CHAPTER 2: MAGNETISM AND MATTER

Test Your Concepts-I (Based on Bar Magnet and Properties)

1. Since we know that

$$W_1 = MB(\cos 0^\circ - \cos 90^\circ)$$

$$\Rightarrow \quad W_1 = MB(1-0) = MB$$

Similarly, $W_2 = MB(\cos 0^\circ - \cos\theta)$

$$\Rightarrow \quad W_2 = MB(1-\cos\theta)$$

Since, $W_1 = 2W_2$

$$\Rightarrow \quad MB = 2MB(1-\cos\theta)$$

$$\Rightarrow \quad \cos\theta = \frac{1}{2}$$

$$\Rightarrow \quad \theta = 60^\circ$$

2. Since $L_g = \frac{6}{5}L_m$

So, the geometric length of the magnet is

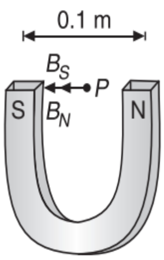
$$L_g = \frac{6}{5}\times 10 = 12 \text{ cm}$$

3. 8×10^{-7} T

Net magnetic field at mid-point P is $B = B_N + B_S$, where B_N is the magnetic field due to N-pole

B_S is the magnetic field due to S-pole

Since, $B_N = B_S = \frac{\mu_0}{4\pi}\frac{m}{r^2}$

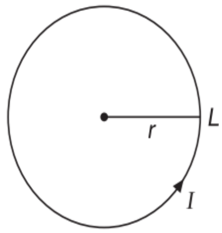


$$\Rightarrow \quad B_N = B_S = 10^{-7}\times\frac{0.01}{\left(\frac{0.1}{2}\right)^2} = 4\times 10^{-7} \text{ T}$$

$$\Rightarrow \quad B_{net} = 2B_N = 2B_S = 8\times 10^{-7} \text{ T}$$

4. Let a wire of length L be bent in a circular loop of radius r. Then, $2\pi r = L$

$$\Rightarrow \quad r = \frac{L}{2\pi}$$



The magnetic dipole moment of a circular loop is

$M = IA$, where $A = \pi r^2$

$$\Rightarrow \quad M = I(\pi r^2)$$

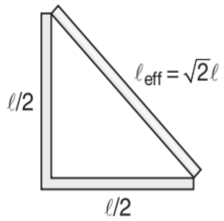
$$\Rightarrow \quad M = I\pi\left(\frac{L}{2\pi}\right)^2$$

$$\Rightarrow \quad M = I\pi\left(\frac{L^2}{4\pi^2}\right)$$

$$\Rightarrow \quad M = \frac{IL^2}{4\pi}$$

5. If m is strength of each pole, then magnetic moment $M = m\times l$

When the wire is bent into L shape, the effective distance between the poles is



$$l_{eff} = \sqrt{\left(\frac{l}{2}\right)^2 + \left(\frac{l}{2}\right)^2} = \frac{l}{\sqrt{2}}$$

However, the magnetic monopole strength m remains the same.

So, new magnetic moment is given by

$$M' = ml_{eff} = m\left(\frac{l}{\sqrt{2}}\right) = \frac{M}{\sqrt{2}}$$

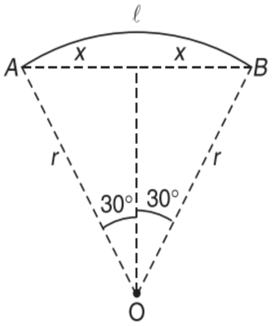
6. Since $l = r\theta$

and $\theta = \frac{\pi}{3}$

$$\Rightarrow \quad l = \frac{\pi r}{3}$$

Also, $M = ml$

From figure, we get



$$x = r\sin(30°) = \frac{r}{2}$$

Hence, new magnetic moment

$$M' = m(2x) = mr = m\left(\frac{3l}{\pi}\right)$$

$$\Rightarrow \quad M' = \frac{3}{\pi}(ml)$$

$$\Rightarrow \quad M' = \frac{3M}{\pi}$$

7. When $\vec{M}$ is parallel to $\vec{B}$, then the magnet is in stable equilibrium, so $\theta = 0°$

PE in this case is minimum and is given by,

$$U_{min} = -\vec{M}\cdot\vec{B} = -MB\cos(0°)$$

$$\Rightarrow \quad U_{min} = -0.32 \times 0.15 \times 1 = -0.048 \text{ J}$$

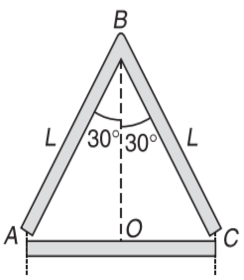
When $\vec{M}$ is anti-parallel to $\vec{B}$, then the magnet will be in unstable equilibrium, so $\theta = 180°$

Thus, potential energy in this case is maximum and is given by

$$U_{max} = -\vec{M}\cdot\vec{B} = -MB\cos(180°)$$

$$\Rightarrow \quad U_{max} = -0.32 \times 0.15 \times (-1) = +0.048 \text{ J}$$

8. On bending the magnet, the new length of the magnetic dipole is



$$AC = AO + OC = L\sin(30°) + L\sin(30°)$$

$$\Rightarrow \quad AC = 2L\sin(30°) = 2L\left(\frac{1}{2}\right) = L$$

9. Let N be the number turns and R radius of the coil. Then, $l = N(2\pi R)$

$$\Rightarrow \quad R = \frac{l}{2\pi N} \qquad \ldots(1)$$

The magnetic moment of the coil is

$$M = NiA = Ni(\pi R^2)$$

$$\Rightarrow \quad M = (Ni\pi)\left(\frac{l}{4\pi^2N^2}\right) = \frac{il^2}{4\pi N}$$

For maximum value of M, we have

$$N = N_{min} = 1$$

$$\Rightarrow \quad M_{max} = \frac{il^2}{4\pi}$$

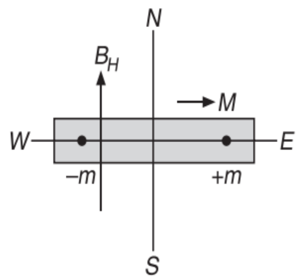
$$\Rightarrow \quad \tau_{max} = M_{max}B\sin 90° = \frac{iBl^2}{4\pi}$$

10. According to Law of Conservation of Energy, we know that the loss in potential energy of the magnet equals the gain in its kinetic energy, so we have

$$\Delta K = U_i - U_f, \text{ where } U = -MB_H\cos\theta$$

$$\Rightarrow \quad \Delta K = -MB_H(\cos\theta_1 - \cos\theta_2)$$

Initially the magnet is along east-west direction, so the angle between M and B_H is 90° i.e. $\theta_1 = 90°$ as shown in Figure.



