Topic 4.2

What are charges and how do they behave?

Key Concepts

- Negative charges are electrons, and positive charges are protons.
- Opposite charges attract each other, and like charges repel each other.
- Negative charges can move through some materials but not others.

Key Skills

Inquiry
Literacy

Key Terms

negative charges
positive charges
electrically neutral
conductor
conductivity
insulator

In a clothes dryer, the clothes constantly rub together as the dryer drum turns. If no anti-cling product was used, some clothes will stick to each other when you take them out of the dryer. People commonly refer to this sticking effect as static cling. The same effect can happen when you put on or pull off a wool or polyester sweater and it rubs against your hair. You might even hear popping or crackling sounds as the fabric rubs against your hair. The term "static electricity" is used to describe effects such as hair sticking to fabric and clothes sticking to each other.

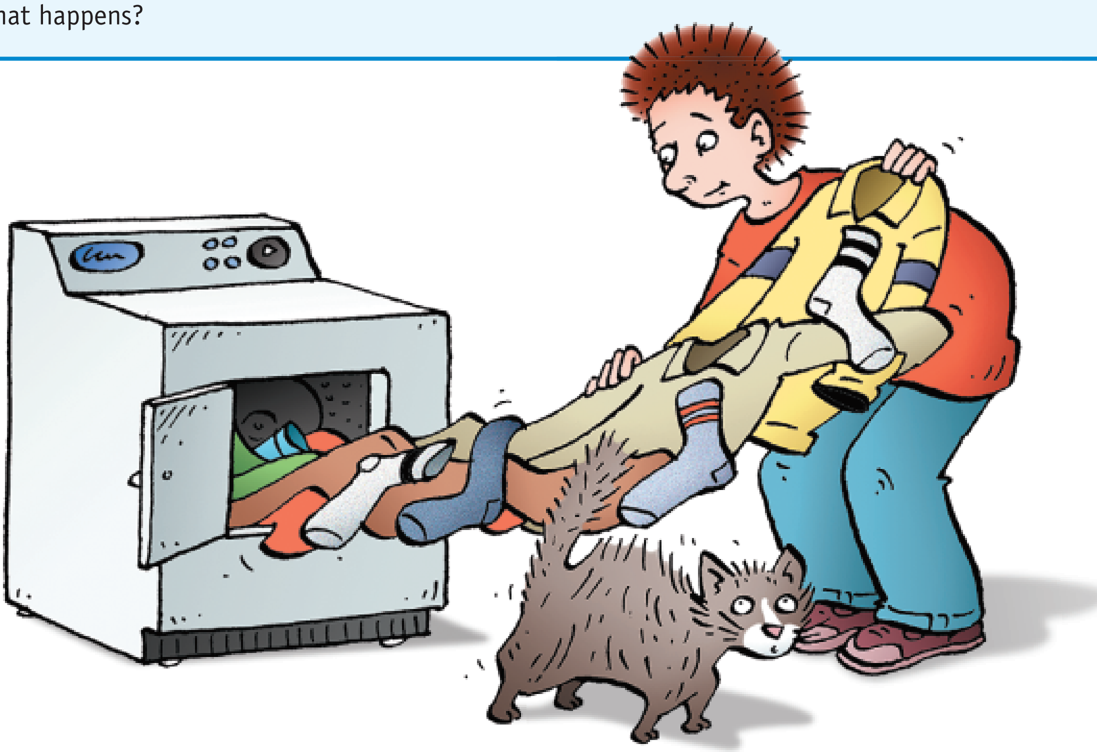
Starting Point Activity

Allergy Alert! If you are allergic to latex, do not touch the balloons.

1. Read the captions that go with the two pictures. Predict what will happen in each case. Give a reason for each prediction. Then test your predictions by doing the steps.
2. How did your results compare with your predictions?
3. What facts or experiences did you use to make your predictions?

- Rub a balloon on your hair.
- Move the balloon away, then bring it near your hair again.
- What happens?

