19

Magnetism and Matter

TOPIC 1
Bar Magnet and Magnetic Dipole

01 Which of the following statements are correct? **[2021, 18 March Shift-II]**

A. Electric monopoles do not exist, whereas magnetic monopoles exist.
B. Magnetic field lines due to a solenoid at its ends and outside cannot be completely straight and confined.
C. Magnetic field lines are completely confined within a toroid.
D. Magnetic field lines inside a bar magnet are not parallel.
E. $\chi = -1$ is the condition for a perfect diamagnetic material, where χ is its magnetic susceptibility.
Choose the correct answer from the options given below.

(a) C and E (b) B and D
(c) A and B (d) B and C

Ans. *(a)*

Statement (A) Magnetic monopoles do not exist, they always exist in pairs as South and North poles but electric monopoles exist. So, statement A is incorrect.

Statement (B) In solenoid have a both ends, so magnetic field lines cannot be confined. Inside the solenoids, the magnetic field lines are parallel to the length of the conductor. So, statement B is incorrect.

Statement (C) In toroid has no ends. It is closed loop conductor, so the magnetic field lines are completely confined. So, the statement C is correct.

Statement (D) Inside the bar magnet, the magnetic field lines are parallel. So, the statement D is incorrect.

Statement (E) Magnetic susceptibility of the diamagnetic material is –1. So, the statement E is correct.

Hence, the correct statements are C and E.

02 A small bar magnet placed with its axis at 30° with an external field of 0.06 T experiences a torque of 0.018 Nm. The minimum work required to rotate it from its stable to unstable equilibrium position is **[2020, 4 Sep Shift-I]**

(a) 9.2×10^{-3} J
(b) 7.2×10^{-2} J
(c) 6.4×10^{-2} J
(d) 11.7×10^{-3} J

Ans. *(b)*

Torque on a bar magnet,

$$\tau = MB \sin\theta$$
$$0.018 = M \times 0.06 \times \sin 30°$$
$$0.018 = M \times 0.06 \times \frac{1}{2}$$
$$M = 0.6 \text{ A-m}^2$$

Now, work done to rotate bar magnet,

$$W = MB[\cos\theta_1 - \cos\theta_2]$$

Here, $\theta_1 = 0°$ (for stable equilibrium position)

and $\theta_2 = 180°$ (for unstable equilibrium position).

So, $W = 0.6 \times 0.06 [\cos(0°) - \cos(180°)]$
$= 0.036 [(1) - (-1)]$
$= 0.036 (2) = 0.072$ J
$= 7.2 \times 10^{-2}$ J

Hence, correct option is (b).

03 A small circular loop of conducting wire has radius a and carries current i. It is placed in a uniform magnetic field B perpendicular to its plane such that when rotated slightly about its diameter and released, it starts performing simple harmonic motion of time period T. If the mass of the loop is m, then **[2020, 9 Jan Shift-II]**

(a) $T = \sqrt{\frac{\pi m}{iB}}$ (b) $T = \sqrt{\frac{2m}{iB}}$
(c) $T = \sqrt{\frac{2\pi m}{iB}}$ (d) $T = \sqrt{\frac{\pi m}{2iB}}$

Ans. *(c)*

Time period of oscillation of a magnetic dipole in a uniform magnetic field,

$$T = 2\pi\sqrt{\frac{I}{\mu B}}$$

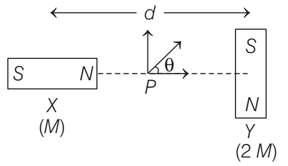
where, μ = magnetic dipole.

Moment of dipole = Current × Area = $\pi a^2 i$

I = moment of inertia of a coil = $ma^2/2$

So, $T = 2\pi\sqrt{\frac{ma^2/2}{\pi a^2 iB}} = 2\pi\sqrt{\frac{m}{2\pi iB}} = \sqrt{\frac{2\pi m}{iB}}$

04 Two magnetic dipoles X and Y are placed at a separation d, with their axes perpendicular to each other. The dipole moment of Y is twice that of X. A particle of charge q is passing through their mid-point P, at angle $\theta = 45°$ with the horizontal line, as shown in figure. What would be the magnitude of force on the particle at that instant?
(d is much larger than the dimensions of the dipole)
[2019, 8 April Shift-II]



(a) $\left(\frac{\mu_0}{4\pi}\right)\frac{M}{(d/2)^3} \times qv$

(b) 0

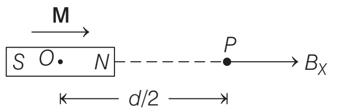
(c) $\sqrt{2}\left(\frac{\mu_0}{4\pi}\right)\frac{M}{(d/2)^3} \times qv$

(d) $\left(\frac{\mu_0}{4\pi}\right)\frac{2M}{(d/2)^3} \times qv$

Ans. ***(b)***

Let $2l_1$ and $2l_2$ be the length of dipole X and Y, respectively.

