Lesson

12 Electricity and Magnetism

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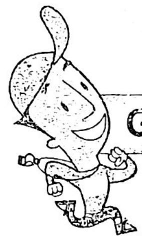


Getting the Idea

Key Words
static electricity
electric force
induction
electric discharge
magnet
magnetism
magnetic field
magnetic domains

Test Tips . . .

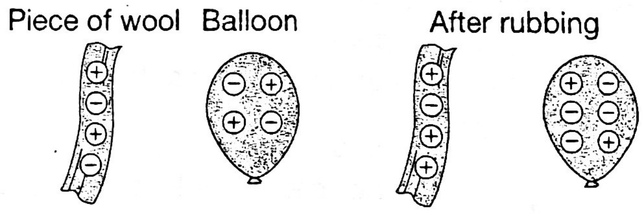
The idea that "likes repel and opposites attract" applies to both magnets and static charges. When you are studying for a test, look for ways to connect different ideas. This type of connection is known as synthesis.

Have you ever walked across a carpet, then touched a doorknob or another metal object? You might have received a shock. Why? The shock was the result of the buildup of electric charges. Why do magnets stick to your refrigerator but not to your hand? As you will find out in this lesson, the temporary or permanent buildup of charges can cause dramatic and remarkable effects. What are these types of energy, and how do they work? What other examples are part of your daily life?

Static electricity

The shock was the result of **static electricity**, the buildup of electric charges in an object. Electric charges build up when electrons are moved from one object to another. Atoms normally have no charge because the negative charge of the electrons equals the positive charge of the protons in the nucleus of the atom. If an object has extra electrons, it has a negative charge. If an object has few electrons, it has a positive charge.

Electrons can be transferred when one object rubs against another. The direction in which the electrons are transferred depends on the objects that are rubbed together. If you rub a balloon with a piece of wool cloth, friction will cause electrons to move from the cloth to the balloon. The balloon then accumulates electrons and becomes negatively charged.



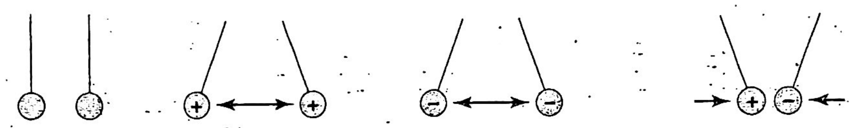
Both are neutral

The wool is positively charged.
The balloon is negatively charged.

If you rub a glass rod with a piece of silk, the silk pulls some electrons from the rod. This makes the silk negatively charged, and the rod becomes positively charged. The loss of electrons from the rod means that the rod now has more positively charged protons than negatively charged electrons. It is important to remember that only electrons are transferred. Protons do not move from one object to another in this way.

Charged objects act in predictable ways. If two negatively charged objects are brought close together, they repel one another. The same thing happens using two positively charged objects. Like charges always repel.

If a negatively charged object is brought near a positively charged object, the two objects will pull toward each other. Opposite charges attract. The force of attraction or repulsion between charged objects is called **electric force**. The area around the charged object over which the force acts is called an **electric field.**



Look closely at the diagram above. Notice that none of the objects are touching. Electrically charged objects can attract or repel other objects without the objects actually touching.

Induction

In the earlier example of the rod and the silk, charges were brought forth when the objects were rubbed together. Another way that an object can gain a charge is by induction. **Induction** is the buildup of an electric charge without direct contact. A static charge can be induced on an object by bringing a charged object close to the uncharged object. The electric field of the charged object can shift electrons in the uncharged object's atoms. This causes one side of the object to become more positively charged and the other side to become more negatively charged.

It is important to note that the object with the induced charge has not gained or lost electrons. Instead, electrons have simply moved from one part to another within the object.

