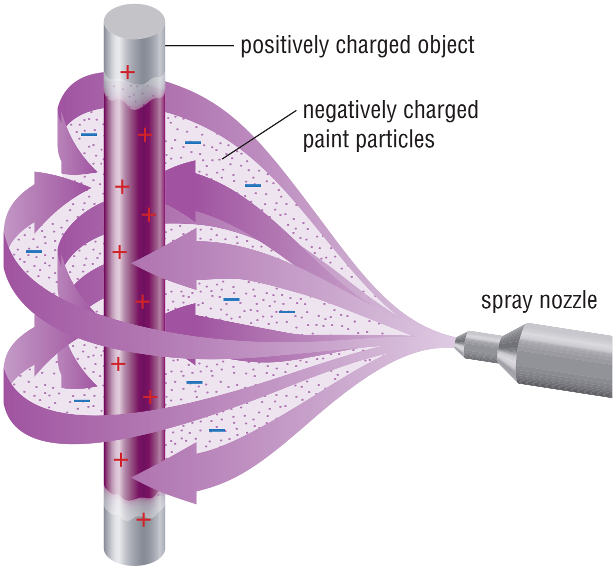


**Figure 11** The charged paint particles are attracted to the oppositely charged object.

**Figure 12** Curved objects and objects with open spaces (such as fencing) are often painted using an electrostatic paint sprayer. The attraction of the paint particles to the oppositely charged object ensures that paint will wrap around the curved portions of the object, rather than fall through the open spaces.

### RESEARCH THIS POWDER COATING

**SKILLS:** Researching, Analyzing the Issue, Communicating, Evaluating

SKILLS HANDBOOK 4.A.

Manufacturers have developed dry paint, which is paint that comes in a powder form. Painting objects with dry paint is called powder coating. Powder paint does not use toxic solvents like liquid paint does. How are these dry paints applied? What benefits does dry paint have compared with liquid paint?

1. Research the process of powder coating using electric charges.
2. Research some applications of powder paint.
3. Research the negative effects of paint solvents on human health and ecosystems.
4. Research the environmental benefits of using powdered paint compared with solvent-based paint.

GO TO NELSON SCIENCE

A. Draw a diagram showing the charges to explain how dry paint works. Include electric charges in your diagram and explain their significance. T/I C

B. How has the use of solvents been affected by the use of powder-coating technologies? How has the use of powder–coating technologies impacted the environment? T/I C A

## UNIT TASK Bookmark

How can you apply what you have learned about static electricity to the Unit Task described on page 586?

## IN SUMMARY

- Static electricity is an imbalance of electric charge on the surface of an object.
- Electric charge is a property of the particles of atoms. Protons have a positive charge, electrons have a negative charge, and neutrons have no charge.
- Electrons can be added to, or removed from, atoms.
- When two different materials come in contact, electrons can be transferred between them, causing an imbalance in charge.
- Neutral objects have equal numbers of protons and electrons. Negatively charged objects have more electrons than protons, and positively charged objects have fewer electrons than protons.
- Objects can become positively charged by losing electrons so that there are fewer electrons than protons.
- Objects can become negatively charged by gaining electrons so that there are more electrons than protons.
- The Law of Electric Charges states that like charges repel while unlike charges attract.
- A charged object can be used to induce a charge separation in a neutral object
- A metal leaf electroscope can be used to detect the presence of an electric charge.
- Static electricity has practical applications.

## CHECK YOUR LEARNING

1. Describe a concept from this section that was already familiar to you. How did your previous knowledge of this concept help with your understanding of other concepts in this section?
2. In your own words, define static electricity. K/U C
3. (a) Which particle(s) are difficult to add to or remove from an atom? K/U
   (b) Which particle(s) are easier to add to or remove from an atom? K/U
   (c) How do your answers to (a) and (b) explain the formation of positively and negatively charged objects? K/U
4. Describe the total charge on each of the following objects as either neutral, positive, or negative. Explain your reasoning. K/U

(a)

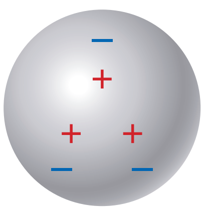


Figure 13

(b)

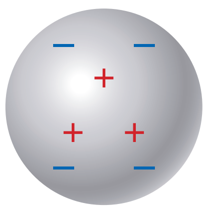


Figure 14

5. What would you do to the object in Figure 15 to make it neutral? K/U

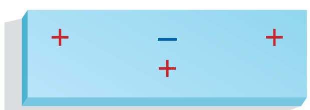


Figure 15

6. What would you do to the object in Figure 16 to make it positively charged? What would you do to the object in Figure 16 to make it negatively charged? K/U

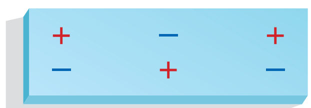


Figure 16

7. Would the following objects repel or attract? Explain your answer using the Law of Electric Charges. K/U C
   (a) A positively charged object is placed beside a negatively charged object.
   (b) A negatively charged object is placed beside a negatively charged object.
8. (a) In your own words, summarize how an electrostatic paint sprayer works. K/U C
   (b) Are electrostatic paint sprayers beneficial? Why or why not? T/I C
9. Use diagrams to illustrate how a positively charged object can be used to induce a charge separation and attract a neutral object. K/U C