For dipole X, point P lies on its axial line. So, magnetic field strength at P due to X is



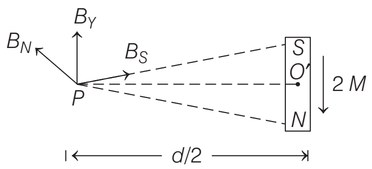
$$B_X = \frac{\mu_0}{4\pi}\cdot\frac{2Mr}{(r^2 - l_1^2)^2}, \text{ along } OP$$

Here, $r = \frac{d}{2}$

Also, $d >> l_1$

$$\Rightarrow \quad |B_X| = \frac{\mu_0}{4\pi}\cdot\frac{2M(d/2)}{(d/2)^4} = \frac{\mu_0}{4\pi}\frac{2M}{(d/2)^3}$$

Similarly, for dipole Y, point P lies on its equatorial line. So, magnetic field strength at P due to Y is



$$B_Y = \frac{\mu_0}{4\pi}\cdot\frac{2M}{(r^2 + l_2^2)^{3/2}},$$

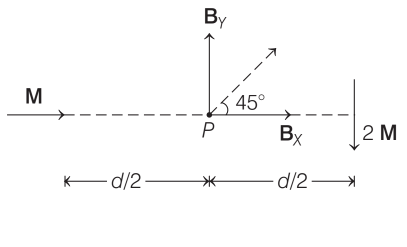
(along a line perpendicular to $O'P$)

Here, $r = \frac{d}{2}$

Also, $d >> l_2$

$$\Rightarrow \quad |B_Y| = \frac{\mu_0}{4\pi}\frac{2M}{(d/2)^3}$$

Thus, the resultant magnetic field due to X and Y at P is



$$B_{net} = B_X + B_Y$$

Since, $|B_Y| = |B_X|$

Thus, the resultant magnetic field (B_{net}) at P will be at $45°$ with the horizontal.

This means, direction of B_{net} and velocity of the charged particle is same.

$\therefore$ Force on the charged particle moving with velocity v in the presence of magnetic field which is

$$B = q(v \times B) = q\,|v||B|\sin\theta$$

where, θ is the angle between B and v.

According to the above analysis, we get

$$\theta = 0 \;\therefore\; F = 0$$

Thus, magnitude of force on the particle at that instant is zero.

05 A magnet of total magnetic moment $10^{-2}\hat{\mathbf{i}}$ A-m^2 is placed in a time varying magnetic field, $B\hat{\mathbf{i}}$ $(\cos\omega t)$, where $B = 1$ T and $\omega = 0.125$ rad/s. The work done for reversing the direction of the magnetic moment at $t = 1$ s is **[2019, 10 Jan Shift-I]**

(a) 0.01 J (b) 0.007 J
(c) 0.014 J (d) 0.028 J

Ans. ***(c)***

Work done in reversing dipole is

$$W = 2\,MB$$

where, M = magnetic dipole moment
$= 10^{-2}$ A-m^2

and B = external field
$= B\cos\omega t = 1 \times \cos(0.125 \times 1)$
$= \cos(7^\circ) = 0.992$

Substituting these values, we get

$$W = 2 \times 10^{-2} \times 0.992 = 0.0198 \text{ J}$$

which is nearest to 0.014 J.

06 A magnetic needle of magnetic moment 6.7×10^{-2} Am^2 and moment of inertia 7.5×10^{-6} kg m^2 is performing simple harmonic oscillations in a magnetic field of 0.01 T. Time taken for 10 complete oscillations is **[JEE Main 2017]**

(a) 8.89 s (b) 6.98 s
(c) 8.76 s (d) 6.65 s

Ans. ***(d)***

Time period of oscillation is

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

$$\Rightarrow \quad T = 2\pi\sqrt{\frac{7.5 \times 10^{-6}}{6.7 \times 10^{-2} \times 0.01}} = 0.665 \text{ s}$$

Hence, time for 10 oscillations is $t = 6.65$ s.

07 The magnetic lines of force inside a bar magnet **[AIEEE 2013]**

(a) are from North-pole to South-pole of the magnet
(b) do not exist
(c) depend upon the area of cross-section of the bar magnet
(d) are from South-pole to North-pole of the magnet

Ans. ***(d)***

Inside bar magnet, lines of force are from South to North.

08 A magnetic needle is kept in a non-uniform magnetic field. It experiences **[AIEEE 2005]**

(a) a torque but not a force
(b) neither a force nor a torque
(c) a force and a torque
(d) a force but not a torque

Ans. ***(c)***

Magnetic needle is placed in non-uniform magnetic field. It experiences force and torque both due to unequal forces acting on poles.

TOPIC 2
Earth Magnetism

09 In a uniform magnetic field, the magnetic needle has a magnetic moment 9.85×10^{-2} A/m^2 and moment of inertia 5×10^{-6} kg-m^2. If it performs 10 complete oscillations in 5 s, then the magnitude of the magnetic field is .... mT. [Take, π^2 as 9.85] **[2021, 27 July Shift-I]**

Ans. ***(8)***

Given,

Magnetic moment, $M = 9.85 \times 10^{-2}$ A/m^2

Moment of inertia, $I = 5 \times 10^{-6}$ kg m^2

$\because$ We know that,

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

where, T = time period of oscillations of a freely suspended magnetic dipole,

I = moment of inertia of the magnet about the axis of angular motion,

M = magnetic dipole moment

and B = magnetic field.

$$\Rightarrow \quad \frac{5}{10} = 2\pi\sqrt{\frac{5 \times 10^{-6}}{9.85 \times 10^{-2} \times B}}$$

$$\Rightarrow \quad B = 8 \times 10^{-3} \text{ T}$$

10 Choose the correct option.

[2021, 22 July Shift-II]

(a) True dip is not mathematically related to apparent dip.
(b) True dip is less than apparent dip.
(c) True dip is always greater than the apparent dip.
(d) True dip is always equal to apparent dip.

Ans. *(b)*

We know that, $\tan\rho' = \dfrac{\tan\rho}{\cos\alpha}$

where, ρ' = apparent dip angle

ρ = true dip angle

and α = angle made by vertical plane with magnetic meridian.

Since, $\cos\alpha \le 1$

$\therefore \quad \tan\rho' \ge \tan\rho$

$\Rightarrow \quad \rho' \ge \rho$

Therefore, true dip is less than or equal to apparent dip.

