

KEY CONCEPT



Magnetism is a force that acts at a distance.

BEFORE, you learned

- A force is a push or pull
- Some forces act at a distance
- Atoms contain charged particles

NOW, you will learn

- How magnets attract and repel other magnets
- What makes some materials magnetic
- Why a magnetic field surrounds Earth

VOCABULARY

magnet p. 207
magnetism p. 208
magnetic pole p. 208
magnetic field p. 209
magnetic domain p. 210

EXPLORE Magnetism

How do magnets behave?

PROCEDURE

- 1 Clamp the clothespin on the dowel so that it makes a stand for the magnets, as shown.
- 2 Place the three magnets on the dowel. If there is a space between pairs of magnets, measure and record the distance between them.
- 3 Remove the top magnet, turn it over, and replace it on the dowel. Record your observations. Experiment with different arrangements of the magnets and record your observations.

MATERIALS

- clothespin
- wooden dowel
- 3 disk magnets
- ruler



WHAT DO YOU THINK?

- How did the arrangement of the magnets affect their behavior?
- What evidence indicates that magnets exert a force?

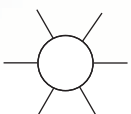
Magnets attract and repel other magnets.

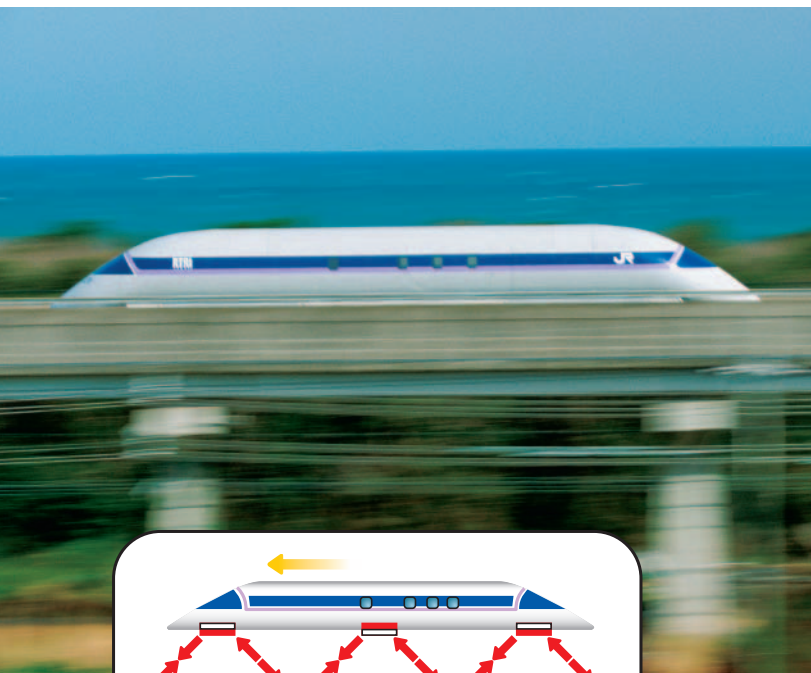
Suppose you get home from school and open the refrigerator to get some milk. As you close the door, it swings freely until it suddenly seems to close by itself. There is a magnet inside the refrigerator door that pulls it shut. A **magnet** is an object that attracts certain other materials, particularly iron and steel.

There may be quite a few magnets in your kitchen. Some are obvious, like the seal of the refrigerator and the magnets that hold notes to its door. Other magnets run the motor in a blender, provide energy in a microwave oven, operate the speakers in a radio on the counter, and make a doorbell ring.

VOCABULARY

Make a description wheel for the term *magnet*.





Magnetism

The force exerted by a magnet is called **magnetism**. The push or pull of magnetism can act at a distance, which means that the magnet does not have to touch an object to exert a force on it. When you close the refrigerator, you feel the pull before the magnet actually touches the metal frame. There are other forces that act at a distance, including gravity and static electricity. Later you will read how the force of magnetism is related to electricity. In fact, magnetism is the result of a moving electric charge.



The train is pushed up by magnets beneath it and pulled forward by magnets ahead of it.

You may be familiar with magnets attracting, or pulling, metal objects toward them. Magnets can also repel, or push away, objects. The train in the photograph at the left is called a maglev train. The word *maglev* is short for *magnetic levitation*, or lifting up. As you can see in the diagram, the train does not touch the track. Magnetism pushes the entire train up and pulls it forward. Maglev trains can move as fast as 480 kilometers per hour (300 mi/h).



How can a train operate without touching the track?



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Find out more about magnetism.

Magnetic Poles

The force of magnetism is not evenly distributed throughout a magnet. **Magnetic poles** are the parts of a magnet where the magnetism is the strongest. Every magnet has two magnetic poles. If a bar magnet is suspended so that it can swing freely, one pole of the magnet always points toward the north. That end of the magnet is known as the north-seeking pole, or north pole. The other end of the magnet is called the south pole. Many magnets are marked with an *N* and an *S* to indicate the poles.