- Rub the balloon on your hair again.
- Hold the balloon against a wall and let go.
- What happens?



Negative charges are electrons, and positive charges are protons.

Literacy Focus

Activity 4.3

REMEMBERING ATOMS

Sketch an atom. Add labels to show protons and electrons, and add a caption to describe their properties. Refer to Unit 2 of this textbook if you need to review the structure of an atom.

negative charges: the type of electrical charges that can be rubbed off a material

positive charges: the type of electrical charges that are left behind when negative charges are rubbed off a material

When you rub certain materials against each other, something comes off one of the materials and goes onto the other. As a result, the two materials attract each other. About 250 years ago, the American scientist Benjamin Franklin used the term **negative charges** to describe the "somethings" that were rubbed off materials. He also said that when negative charges were rubbed off a material, an excess of **positive charges** was left behind.

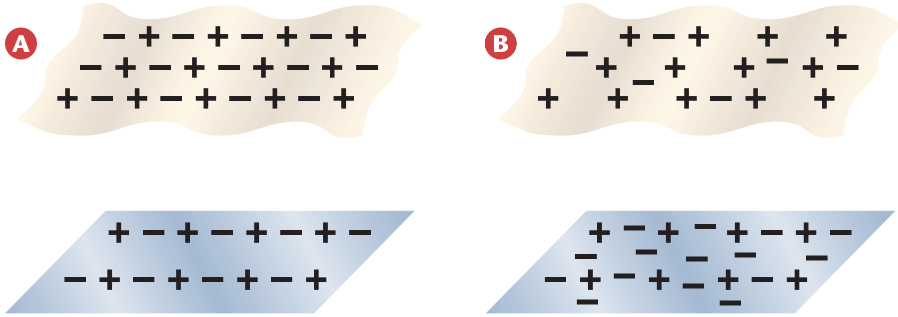
Today, we know that the negative charges are parts of the atom called electrons. The positive charges are protons, which are also parts of atoms. Protons cannot be rubbed off materials, but electrons can be. When electrons are rubbed off a material, it becomes positively charged. The material that gains the electrons becomes negatively charged. This process of charging materials by rubbing is called *charging by friction*.

Positively, Negatively, and Electrically Neutral

You just read that when electrons are rubbed off a material, it becomes positively charged. This means that the positive charges must have been there before the materials were rubbed. If the two materials had positive and negative charges before they were rubbed, why didn't they attract each other? The answer is: The materials had *equal numbers* of positive and negative charges before they were rubbed together. So all of the positive charges were balanced by all of the negative charges.

electrically neutral: having equal numbers of positive charges and negative charges

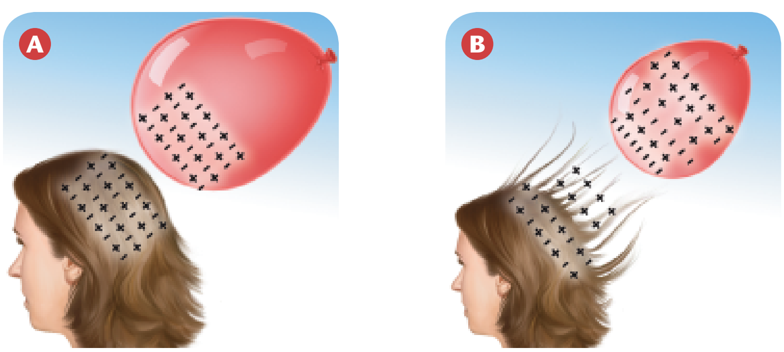
When objects have equal numbers of positive and negative charges, they are **electrically neutral**. It is only when the numbers of positive and negative charges are *unequal* and *unbalanced* that an object is electrically charged. Figure 4.4 shows two materials before and after they were rubbed together to help you understand this idea.



▶ **Figure 4.4** Diagram A shows a paper towel (top) and an acetate strip (bottom) that are electrically neutral. They have equal numbers of positive and negative charges. Diagram B shows the two materials after they are rubbed together. Now the paper towel has fewer negative charges, and the acetate strip has more negative charges. Therefore, the paper towel is positively charged and the acetate strip is negatively charged. Both materials still have the same number of positive charges before and after rubbing.