11 At an angle of 30° to the magnetic meridian, the apparent dip is 45°. Find the true dip.

[2021, 20 July Shift-II]

(a) $\tan^{-1}(\sqrt{3})$ (b) $\tan^{-1}\left(\dfrac{1}{\sqrt{3}}\right)$

(c) $\tan^{-1}\left(\dfrac{2}{\sqrt{3}}\right)$ (d) $\tan^{-1}\left(\dfrac{\sqrt{3}}{2}\right)$

Ans. *(d)*

Given, $\theta = 30°$

Apparent dip, $\delta' = 45°$

Since, $\tan\delta' = \dfrac{B_V}{B_H \cos\theta}$

$$\Rightarrow \quad \tan 45° = \frac{B_V}{B_H \cos 30°}$$

$$\Rightarrow \quad 1 = \frac{B_V}{B_H\left(\dfrac{\sqrt{3}}{2}\right)} \quad \left(\because \cos 30° = \frac{\sqrt{3}}{2}\right)$$

$$\Rightarrow \quad 1 = \frac{2B_V}{\sqrt{3}B_H} \Rightarrow \sqrt{3}B_H = 2B_V$$

$$\Rightarrow \quad B_V = \frac{\sqrt{3}}{2} B_H \quad \text{...(i)}$$

If δ be the true angle of dip, then

$$\tan\delta = \frac{B_V}{B_H}$$

$$\tan\delta = \frac{\frac{\sqrt{3}}{2}B_H}{B_H} \quad \text{[From Eq. (i)]}$$

$$\Rightarrow \quad \tan\delta = \frac{\sqrt{3}}{2}$$

$$\Rightarrow \quad \delta = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$$

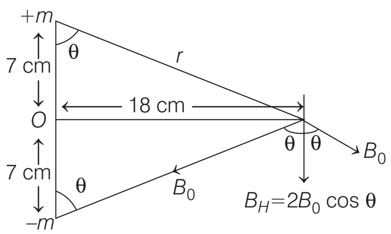
12 A bar magnet of length 14 cm is placed in the magnetic meridian with its North pole pointing towards the geographic North pole. A neutral point is obtained at a distance of 18 cm from the centre of the magnet. If $B_H = 0.4$ G, then the magnetic moment of the magnet is $(1\,\text{G} = 10^{-4}\,\text{T})$

[2021, 16 March Shift-I]

(a) $2.88 \times 10^3\ \text{J T}^{-1}$ (b) $2.88 \times 10^2\ \text{J T}^{-1}$
(c) $2.88\ \text{J T}^{-1}$ (d) $28.8\ \text{J T}^{-1}$

Ans. *(c)*

The given situation can be shown as below



From the above figure, it is clear that the neutral point will lie on equitorial plane.

$$B_0 = \frac{\mu_0 m}{4\pi}\frac{1}{r^2}$$

$$B_H = 2B_0 \cos\theta$$

$$\Rightarrow \quad 0.4 \times 10^{-4} = \frac{2\mu_0 m}{4\pi r^2} \cdot \frac{7 \times 10^{-2}}{r}$$

$$(\because B_H = 0.4\text{G} = 0.4 \times 10^{-4}\text{T})$$

$$\left[\because \cos\theta = \frac{7}{r} \text{ and } r = (7^2 + 18^2)^{1/2}\right]$$

$$\Rightarrow 0.4 \times 10^{-4} = 2 \times 10^{-7} \times \frac{m \times 7}{(7^2 + 18^2)^{3/2}} \times 10^4$$

$$\Rightarrow \quad m = \frac{4 \times 10^{-2} \times (373)^{3/2}}{14} \quad \text{...(i)}$$

$\because$ Magnetic moment,

$$M = m \times 2l = m \times \frac{14}{100} \quad \text{...(ii)}$$

From Eqs. (i) & (ii), we get

$$M = \frac{4 \times 10^{-2} \times (373)^{3/2}}{14} \times \frac{14}{100}$$

$$= 4 \times 10^{-4} \times 7203.82 = 2.88\ \text{J/T}$$

13 A magnetic compass needle oscillates 30 times per minute at a place, where the dip is 45° and 40 times per minute, where the dip is 30°. If B_1 and B_2 are respectively, the total magnetic field due to the earth at the two places, then the ratio B_1/B_2 is best given by

[2019, 12 April Shift-I]

(a) 1.8 T (b) 0.7 T
(c) 3.6 T (d) 2.2 T

Ans. *(b)*

Given, at first place, angle of dip, $\theta_1 = 45°$

Time period, $T_1 = \dfrac{60}{30} = 2$ s

At second place, angle of dip, $\theta_2 = 30°$

Time period, $T_2 = \dfrac{60}{40} = \dfrac{3}{2}$ s

Now, at first place,

$$B_{H_1} = B_1 \cos\theta_1 = B_1 \cos 45° = \frac{B_1}{\sqrt{2}} \quad \text{...(i)}$$

and at second place,

$$B_{H_2} = B_2 \cos\theta_2 = B_2 \cos 30° = \frac{\sqrt{3}}{2} B_2 \quad \text{...(ii)}$$

Also, time period of a magnetic needle is given by

$$T = 2\pi\sqrt{\frac{I}{MB_H}} \quad \text{...(iii)}$$

$$\therefore \quad T \propto \sqrt{\frac{1}{B_H}} \text{ or } \frac{T_1}{T_2} = \sqrt{\frac{B_{H_2}}{B_{H_1}}} \quad \text{...(iv)}$$

By putting the values from Eqs. (i) and (ii) into Eq. (iv), we get

$$\frac{2}{\frac{3}{2}} = \sqrt{\frac{\sqrt{3}\frac{B_2}{2}}{\frac{B_1}{\sqrt{2}}}}$$

$$\text{or} \quad \left(\frac{4}{3}\right)^2 = \frac{\sqrt{3} \times \sqrt{2}\ B_2}{2B_1}$$