As with electric charges, opposite poles of a magnet attract and like poles—or poles that are the same—repel, or push each other away. Every magnet has both a north pole and a south pole. A horseshoe magnet is like a bar magnet that has been bent into the shape of a *U*. It has a pole at each of its ends. If you break a bar magnet between the two poles, the result is two smaller magnets, each of which has a north pole and a south pole. No matter how many times you break a magnet, the result is smaller magnets.



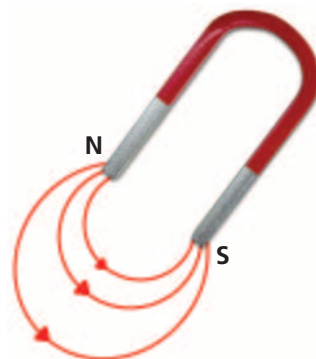
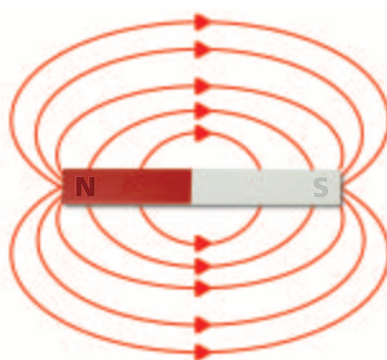
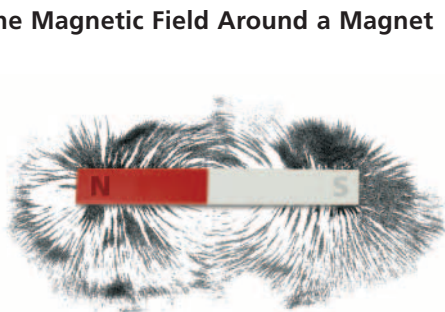
Magnetic Fields

You have read that magnetism is a force that can act at a distance. However magnets cannot exert a force on an object that is too far away. A **magnetic field** is the region around a magnet in which the magnet exerts force. If a piece of iron is within the magnetic field of a magnet, it will be pulled toward the magnet. Many small pieces of iron, called iron filings, are used to show the magnetic field around a magnet. The iron filings form a pattern of lines called magnetic field lines.

READING TIP

Thin red lines in the illustrations below indicate the magnetic field.

The Magnetic Field Around a Magnet

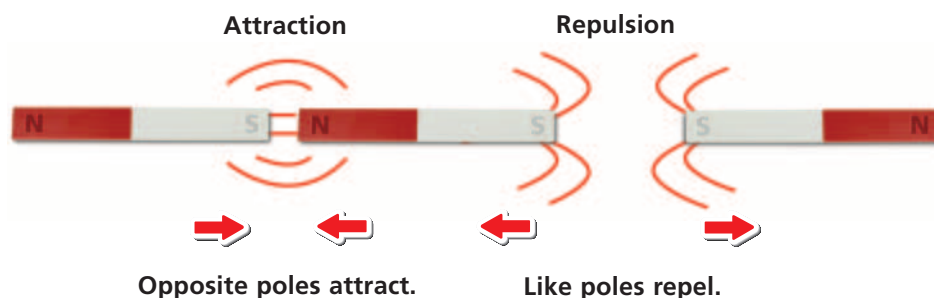


The arrangement of the magnetic field lines depends on the shape of the magnet, but the lines always extend from one pole to the other pole. The magnetic field lines are always shown as starting from the north pole and ending at the south pole. In the illustrations above, you can see that the lines are closest together near the magnets' poles. That is where the force is strongest. The force is weaker farther away from the magnet.

CHECK YOUR READING

Where is the magnetic field of a magnet the strongest?

What happens to the magnetic fields of two magnets when the magnets are brought together? As you can see below, each magnet has an effect on the field of the other magnet. If the magnets are held so that the north pole of one magnet is close to the south pole of the other, the magnetic field lines extend from one magnet to the other. The magnets pull together. On the other hand, if both north poles or both south poles of two magnets are brought near one another, the magnets repel. It is very difficult to push like poles of strong magnets together because magnetic repulsion pushes them apart.



Some materials are magnetic.

Some magnets occur naturally. Lodestone is a type of mineral that is a natural magnet and formed the earliest magnets that people used.

The term *magnet* comes from the name *Magnesia*, a region of Greece where lodestone was discovered. Magnets can also be made from materials that contain certain metallic elements, such as iron.

If you have ever tried picking up different types of objects with a magnet, you have seen that some materials are affected by the magnet and other materials are not.

