7.2 Electric Force

Electric force acts on objects even if they are not touching. Objects with the same charge repel each other. Objects with opposite charges attract each other. Neutral objects are attracted to charged objects. The amount of electric force depends on the amount of charge on each object and the distance separating the objects. Increasing the amount of charge increases the electric force. Decreasing the distance between the charged objects increases the electric force. An object can become charged by either conduction or induction.

Words to Know

action-at-a-distance forces
charging by conduction
charging by induction
contact forces
electric force
force
laws of static charge

Force is defined as a push or a pull. When you shoot a basketball, you are applying a force to the ball. Pulling a desk across the floor is also an example of using a force. In both of these situations, something is touching the object that is being moved. These are examples of **contact forces**, which are forces that can have an effect only on objects that they touch.

Suppose you bring a charged comb near small pieces of paper. Without making contact, the paper will be attracted to the comb as shown in Figure 7.9. An **electric force** is a push or pull between charged objects. The electric force is an example of **action-at-a-distance forces**, which can apply force to an object without touching it.

Figure 7.9 Even though the comb is not touching the paper on the table, the paper is attracted to the charged comb.

7-2A What Is the Attraction to Water? Find Out ACTIVITY

In this activity, you will observe how a stream of water is affected by static charge.

Materials

- water tap
- acetate strip
- paper towel
- ebonite rod
- fur

What to Do

1. Adjust the tap so that it produces a continuous stream of water. The stream should be as small as possible without dripping.
2. Rub an acetate strip with paper towel. Then slowly move the acetate strip beside the flowing water. Observe what happens to the stream of water.
3. Rub the ebonite rod with fur. Repeat step 2, this time using the ebonite rod.

What Did You Find Out?

1. How did the acetate strip affect the stream of water?
2. How did the ebonite rod affect the stream of water?
3. In a sentence, explain your observations in steps 2 and 3.
4. Do you think any charged object could repel the water? Explain.

The Laws of Static Charge

In section 7.1, you learned that objects could be grouped according to three kinds of charges: positive, negative, or neutral. Early scientists, using action-at-a-distance forces, examined how these three groups interacted (Figure 7.10). They discovered that two positively charged objects placed close together *repelled* each other, as did two negatively charged objects. When a positively charged object was brought close to a negatively charged object the two objects *attracted* one another. Charged objects also attracted neutral objects.

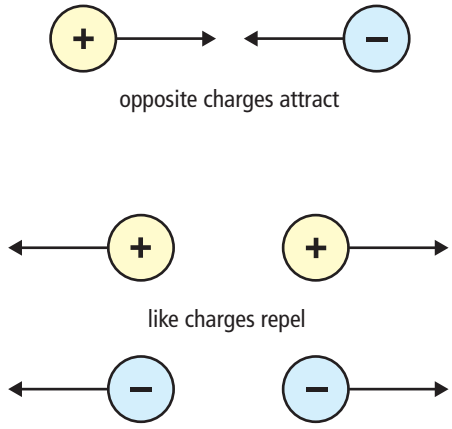


Figure 7.10 Positive and negative charges exert forces on each other.

Many similar experiments to these established the **laws of static charge**:

- Like charges repel.
- Opposite charges attract.
- Neutral objects are attracted to charged objects.

Charles Coulomb observed that electric force is proportional to charge. If you increase the *amount of charge*, you increase the electric force. Likewise, if you decrease the amount of charge, you decrease the electric force. Coulomb also observed that if you increase the *distance* between charged objects, you decrease the electric force. If you decrease the distance between charged objects, you increase the electric force.

Charging by Conduction

When a negative object is touched to a neutral electroscope, electrons are added to the electroscope. These extra electrons spread evenly over the entire metal surface of the electroscope leaves (Figure 7.11). Since both metal leaves now have a negative charge, they repel each other. Charging a neutral object by touching it to a charged object is called **charging by conduction**. Touching the neutral electroscope with a positively charged object would have the same result. Electrons from the metal in the electroscope would be attracted to the positive object. Therefore, the metal leaves would both become positively charged after electrons had been transferred to the positive object.

Suggested Activity

Conduct an Investigation 7-2C on page 263

Did You Know?

Electric force is not the only action-at-a-distance force. Magnetic force and gravitational force also act at a distance.

