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DSC1BT (Electricity and Magnetism) , Topic :- Magnetic Properties of Matter

- **Intensity of Magnetism:** When a magnetic material is placed in magnetic field, the elementary current loops are aligned parallel to the field. The material is then magnetism and experienced a magnetic moment.
  The magnetic moment developed per unit volume of the material is called intensity of magnetization. It is denoted by " I" or "M"

  Where $\bar{I}$ and $\bar{M} = \frac{d\bar{\mu}}{dv}$

  S.I unit- Amp/Met.
- **Magnetic Induction**: The number of lines of inductions per unit area normally is equal to the magnitude of the magnetic induction. It is denoted by "$\bar{B}$". S.I unit – Weber/m^2 or 'Tesla'.
- **Magnetic Intensity**: When a magnetic material is placed in a magnetic field, the material is then magnetism. The capability of the magnetic field to magnetise the material by means of magnetic vector, called the intensity of magnetic field. It is denoted by "$\bar{H}$". S.I unit- Wb/H-m.
- **Magnetic Susceptibility** : The intensity of magnetization is normally directly proportional to the strength of the magnetic field.

$$\textbf{i.e. } \vec{I} \propto \vec{H}$$

$$\vec{I} = \chi \vec{H}$$

$$\boxed{\chi = \frac{\vec{I}}{\vec{H}}}$$, called magnetic susceptibility

Thus , the ratio of the intensity of magnetization to the strength of the magnetic field is known as magnetic susceptibility.

❖ **Magnetic Permeability** : The ratio the number of lines of force passing normally through unit area of the substance to that in air is called magnetic permeability of that magnetic material.

Actually, $\vec{\boldsymbol{B}} \propto \vec{\boldsymbol{H}}$

Or, $\vec{\boldsymbol{B}} = \vec{\boldsymbol{H}}$

Or, $\boxed{\boldsymbol{\mu} = \frac{\vec{\boldsymbol{B}}}{\vec{\boldsymbol{H}}}}$

Thus, the ratio of magnetic induction to the magnetic intensity vector is called magnetic permeability.

1. Paramagnetic Substance

(a) **Defination:-** The substance which , when placed in a strong magnetic field, becomes weakly magnetized in the same sense as the external field , are called paramagnetic substances. Example- Platinum, Aluminium, Copper Sulphate etc.

(b) Paramagnetic substances may be solid, liquid or gas.

(c) The relative permeability (μ_r) is slightly greater than 1 i.e. $\mu_r > 1$

(d) Magnetic susceptibility is small and positive quantity i.e. $\chi =$ small positive.

(e) The susceptibility decreases with rise in temperature.

(f) In non uniform field paramagnetic substances tend to move from weaker to stronger parts of magnetic field.

❖ **Establish The Relation :- (a)** $\vec{\boldsymbol{B}} = \boldsymbol{\mu_0}(\vec{\boldsymbol{H}} + \vec{\boldsymbol{I}})$

(b) $\boldsymbol{\mu} = \boldsymbol{\mu_0}(\boldsymbol{1} + \boldsymbol{\chi})$

➢ Relation:-

We know , $\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}_t$

Where $\vec{J}_t$= Total current density

= True current density + Displacement current density + Magnetic current density

$$= \vec{J} + \frac{\partial \vec{D}}{\partial t} + \vec{\nabla} \times \vec{I}$$

$$\therefore \vec{\nabla} \times \vec{B} = \mu_0(\vec{J} + \frac{\partial \vec{D}}{\partial t} + \vec{\nabla} \times \vec{I})$$

$$\text{Or, } \vec{\nabla} \times (\vec{B} - \mu_0 \vec{I}) = \mu_0(\vec{J} + \frac{\partial \vec{D}}{\partial t})$$

$$\text{Or, } \frac{\vec{\nabla} \times (\vec{B} - \mu_0 \vec{I})}{\mu_0} = (\vec{J} + \frac{\partial \vec{D}}{\partial t})$$

From the above equation, we get a new vector quantity,

$$\vec{H} = \frac{(\vec{B} - \mu_0 \vec{I})}{\mu_0}$$, called magnetic field intensity

$$\text{Or, } \vec{H} = \frac{\vec{B}}{\mu_0} - \vec{I}$$

$$\text{Or, } \boxed{\vec{\boldsymbol{B}} = \boldsymbol{\mu_0}(\vec{\boldsymbol{H}} + \vec{\boldsymbol{I}})} \qquad \textbf{.....(1)}$$

For a simple isotropic medium,

$$\vec{\boldsymbol{I}} \propto \vec{\boldsymbol{H}}$$

$$\vec{\boldsymbol{I}} = \chi \vec{\boldsymbol{H}}$$

$$\boxed{\chi = \frac{\vec{\boldsymbol{I}}}{\vec{\boldsymbol{H}}}}$$, called magnetic susceptibility

$\vec{\boldsymbol{B}} \propto \vec{\boldsymbol{H}} \Rightarrow \vec{\boldsymbol{B}} = \vec{\boldsymbol{H}} \Rightarrow$ Or, $\boldsymbol{\mu} = \frac{\vec{\boldsymbol{B}}}{\vec{\boldsymbol{H}}}$ **;** $\boldsymbol{\mu}$ **=** magnetic permeability

Putting in equation (1) , we get

$$\boldsymbol{\mu}\vec{\boldsymbol{H}} = \boldsymbol{\mu_0}(\vec{\boldsymbol{H}} + \chi \vec{\boldsymbol{H}})$$

$$\boxed{\boldsymbol{\mu} = \boldsymbol{\mu_0}(\mathbf{1} + \chi)} \qquad \textbf{....(2)}$$

2. *D*iamagnetic Substances

(a) **Defination-** The magnetic substances which , when placed in a strong magnetic field, become weakly magnetism in the sense opposite to the applied field, called diamagnetic substances. Examples- Bismuth, Antimony. Gold etc.

