

# UNIT 3

# Static Electricity

## Why You Need to Know

Many processes and devices use static electricity in a productive way. Copy machines, for example, could not operate except for the principles governing static electricity. Other devices such as electronic air cleaners and paint spray operations employ static electricity. The concepts of static electricity and how it can be used or prevented are important to anyone in the electrical field. To fully understand static electricity, this unit presents

- a demonstration of electron flow and how, by adding electrons, an object is negatively charged and how, by removing electrons, an object becomes positively charged.
- an explanation of electron flow in thunderclouds and lightning. This natural element is probably the greatest example of static electricity, and in this unit you can see how it applies to the theory of positive and negative charges in nature.

## Outline

- 3-1 Static Electricity
- 3-2 Charging an Object
- 3-3 The Electroscope
- 3-4 Static Electricity in Nature
- 3-5 Nuisance Static Charges
- 3-6 Useful Static Charges

## Key Terms

- Electroscope
- Electrostatic charges
- Lightning
- Lightning arrestor
- Lightning bolts
- Lightning rods
- Nuisance static charges
- Precipitators
- Selenium
- Static
- Thundercloud
- Useful static charges

## Objectives

After studying this unit, you should be able to

- discuss the nature of static electricity.
- use an electroscope to determine unknown charges.
- discuss lightning protection.
- list nuisance charges of static electricity.
- list useful charges of static electricity.

## Preview

**S**tatic electric charges occur often in everyday life. Almost everyone has received a shock after walking across a carpet and then touching a metal object or after sliding across a car seat and touching the door handle. Almost everyone has combed their hair with a hard rubber or plastic comb and then used the comb to attract small pieces of paper or other lightweight objects. Static electric charges cause clothes to stick together when they are taken out of a clothes dryer. Lightning is without doubt the greatest display of a static electric discharge.

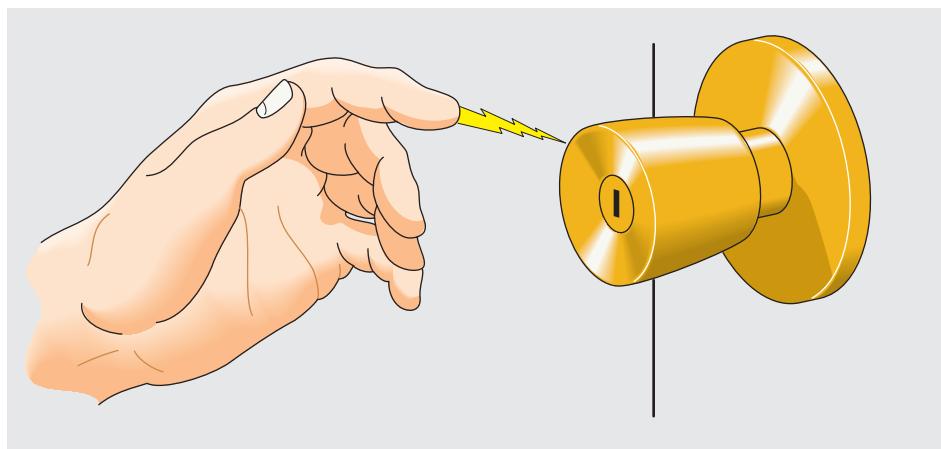
Static electricity can harm sensitive electronic components. Components subject to damage by static electricity are often packages in a special wrapping. Care should be taken when opening the packaging. It is generally a good idea to touch a grounded object to make certain that your body is discharged before handling these components. ■

### 3-1

## Static Electricity

Static electricity is caused by an imbalance of electrical charges (positive and negative). The imbalance occurs, then an object either gains or loses electrons. Objects that gain electrons exhibit a negative charge, and objects that lose electrons exhibit a positive charge. This electrical differential will exist until electrons on the negatively charged object move to the positively charged object. When the electrons are equal on each object, there will no longer be a static charge.

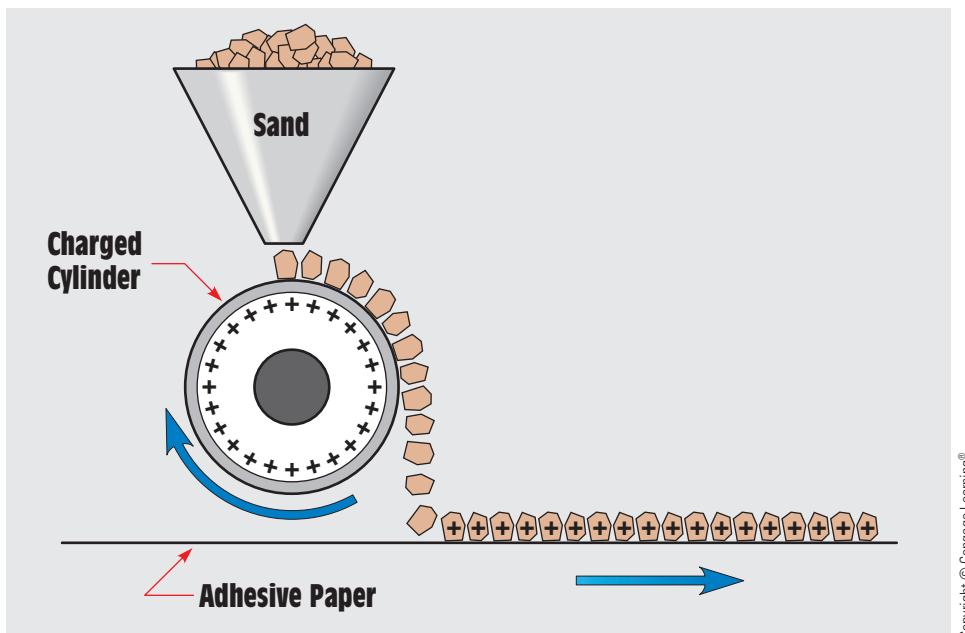
Although static charges can be a nuisance (*Figure 3-1*), or even dangerous, they can also be beneficial. Copy machines, for example, operate on the principle of static electricity. The