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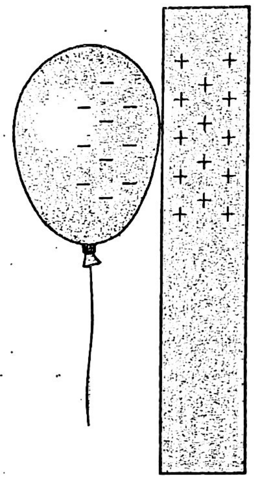
Consider a balloon. Like the plastic rod, the rubber balloon will pick up negative charges if rubbed on fur. If the charged balloon is then put against a wall, it will stick. The wood and plaster that make up walls are insulators. The balloon sticks because the charged balloon induces an opposite charge on the wall. The surface of the wall near the balloon becomes positively charged. Since opposite charges attract, the balloon sticks to the wall.



Discharge of Static Electricity

An electric charge that builds up in one object can leap to another object whose charge is opposite. As was mentioned at the start of the lesson, you have probably experienced this phenomenon when you have touched a metal object after walking across a carpeted floor. Why does this happen?

The rubbing of your shoes on the carpet built up a static electrical charge in your body. When you touched something like a doorknob, the charge jumped between your fingers and the doorknob. Sometimes you will see a spark as visual evidence of the **electric discharge** when electrons jump from the charged object to the uncharged object.

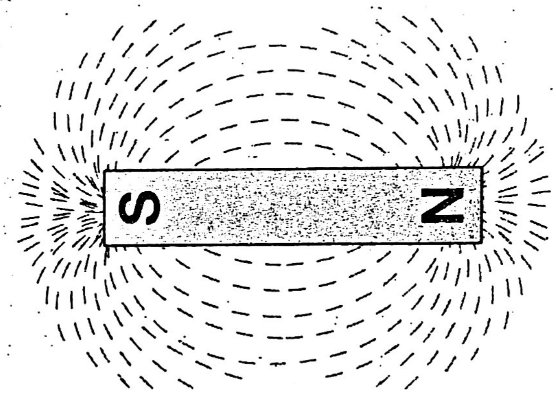
Lightning is the most powerful discharge of static electricity. Lightning is an extremely energetic spark that streaks between two oppositely charged clouds or between a cloud and the ground. Lightning strikes between them because they have opposite charges.

3

Magnetism

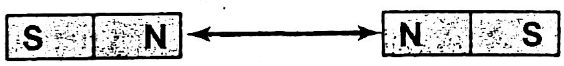
You probably have seen magnets used to hold notes on a refrigerator. A **magnet** is any polarized material made of iron, nickel, or cobalt. Magnets attract objects that are made even partially of these substances. Magnets attract steel for example because steel contains iron. Magnets do not attract other materials, such as copper or aluminum. They do not attract glass, wood, cloth, water, or most other materials.

Like electrically charged objects, magnets can exert forces of attraction or repulsion. **Magnetism** is the general term for the magnetic forces of attraction and repulsion. A magnet has a north pole and a south pole. Surrounding the magnet is a magnetic field, which is the area in which magnetic forces of attraction and repulsion act. The diagram below shows that the field is stronger near the poles of the magnet.

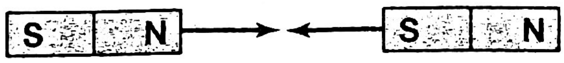


Magnetic poles behave like electric charges. Like poles repel each other; opposite poles attract each other. So if you place two north poles together, they push each other away. If you move the south pole of one magnet near the north pole of another magnet, they attract each other.

Like electric charges, magnets can exert forces even if they are not touching. Objects with opposite static charges lose their charges if they touch. Magnets, however, do not lose their magnetism if they touch. Instead, they will stick together.



Like poles repel or push away.