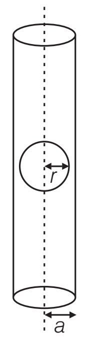
$$\Rightarrow \quad \frac{B_1}{B_2} = \frac{\sqrt{3} \times \sqrt{2}}{2} \times \frac{9}{16}$$

$$\Rightarrow \quad \frac{B_1}{B_2} = \frac{9\sqrt{3}}{16\sqrt{2}}$$

$$\Rightarrow \quad \frac{B_1}{B_2} = \frac{9 \times 1.732}{16 \times 1.414} = \frac{15.588}{22.624}$$

$$\Rightarrow \quad \frac{B_1}{B_2} = 0.689 \approx 0.7\ \text{T}$$

14 A hoop and a solid cylinder of same mass and radius are made of a permanent magnetic material with their magnetic moment parallel to their respective axes. But the magnetic moment of hoop is twice of solid cylinder. They are placed in a uniform magnetic field in such a manner that their magnetic moments make a small angle with the field. If the oscillation periods of hoop and cylinder are T_h and T_c respectively, then **[2019, 10 Jan Shift-II]**



(a) $T_h = 0.5T_c$ (b) $T_h = T_c$
(c) $T_h = 2T_c$ (d) $T_h = 1.5T_c$

Ans. *(b)*

The time-period of oscillations made by a magnet of magnetic moment M, moment of inertia I, placed in a magnetic field is given by

$$T = 2\pi\sqrt{\frac{I}{MB}} \quad \text{...(i)}$$

For the hoop, let us assume its moment of inertia I_h and magnetic moment M_h, then its time period will be

$$T_h = 2\pi\sqrt{\frac{I_h}{M_h B}} \quad \text{...(ii)}$$

Similarly, for solid cylinder, time period is,

$$T_c = 2\pi\sqrt{\frac{I_c}{M_c B}} \quad \text{...(iii)}$$

Dividing Eq. (ii) by Eq. (iii), we get

$$\frac{T_h}{T_c} = \sqrt{\frac{I_h M_c}{M_h I_c}} \quad \text{...(iv)}$$

Now, it is given that,

$$M_h = 2M_c$$

and we know that, moment of inertia of hoop

$I_h = mR^2$ and moment of inertia of solid cylinder $I_c = \frac{1}{2}mR^2$

Substituting these values in Eq. (iv), we get

$$\frac{T_h}{T_c} = \sqrt{\frac{mR^2 \times M_c}{\frac{1}{2}mR^2 \times 2M_c}} = 1$$

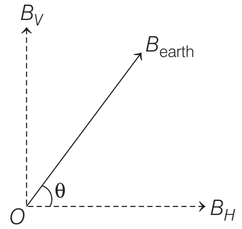
$$\Rightarrow \quad T_h = T_c$$

15 At some location on earth, the horizontal component of earth's magnetic field is 18×10^{-6} T. At this location, magnetic needle of length 0.12 m and pole strength 1.8 A-m is suspended from its mid point using a thread, it makes 45° angle with horizontal in equilibrium. To keep this needle horizontal, the vertical force that should be applied at one of its ends is **[2019, 10 Jan Shift-II]**

(a) 6.5×10^{-5} N (b) 3.6×10^{-5} N
(c) 1.3×10^{-5} N (d) 1.8×10^{-5} N

Ans. *(a)*

Without applied forces, (in equilibrium position) the needle will stay in the resultant magnetic field of earth. Hence, the dip 'θ' at this place is 45° (given).



We know that, horizontal and vertical components of earth's magnetic field (B_H and B_V) are related as

$$\frac{B_V}{B_H} = \tan\theta$$

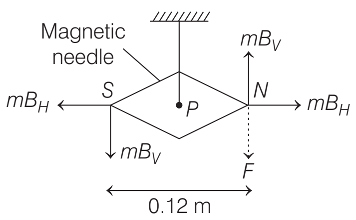
Here, $\theta = 45^\circ$ and $B_H = 18 \times 10^{-6}$ T

$\Rightarrow \quad B_V = B_H \tan 45^\circ$

$\Rightarrow \quad B_V = B_H = 18 \times 10^{-6}$ T

($\because \tan 45^\circ = 1$)

Now, when the external force F is applied, so as to keep the needle stays in horizontal position is shown below,



Taking torque at point P, we get

$$mB_V \times 2l = Fl$$

$$\therefore \quad F = 2 \times mB_V$$

Substituting the given values, we get

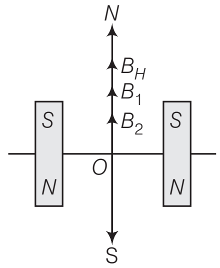
$$= 2 \times 1.8 \times 18 \times 10^{-6}$$
$$= 6.48 \times 10^{-5}$$
$$= 6.5 \times 10^{-5} \text{ N}$$

16 Two short bar magnets of length 1 cm each have magnetic moments 1.20 Am^2 and 1.00 Am^2, respectively. They are placed on a horizontal table parallel to each other with their N poles pointing towards the South. They have a common magnetic equator and are separated by a distance of 20.0 cm. The value of the resultant horizontal magnetic induction at the mid-point O of the line joining their centres is close to (Horizontal component of the earth's magnetic induction is 3.6×10^{-5} Wb/m^2) **[JEE Main 2013]**

(a) 3.6×10^{-5} Wb/m^2
(b) 2.56×10^{-4} Wb/m^2
(c) 3.50×10^{-4} Wb/m^2
(d) 5.80×10^{-4} Wb/m^2