Figure 7.11 A negatively charged rod adds extra electrons to the electroscope.

internet connect

A lightning rod is charged by induction, just like the knob on the electroscope. Find out more about how lightning rods work. Start your search at **www.bcscience9.ca.**

Charging by Induction

The leaves of a neutral electroscope can be made to separate even if the knob is not touched with a charged object. If you bring a negatively charged object near, but not touching, the knob of the electroscope, the negative charge will repel the electrons in the knob. The electroscope is a conductor, so the electrons will move down to the leaves (Figure 7.12). The leaves of the electroscope will have a temporary negative charge and will repel each other. The knob will be positively charged. This is called **charging by induction**. If you move the charged object away, the leaves will go back to their original position. When an object is charged by induction, no electrons are actually transferred from one object to the other. Instead, inducing a charge repositions electrons inside the object.

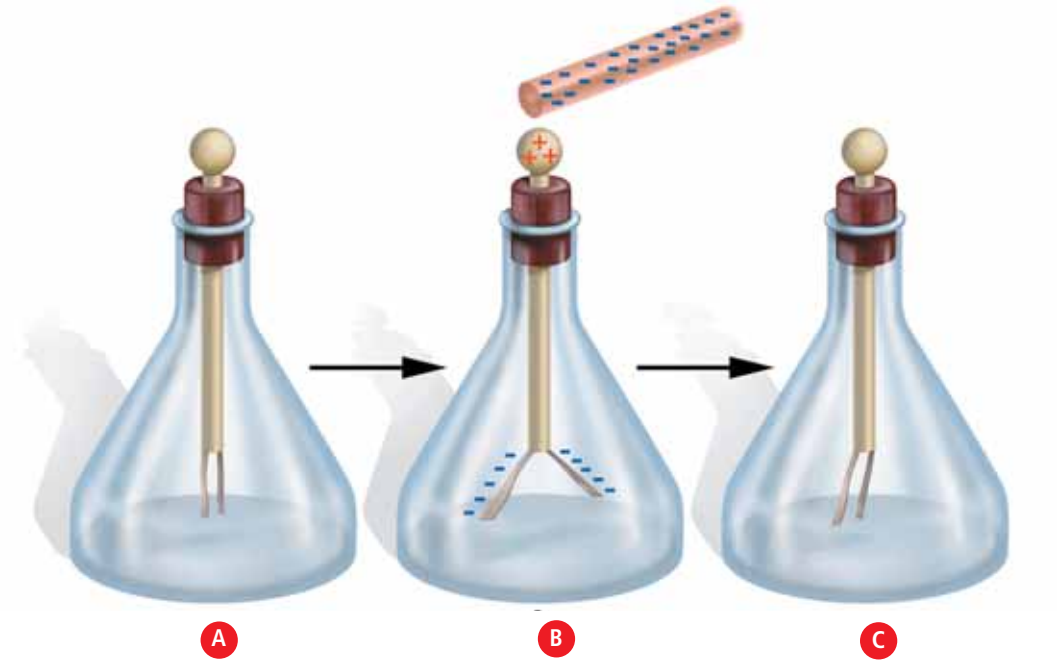


Figure 7.12 In a neutral electroscope, the leaves are not separated (A). When a negative object is brought close to the positive knob, electrons in the knob are pushed down to the leaves, causing the leaves to separate (B). When the negative object is removed, the leaves return to their original position because no charge was transferred between the object and the electroscope (C). The charges simply moved or separated.

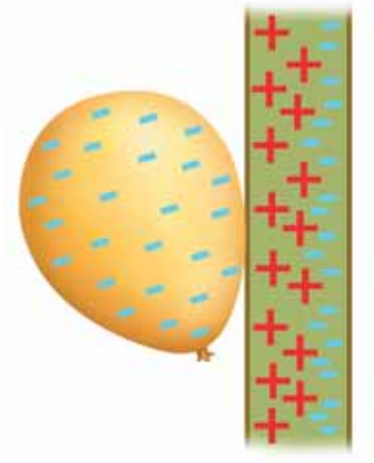


Figure 7.13 A charged balloon sticks to the wall because a positive charge is induced on the surface of the wall.

The Attraction of Neutral Objects

Induction explains why neutral objects and charged objects attract each other. For example, when you rub a balloon in your hair, the balloon becomes negatively charged. Since the balloon is an insulator, the negative charge remains in a nearly fixed location on the balloon. If you place the charged balloon against the wall, the negative charges in the wall are repelled away from the balloon (Figure 7.13). The part of the wall closest to the balloon now has a positive charge because the electrons in that region are repelled due to induction. The negative charge on the balloon will be attracted to the positive wall, and therefore the balloon will stick to the wall.

