Name ______________________ Class ______________ Date ____________

CHAPTER 17 Electricity

SECTION 1

# Electric Charge and Force

**KEY IDEAS**

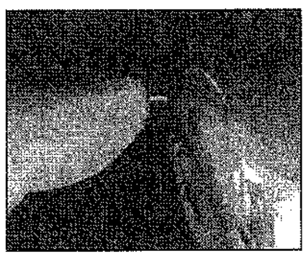
**As you read this section, keep these questions in mind:**

- What are the different kinds of electric charge?
- How do materials become electrically charged?
- How do objects behave in an electric field?

## What Is Electric Charge?

Have you ever reached for a doorknob or other metal object and received a shock? You may even have seen a flash of light that looked like a spark. This happens when electricity flows between your body and the metal object. This happens because your body and the metal object have different electric charges.

You may get a shock when you touch a doorknob because electricity flows between your body and the doorknob.



**Electric charge** is a property of an object that has a different number of protons than electrons. If the object has more electrons than protons, we say it has a *negative charge*. If it has more protons than electrons, we say it has a *positive charge*. If it has an equal number of protons and electrons, it has no electric charge, or a *neutral charge*. Most objects that you are familiar with have a neutral charge most of the time.

Electrons can carry electric charge from one object to another. When you walk across a carpet, electrons move from the carpet into your body. Therefore, your body no longer has a neutral charge. When you reach for the doorknob, electrons flow from your body to the doorknob. The moving electrons produce the shock and light. ☑

Like energy and matter, electric charge cannot be created or destroyed by ordinary chemical processes. In other words, electric charge is *conserved*. If one object loses electrons, another object must gain the same number of electrons.

**READING TOOLBOX**

**Ask Questions** As you read this section, write down questions that you have about the material you read. When you finish reading, work with a partner to figure out the answers to your questions.

**Critical Thinking**

**1. Apply Concepts** A particle contains 25 protons and 23 electrons. What type of electric charge does the particle have?

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**READING CHECK**

**2. Identify** What carries electric charge between your body and a carpet?

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## How Do Electric Charges Behave?

Look at the girl in the picture below. She rubbed the balloon against her hair. When she moves the balloon away from her hair, some of her hair sticks to the balloon. This attraction occurs because electrons have moved from her hair to the balloon. As a result, her hair has a positive charge and the balloon has a negative charge.

**LOOKING CLOSER**
**3. Explain** Why do the balloon and the girl's hair attract one another?

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The opposite charges in the girl's hair and the balloon cause her hair and the balloon to attract each other.

The behavior of the girl's hair and the balloon shows one way that two charged objects can interact. Opposite electric charges—that is, positive and negative charges—attract each other. The positive charge in the girl's hair attracts the negative charge of the balloon.

The balloons in the picture below have both been rubbed against the girl's hair. They both have a negative charge. They *repel* each other, or push each other away. Similar electric charges always repel each other.

**LOOKING CLOSER**
**4. Identify** What type of electric charge do both balloons have?

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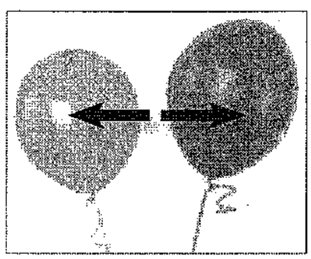

The similar charges in the two balloons cause them to repel each other.

### MEASURING ELECTRIC CHARGE

**Critical Thinking**
**5. Describe** What is the electric charge on a particle that contains two protons and one electron?

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The SI unit of electric charge is the *coulomb* (C). A proton has a charge of $+1.6 \times 10^{-19}$ C. An electron has a charge of $-1.6 \times 10^{-19}$ C. Notice that protons and electrons have the same size electric charge. However, the electron has a negative charge and the proton has a positive charge.

The charge on an electron or proton is very small. For an object to have a noticeable electric charge, it must have a large number of extra protons or electrons. For example, an object with a charge of $-1.0$ C has about $6.25 \times 10^{18}$ extra electrons.

