SHIKSHA CLASSES

Subject : Physics **BOARD ANSWER PAPER** **Total Marks : 20**
Class : XII **Topic: 11. Magnetic Materials**

Section (A)

Q. 1. (a) Select and write the most appropriate answer from given alternatives in each sub-question. [5]

1. Two small magnets each of magnetic moment 10 Am² **are placed in end on position 0.1 m apart from their centres, the force acting between them is ------.**

Ans : c) 0.6N

Force acting on two magnetc

magnetic $F = \frac{\mu_0}{4\pi}\frac{6M_1M_2}{r^4}$

$$F = 10^{-7} \times \frac{6\times10\times10}{(0.1)^4}$$

$$\boxed{F = 0.6\ N}$$

2. **Susceptibility is positive and large for a ....**

Ans : **a)** Ferromagnetic substance

Susceptibility is positive and large for a ferromagnetic substance.

3. **Relative permeability of iron is 5500, then the magnetic susceptibility will be**

Ans: d) 5499

Given, $m_r = 5500,\ \chi_m = ?$

$$\mu_r = (1+\chi_m)$$

$$\chi_m = \mu_r - 1 = 5500 - 1 = 5499$$

4. **The unit of intensity of magnetisation is ------.**

Ans : a) A/m

5. **A magnetic wire of dipole moment 4π Am² is bent in the form of semi-circle, the new magnetic moment is ------.**

Ans : d) Zero

The magnetic moment will be zero because it becomes an open ciruit.

(b) Very short answer type Question [2]

1. **How will the magnetic field intensity at the centre of a circular wire carrying current change, if the current through the wire is doubled and radius of the coil is halved?**

Ans : The magnetic field of centre of coil,

$$\beta \alpha \frac{I}{R}$$

When current I is doubled and radius R is halved, the magnetic field becomes four times the original field.

2. **Calculate the gyromagnetic ratio of electron(given e =1.6 x 10^{-19} C, m_e=9.1 x10 $^{-31}$ kg).**

Ans : **Given :**

$$e = 1.6\times10^{-19}\,C,\ m\ell = 9.1\times10^{-31}\,kg$$

$$\text{Gyromagnetic ratio} = \frac{e}{2m\ell}$$

$$= \frac{1.6\times10^{-19}}{2\times9.1\times10^{-31}}$$

$$\boxed{= 8.8\times10^{10}\,C\,kg^{-1}}$$

Section (B)

Q. 2. Attempt any three question. [6]

1. **The magnetic moment of magnet of dimensions 10 cm × 5 cm × 1.25 cm is 12 Am². Calculate the intensity of magnetisation.**

Ans : Given : $l = 10$ cm $= 10 \times 10^{-2}$ m

$b = 5$ cm $= 5 \times 10^{-2}$ m

$h = 1.25 \text{ cm} = 1.25 \times 10^{-2} \text{ m}$

$$\text{Volume (V)} = l \times b \times h$$
$$= 10\times10^{-2}\times5\times10^{-2}\times1.25\times10^{-2}$$
$$= 62.5\times10^{-6}\text{m}^3$$
$$\boxed{V = 6.25\times10^{-7}\text{m}^3}$$

$M = 12 \text{ Am}^2$ = Magnetic Moment intensity of magnetization,

$$M' = \frac{M}{V} = \frac{12}{6.25\times10^{-7}}$$
$$\boxed{M' = 1.92\times10^{7}\text{ A/m}}$$

2. Define magnetisation and explain magnetic intensity.

Ans : i) **Magnetisation :** The ratio of magnetic moment to the volume of the material is called magnetization .

$$M = \frac{m_{net}}{\text{volume}}$$

M is vector quantity having dimension [L^{-1} 'A'].

ii) **Magnetic intensity :** Magnetic field strength or magnetic field intensity is defined as the magnetic field in that arises from an external current and is not intrinsic to the material ifself, it is vector quantity.

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

Where B - magnetic flux density

μ - Magnetic permeability

M - Magnetisation

3. The maximum value of permeability of A-metal (77% Ni, 16% Fe, 5% Cu, 2% Cr) is 0.126 TmA^{-1}. Find the maximum relative permeability and susceptibility.

Ans : **Given :**

$$\mu = 0.126 \text{ Tm/A}$$
$$\mu_0 = 4\pi\times10^{-7}\text{ Tm/A}$$

Maximum relative permeability

$$\mu r = \frac{\mu}{\mu_0} = \frac{0.126}{4\pi\times10^{-7}}$$
$$= 0.01\times10^{+7} = 1\times10^{5}$$

Maximum susceptibilty

$$x = \mu r.1 \approx 1.0\times10^{5}$$

4. Find the magnetisation of a bar magnet of length 10 cm and cross sectional area 1 cm^2, if the magnetic moment is 5 Am^2.

