Physics Notes

BY

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Class:10+2
Unit: III
Topic: Classification of Magnetic Materials

SYLLABUS: UNIT-III-*D*

Concept of magnetic field, Oersted's experiment, Biot-Savart law, magnetic field due to an infinitely long current carrying straight wire and a circular loop; Ampere's circuit law and its applications to straight and toroidal solenoids; Force on a moving charge in uniform magnetic and electric fields, Cyclotron; Force on current – carrying conductor in a uniform magnetic field. Forces between two parallel current- carrying conductors-definition of ampere; Torque experienced by a current loop in a uniform magnetic field, moving coil galvanometer- its current sensitivity and conversion to ammeter and voltmeter.

Current loop as a magnetic dipole and its magnetic dipole moment; Magnetic dipole moment of a revolving electron; Magnetic field intensity due to magnetic dipole (bar magnet) along the axis and perpendicular to the axis; Torque on a magnetic dipole (bar magnet) in a uniform magnetic field; Bar magnet as an equivalent solenoid, Magnetic field lines' Earth's magnetic field and magnetic elements; Para-dia and ferro-magnetic substances with examples, Electromagnets and permanent magnets.

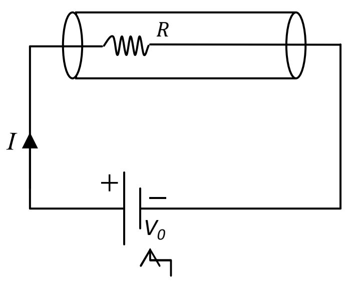
Q.1. Compare Electric and Magnetic Circuit?

Ans.

Electric Circuit

1. What causes current in the Electric Circuit?

Ans. *Emf* (Electro motive force)



2. Current, I

3. Resistance, $R = \dfrac{l}{\sigma . A}$

   σ → Conductivity of material

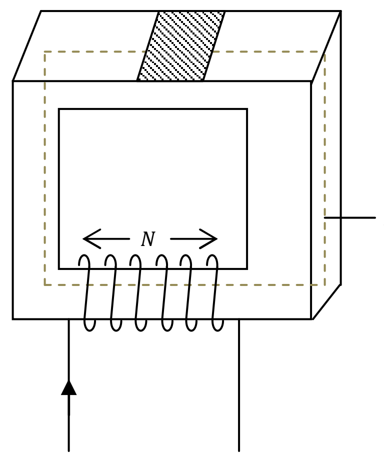
4. E, Electric field intensity =

$$E = \frac{V}{l} = \frac{e.m.f}{length}$$

Magnetic Circuit

1. What causes magnetic flux in magnetic circuit?

Ans. *Mmf* (Magneto motive force)



2. Magnetic flux, ϕ

3. Reluctance, R_e {opposition to flow of magnetic flux}

$$R_e = \frac{l}{\mu . A}$$

μ → Permeability

Iron has high permeability
wood has low permeability

$\mu = \mu_0 . \mu_r$

μ_r → [1,2,3,4,.....] is relative permeability

μ_0 → permeability of free space and
$\mu_0 = 4\pi \times 10^{-7}$ in SI units.

4. H, Magnetising field intensity =

$$H = \frac{m.m.f}{l} = \frac{NI}{l}$$

N → number of turns
l → length of magnetic circuit

Electric Circuit	Magnetic Circuit
5. J $= \frac{I}{A}$ Current density	5. Magnetic flux density $\vec{B} = \frac{manetic\ flux}{Area} = \frac{\phi}{A}$
6. Ohm's Law V = IR; I $= \frac{V}{R} = \frac{e.m.f}{R}$	6. Flux