## How Can Electrons Move Between Objects?

Remember that protons and neutrons are in the nucleus of an atom. Because they are inside the atom and are bound tightly together, they usually do not move out of the atom. However, electrons are located outside the nucleus of an atom. In many cases, electrons can easily move from one atom to another. Electrons can move more easily in some materials than in other materials. ☑

**READING CHECK**

**6. Explain** Why can electrons move between atoms more easily than protons?

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### ELECTRICAL CONDUCTORS AND INSULATORS

You have probably noticed that the cords on electric appliances, such as toasters, are plastic on the outside. However, the cord is not plastic all the way through. The wire inside the cord contains copper metal.

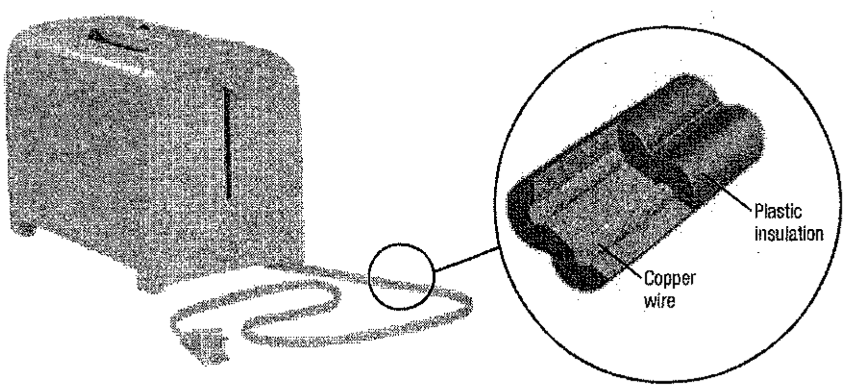
Why is the inside of the cord made of a different material than the outside of the cord? The answer has to do with how electrons flow in different materials. Electrons can flow easily through some materials. These materials are called **electrical conductors**. Copper, like most metals, is a good electrical conductor. The electricity that flows to the toaster moves through the copper easily.

Electrons cannot easily move through the plastic on the outside of the wire. Therefore, the plastic is an **electrical insulator**. The plastic prevents electrons from moving out of the wire and into objects other than the toaster.

## Talk About It

**Brainstorm** Make a list of five substances that you think are electrical conductors and five substances that you think are electrical insulators. Share your list with a small group. Explain why you think each substance is an electrical conductor or insulator.

Copper is used in wires because it is a good electrical conductor. Plastic is used on the outside of the cord because it is a good electrical insulator.




## LOOKING CLOSER

**7. Predict** Would the toaster work if the entire cord was made of plastic? Explain your answer.

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Whether a material is an electrical conductor or an electrical insulator affects what people use it for. As you've just seen, one of the reasons that people use metal for wires is because metals are electrical conductors.

## INDUCED CHARGES IN CONDUCTORS

If an object gains or loses electrons, it will have an electric charge. However, sometimes part of an object can have an electric charge, even if the whole object does not.

For example, the end of the rod in the figure below has a negative electric charge. The negative electric charge on the rod repels electrons in the doorknob. The electrons in the doorknob move away from the rod. Therefore, part of the doorknob has a slight negative charge. The other part has a slight positive charge. However, the whole doorknob does not have an electric charge, because it has not gained or lost electrons. ☑

READING CHECK

**8. Explain** How can the whole doorknob have a neutral charge, even though part of the doorknob has a positive charge and part has a negative charge?

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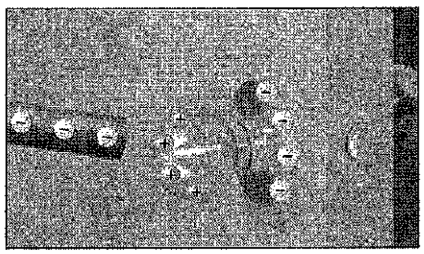

The charged rod can *induce*, or cause, parts of the doorknob to become charged.

If you moved the rod away from the doorknob, the charges on the doorknob would disappear. The charges are only there when the rod is near the doorknob. In other words, they are *induced charges*.

