Lesson 1 - Section 2

Magnetism

The main experimental facts underlying magnetism are the following:

The ancient Greeks knew that the mineral *loadstone* or *magnetite* (Fe_3O_4) attracts pieces of iron at some zones on its surface. Magnetite in fact is a natural magnet.

If a piece of magnetite is brought near a bar of hard iron, this too acquires the property of attracting iron filings; it has become an artificial magnet. This process is known as magnetic induction.

When iron bars become magnetized, the quality of attracting pieces of iron is found at two regions at the ends of the bars. These regions are called

the poles of the magnet.

If we bring two magnets together, with one magnet fixed and the other free to turn, we see that the first magnet exerts some forces on the second. A magnet produces a magnetic field in the space around it. In a similar way, we have seen that electric charges produce an electric field.

The fact that a magnetic bar or a compass needle comes to rest in a roughly north-south direction when freely suspended near the surface of the earth is evidence that the earth itself acts as a magnet. By convention we give the name north pole to that pole of the magnetic bar or needle which seeks the geographic north, the other pole being known as the south pole.

If we take a given pole of a magnet and place it first at one and then at the other pole of a second magnet, in one case the two poles will attract each other and in the other case they will repel each other. It is found that unlike poles attract whereas like poles repel each other.

In a magnet it is not possible to separate the north pole from the south pole. In fact, if we break a magnet in two we find a south pole at the broken end of the part that had the original north pole, and a north pole at the broken end of the part that had the original south pole.

Of all the metals or elements, only iron, cobalt and nickel and some of their alloys have pronounced magnetic properties. These materials are known as *ferromagnetic* materials. Other elements and metals have slight magnetic properties, and they are called *paramagnetic* materials. There is a third series of materials that have magnetic properties less than those of a vacuum, and these are called *diamagnetic* materials.

Ousted in 1820 showed that a current flowing in an electric circuit exerts forces on a nearby magnet and so demonstrated that a magnetic field is generated around an electric current. Consequently, if we place an electric circuit in a magnetic field, the circuit is subject to forces.

The fact that a magnetic field can be produced either by a magnet or by an electric current may seem strange. But we must remember that in matter we have microscopic circuits due to the movement of electrons, and these circuits are responsible for the magnetic effects of ferromagnetic materials. However, the causes which underlie the magnetic forces produced by electric circuits are not fully understood (just as there are still problems in our understanding of the forces between electric charges and the nature of the force of gravity), although we know the laws that govern their actions and can therefore use them. We know that atoms consist of a heavy central positive nucleus and a number of electrons, in either circular or elliptical orbits, around the nucleus. Recently there has been added the concept that each electron itself is spinning about an axis through its centre, this motion being known as *electron spin.* Here, it is impossible to offer a complete explanation of this and we must limit ourselves lo saying that the fundamental magnetic particles in ferromagnetic materials are the spinning electrons. these elec - trons occupy definite shells in the atom, and some spin in one direction and some in the other. Their magnetic effects tend to neutralize each other partially but not wholly. The excess of those spinning in one direction over those spinning in the other causes each atom as a whole to act as a small permanent magnet. Moreover, in ferromagnetic materials there is the existence of some kinds of interatomic forces that cause the alignment of all magnetic effects of large groups of atoms to give highly magnetic domains. In an unmagnetized ferromagnetic substance these domains are oriented at random with their magnetic axes pointing in various directions, so that the resultant magnetic effect is zero. The application of an external field lines up the domain axes, thereby giving rise to the magnetic effect of a ferromagnetic material.

In hard iron the domains do not easily return to their previous positions when the external field is removed, while in soft iron this occurs fairly readily. Paramagnetic and diamagnetic materials, on the other hand, are substances in which the arrangement of the spinning electrons does not give appreciable magnetic properties. When the temperature of a ferromagnetic material is raised beyond a certain value (known as the *Curie point),* thermal agitation destroys the alignment within the domains and the materials lose their ferromagnetic properties. These properties return when the materials are cooled. The Curie point for iron is of the order of 700°C. As in the case of an electric field, a magnetic field at each point may be defined by its field strength. This is represented by the vector *H.* The direction is that in which a north pole subjected to this field tends to move. Because the magnetic field may be produced by a current, the strength can be defined in terms of current. In order to do this we consider a solenoid, i.e., a coil of wire wound uniformly on a cylindrical former. If the solenoid is long compared with its radius, we can consider that a uniform magnetic field is produced inside the coil, parallel to its axis. If *N* is the number of turns, *I* the length of the solenoid and *I* the current that flows in the coil, we have $H=NI/I$ .The magnitude of *H* is measured in amperes per metre, and the quantity *NI* is expressed in amperes.

Comprehension Exercises

A. Choose a, b, c, or d which best completes each item.

1.If we break a magnetic bar into two pieces, the two poles at the point of breakage will ……. .

a. be two north poles
b. be a north pole and a south pole
c. pronounce greater attraction
d. pronounce smaller attraction

2.It is true that ……. .

a. the circuits in matter produce magnetic forces
b. the circuits in an electric current produce magnetic forces
c. paramagnetic materials have smaller magnetic properties than diamagnetic materials
d. diamagnetic materials have greater magnetic properties than ferromagnetic materials

3. The factors bringing about the magnetic properties of materials are the spinning ……. .

a. nuclei b. atoms
c. neutrons d. electrons

4. Paragraph ten mainly discusses ……. .

a. the magnetic field b. the electric field
c. the theory of magnetism d. the theory of gravity

5. When the temperature of cobalt is below the Curie point ….... .

a. all magnetism disappears
b. some magnetism disappears

c. the metal has appreciable magnetic properties
d. the alignment of the magnetic domains is destroyed

6. The vector *H* representing the field strength of a magnetic field may be expressed as the product of ……. .
   a. the number of turns in a coil and the current in amperes which flows through it
   b. the number of turns in a coil and the current in amperes which flows through it per unit length
   c. the current flowing through a coil and the length of the coil
   d. the current flowing through a coil per unit length
7. In a bar magnet, the magnetic domains …….. .
   a. neutralize each other b. repel each other
   c. are at random d. are aligned
8. A magnet and an electric current in a circuit produce a magnetic field by virtue of …….. .
   a. the position of the magnetic domains
   b. the orientation of the atomic nuclei
   c. the movement of the electrons
   d. the alignment of the interatomic forces

B. Write the answers to the following questions.

1. How have the poles of a magnetic bar been initially named?
2. How do you describe the process of magnetic induction?
3. How is an electric field compared with a magnetic field?
4. How may a magnetic field be demonstrated?
5. How are paramagnetic materials different from diamagneti materials?
6. What did Oersted prove in 1820?
7. What is the difference between the soft iron and the ilard iron?
8. How do you describe the vector *H?*