Electricity & Magnetism

Sem-2 (Hons)

Semester II

CC- III: ELECTRICITY AND MAGNETISM

(Credits: Theory-04, Practicals-02)

F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Internal Assessment [Class Attendance (Theory) – 05, Theory (Class Test/ Assignment/ Seminar) – 05, Practical (Sessional Viva-voce) - 05]

Theory: **60 Lectures**

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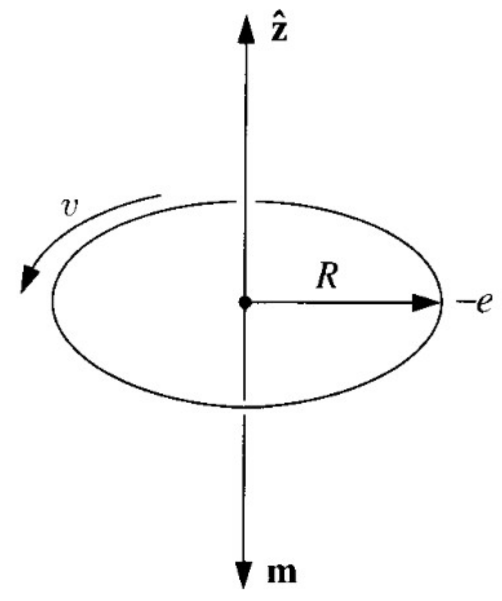
Syllabus

Magnetic Properties of Matter: Magnetization vector (M). Magnetic Intensity(H). Magnetic Susceptibility and permeability.Relation between B, H, M. Ferromagnetism.B-H curve and hysteresis. (4 Lectures)

Magnetization **M**

$\mathbf{M} \equiv$ *magnetic dipole moment per unit volume.*

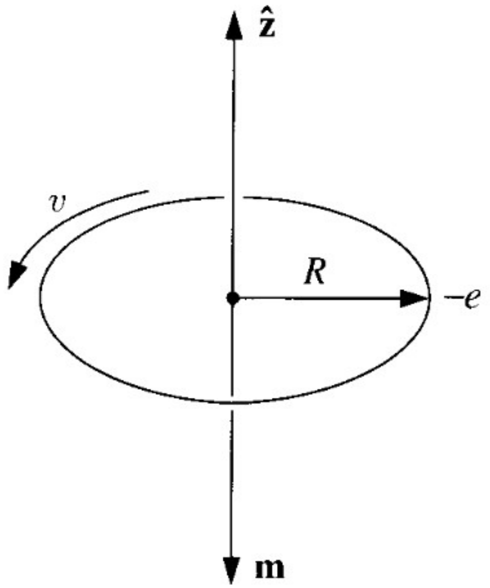


Magnetization **M**

$\mathbf{M} \equiv$ *magnetic dipole moment per unit volume.*

Concept of bound current:

$$\mathbf{A}(\mathbf{r}) = \frac{\mu_0}{4\pi} \frac{\mathbf{m} \times \hat{\boldsymbol{\imath}}}{\imath^2}.$$



$$\mathbf{A}(\mathbf{r}) = \frac{\mu_0}{4\pi} \int \left[\mathbf{M}(\mathbf{r}') \times \left(\nabla' \frac{1}{\imath} \right) \right] d\tau'.$$

Magnetization $\mathbf{M}$

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Concept of bound current:

$$\mathbf{A}(\mathbf{r}) = \frac{\mu_0}{4\pi} \int \left[\mathbf{M}(\mathbf{r}') \times \left(\nabla' \frac{1}{\mathscr{r}} \right) \right] d\tau'.$$

$$\mathbf{A}(\mathbf{r}) = \frac{\mu_0}{4\pi} \int \frac{1}{\mathscr{r}} [\nabla' \times \mathbf{M}(\mathbf{r}')] \, d\tau' + \frac{\mu_0}{4\pi} \oint \frac{1}{\mathscr{r}} [\mathbf{M}(\mathbf{r}') \times d\mathbf{a}'].$$

$$\boxed{\mathbf{J}_b = \nabla \times \mathbf{M},}$$

$$\boxed{\mathbf{K}_b = \mathbf{M} \times \hat{\mathbf{n}},}$$

Magnetization $\mathbf{M}$

$\mathbf{M} \equiv$ *magnetic dipole moment per unit volume.*

$$\mathbf{J}_b = \nabla \times \mathbf{M},$$

$$\nabla \cdot \mathbf{J}_b = 0.$$

the divergence of a curl is *always* zero.

Magnetic Intensity $\mathbf{H}$

Current density = Bound Current + Free current

$$\mathbf{J} = \mathbf{J}_b + \mathbf{J}_f .$$

$$\frac{1}{\mu_0}(\nabla \times \mathbf{B}) = \mathbf{J} = \mathbf{J}_f + \mathbf{J}_b = \mathbf{J}_f + (\nabla \times \mathbf{M}),$$

$$\nabla \times \left(\frac{1}{\mu_0}\mathbf{B} - \mathbf{M}\right) = \mathbf{J}_f .$$

Magnetic Intensity H

$$\nabla \times \left(\frac{1}{\mu_0} \mathbf{B} - \mathbf{M} \right) = \mathbf{J}_f .$$

This is the relation between **B, H** and **M**

$$\mathbf{H} \equiv \frac{1}{\mu_0} \mathbf{B} - \mathbf{M}.$$

Ampere's Circuital Law

$$\oint \mathbf{H} \cdot d\mathbf{l} = I_{f_{\text{enc}}},$$

$$\mathbf{M} = \chi_m \mathbf{H}.$$

Typical values are around 10^{-5}

The constant of proportionality χ_m is called the **magnetic susceptibility**;

Magnetic properties of materials:

- Revise the following topics from any text book: (NCERT Class 12)
- Magnetic intensity, magnetic induction, permeability, magnetic susceptibility.
- Brief introduction of dia-, para- and ferro-magnetic materials.