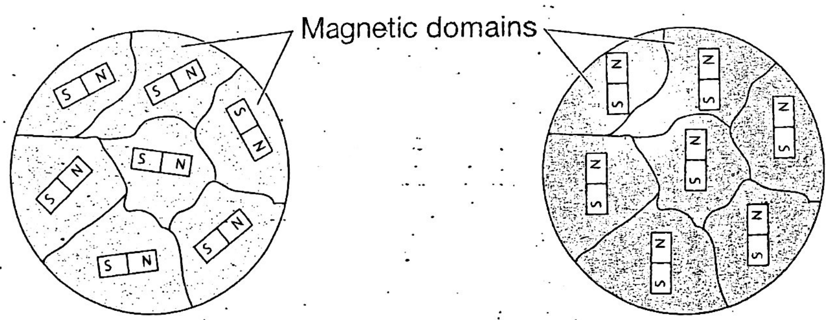


Opposite poles create an attractive force.

Magnetic Domains

Not all materials can be made into magnets. Only materials that contain magnetic domains can be magnetized. Within a **magnetic domain**, groups of atoms have their magnetic poles aligned in the same direction so the domain becomes a tiny magnet. However, the many domains are aligned in different directions, and the magnetic forces of the domains cancel each other out. This keeps the domains from exerting a magnetic force.

Rubbing iron with a magnet makes most of the unaligned domains line up. When this happens, the small magnetic forces combine, and the iron bar becomes a magnet. If the magnetism remains in the bar, it becomes a permanent magnet. Some metal alloys make very strong permanent magnets. Alnico, an alloy of aluminum, nickel, and cobalt, is an example.



Nonmagnet

Magnet

You have seen that a charged object can attract an uncharged object. Similarly, a magnet can attract certain substances, even if they are not magnets. If you hold two steel paper clips close together, they will not attract each other. But if you hold a magnet near the paper clips, the magnet will attract them. If the magnet gets close enough to them, it will pick up the paper clips.

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Magnets attract a steel paper clip by inducing the domains in the steel to align themselves temporarily. This makes the paper clip into a magnet, with its temporary poles opposite to those of the permanent magnet. Because the poles are opposite, the magnet and paper clip are attracted. The paper clip is not permanently magnetized. When the paper clip and magnet are separated, the domains in the paper clip do not remain lined up and the paper clip loses its magnetism.

DISCUSSION QUESTION

Give one example of how to put a static electrical charge on an object.

LESSON REVIEW

1. A balloon is rubbed all over with wool. The balloon will now attract the wool because

   A. the balloon and the wool are now permanent magnets.

   B. the balloon and the wool have opposite charges.

   C. the balloon and the wool have like charges.

   D. the balloon and the wool are neutral.

2. If you hold a negatively charged plastic rod up to a ball hanging on a thread, and the ball moves away from the rod, you know that the ball has

   A. no charge.

   B. no mass.

   C. a positive charge.

   D. a negative charge.

3. If you bring the north pole of a magnet near the south pole of another magnet, what will happen?

   A. They will attract each other.

   B. They will repel each other.

   C. They will do nothing.

   D. They will release a spark between them.

4. Which of these objects will be attracted to a magnet?

   A. plastic paper clips

   B. steel pins

   C. copper wire

   D. glass rod

SOUND WAVES

Sound waves transmit the energy of a vibrating object through matter in the form of longitudinal waves. In a ***longitudinal wave***, the individual particles of a medium vibrate back and forth in the direction in which the waves travel. See Figure 14.6. In air, sound waves spread out from a vibrating object in the form of a series of pressure fluctuations.

Consider a tuning fork. When a tuning fork is struck, its prongs vibrate rapidly. When a prong moves outward, the air molecules next to it are pushed closer together. This forms a region of high pressure that pushes outward in front of the prong. The prong then moves inward, thereby increasing the volume available to nearby air molecules. Air molecules spread out to fill the space and form a region of low pressure right behind the high-pressure region. The continued vibrations of the prong send out successive layers of air that are squeezed together and spread apart. When these changes in pressure come into contact with your eardrum, they cause it to vibrate with the same frequency. This is what causes the sensation of sound.

