SECTION 2

Magnetism from Electricity

Most of the trains you see roll on wheels on top of a track. But engineers have developed trains that have no wheels. The trains actually float above the track.

They float because of magnetic forces between the track and the train cars. Such trains are called maglev trains. The name *maglev* is short for magnetic levitation. To levitate, maglev trains use a kind of magnet called an electromagnet. Electromagnets can make strong magnetic fields. In this section, you will learn how electricity and magnetism are related and how electromagnets are made.

What You Will Learn

- Identify the relationship between an electric current and a magnetic field.
- Compare solenoids and electromagnets.
- Describe how electromagnetism is involved in the operation of doorbells, electric motors, and galvanometers.

Vocabulary

electromagnetism
solenoid
electromagnet
electric motor

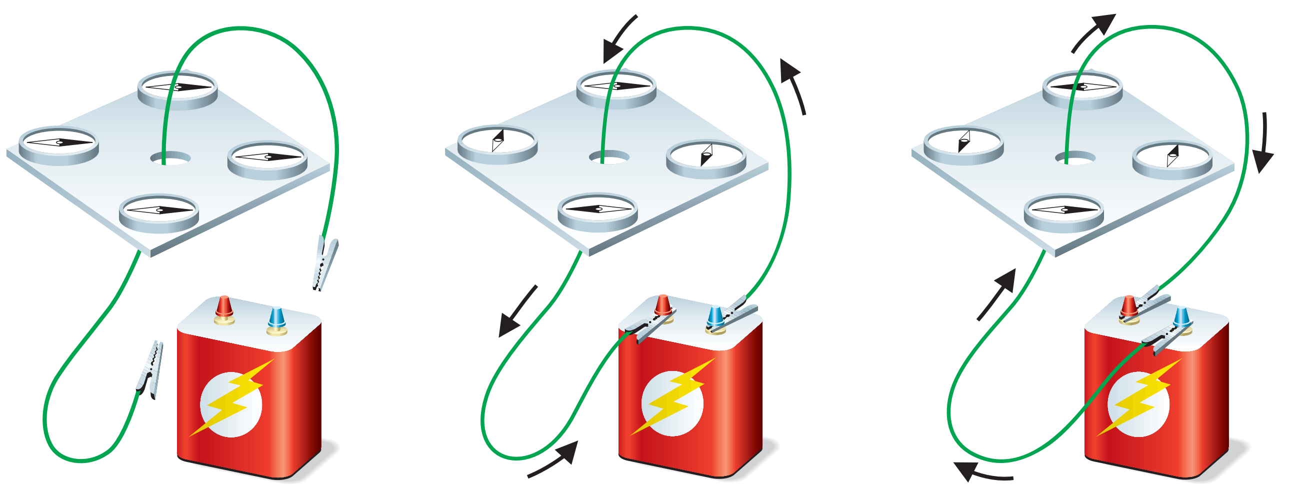
READING STRATEGY

Reading Organizer As you read this section, make a table comparing solenoids and electromagnets.

The Discovery of Electromagnetism

Danish physicist Hans Christian Oersted (UHR STED) discovered the relationship between electricity and magnetism in 1820. During a lecture, he held a compass near a wire carrying an electric current. Oersted noticed that when the compass was close to the wire, the compass needle no longer pointed to the north. The result surprised Oersted. A compass needle is a magnet. It moves from its north-south orientation only when it is in a magnetic field different from Earth's. Oersted tried a few experiments with the compass and the wire. His results are shown in **Figure 1.**

Figure 1 **Oersted's Experiment**



a If no electric current exists in the wire, the compass needles point in the same direction.

b Electric current in one direction in the wire causes the compass needles to deflect in a clockwise direction.

c Electric current in the opposite direction makes the compass needles deflect in a counterclockwise direction.

More Research

From his experiments, Oersted concluded that an electric current produces a magnetic field. He also found that the direction of the field depends on the direction of the current. The French scientist André-Marie Ampère heard about Oersted's findings. Ampère did more research with electricity and magnetism. Their work was the first research of electromagnetism. **Electromagnetism** is the interaction between electricity and magnetism.

electromagnetism the interaction between electricity and magnetism

solenoid a coil of wire with an electric current in it

Reading Check **What is electromagnetism?** (*See the Appendix for answers to Reading Checks.*)

Using Electromagnetism

The magnetic field generated by an electric current in a wire can move a compass needle. But the magnetic field is not strong enough to be very useful. However, two devices, the solenoid and the electromagnet, strengthen the magnetic field made by a current-carrying wire. Both devices make electromagnetism more useful.