Finally, when the magnet takes the north-south position, then it aligns along the earth's magnetic field, so the angle between M and B_H is 0° i.e. $\theta_2 = 0°$

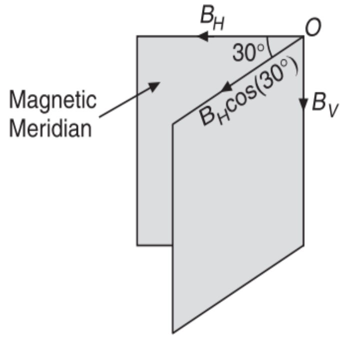
$$\Rightarrow \quad \Delta K = -MB_H(\cos 90° - \cos 0°) = MB_H$$

$$\Rightarrow \quad \Delta K = MB_H = 4(25 \times 10^{-6}) = 100 \times 10^{-6} \text{ J}$$

$$\Rightarrow \quad \Delta K = 100 \ \mu\text{J}$$

Test Your Concepts-II (Based on Earth's Magnetism)

1. In a vertical plane at 30° from the magnetic meridian, the horizontal component is



$$B'_H = B_H \cos(30°)$$

However, vertical component is still B_V. Therefore, apparent dip will be given by

$$\tan\phi' = \frac{B_V}{B'_H} = \frac{B_V}{B_H \cos(30°)}.$$

Since, $\frac{B_V}{B_H} = \tan\phi$, where ϕ is the true angle of dip.

$$\Rightarrow \quad \tan\phi' = \frac{\tan\phi}{\cos(30°)}$$

It is given that $\phi' = 45°$

$$\Rightarrow \quad \tan\phi = \tan(45°)\cos(30°) = \frac{\sqrt{3}}{2}$$

$$\Rightarrow \quad \tan\phi = 0.866$$

$$\Rightarrow \quad \phi \approx 41°$$

2. At neutral point

$$\left|\begin{matrix}\text{Magnetic field due}\\ \text{to magnet}\end{matrix}\right| = \left|\begin{matrix}\text{Horizontal Magnetic}\\ \text{field due to earth}\end{matrix}\right|$$

$$\Rightarrow \quad \frac{\mu_0}{4\pi}\left(\frac{2M}{d^3}\right) = 5\times10^{-5}$$

$$\Rightarrow \quad 10^{-7}\times\frac{2\times6.75}{d^3} = 5\times10^{-5}$$

$$\Rightarrow \quad d = 0.3 \text{ m} = 30 \text{ cm}$$

3. Let ϕ_1 and ϕ_2 be the angles of dip in two arbitrary planes which are perpendicular to each other, then $\phi_1 = 45°$ and $\phi = 30°$. Since, we know that

$$\cot^2\phi = \cot^2\phi_1 + \cot^2\phi_2$$

where, ϕ is true dip. So, we get

$$\cot^2 30° = \cot^2 45° + \cot^2\phi_2$$

$$\Rightarrow \quad \cot^2\phi_2 = 3 - 1 = 2$$

$$\Rightarrow \quad \cot\phi_2 = 1.414$$

$$\Rightarrow \quad \phi_2 = 35.2°$$

4. A compass needle in stable equilibrium position points towards magnetic north i.e., along the horizontal component B_H of earth's magnetic field. When it is turned through the angle of declination θ, so as to point geographical north, then it experiences a torque of magnitude $MB_H\sin\theta$

$$\Rightarrow \quad MB_H\sin\theta = 1.2\times10^{-3} \text{ Nm}$$

where, $M = 60 \text{ Am}^2$

$$B_H = 40\times10^{-6} \text{ Wbm}^{-2}$$

$$\Rightarrow \quad \sin\theta = \frac{1.2\times10^{-3}}{60\times40\times10^{-6}} = 0.5$$

$$\Rightarrow \quad \theta = 30°$$

5. Since, $B_H = B_e\cos\phi$

$$\Rightarrow \quad B_e = \frac{B_H}{\cos\phi} = \frac{0.16}{\cos(60°)} = \frac{0.16}{\left(\frac{1}{2}\right)}$$

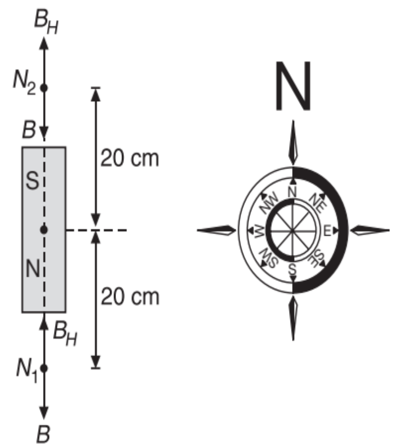
$$\Rightarrow \quad B_e = 0.16\times2 = 0.32 \text{ G}$$

$$\Rightarrow \quad B_e = 0.32\times10^{-4} \text{ T} \qquad \{\because 1\text{ G} = 10^{-4}\text{ T}\}$$

$$\Rightarrow \quad B_e = 32\ \mu\text{T}$$

Direction of B_e: The earth's magnetic field lies in a vertical plane 12° west of geographic meridian at an angle of 60° above the horizontal line.

6. At neutral point, we have the magnetic field due to bar magnet must be cancelled by the horizontal component of earth's magnetic field as shown in Figure.



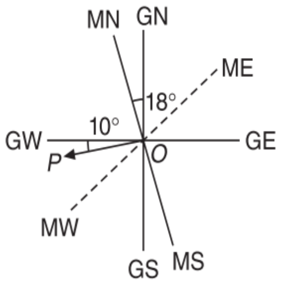
So, at the neutral point, we have

$$|B_H| = |B_{\text{axial}}|$$

$$\Rightarrow \quad \frac{2M}{(20)^3} = 0.3$$

$$\Rightarrow \quad M = 1.2\times10^3 \text{ e.m.u.}$$

7. Since the ship has to reach a place 10° south of west i.e., along OP, so it should be steered west of magnetic north at angle of $90^\circ - 18^\circ + 10^\circ = 82^\circ$



8. Since, $B_H = 0.22$ G, $B_v = 0.38$ G

and $\tan\phi = \dfrac{B_V}{B_H} = \dfrac{0.38}{0.22} = 1.7272$

So, angle of dip is $\phi = 59^\circ\ 56'$

Resultant magnetic field of the earth is

$$B = \sqrt{B_V^2 + B_H^2}$$

$$\Rightarrow \quad B = \sqrt{(0.38)^2 + (0.22)^2} = 0.427 \text{ G}$$

9. Since $\tan\phi = \dfrac{B_V}{B_H}$ ...(1)

If apparent dip is ϕ', then

$$\tan\phi' = \frac{B_V}{B'_H} = \frac{B_V}{B_H\cos(30^\circ)} = \frac{B_V}{B_H\left(\frac{\sqrt{3}}{2}\right)}$$

$$\Rightarrow \quad \tan\phi' = \left(\frac{2}{\sqrt{3}}\right)\tan\phi \qquad \left\{\because\ \tan\phi = \frac{B_V}{B_H}\right\}$$

$$\Rightarrow \quad \tan\phi' = \left(\frac{2}{\sqrt{3}}\right)\tan 60^\circ = 2$$

$$\Rightarrow \quad \phi' = \tan^{-1}(2)$$

10. Since we know that

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

Given that $B_H = 0.26$ G and $\phi = 60^\circ$

$$\Rightarrow \quad B_V = B_H\tan\phi = (0.26)\tan(60^\circ) = 0.45 \text{ G}$$

Also, we have $B_H = B_e\cos\phi$

$$\Rightarrow \quad B_e = \frac{B_H}{\cos\phi} = \frac{0.26}{\cos(60^\circ)} = 0.52 \text{ G}$$

Test Your Concepts-III (Based on Tangent Law, Tangent Galvanometer and Vibration Magnetometer)