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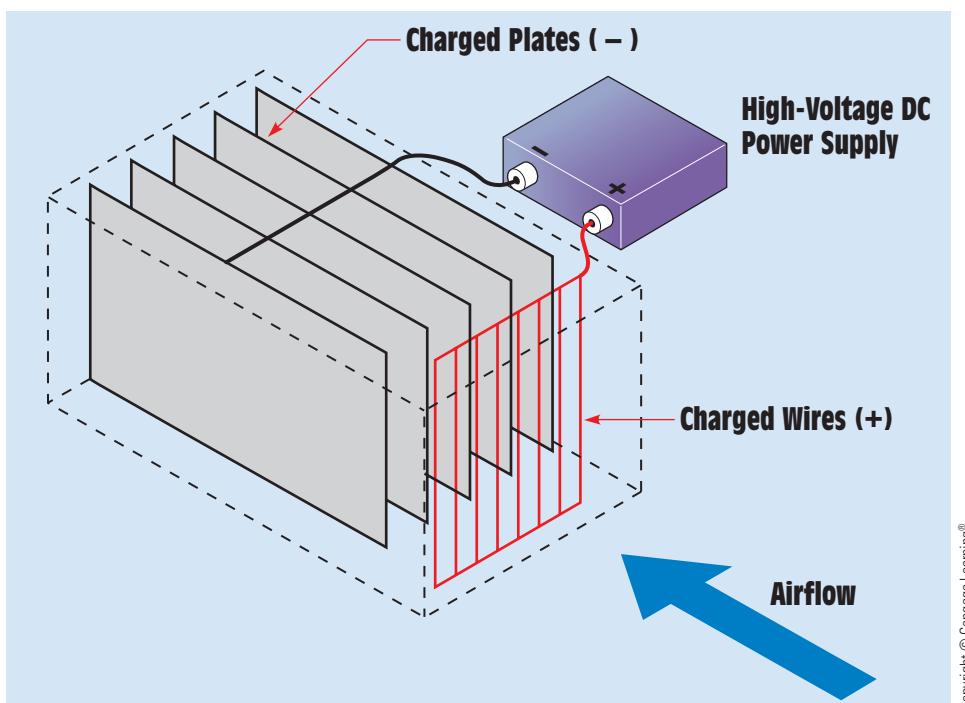
**FIGURE 3-1** Static electric charges can cause a painful shock.

manufacture of sandpaper also relies on the application of static electricity. Grains of sand receive a static charge to make them stand apart and expose a sharper edge (Figure 3–2). Electronic air filters—**precipitators**—use static charges to attract small particles of smoke, dust, and pollen (Figure 3–3). The precipitator uses a high-voltage DC power supply to provide a set of wires with a positive charge and a set of plates with a negative charge. As a blower circulates air through the unit, small particles receive a positive charge as they move



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**FIGURE 3–2** Grains of sand receive a charge to help them stand apart.



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**FIGURE 3–3** Electronic air cleaner.

across the charged wires. The charged particles are then attracted to the negative plates. The negative plates hold the particles until the unit is turned off and the plates are cleaned.

The word **static** means not moving or sitting still. Static electricity refers to electrons that are sitting still and not moving. Static electricity is therefore a charge and not a current. **Electrostatic charges** are built up on insulator materials because insulators are the only materials that can hold the electrons stationary and keep them from flowing to a different location. A static charge can be built up on a conductor only if the conductor is electrically insulated from surrounding objects. A static charge can be either positive or negative. If an object has a lack of electrons, it has a positive charge; and if it has an excess of electrons, it has a negative charge.

### 3–2

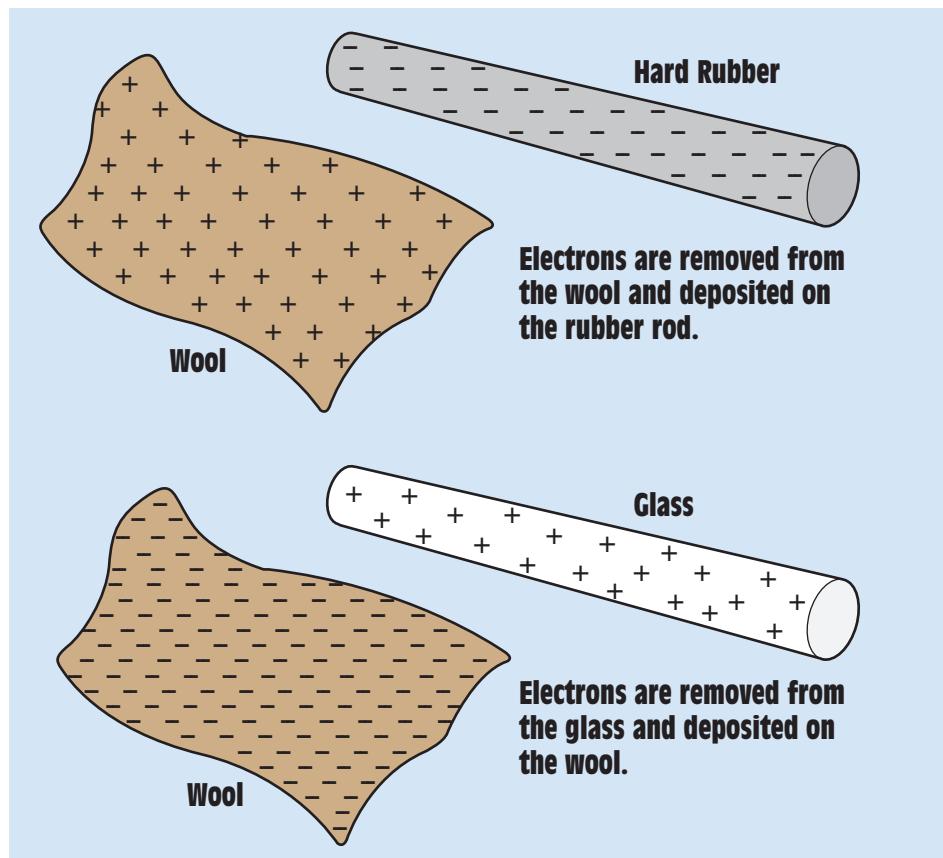
## Charging an Object

The charge that accumulates on an object is determined by the materials used to produce the charge. If a hard rubber rod is rubbed on a piece of wool, the wool deposits excess electrons on the rod and gives it a negative charge. If a glass rod is rubbed on a piece of wool, electrons are removed from the rod, thus producing a positive charge on the rod (*Figure 3–4*).