Ans. *(b)*

Net magnetic field, $B_{net} = B_1 + B_2 + B_H$



$$B_{net} = \frac{\mu_0}{4\pi}\frac{(M_1 + M_2)}{r^3} + B_H$$
$$= \frac{10^{-7}(1.2 + 1)}{(0.1)^3} + 3.6 \times 10^{-5}$$
$$= 2.56 \times 10^{-4} \text{ Wb/m}^2$$

17 The length of a magnet is large compared to its width and breadth. The time period of its oscillation in a vibration magnetometer is 2 s. The magnet is cut along its length into three equal parts and three parts are then placed on each other with their like poles together. The time period of this combination will be **[AIEEE 2004]**

(a) 2 s (b) $\frac{2}{3}$ s
(c) $2\sqrt{3}$ s (d) $\frac{2}{\sqrt{3}}$ s

Ans. *(b)*

The time period of oscillations of magnet,

$$T = 2\pi\sqrt{(I/MH)} \quad \text{...(i)}$$

where, I = moment of inertia of magnet

$$= \frac{mL^2}{12}$$

[m, being the mass of magnet]

M = Pole strength $\times L$

and H = horizontal component of the earth's magnetic field.

When the three equal parts of magnet are placed on one another with their like poles together, then

$$I' = \frac{1}{12}\left(\frac{m}{3}\right)\times\left(\frac{L}{3}\right)^2 \times 3$$
$$= \frac{1}{12}\frac{mL^2}{9} = \frac{I}{9}$$

and $M' = \text{Pole strength} \times \frac{L}{3} \times 3 = M$

Hence, $T' = 2\pi\sqrt{\left(\frac{I/9}{MH}\right)}$

or $T' = \frac{1}{3} \times T$

or $T' = \frac{2}{3}$ s

18 A thin rectangular magnet suspended freely has a period of oscillation equal to T. Now, it is broken into two equal halves (each having half of the original length) and one piece is made to oscillate freely in the same field. If its period of oscillation is T', the ratio T'/T is

[AIEEE 2003]

(a) $\frac{1}{2\sqrt{2}}$ (b) $\frac{1}{2}$

(c) 2 (d) $\frac{1}{4}$

Ans. *(b)*

When magnet is divided into two equal parts, the magnetic dipole moment

$$M' = \text{Pole strength} \times \frac{l}{2} = \frac{M}{2}$$

[∵ pole strength remains same]

Also, the mass of magnet becomes half *i.e.*,

$$m' = \frac{m}{2}$$

Moment of inertia of magnet, $I = \frac{ml^2}{12}$

New moment of inertia,

$$I' = \frac{1}{12}\left(\frac{m}{2}\right)\left(\frac{l}{2}\right)^2 = \frac{ml^2}{12 \times 8}$$

∴ $I' = \frac{I}{8}$

Now, $T = 2\pi\sqrt{\left(\frac{I}{MB}\right)}$

$$T' = 2\pi\sqrt{\left(\frac{I'}{M'B}\right)}$$
$$= 2\pi\sqrt{\left(\frac{I/8}{MB/2}\right)}$$

∴ $T' = \frac{T}{2}$

⇒ $\frac{T'}{T} = \frac{1}{2}$

TOPIC 3
Magnetic Materials

19 A long solenoid with 1000 turns/m has a core material with relative permeability 500 and volume 10^3cm^3. If the core material is replaced by another material having relative permeability of 750 with same volume maintaining same current of 0.75 A in the solenoid, the fractional change in the magnetic moment of the core would be approximately $(\chi/499)$. Find the value of χ.

[2021, 31 Aug Shift-II]

Ans. *(250)*

Given, number of turns, $n = 1000 \text{ m}^{-1}$

Electric current, $i = 0.75$ A

Relative permeability of 1st material

$$\mu_1 = 500$$

Relative permeability of 2nd material

$$\mu_2 = 750$$

we know that $\mu_r = 1 + \chi \Rightarrow \chi = \mu_r - 1$

For 1st and 2nd material,

$$\chi_1 = \mu_1 - 1 = 500 - 1 = 499$$

and $\chi_2 = \mu_2 - 1 = 750 - 1 = 749$

Now, magnetic intensity, $M = ni$

Let M_1 and M_2 be the magnetisation and m_1 and m_2 be the magnetic moments of material 1st and 2nd.

Using, $\frac{I_1}{M} = \chi_1$ ...(i)

and $\frac{I_2}{M} = \chi_2$ ...(ii)

Dividing Eqs. (i) and (ii),

$$\frac{I_1}{I_2} = \frac{\chi_1}{\chi_2} \quad \text{...(iii)}$$

We also know that,

Magnetisation = $\frac{\text{Dipole moment in core material}}{\text{Volume}}$

i.e $I = \frac{m}{V}$

∴ $\frac{I_1}{I_2} = \frac{m_1}{m_2}$ ...(iv)

From Eqs. (iii) and (iv), we get

$$\frac{m_1}{m_2} = \frac{\chi_1}{\chi_2} = \frac{499}{749}$$

Hence, fraction change in magnetic moment,

$$\frac{\Delta m}{m_1} = \frac{m_2 - m_1}{m_1} = \left(\frac{m_2}{m_1} - 1\right)$$
$$= \left(\frac{749}{499} - 1\right) = \frac{250}{499}$$

Thus, value of χ is 250.

20 **Statement I** The ferromagnetic property depends on temperature. At high temperature, ferromagnet becomes paramagnet.

Statement II At high temperature, the domain wall area of a ferromagnetic substance increases.

In the light of the above statements, choose the most appropriate answer from the options given below.