1. Since, $B_H = B\cos\phi$

Then, $H_1 = B_1\cos\phi_1$ and $H_2 = B_2\cos\phi_2$

Further, $T_1 = 2\pi\sqrt{\dfrac{I}{MB_{H_1}}} = 2\pi\sqrt{\dfrac{I}{MB_1\cos\phi_1}}$

and $T_2 = 2\pi\sqrt{\dfrac{I}{MB_{H_2}}} = 2\pi\sqrt{\dfrac{I}{MB_2\cos\phi_2}}$

$$\Rightarrow \quad \frac{T_1^2}{T_2^2} = \frac{B_2\cos\phi_2}{B_1\cos\phi_1}$$

$$\Rightarrow \quad \cos\phi_2 = \frac{B_1}{B_2}\times\frac{T_1^2}{T_2^2}\cos\phi_1$$

$$\Rightarrow \quad \cos\phi_2 = \frac{B_1}{B_2}\times\left(\frac{v_2}{v_1}\right)^2\cos\phi_1$$

$$\Rightarrow \quad \cos\phi_2 = \left(\frac{0.5}{0.6}\right)\left(\frac{20}{15}\right)^2\cos 60^\circ = 0.74$$

$$\Rightarrow \quad \phi_2 = \cos^{-1}(0.74) = 42.2^\circ$$

2. In case of tangent galvanometer as

$$i = k\tan\theta$$

Differentiating both side w.r.t. θ

$$\frac{di}{d\theta} = k\sec^2\theta$$

$$\Rightarrow \quad di = k\sec^2\theta\, d\theta$$

$$\Rightarrow \quad \frac{di}{i} = \frac{d\theta}{\sin\theta\cos\theta} = \frac{2d\theta}{\sin(2\theta)}$$

Hence, the error in the measurement will be least when we have

$$\sin(2\theta) = \text{MAX} = 1$$

$$\Rightarrow \quad 2\theta = 90^\circ$$

$$\Rightarrow \quad \theta = 45^\circ$$

3. (a) Moment of inertia of magnet is given by,

$$I = \frac{m(l^2 + b^2)}{12}$$

where m is the mass of magnet

$$\Rightarrow \quad I = \frac{250(5^2 + 3^2)\times 10^{-4}\times 10^{-3}}{12}$$

$$\Rightarrow \quad I = 7.08\times 10^{-5}\ \text{kgm}^2$$

Also, $T = 2\pi\sqrt{\frac{I}{MB_H}}$

$$\Rightarrow \quad M = \frac{4\pi^2 I}{B_H T^2}$$

$$\Rightarrow \quad M = \frac{4\times(3.14)^2\times(7.08\times10^{-5})}{20\times10^{-6}\times5\times5}$$

$$\Rightarrow \quad M = 5.58\ \text{Am}^2$$

(b) New moment of inertia is given by

$$I' = \frac{m(l^2+h^2)}{12}$$

Since, $T' = 2\pi\sqrt{\frac{I'}{MB_H}}$

$$\Rightarrow \quad \frac{T'}{T} = \sqrt{\frac{I'}{I}} = \sqrt{\frac{l^2+h^2}{l^2+b^2}} = \sqrt{\frac{5^2+(0.5)^2}{5^2+3^2}}$$

$$\Rightarrow \quad \frac{T'}{T} = 0.86$$

$$\Rightarrow \quad T' = T\times0.86 = 5\times0.86 = 4.30\ \text{s}$$

4. We have

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

If B is resultant earth's magnetic field and θ is angle of dip, then $B_H = B\cos\theta$

$$\Rightarrow \quad T = 2\pi\sqrt{\frac{I}{MB\cos\theta}}$$

In first case

$$T_1 = \frac{60}{20}\ s = 3\ \text{s},\ \theta_1 = 30°,\ B = B_1$$

In second case

$$T_2 = \frac{60}{15}\ \text{s} = 4\ \text{s},\ \theta_2 = 60°,\ B = B_2$$

Since $T_1 = 2\pi\sqrt{\frac{I}{MB_1\cos\theta_1}}$ and

$$T_2 = 2\pi\sqrt{\frac{I}{MB_2\cos\theta_2}}$$

$$\Rightarrow \quad \frac{T_1}{T_2} = \sqrt{\frac{B_2\cos\theta_2}{B_1\cos\theta_1}}$$

$$\Rightarrow \quad \frac{B_1}{B_2} = \left(\frac{T_2}{T_1}\right)^2\frac{\cos\theta_2}{\cos\theta_1}$$

$$\Rightarrow \quad \frac{B_1}{B_2} = \left(\frac{4}{3}\right)^2\frac{\cos60°}{\cos30°}$$

$$\Rightarrow \quad \frac{B_1}{B_2} = \left(\frac{4}{3}\right)^2\frac{\frac{1}{2}}{\frac{\sqrt{3}}{2}} = \frac{16}{9\sqrt{3}}$$

5. For the first galvanometer, we have

$$i_1 = K_1\tan\theta_1 = K_1\tan60° = K_1\sqrt{3}$$

For the second galvanometer, we have

$$i_2 = K_2\tan\theta_2 = K_2\tan45°K_2$$

When connected in series, we have

$$i_1 = i_2$$

$$\Rightarrow \quad K_1\sqrt{3} = K_2$$

$$\Rightarrow \quad \frac{K_1}{K_2} = \frac{1}{\sqrt{3}}$$

Also, we know that

$$K \propto \frac{1}{N}$$

$$\Rightarrow \quad \frac{K_1}{K_2} = \frac{N_2}{N_1}$$

$$\Rightarrow \quad \frac{N_1}{N_2} = \frac{\sqrt{3}}{1}$$

6. Since $I \propto \tan\theta$

$$\Rightarrow \quad \frac{I_2}{I_1} = \frac{\tan\theta_2}{\tan\theta_1}$$

Given that $I_1 = 10\ \text{mA}$, $\theta_1 = 31°$, $\theta_2 = 42°$

$$\Rightarrow \quad I_2 = I_1\frac{\tan\theta_2}{\tan\theta_1} = 10\times\frac{\tan42°}{\tan31°}$$

$$\Rightarrow \quad I_2 = \frac{10\times0.9}{0.6} = 15\ \text{mA}$$

Percentage increase in current is

$$\left(\frac{I_2-I_1}{I_1}\right)\times100\% = \frac{(15-10)}{10}\times100 = 50\%$$

7. For $\tan A$ position, we have

$$\frac{\mu_0}{4\pi}\frac{2M}{r^3} = B_H\tan\theta$$

$$\Rightarrow \quad \tan\theta \propto \frac{1}{r^3}$$

$$\Rightarrow \frac{\tan\theta_2}{\tan\theta_1} = \left(\frac{r}{r(3)^{\frac{1}{3}}}\right)^3 = \frac{1}{3}$$

$$\Rightarrow \tan\theta_2 = \frac{\tan\theta_1}{3} = \frac{\tan 60^\circ}{3}$$

$$\Rightarrow \tan\theta_2 = \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}}$$

$$\Rightarrow \theta_2 = 30^\circ$$

8. Here, $T_1 = 3\text{ s}$, $T_2 = \frac{1}{12}\text{ min} = \frac{60\text{ s}}{12} = 5\text{ s}$

Since, $\frac{M_1}{M_2} = \frac{T_2^2 + T_1^2}{T_2^2 - T_1^2}$

$$\Rightarrow \frac{M_1}{M_2} = \frac{5^2+3^2}{5^2-3^2} = \frac{34}{16} = \frac{17}{8}$$

