KEY CONCEPT

Materials can become electrically charged.

VOCABULARY
- electric charge p. 342
- electric field p. 342
- static charge p. 343
- induction p. 345

BEFORE, you learned
- Atoms are made up of particles called protons, neutrons, and electrons
- Protons and electrons are electrically charged

NOW, you will learn
- How charged particles behave
- How electric charges build up in materials
- How static electricity is used in technology

EXPLORE Static Electricity

How can materials interact electrically?

PROCEDURE

1. Hold the newspaper strips firmly together at one end and let the free ends hang down. Observe the strips.
2. Put the plastic bag over your other hand, like a mitten. Slide the plastic down the entire length of the strips and then let go. Repeat several times.
3. Notice how the strips of paper are hanging. Describe what you observe.

WHAT DO YOU THINK?
- How did the strips behave before step 2?
- How did they behave after step 2?
- How might you explain your observations?

Electric charge is a property of matter.

You are already familiar with electricity, static electricity, and magnetism. You know electricity as the source of power for many appliances, including lights, tools, and computers. Static electricity is what makes clothes stick together when they come out of a dryer and gives you a shock when you touch a metal doorknob on a dry, winter day. Magnetism can hold an invitation or report card on the door of your refrigerator.

You may not know, however, that electricity, static electricity, and magnetism are all related. All three are the result of a single property of matter—electric charge.
The smallest unit of a material that still has the characteristics of that material is an atom or a molecule. A molecule is two or more atoms bonded together. Most of an atom’s mass is concentrated in the nucleus at the center of the atom. The nucleus contains particles called protons and neutrons. Much smaller particles called electrons move at high speeds outside the nucleus.

Protons and electrons have electric charges. Electric charge is a property that allows an object to exert an electric force on another object without touching it. Recall that a force is a push or a pull. The space around a particle through which an electric charge can exert this force is called an electric field. The strength of the field is greater near the particle and weaker farther away.

All protons have a positive charge (+), and all electrons have a negative charge (–). Normally, an atom has an equal number of protons and electrons, so their charges balance each other, and the overall charge on the atom is neutral.

Particles with the same type of charge—positive or negative—are said to have like charges, and particles with different charges have unlike charges. Particles with like charges repel each other, that is, they push each other away. Particles with unlike charges attract each other, or pull on each other.

**Electric Charge**

Charged particles exert forces on each other through their electric fields.

** Charged Particles **

Electric charge can be either negative or positive.

1. **Attraction**
   - Particles with unlike charges attract—pull on each other.

2. **Repulsion**
   - Particles with like charges repel—push each other away.

* = electron
+ = proton
--- = lines of force

How do the force lines change when particles attract?
Static charges are caused by the movement of electrons.

You have read that protons and electrons have electric charges. Objects and materials can also have charges. A static charge is a buildup of electric charge in an object caused by the presence of many particles with the same charge. Ordinarily, the atoms that make up a material have a balance of protons and electrons. A material develops a static charge—or becomes charged—when it contains more of one type of charged particle than another.

If there are more protons than electrons in a material, the material has a positive charge. If there are more electrons than protons in a material, it has a negative charge. The amount of the charge depends on how many more electrons or protons there are. The total number of unbalanced positive or negative charges in an object is the net charge of the object. Net charge is measured in coulombs (KOO-LAHMZ). One coulomb is equivalent to more than $10^{19}$ electrons or protons.

Electrons can move easily from one atom to another. Protons cannot. For this reason, charges in materials usually result from the movement of electrons. The movement of electrons through a material is called conduction. If electrons move from one atom to another, the atom they move to develops a negative charge. The atom they move away from develops a positive charge. Atoms with either a positive or a negative charge are called ions.

A static charge can build up in an uncharged material when it touches or comes near a charged material. Static charges also build up when some types of uncharged materials come into contact with each other.

Charging by Contact

When two uncharged objects made of certain materials—such as rubber and glass—touch each other, electrons move from one material to the other. This process is called charging by contact. It can be demonstrated by a balloon and a glass rod, as shown below.
A Van de Graaff generator is a device that builds up a strong static charge through contact. This device is shown at left. At the bottom of the device, a rubber conveyor belt rubs against a metal brush and picks up electrons. At the top, the belt rubs against metal connected to the sphere, transferring electrons to the sphere. As more and more electrons accumulate on the sphere, the sphere takes on a strong negative charge. In the photograph, the student touches the sphere as it is being charged. Some of the electrons spread across her arm to her head. The strands of her hair, which then all have a negative charge, repel one another.

How can a Van de Graaff generator make a person’s hair stand on end?

How Materials Affect Static Charging

Charging by contact occurs when one material’s electrons are attracted to another material more than they are attracted to their own. Scientists have determined from experience which materials are likely to give up or to accept electrons. For example, glass gives up electrons to wool. Wool accepts electrons from glass, but gives up electrons to rubber. The list at left indicates how some materials interact. Each material tends to give up electrons to anything below it on the list and to accept electrons from anything above it. The farther away two materials are from each other on the list, the stronger the interaction.

