

Key Terms

electroscope
charging by contact
laws of electric charges
electric field
induced charge separation

10.2 Charging by Contact and by Induction

A charged comb can be used to attract small pieces of paper that are electrically neutral. As the comb approaches the pieces of paper, some of the pieces jump off the table and onto the comb. Although the charged comb and the neutral pieces of paper are not initially in contact, there must be an attraction between them. Why does a charged comb attract small pieces of neutral paper? Why may some of the pieces fly off the comb later?

Detecting Charges

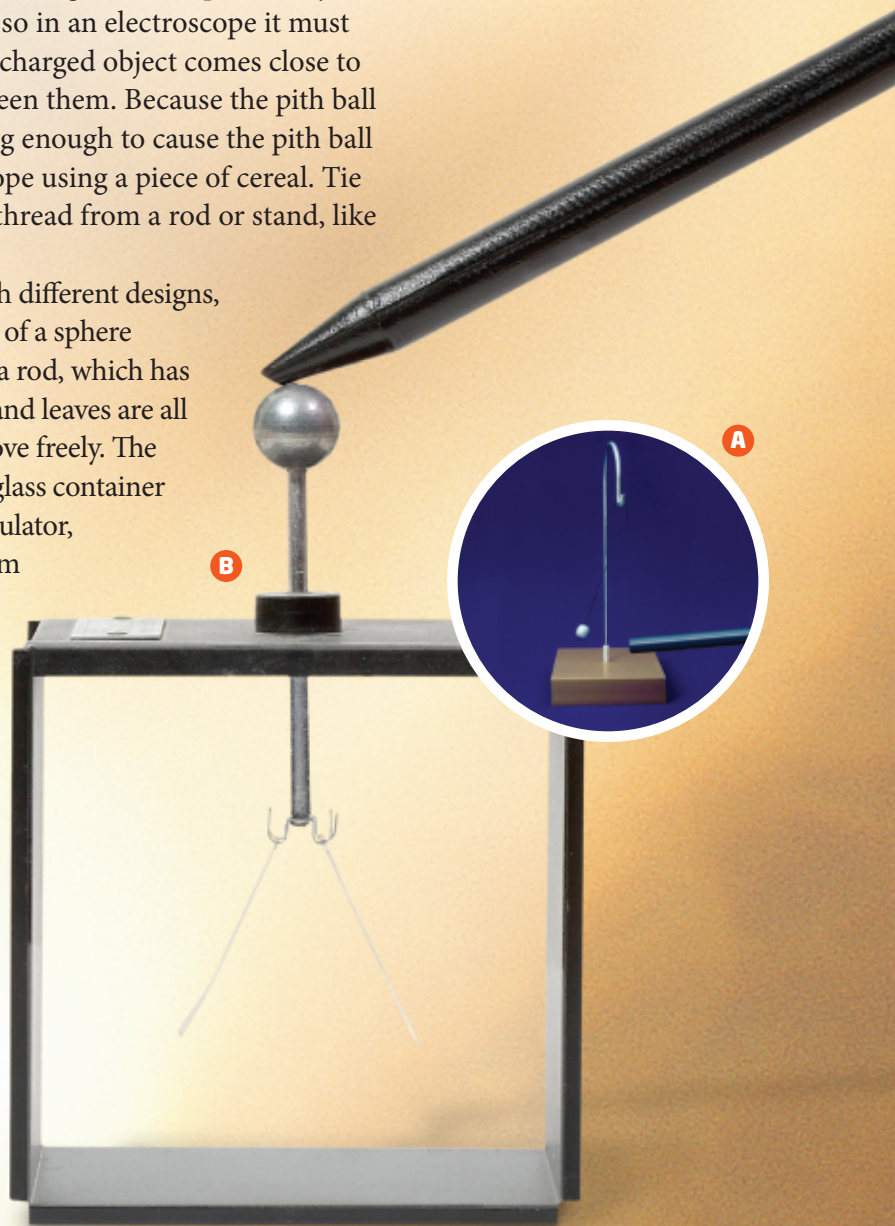
An **electroscope** is a simple device that is used to detect the presence of electric charges. In schools, the pith ball electroscope and the metal leaf electroscope are commonly used. Both types are shown in **Figure 10.10**.

A pith ball electroscope consists of a small, light ball suspended by a piece of cotton thread. Pith is an insulator, so in an electroscope it must be covered by a conducting substance. If a charged object comes close to the pith ball, there is an electric force between them. Because the pith ball has a small mass, this electric force is strong enough to cause the pith ball to move. You can make a similar electroscope using a piece of cereal. Tie a cotton thread to the cereal and hang the thread from a rod or stand, like the one in a pith ball electroscope.

