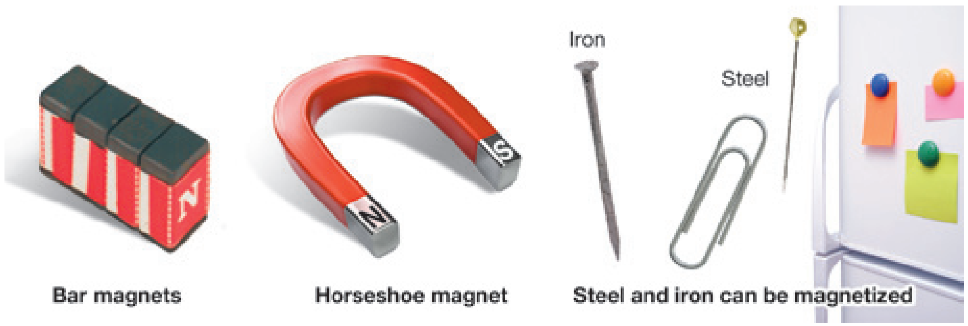
15.1 Properties of Magnets

Magnetism has fascinated people since the earliest times. We know that magnets stick to steel refrigerator doors and pick up paper clips or pins. They are also found in electric motors, computer disk drives, burglar alarm systems, and many other common devices. This chapter explains magnetic force, some of the properties of magnets, and magnetic materials.

What is a magnet?

Magnets and magnetic materials If a material is **magnetic**, it has the ability to exert forces on magnets or other magnetic materials. A refrigerator magnet is attracted to the steel in the refrigerator's door or sides. A *magnet* is a material that produces magnetism by itself. *Magnetic materials* are affected by magnets but do not produce magnetism. Iron and steel are magnetic materials that can also be made magnetic.

Permanent magnets A **permanent magnet** is a material that keeps its magnetic properties even when it is not close to other magnets. Bar magnets, refrigerator magnets, and horseshoe magnets are good examples of permanent magnets.



Poles The location on a magnet where the magnetic field is the strongest is called a **magnetic pole**. All magnets have two opposite magnetic poles, called the north pole and south pole. If a magnet is cut in half, each half will have its own north and south poles (Figure 15.1). It is impossible to have only a north or south pole by itself. The north and south poles are like the two sides of a coin. You cannot have a one-sided coin, and you cannot have a north magnetic pole without a south magnetic pole.

magnetic - the ability to exert forces on magnets or other magnetic materials

permanent magnet - a material that retains its magnetic properties even when no external energy is supplied

magnetic pole - north or south; one of the two opposite places on a magnet where the magnetic field is the strongest; all magnets have at least one north pole and one south pole

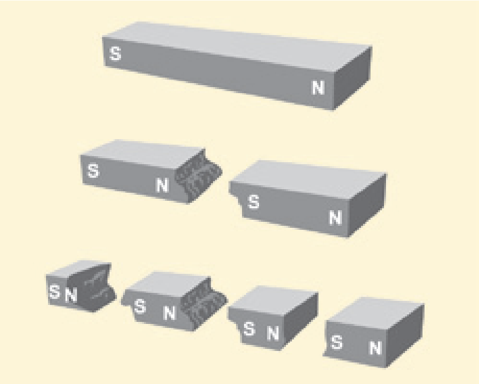
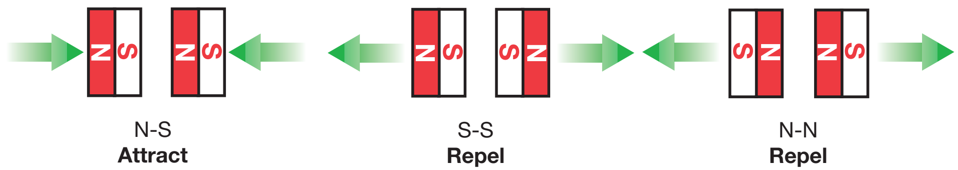


Figure 15.1: *If a magnet is cut in half, each half will have both a north pole and a south pole.*

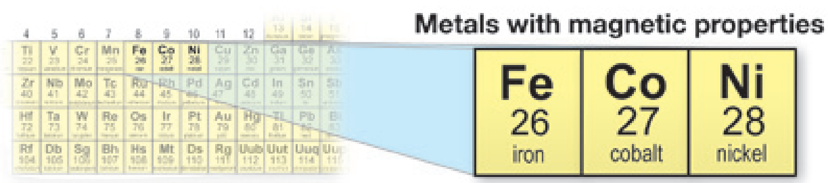
The magnetic force

Attraction and repulsion When near each other, magnets exert forces on each other. Two magnets can either attract or repel. Whether the force between two magnets is attractive or repulsive depends on which poles face each other. If two opposite poles face each other, the magnets attract. If two like poles face each other, the magnets repel.