### 3–3

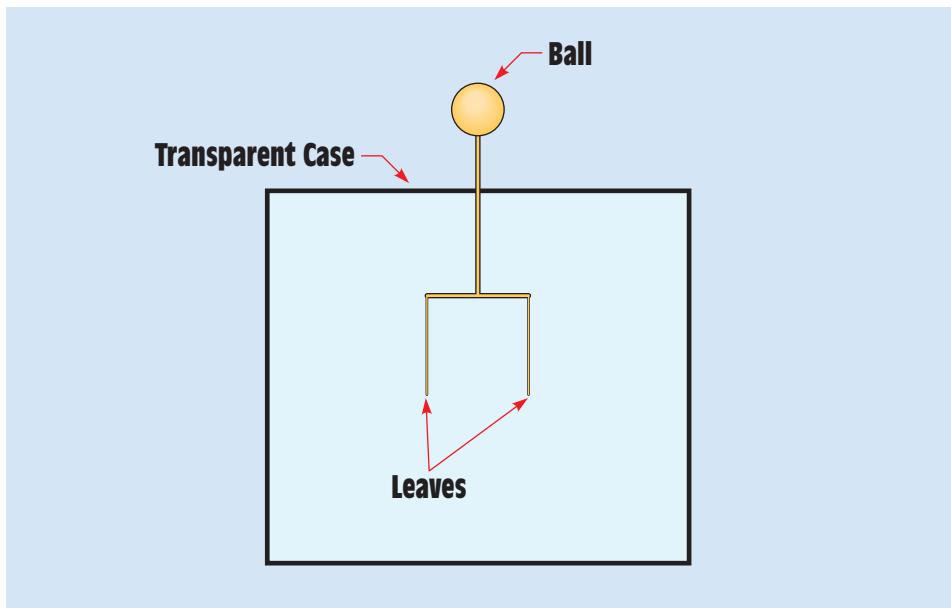
## The Electroscope

An early electric instrument that can be used to determine the polarity of the electrostatic charge of an object is the **electroscope** (*Figure 3–5*). An electroscope is a metal ball attached to the end of a metal rod. The other end of the rod is attached to two thin metal



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**FIGURE 3–4** Producing a static charge.

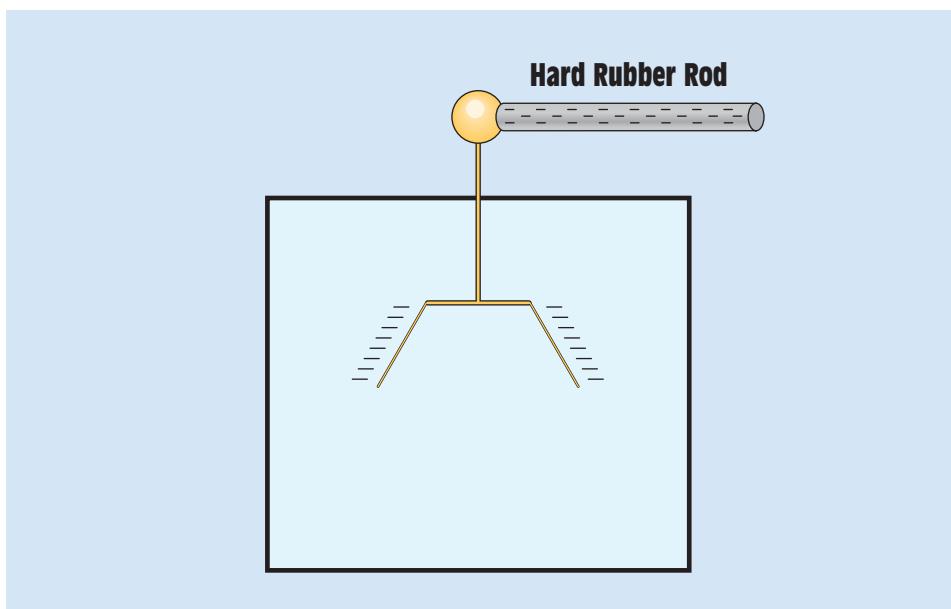


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**FIGURE 3–5** An electroscope.

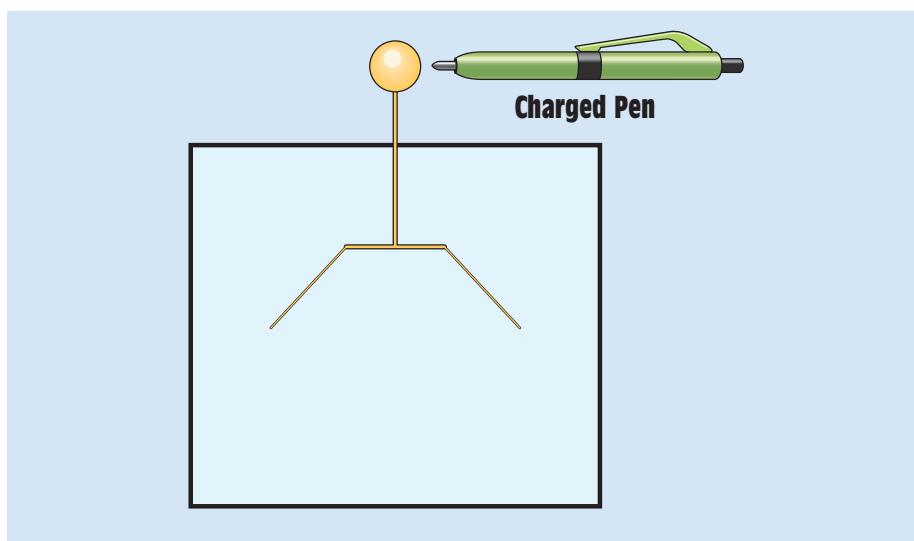
leaves. The metal leaves are inside a transparent container that permits the action of the leaves to be seen. The metal rod is insulated from the box. The metal leaves are placed inside a container so that air currents cannot affect their movement.