Metal leaf electroscopes are available with different designs, but all have the same key parts. They consist of a sphere (sometimes a flat plate) that is connected to a rod, which has metal leaves attached to it. The sphere, rod, and leaves are all made of metal, which allows electrons to move freely. The rod and the leaves are usually enclosed in a glass container to shield the leaves from air currents. An insulator, such as a rubber stopper, isolates the rod from the glass container. The leaves of a metal leaf electroscope spread apart when a charge is near the sphere or when the electroscope has a charge.

electroscope a device for detecting the presence of an electric charge

Figure 10.10 Electroscopes show the presence of a net electric charge. **A** In a pith ball electroscope, the ball is covered with a conducting substance. **B** The key parts of a metal leaf electroscope—the sphere, the rod, and the leaves—are all made of metal.



charging by contact
generating a charge on a neutral object by touching it with a charged object

Study Toolkit

Identifying the Main Idea and Details Finding the main idea and details in the paragraph on the right can help you understand the concept of charging by contact.

Charging by Contact

Charging by contact takes place when contact is made between a neutral object and an object that is charged. **Figure 10.11** illustrates charging by contact in two ways. **Figure 10.11A** shows a negatively charged object and a neutral pith ball. On contact, electrons flow from the negatively charged object into the pith ball. After the object and the pith ball have touched, the negatively charged object has a reduced charge, but it is still negative. The pith ball is now negatively charged.

Examine **Figure 10.11B** to see how touching a neutral pith ball with a positively charged object gives the pith ball a positive charge.

An object that becomes charged by contact always gets the same type of charge that is on the object that charges it.

Activity 10-2

Detecting Static Charge Using an Electroscope

How do electroscopes detect static charges? In this activity, you will use an electrostatic series to predict how the net charge on objects made from different materials will change when you rub them together. Then you will observe how a pith ball electroscope and a metal leaf electroscope detect the presence of a known static charge.

Safety Precautions

If you are allergic to animal fur, do not handle it.

Materials

- different materials listed in the electrostatic series in **Table 10.1** on page 405
- metal leaf electroscope
- pith ball electroscope

Procedure

1. Skim through the steps of this activity, and then create an appropriate data table to record your observations.
2. Use the electrostatic series to predict the type of charge on all the materials that you plan to rub together. Record your predictions.
3. Choose two of the materials. Rub them together to create two oppositely charged materials. Bring one of the materials toward the sphere of a metal leaf electroscope, without making contact. Record your observations of the electroscope leaves. Now remove the charged material and see what happens to the leaves.

4. Touch the sphere of the metal leaf electroscope with the charged material, and record the position of the leaves.
5. Remove the charged material, and again record the position of the leaves.
6. Touch the sphere of the metal leaf electroscope with one of your fingers, and record what happens to the leaves.
7. Repeat steps 3 through 6, using a material with a different charge.
8. In steps 3 through 7, you used a metal leaf electroscope. Repeat step 3, using a pith ball electroscope. Record what happens to the pith ball as you bring a charged material close to it. Then allow the pith ball and the charged material to make contact, and record your observations.

Questions

1. Compare the metal leaf electroscope with the pith ball electroscope. How does each electroscope indicate the presence of an electric charge?
2. What happened to the leaves of the metal leaf electroscope when a charged object made contact with the sphere? Did it make a difference whether the charged object had a positive charge or a negative charge?
3. What happened in step 6, when you touched the sphere of the metal leaf electroscope with your finger? Explain your observation.

A Giving an Object a Negative Charge

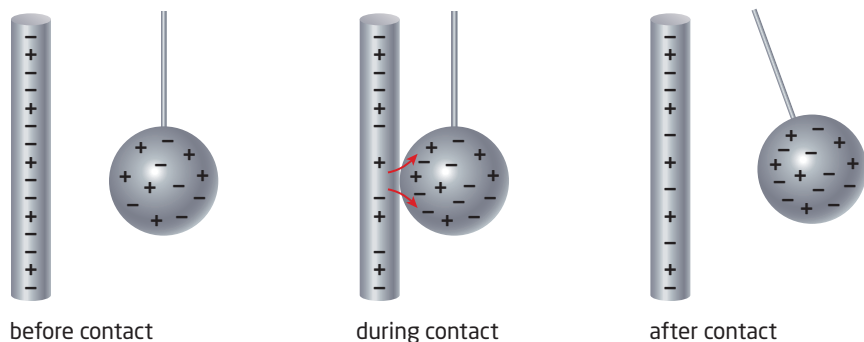
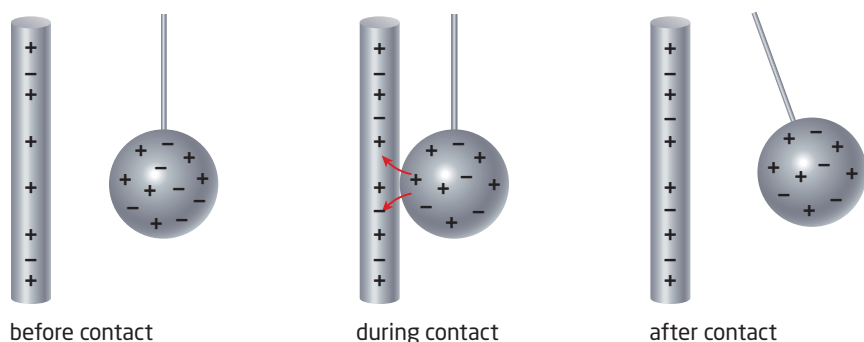