The three interactions between two magnets



Most materials are transparent to magnetic forces Magnetic forces can pass through many materials with no apparent decrease in strength. For example, one magnet can drag another magnet even when there is a piece of wood between them (Figure 15.2). Plastics, wood, and most insulating materials are transparent to magnetic forces. Conducting metals, such as aluminum, also allow magnetic forces to pass through, but may change the forces. Iron, cobalt, and nickel, metals that are near each other on the periodic table, have strong magnetic properties.



Using magnetic forces Magnetic forces are used in many applications because they are relatively easy to create and can be very strong. There are large magnets that create forces strong enough to lift a car (Figure 15.3). Small magnets are everywhere. For example, some doors are sealed with magnetic weather stripping that blocks out drafts. There are several patents for magnetic zippers, and many handbags, briefcases, and cabinet doors close with magnetic latches. Many everyday devices rely on magnetic forces to make objects attract or repel one another.

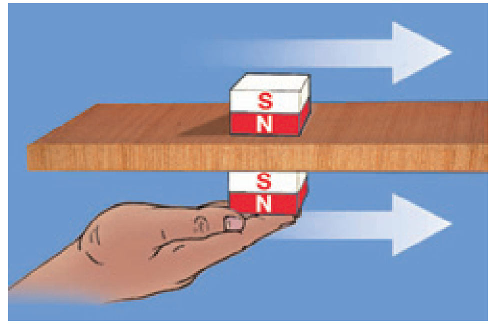


Figure 15.2: *One magnet attracts and can move another magnet even when there is a material like wood between them.*

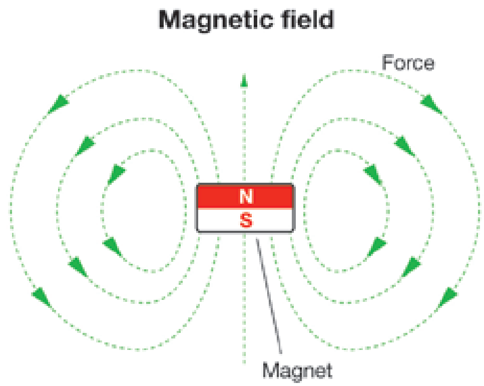
Figure 15.3: *Powerful magnets are used to lift discarded cars in a junkyard.*

The magnetic field

How to describe magnetic forces Two magnets create forces on each other at a distance much larger than the size of the magnets. How do you describe these forces everywhere around a magnet? One way is with a formula that is similar to Newton's law of universal gravitation. Unfortunately, magnetic forces are more complex than gravity because magnets can attract and repel. Gravity can only attract. Also, magnets have two poles. That means part of the same magnet feels an attracting force and part feels a repelling force.

The test magnet A convenient way to show the magnetic force around a magnet is with a drawing. The standard drawing shows the force acting on the north pole of an imaginary test magnet. The test magnet is so small that it does not affect the magnetic force. Also, since the test magnet is imaginary, we can let it have only a north pole. Having only one pole makes it easier to visualize the direction of the magnetic forces (Figure 15.4).

Drawing the force The diagram at the right shows a drawing of the magnetic force around a magnet. The force points away from the north pole because a north pole would be repelled from a north pole. The force points toward the south pole because a north pole magnet would be attracted. How does Figure 15.4 relate to this diagram?