Before the electroscope can be used, it must first be charged. This is done by touching the ball with an object that has a known charge. For this example, assume that a hard rubber rod has been rubbed on a piece of wool to give it a negative charge. When the rubber rod is wiped against the metal ball, excess electrons are deposited on the metal surface of the electroscope. Because both of the metal leaves now have an excess of electrons, they repel each other, as shown in *Figure 3–6*.



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**FIGURE 3–6** The electroscope is charged with a known static charge.



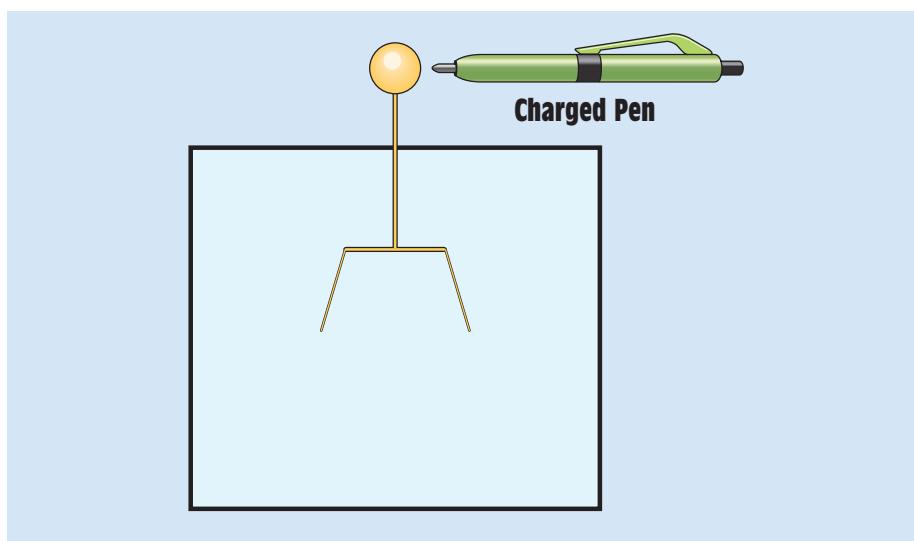
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**FIGURE 3-7** The leaves are deflected farther apart, indicating that the object has a negative charge.

### Testing an Object

A charged object can now be tested to determine whether it has a positive or negative polarity. Assume that a ballpoint pen is charged by rubbing the plastic body through a person's hair. Now bring the pen close to but not touching the ball and observe the action of the leaves. If the pen has taken on a negative charge, the leaves will move farther apart, as shown in *Figure 3-7*. The field caused by the negative electrons on the pen repels electrons from the ball. These electrons move down the rod to the leaves, causing the leaves to become more negative and to repel each other more, forcing the leaves to move farther apart.

If the pen has a positive charge, the leaves will move closer together when the pen is moved near the ball (*Figure 3-8*). This action is caused by the positive field of the pen attracting electrons. When electrons are attracted away from the leaves, they become less negative and move closer together. If the electroscope is charged with a positive charge in the beginning, a negatively charged object will cause the leaves to move closer together and a positively charged object will cause the leaves to move farther apart.



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**FIGURE 3-8** The leaves move closer together, indicating that the object has a positive charge.