[2021, 22 July Shift-II]

(a) Statement I is true but Statement II is false
(b) Both Statement I and Statement II are true
(c) Both Statement I and Statement II are false
(d) Statement I is false but Statement II is true

Ans. *(a)*

Given, As we know that, ferromagnetism of any object decreases with increase in temperature and above Curie temperature, ferromagnetic material become paramagnetic material.

Hence, statement I is true.

But, in case of ferromagnetic material below Curie temperature, atoms are alligned and parallel. But above Curie temperature atoms losses their ordered magnetic moments.

Hence, statement II is false.

21 The magnetic susceptibility of a material of a rod is 499. Permeability in vacuum is $4\pi \times 10^{-7}$ H/m. Absolute permeability of the material of the rod is

[2021, 20 July Shift-II]

(a) $4\pi \times 10^{-4}$ H/m (b) $2\pi \times 10^{-4}$ H/m
(c) $3\pi \times 10^{-4}$ H/m (d) $\pi \times 10^{-4}$ H/m

Ans. *(b)*

Given,

Magnetic susceptibility, $\chi_m = 499$

Permeability in vacuum, $\mu_0 = 4\pi \times 10^{-7}$ H/m

Absolute permeability of the material,

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

⇒ $\mu = 4\pi \times 10^{-7}(1 + 499)$

$$= 4\pi \times 10^{-7} \times 500$$
$$= 2\pi \times 10^{-4} \text{ H/m}$$

22 A solenoid of 1000 turns per metre has a core with relative permeability 500. Insulated windings of the solenoid carry an electric current of 5 A. The magnetic flux density produced by the solenoid is

(Permeability of free space $= 4\pi \times 10^{-7}$ H/m) **[2021, 17 March Shift-I]**

(a) πT (b) $2 \times 10^{-3} \pi$T

(c) $\frac{\pi}{5}$T (d) $10^{-4} \pi$T

Ans. *(a)*

Given, number of turns per unit length,

$$n = 1000$$

Relative magnetic permeability,

$$\mu_r = 500$$

Current flowing through solenoid, $I = 5$ A

Magnetic permeability of free space,

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

We know that, magnetic field inside the solenoid can be given as

$$B = \mu n I \quad \text{...(i)}$$

where, $\mu =$ permeability of medium.

As, $\mu = \mu_r \mu_0$ ...(ii)

From Eqs. (i) and (ii), we get

$$\therefore \quad B = \mu_r \mu_0 nI$$
$$= 500 \times 4\pi \times 10^{-7} \times 1000 \times 5$$
$$= 100\pi \times 10^{-7} \times 10^5$$
$$= \pi \text{ T}$$

23 In a ferromagnetic material, below the Curie temperature, a domain is defined as **[2021, 25 Feb Shift-II]**

(a) a macroscopic region with zero magnetisation
(b) a macroscopic region with saturation magnetisation
(c) a macroscopic region with randomly oriented magnetic dipoles
(d) a macroscopic region with consecutive magnetic dipoles oriented in opposite direction

Ans. *(b)*

Since, in ferromagnetic material, with increase in temperature susceptibility decreases,

$\therefore$ Ferromagnetic material below Curie temperature will show saturation magnetisation.

Hence, option (b) is the correct i.e. domain is defined as a macroscopic region with saturation magnetisation.

24 An iron rod of volume 10^{-3} m^3 and relative permeability 1000 is placed as core in a solenoid with 10 turns/cm. If a current of 0.5 A is passed through the solenoid, then the magnetic moment of the rod will be **[2020, 5 Sep Shift-II]**

(a) 50×10^2 Am^2 (b) 5×10^2 Am^2
(c) 500×10^2 Am^2 (d) 0.5×10^2 Am^2

Ans. *(b)*

Magnetic moment of an iron core solenoid, $M = \mu_r NiA$

where, $\mu_r =$ relative permeability $= 1000$,
$N =$ number of turns $= 10$ turns/cm,
$i =$ current $= 0.5$ A

and $A =$ area of cross-section.

Now, $M = \mu_r Ni\frac{V}{l}$ $\left\{\because A = \frac{V}{l}\right\}$

Substituting all the given values in above equation, we get

$$M = 1000 \times \frac{10}{10^{-2}} \times 0.5 \times 10^{-3} \quad [V = 10^{-3} \text{m}^3]$$
$$= 500 \text{ Am}^2 = 5 \times 10^2 \text{ Am}^2$$

Hence, correct option is (b).

25 A paramagnetic sample shows a net magnetisation of 6 A/m, when it is placed in an external magnetic field of 0.4 T at a temperature of 4 K. When the sample is placed in an external magnetic field of 0.3 T at a temperature of 24 K, then the magnetisation will be **[2020, 4 Sep Shift-II]**

(a) 4 A/m (b) 0.75 A/m
(c) 1 A/m (d) 2.25 A/m

Ans. *(b)*

If permeability of free space $= \mu_0$

External magnetic field $= B_0$

Magnetisation $= I$

Intensity of magnetising field $= H = \frac{B_0}{\mu_0}$

Magnetic susceptibility $= \chi_m = \frac{I}{H}$

Temperature $= T$

Then, from Curie's law for paramagnetic materials,

$$\chi_m \propto \frac{1}{T} \Rightarrow \frac{I}{H} \propto \frac{1}{T}$$

$$\Rightarrow \quad \frac{I}{(B_0/\mu_0)} \propto \frac{1}{T} \Rightarrow \frac{\mu_0 I}{B_0} \propto \frac{1}{T}$$

$$\Rightarrow \quad I \propto \frac{B_0}{\mu_0 T} \Rightarrow I \propto \frac{B_0}{T} \quad (\because \mu_0 = \text{constant})$$

$$\Rightarrow \quad \frac{I_1}{I_2} = \frac{(B_0)_1}{(B_0)_2} \times \frac{T_2}{T_1}$$

On putting the given values in above equation, we get

$$\frac{6}{I_2} = \frac{0.4}{0.3} \times \frac{24}{4} \Rightarrow \frac{6}{I_2} = \frac{4}{3} \times \frac{6}{1}$$

$$\Rightarrow \frac{6}{I_2} = 8 \Rightarrow I_2 = \frac{6}{8}$$

$$\Rightarrow I_2 = \frac{3}{4} \text{ A/m} \Rightarrow I_2 = 0.75 \text{ A/m}$$

Hence, option (b) is correct.