Iron, nickel, cobalt, and a few other metals have properties that make them magnetic. Other materials, such as wood, cannot be made into magnets and are not affected by magnets. Whether a material is magnetic or not depends on its atoms—the particles that make up all matter.

You read in Chapter 5 that the protons and electrons of an atom have electric fields. Every atom also has a weak magnetic field, produced by the electron's motion around a nucleus. In addition, each electron spins around its axis, an imaginary line through its center. The spinning motion of the electrons in magnetic materials increases the strength of the magnetic field around each atom. The magnetic effect of one electron is usually cancelled by another electron that spins in the opposite direction.

Inside Magnetic Materials

The illustration on page 211 shows how magnets and the materials they affect differ from other materials.

- 1 In a material that is not magnetic, such as wood, the magnetic fields of the atoms are weak and point in different directions. The magnetic fields cancel each other out. As a result, the overall material is not magnetic and could not be made into a magnet.
- 2 In a material that is magnetic, such as iron, the magnetic fields of a group of atoms align, or point in the same direction. A **magnetic domain** is a group of atoms whose magnetic fields are aligned. The domains of a magnetic material are not themselves aligned, so their fields cancel one another out. Magnetic materials are pulled by magnets and can be made into magnets.
- 3 A magnet is a material in which the magnetic domains are all aligned. The material is said to be magnetized.



How do magnets differ from materials that are not magnetic?

READING TIP

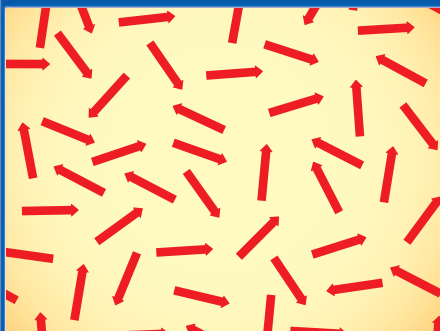
The red arrows in the illustration on page 211 are tiny magnetic fields.

How Magnets Differ from Other Materials

Magnets, and the materials they attract, contain small regions called magnetic domains. In a magnet, the domains are aligned.

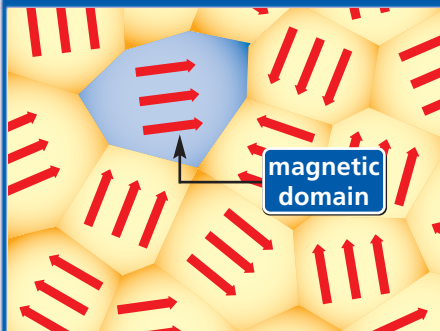


1 Nonmagnetic Materials



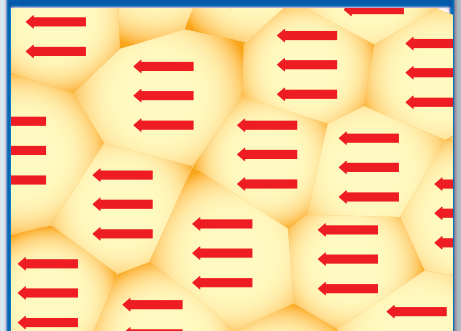
Some materials, like wood, are not magnetic. The tiny magnetic fields of their spinning electrons point in different directions and cancel each other out.

2 Magnetic Materials



Other materials, like iron, are magnetic. Magnetic materials have magnetic domains, but the fields of the domains point in different directions.

3 Magnets



When a material is magnetized, the magnetic fields of all the domains point in the same direction.

READING VISUALS

Do the paper clips in this photograph contain magnetic domains? Why or why not?

Temporary and Permanent Magnets

If you bring a magnet near a paper clip that contains iron, the paper clip is pulled toward the magnet. As the magnet nears the paper clip, the domains within the paper clip are attracted to the magnet's nearest pole. As a result, the domains within the paper clip become aligned. The paper clip develops its own magnetic field.

You can make a chain of paper clips that connect to one another through these magnetic fields. However, if you remove the magnet, the chain falls apart. The paper clips are temporary magnets, and their domains return to a random arrangement when the stronger magnetic field is removed.

Placing magnetic materials in very strong magnetic fields makes permanent magnets, such as the ones you use in the experiments in this chapter. You can make a permanent magnet by repeatedly stroking a piece of magnetic material in the same direction with a strong magnet. This action aligns the domains. However, if you drop a permanent magnet, or expose it to high temperatures, some of the domains can be shaken out of alignment, weakening its magnetism.