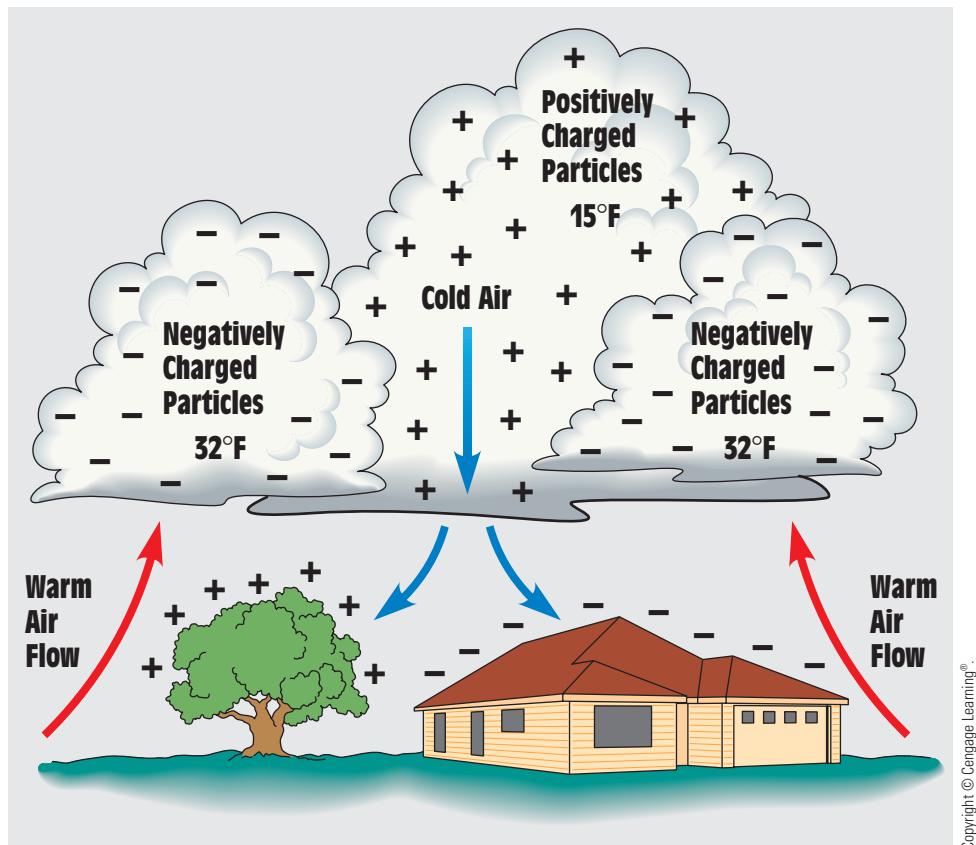
**3–4**

## Static Electricity in Nature

When static electricity occurs in nature, it can be harmful. The best example of natural static electricity is **lightning**. A static charge builds up in clouds that contain a large amount of moisture as they move through the air. It is theorized that the movement causes a static charge to build up on the surface of drops of water. Large drops become positively charged, and small drops become negatively charged. *Figure 3–9* illustrates a typical **thundercloud**. Notice that both positive and negative charges can be contained in the same cloud. Most lightning discharges, or **lightning bolts**, occur within the cloud. Lightning discharges can also take place between different clouds, between a cloud and the ground, and between the ground and the cloud (*Figure 3–10*). Whether a lightning bolt travels from the cloud to the ground or from the ground to the cloud is determined by which contains the negative and which the positive charge. Current always flows from negative to positive. If a cloud is negative and an object on the ground is positive, the lightning discharge travels from the cloud to the ground. If the cloud has a positive charge and the object on the ground has a negative charge, the discharge travels from the ground to the cloud. A lightning bolt has an average voltage of about 15,000,000 volts.

### Lightning Protection

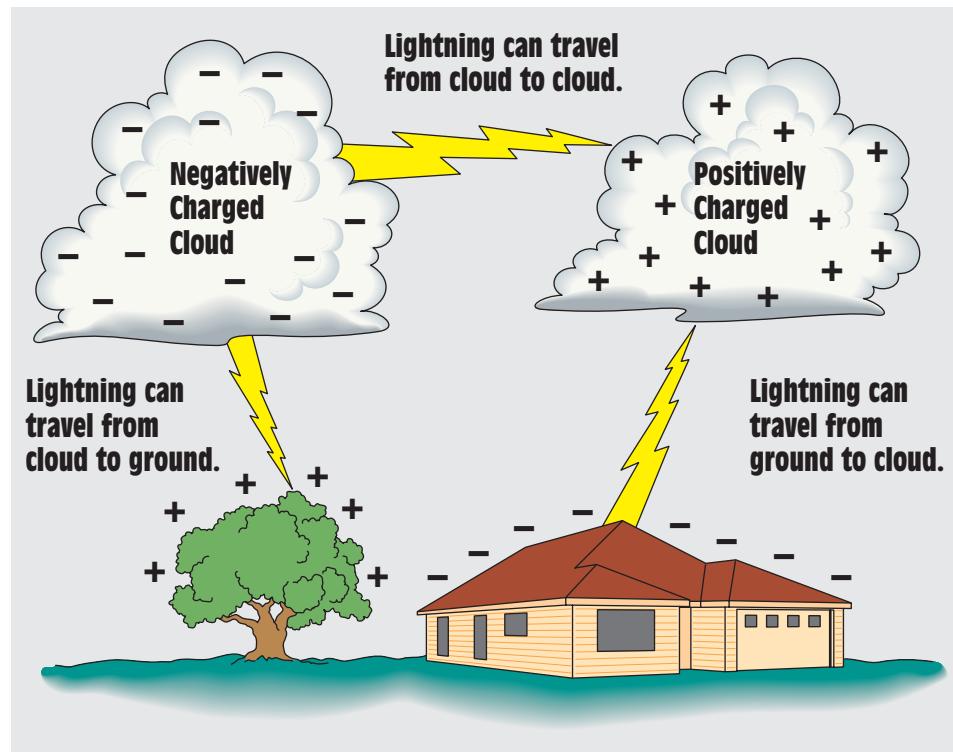
**Lightning rods** are sometimes used to help protect objects from lightning. Lightning rods work by providing an easy path to ground for current flow. If the protected object is struck by a lightning bolt, the lightning rod bleeds the lightning discharge to ground before the protected object can be harmed (*Figure 3–11*). Lightning rods were invented by Benjamin Franklin.



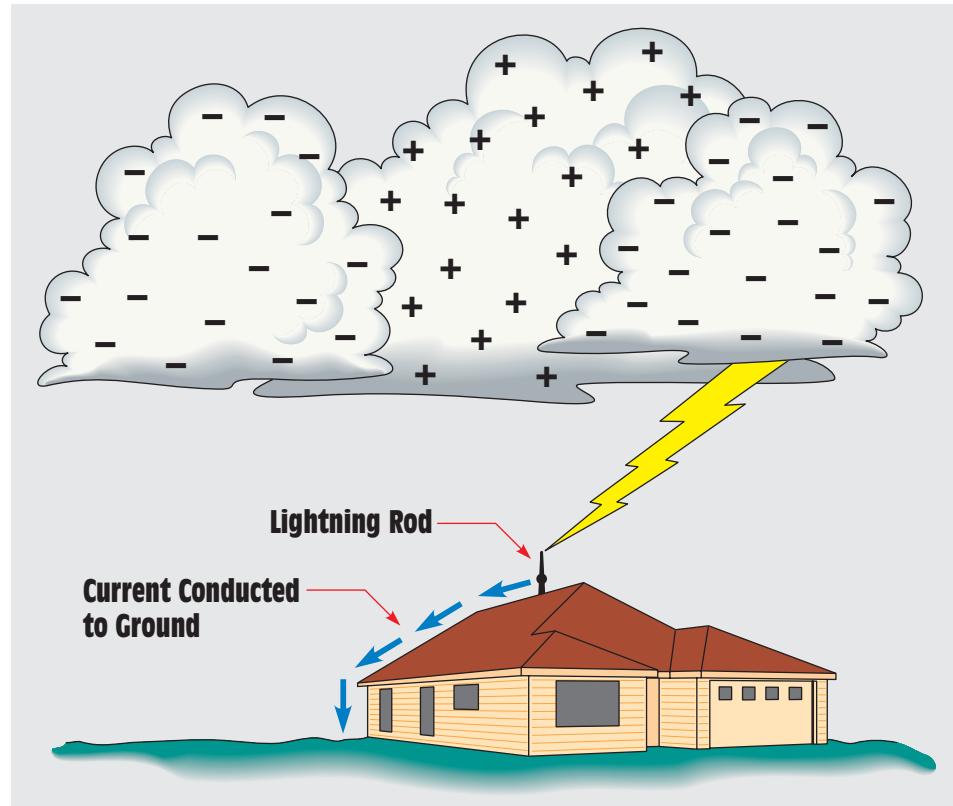
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**FIGURE 3–9** The typical thundercloud contains both negatively and positively charged particles.