9. By sum and difference method, we have

$$\frac{M_1}{M_2} = \frac{v_s^2 + v_d^2}{v_s^2 - v_d^2}$$

$$\Rightarrow \frac{13}{5} = \frac{(15)^2 + v_d^2}{(15)^2 - v_d^2}$$

$$\Rightarrow v_d = 10\text{ oscillation/min}$$

Test Your Concepts-IV (Based on Magnetic Properties of Materials)

1. The bar magnet has coercivity $4\times10^3\text{ Am}^{-1}$ i.e. it requires a magnetic intensity $H = 4\times10^3\text{ Am}^{-1}$ to get demagnetised. Let i be the current carried by solenoid having n number of turns per metre length, then by definition

$$H = ni$$

Here $H = 4\times10^3$ Amp turn metre^{-1}

Since $n = \frac{N}{l} = \frac{60}{0.12} = 500$ turn metre^{-1}

$$\Rightarrow i = \frac{H}{n} = \frac{4\times10^3}{500} = 8.0\text{ A}$$

2. Given, magnetic moment, $M = 1.2\text{ Am}^2$

Volume, $V = (15\times2\times1)\times10^{-6}\text{ m}^3 = 30\times10^{-6}\text{ m}^3$

So, intensity of magnetisation is

$$I = \frac{M}{V} = \frac{1.2}{(15\times2\times1)\times10^{-6}} = 4\times10^4\text{ Am}^{-1}$$

3. $I = \frac{M_{net}}{V}$, where $M_{net} = NM$

$$\Rightarrow I = \frac{NM}{V} = \left(\frac{N}{V}\right)M$$

$$\Rightarrow \frac{MN}{V} = \frac{1.5\times10^{-23}\times2\times10^{26}}{1}$$

$$\Rightarrow I = 3\times10^3\text{ Am}^{-1}$$

4. The coercivity of $4\times10^4\text{ Am}^{-1}$ for the permanent magnet implies that a magnetic intensity $H = 4\times10^4\text{ Am}^{-1}$ is required to be applied in opposite direction to demagnetise the magnet.

Since, $n = \frac{700}{20\text{ cm}} = \frac{700}{20\times10^{-2}\text{ m}} = 3500\text{ turnsm}^{-1}$

Also, $H = ni$

So, current, $i = \frac{H}{n} = \frac{4\times10^4}{3500} = 11.5\text{ A}$

5. Since, we know that

$$\mu_r = \frac{\mu}{\mu_0} = 1 + \chi$$

$$\Rightarrow \mu = \mu_0(1+\chi)$$

$$\Rightarrow \mu = 4\pi\times10^{-7}(1+599)$$

$$\Rightarrow \mu = 7.536\times10^{-4}T\text{ m}^{A-1}$$

$$\Rightarrow B = \mu H = 7.536\times10^{-4}\times1200\ T$$

$$\Rightarrow \phi = BA = 7.536\times10^{-4}\times1200\times0.2\times10^{-4}\text{ Wb}$$

$$\Rightarrow \phi = 1.81\times10^{-5}\text{ Wb}$$

6. Magnetic susceptibility,

$\chi_{m_1} = 0.0075$,

$T_1 = -73\ ^\circ\text{C} = (-73+273)\text{ K} = 200\text{ K}$

$\chi_{m_2} = ?$,

$T_2 = -173\ ^\circ\text{C} = (-173+273)\text{ K} = 100\text{ K}$

According to Curie's law, we have

$$\chi_m \propto \frac{1}{T}$$

So, ratio of magnetic susceptibilities is

$$\frac{\chi_{m_2}}{\chi_{m_1}} = \frac{T_1}{T_2} = \frac{200}{100} = 2$$

$$\Rightarrow \chi_{m_2} = 2\chi_{m_1} = 2\times0.0075 = 0.015$$

7. Let Q be the energy dissipated per unit volume per hysteresis cycle in the given sample. Then the total energy lost by the volume V of the sample in time t will be

$$W = Q \times V \times \nu \times t$$

where ν is the number of hysteresis cycles per second. Given that $Q = 300\ \text{Jm}^{-3}\ \text{cycle}^{-1}$, $\nu = 25\ \text{cycle s}^{-1}$, $t = 1\ \text{h} = 3600\ \text{s}$. Also, volume of the iron specimen is

$$V = \frac{\text{Mass}}{\text{Density}} = \frac{15}{7500}\ \text{m}^3$$

So, hysteresis loss is given by

$$W = 300 \times \frac{15}{7500} \times 25 \times 3600\ \text{J} = 54000\ \text{J}$$

8. Since, $M = I \times V$, where V is volume of the cylinder i.e. $V = \pi r^2 l$, where r is the radius and l is the length of the cylinder.
The dipole moment is given by

$$M = I(\pi r^2 l)$$

$$\Rightarrow \quad M = (5.30 \times 10^3) \times \frac{22}{7} \times (0.5 \times 10^{-2})^2 (5 \times 10^{-2})$$

$$\Rightarrow \quad M = 2.08 \times 10^{-2}\ \text{JT}^{-1}$$

9. Since, $\mu_r = 1 + \chi_m$

$$\Rightarrow \quad 5500 = 1 + \chi_m$$

$$\Rightarrow \quad \chi_m = 5500 - 1 = 5499$$

Single Correct Choice Type Questions

1. $\chi_m = (\mu_r - 1)$

$$\Rightarrow \quad \chi_m = (5500 - 1) = 5499$$

Hence, the correct answer is (D).

2. In sum position, we have

$$T_s = 2\pi \sqrt{\frac{I_1 + I_2}{(M_1 + M_2) B_H}}$$

In difference position, we have

$$T_d = 2\pi \sqrt{\frac{I_1 + I_2}{(M_1 - M_2) B_H}}$$

$$\Rightarrow \quad T_d > T_s$$

Hence, the correct answer is (B).

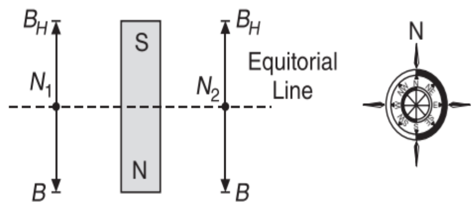
3. Work done $W = MB_H(1 - \cos\theta)$

$$\Rightarrow \quad W = 20 \times 0.3(1 - \cos 30^\circ)$$

$$\Rightarrow \quad W = 6\left(1 - \frac{\sqrt{3}}{2}\right) = 3(2 - \sqrt{3})$$

Hence, the correct answer is (C).

4. N_1 and N_2 are two null points on equitorial line, where B_H (Horizontal component of earth's magnetic field) and B (Magnetic field due to bar magnet) cancel to give neutral points N_1 and N_2 as shown in Figure.

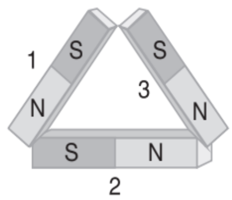


Hence, the correct answer is (A).

