Magnets and Magnetism

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CHAPTER 1 Magnets and Magnetism

Lesson Objectives

- Identify properties of magnets.
- Explain why some materials are magnetic.

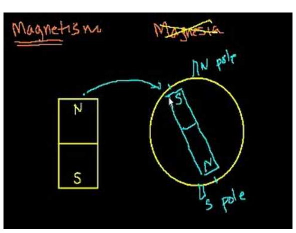
Lesson Vocabulary

- ferromagnetic material
- magnet
- magnetic domain
- magnetic field
- magnetic force
- magnetic pole
- magnetism

Introduction

The futuristic-looking train in **Figure** 1.1 is called a maglev train. The word "maglev" stands for "magnetic levitation." Magnets push the train upward so it hovers, or levitates, above the track without actually touching it. This eliminates most of the friction acting against the train when it moves. Other magnets pull the train forward along the track. Because of these magnets, the train can go very fast. It can fly over the countryside at speeds up to 480 kilometers (300 miles) per hour! What are magnets and how do they exert such force? In this lesson, you'll find out.

You can watch a video introduction to lesson concepts at this URL: http://www.youtube.com/watch?v=8Y4JSp5U82I (10:44).



MEDIA

Click image to the left or use the URL below.

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Properties of Magnets

A **magnet** is an object that attracts certain materials such as iron. You're probably familiar with common bar magnets, like the one in **Figure** 1.2. Like all magnets, this bar magnet has north and south poles and attracts objects such as paper clips that contain iron.

FIGURE 1.1
Magnets cause this maglev train to speed along its track.

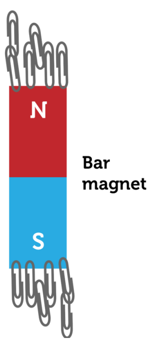

FIGURE 1.2
The north and south poles of a bar magnet attract paper clips.

Magnetic Poles

All magnets have two **magnetic poles**. The poles are regions where the magnet is strongest. The poles are called north and south because they always line up with Earth's north-south axis if the magnet is allowed to move freely. (Earth's axis is the imaginary line around which the planet rotates.) What do you suppose would happen if you cut the bar magnet in **Figure** 1.2 in half along the line between the north and south poles? Both halves would also have north and south poles. If you cut each of the halves in half, all those pieces would have north and south poles as well. Pieces of a magnet always have both north and south poles no matter how many times you cut the magnet.

Magnetic Force

The force that a magnet exerts on certain materials is called **magnetic force**. Like electric force, magnetic force is exerted over a distance and includes forces of attraction and repulsion. North and south poles of two magnets attract each other, while two north poles or two south poles repel each other.

Magnetic Field

Like the electric field that surrounds a charged particle, a **magnetic field** surrounds a magnet. This is the area around the magnet where it exerts magnetic force. **Figure** 1.3 shows the magnetic field surrounding a bar magnet. Tiny bits of iron, called iron filings, were placed under a sheet of glass. When the magnet was placed on the glass, it attracted the iron filings. The pattern of the iron filings shows the lines of force that make up the magnetic field of the magnet. The concentration of iron filings near the poles indicates that these areas exert the strongest force. To see an animated magnetic field of a bar magnet, go to this URL: http://elgg.norfolk.e2bn.org/jsmith112/files/68/149/Bar+magnet.swf .

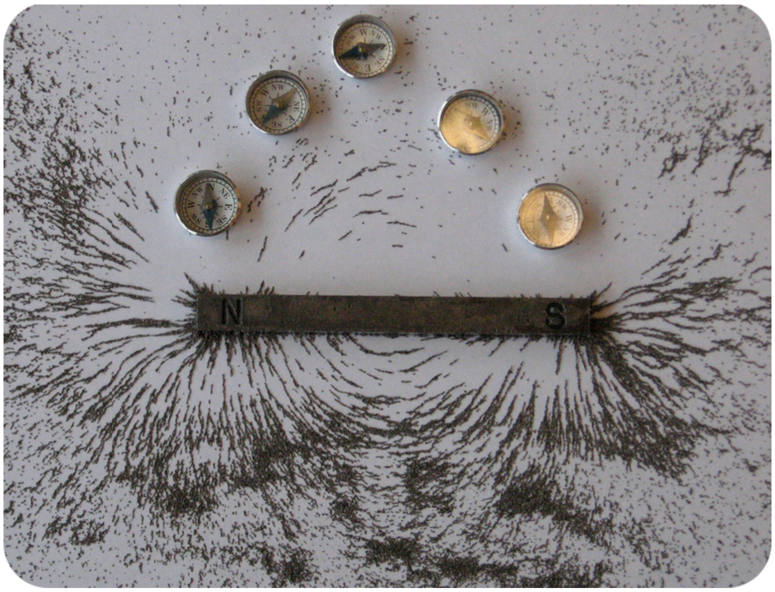

FIGURE 1.3
Lines of magnetic force are revealed by the iron filings attracted to this magnet.