Explaining Why Rubbed Hair Is Attracted to a Balloon

You now have enough information to explain why your hair is attracted to a balloon after it has been rubbed on your hair. As shown in **Figure 4.5**, some negative charges (electrons) have been rubbed off your hair and are now on the balloon. The excess negative charges on the balloon attract the excess positive charges on your hair.



◀ **Figure 4.5** (A) Before rubbing a balloon on hair, both have equal numbers of positive and negative charges. They are electrically neutral. (B) When the balloon is rubbed on the hair, negative charges are transferred from the hair to the balloon. So now the hair has an excess of positive charges and the balloon has an excess of negative charges.

LEARNING CHECK

1. Explain the relationship among negative charges, positive charges, electrons, and protons.
2. Refer to **Figure 4.4**. Describe what happens when you rub two different materials together.
3. Make a sketch that shows the positive and negative charges on the following objects:
   a) a balloon that is neutrally charged
   b) a rubber duck that is negatively charged
   c) a wool sweater that is neutrally charged
   d) a wool sweater that is positively charged

ACTIVITY LINK
Activity 4.4, on page 256

INVESTIGATION LINK
Investigation 4B, on page 252

Opposite charges attract each other, and like charges repel each other.

Inquiry Focus

Activity 4.4

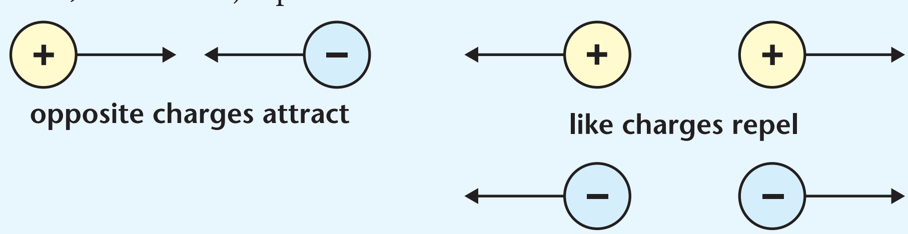
LIKE CHARGES REPEL

Allergy Alert! If you are allergic to latex, do not touch the balloons.

1. Tie strings on two balloons.
2. Rub both balloons on your hair.
3. Dangle the balloons on the ends of the strings, and slowly bring them together.
4. Describe what happens.

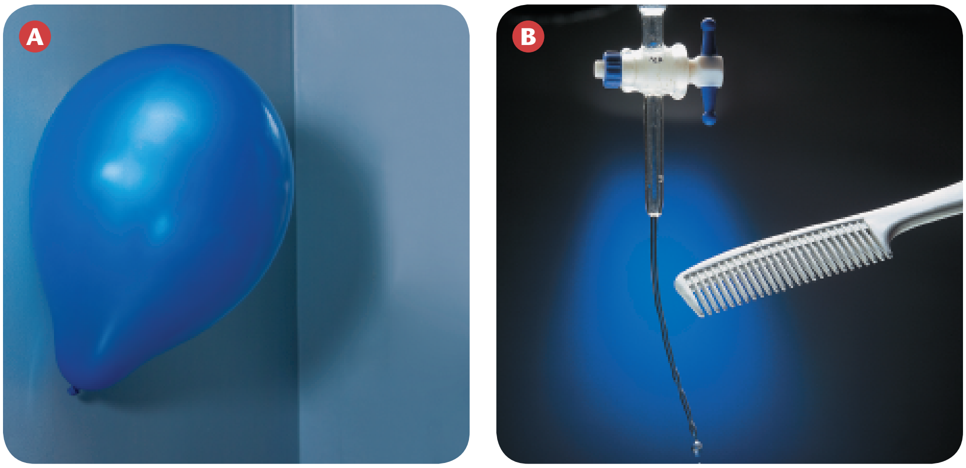
You have learned that objects that are positively charged attract objects that are negatively charged. If you brought two negatively charged balloons near each other, you saw that they repelled each other—pushed each other away. All of these ideas are summarized by the law of electric charge in the box below.