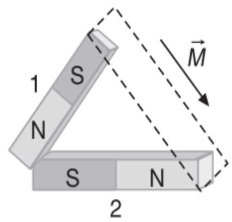
5. Magnetic lines of force are closed curves. Outside the magnet they are directed from north to south while inside the magnet, they are directed from south to north.

Hence, the correct answer is (D).

6. The resultant magnetic moment is $\vec{M} = \vec{M}_1 + \vec{M}_2 + \vec{M}_3$

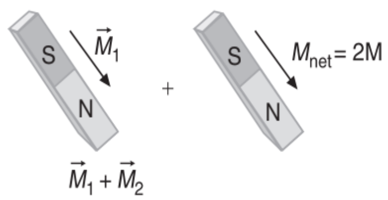


Since $\vec{M}_1 + \vec{M}_2 = M$ as shown in Figure.



Also, $\vec{M}_3 = \vec{M}$

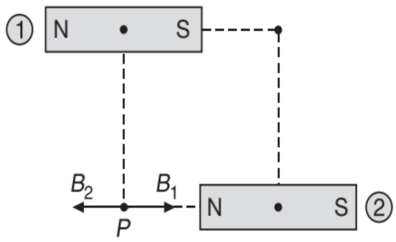
$$\Rightarrow \quad \vec{M}_1 + \vec{M}_2 + \vec{M}_3 = 2\vec{M}$$



Hence, the correct answer is (B).

CHAPTER 2

7. Point P lies on equatorial line of magnet (1) and axial line of magnet (2) as shown in Figure.



So, $B_1 = \frac{\mu_0}{4\pi}\frac{M}{d^3} = 10^{-7} \times \frac{1000}{(0.1)^3} = 0.1\text{ T}$

$$B_2 = \frac{\mu_0}{4\pi}\frac{2M}{d^3} = 10^{-7} \times \frac{2\times 1000}{(0.1)^3} = 0.2\text{ T}$$

$$\Rightarrow \quad B_{net} = B_2 - B_1 = 0.1\text{ T}$$

Hence, the correct answer is (A).

8. $\tau = MB_H \sin\theta$

$$\Rightarrow \quad \frac{d\tau}{d\theta} = MB_H \cos\theta$$

This will be maximum, when $\theta = 0°$

Hence, the correct answer is (A).

9. $E = VAnt = \left(\frac{m}{\rho}\right)Ant = \frac{50\times 250\times 10\times 3600}{7.5\times 10^3}$

$$\Rightarrow \quad E = 6\times 10^4\text{ J}$$

Hence, the correct answer is (A).

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

$$\Rightarrow \quad \frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}}$$

$$\Rightarrow \quad \frac{M_1}{M_2} = \frac{T_2^2}{T_1^2} = \frac{\left(\frac{60}{15}\right)^2}{\left(\frac{60}{10}\right)^2} = \frac{4}{9}$$

Hence, the correct answer is (A).

11. Sensitivity $S = \frac{\theta}{i} = \frac{\theta}{K\tan\theta}$ where $K = \frac{2RB_H}{\mu_0 N}$

For increasing sensitivity K should be decreased and hence number of turns should be increased.

Hence, the correct answer is (B).

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

$$\Rightarrow \quad F \propto \frac{1}{r^4}$$

$$\Rightarrow \quad \frac{F'}{F} = \left(\frac{r}{r'}\right)^4 = \left(\frac{1}{2}\right)^4$$

$$\Rightarrow \quad F' = \frac{F}{16} = \frac{4\cdot 8}{16} = 0.3\text{ N}$$

Hence, the correct answer is (D).

13. Net magnetic moment

$$M = \sqrt{M_1^2 + M_2^2 + 2M_1M_2\cos\theta}$$

$$\Rightarrow \quad M = \sqrt{M_0^2 + M_0^2 + 2M_0^2\cos 60°}$$

$$\Rightarrow \quad M = \sqrt{3}M_0$$

Hence, the correct answer is (C).

14. Since, $T = 2\pi\sqrt{\frac{I}{MB_H}}$

For CASE-1, we have

$$T_1 = \frac{60}{10}\text{ s}$$

$$\frac{60}{10} = 2\pi\sqrt{\frac{I}{MB_H}} \quad \ldots(1)$$

For CASE-2, we have

$$T = \frac{60}{14}\text{ s}$$

$$\frac{30}{7} = 2\pi\sqrt{\frac{I}{M(B_H+B)}} \quad \ldots(2)$$

Divide (2) by (1), we get

$$\frac{\frac{30}{7}}{6} = \sqrt{\frac{B_H}{B_H+B}}$$

$$\Rightarrow \quad B = \left(\frac{24}{25}\right)B_H \quad \ldots(3)$$

For CASE-3,

Let the magnet make n oscillations per minute, then

$$T = \frac{60}{n}$$

$$\Rightarrow \quad \frac{60}{n} = 2\pi\sqrt{\frac{I}{M(B_H-B)}}$$

$$\Rightarrow \frac{60}{n} = 2\pi\sqrt{\frac{I}{M\left(B_H - \frac{24}{25}B_H\right)}} \qquad \left\{\because B = \frac{24}{25}B_H\right\}$$

$$\Rightarrow \frac{60}{n} = 2\pi \times 5 \times \sqrt{\frac{I}{MB_H}} \qquad \ldots(4)$$

From equations (1), we get

$$2\pi\sqrt{\frac{I}{MB_H}} = 6$$

So, equation (4), becomes,

$$\frac{60}{n} = 5(6)$$

$\Rightarrow n = 2$ vibrations per minute

Hence, the correct answer is (D).

15. Initially magnetic moment of system is

$M_1 = \sqrt{M^2 + M^2} = \sqrt{2}M$ and

moment of inertia is

$I_1 = I + I = 2I$

Finally, when one of the magnets is removed then

$M_2 = M$ and $I_2 = I$

Since, $T = 2\pi\sqrt{\frac{I}{MB_H}}$

$$\Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{I_1}{I_2} \times \frac{M_2}{M_1}} = \sqrt{\frac{2I}{I} \times \frac{M}{\sqrt{2}M}}$$

$$\Rightarrow T_2 = \frac{2^{\frac{5}{4}}}{2^{\frac{1}{4}}} = 2 \text{ s}$$

Hence, the correct answer is (C).

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

$$\Rightarrow \frac{T}{T'} = \sqrt{\frac{B'}{B}} = \sqrt{\frac{B}{B_H}}$$

$$\Rightarrow \frac{T}{T'} = \sqrt{\frac{1}{\cos\phi}} = \sqrt{\frac{1}{\cos 60^\circ}} = \sqrt{2}$$

$$\Rightarrow T' = \frac{T}{\sqrt{2}}$$

Hence, the correct answer is (A).

17. $B = B_1 + B_2 = \frac{\mu_0}{4\pi}\left(\frac{m_1}{r_1^2} + \frac{m_2}{r_2^2}\right)$

As $m_1 = m_2$ and $r_1 = r_2$

$$\Rightarrow B = \frac{\mu_0}{4\pi}\frac{2m_1}{r_1^2} = 10^{-7} \times \frac{2 \times 10^{-4}}{\left(5 \times 10^{-2}\right)^2}$$

$$\Rightarrow B = 8 \times 10^{-9} \text{ T}$$

Hence, the correct answer is (D).

