10.2 The Transfer of Static Electric Charges

Here is a summary of what you will learn in this section:

- Electroscopes are instruments that detect static charge.
- In charging by contact, an orginally neutral substance gains the same charge as the charged object that touched it.
- In charging by induction, an originally neutral substance gains the opposite charge to the charged object.
- Neutral objects are attracted to charged objects.
- Grounding an object transfers electrons between the object and the ground, making the object neutral.
- An electrical discharge occurs when charges are transferred quickly.

Figure 10.11 The bits of paper are attracted to the statically charged comb.

Charged Objects

What does dust on a computer screen have in common with paper on a comb (Figure 10.11)? In both examples, there is attraction between objects with unlike charges. You may have noticed a similar effect when you unpack a box containing polystyrene packing foam and the little pieces of foam stick to your skin and clothes. Polystyrene is very low on the triboelectric series and becomes charged very easily.

How do you know when an object is charged? Rather than testing whether the object sticks to something else, you can use an **electroscope**, which is an instrument that can detect static charge. The electroscope was first invented in 1748 by a French clergyman and physicist named Jean Nollet.

A metal-leaf electroscope has two very thin metal pieces, called leaves, suspended from a metal rod (Figure 10.12 on the next page). The metal rod is attached to a top plate or metal knob. When a charge is transferred to the plate or knob, the charges spread out over the whole structure, including the leaves. The greater the charge, the greater the separation between the leaves.

An electroscope is one of the devices that can be used to study static electricity. The study of static electric charges is called **electrostatics**.

D4 *Quick Lab*

Using an Electroscope

Purpose

To determine what happens to an electroscope when different charged objects are brought near it

Materials & Equipment

- plastic comb or straw or ebonite rod
- metal-leaf and/or pith-ball electroscope
- glass, acrylic, or acetate rod
- wool sweater
- silk fabric

Procedure

Part 1 — Metal-Leaf Electroscope

1. Charge the comb or straw by running it through your hair, or rub an ebonite rod on a wool sweater.
2. Bring the charged object near, but not touching, the top of the electroscope (Figure 10.12). Observe the motion of the metal leaves. Then, move the object away and observe the leaves again. Record your observations.
3. This time, touch the charged object to the top of the electroscope. You can rub the object along the top of the electroscope if necessary. Observe the motion of the metal leaves. Then, move the object away and observe the leaves again. Record your observations.
4. Charge the glass, acrylic, or acetate rod by rubbing it with the silk fabric. Repeat steps 2 and 3 using this charged rod.

Part 2 — Pith-Ball Electroscope

5. Charge the comb or straw by running it through your hair, or rub an ebonite rod on a wool sweater.
6. Bring the charged object near the pith ball but do not touch it (Figure 10.13). Record your observations.
7. This time, touch the pith ball with the charged object. Then, touch it again. Record your observations.
8. Charge the glass, acrylic, or acetate rod by rubbing it with the silk fabric. Repeat steps 6 and 7 using this charged rod.

Questions

9. What role did friction play in this activity?
10. With your group, explain what happened in Part 1, using your knowledge about charges. Assume your object had a negative charge placed on it.
11. With your group, explain what happened in Part 2, using your knowledge about charges. Assume your object had a negative charge placed on it.

Figure 10.12 Metal-leaf electroscope

Figure 10.13 Pith-ball electroscope

Detecting Static Charge

In order to predict what charge is transferred to an electroscope, you can use a standard set of charged objects, such as ebonite and glass. Ebonite is a hard rubber material that is low on the triboelectric series and readily accepts electrons. When ebonite is rubbed with fur, it becomes negative (Figure 10.14). Glass is high on the triboelectric series and tends to give away electrons. When glass is rubbed with silk or plastic, it becomes positive, as shown in Figure 10.14.