26 Magnetic materials used for making permanent magnets (P) and magnets in a transformer (T) have different properties, of the following, which property best matches for the type of magnet required? **[2020, 2 Sep Shift-I]**

(a) T: Large retentivity, small coercivity
(b) P : Large retentivity, large coercivity
(c) P : Small retentivity, large coercivity
(d) T : Large retentivity, large coercivity

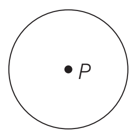
Ans. *(b)*

Permanent magnets (P) must be able to hold large magnetism for a long time. So, they must have large coercivity and large retentivity.

Electromagnet and transformer cores (T) must be able to loose magnetisation quickly when current in their coils are zero. So, they must have small retentivity.

Hence, correct option is (b).

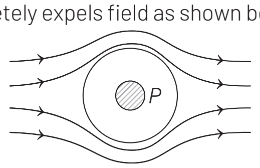
27 A perfectly diamagnetic sphere has a small spherical cavity at its centre,which is filled with a paramagnetic substance. The whole system is placed in a uniform magnetic field $\mathbf{B}$. Then, the field inside the paramagnetic substance is **[2020, 3 Sep Shift-II]**



(a) much larger than $|\mathbf{B}|$ and parallel to $\mathbf{B}$
(b) $\mathbf{B}$
(c) zero
(d) much larger than $|\mathbf{B}|$ but opposite to $\mathbf{B}$

Ans. *(c)*

As, the sphere is perfectly diamagnetic, it completely expels field as shown below:

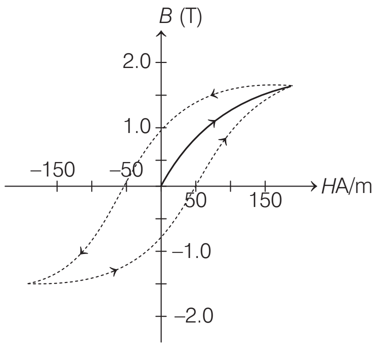


Therefore, there will be no magnetic field inside the cavity of sphere.

So, the paramagnetic sample at the spherical cavity at the centre of sphere remains uneffected by external field and field inside paramagnetic sample is zero.

Hence, correct option is (c).

28

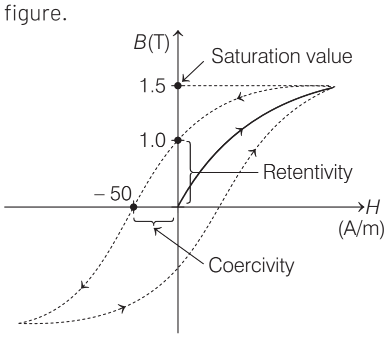


The figure gives experimentally measured *B versus H* variation in a ferromagnetic material. The retentivity, coercivity and saturation respectively of the material are **[2020, 7 Jan Shift-II]**

(a) 1.0 T, 50 A/m and 1.5 T
(b) 150 A/m, 1.0 T and 1.5 T
(c) 1.5 T, 50 A/m and 1.0 T
(d) 1.5 T, 50 A/m and 1.0 T

Ans. *(a)*

We can obtain the values of retentivity (the remaining value of magnetic field B when $H = 0$), coercivity (value of H when $B = 0$) and saturation value of induced magnetic field ($B_{\max}$) as shown in the figure.



Clearly, retentivity = 1 T, coercivity = 50 Am^{-1}

and saturation value = 1.5 T

29 A bar magnet is demagnetised by inserting it inside a solenoid of length 0.2 m, 100 turns and carrying a current of 5.2 A. The coercivity of the bar magnet is **[2019, 9 Jan Shift-I]**

(a) 1200 A/m
(b) 285 A/m
(c) 2600A/m
(d) 520A/m

Ans. *(c)*

Coercivity of a bar magnet is the value of magnetic field intensity (H) that is needed to reduce magnetisation to zero.

Since, for a solenoid magnetic induction is given as,

$$B = \mu_0 nI \quad \text{...(i)}$$

where, n is the number of turns (N) per unit, length (l) and I is the current.

Also, $B = \mu_0 H$ ...(ii)

$\therefore$ From Eqs. (i) and (ii), we get

$$\mu_0 nI = \mu_0 H \text{ or } H = nI = \frac{N}{l} I$$

Substituting the given values, we get

$$H = \frac{100}{0.2} \times 5.2 = 2600 \text{ A/m}$$

Thus, the value of coercivity of the bar magnet is 2600 A/m.