18. Magnetic moment of circular loop carrying current

$$M = iA = i\left(\pi R^2\right) = i\pi\left(\frac{L}{2\pi}\right)^2 = \frac{iL^2}{4\pi}$$

$$\Rightarrow L = \sqrt{\frac{4\pi M}{i}}$$

Hence, the correct answer is (B).

19. Since, $B = \frac{\mu_0}{4\pi}\frac{2Mr}{\left(r^2 - l^2\right)^2}$

$$\Rightarrow \frac{B_1}{B_2} = \frac{r_1}{r_2}\left(\frac{r_2^2 - l^2}{r_1^1 - l^2}\right)^2$$

$$\Rightarrow \frac{12.5}{1} = \frac{10}{20}\left(\frac{400 - l^2}{100 - l^2}\right)^2$$

$\Rightarrow l = 5$ cm

Hence, length of magnet is $L = 2l = 10$ cm

Hence, the correct answer is (C).

20. Since $W = -MB\left(\cos\theta_2 - \cos\theta_1\right)$

When the magnet is rotated from 0° to 60°, then work done is 0.8 J

$$\Rightarrow 0.8 = -MB\left(\cos 60^\circ - \cos 0^\circ\right) = \frac{MB}{2}$$

$\Rightarrow MB = 1.6$ Nm

In order to rotate the magnet further through an angle of 30° i.e., from 60° to 90°, the work done is

$$W' = -MB\left(\cos 90^\circ - \cos 60^\circ\right) = -MB\left(0 - \frac{1}{2}\right)$$

$$\Rightarrow W' = \frac{MB}{2} = \frac{1.6}{2} = 0.8 \text{ J} = 0.8 \times 10^7 \text{ erg}$$

Hence, the correct answer is (A).

21. Since $B_H = B_V = B_0$

$$\Rightarrow B = \sqrt{B_H^2 + B_V^2} = \sqrt{B_0^2 + B_0^2}$$

$$\Rightarrow B = \sqrt{2}B_0$$

Hence, the correct answer is (D).

22. Since, $B = B_H \tan\theta$

$$\Rightarrow \frac{\mu_0 Ni}{2r} = B_H \tan\theta$$

$$\Rightarrow i = \frac{2rB_H \tan\theta}{\mu_0 N} = \frac{2 \times 0.1 \times 4 \times 10^{-5}}{10 \times 4\pi \times 10^{-7}} = 1.1 \text{ A}$$

Hence, the correct answer is (B).

23. $F = mB$

$$\Rightarrow m = \frac{F}{B} = \frac{1.224 \times 10^{-4}}{0.36 \times 10^{-4}}$$

$$\Rightarrow m = 4 \text{ Am}$$

Since, $M = m(2\ell)$

$$\Rightarrow 2\ell = \frac{M}{m} = \frac{0.1}{4} \text{ m} = \frac{10}{4} \text{ cm}$$

$$\Rightarrow 2\ell = 2.50 \text{ cm}$$

Hence, the correct answer is (C).

24. Given $B_e = 0.36$ G, $\theta = 60°$

Horizontal component of earth's magnetic field is

$$B_H = B_e \cos 60° = 0.36 \times \cos 60°$$

$$\Rightarrow B_H = 0.36 \times \frac{1}{2} = 0.18 \text{ G}$$

Vertical component of earth's magnetic field is

$$B_V = B_e \sin 60° = 3.36 \sin 60°$$

$$\Rightarrow B_V = 0.36 \times \frac{\sqrt{3}}{2} = 0.18\sqrt{3} \text{ G}$$

Hence, the correct answer is (D).

25. Since $\tan\phi = \dfrac{B_V}{B_H}$ ...(1)

If apparent dip is ϕ', then

$$\tan\phi' = \frac{B_V}{B'_H} = \frac{B_V}{B_H \cos(30°)} = \frac{B_V}{B_H\left(\frac{\sqrt{3}}{2}\right)}$$

$$\Rightarrow \tan\phi' = \left(\frac{2}{\sqrt{3}}\right)\tan\phi \qquad \left\{\because \tan\phi = \frac{B_V}{B_H}\right\}$$

$$\Rightarrow \tan\phi' > \tan\phi$$

$$\Rightarrow \phi' > \phi$$

Hence, the correct answer is (C).

26. Along the axis of magnet, we have

$$B_{\text{axial}} = \frac{2M}{X^3} = 200 \text{ G}$$

$$\Rightarrow B_{\text{equitorial}} = \frac{M}{X^3} = 100 \text{ G}$$

Hence, the correct answer is (A).

27. $v = \dfrac{1}{2\pi}\sqrt{\dfrac{MB_H}{I}}$

$$\Rightarrow v \propto \sqrt{M}$$

$$\Rightarrow \frac{v_A}{v_B} = \sqrt{\frac{M_A}{M_B}}$$

$$\Rightarrow \frac{2}{1} = \sqrt{\frac{M_A}{M_B}}$$

$$\Rightarrow M_A = 4M_B$$

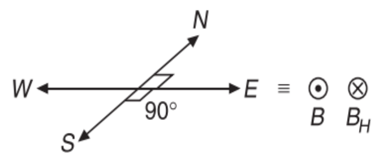
Hence, the correct answer is (C).

28. Magnetic field at the centre of short magnet very long wire is

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 18}{2\pi \times 0.2} T = 18\ \mu\text{T}$$

Since $T = 2\pi\sqrt{\dfrac{I}{MB_H}}$ and $T' = 2\pi\sqrt{\dfrac{I}{M(B_H - B)}}$

Dividing, we get



$$\frac{T'}{T} = \sqrt{\frac{B_H}{B_H - B}}$$

$$\Rightarrow \frac{T'}{T} = \sqrt{\frac{24}{24 - 18}} = 2$$

$$\Rightarrow T' = 2 \times 0.1 \text{ s} = 0.2 \text{ s}$$

Hence, the correct answer is (B).

29. In two planes at right angles to each other if apparent dips are ϕ_1 and ϕ_2, then true dip at that place is

$$\cot^2\phi = \cot^2\phi_1 + \cot^2\phi_2$$

$$\Rightarrow \cot^2\phi = \cot^2(30°) + \cot^2(45°)$$

$$\Rightarrow \cot^2\phi = 4$$

$$\Rightarrow \cot\phi = 2$$

$$\Rightarrow \phi = \cot^{-1}(2)$$

Hence, the correct answer is (C).

30. Since, $T = 2\pi\sqrt{\dfrac{I}{MB_H}}$

$$\Rightarrow \quad T \propto \frac{1}{\sqrt{M}}$$

$$\Rightarrow \quad \frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}},$$

If $M_1 = 100$, then $M_2 = (100 - 36) = 64$

$$\Rightarrow \quad \frac{T_1}{T_2} = \sqrt{\frac{64}{100}} = \frac{8}{4}$$

$$\Rightarrow \quad T_2 = \frac{10}{8}T_1 = 1.25T_1$$

So, increase in time period is 25%

Hence, the correct answer is (B).

31. $B_H = B_e\cos\theta$

$$\Rightarrow \quad B_e = \frac{B_H}{\cos\theta} = \frac{0.5}{\cos 30^\circ} = \frac{0.5}{\sqrt{3}/2} = \frac{1}{\sqrt{3}}$$

Hence, the correct answer is (C).

