Magnetic Properties

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Introduction

- Magnetism arises from the Magnetic Moment or Magnetic dipole of Magnetic Materials.

- When the electrons revolves around the nucleus Orbital magnetic moment arises, similarly when the electron spins, spin Magnetic moment arises.

- The permanent Magnetic Moments can arise due to the
  1. The orbital magnetic moment of the electrons
  2. The spin magnetic moment of the electrons, and
  3. The spin magnetic moment of the nucleus.

Magnetic Induction or Magnetic flux Density

The Magnetic induction in any material is the number of lines of magnetic force passing through unit area perpendicularly. Units: wb/m^2 or Tesla.

Magnetic field intensity (H)

The Magnetic field intensity at any point in the magnetic field is the force experienced by an unit north pole placed at that point.

Units : A/m

Permeability: (μ)

The Magnetic induction B is proportional to the applied Magnetic field intensity H.

$$B \alpha H$$

$$B = \mu H$$

$$\mu = \frac{B}{H}$$

Where µ permeability of a medium

Relative permeability μ_r

The ratio of permeability of medium to the permeability of free space is called relative permeability μ_r of the solid.

$$\mu_r = \frac{\mu}{\mu_0}$$

$$\mu_r = \frac{\dfrac{B}{H}}{\dfrac{B_0}{H}} = \frac{B}{B_0}$$

Magnetization

- Magnetization refers to the process of converting a non-magnetic material into a Magnetic material.

- The intensity of Magnetization is directly related to the applied field H.

$$M \alpha H$$

$$M = \chi_m H$$

$$\text{magnetic susceptibi lity} \quad \chi_m = \frac{M}{H}$$

$$B \alpha H$$

$$B = \mu H$$

$$B = \mu_0 \mu_r H$$

$$B = \mu_0 \mu_r H + \mu_0 H - \mu_0 H$$

$$B = \mu_0 H + \mu_0 H (\mu_r - 1)$$

$$B = \mu_0 H + \mu_0 M$$

Where M is the magnetizat ion

$$B = \mu_0 (H + M)$$

$$\mu_0 = \frac{B}{(H + M)}$$

relative permeabili ty $\mu_r = \dfrac{\mu}{\mu_0} \rightarrow \dfrac{B/H}{B/(H+M)}$
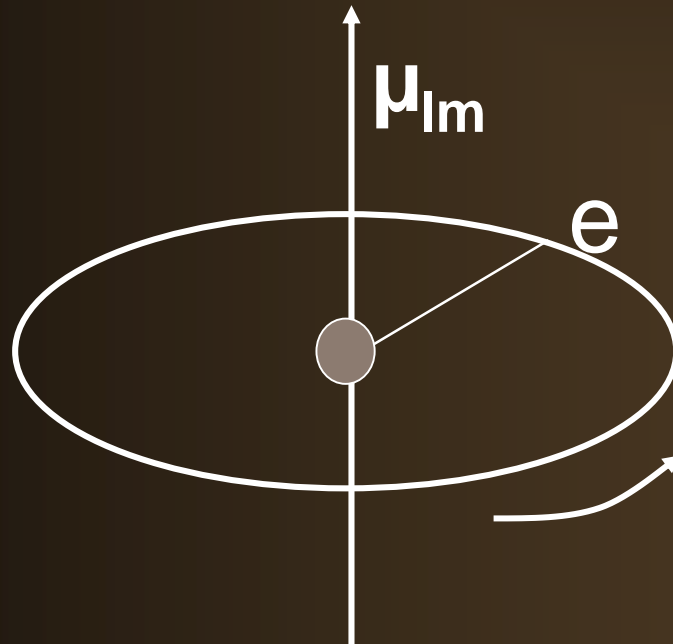
$$\mu_r = \frac{H + M}{H}$$

$$\mu_r = 1 + \frac{M}{H}$$

$$\mu_r = 1 + \chi_m$$

Origin of Magnetic Moment

The Magnetic moment in a material originates from the orbital motion and spinning motion of electrons in an atom.

Consider an atom & each electron in that, orbiting around the nucleus produces a loop current

$$i = q / t$$

$$i = q f$$

Where f is a frequency of electron..