30 A paramagnetic substance in the form of a cube with sides 1 cm has a magnetic dipole moment of 20×10^{-6} J/T when a magnetic intensity of 60×10^3 A/m is applied. Its magnetic susceptibility is **[2019, 11 Jan Shift-II]**

(a) 3.3×10^{-4} (b) 3.3×10^{-2}
(c) 4.3×10^{-2} (d) 2.3×10^{-2}

Ans. *(a)*

Given, side of cube = 1 cm = 10^{-2} m

$\therefore$ Volume, $V = 10^{-6} m^3$

Dipole moment, $M = 20 \times 10^{-6}$ J/T

Applied magnetic intensity,

$$H = 60 \times 10^3 \text{ A/m}$$

Intensity of magnetisation

$$I = \frac{M}{V} = \frac{20 \times 10^{-6}}{10^{-6}} = 20 \text{ A/m}$$

Now, magnetic susceptibility χ is

$$\chi = \frac{\text{Intensity of magnetisation}}{\text{Applied magnetic intensity}} = \frac{I}{H}$$

$$= \frac{20}{60 \times 10^3}$$

$$\Rightarrow \quad \chi = \frac{1}{3} \times 10^{-3}$$

$$= 3.3 \times 10^{-4}$$

31 A paramagnetic material has 10^{28} atoms/m^3. Its magnetic susceptibility at temperature 350 K is 2.8×10^{-4}. Its susceptibility at 300 K is **[2019, 12 Jan Shift-II]**

(a) 3.726×10^{-4}
(b) 3.672×10^{-4}
(c) 2.672×10^{-4}
(d) 3.267×10^{-4}

Ans. *(d)*

From Curie's law for paramagnetic substance, we have

Magnetic susceptiblity $\chi \propto \dfrac{1}{T}$

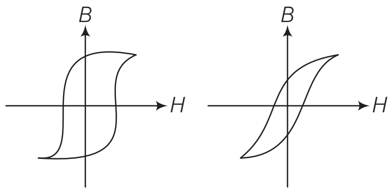
$$\therefore \quad \frac{\chi_2}{\chi_1} = \frac{T_1}{T_2}$$

$$\Rightarrow \quad \chi_2 = \frac{\chi_1 . T_1}{T_2}$$

$$\Rightarrow \quad \chi_2 = \frac{2.8 \times 10^{-4} \times 350}{300}$$

$$= 3.267 \times 10^{-4}$$

32 Hysteresis loops for two magnetic materials *A* and *B* are as given below



(*A*) (*B*)

These materials are used to make magnets for electric generators, transformer core and electromagnet core. Then, it is proper to use **[JEE Main 2016]**

(a) *A* for electric generators and transformers
(b) *A* for electromagnets and B for electric generators
(c) *A* for transformers and B for electric generators
(d) *B* for electromagnets and transformers

Ans. *(d)*

Key Idea Area of hysteresis loop is proportional to the net energy absorbed per unit volume by the material, as it is taken over a complete cycle of magnetisation.

For electromagnets and transformers, energy loss should be low.

i.e. thin hysteresis curves.

Also, $|B| \to 0$ when $H = 0$ and $|H|$ should be small when $B \to 0$.

33 The coercivity of a small magnet where the ferromagnet gets demagnetised is 3×10^3 Am^{-1}. The current required to be passed in a solenoid of length 10 cm and number of turns 100, so that the magnet gets demagnetised when inside the solenoid is **[JEE Main 2014]**

(a) 30 mA
(b) 60 mA
(c) 3 A
(d) 6 A

Ans. *(c)*

For solenoid, the magnetic field needed to be magnetised, the magnet is given by

$$B = \mu_0 nI$$

where, n is number of turns per unit length $= \frac{N}{l}$

and $N = 100$, $l = 10$ cm $= \frac{10}{100}$ m $= 0.1$ m

$$\Rightarrow \quad 3 \times 10^3 = \frac{100}{0.1} \times I$$

$$\Rightarrow \quad I = 3\text{ A}$$

34 Relative permittivity and permeability of a material are ε_r and μ_r, respectively. Which of the following values of these quantities are allowed for a diamagnetic material? **[AIEEE 2008]**

(a) $\varepsilon_r = 0.5, \mu_r = 1.5$
(b) $\varepsilon_r = 1.5, \mu_r = 0.5$
(c) $\varepsilon_r = 0.5, \mu_r = 0.5$
(d) $\varepsilon_r = 1.5, \mu_r = 1.5$

Ans. *(b)*

For diamagnetic material, $0 < \mu_r < 1$ and for any material, $\varepsilon_r > 1$.

35 Needles N_1, N_2 and N_3 are made of a ferromagnetic, a paramagnetic and a diamagnetic substance respectively. A magnet when brought close to them will **[AIEEE 2006]**

(a) attract N_1 and N_2 strongly but repel N_3
(b) attract N_1 strongly, N_2 weakly and repel N_3 weakly
(c) attract N_1 strongly, but repel N_2 and N_3 weakly
(d) attract all three of them

Ans. *(b)*

Ferromagnetic substances have strong tendency to get magnetised (induced magnetic moment) in the same direction as that of applied magnetic field, so magnet attracts N_1 strongly.

Paramagnetic substances get weakly magnetised (magnetic moment induced is small) in the same direction as that of applied magnetic field, so magnet attracts N_2 weakly.

Diamagnetic substances also get weakly magnetised when placed in an external magnetic field but in opposite direction and hence N_3 is weakly repelled by magnet.

36 The materials suitable for making electro- magnets should have **[AIEEE 2004]**

(a) high retentivity and high coercivity
(b) low retentivity and low coercivity
(c) high retentivity and low coercivity
(d) low retentivity and high coercivity

Ans. *(c)*

Electromagnets are made of soft iron. The soft iron has high retentivity and low coercivity.

37 Curie temperature is the temperature above which **[AIEEE 2003]**

(a) a ferromagnetic material becomes para-magnetic
(b) a paramagnetic material becomes dia-magnetic
(c) a ferromagnetic material becomes dia-magnetic
(d) a paramagnetic material becomes ferro-magnetic

Ans. *(a)*

At Curie temperature, a ferromagnetic substance transits into paramagnetic substance.