$$\phi = \frac{m.m.f}{R_e}$$

$$\phi = \frac{N.I}{R_e}$$

$$\phi = \frac{N.I}{R_e} = \frac{N.I}{\left(\frac{l}{\mu A}\right)}$$

$$\frac{\phi}{A} = \frac{N.I\mu}{l}$$

$$B = \frac{\mu(N.I)}{l}$$

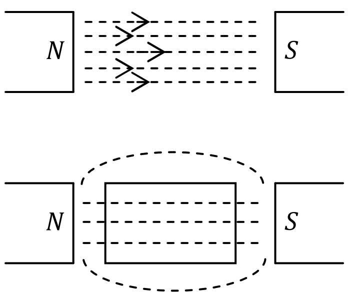
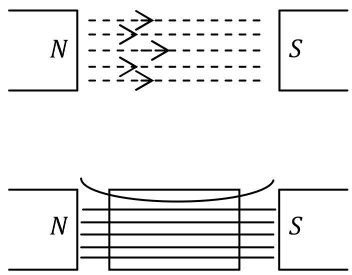
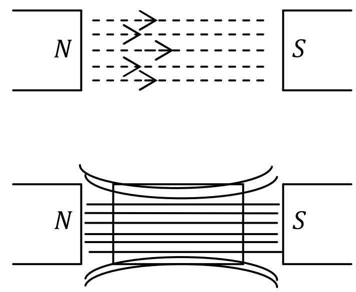
[H = $\frac{N.I}{l}$ is *m.m.f.* per unit length]

$$B = \mu H$$

Magnetic flux density depends upon material but *H* does not depend on material.

Q2. Compare Para, Dia, Ferro magnetic materials?

Ans.

Dia	**Para**	**Ferro**
1. 	1. 	1. 
B_{in} → decreases slightly	B_{in} → increases slightly	B_{in} → increases strongly
2. B = $\mu_0\mu_r$H = μ_0 (1-0.0001)H'	2. B = $\mu_0\mu_r$H = μ_0 (1+0.001)H	2. B = $\mu_0\mu_r$H = μ_0 (1+1000)H
3. Susceptibility and Relative permeability	3.	3.
μ_r = 1 + Y_m χ = 1 + (-0.0001)	μ_r = 1 + Y_m = 1 + (-0.0001)	μ_r = 1 + Y_m = 1 + (1000)
$\left[Y_m = \frac{I}{H}\right]$		
Relative permeability slightly lesser than unity	Slightly greater than unity	much greater than unity

Dia	**Para**	**Ferro**

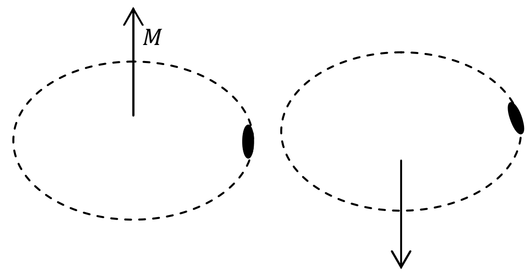
Q3. Discuss behavior of Dia, Para, Ferro magnetic material on the basis of atomic molecular theory?

Ans. <u>**Dia**</u>

<u>**Case I**</u>:-

When there is no external magnetic field.

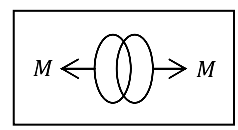
M_{net} = 0 if B_{ext} = 0



<u>**Case II**</u>:-

When B_{ext} is applied

F = q$(\vec{V} \times \vec{B})$



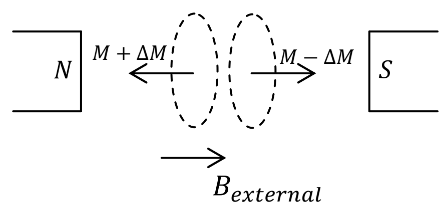
Direction of B is same

Direction of $\vec{V}$ is opposite

So, direction of $\vec{F}$ is opposite

So, magnetic moment of one electron increase to M + ΔM

magnetic moment of 2nd electron decrease to M - ΔM

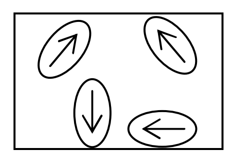


$\vec{M}_{net}$ = $(\vec{M} + \Delta\vec{M})$ - $(\vec{M} - \Delta\vec{M})$

$\vec{M}_{net}$ = 2 ΔM, opposite to $\vec{B}$

<u>**Para**</u>

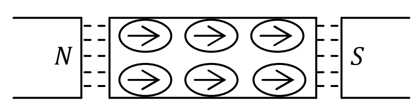
<u>**Case I**</u>:-



When there is no external magnetic field

B_{ext} = 0

Magnetisation = 0



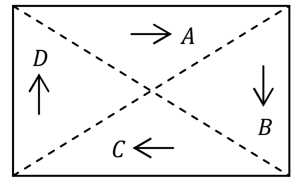
When $\vec{B}_{ext}$ is present:

Atoms orient in the direction of field *B* inside, *B* increases '*slightly*'.

