5.12. MAGNETIC SUSCEPTIBILITY AND PERMEABILITY

In 1845, Faraday proved that substances other than iron, nickel and cobalt, which were supposed to be the only magnetisable substances prior to his discovery, were also capable of being magnetised, though to a much smaller degree as compared with iron. Substances in the first class were termed by Faraday *paramagnetics* ; those in the second class were termed *diamagnetics;* the ferromagnetics were stated as special class of magnetic materials which could be magnetised to a very high degree.

Magnetic Susceptibility : A magnetic substance when placed in a magnetic field exhibits induced magnetism and acquires a magnetic moment. This magnetic moment per unit volume is called *intensity of magnetisation* or simply magnetisation denoted by **M** or in other words it is a measure of the extent to which a body can be magnetised. If m^* be the magnetic moment and V be the volume of magnetised material, then

$$\mathbf{M} = \frac{m^*}{V}$$

The ratio of intensity of magnetisation **M** for any materials is proportional to the magnetising field, *i.e.,*

$$\mathbf{M} \propto \mathbf{H}$$

$$\mathbf{M} = \chi \mathbf{H}$$

or

$$\chi = \frac{\mathbf{M}}{\mathbf{H}} \quad \text{or} \quad \chi = \frac{\mathbf{M}}{\mathbf{H}},$$

where χ is called *magnetic* (*or magnetic volume*) *susceptibility* and is the measure of the capability of the medium to take up magnetisation.

The quantity magnetic moment per unit mass of the substance divided by the field strength is termed as *magnetic mass susceptibility* χ_m. Thus if ρ be density of the material, the mass per unit volume is ρ (numerically) then mass susceptibility is

$$\chi_m = \frac{\chi}{\rho}. \qquad \ldots(3)$$

When χ_m is multiplied by the relative molecular mass of the substance, we obtain *molar susceptibility.*

In the case of para and dia-magnetics, the intensity of magnetisation, under ordinary conditions, is proportional to the applied field, with the result that their susceptibility is independent of field strength. The diamagnetic substances magnetise in the opposite direction to the applied field so that χ, the susceptibility, is negative, while in paramagnetic substances magnetisation is in the same direction giving positive values of susceptibility, Weber predicts that the paramagnetism arises due to intrinisic molecular currents which give the molecule permanent magnetic moment, while diamagnetism is due to molecular currents induced by an external field which gives rise to a magnetic moment in a direction opposite to that of the field, hence to a negative magnetic moment. Ferromagnetics exhibit large values of χ dependent on field strength. They may have magnetic moment even in the absence of applied field.

Refer to art. 5.11, where we have expressed

$$\mathbf{B} = \mu_0 \mathbf{H} + \mu_0 \mathbf{M}$$

$$\frac{\mathbf{B}}{\mathbf{H}} = \mu_0 \left(1 + \frac{\mathbf{M}}{\mathbf{H}}\right)$$

$$\mu = \mu_0 (1 + \chi) \text{ from eq. (2)}$$

or

$$\mu_r = 1 + \chi,$$

is called relative permeability of magnetic medium. It represents the degree to which the lines of force can penetrate or permeate the medium. For paramagnetics $\mu_r > 1$ for diamagnetics $\mu_r < 1$ and ferromagnetics have very large values of μ_r.