If L is the angular momentum of electron, the Magnetic moment of the electron

$$\mu_{lm} = (\text{Area of loop}) \times (\text{Current})$$

$$\mu_{lm} = (\pi r^2)(\frac{q}{t})$$

$$\mu_{lm} = (\pi r^2)(qf)$$

$$\mu_{lm} = (\pi r^2)(\frac{q}{2\pi} \times 2\pi f)$$

$$\mu_{lm} = (\pi r^2)(\frac{q}{2\pi} \times \omega)$$

$$\mu_{lm} = (\pi r^2)(\frac{q}{2\pi} \times \frac{v}{r})$$

$$\mu_{lm} = \frac{qvr}{2}$$

$$\mu_{lm} = \frac{q}{2m}.mvr$$

$$\mu_{lm} = \frac{q}{2m}.L$$

Where L is a Angular Momentum of electron

$$L = mvr = \frac{lh}{2\pi}$$

$$L = mvr = \sqrt{l(l+1)}\,\frac{h}{2\pi}$$

$$\mu_{lm} = \frac{q}{2m}.L$$

$$\mu_{lm} = \frac{q}{2m}.\sqrt{l(l+1)}\,\frac{h}{2\pi}$$

$$\mu_{lm} = \frac{qh}{4\pi m}.\sqrt{l(l+1)}$$

$$\mu_{lm} = \mu_B.\sqrt{l(l+1)}$$

$$where., \mu_B(Bhor,.magnaton) = \frac{qh}{4\pi m} \rightarrow 9.27408 \times 10^{-24}\,A - m^2$$

Classification of Magnetic Materials

1. Dia
2. Para
3. Ferro
4. Anti Ferro
5. Ferri Magnetic materials.

Dia Magnetic Materials

Diamagnetism is the phenomenon by which the induced Magnetic moment is always in the opposite direction of the applied Magnetic field.
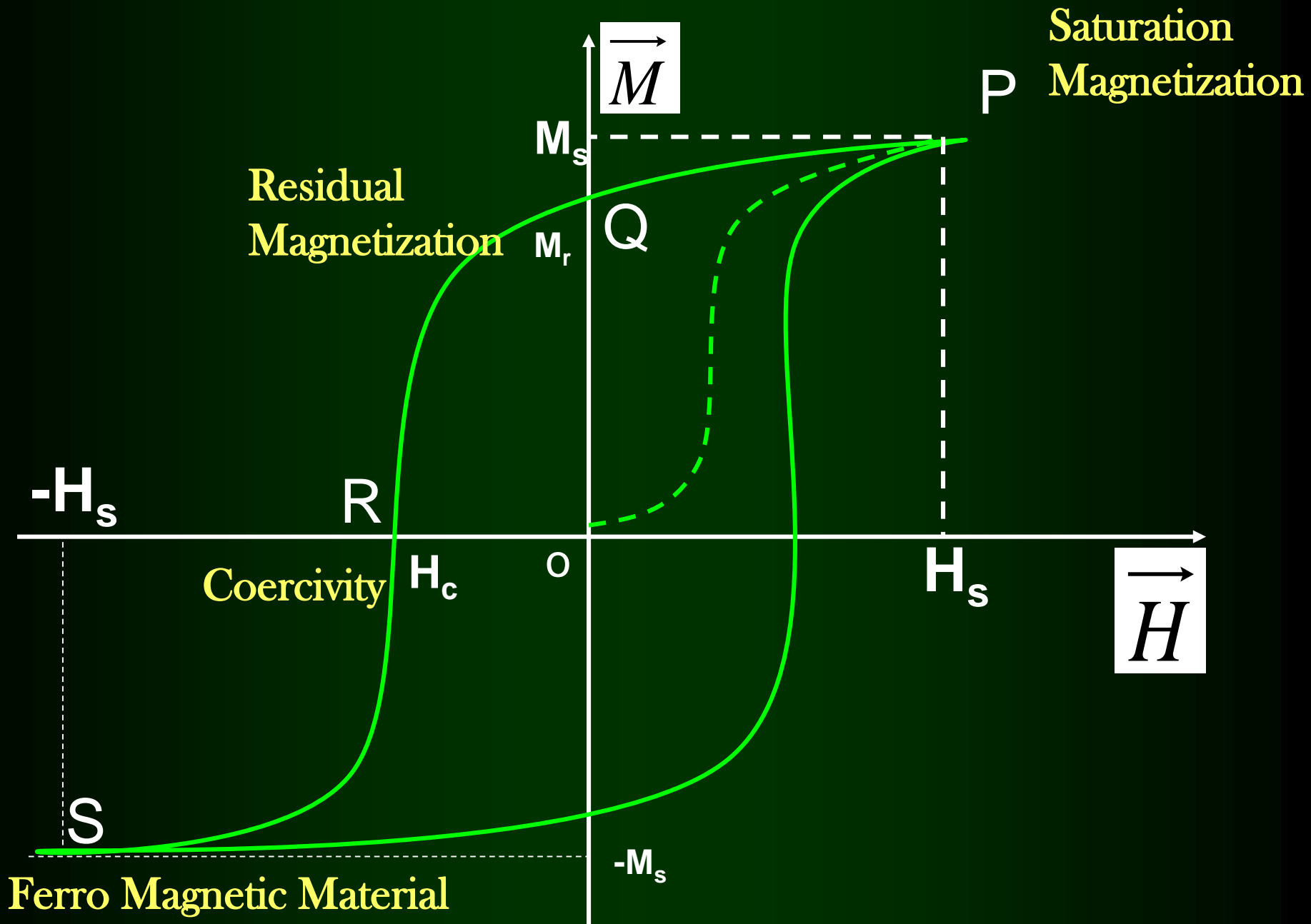
Properties