The Law of Electric Charge
Opposite charges attract each other, and like charges (charges that are alike, or the same) repel each other.



The law of electric charge applies to individual charges, such as electrons and protons. Every negative charge attracts every positive charge, every negative charge repels every other negative charge, and every positive charge repels every other positive charge. When you bring together objects that have an excess of charges, you see the overall result of the attractions and the repulsions.

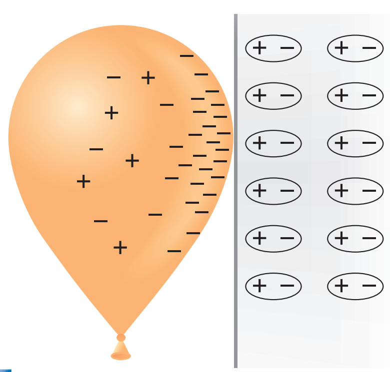
Charged Objects and Neutral Objects



◀ **Figure 4.6** The balloon in photo A is charged, but the wall is not. The comb in photo B is charged, but the water is not.

Examine the photographs in **Figure 4.6**. You have probably seen charged balloons sticking to walls before. But have you ever seen a charged object such as a comb brought close to a stream of water? Notice how the water is actually attracted to the charged comb.

You can use the law of electric charge to explain why charged objects attract neutral objects. As you know, all neutral objects have an equal number of positive and negative charges. When you bring a charged object near a neutral object, the charges in the neutral object do not come off the object. Instead, they stretch out apart from each other. **Figure 4.7** shows this happening to a neutral wall when a charged balloon is close to it. The positive charges in the wall are pulled to the surface by the negative charges on the balloon. Then the positive charges in the wall are attracted to the negative charges on the balloon enough to make the balloon stick to the wall.



◀ **Figure 4.7** This diagram shows why a charged balloon sticks to an electrically neutral wall.

LEARNING CHECK

1. State the law of electric charge.
2. Make a labelled sketch, including charges, to show what happens when you bring two negatively charged balloons together.
3. Refer to **Figure 4.6B**. Make a labelled sketch, including charges, to explain why a stream of neutral water bends toward a positively charged comb.

ACTIVITY LINK

Activity 4.6, on page 260

INVESTIGATION LINK

Investigation 4B, on page 262

Negative charges can move through some materials but not others.

conductor: a material in which electrical charges can move easily

conductivity: an indication of how easily charges move within a material

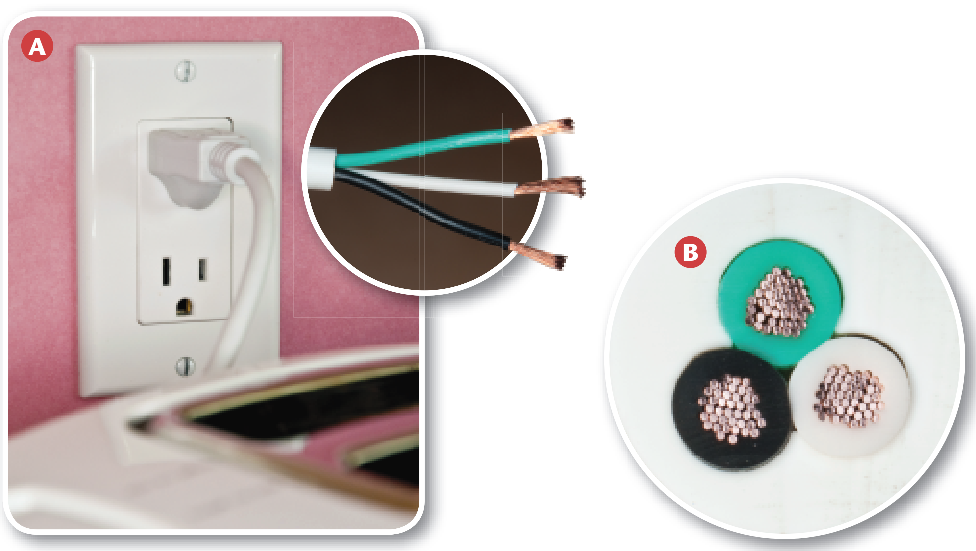
insulator: a material in which electrical charges cannot move easily