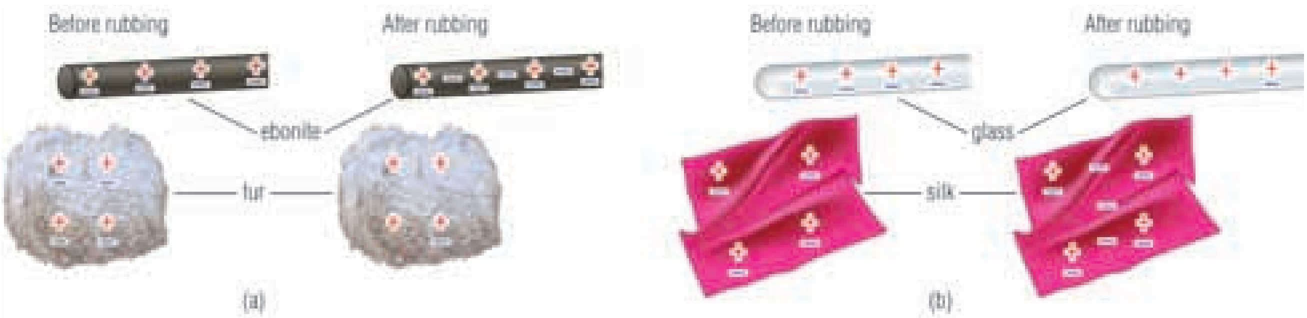


Figure 10.14 To test unknown charges, you can use the known charges on an ebonite rod (a) and a glass rod (b).

Suggested Activity •
D5 Quick Lab on page 412

When a negatively charged rod is brought near a neutral electroscope, the electrons in the electroscope are repelled by the rod. The electrons move down into the leaves of the electroscope. The leaves are now both negatively charged, so they repel each other and move apart (Figure 10.15). When the negatively charged rod is taken away, the negative charges in the electroscope are no longer repelled, so they move throughout the leaves, stem, and knob. The leaves drop down, and the electroscope is neutral again.

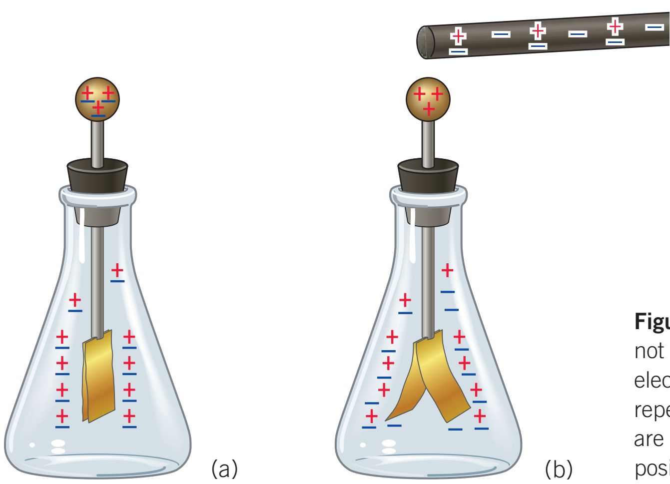


Figure 10.15 The leaves are not separated in the neutral electroscope (a). The leaves repel each other when they are charged negatively or positively (b).

Charging by Contact

As you learned in section 10.1, electrons can be transferred through friction. Electrons can also be transferred through contact and conduction. You can charge a neutral object by contact when you touch it with a charged object. **Charging by contact** occurs when electrons transfer from the charged object to the neutral object that it touches. The neutral object gains the same type of charge as the object that touched it because the electrons move from one object to the other (Figure 10.16).