Solenoids

A single loop of wire carrying a current does not have a very strong magnetic field. But suppose you form many loops into a coil. The magnetic fields of the individual loops will combine to make a much stronger field. A **solenoid** is a coil of wire that produces a magnetic field when carrying an electric current. In fact, the magnetic field around a solenoid is very similar to the magnetic field of a bar magnet, as shown in **Figure 2.** The strength of the magnetic field of a solenoid increases as more loops per meter are used. The magnetic field also becomes stronger as the current in the wire is increased.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5EMGW.**

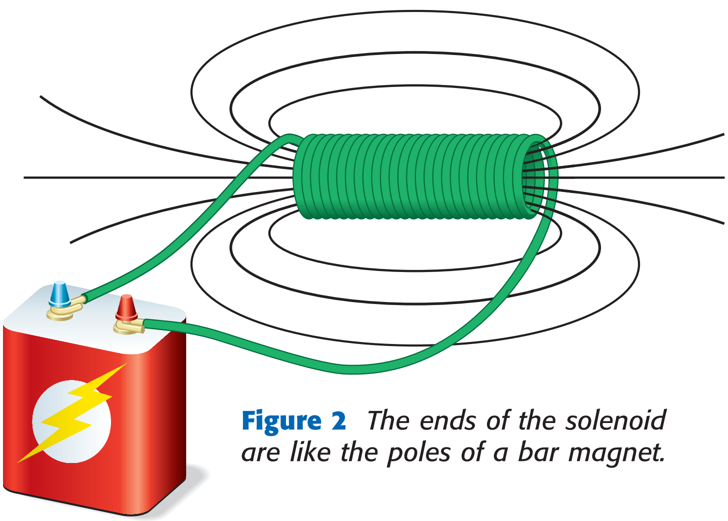


Figure 2 *The ends of the solenoid are like the poles of a bar magnet.*

Electromagnets

An **electromagnet** is made up of a solenoid wrapped around an iron core. The magnetic field of the solenoid makes the domains inside the iron core line up. The magnetic field of the electromagnet is the field of the solenoid plus the field of the magnetized core. As a result, the magnetic field of an electromagnet may be hundreds of times stronger than the magnetic field of just the solenoid.

You can make an electromagnet even stronger. You can increase the number of loops per meter in the solenoid. You can also increase the electric current in the wire. Some electromagnets are strong enough to lift a car or levitate a train! Maglev trains levitate because strong magnets on the cars are pushed away by powerful electromagnets in the rails.

Reading Check **What happens to the magnetic field of an electromagnet if you increase the current in the wire?**

Turning Electromagnets On and Off

Electromagnets are very useful because they can be turned on and off as needed. The solenoid has a field only when there is electric current in it. So, electromagnets attract things only when a current exists in the wire. When there is no current in the wire, the electromagnet is turned off. **Figure 3** shows an example of how this property can be useful.

Quick Lab

Electromagnets

1. Tightly wrap an **insulated copper wire** around a **large iron nail,** and leave 10 cm of wire loose at each end.
2. Use **electrical tape** to attach the bare ends of the wire against the top and bottom of a **D-cell.**
3. Hold the end of the nail near some **paper clips,** and try to lift them up.
4. While holding the clips up, remove the wires from the cell. Then, record your observations.
5. What advantage of electromagnets did you see?

electromagnet a coil that has a soft iron core and that acts as a magnet when an electric current is in the coil

Figure 3 *Electromagnets used in salvage yards are turned on to pick up metal objects and turned off to put them down again.*

Applications of Electromagnetism

Electromagnetism is useful in your everyday life. You already know that electromagnets can be used to lift heavy objects containing iron. But did you know that you use a solenoid whenever you ring a doorbell? Or that there are electromagnets in motors? Keep reading to learn how electromagnetism makes these things work.