If an object is charged and the charges are repelling each other, why don't the charges just move away from each other? Actually, sometimes the charges *do* move. Whether or not they move depends on two things.

First, negative charges are the only kind of charge that can move in solid materials. (In other words, negative charges can move easily in solid materials, but positive charges can't.) However, both negative charges and positive charges are able to move in liquids.

Second, electrical charges can move only in certain types of materials. Any material in which electrical charges can move is called a **conductor**. How easily charges move through a material is called the material's **conductivity**. Any material in which electrical charges can't move easily is called an **insulator**. Refer to **Figure 4.8**.

Metals such as copper, iron, gold, and silver are conductors. In fact, most metals are conductors. Materials that are not metals, such as glass, plastic, wood, and Styrofoam®, are insulators. In fact, most non-metals (materials that are not metals) are insulators.



A Electrical cords have a metal conductor, such as copper wires, in the centre. Charges can move easily along the conductor.

B The metal conductor must be covered by an insulator, such as plastic to prevent the charges from moving from one wire to the other. The insulator also prevents the charges from moving to other objects outside of the wire.

▲ **Figure 4.8** The electrical cords of most appliances and electrical tools are made of a conductor that is covered by an insulator.

LEARNING CHECK

1. Name the type of charge that can move only in a solid.
2. Use a t-chart to compare a conductor and an insulator.
3. Explain why electrical wires are covered by an insulator.

Inquiry Focus

Activity 4.5

CONDUCTORS OR INSULATORS?

You will use a conductivity meter to test materials and find out if they are conductors or insulators. Many conductivity meters have two metal probes. When the meter is turned on, one probe is positive and the other is negative. When you touch the two probes to a material, the dial or digital display will tell you whether any charges are moving from one probe, through the material, and to the other probe. Numbers on the meter indicate the amount of movement of charges. Zero means that no charges are moving.

What You Need

conductivity meter

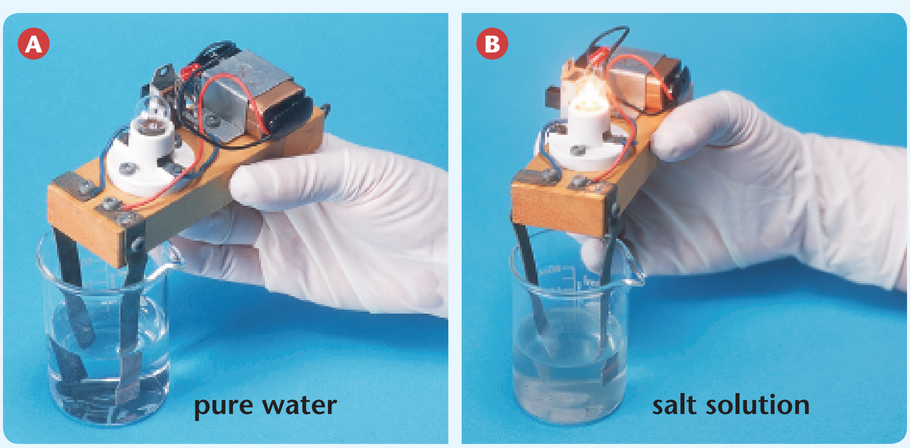
a variety of materials such as paper, glass, plastic, metal, water, salt solution, and sugar solution

What To Do

1. Make a t-chart, with the first column labelled *Material* and the second column labelled *Meter Reading*.
2. Turn on the conductivity meter. Choose a material to test its conductivity.
3. To test it, touch one probe to the material and—keeping that probe in contact—touch the other probe to the material. If the material you're testing is a liquid, put the tips of the probes in the liquid. Rinse and dry the probes before using the meter again.
4. Record the values on the meter in your t-chart for each material.
5. Make two lists. First list the materials that gave a value of zero, or very close to zero. Then list the materials that gave readings with values greater than zero.