## SECTION 1 Safety, Basic Electricity, and Ohm's Law



**FIGURE 3–10** Lightning travels from negative to positive.



**FIGURE 3–11** A lightning rod provides an easy path to ground.

Another device used for lightning protection is the **lightning arrestor**. The lightning arrestor works in a manner very similar to the lightning rod except that it is not designed to be struck by lightning itself and it does not provide a direct path to ground. The lightning arrestor is grounded at one end, and the other end is brought close to but not touching the object to be protected. If the protected object is struck, the high voltage of the lightning arcs across to the lightning arrestor and bleeds to ground.

Power lines are often protected by lightning arrestors that exhibit a very high resistance at the normal voltage of the line. If the power line is struck by lightning, the increase of voltage causes the resistance of the arrestor to decrease and conduct the lightning discharge to ground.

### **3-5 Nuisance Static Charges**

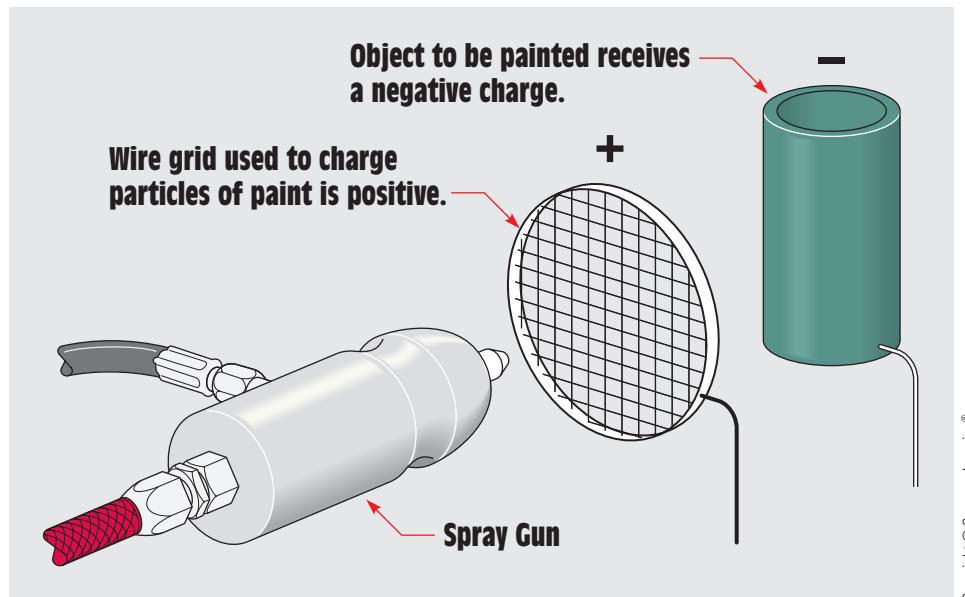
Static charges are sometimes a nuisance. Some examples of **nuisance static charges** are listed here:

1. *The static charge that accumulates on automobiles as they move through dry air.* These static charges can cause dangerous conditions under certain circumstances. For that reason, trucks carrying flammable materials such as gasoline or propane use a drag chain. One end of the drag chain is attached to the frame of the vehicle, and the other end drags the ground. The chain is used to provide a path to ground while the vehicle is moving and to prevent a static charge from accumulating on the body of the vehicle.
2. *The static charge that accumulates on a person's body as he or she walks across a carpet.* This charge can cause a painful shock when a metal object is touched and it discharges in the form of an electric spark. Most carpets are made from man-made materials that are excellent insulators such as nylon. In the winter, the heating systems of most dwellings remove moisture from the air and cause the air to have a low humidity. The dry air combined with an insulating material provides an excellent setting for the accumulation of a static charge. This condition can generally be eliminated by the installation of a humidifier. A simple way to prevent the painful shock of a static discharge is to hold a metal object, such as a key or coin, in one hand. Touch the metal object to a grounded surface, and the static charge will arc from the metal object to ground instead of from your finger to ground.
3. *The static charge that accumulates on clothes in a dryer.* This static charge is caused by the clothes moving through the dry air. The greatest static charges generally are built up on man-made fabrics because they are the best insulators and retain electrons more readily than natural fabrics such as cotton or wool.

### **3-6 Useful Static Charges**

Not all static charges are a nuisance. Some examples of **useful static charges** follow:

1. Static electricity is often used in spray painting. A high-voltage grid is placed in front of the spray gun. This grid has a positive charge. The

