11.6

Charging by Induction

charging by induction charging a neutral object by bringing another charged object close to, but not touching, the neutral object

You have learned that objects can be charged by conduction when they come in contact with a charged object. However, the same charged object can also be used to charge a neutral object without contact. This process is called **charging by induction**. Objects can be temporarily or permanently charged by induction.

Charging Objects Temporarily by Induction

Recall from Section 11.1 that when a charged object is brought near a neutral object it causes (induces) the electrons to shift in position, resulting in an uneven distribution of charges. This will only be temporary as the electrons will move back to their original positions once the charged object is taken away.

Figure 1 shows a negatively charged balloon that is brought near a neutral wall. The electrons in the balloon repel the electrons in the wall, causing an induced charge separation in the wall (the electrons in the wall move away from the balloon). This creates a positive charge on the surface of the wall, which the negatively charged balloon is attracted to. The result is that the balloon moves toward the wall. The wall remains neutral because it still contains the same number of positive charges as negative charges.

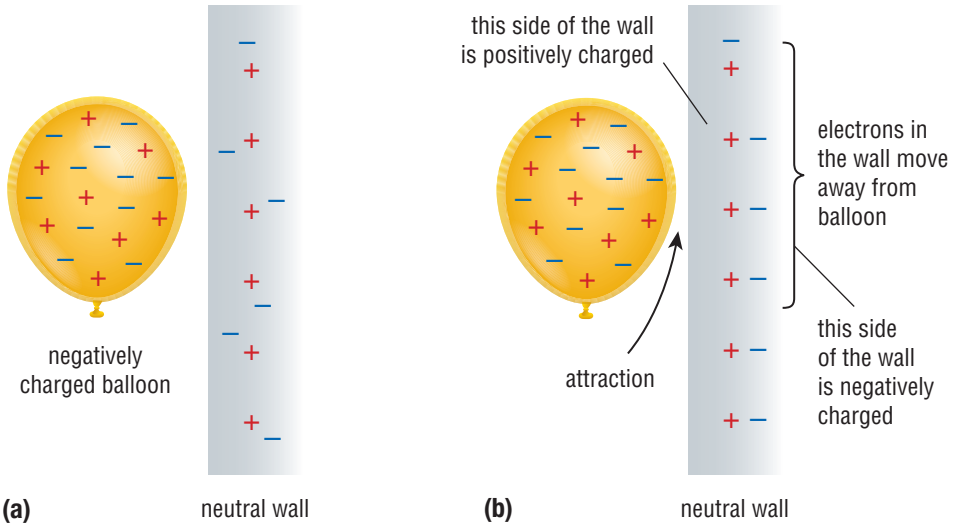

Figure 1 A negatively charged balloon (a) is brought near a neutral wall, causing an induced charge separation in the wall. (b) The wall becomes temporarily charged by induction.

An everyday example of charging by induction occurs with the buildup of dust on the screen of a television or computer monitor (Figure 2). When a computer monitor or television screen is turned on it begins to build up a charge. When a neutral dust particle comes near the screen, the charge on the screen induces an opposite charge on the near side of the dust particle and a charge, similar to that on the screen, on the far side. The result is that the dust is attracted to the screen.

Figure 2 After being charged by induction, the dust is attracted to the computer screen.

TRY THIS BENDING WATER

SKILLS: Predicting, Observing, Communicating

SKILLS HANDBOOK 3.B.3., 3.B.6., 3.B.9.

You have read about charge interactions between solid objects. In this activity, you will observe charge interactions between a solid and a liquid.

Equipment and Materials: faucet; balloon

1. Blow up the balloon.
2. Run a gentle stream of water from a faucet. Place the balloon beside, but not touching, the stream of water. Record your observations in a diagram.
3. Rub the balloon against your hair to charge it.
4. Predict what you think will happen when you bring the charged balloon near, but not touching, the stream of water. Test your predictions and use a diagram to record your observations.
5. Try moving the charged balloon to the other side of the stream of water. Does the same thing happen?

A. Does your observation from step 2 prove that both the balloon and the water are neutral? Explain. T/I

B. Use your knowledge of electrons to explain your observations in step 4. T/I

C. Predict whether it is possible to bend water away from a charged object. Explain your reasoning. T/I

Charging Objects Permanently by Induction

An object can be permanently charged by induction by grounding the object. For example, consider a negatively charged ebonite rod and a neutral pith ball. When the rod is brought near but not touching the pith ball, the electrons in the pith ball are repelled by the electrons in the rod. As a result, the side of the pith ball closest to the rod becomes temporarily positively charged, while the side farthest from the rod becomes temporarily negatively charged (Figure 3(a)). If you then ground the negatively charged side with your hand, some of the electrons travel from the pith ball into your hand, and the pith ball is left with a positive charge. You could also remove the electrons by connecting a conducting wire to the ground (Figure 3(b)). When the conducting wire is disconnected from the pith ball, the pith ball is left with a permanent positive charge (Figure 3(c)). For the charge to be permanent, the ground must be disconnected or removed before the charged object is removed.