Doorbells

Look at **Figure 4.** Have you ever noticed a doorbell button that has a light inside? Have you noticed that when you push the button, the light goes out? Two solenoids in the doorbell allow the doorbell to work. Pushing the button opens the circuit of the first solenoid. The current stops, causing the magnetic field to drop and the light to go out. The change in the field causes a current in the second solenoid. This current induces a magnetic field that pushes an iron rod that sounds the bell.

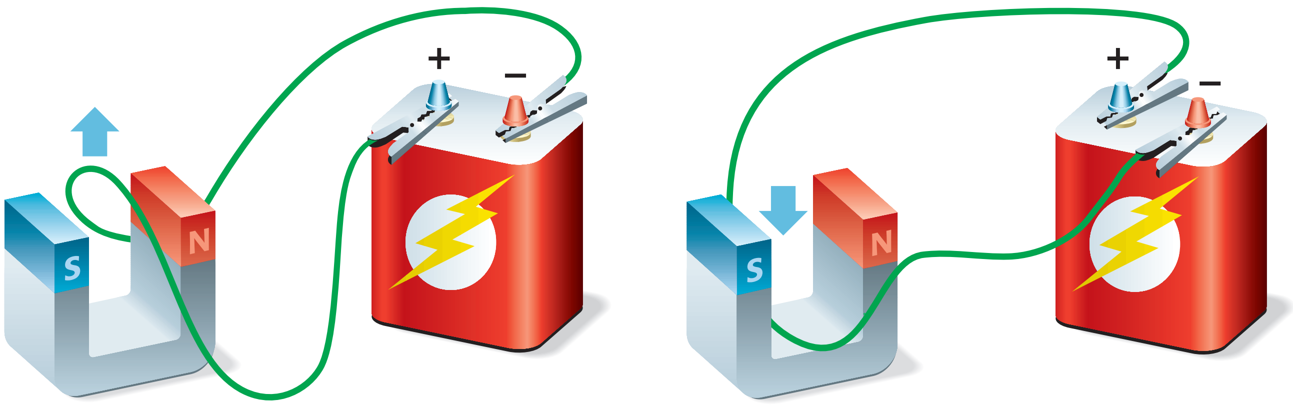
Figure 4 *Ringing this doorbell requires two solenoids.*

Magnetic Force and Electric Current

An electric current can cause a compass needle to move. The needle is a small magnet. The needle moves because the electric current in a wire creates a magnetic field that exerts a force on the needle. If a current-carrying wire causes a magnet to move, can a magnet cause a current-carrying wire to move? **Figure 5** shows that the answer is yes. This property is useful in electric motors.

Reading Check **Why does a current-carrying wire cause a compass needle to move?**

Figure 5 Magnetic Force on a Current-Carrying Wire



a When a current-carrying wire is placed between two poles of a magnet, the wire will jump up.

b Switching the wires at the battery reverses the direction of the current, and the wire is pushed down.