Putting Static Charge to Work

In a photocopier (Figure 7.14), light and powdered toner are used to produce an image using static electricity.

1. Light moves across the document that you place on the copier's glass surface. This light reflects off the white sections of your original and strikes the drum.
2. The charged drum of a photocopier is made of photoconductive material. Where light hits the surface of the photoconductive material, the static charge is removed, so less toner will be attracted to these areas. This is now a copy—in static electricity—of your original.
3. The machine then spreads the neutral toner over the surface of the drum. The toner sticks only where the drum has a static charge.
4. A positively charged blank sheet of paper passes over the surface of the drum. This sheet of paper has a larger charge than the drum. The toner is pulled off the drum and onto the paper by the large positive charge.
5. The toner is then baked onto the paper with heat as soon as the page comes off the drum. Finally, an exact copy of your original is ejected from the photocopier.
6. The drum retains the static charge image for the remainder of your copies. Once all your copies are made, the drum is neutralized, and the whole process is ready to be repeated.

Word Connect

The word "photocopier" is related to "photograph," "photoelectric," and "photoconductive." The prefix "photo-" means light in Greek.

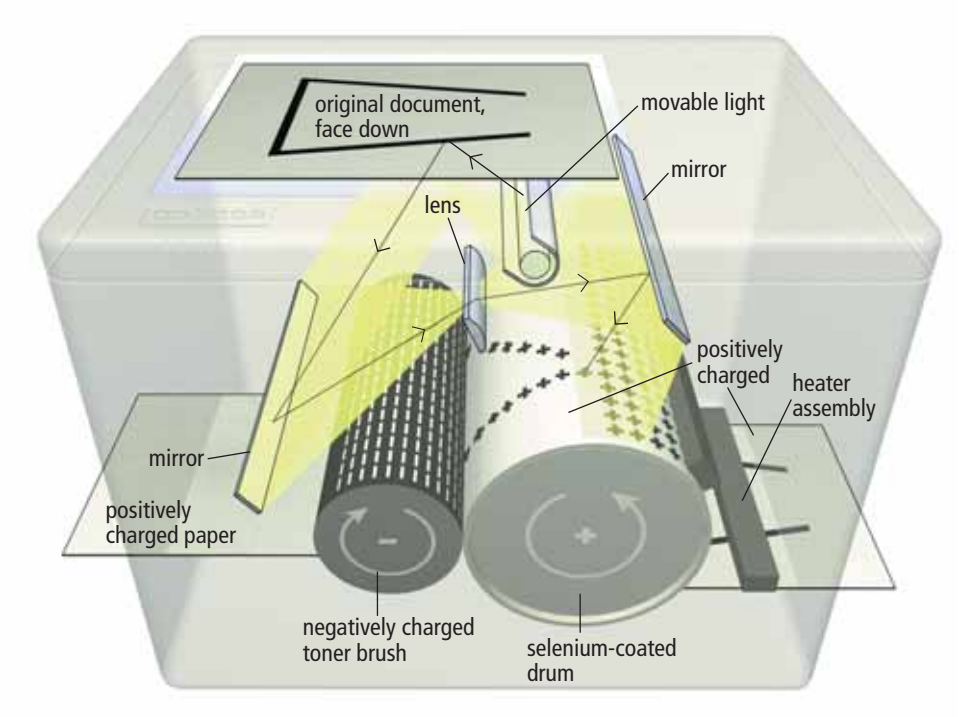


Figure 7.14 Photocopiers use an image produced by a static charge to attract the toner.

Explore More

Laser printers also use static electricity to produce an image on paper. Find the similarities and differences between a photocopier and a laser printer. Begin your research at **www.bcscience9.ca.**

Reading Check

1. What is the definition of an electric force?
2. Explain what is meant by action-at-a-distance force.
3. According to the laws of static charge, explain how:
   (a) like charges react
   (b) opposite charges react
   (c) neutral objects react to charged objects
4. What is electric force proportional to?
5. In terms of charge transfer, what is the difference between charging by conduction and charging by induction?
6. When a charged balloon sticks to the wall, does the wall become charged by induction or conduction?

7-2B Static Copier

Find Out ACTIVITY

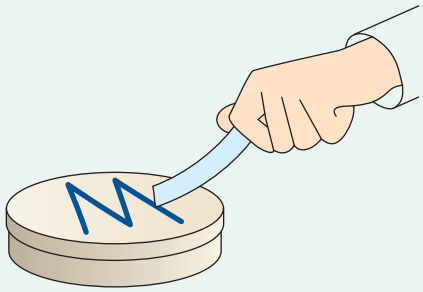
Static electricity can attract small objects and hold them in one place. In this activity, you will write your first initial using yeast and a static charge.