1. These materials having negative susceptibility value.
2. No permanent Magnetic Moment.
3. Dia Magnetic materials repel magnetic lines of force.
4. The value of Diamagnetic susceptibility is independent of temperature and applied Magnetic field.

Examples: Organic materials, Alkali earth elements, Bismuth

Hysteresis

The striking property of Ferro Magnetic materials is the relation between Magnetization and the strength of Magnetic field. This property is called Hysteresis.

Saturation Magnetization

$\overrightarrow{M}$

P

M_s

Residual Magnetization

M_r Q

-H$_s$

R

Coercivity H_c

O

H$_s$

$\overrightarrow{H}$

S

-M$_s$

Ferro Magnetic Material

- If we start with no **Magnetized** specimen (M= 0) with the increasing values of magnetizing field H.

- The **Magnetization** of the specimen increases from zero to higher values and attains its maximum value at a point **P**, at this point the **Magnetization** referred as Saturation **Magnetization**..

- When we increase Magnetic field H there is no further increment in Magnetic moment.

- When we decrease Magnetic field H to Zero, the Magnetization M attains point Q.

- At this point Magnetization referred as residual Magnetization M_r.

- Further if we increase the Magnetic field from zero to negative values, the Magnetization of material becomes zero at a point R, at that point the Magnetic field H_c is referred as Coercivity of the specimen.

- If we increase Magnetic field H in reverse direction Magnetization of material reaches its peak value at a points S.

- On reversing the polarities of Magnetic field and increasing its strength the Magnetization slowly decreases first to residual value then to zero and finally increases to saturation state and touches the original saturation curve.

- The area of loop indicates the amount of energy wasted in one cycle of operation.

Hard Magnetic Materials

- Hard magnetic materials have large hysteresis loss due to large hysteresis loop area.

- The Coercivity and retentivity are large hence these materials cannot be easily magnetized and demagnetized.

- These materials have small values of permeability and susceptibility.

- These are used to make permanent magnets. Ex. Alnico alloy

Soft Magnetic Materials

- Soft Magnetic materials have low hysteresis loss due to small hysteresis loop area.

- The coercivity and retentivity are small, hence these materials can be easily magnetized and demagnetized.

- These materials have large values of permeability and susceptibility.

- These are used to make electromagnets.

  Ex: Iron silicon alloys, Ferrous nickel alloy

Superconductivity

- Certain metals and alloys exhibit almost zero resistivity (infinite conductivity) when they are cooled to sufficiently low temperatures. This phenomenon is called Superconductivity.

General properties of Superconductors

1. The temperature at which the transition from normal state to superconducting state takes place on cooling in the absence of magnetic field is called the critical temperature (T_c) or the transition temperature.