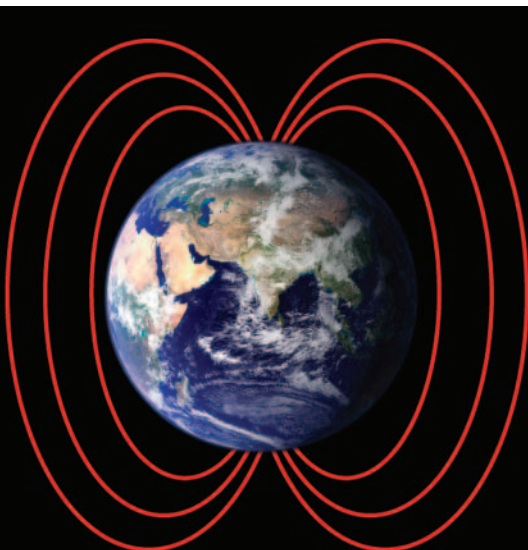


CHECK YOUR READING

How can you make a permanent magnet?

Earth is a magnet.

People discovered long ago that when a piece of lodestone was allowed to turn freely, one end always pointed toward the north. Hundreds of years ago, sailors used lodestone in the first compasses for navigation. A compass works because Earth itself is a large magnet. A compass is simply a magnet that is suspended so that it can turn freely. The magnetic field of the compass needle aligns itself with the much larger magnetic field of Earth.



Earth's Magnetic Field

The magnetic field around Earth acts as if there were a large bar magnet that runs through Earth's axis. Earth's axis is the imaginary line through the center of Earth around which it rotates. The source of the magnetic field that surrounds Earth is the motion of its core, which is composed mostly of iron and nickel. Charged particles flow within the core. Scientists have proposed several explanations of how that motion produces the magnetic field, but the process is not yet completely understood.



CHECK YOUR READING

What is the source of Earth's magnetic field?

INVESTIGATE Earth's Magnetic Field

What moves a compass needle?

PROCEDURE

- 1 Gently place the aluminum foil on the water so that it floats.
- 2 Rub one pole of the magnet along the needle, from one end of the needle to the other. Lift up the magnet and repeat. Do this about 25 times, rubbing in the same direction each time. Place the magnet far away from your set-up.
- 3 Gently place the needle on the floating foil to act as a compass.
- 4 Turn the foil so that the needle points in a different direction. Observe what happens when you release the foil.

WHAT DO YOU THINK?

- What direction did the needle move when you placed it in the bowl?
- What moved the compass's needle?

CHALLENGE How could you use your compass to answer a question of your own about magnetism?

SKILL FOCUS
Inferring



MATERIALS

- small square of aluminum foil
- bowl of water
- strong magnet
- sewing needle

TIME

15 minutes



Earth's magnetic field affects all the magnetic materials around you. Even the cans of food in your cupboard are slightly magnetized by this field. Hold a compass close to the bottom of a can and observe what happens. The magnetic domains in the metal can have aligned and produced a weak magnetic field. If you twist the can and check it again several days later, you can observe the effect of the domains changing their alignment.

Sailors learned many centuries ago that the compass does not point exactly toward the North Pole of Earth's axis. Rather, the compass magnet is currently attracted to an area 966 kilometers (600 mi) from the end of the axis of rotation. This area is known as the magnetic north pole. Interestingly, the magnetic poles of Earth can reverse, so that the magnetic north pole becomes the magnetic south pole. This has happened at least 400 times over the last 330 million years. The most recent reversal was about 780,000 years ago.

The evidence that the magnetic north and south poles reverse is found in rocks in which the minerals contain iron. The iron in the minerals lines up with Earth's magnetic field as the rock forms. Once the rock is formed, the domains remain in place. The evidence for the reversing magnetic field is shown in layers of rocks on the ocean floor, where the domains are arranged in opposite directions.

Magnetism and the Atmosphere

A constant stream of charged particles is released by reactions inside the Sun. These particles could be damaging to living cells if they reached the surface of Earth. One important effect of Earth's magnetic field is that it turns aside, or deflects, the flow of the charged particles.

Observers view a beautiful display of Northern Lights in Alaska.



Many of the particles are deflected toward the magnetic poles, where Earth's magnetic field lines are closest together. As the particles approach Earth, they react with oxygen and nitrogen in Earth's atmosphere. These interactions can be seen at night as vast, moving sheets of color—red, blue, green or violet—that can fill the whole sky. These displays are known as the Northern Lights or the Southern Lights.



CHECK YOUR READING

Why do the Northern Lights and the Southern Lights occur near Earth's magnetic poles?

7.1 Review

KEY CONCEPTS

1. What force causes magnets to attract or repel one another?
2. Why are some materials magnetic and not others?
3. Describe three similarities between Earth and a bar magnet.

CRITICAL THINKING

4. **Apply** A needle is picked up by a magnet. What can you say about the needle's atoms?
5. **Infer** The Northern Lights can form into lines in the sky. What do you think causes this effect?

CHALLENGE

6. **Infer** Hundreds of years ago sailors observed that as they traveled farther north, their compass needle tended to point toward the ground as well as toward the north. What can you conclude about the magnet inside Earth from this observation?