Materials

- plastic petri dish with lid
- felt marker
- dry yeast
- acetate strip
- paper towel

What to Do

1. Write your first initial on the lid of the petri dish using the felt marker.
2. Put a small amount of yeast in the petri dish. Place the lid on the dish.
3. Rub the acetate strip with the paper towel. Use the charged corner of the acetate strip to trace your initial on the petri dish. Repeat this several times making sure to recharge the acetate strip each time.



4. Holding the lid on, but touching only the edges, turn the petri dish upside down and then right side up. Observe the lid.
5. Clean up and put away the equipment you have used.

What Did You Find Out?

1. Describe the appearance of the lid after you turned the petri dish right side up.
2. What caused the yeast to take the shape of your initial?
3. How is this activity similar to the process of photocopying?

7-2C Investigating Static Electricity — Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

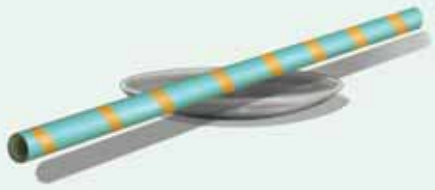
- Observing
- Classifying
- Communicating
- Evaluating information

Safety

- Handle the glass rods with care.

Materials

- watch glass
- 2 plastic straws
- wool
- 2 acetate strips
- paper towel
- 2 glass rods
- plastic bag
- 2 ebonite rods
- fur



Question

How do charged objects affect each other?

Procedure

1. Copy the following table into your notebook.

Charged Object on Watch Glass	Charged Object in Hand			
	Plastic straw	Acetate strip	Glass rod	Ebonite rod
Plastic straw				
Acetate strip				
Glass rod				
Ebonite rod				

2. Place a watch glass, curved side down, on your desk. Rub along a plastic straw with wool. Place the straw on the watch glass so that it is free to rotate.
3. Rub along the second plastic straw with wool. Slowly bring the end of the rubbed straw close to the straw on the watch glass.
4. Record your observations in your table. Use the words "attract" or "repel."
5. Rub along the acetate strip with paper towel. Bring the strip towards the plastic straw on the watch glass. Record the interaction between the two objects in your table.
6. Repeat step 5, using the glass rod rubbed with a plastic bag.
7. Repeat step 5, using the ebonite rod rubbed with fur.
8. Repeat steps 2 to 7, placing the other charged objects, one at a time, on the watch glass.

Analyze

1. Analyze the data you collected. When two identically charged objects were brought together, such as the two plastic straws, how did they interact with each other?
2. List all the pairs of objects that interacted in the same way as identically charged objects.
3. List all the pairs of objects that interacted in an opposite way to identically charged objects.

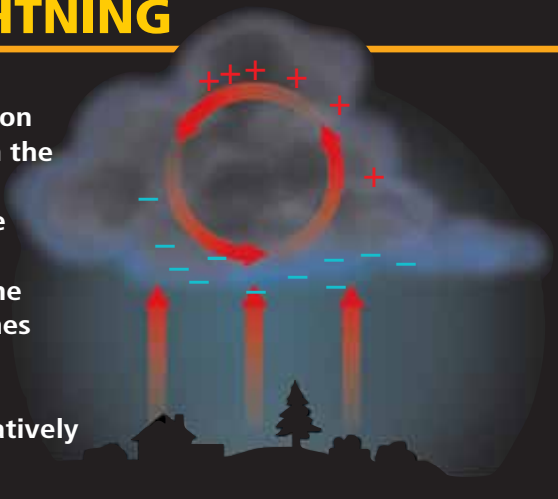
Conclude and Apply

1. Based on your observations, state:
   (a) how two objects with the same charge interact
   (b) how two objects with opposite charges interact