2. For superconducting elements in a given row in the periodic table, T_c versus Z^2 gives straight line.
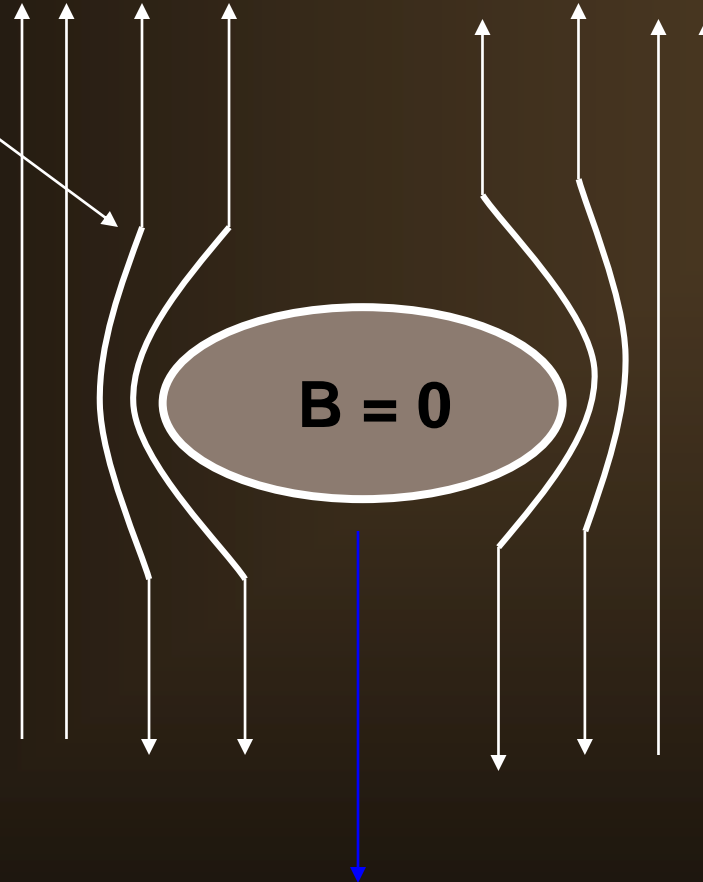
Meissner Effect

When a weak Magnetic field is applied to a superconducting specimen at a temperature T_c, the magnetic flux lines are expelled & the specimen acts as an ideal Dia magnet. This effect is called Meissner effect.

$$T \succ T_c$$

MAGANTIC FIELD

$T \prec T_c$

B = 0
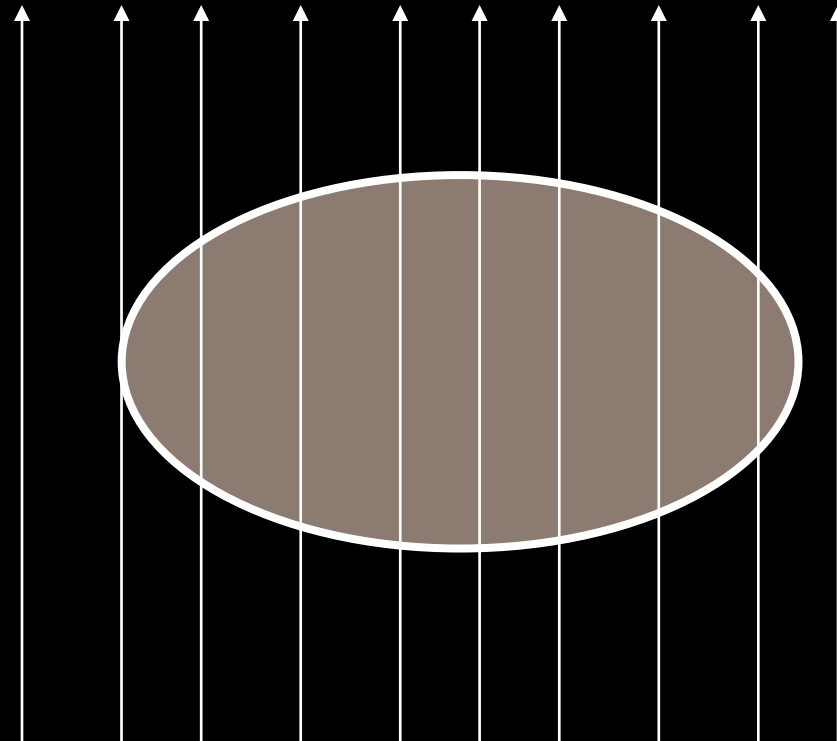
$B = \mu_0(H + M)$

$B = \mu_0(H + M)$

$B = 0$

$0 = \mu_0(H + M)$

$H + M = 0$

$H = -M$

$\dfrac{M}{H} = -1$

$\chi = -1$

PER FECT DIAMAGNATIC MATIRIAL OR SUPER CONDUCTING MATERIAL