When you walk across a carpet, your body can become either positively or negatively charged. The type of charge depends on what materials the carpet and your shoes are made of. If you walk in shoes with rubber soles across a wool carpet, you will probably become negatively charged, because wool gives up electrons to rubber. But if you walk in wool slippers across a rubber mat, you will probably become positively charged.

<table>
<thead>
<tr>
<th>Charging by Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>skin</td>
</tr>
<tr>
<td>glass</td>
</tr>
<tr>
<td>hair</td>
</tr>
<tr>
<td>nylon</td>
</tr>
<tr>
<td>wool</td>
</tr>
<tr>
<td>fur</td>
</tr>
<tr>
<td>silk</td>
</tr>
<tr>
<td>paper</td>
</tr>
<tr>
<td>rubber</td>
</tr>
<tr>
<td>polyester</td>
</tr>
</tbody>
</table>

Materials higher on the list tend to give up electrons to materials lower on the list.
Charging by Induction

Charging can occur even when materials are not touching if one of the materials already has a charge. Remember that charged particles push and pull each other through their electric fields without touching. The pushing and pulling can cause a charge to build in another material. The first charge is said to induce the second charge. The buildup of a charge without direct contact is called induction.

Induction can produce a temporary static charge. Consider what happens when a glass rod with a negative charge is brought near a balloon, as shown below. The unbalanced electrons in the rod repel the electrons in the material of the balloon. Many electrons move to the side of the balloon that is farthest away from the rod. The side of the balloon that has more electrons becomes negatively charged. The side of the balloon with fewer electrons becomes positively charged. When the rod moves away, the electrons spread out evenly once again.

If the electrons cannot return to their original distribution, however, induction can leave an object with a stable static charge. For example, if a negatively charged rod approaches two balloons that are touching each other, electrons will move to the balloon farther from the rod. If the balloons are then separated, preventing the electrons from moving again, the balloon with more electrons will have a negative charge and the one with fewer electrons will have a positive charge. When the rod is taken away, the balloons keep their new charges.
**Charge Polarization**

Induction can build a charge by changing the position of electrons, even when electrons do not move between atoms. Have you ever charged a balloon by rubbing it on your head, and then stuck the balloon to a wall? When you bring the balloon close to the wall, the balloon’s negative charge pushes against the electrons in the wall. If the electrons cannot easily move away from their atoms, the negative charges within the atoms may shift to the side away from the balloon. When this happens, the atoms are said to be polarized. The surface of the wall becomes positively charged, and the negatively charged balloon sticks to it.

![Image of a balloon and a wall with arrows showing charge polarization](image)

1. Before the charged balloon comes near the wall, the atoms in the surface of the wall are not polarized.

2. As the balloon nears the wall, atoms in the surface of the wall become polarized and attract the balloon.

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**INVESTIGATE Making a Static Detector**

**How can you detect a static electric charge?**

**PROCEDURE**

1. Straighten one end of the paper clip and insert it through the hole in the cup. Use clay to hold the paper clip in place. Stick the ball of foil onto the straight end. Hang both foil strips from the hook end.

2. Give the balloon a static charge by rubbing it over your hair. Slowly bring the balloon near the ball of foil without letting them touch. Observe what happens to the foil strips inside the cup.

**WHAT DO YOU THINK?**

- What happened to the strips hanging inside the cup when the charged balloon came near the ball of foil?
- How can you explain what you observed?

**CHALLENGE** Suppose the balloon had the opposite charge of the one you gave it. What would happen to the strips if you brought the balloon near the ball of foil? Explain your answer.
Technology uses static electricity.

Static charges can be useful in technology. An example is the photocopy machine. Photocopiers run on electricity that comes to them through wires from the power plant. But static charges play an important role in how they work.

How a Photocopier Works

A photocopier uses static charges to make copies.

**Input** An original document goes into the copier. A bright light shines on the page.

**Inside the Copier**
The letters or images are transferred from the original to the copy, as shown in the box at right.

**Output** Heat fixes the toner to the paper, creating a permanent copy of the original.

**Why does the copy have the same pattern of light and dark areas as the original?**

1. A mirror reflects light from white areas of the original onto drum 1, which is positively charged. These lighted areas of the drum become negatively charged.

2. Negatively charged toner (powdered ink) is attracted to the positive areas of drum 1 in the pattern of the original.

3. Drum 1 rolls against a fresh, positively charged piece of paper on drum 2. The toner on drum 1 sticks to the paper.
Static electricity is also used in making cars. When new cars are painted, the paint is given an electric charge and then sprayed onto the car in a fine mist. The tiny droplets of paint stick to the car more firmly than they would without the charge. This process results in a coat of paint that is very even and smooth.

Another example of the use of static electricity in technology is a device called an electrostatic air filter. This device cleans air inside buildings with the help of static charges. The filter gives a static charge to pollen, dust, germs, and other particles in the air. Then an oppositely charged plate inside the filter attracts these particles, pulling them out of the air. Larger versions of electrostatic filters are used to remove pollutants from industrial smokestacks.

How can static charges help clean air?