Figure 10.11 A change in the net charge of an object is the result of the movement of electrons either onto or off the object. In **A**, contact with a negatively charged object gives a neutral pith ball a negative charge. In **B**, contact with a positively charged object gives a neutral pith ball a positive charge.

B Giving an Object a Positive Charge



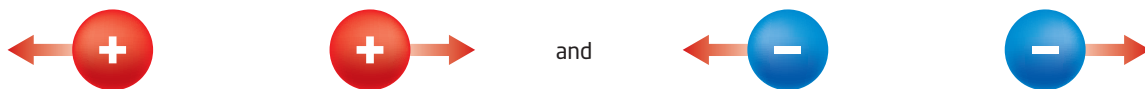
The Laws of Electric Charges

As you know, an object may be positively or negatively charged, or it may be electrically neutral. The net charge on a solid object is best described in terms of the electrons in its atoms, because the electrons are the charged particles that can move from atom to atom and from one material to another. Protons are bound in the nucleus, and thus cannot move from one atom to another. Scientists have established the **laws of electric charges** through experiments using objects with known charges and an electroscope. These three laws are summarized in **Figure 10.12**.

laws of electric charges
laws that describe how two objects interact electrically when one or both are charged

Laws of Electric Charges

1. Like charges repel.



2. Opposite charges attract.



3. Charged and neutral objects attract each other.

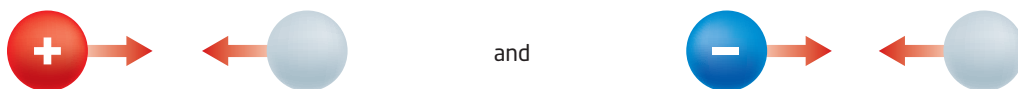


Figure 10.12 The three laws of electric charges describe how two objects interact electrically when one or both are charged.

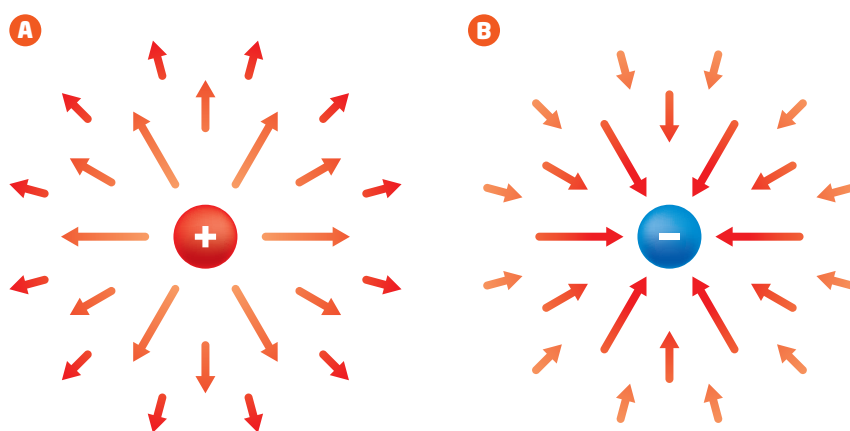
The Amount and Type of Charge

The amount of net charge on an object depends on the difference between the number of protons and the number of electrons that it contains. The size of the electric force between two charged objects is directly proportional to the amount of charge on each object. This is true whether the electric force is an attraction that pulls the objects toward each other or a repulsion that pushes them apart.

If the distance between two charged objects is increased, the electric force between them will decrease. The force of gravity is similar in this way. Increasing your distance from Earth in a spaceship would result in a decreased force of gravity between you and Earth.