To learn more about charging by induction,
GO TO NELSON SCIENCE

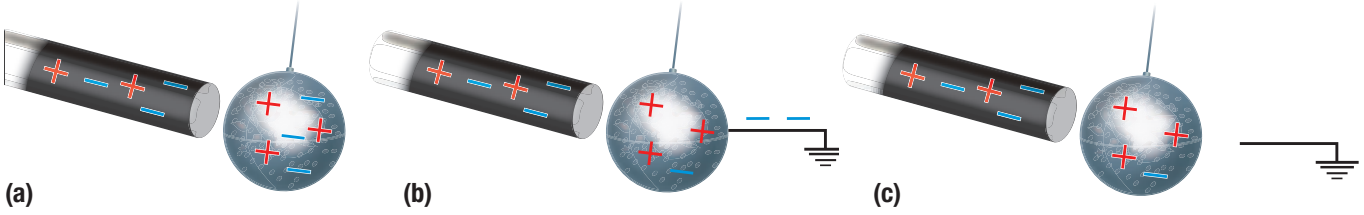

Figure 3 (a) When a negatively charged ebonite rod is brought near a neutral pith ball, the electrons in the pith ball are repelled and it becomes temporarily negatively charged on its right side. (b) Attaching a ground wire to the pith ball conducts the repelled electrons on the right side into the ground. (c) After removing the ground wire, the pith ball remains permanently positively charged.

Charging by induction always results in two objects with opposite charges. The object that induces the charge keeps its original charge, while the object whose charge was induced receives the opposite charge.

Figure 4 An electrostatic lifting apparatus is used in forensics to create a copy of a footprint from a crime scene.

To learn more about being a forensic investigator,
GO TO NELSON SCIENCE

Technological Applications of Charging by Induction

Charging by induction has many useful applications, including forensics and air-cleaning technologies.

Electrostatic Lifting Apparatus

Footprints are often left behind at crime scenes. Investigators can use this important evidence to help determine who was present at the time of the crime. But how can you make a copy of a footprint if it is very difficult to see? Investigators use an electrostatic lifting apparatus (ESLA) (Figure 4). Special film or foil is placed over the footprint. The black side of the film is placed over the footprint. The film is then electrostatically charged. The dust and dirt particles from the footprint are attracted to the black side of the film. The dust particles "jump" off the floor onto the black film, revealing the details of the footprint. Now investigators have a copy of the footprint on the film that they can take to a laboratory to analyze.

Electrostatic Speakers

Figure 5 Electrostatic loudspeakers operate on the principles of induction.

You have probably already heard the results of one application of charging by induction—that of electrostatic loudspeakers (Figure 5). These speakers are constructed of three thin layers. The outer two layers, called stators, are fixed in place and are made of a porous material. The inner layer is a flexible film called the diaphragm. In order to produce sound, the diaphragm must vibrate. This is accomplished using the principles of induction and the Law of Electric Charges. First, the inner surface is given a permanent electrical charge. Then an audio transformer is used to induce opposite charges in the two outer plates. This causes the diaphragm to move—as it is simultaneously attracted to one outer plate and repelled by the other (Figure 6(a)). The audio transformer then rapidly induces the static charges in the outer plates to reverse themselves. This causes the diaphragm to now move toward the opposite outer plate (Figure 6(b)). This reversing of charges on the outer plates happens repeatedly and at variable frequencies causing the diaphragm to rapidly vibrate back and forth between the plates, producing sound waves in the air.

Electrostatic speakers have the advantage of being extremely thin and light weight. A disadvantage is their poor bass response.

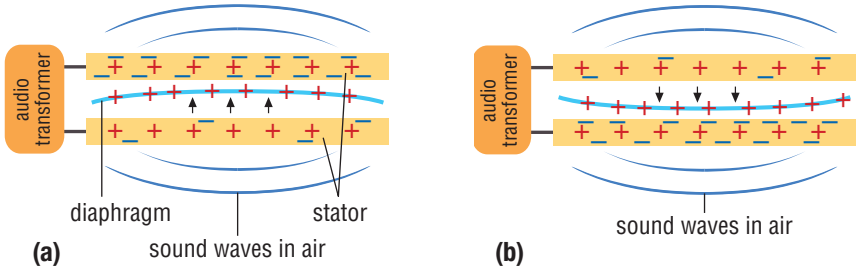

Figure 6 (a) In an electrostatic speaker, an audio transformer induces opposite electrical charges on two outer plates (stators) and then (b) reverses them. This process is repeated rapidly causing a flexible and charged inner membrane (diaphragm) to vibrate back and forth between the plates, producing sound waves in the air.

IN SUMMARY

- A temporary charge imbalance can be induced in a neutral object by bringing a charged object near it.
- Objects can be charged permanently by induction by bringing a charged object near a neutral object and then grounding the neutral object.
- Charging by induction produces a separation of charge in the object that is charged.
- Charging by induction has many applications, including electrostatic loud speakers and lifting footprints.

CHECK YOUR LEARNING

1. Identify a concept that you found particularly difficult or confusing. Have a classmate explain the concept to you. Write a brief description of the concept with your new understanding of it. Then help your classmate understand a concept he or she found challenging. K/U C
2. Copy and complete Table 1 in your notebook. Assume that the object getting charged is neutral just prior to using the charging method. K/U

Table 1 Charges on Objects

Charging method	Object doing the charging	Object getting charged	Explanation of the movement of charge
charging by induction (temporary)	positive		
charging by induction (temporary)	negative		
charging by induction (permanent)	positive		
charging by induction (permanent)	negative		

3. Use diagrams to show how you would
   (a) induce a positive, temporary charge on the right side of a metal ball
   (b) induce a permanent negative charge on a metal ball K/U C
4. Identify and explain one kind of technology that uses charging by induction. A
5. The leaves on a metal leaf electroscope repel each other even though no other objects are near it. With the use of diagrams, explain what must have happened if no charged object ever touched the electroscope. T/I C
6. (a) What would happen if you charged a balloon by rubbing it against your hair and then brought it near another balloon that is neutral? Explain. K/U
   (b) What would happen if the charged balloon were allowed to touch the neutral balloon? Explain. K/U