Ferro

Case I:-

When there is no external magnetic field



$B_{ext} = 0$

Dipole in different domains are oriented in different directions

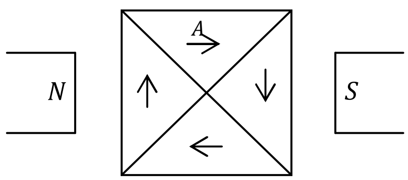
Result → Zero

Case II:-

When B_{ext} is present

Theory I

(Domain Expansion Theory)

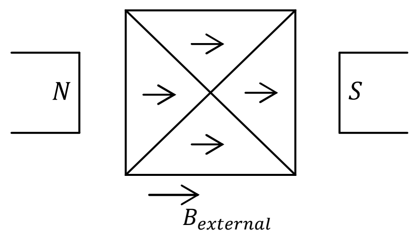


Domain A is parallel to B_{ext}. So domain A expands at the cost of others.

Result ≠ 0

Theory II

(Domain Orientation Theory)

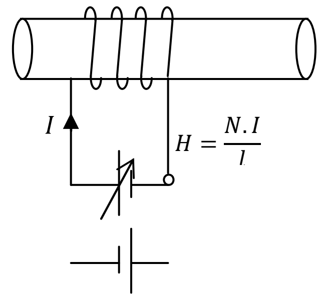


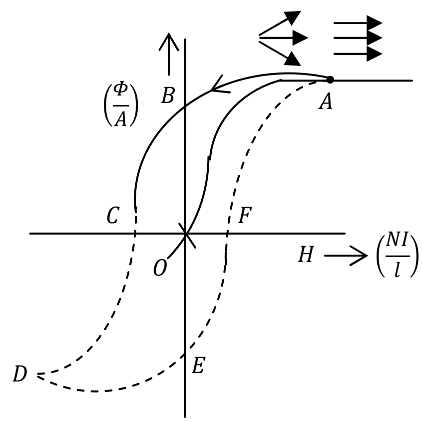
All atoms orient in the direction of B_{ext}.

Q4. a) What is Hysteresis?

b) What is significance of area under the B-H loop?

Ans.a) The phenomenon of lagging of I or B behind H when a specimen of a magnetic material is subjected to a cycle of magnetization is called Hysteresis.





b) area → B x H

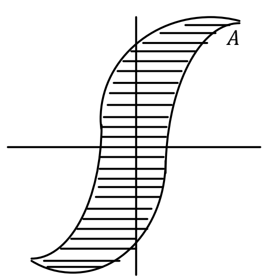
$$\frac{F}{Il} \times \frac{NI}{l}$$

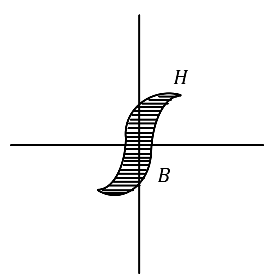
$$= \frac{F}{l^2} = \frac{Force}{area} \times \frac{l}{l} = \frac{work}{volume}$$

It indicates losses per unit volume.

<u>Example</u>:-

More area losses per unit volume





Less loss of heat

More Area means more losses per unit volume

Less Area means less losses per unit volume

Q5. What is the effect of temperature on Dia, Para, Ferro?

Ans. **<u>Dia</u>**

It is practically independent of temperature. The appearance of induced magnetic moment in atoms is not affected by the thermal motion of the atoms, therefore, magnetic susceptibility of such material does not depend on temperature of the materials.