electric motor a device that converts electrical energy into mechanical energy

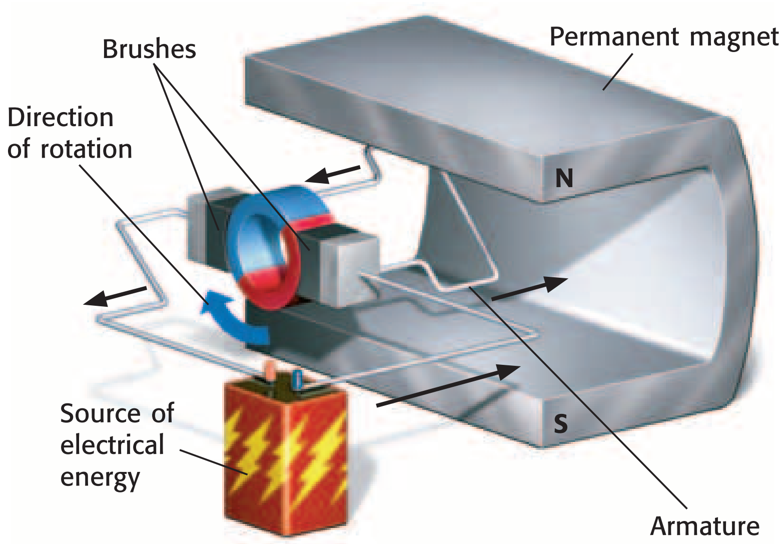
Electric Motors

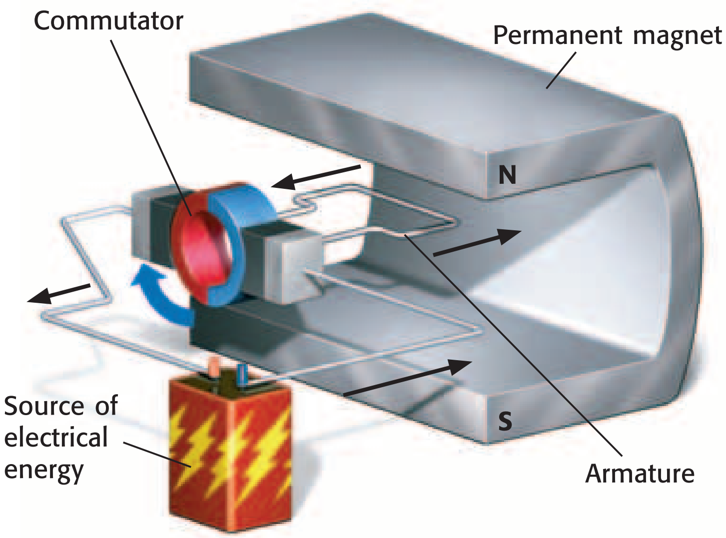
An **electric motor** is a device that changes electrical energy into mechanical energy. All electric motors have an *armature*—a loop or coil of wire that can rotate. The armature is mounted between the poles of a permanent magnet or electromagnet.

In electric motors that use direct current, a device called a *commutator* is attached to the armature to reverse the direction of the electric current in the wire. A commutator is a ring that is split in half and connected to the ends of the armature. Electric current enters the armature through brushes that touch the commutator. Every time the armature and the commutator make a half turn, the direction of the current in the armature is reversed. **Figure 6** shows how a direct-current motor works.

Figure 6 A Direct-Current Electric Motor

Getting Started An electric current in the armature causes the magnet to exert a force on the armature. Because of the direction of the current on either side of the armature, the magnet pulls up on one side and down on the other side. This pulling makes the armature rotate.





Running the Motor As the armature rotates, the commutator causes the electric current in the coil to change directions. When the electric current is reversed, the side of the coil that was pulled up is pulled down and the side that was pulled down is pulled up. This change of direction keeps the armature rotating.

Galvanometers

A galvanometer (GAL vuh NAHM uht uhr) measures current. Galvanometers are sometimes found in equipment used by electricians, such as ammeters and voltmeters, as shown in **Figure 7.** A galvanometer has an electromagnet placed between the poles of a permanent magnet. The poles of the electromagnet are pushed away by the poles of the permanent magnet. The electromagnet is free to rotate and is attached to a pointer. The pointer moves along a scale that shows the size and direction of the current.

Reading Check **What does a galvanometer measure?**

Figure 7 *This ammeter uses a galvanometer to measure electric current.*

SECTION Review

Summary

- Oersted discovered that a wire carrying a current makes a magnetic field.
- Electromagnetism is the interaction between electricity and magnetism.
- An electromagnet is a solenoid that has an iron core.
- A magnet can exert a force on a wire carrying a current.
- A doorbell, an electric motor, and a galvanometer all make use of electromagnetism.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *electromagnet* and *solenoid*

Understanding Key Ideas

2. Which of the following actions will decrease the strength of the magnetic field of an electromagnet?
   a. using fewer loops of wire per meter in the coil
   b. decreasing the current in the wire
   c. removing the iron core
   d. All of the above
3. Describe what happens when you hold a compass close to a wire carrying a current.
4. What is the relationship between an electric current and a magnetic field?
5. What makes the armature in an electric motor rotate?

Critical Thinking

6. **Applying Concepts** What do Hans Christian Oersted's experiments have to do with a galvanometer? Explain your answer.
7. **Making Comparisons** Compare the structures and magnetic fields of solenoids with those of electromagnets.

Interpreting Graphics

8. Look at the image below. Your friend says that the image shows an electromagnet because there are loops with a core in the middle. Is your friend correct? Explain your reasoning.

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