To determine whether an object is charged and, if so, what type of charge it has, you must observe repulsion between it and another object. Once you observe repulsion occurring, you can be certain that the object is charged. Then you can use the laws of electric charges to determine the type of charge (positive or negative). If the object with an unknown charge is attracted to both positive and negative charges, you know that the object is neutral.

Figure 10.13 A charged object produces an electric field, which gives rise to electrical forces near the object. The arrows in these diagrams represent the direction of the force on a second, positively charged object that is in the field of the central object. The length of each arrow represents the relative magnitude of the force on an object in the field. In **A**, a positively charged object repels positive objects in its field. In **B**, a negatively charged object attracts positive objects in its field.



Electric Fields

The laws of electric charges describe the electrical interactions between objects. How is it possible for a positively or negatively charged object to exert an electric force on another object if the two objects are not in contact?

You are familiar with the force of gravity, which exists between any two objects that have mass, even though they may not be in contact. Similarly, electric forces exist between two objects that are not in contact if at least one of them is charged. These forces are transmitted by an **electric field**. It is a property of the space around a charged object, where the effect of its charge can be felt by other objects. An electric field produces an electric force on any other objects that are in the field. See **Figure 10.13**.

Objects with greater net charges have stronger electric fields. The greater the distance from a charged object, the weaker the electric field of the object is. Also, all electric forces between two objects are transmitted through the electric field at the speed of light.

electric field a property of the space around a charged object, where the effect of its charge can be felt by other objects

Learning Check

1. Why is it important for the ball in a pith ball electroscope to have a small mass? See **Figure 10.10**.
2. Describe how charging by contact occurs.
3. How is the force of gravity between two masses similar to the electric force between two charges? How is it different?
4. Describe how you could make your own metal leaf electroscope using materials you have at home.

Suggested Investigation

Plan Your Own Investigation
10-B, Be a Charge Detective,
on page 430

Go to **scienceontario**
to find out more



Charging by Induction

A third method of charging is charging by induction. When a charged object is close to a neutral object, the electric field of the charged object produces a force on the neutral object. According to the laws of electric charges, the force is attractive. Although the charged object exerts a force on the protons and electrons in a solid neutral object, only electrons can move in the solid. Thus, the charged object causes (induces) electrons in the neutral object to move. An **induced charge separation** is the movement of electrons in a substance, caused by the electric field of a nearby charged object, without direct contact between the substance and the object.

Figure 10.14 shows what happens when a negatively charged rod is brought near a neutral pith ball. The electric field of the rod is strong enough to have an effect on the pith ball. The result is an induced charge separation on the pith ball. The force from the rod causes some of the electrons on the pith ball to move away from the side that is closer to the rod. This side of the pith ball thus has a positive charge. The attractive force between the rod and this positive side of the ball is stronger than the repulsive force between the rod and the other, negative side of the ball, because the negative side of the ball is farther away from the rod. Therefore, even though the ball has equal numbers of positive and negative charges overall, it is attracted to the negatively charged rod.

induced charge separation

the movement of electrons in a substance, caused by the electric field of a nearby charged object, without direct contact between the substance and the object

Study Toolkit

Word Families What base do the words *induced* and *induction* share? How does knowing the meaning of the base help you remember the meanings of the words?

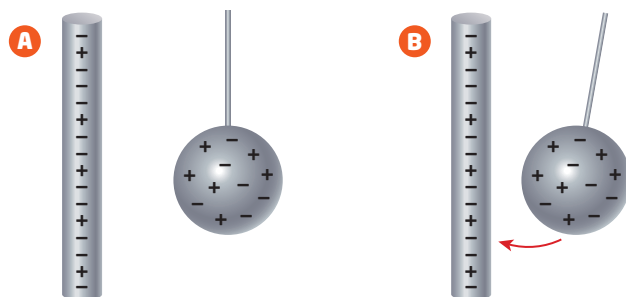


Figure 10.14 **A** The rod is negatively charged, and the pith ball is neutral.
B The induced charge separation on the pith ball causes it to swing toward the rod.

Activity 10-3

Drawing Charges You Cannot See

How can you draw diagrams to explain induced charges? In Part 1 of this activity, you will draw diagrams to show the movement of electrons when a positively charged object is brought close to a neutral pith ball electroscope. In Part 2 of this activity, you will draw diagrams to show the induced charge separation caused by the electric field of a charged object when it is moved close to a metal leaf electroscope.