Magnetic properties of materials:

Important to know for future experimental physicists:

Material	Susceptibility	Material	Susceptibility
Diamagnetic:		*Paramagnetic:*	
Bismuth	-1.6×10^{-4}	Oxygen	1.9×10^{-6}
Gold	-3.4×10^{-5}	Sodium	8.5×10^{-6}
Silver	-2.4×10^{-5}	Aluminum	2.1×10^{-5}
Copper	-9.7×10^{-6}	Tungsten	7.8×10^{-5}
Water	-9.0×10^{-6}	Platinum	2.8×10^{-4}
Carbon Dioxide	-1.2×10^{-8}	Liquid Oxygen ($-200°$ C)	3.9×10^{-3}
Hydrogen	-2.2×10^{-9}	Gadolinium	4.8×10^{-1}

dia-, para- and ferro-

Diamagnetic	Paramagnetic	Ferromagnetic
Atoms do not have intrinsic magnetic moment.	Atoms have intrinsic magnetic moment.	Atoms have intrinsic magnetic moment.
On application of external magnetic field (**B**) magnetisation ***m*** grows and it is opposite to **B**	When external magnetic field (**B**) applied, the magnetisation ***m*** align along **B**, and when removed, net magnetisation is zero.	When external magnetic field (**B**) applied, the magnetisation ***m*** align along **B** and when ext. field is removed, the magnetisation persists.
U = - **m**.**B** **U is +ve**	U = - **m.B** U is -ve	U = - **m.B** U is -ve
Water, Superconductor, Cu, Pb, NaCl, S	Al, Na, $CuCl_2$	Fe, Co, Ni

Important formula..

This is example of linear media, where **M** and **H** is linearly proportional..

$$\mathbf{B} = \mu_0(\mathbf{H} + \mathbf{M}) = \mu_0(1 + \chi_m)\mathbf{H},$$

$$\mathbf{B} = \mu\mathbf{H},$$

$$\mu \equiv \mu_0(1 + \chi_m).$$

Ferromagnetism and **B-H** loop

This is example of non-linear media, where **M** and **H** is not linearly proportional..

$$\mathbf{B} = \mu_0(\mathbf{H} + \mathbf{M}) = \mu_0(1 + \chi_m)\mathbf{H},$$

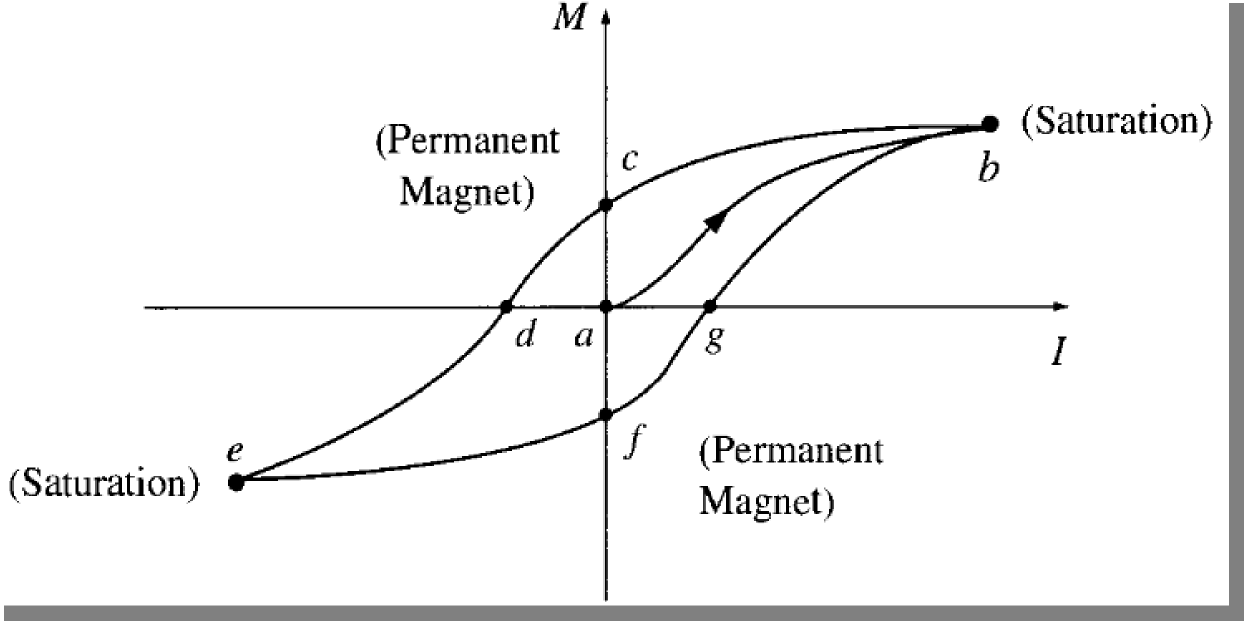
$$\mathbf{B} = \mu\mathbf{H},$$

$$\mu \equiv \mu_0(1 + \chi_m).$$

We do not know exact formula relating M and H..

Ferromagnetism and **B-H** loop

This is example of non-linear media, where **M** and **H** is not linearly proportional..



There are lots of questions you should ask from this figure.. **please attend class**

Thank you