Ans : **Given :**

$M = 5 \text{ Am}^2$, $A = 1\text{cm} = 1 \times 10^{-4}\text{m}^2$

$L = 10 \text{ cm} = 10 \times 10^{-2}\text{m} = 10^{-1}\text{m}$

magnetisation = ?

Volume

$= A \times L = 1 \times 10^{-4} \times 10^{-1} = 10^{-5} \text{ m}^3$

$$\text{Magnetisation} = \frac{M_{net}}{\text{Volume}}$$
$$= \frac{5}{10^{-5}} = 5\times10^{5}\text{ A/m}$$

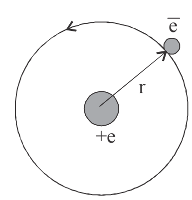
Section (C)

Q. 3. Attempt any one question. [3]

1. Derive an expression for the magnetic dipole moment of a revolving electron.

Ans : Magnetic dipole moment of a revolving electron

i) Consider an electron of charge (– e) is performing U.C.M. around a stationary nucleus as shown in fig.



U.C.M. of electron in an atom

ii) Let,

r = radius of the orbit of revolution of the electron

v = orbital speed or velocity

The period of revolution (T) of the electron is given by

$$T = \frac{\text{circumference}}{\text{Velocity}}$$

$$\therefore \ T = \frac{2\pi r}{V} \text{ ----- (i)}$$

iii) Circulating current (I),

$$I = \frac{e}{T}$$

$$\therefore \ I = \frac{e}{\frac{2\pi r}{v}} \quad \text{(from (i))}$$

$$\therefore \ I = \frac{eV}{2\pi r} \text{ ------- (ii)}$$

iv) The motion of electron constitutentes an orbital current. So U.C.M. of an electron is considered as current loop.

Magnitude of magnetic moment associated with circulating current,

M= IA

$$\therefore \ M = \frac{eV}{2\pi r} \times \pi r^2 \text{ ----- from (ii)}$$

$$\left(\because \ A = \pi r^2\right)$$

$$\therefore \ M = \frac{evr}{2} \text{ -------- (iii)}$$

The direction of this magnetic moment is into the plane of paper.

v) The orbital angular moment (L),

L = mvr

where, m = mass of an electron

$$\therefore \ vr = \frac{L}{m} \text{ ------- (iv)}$$

putting (iv) into equation (iii),

$$M = \frac{eL}{2m}$$

In vector form

$$\vec{M} = -\frac{e}{2m}\vec{L}$$

The negative sign shows that the orbital angular momentum of electron is opposite in the direction to the orbital magnetic moment.

2. **The susceptiblity of calcium at 500 K is 1.2 × 10^{–5}. At what temperature will the susceptibility increase to 1.8 × 10^{–5}?**

Ans : Given :

$$x_1 = 1.2 \times 10^{-5}$$

$$T_1 = 500k$$

$$x_2 = 1.8 \times 10^{-5}$$

$$T_2 = ?$$

$$x_1 T_1 = x_2 T_2$$

$$\therefore \ T_2 = \frac{x_1 T_1}{x_2} = \frac{1.2 \times \cancel{10^{-5}} \times 500}{1.8 \times \cancel{10^{-5}}}$$

$$\therefore T_2 = \frac{600}{1.8}$$

$$\boxed{T_2 = 333.33 \text{ k}}$$

Section (D)

Q.4. Attempt any one question. [4]

1) **a. Derive an expression of magnetic permeability of the material by using the term relative magnetic permeability of the substance.**

Ans: Consider a rod of such a material with some net magnetization, placed in a solenoid with n turns per unit length, and carrying current I. Magnetic field inside the solenoid is given by

$$B_0 = \mu_0 \, n \, I$$

Let us denote the magnetic field due to the material kept inside the solenoid by B_m.

Thus, the net magnetic field inside the rod can be expressed as

$$B = B_0 + B_m \quad \text{---(i)}$$

It has been observed that B_m is proportional to magnetisation M of the material

$$B_m = \mu_0 \, M,$$

where μ_0 is permeability of free space.

$$\therefore\ B = \mu_0\ n\ I + \mu_0\ M \quad \text{---(ii)}$$

Here we will introduce one more quantity called magnetic field intensity H, where H = nI. The noticeable difference between the expression for B and H is that H does not depend on the material rod which is placed inside the solenoid.