What Did You Find Out?

1. Which materials are conductors and which are insulators? Explain how you know.
2. Which of the conductors has the greatest conductivity? The least?
3. Why might it be helpful to be able to rank the conductivity of different conductors? (Hint: Think about uses for conductors.)



The light bulb of the conductivity meter in A is not lit, so the liquid is a poor conductor. The light bulb in B is lit, so the liquid is a conductor.

Inquiry Focus

Activity 4.6

RUBBING AND STATIC ELECTRICITY

When some objects are rubbed together, static electricity is produced. How do these objects interact with each other and with objects that have not been rubbed?

What You Need

ebonite rod   fur   small pieces of paper

What To Do

1. Make a table like the one shown here to record your data.

Table of Observations: Predicted interactions between an ebonite rod, fur, and pieces of paper when the rod is rubbed with fur

Object	Ebonite Rod	Fur	Pieces of Paper
ebonite rod	X	Your prediction: Your observations:	Your prediction: Your observations:
fur		X	Your prediction: Your observations:

2. Predict what will happen when you rub the ebonite rod with the fur, and then bring the rod and fur near each other and near small pieces of paper. Record your predictions in the table.
3. Place several bits of paper on your desk.
4. Rub the ebonite rod with the fur. Then separate them.
5. Slowly move the rod close to the fur. Record your observations of the interaction between the rod and the fur.
6. Move the rod close to the pieces of paper. Record your observations of the interaction between the rod and the paper.
7. Rub the ebonite rod with the fur again. Move the fur close to the pieces of paper. Record your observations of the interaction between the fur and the paper.

What Did You Find Out?

1. How did your predictions compare with your observations?
2. Imagine any situation in which you bring two charged objects (one positively charged and one negatively charged) near each other. Predict what would happen in such a situation. Record your prediction in the form of a statement.
3. Imagine any situation in which you bring a charged object near an uncharged (electrically neutral) object. Predict what would happen in such a situation. Record your prediction in the form of a statement.

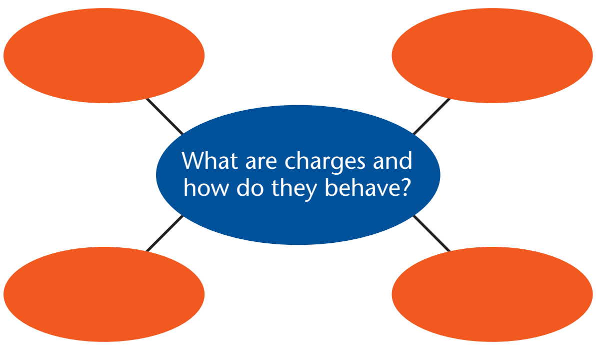
Topic 4.2 Review

Key Concept Summary

- Negative charges are electrons, and positive charges are protons.
- Opposite charges attract each other, and like charges repel each other.
- Negative charges can move through some materials but not others.

Review the Key Concepts

1. **K/U** Answer the question that is the title of this topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words.



2. **K/U** Use a Venn diagram to compare the similarities and differences between negative charges and positive charges. Include how these charges are related to the parts of an atom.

3. **K/U** Define "insulators" and "conductors", and provide some common examples of each.

4. **C** In your notebook, draw and label a diagram of an electrically neutral balloon. Write a caption for your diagram, describing an electrically neutral object.

5. **C** Refer to **Figure 4.8B**. In your notebook, draw and label a sketch showing the cross section of an electrical cord. Indicate the part of the cord that is a conductor and the part that is an insulator.

6. **C** Using words or diagrams, explain what happens to the positive and negative electric charges when you rub two different materials.