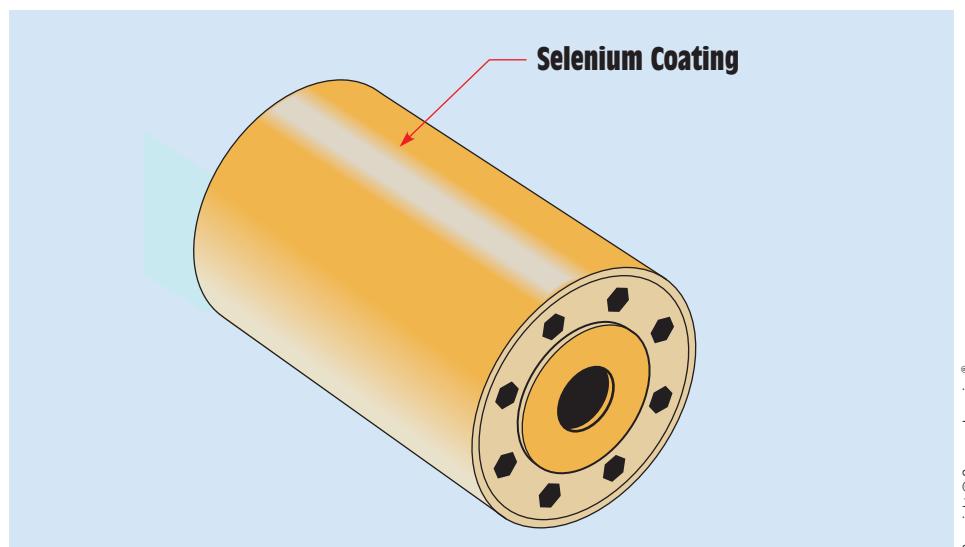


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**FIGURE 3-12** Static electric charges are often used in spray painting.

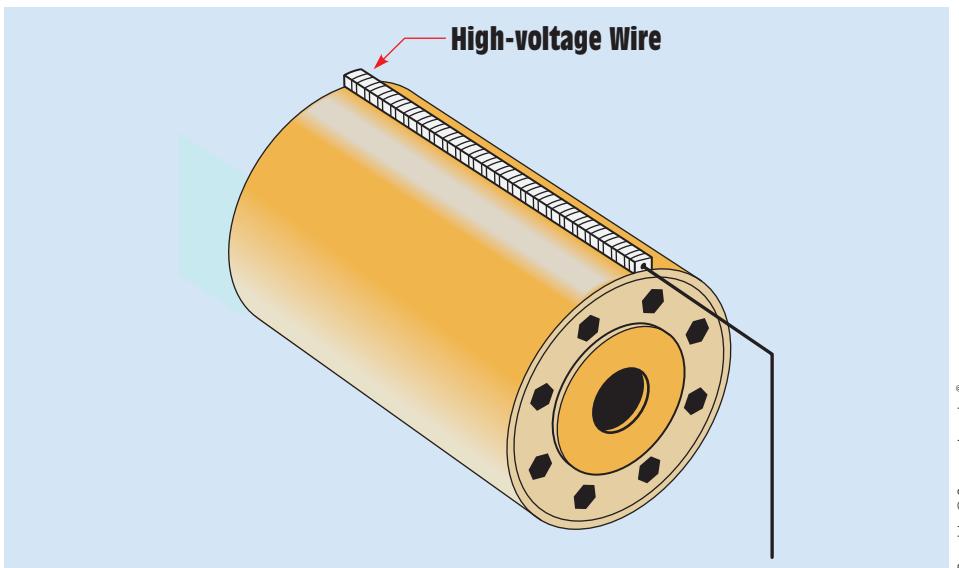
object to be painted has a negative charge (*Figure 3-12*). As the droplets of paint pass through the grid, the positive charge causes electrons to be removed from the paint droplets. The positively charged droplets are attracted to the negatively charged object. This static charge helps to prevent waste of the paint and at the same time produces a uniform finish.

2. Another device that depends on static electricity is the dry copy machine. The copy machine uses an aluminum drum coated with **selenium** (*Figure 3-13*). Selenium is a semiconductor material that changes its conductivity with a change of light intensity. When selenium is in the presence of light, it has a very high conductivity. When it is in darkness, it has a very low conductivity.

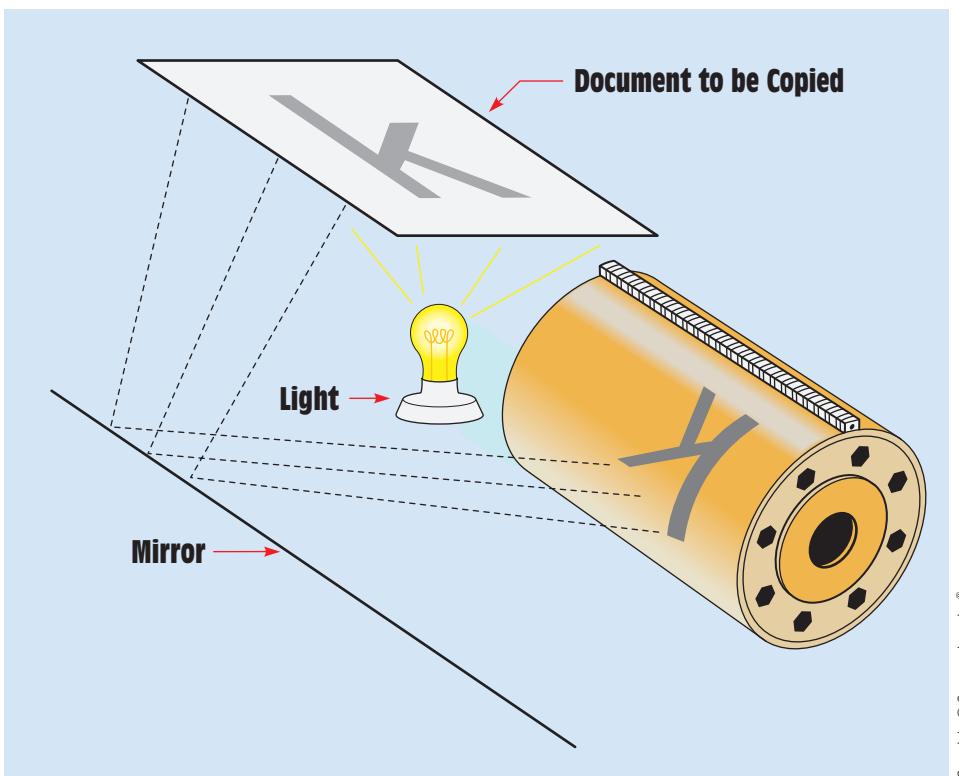


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**FIGURE 3-13** The drum of a copy machine is coated with selenium.