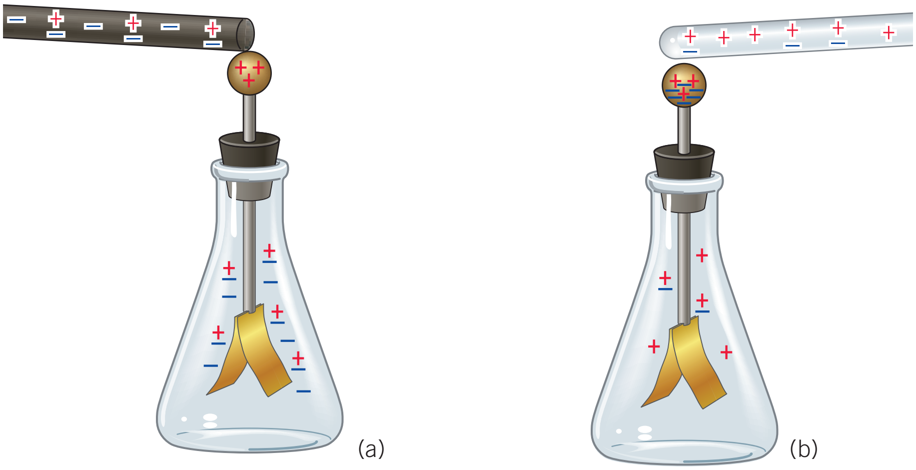


Figure 10.16 (a) When a negatively charged object touches a neutral object, electrons move to the neutral object, making it negative. (b) When a positively charged object touches a neutral object, electrons move from the neutral object to the positive object and make the neutral object positive.

Induction

Induction is the movement of electrons within a substance caused by a nearby charged object, without direct contact between the substance and the object.

If you rub a rubber balloon on your hair, electrons will transfer from your hair to the balloon, making the balloon negative. The charges stay in a nearly fixed, or static, position on the balloon because rubber is an insulator. When you bring the negatively charged balloon near a neutral wall, the negatively charged electrons on the balloon repel the negative charges on the wall, making that part of the wall a positive surface. The balloon is said to induce a charge on the wall because it charges the wall without contacting it (Figure 10.17).

During Reading

Understanding Terms and Concepts

A Frayer quadrant can help you understand a term or the concept it represents. Divide a rectangle into four sections, and put the term or concept as the rectangle's title above it (e.g., *Charging by Contact*). In the top left section, write a definition of the term using your own words and words from the text. In the top right section, write facts related to the term. In the lower left section, write examples of the term from the textbook. In the lower right section, write non-examples of the term.

Suggested Activities

- D6 Inquiry Activity on page 413
- D7 Inquiry Activity on page 414

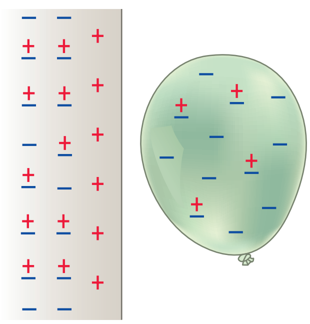


Figure 10.17 The negatively charged balloon has induced a positive charge on the wall's surface without touching the wall.

Charging by Induction

When you charge an object by induction, you use a charged object to induce a charge in a neutral object and then ground the charged object so it retains the charge. This newly charged object has the opposite charge to the charge on the charging object. **Grounding** is the process of connecting a charged object to Earth's surface. When you connect a charged object to the ground, you provide a path for charges to travel to or from the ground. Figures 10.18 and 10.19 show the process of charging by induction. Grounding occurs in diagram (b).