When two magnets are brought close together, their magnetic fields interact. You can see how in **Figure** 1.4. The drawings show how lines of force of north and south poles attract each other whereas those of two north poles repel each other. The animations at the URL below show how magnetic field lines change as two or more magnets move in relation to each other.

http://www.coolmagnetman.com/magmotion.htm

You can take an animated quiz to check your understanding of magnetic field interactions at this URL: http://elgg.norfolk.e2bn.org/jsmith112/files/68/151/Law+of+magnetism.swf .

Magnetism and Materials

Magnetism is the ability of a material to be attracted by a magnet and to act as a magnet. No doubt you've handled refrigerator magnets like the ones in **Figure** 1.5. You probably know first-hand that they stick to a metal refrigerator but not to surfaces such as wooden doors and glass windows. Wood and glass aren't attracted to a magnet, whereas the steel refrigerator is. Obviously, only certain materials respond to magnetic force.

What Makes a Material Magnetic?

Magnetism is due to the movement of electrons within atoms of matter. When electrons spin around the nucleus of an atom, it causes the atom to become a tiny magnet, with north and south poles and a magnetic field. In most materials, the electrons orbiting the nuclei of the atoms are arranged in such a way that the materials have no magnetic properties. Also, in most types of matter, the north and south poles of atoms point in all different

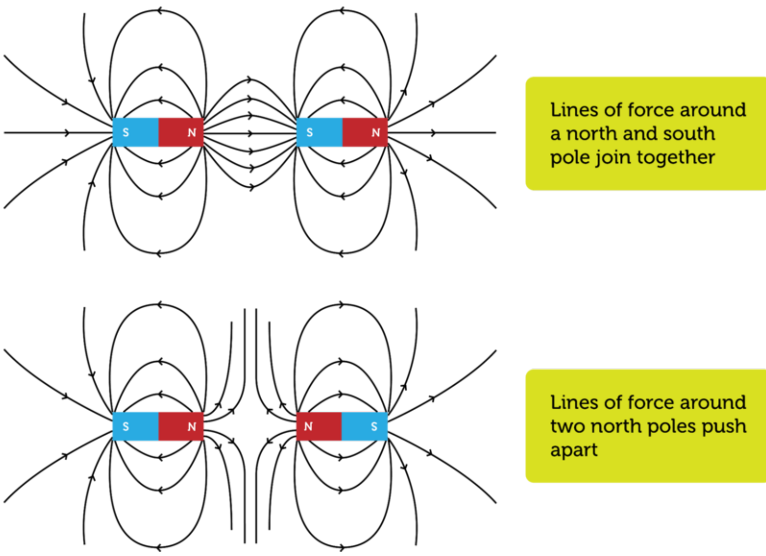

FIGURE 1.4
When it come to magnets, there is a force of attraction between opposite poles and a force of repulsion between like poles.

FIGURE 1.5
Refrigerator magnets stick to a refrigerator door because it contains iron. Why won't the magnets stick to wooden cabinet doors?

directions, so overall the matter is not magnetic. Examples of nonmagnetic materials include wood, glass, plastic, paper, copper, and aluminum. These materials are not attracted to magnets and cannot become magnets.

In other materials, electrons fill the orbitals of the atoms that make up the material in a way to allow for each atom to have a tiny magnetic field, giving each atom a tiny north and south pole. There are large areas where the north and south poles of atoms are all lined up in the same direction. These areas are called **magnetic domains**. Generally, the magnetic domains point in different directions, so the material is still not magnetic. However, the material can be magnetized by placing it in a magnetic field. When this happens, all the magnetic domains become aligned, and the material becomes a magnet. This is illustrated in **Figure** 1.6. Materials that can be magnetized are called **ferromagnetic materials**. They include iron, cobalt, and nickel.

Temporary and Permanent Magnets

Materials that have been magnetized may become temporary or permanent magnets. An example of each type of magnet is described below. Both are demonstrated in **Figure** 1.7.

- If you bring a bar magnet close to pile of paper clips, the paper clips will become temporarily magnetized, as

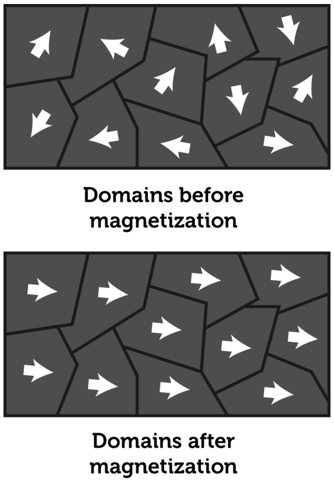

FIGURE 1.6
Magnetic domains must be aligned by an outside magnetic field for most ferromagnetic materials to become magnets.

all their magnetic domains align. As a result, the paper clips will stick to the magnet and also to each other. However, if you remove the paper clips from the bar magnet's magnetic field, their magnetic domains will no longer align. As a result, the paper clips will no longer be magnetized or stick together.

- If you stroke an iron nail with a bar magnet, the nail will become a permanent (or at least long-lasting) magnet. Its magnetic domains will remain aligned even after you remove it from the magnetic field of the bar magnet. Permanent magnets can be demagnetized, however, if they are dropped or heated to high temperatures. These actions move the magnetic domains out of alignment.