32. Torque acting on magnet is

$$\tau = MB_H\sin\theta$$

$$\Rightarrow \quad \tau = 0.1\times10^{-3}\times4\pi\times10^{-3}\times\sin 30^\circ = 10^{-7}\times4\pi\times\frac{1}{2}$$

$$\Rightarrow \quad \tau = 2\pi\times10^{-7}\ \text{Nm}$$

Hence, the correct answer is (A).

33. If ϕ is true angle of dip, then

$$\tan\phi = \frac{B_V}{B_H} \quad \ldots(1)$$

When the dip circle is rotated in the horizontal plane through an angle θ from the magnetic meridian, the effective horizontal component in the new plane becomes $B'_H = B_H\cos\theta$, while the vertical component remains the same. If ϕ' is apparent dip, then

$$\tan\phi' = \frac{B_V}{B'_H} = \frac{B_V}{B_H\cos\theta} = \frac{\tan\phi}{\cos\theta} \quad \ldots(2)$$

$$\Rightarrow \quad \frac{\tan\phi'}{\tan\phi} = \frac{1}{\cos\theta}$$

Hence, the correct answer is (C).

34. $T_{\text{sum}} = T_s = 2\pi\sqrt{\dfrac{I_1 + I_2}{(M_1 + M_2)B_H}}$

$$T_{\text{diff}} = T_d = 2\pi\sqrt{\frac{I_1 + I_2}{(M_1 - M_2)B_H}}$$

$$\Rightarrow \quad \frac{T_s}{T_d} = \frac{T_1}{T_2} = \sqrt{\frac{M_1 - M_2}{M_1 + M_2}} = \sqrt{\frac{2M - M}{2M + M}} = \frac{1}{\sqrt{3}}$$

Hence, the correct answer is (C).

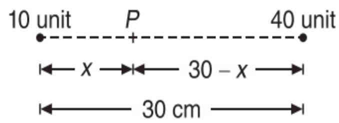
35. Since $\tan\phi' = \dfrac{\tan\phi}{\cos\beta}$

$$\Rightarrow \quad \tan\phi' = \frac{\tan\phi}{\cos\theta}$$

$$\Rightarrow \quad \tan\phi' = \tan\phi\sec\theta$$

Hence, the correct answer is (B).

37. Suppose magnetic field is zero at point P. Which lies at a distance x from 10 unit pole. Hence, at P



$$\frac{\mu_0}{4\pi}\frac{10}{x^2} = \frac{\mu_0}{4\pi}\frac{40}{(30 - x)^2}$$

$$\Rightarrow \quad x = 10\ \text{cm}$$

So, from stronger pole distance is 20 cm

Hence, the correct answer is (B).

38. If $M(= m\ell)$ is magnetic moment of original magnet, then magnetic moment of each part is M' given by

$$M' = \left(\frac{m}{2}\right)(\ell) = \frac{m\ell}{2} = \frac{M}{2}$$

Moment of inertia of original magnet,

$$I = \frac{m_0\ell^2}{12},\ m_0 = \text{mass of magnet}$$

Moment of inertia of each part $= \dfrac{(m_0/2)\ell^2}{12} = \dfrac{I}{2}$

Time period of original magnet is

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

Time period of each part

$$T' = 2\pi\sqrt{\frac{(I/2)}{(M/2)H}} = T$$

i.e. time period remains unchanged.

Hence, the correct answer is (B).

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

Moment of inertia (I) is directly proportional to mass so, when mass is quadrupled (made four times), moment of inertia becomes 4 times and so time period T will be doubled.

Hence, the correct answer is (D).

40. As we know for circulating electron magnetic moment

$$M = \frac{1}{2}evr \quad \ldots(1)$$

And angular momentum

$$J = mvr \quad \ldots(2)$$

From equation (1) and (2), we get

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

Hence, the correct answer is (B).

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

$$T' = 2\pi\sqrt{\frac{I}{M(B_H + B)}} = 1 \text{ sec}$$

Dividing $2 = \sqrt{\frac{B_H + B}{B_H}}$

$$\Rightarrow \frac{B_H}{B} = \frac{1}{3}$$

Hence, the correct answer is (B).

42. $T_1 \propto \frac{1}{\sqrt{B_H}}$ and $T_2 \propto \frac{1}{\sqrt{B_H + B}}$

$$\Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{B_H + B}{B_H}}$$

$$\Rightarrow \frac{2}{1} = \sqrt{\frac{B_H + B}{B_H}}$$

$$\Rightarrow B = 3B_H$$

$$\Rightarrow \frac{B_H}{B} = \frac{1}{3}$$

Hence, the correct answer is (B).

43. $B_1 = \frac{2M}{x^3}$ and $B_2 = \frac{M}{y^3}$

Since $B_1 = B_2$

$$\Rightarrow \frac{2M}{x^3} = \frac{M}{y^3}$$

$$\Rightarrow \frac{x^3}{y^3} = 2$$

$$\Rightarrow \frac{x}{y} = 2^{\frac{1}{3}}$$

Hence, the correct answer is (D).

44. Since $\tan\phi' = \frac{\tan\phi}{\cos\beta}$

$$\Rightarrow \tan(45°) = \frac{\tan\phi}{\cos(30°)}$$

$$\Rightarrow \tan\phi = \frac{\sqrt{3}}{2}$$

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

Hence, the correct answer is (A).

45. The energy lost per unit volume of a substance in a complete cycle of magnetisation is equal to the area of the hysteresis loop.

Hence, the correct answer is (C).

46. Since, $\frac{\mu}{4\pi}\left(\frac{2M_1}{r_1^3}\right) = \frac{\mu_0}{4\pi}\left(\frac{2M_2}{r_2^3}\right)$

$$\Rightarrow \frac{M_1}{M_2} = \left(\frac{r_1}{r_2}\right)^3$$

$$\Rightarrow \frac{1}{2} = \left(\frac{20}{r_2}\right)^3$$

$$\Rightarrow r_2 = 20(2)^{\frac{1}{3}} \text{ cm}$$

Hence, the correct answer is (B).

47. Let ℓ be initial length of magnet. When magnet of magnetic moment $M(= m\ell)$ is cut in two equal parts, the magnetic moment of each part

$$M' = m\left(\frac{\ell}{2}\right) = \frac{m\ell}{2} = \frac{M}{2}$$

Moment of inertia of initial magnet

$$I = \frac{\text{mass} \times (\text{length})^2}{12} = \frac{m_0\ell^2}{12}$$

Moment of inertia of each half part

$$I' = \frac{\left(\frac{m_0}{2}\right)\left(\frac{\ell}{2}\right)^2}{12} = \frac{1}{8}\left[\frac{m_0\ell^2}{12}\right] = \frac{I}{8}$$

Initial time period is

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

Time period of vibration of each half part

$$T' = 2\pi\sqrt{\frac{(I/8)}{(M/2)H}}$$

$$\Rightarrow \quad T' = \frac{1}{2}\left(2\pi\sqrt{\frac{I}{MH}}\right) = \frac{T}{2}$$

i.e. period is halved.

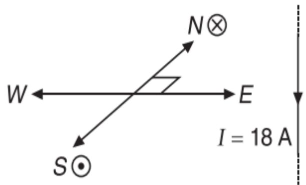
Hence, the correct answer is (A).

