Vivekanand college, Kolhapur

Lecture on : Static Magnetic Field

by:-

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Static Magnetic Field

Diamagnetic Materials (copper, germanium, silver, gold)

- **Due to orbital motion of electrons**
- **Magnetic susceptibility of most diamagnetic materials is on the order of -10^{-5}**

Paramagnetic Materials (aluminum, magnesium, titanium)

- **Due to spinning motion of electrons**
- **Magnetic susceptibilty of paramagnetic materials is of the order of 10^{-5}**

Diamagnetic, if $\mu_r \lesssim 1$ (χ_m is a very small negative number).

Paramagnetic, if $\mu_r \gtrsim 1$ (χ_m is a very small positive number).

Ferromagnetic, if $\mu_r \gg 1$ (χ_m is a large positive number).

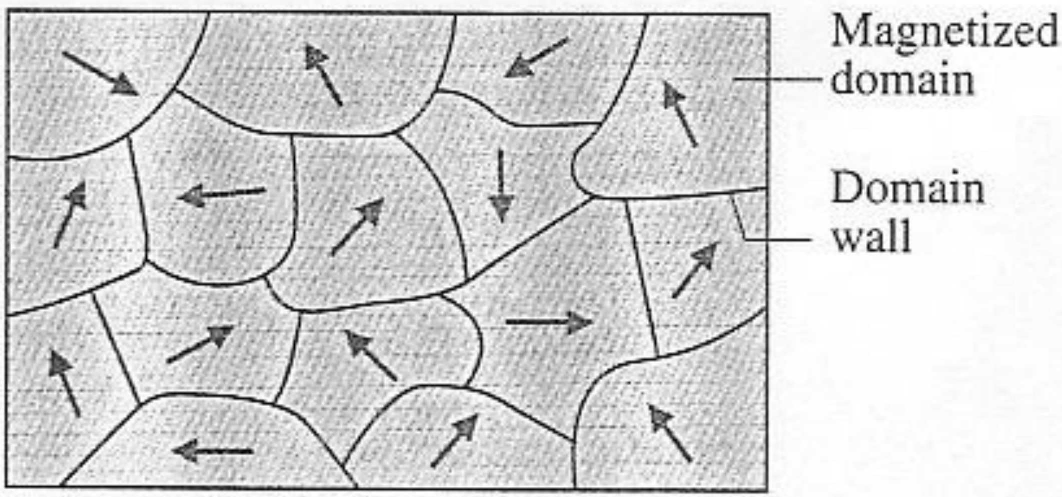
Static Magnetic Field

Ferromagnetic Materials

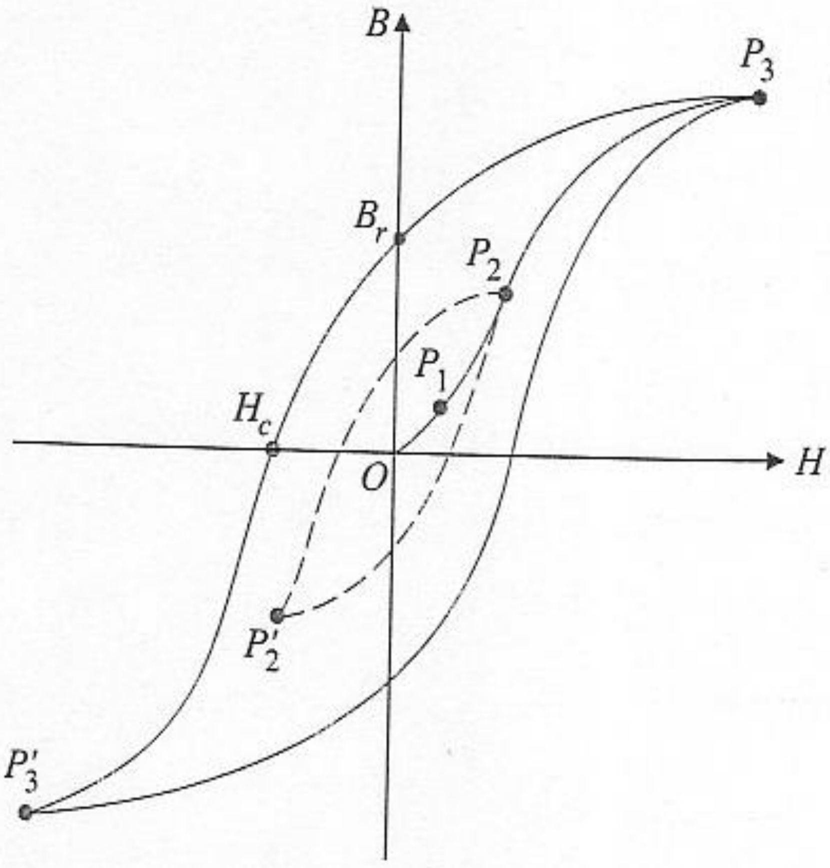
- Ferromagnetic materials have magnetized domains
- Domains range from a few microns to 1 mm
- They contain about 10^{15} to 10^{16} atoms
- Fully magnetized and contain dipole moments
- Strong coupling forces keep the dipole moments parallel in the domain
- Between adjacent domains there are domain walls

