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MAGNETIC PROPERTIES

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(a) Magnetising field

The magnetic field which is used to magnetize a sample or specimen is called the magnetising field. Magnetising field is a vector quantity and it denoted by $\vec{H}$ and its unit is A m^{-1}.

Inference: An external magnetic filed is needed to magnetise a magnetic material.

(b) Magnetic permeability

The magnetic permeability can be defined as the measure of ability of the material to allow the passage of magnetic field lines through it or measure of the capacity of the substance to take magnetisation or the degree of penetration of magnetic field through the substance.

Magnetic permeability

The magnetic permeability can be defined as

- ***the measure of ability of the material to allow the passage of magnetic field lines through it***

or

- ***measure of the capacity of the substance to take magnetization***

or

- ***the degree of penetration of magnetic field through the substance*.**

- In free space, the permeability (or absolute permeability) is denoted by μ_0
- for any medium it is denoted by μ.
- **The relative permeability μ_r is defined as the ratio between permeability of the medium to the permeability of free space.**

$$\mu_r = \frac{\mu}{\mu_o}$$

Relative permeability is a dimensionless number and has no units. For free space (air or vacuum), the relative permeability is unity i.e., $\mu_r = 1$. In isotropic medium, μ is a scalar but for non-isotropic medium, μ is a tensor.

(c) Intensity of magnetization:

Any bulk material (any object of finite size) contains a large number of atoms.

Each atom consists of electrons which undergoes orbital motion.

Due to orbital motion, electron has magnetic moment which is a vector quantity.

- In general, these magnetic moments orient randomly, therefore, the net magnetic moment is zero per unit volume of the material.

No external magnetic field

- When we keep such a material in an external magnetic field, atomic dipoles are created and will try to align partially or fully along the direction of external field.

In the external magnetic field

The net magnet moment per unit volume of material is known as intensity of magnetization or magnetization vector or magnetization.

It is a vector quantity.

$$\vec{M} = \frac{magnetic\ moment}{volume} = \frac{1}{V}\bar{p}_m$$

Bar Magnet – Intensity of Magnetisation

The SI unit of intensity of magnetisation is ampere metre^{-1}. For a bar magnet of pole strength q_m, length $2l$ and area of cross-section A, the magnetic moment of the bar magnet is $\vec{p}_m = q_m \overrightarrow{2l}$ and volume of the bar magnet is $V = A\left|\overrightarrow{2l}\right| = 2l\,A$. The intensity of magnetisation for a bar magnet is

$$\vec{M} = \frac{magnetic\,moment}{volume} = \frac{q_m \overrightarrow{2l}}{2l\,A} \qquad (3.34)$$

In magnitude, equation (3.34) is

$$\left|\vec{M}\right| = M = \frac{q_m \times 2l}{2l \times A} \Rightarrow M = \frac{q_m}{A}$$

This means, **for a bar magnet the intensity of magnetisation can be defined as the pole strength per unit area (face area).**

(d) Magnetic induction or total magnetic field:

When a substance like soft iron bar is placed in an uniform magnetising field $\vec{H}$, it becomes a magnet, which means that the substance gets magnetized.

The magnetic induction (total magnetic field) inside the specimen $\vec{B}$ is equal to the sum of the magnetic field $\vec{B}_0$ produced in vacuum due to the magnetising field and the magnetic field $\vec{B}_m$ due to the induced magnetisation of the substance.

$$\vec{B} = \vec{B}_0 + \vec{B}_m = \mu_0\vec{H} + \mu_0\vec{M}$$

$$\Rightarrow \quad \vec{B} = \vec{B}_0 + \vec{B}_m = \mu_0(\vec{H} + \vec{M})$$

$$\vec{B} = \vec{B}_o + \vec{B}_m = \mu_o\vec{H} + \mu_o\vec{I}$$

Due to the external magnetising field ($\vec{B}_o$)

Due to the internal aligned magnetic moments – internal magnetisation ($\vec{B}_m$)

(e) Magnetic susceptibility

- When a substance is kept in a magnetizing field $\vec{H}$, magnetic susceptibility gives us information about how a material respond to the external (applied) magnetic field.

- The magnetic susceptibility measures how easily and how strongly a material can be magnetized.

- It is defined as the ratio of the intensity of magnetization ($\overrightarrow{M}$) induced in the material due to the magnetizing field ($\overrightarrow{H}$).

$$\chi_m = \frac{|\overrightarrow{M}|}{|\overrightarrow{H}|}$$

It is a dimensionless quantity.
For isotropic medium, susceptibility is a scalar but for non-isotropic medium, susceptibility is a tensor.