<u>Para</u>

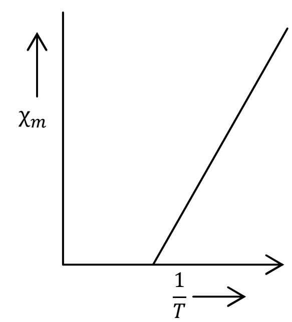
It decreases with rise in temperature

$\chi_m \; \alpha \; \frac{1}{T}$

(χ_r = It χ_m also decreases with heating).

<u>Ferro</u>

It decreases with rise in temperature and above curie temperature becomes para.



Curie Law in magnetism

$$\chi_m = \frac{C}{T}$$

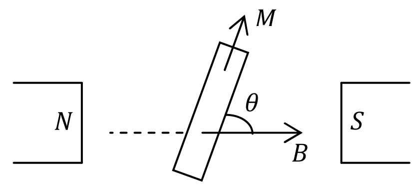
Where C is a constant of proportionality and is called curie constant.

Q6. Derive an Expression for $Time\ period, T$ of a magnet in magnetic field?

Ans. **Step 1**:-

Displace the object from its mean position.

Check object tries to regain its original position.



Step 2:-

Find restoring Force/Torque

$\vec{\tau} = \vec{M} \times \vec{B}$

$\tau = -MB \sin\theta$ ——— ①

[If we rotate the magnet anticlockwise, Torque acts clockwise]

Step 3:-

$\tau = I\alpha$ ——— ②

Step 4:-

From ① and ②

$I\alpha = -MB \sin\theta$

$\alpha = -\frac{M}{I} \sin\theta$ (Not S.H.M.)

For small angles $\sin\theta \simeq \theta$

$\alpha = -\frac{MB\theta}{I}$

$\frac{d^2\theta}{dt^2} = -\left(\frac{MB}{I}\right).\theta$

Acc = (const.) displacement condition for S.H.M.

Step 5:-

Compare it with standard equation

acc $= -(\omega^2)$ displacement

$\omega^2 = \frac{MB}{I}$

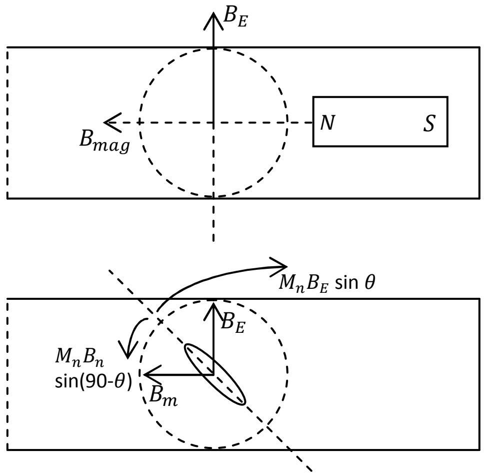
$\omega = \sqrt{\frac{MB}{I}}$

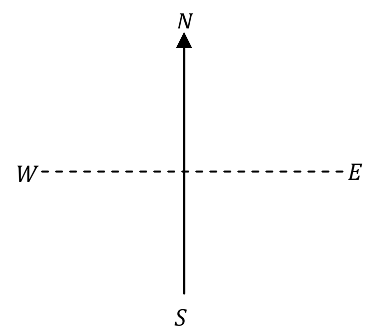
$\frac{2\pi}{T} = \sqrt{\frac{MB}{I}}$

$T = 2.\pi\sqrt{\frac{I}{MB}}$

Magnetic Magnetometers

Tan A





$$\text{Tan } \theta = \frac{B_M}{B_E}$$

$$\text{Tan } \theta = \frac{\left(\frac{\mu_0}{4\pi}\right)\left(\frac{2M}{r^3}\right)}{B_E}$$

We can find (i) Magnetic moment, deflection
(ii) to compare the value of *M*

$$\frac{Tan\ \theta_1}{Tan\ \theta_2} = \frac{M_1}{M_2}$$

Tan B

$$\text{Tan } \theta = \frac{B_M}{B_E}$$

$$\text{Tan } \theta = \frac{\left(\frac{\mu_0}{4\pi}\right)\left(\frac{M}{r^3}\right)}{B_E}$$

To find :- *M*

Ratio to compare the value of *M*

$$\frac{Tan\ \theta_1}{Tan\ \theta_2} = \frac{M_1}{M_2}$$