Nature of Magnetism

Thousands of years ago, some unknown scientist experimented with a type of rock known as a **lodestone** (leading stone). He suspended an elongated piece of this rock from a cord and discovered that one end of the rock always pointed toward the north. Using this crude device, the captain of an ancient sailing ship could keep his vessel on course, even when the sky was overcast and the stars were hidden.

Today we know that the lodestone points towards the north because of the property called **magnetism.** This property is the ability of a substance to attract certain materials such as iron. An understanding of magnetism explains the behavior of the lodestone as well as the operation of many modern devices such as telephones, electric generators, and various kinds of electric motors.

MAGNETIC AND NONMAGNETIC SUBSTANCES

All substances can be classified as either magnetic or nonmagnetic. A **magnetic** substance is one that is attracted to a magnet. Examples include iron, cobalt, nickel, and lodestone. These are also called **ferromagnetic** substances. A **nonmagnetic** substance is not attracted to a magnet; however, magnetism passes through such a substance. If we place an iron nail on a sheet of thin cardboard and hold a magnet under the cardboard, the nail will be attracted to the magnet. As we move the magnet about, the nail will "follow" it. It is apparent that the magnetism passes through the nonmagnetic cardboard. Other examples of nonmagnetic substances are plastic, wood, and nonferrous metals such as copper.

TYPES OF MAGNETS

Lodestone is classed as a **natural magnet** because it is a naturally occurring iron ore called **magnetite,** Fe_3O_4. Except for such iron ores, most magnets in use today are man-made and are called **artificial magnets.** Artificial magnets are usually made of alloys (combinations of iron and other metals). For example, a very powerful artificial magnet, called an **alnico magnet,** consists of aluminum, nickel, cobalt, and iron.

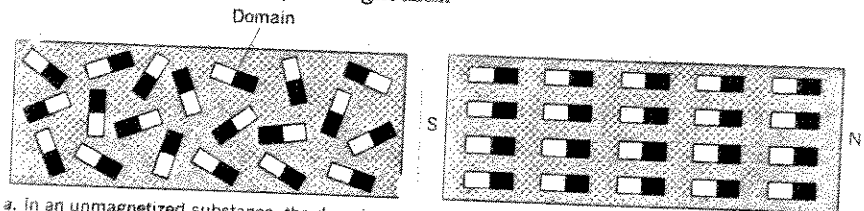
A THEORY OF MAGNETISM

Scientists have found that moving electric charges have magnetic properties. Later in this chapter, it will be shown that certain types of magnets can be made by using this principle.

We know that matter consists of atoms. Each atom contains a positively charged nucleus and negatively charged electrons moving around the nucleus. Not only do electrons revolve around the nucleus, but each electron spins around on its own axis, just as the earth does. The spinning motions of the electrons produce oppositely charged magnetic poles. In most elements, however, the spins of electrons oppose one another; that is, the motions are in opposite directions and thus the magnetic forces cancel each other. Most substances, therefore, do not display any magnetic properties. We will be concerned only with ferromagnetism, the magnetism of iron and some of its related elements.

In ferromagnetic elements, spinning motions of the electrons do not oppose each other; instead, they reinforce each other. The atoms in a piece of iron can be thought of as groups of tiny magnets called **domains.** Ordinarily, these domains are arranged in a random fashion, as shown in Fig. 16-1*a*. Note that the poles of these tiny magnets are arranged in every possible direction, which tends to weaken or cancel any net magnetic effect. However, when the domains are lined up as shown in Fig. 16-1*b*, there is a net magnetic effect and the object has magnetic properties. Breaking or cutting a large magnet does not disturb the regular arrangement of magnetic domains and hence the remaining smaller pieces retain their magnetism.

Fig. 16-1. A theory of magnetism.



a. In an unmagnetized substance, the domains are arranged in random fashion.

b. In a magnetized substance, the domains line up with all north poles facing one end and all south poles facing the other end.