The ***wavelength*** of a sound wave is the distance from one high-pressure region to the next. The number of waves that pass a given point in a given time is called the ***wave frequency***. The unit of frequency is the hertz (Hz); 1 Hz means one wave passes a given point in one second. The human ear responds to sound waves with frequencies between 20 and 20,000 Hz. Sound waves with frequencies higher than 20,000 Hz are called *ultrasonic*. Smaller hearing organs are better suited to respond to high frequencies. Therefore, many animals whose hearing organs are smaller than those of humans can hear ultrasonic waves. That is why a dog whistle can be heard by a dog but not by a human.

The higher the wave frequency, the higher the ***pitch*** of a sound, or how high or low it sounds. A violin produces high-pitched sounds, and a cello produces low-pitched sounds. The differences in pressure between the high- and low-pressure regions in a sound wave are called its ***amplitude***. The greater the amplitude of a sound wave, the louder it sounds.

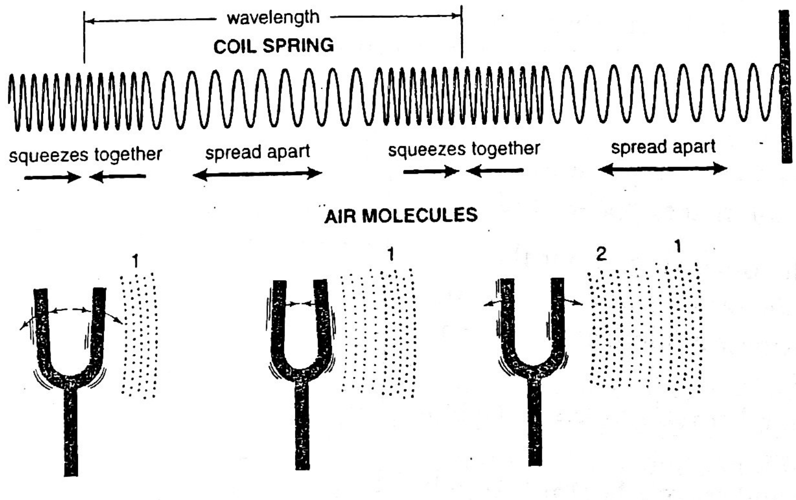

Figure 14.6
Longitudinal waves (*a*) in a coil spring and (*b*) in air around a tuning fork.

THE SPEED OF SOUND

Sound waves can travel through solids, liquids, and gases. However, they cannot travel through a vacuum because there is no matter to be squeezed together or spread apart. In air, at sea level and 0°C, sound waves travel at 331 meters per second, or 1,096 feet per second. In general, the denser and stiffer the material, the faster the sound waves travel through it. See Table 14.2. This makes sense, because density and stiffness depend on how tightly particles are packed and coupled together. The closer and more tightly coupled the particles, the more immediately they respond to one another's movements. Imagine two people with arms linked tightly together and another two people holding on to the ends of a bungee cord. If one of the persons with linked arms moves, the other moves immediately. If the person on one end of the bungee cord moves, a time lag occurs as the cord stretches out before it pulls hard enough to cause the other person to move. The greater the distance between the people, the longer the cord, the more it stretches before pulling hard enough, and the longer the time lag.

The speed of sound is also affected by temperature. Raising temperature speeds up the particles that make up matter. This, in turn, increases the speed at which pressure changes pass through the matter. Therefore, the speed of sound increases with temperature.

TRY THIS

Base your answers to the following questions on Table 14.2, which shows the speed of sound in different materials.

1. How much faster does sound travel through aluminum than through wood?
   1. 1,050 meters per second
   2. 1,150 meters per second
   3. 2,364 meters per second
   4. 8,850 meters per second

Table 14.2 The Speed of Sound in Various Substances

Material	Speed (meters per second)
Air	331
Aluminum	5,000
Carbon dioxide gas	259
Water	1,486
Wood (oak)	3,850

2. Which conclusion about the speed of sound in different materials is best made from the data table?
   1. Sound travels fastest through gases.
   2. Sound travels fastest through solids.
   3. Sound travels slowest through solids.
   4. Sound travels slowest through liquids.