7. **T/I** Refer to "The Law of Electric Charge" box on page 256. Copy the table into your notebook. (Do not write in your textbook.)

a) Complete Row 3 of the table.

b) Complete Row 4 of the table.

Summarizing the Law of Electric Charge

Row 1			
Row 2	− −	+ −	+ +
Row 3	The two objects repel each other.		
Row 4			Objects with like charges repel each other.

8. **A** Air purifiers rid the air of impurities and airborne irritants. Air purifiers can filter out smoke, mould, pollen, pet dander, and some viruses that can damage your lungs and immune system. One type of air purifier is called an electrostatic purifier. Electrostatic purifiers draw air into a home by means of a fan. The particles in the air pass by a series of electrical wires. The particles become charged when they pass by these wires. The air and the charged particles then pass over several metal plates. The metal plates carry the opposite charge. Based on this information and your understanding of the law of electric charge, draw a diagram showing how you think an electrostatic air purifier removes impurities from the air entering a home.

Investigation 4B

Skill Check

Initiating and Planning

✓ **Performing and Recording**

✓ **Analyzing and Interpreting**

Communicating

Safety

- Handle the glass rod carefully.
- Do not use a chipped or broken glass rod.

What You Need

support stand
iron ring
invisible tape
plastic comb
acetate strip
glass rod
ebonite rod
polyethylene
fur
wool

Charging Materials

In this Investigation, you will test several different materials for their ability to become charged. As well, you will learn another way to charge certain materials.

What To Do

1. Fold over a 5 mm “handle” on a 10 cm piece of invisible tape, and stick it to your desk. Do the same with a second piece of tape, and stick it beside the first.
2. Hold the two pieces of tape by their handles. Then quickly pull the pieces of tape off the desk, and hold the two pieces close together. Record your results.

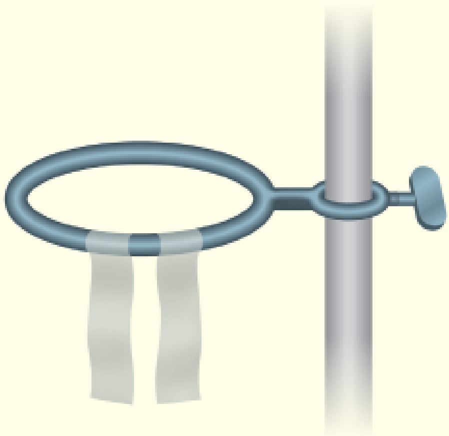
3. Make a table like the one below to record your results.

Table of Observations: Interaction of objects with charged invisible tape

Object	Tape 1	Tape 2
glass rod rubbed with polyethylene		
ebonite rod rubbed with fur		
plastic comb rubbed with wool		
finger		

4. Repeat step 2, but place the second piece of tape *on top* of the first piece of tape.

5. Quickly pull both pieces of tape off the desk, and then pull them apart.
6. Stick the two pieces of tape on the iron ring, so that they hang a short distance apart.



7. Rub the glass rod with polyethylene. Bring the rod close to one of the pieces of tape. Record your results.
8. Bring the rod close to the other piece of tape. Record your results.
9. Repeat steps 7 and 8 with the ebonite rod rubbed with fur and the plastic comb rubbed with wool.
10. Bring your finger close to one of the pieces of tape. Record your results.
11. Bring your finger close to the other piece of tape. Record your results.

What Did You Find Out?

1. Use the law of electric charge to describe the charges on the tape in step 2.
2. Use the law of electric charge to describe the charges (same or opposite) on:
   - **a)** the two pieces of tape and the glass rod rubbed with polyethylene.
   - **b)** the two pieces of tape and the ebonite rod rubbed with fur
   - **c)** the two pieces of tape and the plastic comb rubbed with wool
   - **d)** the two pieces of tape and your finger
3. Did any of the materials attract both pieces of tape? Explain this result.
4. Did any of the materials repel both pieces of tape? Explain this result.