## CHARGES MOVING THROUGH CONTACT

If a charged object touches a neutral object, electrons can move between the objects. The neutral object can become charged. For example, in the figure below, the negatively charged rod touches the doorknob. Electrons move from the rod into the doorknob. When the rod is removed, the doorknob remains charged.

## LOOKING CLOSER

**9. Describe** After the rod touches it, does the doorknob have more electrons than protons or more protons than electrons? Explain your answer.

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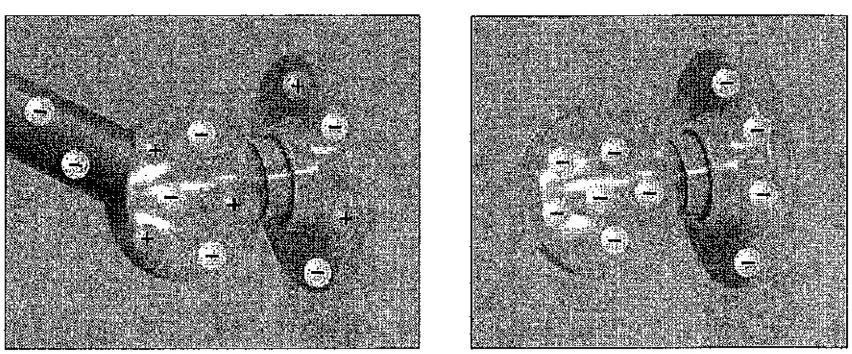

When the negatively charged rod touches the doorknob, electrons move from the rod to the doorknob. The doorknob ends up with a negative charge.

## CHARGING OBJECTS BY FRICTION

When two neutrally charged objects rub together, electrons can move from one object to the other. The direction the electrons move depends on the kinds of materials that are rubbing together. One material gains electrons and becomes negatively charged. The other material loses electrons and becomes positively charged. This is an example of *charging by friction*. Friction causes electrons to move between the objects. ☑

Have you ever pulled clothes out of the dryer and seen them stick together? They stick together because of *static electricity*. Your clothes are charged by friction when they rub against each other in the dryer. Electric charges build up on the clothes. These charges cause the clothes to stick together.

**READING CHECK**

**10. Identify** What causes electrons to move between objects that are rubbed together?

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## SURFACE CHARGES ON INSULATORS

Remember that you can induce a charge in a conductor by bringing it near a charged object. It is possible for insulators to become charged, too. However, because electrons cannot move easily through an insulator, only its surface becomes charged. ☑

When a charged object is brought near an insulator, the electrons in the molecules of the insulator move slightly. One side of a molecule becomes slightly positively charged. The other side becomes slightly negatively charged. Then, the molecule is *polarized*.

For example, the balloon in the figure below has been rubbed with wool. It has become negatively charged through friction. The negative charge on the balloon induces a positive surface charge on the stream of water. The water molecules become polarized. The positive and negative charges attract each other, causing the water to bend toward the balloon.

**READING CHECK**

**11. Explain** Why does only the surface of an insulator become charged when a charged object is near it?

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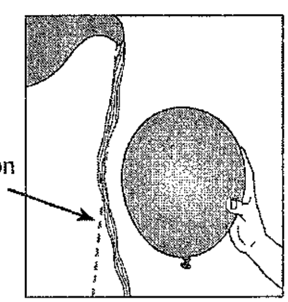
Path of water if balloon was not charged.



This balloon has been charged by friction with wool. The charge on its surface induces a surface charge on the water molecules, causing the stream of water to bend.

## LOOKING CLOSER

**12. Describe** What type of electric charge does the surface of the water molecules nearest the balloon have?

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## What Is an Electric Force?

Pushing or pulling on an object—that is, applying a force to it—can cause the object's motion to change. In a similar way, electric forces can change the motions of charged particles. An **electric force** is a force that a charged object experiences when it interacts with other charged objects. ☑

**READING CHECK**

**13. Define** What is an electric force?

Electric forces cause many things that we see every day. For example, friction is produced by electric forces between the molecules on the surfaces of objects that are touching.