- Application of external magnetic field causes some domains to grow with the expense of others
- Those domains grow which have magnetic moments aligned with the applied field
- As a result, magnetic flux density is increased

Static Magnetic Field



Domain structure of a polycrystalline ferromagnetic specimen.

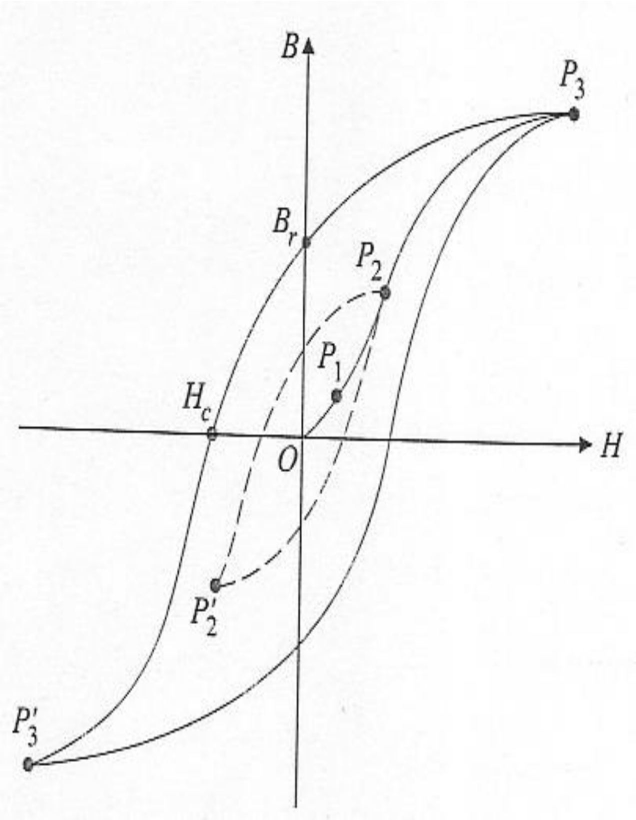


Hysteresis loops in the B–H plane for ferromagnetic material.

Static Magnetic Field

Hysteresis

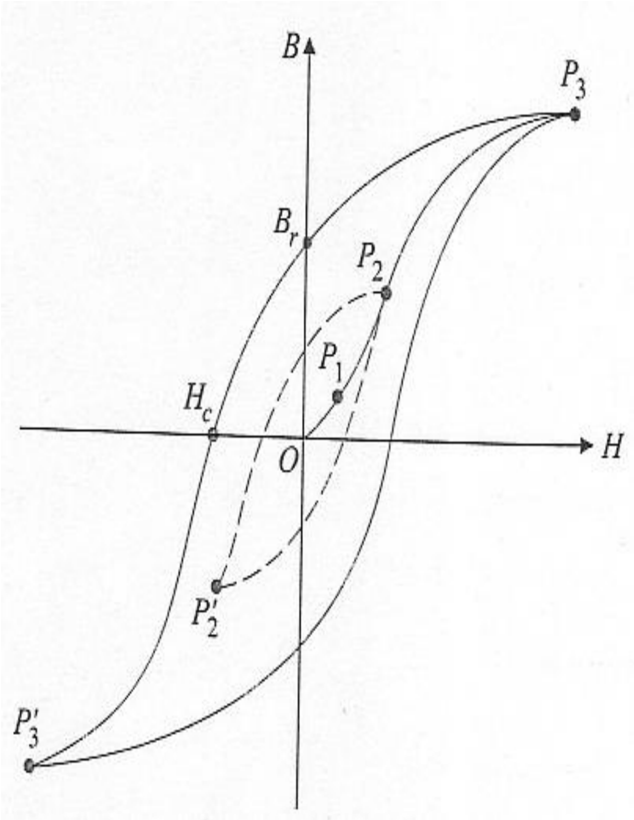
For weak applied fields up to point P_1 on the B-H curve is reversible. For fields stronger than that domain wall movement is irreversible. If the applied field is reduced to zero at point P_2, the B-H relationship will not follow the path P_2P_1O. Rather movement will occur along P_2P_2'. This phenomenon of magnetization lagging behind the field producing it is called hysteresis.