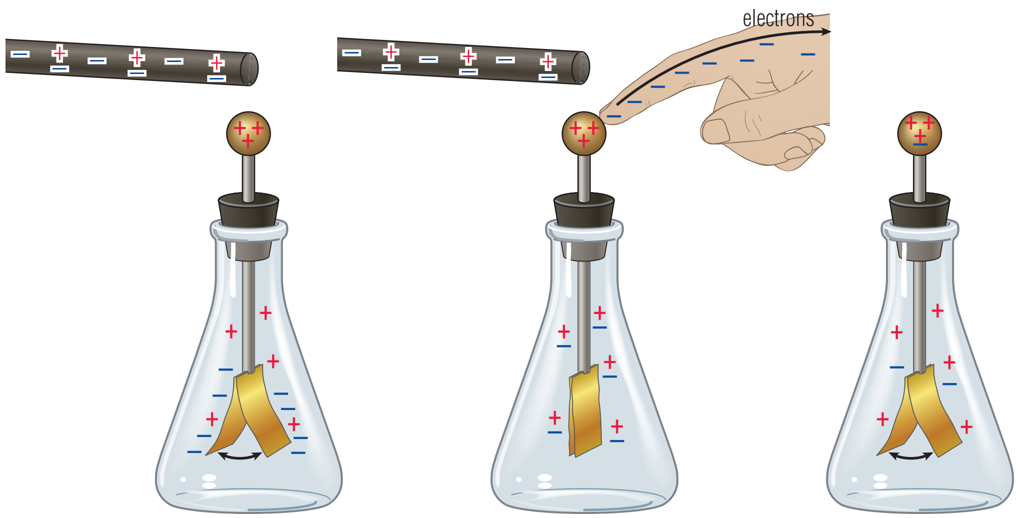


Figure 10.18 **(a)** When a negatively charged object comes near a neutral electroscope, it repels the electrons in the neutral electroscope. **(b)** When you ground the neutral electroscope, you provide its electrons with a path away from the repulsive influence. Some electrons leave the electroscope. **(c)** When you remove the ground and the charged object, the electroscope is left with a positive charge because it has lost some electrons.

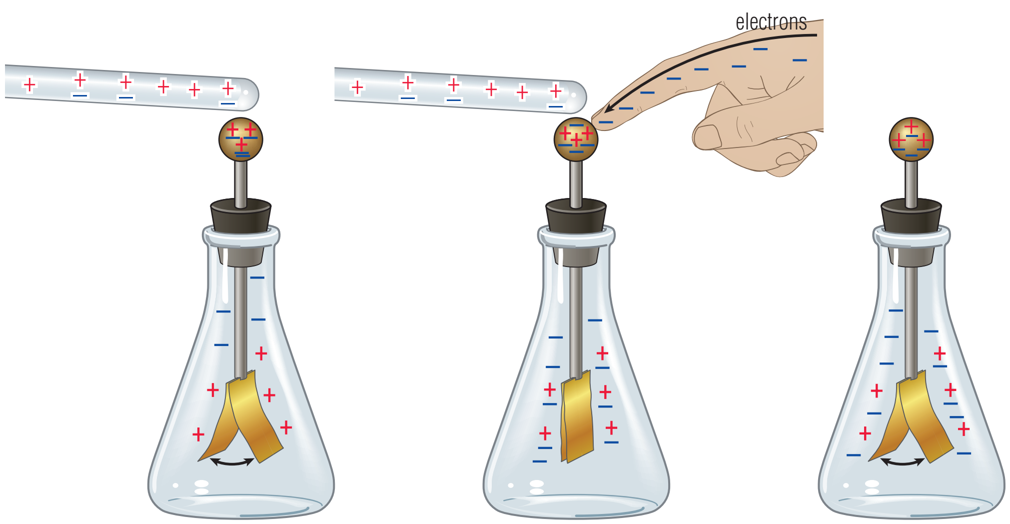


Figure 10.19 **(a)** When a positively charged object comes near a neutral electroscope, it attracts electrons in the neutral electroscope. **(b)** When you ground the neutral electroscope, you provide a path for electrons to go toward the positive influence. **(c)** When you remove the ground and the charged object, the electroscope is left with a negative charge because extra electrons are trapped on it.

Learning Checkpoint

1. What does an electroscope detect?
2. In the contact method of charging, what charge does a neutral substance gain compared to the object that touched it?
3. In induction, what charge does a neutral substance gain compared to the object brought near it?
4. What is the difference between charging by contact and charging by induction in terms of electron transfer?
5. What is grounding?