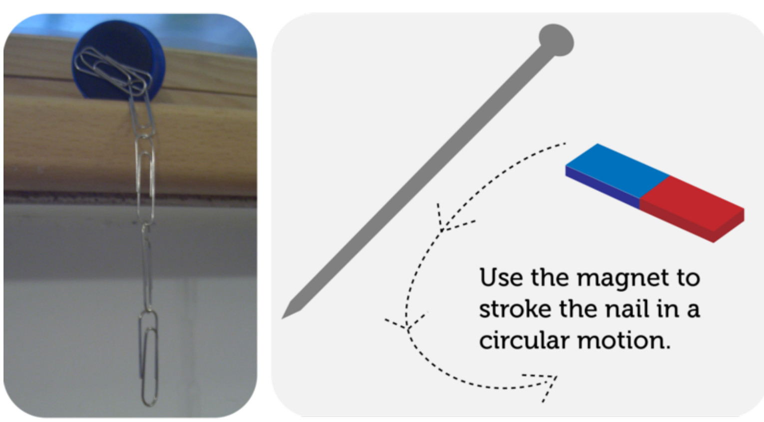

FIGURE 1.7
Paper clips become temporary magnets when placed in a magnetic field. An iron nail becomes a permanent magnet when stroked with a bar magnet.

Some materials are natural permanent magnets. The most magnetic material in nature is the mineral magnetite, also called lodestone. The magnetic domains of magnetite naturally align with Earth's axis. **Figure** 1.8 shows a chunk of magnetite attracting iron nails and iron filings. The magnetic properties of magnetite have been recognized for thousands of years. The earliest compasses used magnetite pointers to show direction. The magnetite spoon compass in **Figure** 1.8 dates back about 2000 years and comes from China.

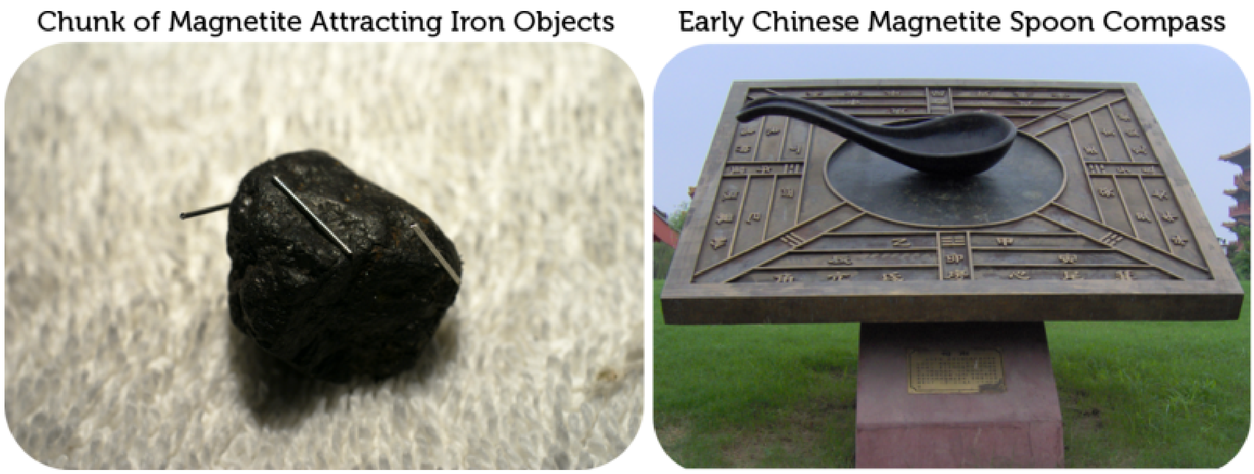

FIGURE 1.8

Magnetite naturally attracts iron nails and filings. Its natural magnetism was discovered thousands of years ago.

Lesson Summary

- A magnet is an object that attracts certain materials such as iron. All magnets have two magnetic poles and a magnetic field over which they exert force. Opposite magnetic poles attract each other, and like magnetic poles repel each other.
- Magnetism is the ability to be attracted by a magnet and to act as a magnet. Only ferromagnetic materials have this property. They include iron, cobalt, and nickel. When these materials are magnetized, they become temporary or permanent magnets. Magnetite is a natural permanent magnet.

Lesson Review Questions

Recall

1. What is a magnet?
2. Define magnetic force.
3. Give examples of objects that are attracted by magnets.
4. Identify ferromagnetic materials.

Apply Concepts

5. Draw magnetic field lines around the bar two magnets pictured below.

6. Sasha dropped a magnet on the sidewalk. Now it no longer attracts paper clips. Apply lesson concepts to explain why.

Think Critically

7. Explain how and why a ferromagnetic material can be magnetized.

Points to Consider

The northern lights that you saw in the opening photo of this chapter are caused by Earth's magnetic field. You will read about Earth's magnetic field in the next lesson, "Earth as a Magnet."

- If you could see Earth's magnetic field, what do you think it would look like? (*Hint:* Look at **Figure** 1.3.)
- After reading this lesson, can you predict why northern lights are most likely to be visible near Earth's poles?

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