Saturation and normal magnetization curve

further increase in applied field will cause the flux to grow and reach saturation at point P_3. The curve $OP_1P_2P_3$ on the B-H plane is called normal magnetization curve.

Static Magnetic Field



Residual or remnant flux density

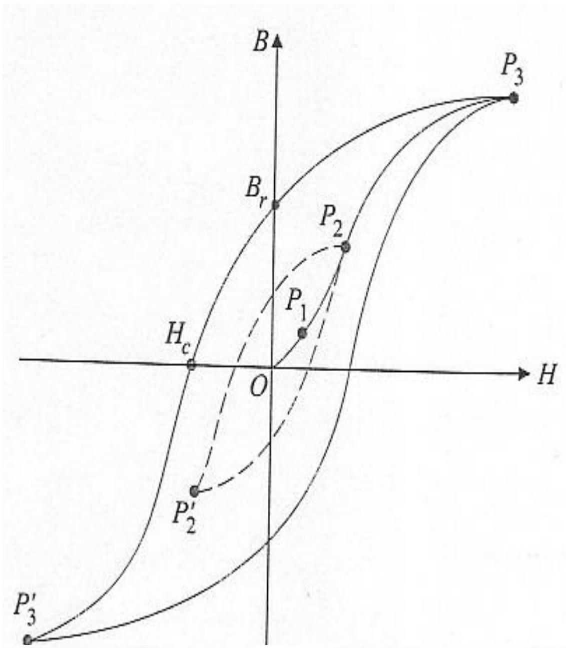
If the applied field is reduced to zero the magnetic flux density does not go to zero but assumes a value B_r. This value is called the residual or remnant flux density.

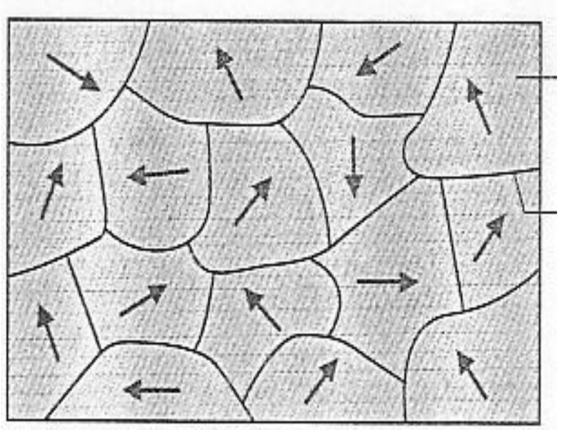
Coercive field intensity

To make B=0 it is necessary to apply a magnetic field intensity H_c in the opposite direction. This required field is called the coercive field intensity.

Static Magnetic Field

Ferromagnetic Materials

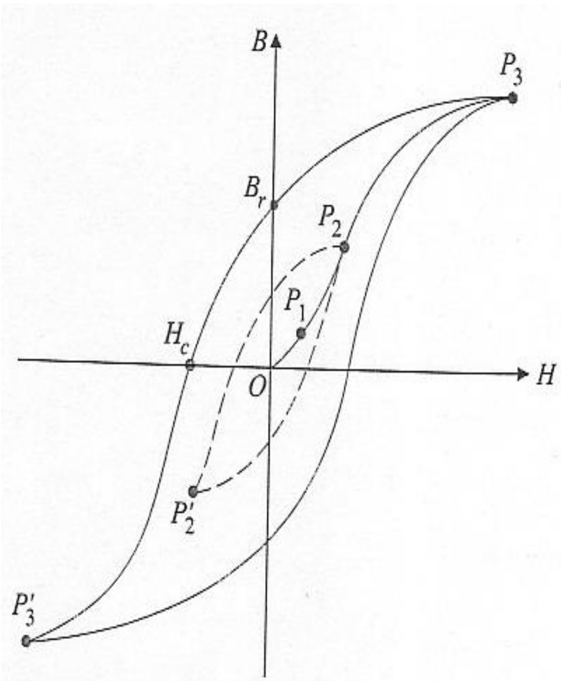




- For generators, motors, and transformers ferromagnetic materials should have tall narrow hysteresis loops.
- With an applied H field varying between +- H_{max}, the loop is traced once per cycle.
- The area of the loop represents the hysteresis loss per unit vol/cycle.
- Hysteresis loss is the energy lost in the form of heat in overcoming the friction encountered during domain wall movement.
- Ferromagnetic materials with tall narrow hysteresis loops are called soft materials.