Electrical Discharge

Once an object is charged, the charges are trapped on it until they are given a path to escape. When electric charges are transferred very quickly, the process is called an **electrical discharge**. Sparks are an example of electrical discharge (Figure 10.20).

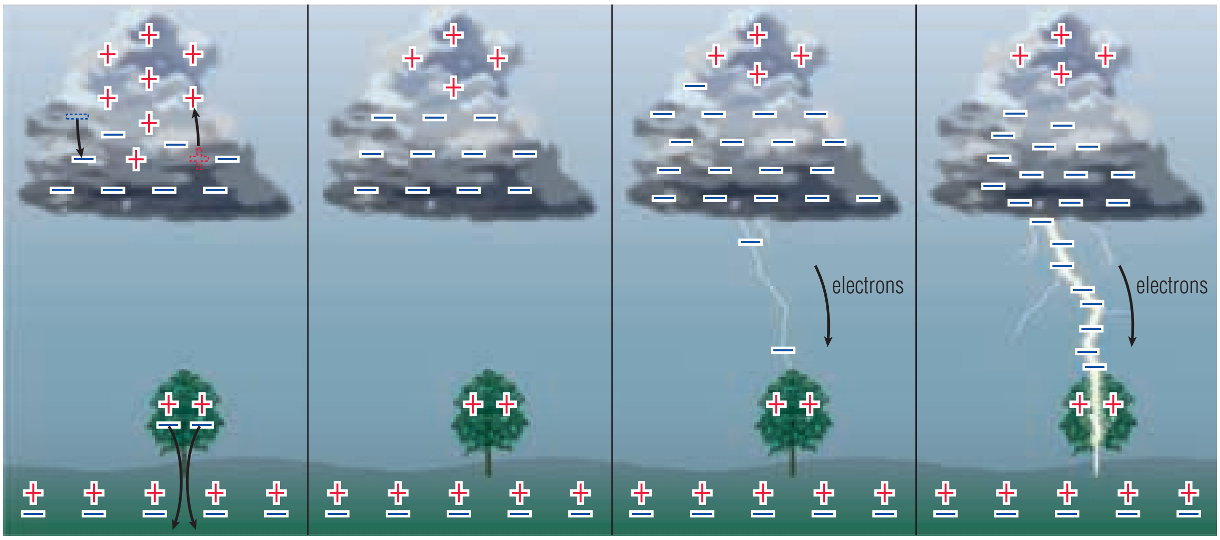
Have you walked across a carpet and reached for a doorknob only to be shocked when you created a spark (Figure 10.21)? When you shuffle your feet in slippers or socks on a carpet, electrons are transferred through friction and you build up a static charge. When your hand reaches toward the neutral doorknob, the excess electrons transfer due to induction.

Figure 10.20 When a spark occurs, the air becomes a passage for the electrons to travel. Collisions between moving electrons and air particles release light and can also make a crackling sound.

Figure 10.21 When electrons jump between your hand and a doorknob, you can receive a surprising shock.

Lightning

Lightning is an example of a very large electrical discharge caused by induction. In a thunderstorm, a charged area, usually negative, builds at the base of the cloud (Figure 10.22 (a)). The negative charge at the base of the cloud creates a temporary positive area on the ground through the induction process (Figure 10.22 (b)). When enough charge has built up, a path of charged particles forms (Figure 10.22 (c)). The cloud then discharges its excess electrons along the temporary path to the ground, creating a huge spark — lightning (Figure 10.22 (d)). This discharge creates a rapid expansion of the air around it, causing the sound of thunder.



(a) (b) (c) (d)

Figure 10.22 Lightning is an atmospheric discharge of electricity.

It is interesting to note that air is normally an insulator. If it were not, lightning would occur every time that clouds formed. For lighting to occur, charges in the clouds must build up to the point where the air cannot keep the charges separated from the ground. At this point, the air stops being an insulator and becomes a fair conductor, resulting in a lightning strike.

