MAGNETIC DOMAINS

The magnetic properties of many materials are explained in terms of a model in which an electron is said to spin on its axis much like a top does. (This classical description should not be taken literally. The property of electron spin can be understood only with the methods of quantum mechanics.) The spinning electron represents a charge that is in motion. As you will learn in the next section of this chapter, moving charges create magnetic fields.

In atoms containing many electrons, the electrons usually pair up with their spins opposite each other causing their fields to cancel each other. For this reason, most substances, such as wood and plastic, are not magnetic. However, in materials such as iron, cobalt, and nickel, the magnetic fields produced by the electron spins do not cancel completely. Such materials are said to be *ferromagnetic.*

In ferromagnetic materials, strong coupling occurs between neighboring atoms to form large groups of atoms whose net spins are aligned; these groups are called **magnetic domains.** Domains typically range in size from about 10^{-4} cm to 10^{-1} cm. In an unmagnetized substance, the domains are randomly oriented, as shown in **Figure 2.** When an external magnetic field is applied, the orientation of the magnetic fields of each domain may change slightly to more closely align with the external magnetic field, or the domains that are already aligned with the external field may grow at the expense of the other domains. This alignment enhances the applied magnetic field.

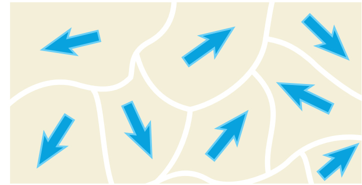

Figure 2
When a substance is unmagnetized, its domains are randomly oriented.

magnetic domain

a region composed of a group of atoms whose magnetic fields are aligned in the same direction

Some materials can be made into permanent magnets

Just as two materials, such as rubber and wool, can become charged after they are rubbed together, an unmagnetized piece of iron can become a permanent magnet by being stroked with a permanent magnet. Magnetism can be induced by other means as well. For example, if a piece of unmagnetized iron is placed near a strong permanent magnet, the piece of iron will eventually become magnetized. The process can be reversed either by heating and cooling the iron or by hammering the iron, because these actions cause the magnetic domains to jiggle and lose their alignment.

A magnetic piece of material is classified as magnetically *hard* or *soft,* depending on the extent to which it retains its magnetism. Soft magnetic materials, such as iron, are easily magnetized but also tend to lose their magnetism easily. In hard magnetic materials, domain alignment persists after the external magnetic field is removed; the result is a permanent magnet. In contrast, hard magnetic materials, such as cobalt and nickel, are difficult to magnetize, but once they are magnetized, they tend to retain their magnetism. In soft magnetic materials, once the external field is removed, the random motion of the particles in the material changes the orientation of the domains and the material returns to an unmagnetized state.

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