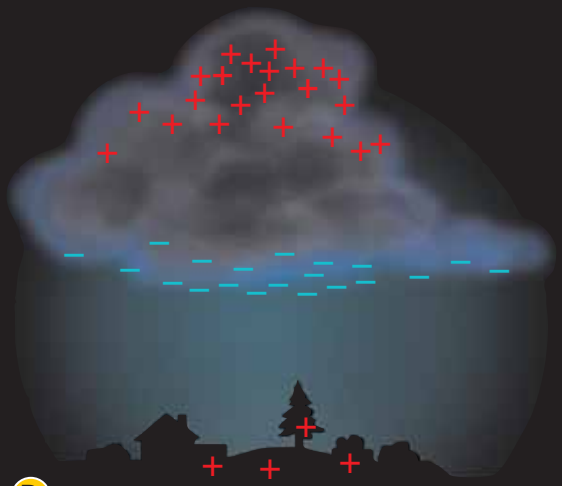
NATIONAL GEOGRAPHIC

VISUALIZING LIGHTNING

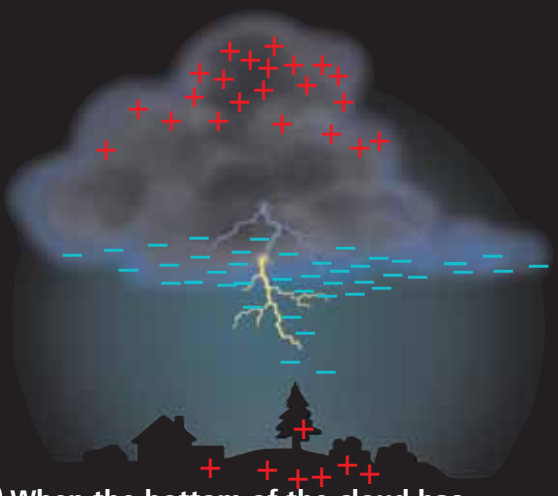
Storm clouds can form when humid, warm air rises to meet a colder air layer. As these air masses churn together, the stage is set for the explosive electrical display we call lightning. Lightning strikes when negative charges at the bottom of a storm cloud are attracted to positive charges on the ground.



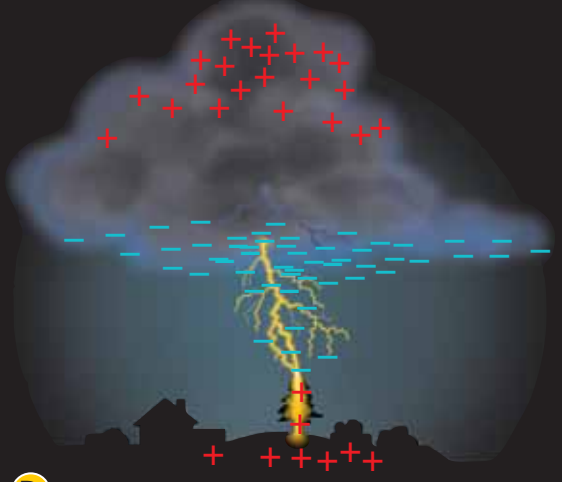
A Convection currents in the storm cloud cause charge separation. The top of the cloud becomes positively charged, the bottom negatively charged.



B Negative charges on the bottom of the cloud induce a positive charge on the ground below the cloud by repelling negative charges in the ground.



C When the bottom of the cloud has accumulated enough negative charges, the attraction of the positive charges below causes electrons in the bottom of the cloud to move toward the ground.



D When the electrons get close to the ground, they attract positive charges that surge upward, completing the connection between cloud and ground. This is the spark you see as a lightning flash.

INTRA-CLOUD LIGHTNING never strikes Earth and can occur 10 times more often in a storm than cloud-to-ground lightning.

T. Wiewandt/DRK Photo

Check Your Understanding

Checking Concepts

1. (a) How are contact forces and action-at-a-distance forces different?
   (b) Describe a situation that involves a contact force.
   (c) Describe a situation that involves an action-at-a-distance force.
2. State the three laws of static charge.
3. A positively charged object is brought near another object. If the two objects repel, what is the charge on the second object?
4. A charge is transferred from one conductor to another by touching. What kind of charging process is this?
5. A charge is relocated within a conductor because there is a charged object nearby. What kind of charging process is this?

Understanding Key Ideas

6. A positively charged object is brought near another object. The two objects attract. Does this observation prove that the unknown object must be negatively charged? Explain.
7. An unknown material is rubbed with silk and becomes charged. Explain how you could use a negative acetate strip or a positive glass rod to determine the type of charge on the unknown material.
8. Suppose you are handed an electroscope that another student just used. You observe that the leaves are already spread apart. You now slowly bring a positive glass rod near the knob of the electroscope and the leaves begin to get closer together. Why did the leaves move closer together when you brought the glass rod near the knob of the electroscope?
9. State the similarities and differences between charging by conduction and charging by induction.
10. State the relationship of the distance between two charged objects and their force of interaction.
11. Use your understanding of static charge to explain how plastic wrap clings to a neutral glass bowl.