Earth is a donator or receiver of charge and is so large that overall it is not affected by the electron transfer of huge lightning strikes. As a result, the ground is always considered neutral.

Electrostatic Generators

Scientists use several devices in the laboratory to study how static charges create lightning and other phenomena, such as the static that affects clothes coming out of the dryer.

Early electrostatic generators were called "friction machines" because they used direct contact between different surfaces to create charged areas. A glass sphere or cylinder was rubbed mechanically by a pad to charge it up.

More recent machines, such as the Van de Graaff generator, create charge through friction between the roller and belt and then transfer the charge to a large metal sphere, as shown in Figure 10.23.

Take It Further

Sometimes, lightning strikes start from the ground and go to a cloud. There are also cloud-to-cloud lightning strikes. Find out more about different types of lightning. Create a visual display of your findings. Use ***ScienceSource*** as a starting point.

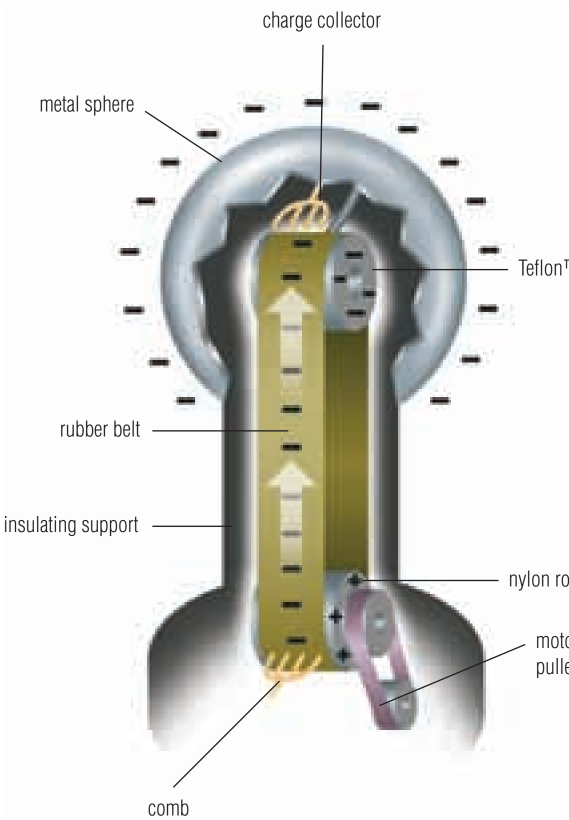


Figure 10.23 (a) This Van de Graaff generator is set up so its dome is negatively charged. A Van de Graaff generator can also be charged positively by using different roller materials.

Figure 10.23 (b) The static charge on a Van de Graaff generator has a hair-raising effect on these students.

A Wimshurst machine creates charges on two slowly rotating disks with metal strips placed around the disks (Figure 10.24). The charge is built up using induction between the front and back plates as the disks turn in opposite directions. The excess charge is collected by metal combs with points near the turning disks.

Figure 10.24 The Wimshurst machine uses induction to build up charge and create sparks.

D5 *Quick Lab*

Charge Sorter

Materials that tend to lose electrons are higher on a triboelectric series. Materials that tend to gain electrons are lower on a triboelectric series.

Purpose

To sort materials based on their ability to hold on to static charge

Materials & Equipment

- materials such as fur, silk, aluminum, paper towel, leather, wood, amber, hard rubber, Styrofoam®, plastic wrap, vinyl (PVC) and Teflon®
- metal-leaf electroscope
- known charged object, such as an ebonite rod rubbed on fur to create a negative charge

CAUTION: Some people are allergic to fur.

Procedure

1. Make a table like the one below to list your materials, predictions, and results. Give your chart a title. Record your predictions.