Electric forces also affect things that are too small for us to see. For example, atoms bond to each other and form molecules because of electric forces. Electric forces help proteins and other molecules in our bodies interact with one another. Without electric forces, life on Earth would be impossible.

### EFFECTS OF CHARGE AND DISTANCE ON ELECTRIC FORCE

The electric force between two charged objects depends on two things. They are:

- the amount of charge each object has
- the distance between the objects ☑

**READING CHECK**

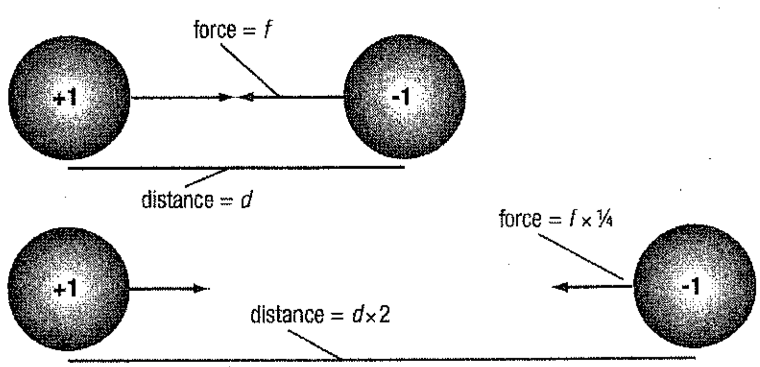
**14. Identify** What are two factors that affect the electric force between two charged objects?

The electric force between two objects is directly proportional to the charges of the objects. In other words, the greater the charges on the objects, the stronger the electric force between them.

The electric force is inversely related to the square of the distance between the objects. If the distance between the objects triples, the electric force between the object decreases by $3^2 = 9$ times. If the distance doubles, the force decreases by $2^2 = 4$ times, as shown below.

**LOOKING CLOSER**

**15. Apply Concepts** If both objects in the figure were negatively charged, in which directions would the arrows point?

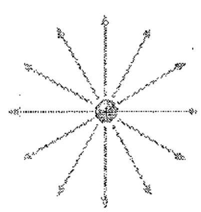


## ELECTRIC FIELDS

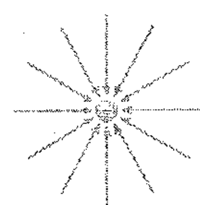
Remember that some forces can only act between objects that are touching. Other forces, such as gravity, are *field forces*—that is, they can affect objects without touching them. Electric forces are field forces. Charged objects do not have to be touching in order to produce electric forces on one another. ☑

Every charged object produces an electric field. An **electric field** is the space around a charged object that will produce an electric force on another charged object that moves into the space. We cannot see electric fields, but we can observe their effects on charged particles.

Although we cannot see electric fields, we can describe them in drawings by using electric field lines. *Electric field lines* are lines that show the effects of an electric field on a positively charged object. For example, the figures below show electric field lines around two differently charged objects.

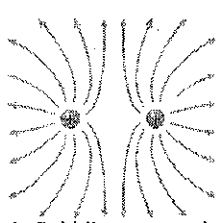


Electric field lines point away from positive charges because a positively charged object will repel another positively charged object.

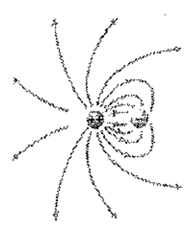


Electric field lines point toward negative charges because a negatively charged object will attract a positively charged object.

The electric field lines in the figures above show the electric fields around single charges. You can also draw electric field lines around groups of charges, as shown below.



The electric field lines around these two positively charged objects show that the objects repel each other.



The positive charge is twice as strong as the negative charge. Therefore, half the field lines that start at the positive charge end at the negative charge.

When drawing field lines, remember these rules:

- Electric field lines can never cross one another.
- Electric field lines point in the direction a positive charge would move.

**READING CHECK**

**16. Define** What is a field force?

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**LOOKING CLOSER**

**17. Explain** Why do electric field lines point away from a positively charged object?

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**LOOKING CLOSER**

**18. Explain** Why do all of the electric field lines in the image of two positively charged particles point away from the particles?

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