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

$$B = \mu_0 (H + M) \quad \text{---(iii)}$$

$$\therefore\ H = \frac{B}{\mu_0} - M \quad \text{---(iv)}$$

From the above expression we conclude that H and M have the same unit i.e., ampere per metre. and also have the same dimensions. Thus the magnetic field induced in the material (B) depends on H and M. Further it is observed that if H is not too strong the magnetization M induced in the material is proportional to the magnetic intensity.

$$M = X\, H, \quad \text{---(v)}$$

where X is called Magnetic Susceptibility. It is a measure of the magnetic behaviour of the material in external applied magnetic field. X is the ratio of two quantities with the same units (Am^{-1}). Hence it is a dimensionless constant.

From Eq. (iv) and Eq. (v) we get

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

$$B = \mu_0 (1 + x) H$$

$$B = \mu_0\ \mu_r H$$

$$\mu_r = 1 + x$$

$$B = \mu\ H$$

$$\mu + \mu_0 \mu_r$$

$$\mu = \mu_0 (1 + x)$$

b. The susceptibility of a metal at saturation is 5000. Find its permeability at saturation.

Ans: **Given :** x = 5000

$$\mu = \mu_0 (1 + x)$$

$$\mu = 4\pi \times 10^{-7} (1 + 5000)$$

$$\mu = 62812 \times 10^{-7}$$

$$\mu = 6.2812 \times 10^{4} \times 10^{-7}$$

$$\boxed{\mu = 6.281 \times 10^{-3}}$$

OR

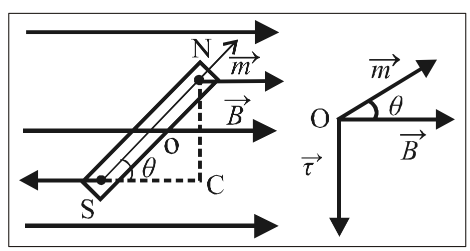
2) a. Derive an expression for torque acting on a magnetic dipole in a uniform magnetic field.

Ans: The torque acting on a rectangular current carrying coil kept in a uniform magnetic field is given by

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

$$\tau = mB \sin\theta, \quad \text{---(i)}$$

where θ is the angle between $\vec{m}$ and $\vec{B}$, the magnetic dipole moment and the external applied uniform magnetic field, respectively as shown in fig. The same can be observed when a small bar magnet is placed in a uniform magnetic field. The forces exerted on the poles of the bar magnet due to magnetic field are along different lines of action. These forces form a couple. The couple produces pure rotational motion. Analogous to rectangula magnetic coil in uniform magnetic field, the bar magnet will follow the same Eq. (i).



Magnet kept in a Uniform Magnetic field.

$\tau = mB\sin\theta$ (m is the magnetic dipole moment of bar magnet and B the uniform magnetic field).

Due to the torque the bar magnet will undergo rotational motion. Whenever a displacement (linear or angular) is taking place, work is being done. Such work is stored in the form of potential energy in the new position. When the electric dipole is kept in the electric field the energy stored is the electrostatic potential energy.

Magnetic potential energy

$$U_m = \int_0^\theta \tau(\theta)d\theta \quad \text{---(ii)}$$

$$U_m = \int_0^\theta mB\sin\theta\, d\theta$$

$$U_m = -mB\cos\theta \quad \text{---(iii)}$$

b. In a hydrogen atom, an electron is making 6.6×10^{15} r.p.s around the nucleus in an orbit of radius 0.523 A.U. calculate the equivalent magnetic moment. orbit of radius 0.523 A.U. calculate the equivalent magnetic moment.

Ans: **Given :** Frequency - $6.6 \times 10^{15} H_2$

$r = 0.523$ A.U. $= 0.523 \times 10^{-10}$m

$M = ?$

$$\text{Period} = T = \frac{1}{f} = \frac{1}{6.6\times10^{15}}$$

Current

$$= I = \frac{e}{T} = 1.6\times10^{-19}\times6.6\times10^{15}$$

Magnetic moment (M) = IA

$$= I\times\pi r^2$$

$$\therefore M = 1.6\times10^{-19}\times6.6\times10^{15}\times3.142\times(0.523\times10^{-10})^2$$

$$M = 1.6\times6.6\times3.142\times(0.523)^2\times10^{-19+15-20}$$

$$\boxed{M = 9.074\times10^{-24}\,Am^2}.$$

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