Materials			Prediction of Charge		Actual Charge	
	A	B	A	B	A	B
1.	fur	silk				
2.	fur	aluminum				
3.	silk	aluminum				
4.	silk	paper				

2. Record your predictions for what charge each material in each pair will have when the materials are rubbed together.
3. Rub together the first pair of materials, A and B. Then, touch material A to the knob of the electroscope to charge the electroscope.
4. Use a charged ebonite rod to test the charge on the electroscope by bringing it near the knob. Do not touch the rod to the electroscope (Figure 10.25). Observe the motion of the leaves.
5. Record the charge of material A.
6. Ground the electroscope by touching it with your hand. Then, charge the electroscope using material B.
7. Use a charged ebonite rod to test the charge on the electroscope by bringing it near the knob. Do not touch the rod to the electroscope. Observe the motion of the leaves.
8. Record the charge of material B.
9. Repeat steps 3–8 for each pair of materials.

Questions

10. Which materials were good electron receivers and would appear lower on a triboelectric series?
11. Which materials were good electron donors and would appear higher on a triboelectric series?
12. Create a triboelectric series by listing the materials you used in order, according to their electron affinity.

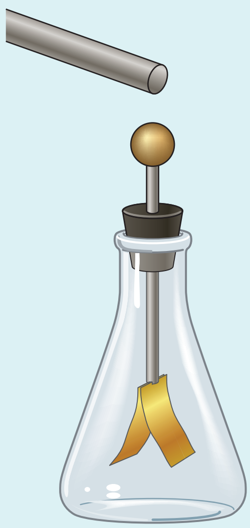


Figure 10.25 To test the charge on the electroscope, bring the charged ebonite rod near it. Do not touch it.

D6 *Inquiry Activity* Skills Reference 2

SKILLS YOU WILL USE
- Making predictions
- Observing, and recording observations

Charging by Contact

Question

What charge does the electroscope gain compared to the charging rod?

Materials & Equipment

- ebonite rod
- fur
- metal-leaf electroscope
- glass rod
- silk

CAUTION: Some people are allergic to fur.

Procedure

1. Make a table like the following to record your predictions and observations. Give your table a title. Record your predictions.

Trial		Motion of Leaves	
		Predictions	Observations
Trial A	ebonite rod touching		
	ebonite rod near		
	glass rod near		
Trial B	glass rod touching		
	glass rod near		
	ebonite rod near		

Trial A

2. Charge the ebonite rod by rubbing it with the fur.
3. Brush the ebonite rod against the top of the electroscope. Record your observations of the electroscope leaves using a labelled diagram.
4. Rub the ebonite rod with the fur again. Bring it near, but not touching, the top of the electroscope. Record your observations using a labelled diagram.
5. Charge the glass rod by rubbing it with silk. Bring the glass rod near, but not touching, the top of the electroscope. Record your observations using a labelled diagram.
6. Touch the top of the electroscope with your hand.

Trial B

7. Repeat steps 2–4 using a glass rod charged with silk. Use a charged ebonite rod in steps 5. Repeat step 6.
8. Return all materials to the areas designated by your teacher.

Analyzing and Interpreting

9. (a) Explain why the leaves moved when the ebonite rod touched the electroscope in step 3.
   (b) What charge was left on the electroscope?
10. (a) Explain why the leaves moved when the glass rod touched the electroscope in step 5.
    (b) What charge was left on the electroscope?
11. How do your predictions compare with your observations?
12. In terms of charge movement, explain in words and diagrams the effect of:
    (a) an identically charged rod near the electroscope
    (b) an oppositely charged rod near the electroscope

Skill Practice

13. Explain how you would find the charge of an unknown material.

Forming Conclusions

14. Write a summary statement about the charge the electroscope gains and the charge of the influencing rod.

D7 *Inquiry Activity* Skills Reference 2

SKILLS YOU WILL USE
- Gathering, organizing, and recording relevant data from inquiries
- Interpreting data/information to identify patterns or relationships

Charging by Induction

Question

What charge does the electroscope get compared to the charging rod?