The magnetic field The drawing also shows what physicists call the **magnetic field**. A *field* in physics is a quantity that has a value at all points in space. A magnet creates a field because it creates a force on other magnets at all points around itself. The interaction between two magnets really occurs in two steps. First, a magnet creates a magnetic field. Then, the magnetic field creates forces on other magnets. In the drawing, the field is represented by the arrows and lines.

magnetic field - the magnetic forces that surround an object at all points in space

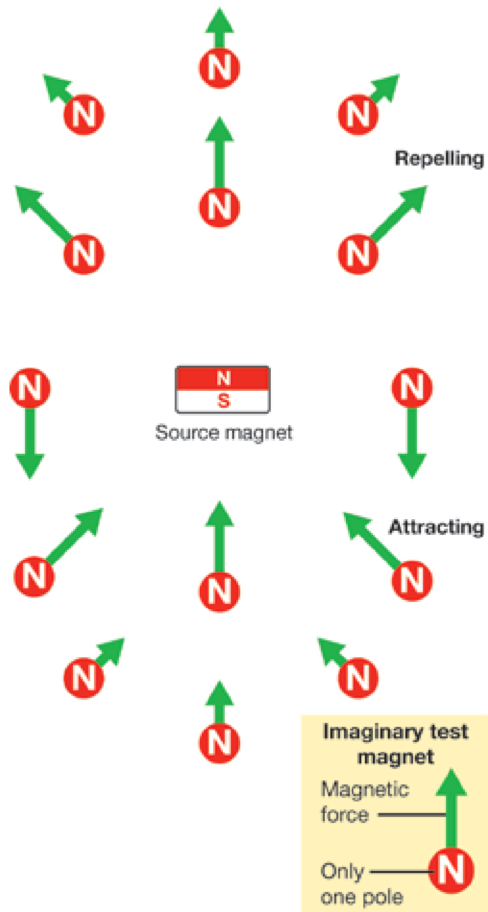


Figure 15.4: *The force on an imaginary test magnet near a source magnet.*

Drawing the magnetic field

Describing magnetic force The magnetic field is a *force field*, because it represents forces at all points in space. Every magnet creates a magnetic field in the space around it. The magnetic field then creates forces on other magnets.

Field lines The magnet that creates a field is called the *source magnet*. In the standard drawing of a magnetic field, the arrows for the imaginary test magnet's field are connected by lines. Each line is called a **magnetic field line**. Magnetic field lines point in the direction of the force on an imaginary north pole test magnet. Magnetic field lines always point from the north to the south pole.

Magnetic field lines always point away from a magnet's north pole and toward its south pole.

Understanding magnetic field lines A field line must start on a north pole and finish on a south pole. You cannot just "stop" a field line anywhere. In the drawing in Figure 15.5, notice that the field lines spread out as they get farther from the source magnet. If field lines are close together, the force is stronger at that location. If field lines are farther apart, the force is weaker. The field lines spread out because the force from a magnet gets weaker as the distance from the magnet increases.

How a magnetic field affects another magnet Figure 15.5 shows how a magnetic field affects another magnet. Magnets A and C feel a net attracting force toward the source magnet. The north pole of magnet A does feel a repelling force, but the south pole of magnet A is closer to the north pole of the source magnet, so the net force is attracting. Magnets B and D feel a twisting force, or torque, because one pole is repelled and the opposite pole is attracted with approximately the same strength.

magnetic field line - one of many lines with arrows used to show the direction of the forces in a magnetic field; magnetic field lines always point away from a magnet's north pole and toward a magnet's south pole

How a magnetic field affects another magnet

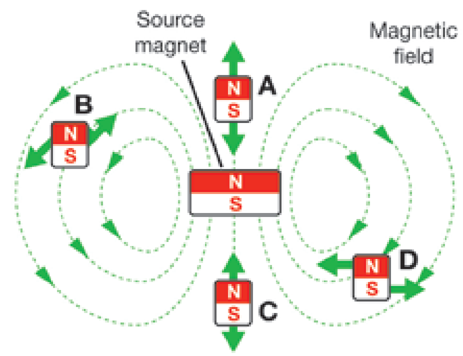


Figure 15.5: *Forces are exerted on both poles of another magnet in a magnetic field.*

15.1 Section Review

1. Is it possible for a magnet to have a south pole without a north pole? Explain your answer.
2. Describe the interaction between each pair of magnetic poles: two north poles; a north and south pole; two south poles.
3. What does the spacing of magnetic field lines mean? Where are forces strongest on a magnet?
4. Give an example of an everyday object that works using magnetic force.