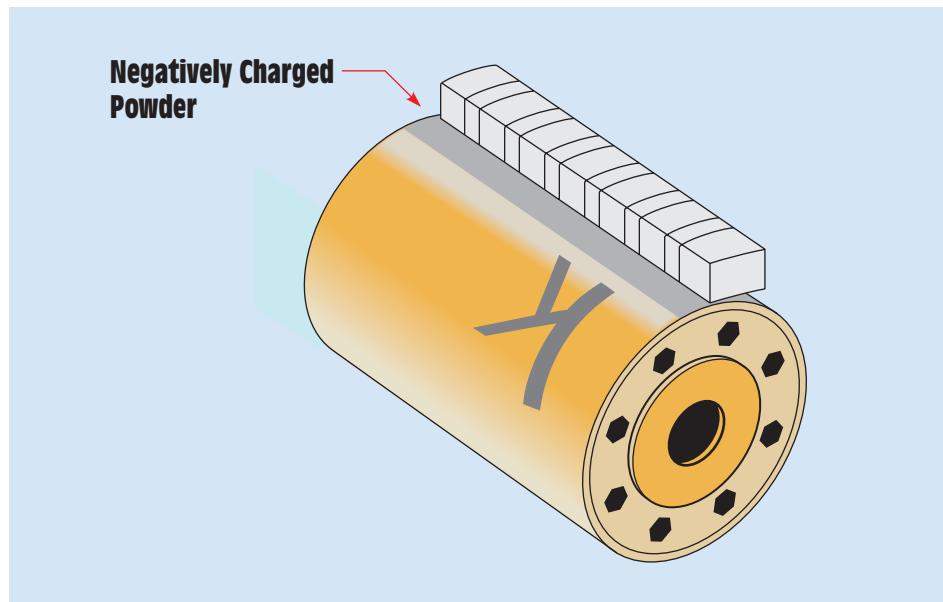
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**FIGURE 3–14** The drum receives a positive charge.

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**FIGURE 3–15** The image is transferred to the selenium drum.

A high-voltage wire located near the drum causes the selenium to have a positive charge as it rotates (*Figure 3–14*). The drum is in darkness when it is charged. An image of the material to be copied is reflected on the drum by a system of lenses and mirrors (*Figure 3–15*). The light portions of the paper reflect more light than the dark portions. When the reflected light strikes the drum, the conductivity of the selenium increases greatly, and negative electrons from the aluminum drum neutralize the



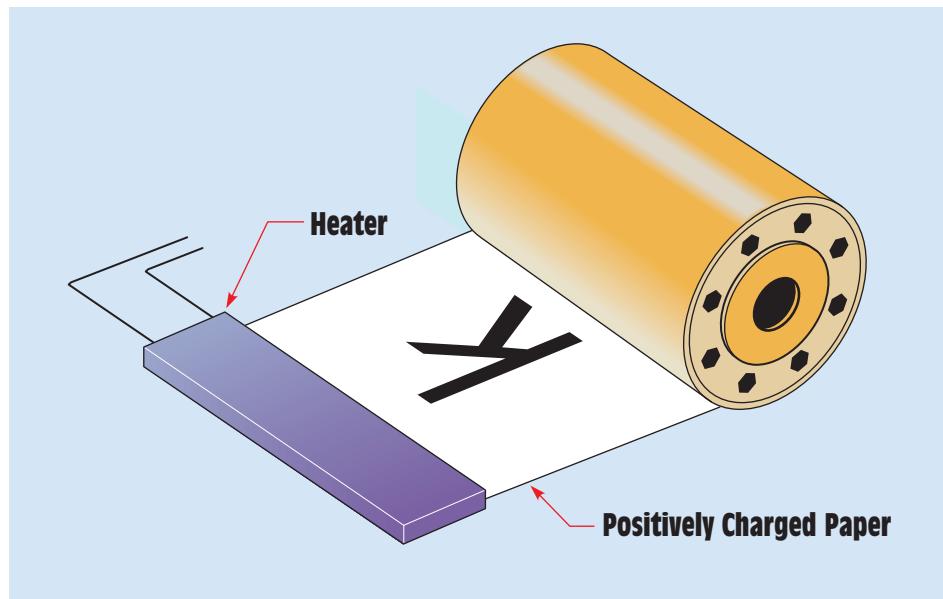
**FIGURE 3–16** Negatively charged powder is applied to the positively charged drum.

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selenium charge at that point. The dark area of the paper causes the drum to retain a positive charge.

A dark powder that has a negative charge is applied to the drum (*Figure 3–16*). The powder is attracted to the positively charged areas on the drum. The powder on the neutral areas of the drum falls away.

A piece of positively charged paper passes under the drum (*Figure 3–17*) and attracts the powder from the drum. The paper then passes under a heating element, which melts the powder into the paper and causes the paper to become a permanent copy of the original.



**FIGURE 3–17** The negatively charged powder is attracted to the positively charged paper.

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## SUMMARY

- The word *static* means not moving.
- An object can be positively charged by removing electrons from it.
- An object can be negatively charged by adding electrons to it.
- An electroscope is a device used to determine the polarity of an object.
- Static charges accumulate on insulator materials.
- Lightning is an example of a natural static charge.

## REVIEW QUESTIONS

1. Why is static electricity considered to be a charge and not a current?
2. If electrons are removed from an object, is the object positively or negatively charged?
3. Why do static charges accumulate on insulator materials only?
4. What is an electroscope?
5. An electroscope has been charged with a negative charge. An object with an unknown charge is brought close to the electroscope. The leaves of the electroscope come closer together. Does the object have a positive or a negative charge?
6. Can one thundercloud contain both positive and negative charges?
7. A thundercloud has a negative charge, and an object on the ground has a positive charge. Will the lightning discharge be from the cloud to the ground or from the ground to the cloud?
8. Name two devices used for lightning protection.
9. What type of material is used to coat the aluminum drum of a copy machine?
10. What special property does this material have that makes it useful in a copy machine?