Materials & Equipment

- ebonite rod
- glass rod
- silk
- fur
- metal-leaf electroscope

CAUTION: Some people are allergic to fur.

Procedure

1. Make a table like the following. Give your table a title. Record your predictions.

Trial		Motion of Leaves	
		Predictions	Observations
Trial A	ebonite rod away		
	ebonite rod near		
	glass rod near		
Trial B	glass rod away		
	glass rod near		
	ebonite rod near		

Trial A

2. Charge the ebonite rod by rubbing it against the fur.
3. Bring the ebonite rod near the electroscope. Be careful not to touch the rod to the electroscope. While you hold the rod there, touch the top of the electroscope with your hand.
4. Remove your hand from the electroscope, and then move the ebonite rod away. Observe what happens to the leaves of the electroscope. Record your observations.
5. Bring a charged ebonite rod near the electroscope. Record what happens to the electroscope leaves.
6. Bring a charged glass rod near the electroscope. Record what happens to the electroscope leaves.

Trial B

7. Repeat steps 2–5 except start by charging a glass rod against silk in step 2. Use a charged ebonite rod for step 6.

Analyzing and Interpreting

8. (a) Compared to the original rod that was brought near the electroscope, what charge did the electroscope end up with?

   (b) How do you know?
9. Explain what happens to the electrons in the electroscope when your hand touches the electroscope.
10. (a) Why did you have to remove your hand first before you moved the rod away?

    (b) What would have happened if you had moved the rod away and then your hand?

Skill Practice

11. How else could you ground the electroscope?

Forming Conclusions

12. Summarize the method of charging by induction by using diagrams labelled with the motions of charges.

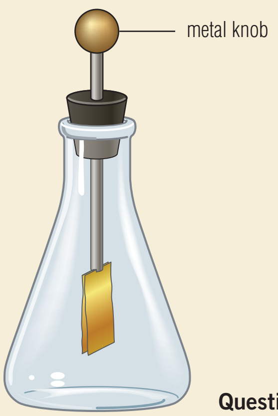
10.2 CHECK and REFLECT

Key Concept Review

1. How are lightning and a spark similar?
2. (a) How do objects become negatively charged using the contact method?
   (b) How do objects become positively charged using the contact method?
3. Explain how a substance becomes temporarily charged by induction when a charged object is brought near.
4. Explain how to charge an object permanently using induction.
5. Using a sequence of labelled diagrams, explain how a positive balloon will stick to a neutral wall. Under each diagram, describe the motion of the charges.

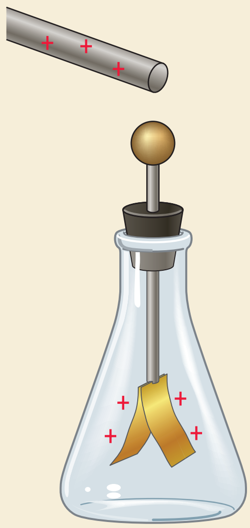
Connect Your Understanding

6. (a) How does the process of grounding occur when you receive a spark from touching a metal shopping cart?
   (b) How does the process of grounding occur during a lightning strike?
7. What would change about the way an electroscope worked if its metal knob were replaced with a plastic knob?



Question 7

8. (a) Why do the leaves of the charged electroscope shown below move farther apart if a rod with the same charge is brought near?
   (b) Why would the leaves move closer together if the rod had the opposite charge to the electroscope?



Question 8

9. A person walks across a carpet, touches a metal doorknob, and receives a shock. If the same person were carrying a metal rod, she would not experience a shock when touching the doorknob. Why?
10. Suppose a five-year-old child asks you to explain why there is lightning. Write a simple explanation that you could share with the child. You may wish to include a diagram.

Reflection

11. What are two things about static electricity that you know now but you did not know before you started this chapter?

For more questions, go to ***ScienceSource***.