(b) Diamagnetic substances may be solid , liquid or gas.

(c) The relative permeability is slightly less than 1.

(d) Magnetic susceptibility is independent of temperature.

(e) Magnetic susceptibility is small and negative quantity i.e. $\chi =$ small negative

(f) In a non uniform field the diamagnetic substances tends to move from the stronger to weaker parts of the field.

3. **Ferromagnetic Substances**

(a) **Defination :** The substances which, when placed in a weak magnetized field, become strongly magnetized in the sense of applied field, called ferromagnetic substances. Examples- Iron, nickel Cobalt etc.

(b) The ferromagnetic substances are always solid not liquid or gas.

(c) The relative permeability is much much greater than 1 i.e. $\mu_r >> 1$

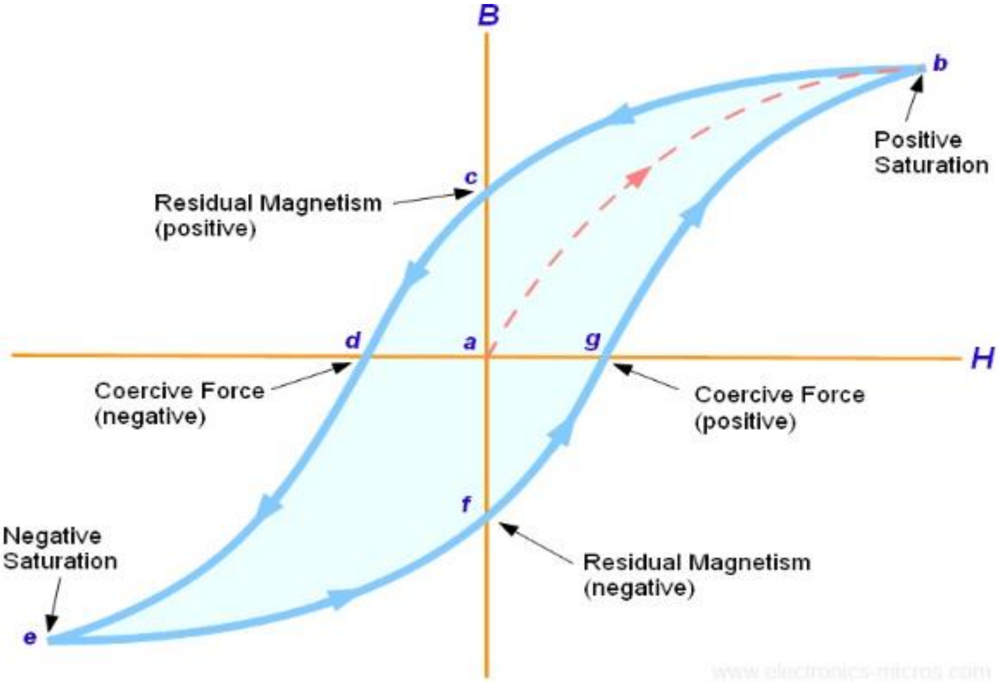
(d) Magnetic susceptibility is positive and large.

(e) The permeability decreases with rise in temperature and becomes μ_0 at a certain temperature, called Currie Temperature, Above Currie temperature ferromagnetic substance becomes paramagnetic.

HYSTERISIS

❖ **Cycle of Magnetisation :** When the magnitude of the magnetizing field (H) is increased then intensity of magnetization (I) or magnetic induction through or magnetic material (iron) increases along the curve ***ab*** and become saturated at ***b***.

If H is now gradually decreased, the intensity of magnetization gradually decreases. But does not vanish even if the magnetizing field be withdrawn which is shown in the portion ***bc***. Some magnetization (***ca***) retains even when the magnetic field (H) is withdrawn. This residual magnetization is called retentivity.



To destroy this residual magnetization, we apply a reverse magnetizing field, shown in the portion ***cd***. The reverse magnetizing field (***ad***) to destroy the magnetization (I=0) is called coersitivity.

Further increase of reverse magnetizing field, the intensity of magnetizing field, the intensity of magnetization increases in the opposite direction until a state of saturation in reached which shown in the portion ***de***.

Now if the reverse magnetizing field is gradually decreases I shown in the portion ***ef***. But decreases residual magnetization ***af*** even H=0.

To destroy this residual magnetization (opposite) a forward magnetizing field is necessary shown in portion ***fg***.

Further increase of magnetizing field I increases and become saturated shown in the portion ***gb***.

The loop " ***bcdefgb***" is called cycle of magnetization.

- **Hysteresis Loop:-** The graph showing I or B increases with H from zero to a maximum in one direction and then taken through zero to a maximum in the opposite and finally back again through zero to the first maximum is called **hysteresis**.