Static Magnetic Field

Ferromagnetic Materials



- Good permanent magnets on the other hand are called hard ferromagnetic materials.
- They have fat hysteresis loops, large H_c and hence are more resistant to demagnetization.
- Hc for hard ferromagnetic materials can be 105 (A/m) while that for soft materials can be 50 (A/m).

<u>Curie temperature</u>

With an increase in temperature as such that the thermal energy exceeds the coupling energy of magnetic dipoles the magnetized domains become disorganized and the ferromagnetic material behaves as a paramagnetic material. This temperature is called the Curie temperature and for iron it is 770^{o}C.

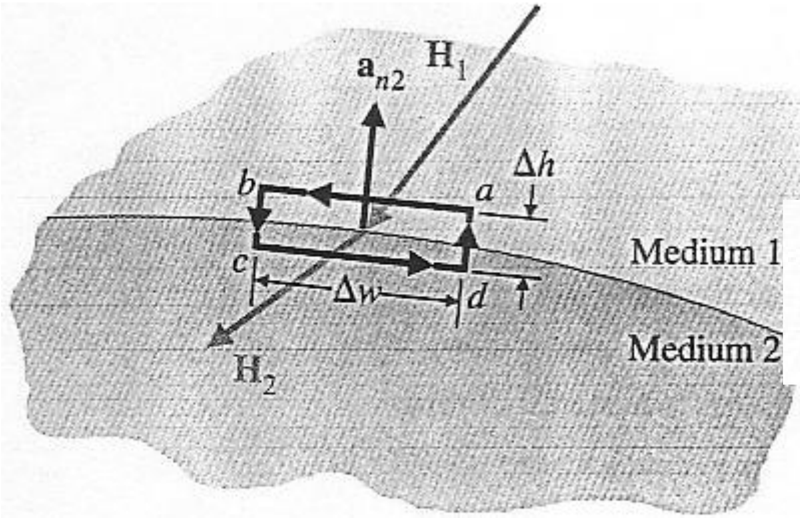
Static Magnetic Field

Ferrimagnetic Materials

- Ferrites belong to another class of materials
- Some ferrites can have conductivities as low as 10^{-4} to 1 (S/m) compared to iron with 10^{7} (S/m).
- Low conductivity limits losses due to eddy currents at high frequencies.
- Wide application at high frequencies, such as FM antennas, high frequency transformers, and phase shifters.
- They are also used in computer magnetic core and magnetic-disk memory devices.

Static Magnetic Field

Boundary Conditions for Magnetic Fields



$$B_{1n} = B_{2n} \qquad \text{(T)}. \qquad (5\text{-}68)$$

$$\oint_{abcda} \mathbf{H}_i \cdot d\boldsymbol{\ell} = \mathbf{H}_1 \cdot \Delta\mathbf{w} + \mathbf{H}_2 \cdot (-\Delta\mathbf{w}) = \mathbf{J}_{sn},$$

$$H_{1t} - H_{2t} = J_{sn} \qquad \text{(A/m)}, \qquad (5\text{-}70)$$

$$\mathbf{a}_{n2} \times (\mathbf{H}_1 - \mathbf{H}_2) = \mathbf{J}_s \qquad \text{(A/m)}, \qquad (5\text{-}71)$$

Static Magnetic Field

REVIEW QUESTIONS

Q.5-13 Define *magnetization vector*. What is its SI unit?

Q.5-14 What is meant by "equivalent magnetization current densities"? What are the SI units for $\nabla \times \mathbf{M}$ and $\mathbf{M} \times \mathbf{a}_n$?

Q.5-15 Define *magnetic field intensity vector*. What is its SI unit?

Q.5-16 Write the two fundamental governing differential equations for magnetostatics.

Q.5-17 Define *magnetic susceptibility* and *relative permeability*. What are their SI units?

Q.5-18 Does the magnetic field intensity due to a current distribution depend on the properties of the medium? Does the magnetic flux density?

Q.5-19 Define *diamagnetic*, *paramagnetic*, and *ferromagnetic* materials.

Q.5-20 What is a hysteresis loop?

Q.5-21 Define *remanent flux density* and *coercive field intensity*.

THANK YOU