12. A positively charged object is positioned near one end of a neutral metal rod. If you briefly touch the opposite end of the metal rod with your finger, the rod becomes positively charged. Explain how the metal rod became charged without being touched by the charged object.

Pause and Reflect

In section 7.1, you learned that acetate becomes negatively charged when rubbed with paper towel. In section 7.2, you studied how charged objects interact with each other. What is an experiment you could do to find out if combing your hair produces a negative or positive charge on a comb? To design the experiment, use what you know about the effect of rubbing the acetate and the interactions between charged objects.

Prepare Your Own Summary

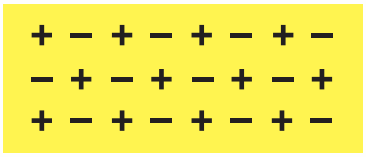
In this chapter, you investigated how static charge is produced by electron transfer. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 12 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Electric Charge and the Atom
2. Charge Distribution in Neutral, Positive, and Negative Objects
3. Transferring Charge
4. Laws of Static Charge
5. Insulators and Conductors

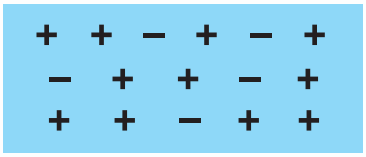
Checking Concepts

1. Draw and label a diagram showing the three parts of the atom. State the electric charge on each part.
2. Using (−) to represent electrons, and (+) to represent protons, draw:
   (a) a neutral object
   (b) a negative object
   (c) a positive object
3. Which type of particles are transferred during static charging?
4. What type of charge do plastics, such as acetate, gain when charged by friction?
5. A neutral piece of amber becomes negatively charged when rubbed with fur. What charge would the fur possess after charging the amber?
6. What is the purpose of
   (a) an electroscope?
   (b) a Van de Graaff generator?
7. What effect does grounding have on a charged object?
8. What is the difference between a conductor and an insulator?
9. Use the word "attracts" or "repels" to state what happens when each of the following objects interact.
   (a) positive—positive
   (b) positive—negative
   (c) negative—positive
   (d) negative—negative
10. Use the word "increases" or "decreases" to complete each of the following sentences in your notebook.
    (a) When two charged objects are moved farther apart, the electric force ___.
    (b) When two charged objects are moved closer together, the electric force ___.
    (c) Increasing the amount of charge ___ the electric force between two charges.
    (d) Decreasing the amount of charge ___ the electric force between two charges.
11. Describe the movement of electrons when an object is charged by:
    (a) conduction
    (b) induction
12. State whether each of the objects below is negative, positive, or neutral.

A



B



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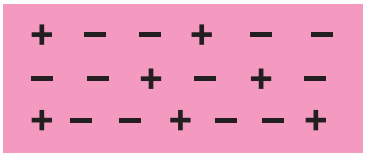

Understanding Key Ideas

13. Explain how an object containing many electrons can be neutral.
14. Explain why clothes dried in the clothes dryer have more static electricity than those dried on a clothesline.
15. Antistatic carpets have metal fibres woven into their material. Explain how these fibres could prevent a static charge build-up on a person shuffling across the carpet.
16. If the picture tube in a television gains a static charge when the television is on, is the picture tube a conductor or an insulator? Explain your answer.
17. Is lightning a static charge, or is it produced by static charge? Explain your answer.
18. Explain one way in which electric force and the force of gravity are similar.
19. A positive rod attracts an unknown object. Explain what this indicates about the charge on the unknown object.
20. Use a Venn diagram to compare induction and conduction.
21. Explain why a charged balloon will "stick" to a wooden wall but not to a metal wall.
22. Imagine that it is a cold winter day and you are removing your wool sweater. As you pull it over your head, you see little sparks and you hear popping and crackling sounds in the sweater. Explain what might be causing the sparks and sounds.
23. When you comb your hair, the comb can become positively charged. Can your hair remain neutral? Explain.
24. Explain what happens to the leaves of a negatively charged electroscope when objects with the following charges are brought close to, but are not touching, the electroscope.
    (a) negative
    (b) positive

Pause and Reflect

You have seen how a Van de Graaff generator affects the hair of anyone touching it. Assume that the dome of the generator is positively charged. Since a person's hair is initially neutral, why does the hair "stand on end" after the person touches the dome for a period of time? Your explanation should include a discussion of electron transfer and the laws of static charge.