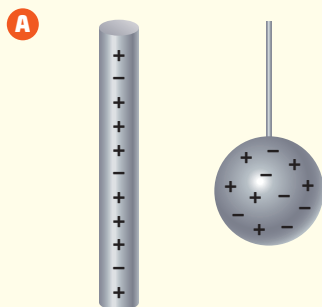
Materials

- paper
- coloured pencils

Procedure

Part 1 The Effect of a Positively Charged Object

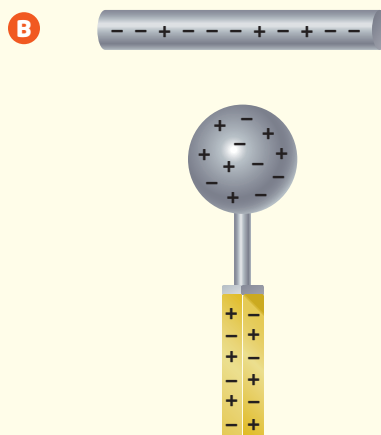
1. Copy diagram **A** into your notebook to show a positively charged rod and a neutral pith ball before they interact.



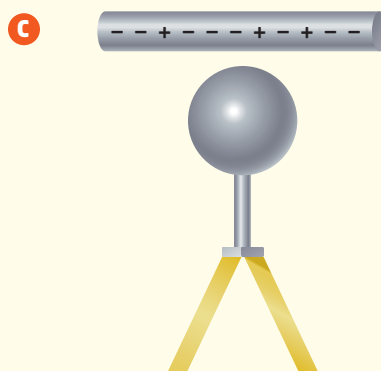
2. Make a second drawing to show the charged rod after it has been moved closer to the pith ball. Include charges on the rod and the pith ball.
3. Below your second drawing, answer the following questions. As you answer these questions, check your drawing and make corrections if necessary.
 - a. How does the position of the positive charges in your second drawing compare with their position in the first drawing?
 - b. What type of charge is on the side of the pith ball that is closer to the charged rod? How does this charge compare with the charge on the rod?
 - c. Considering all the charges on the pith ball, is it neutral or charged? Does your second drawing show this?

Part 2 The Effect of a Negatively Charged Object

4. Diagram **B** shows a neutral metal leaf electroscope and a charged rod before they interact. Sketch a diagram like this in your notebook. What kind of charge is on the rod?



5. Diagram **C** shows the same charged rod close to the sphere of the metal leaf electroscope. No charges are shown, however. The leaves of the electroscope are spread apart, as you observed in Activity 10-2 when you brought a charged material close to a metal leaf electroscope. Copy and complete this diagram to show the positions of the charges on the metal leaf electroscope and the rod.



Questions

1. Explain why an induced charge separation causes the leaves on a metal leaf electroscope to spread apart.
2. What do you think will happen to the charges on the electroscope when the charged rod is withdrawn?
3. Summarize what you need to know about charges when you draw diagrams to explain static and induced charges.

Section 10.2 Review

Section Summary

- An electroscope is a device that is used to detect the presence of an electric charge.
- There are three laws of electric charges:
 1. Like charges repel.
 2. Opposite (unlike) charges attract.
 3. Neutral objects and charged objects are attracted to each other.
- An object that is charged by contact has the same type of charge as the charging object.
- An electric force between two objects is transmitted by an electric field.
- An induced charge separation is the movement of electrons in a substance, caused by the electric field of a nearby charged object.

Review Questions

- K/U** 1. Compare and contrast charging by contact, charging by friction, and charging by induction.
- C** 2. The leaves of a metal leaf electroscope are slightly separated, indicating that it is charged. When you bring a positively charged rod near the sphere, the leaves spread farther apart. What charge is on the electroscope? Draw diagrams to explain your answer.
- K/U** 3. See **Figure 10.13**. How does the strength of an object's electric field change with distance?
- K/U** 4. A metal leaf electroscope has a sphere, rod, and leaves. Why would the electroscope not work if any of these parts were made using an insulator?
- A** 5. You can charge a balloon by rubbing it against your clothing. Then you can stick the charged balloon to a wall.
 - a. Is the wall charged by contact or by induction? Explain.
 - b. Why does the balloon eventually fall from the wall?
- C** 6. When you bring a negatively charged ebonite rod near a pith ball electroscope, the pith ball moves toward the rod. Is the pith ball positively charged? Explain.
- T/I** 7. You are given two objects made from different materials. How could you use a pith ball electroscope to learn which material holds on to its electrons more strongly?
- T/I** 8. The diagram on the right shows representative charges on a rod and two identical metal spheres.
 - a. What is the charge on the rod?
 - b. Draw a diagram to show the rod close to the spheres. Indicate the resulting charges.
 - c. Keep the rod near one sphere, and move the other sphere away. Draw a diagram to show the charges on the rod and the spheres.
 - d. Remove the rod. Draw the charges on the spheres and the rod.