48. The horizontal magnetic field due to earth points from South to North i.e. inwards $\otimes$. Due to the wire magnetic field at the magnet is also directed inwards $\otimes$. So, both get added up.

Initially, $T = 2\pi\sqrt{\frac{I}{mB_H}}$ ...(1)

Finally, $T' = 2\pi\sqrt{\frac{I}{m(B+B_H)}}$ ...(2)

where B is the magnetic field due to the wire given by



$$B = \frac{\mu_0 i}{2\pi r} = 18\ \mu\text{T}$$

From (1) and (2), we get

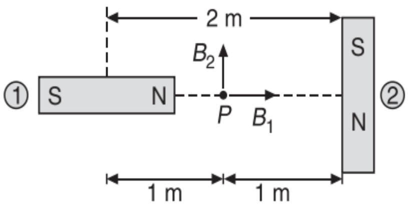
$$\frac{T'}{T} = \sqrt{\frac{B}{B+B_H}}$$

$$\Rightarrow \quad \frac{T'}{0.1} = \frac{24}{18+24}$$

$$\Rightarrow \quad T' = 0.076\ \text{s}$$

Hence, the correct answer is (C).

49. With respect to magnet 1, the point P lies at axial line, so



$$B_1 = \frac{\mu_0}{4\pi}\left(\frac{2M}{r^3}\right), \text{ rightwards}$$

$$\Rightarrow \quad B_1 = 10^{-7} \times \frac{2\times 1}{1} = 2\times 10^{-7}\ T$$

With respect to magnet 2, the point P lies at equitorial line, so

$$B_2 = \frac{\mu_0}{4\pi}\left(\frac{M}{r^3}\right), \text{ upwards}$$

$$\Rightarrow \quad B_2 = \frac{B_1}{2} = 10^{-7}\ \text{T}$$

Since B_1 and B_2 are mutually perpendicular, so the resultant magnetic field is

$$B_R = \sqrt{B_1^2 + B_2^2} = \sqrt{(2\times 10^{-7})^2 + (10^{-7})^2}$$

$$\Rightarrow \quad B_R = \sqrt{5}\times 10^{-7}\ \text{T}$$

Hence, the correct answer is (B).

50. In tangent galvanometer, $i \propto \tan\theta$

$$\Rightarrow \quad \frac{i_1}{i_2} = \frac{\tan\theta_1}{\tan\theta_2}$$

$$\Rightarrow \quad \frac{i_1}{\frac{i_1}{\sqrt{3}}} = \frac{\tan 45^\circ}{\tan\theta_2}$$

$$\Rightarrow \quad \sqrt{3}\tan\theta_2 = 1$$

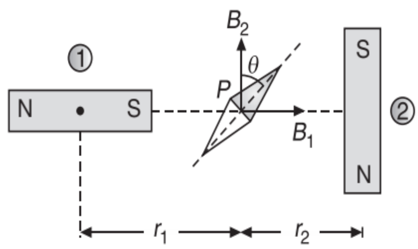
$$\Rightarrow \quad \tan\theta_2 = \frac{1}{\sqrt{3}}$$

$$\Rightarrow \quad \theta_2 = 30^\circ$$

So, deflection will decrease by $45^\circ - 30^\circ = 15^\circ$

Hence, the correct answer is (B).

51. At equilibrium $B_1 = B_2\tan\theta$



$$\Rightarrow \quad \frac{\mu_0}{4\pi}\frac{2M}{r_1^3} = \frac{\mu_0}{4\pi}\frac{M}{r_2^3}\tan\theta$$

$$\Rightarrow \quad \frac{r_1}{r_2} = (2\cot\theta)^{\frac{1}{3}}$$

Hence, the correct answer is (C).

52. $n = \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}}$

$$\Rightarrow \quad n \propto \sqrt{M}$$

CHAPTER 2

Given $n_A = 2n_B$

$\Rightarrow \quad \dfrac{n_A}{n_B} = 2$

$\Rightarrow \quad \sqrt{\dfrac{M_A}{M_B}} = 2$

$\Rightarrow \quad \dfrac{M_A}{M_B} = 4$

Hence, the correct answer is (C).

53. $K = \dfrac{2RB_H}{\mu_0 N}$

$\Rightarrow \quad N = \dfrac{2RB_H}{\mu_0 K} = \dfrac{2\times 0.1\times 3.6\times 10^{-5}}{4\pi\times 10^{-7}\times 10\times 10^{-3}}$

$\Rightarrow \quad N = \dfrac{1.8\times 10^{3}}{3.14} = 570$

Hence, the correct answer is (C).

54. $\dfrac{\mu_0}{4\pi}\dfrac{2M}{d^3} = B_H \tan\theta$

$\Rightarrow \quad M \propto \tan\theta$

$\Rightarrow \quad \dfrac{M_1}{M_2} = \dfrac{\tan\theta_1}{\tan\theta_2}$

$\Rightarrow \quad \dfrac{M_1}{M_2} = \dfrac{\tan 45^\circ}{\tan 30^\circ}$

$\Rightarrow \quad \dfrac{M_1}{M_2} = \dfrac{1}{1/\sqrt{3}} = \dfrac{\sqrt{3}}{1}$

Hence, the correct answer is (B).

55. Given that, $r_1 = 7.5$ cm, $r_2 = 10$ cm

$n_1 = 15$, $n_2 = 10$

$R_1 = 8$, $R_2 = 12$

$\theta_1 = 60^\circ$, $\theta_2 = ?$

Since $\dfrac{\mu_0}{2}\dfrac{n_1}{r_1}\times I_1 = \tan\theta_1$ and ...(1)

$\dfrac{\mu_0}{2}\dfrac{n_2}{r_2}\times I_2 = \tan\theta_2$ ...(2)

$\dfrac{\tan\theta_2}{\tan\theta_1} = \dfrac{n_2}{n_1}\times\dfrac{r_1}{r_2}\times\dfrac{I_2}{I_1}$ ...(3)

However, $I_1 = \dfrac{R_2}{R_1+R_2}\times\dfrac{V}{R_p}$

$\Rightarrow \quad I_2 = \dfrac{R_2}{R_1+R_2}\times\dfrac{V}{R_p}$ ...(4)

$\Rightarrow \quad \dfrac{I_2}{I_1} = \dfrac{R_1}{R_2}$

From equation (3), we get

$\dfrac{\tan\theta_2}{\tan\theta_1} = \dfrac{10}{15}\times\dfrac{75}{10}\times\dfrac{8}{12} = \dfrac{1}{3}$

$\Rightarrow \quad \tan\theta_2 = \dfrac{\sqrt{3}}{3} = \dfrac{1}{\sqrt{3}}$

$\Rightarrow \quad \theta_2 = 30^\circ$

Hence, the correct answer is (B).

56. The weight of upper magnet should be balanced by the force of repulsion between the two magnets.

$\Rightarrow \quad \dfrac{\mu_0}{4\pi}\dfrac{m^2}{r^2} = 50$ gwt

$\Rightarrow \quad 10^{-7}\times\dfrac{m^2}{(9\times 10^{-6})} = 50\times 10^{-3}\times 9.8$

$\Rightarrow \quad m = 6.64$ Am

Hence, the correct answer is (A).

57. Since $\tan\phi' = \dfrac{\tan\phi}{\cos\beta}$

$\Rightarrow \quad \tan\phi_1 = \dfrac{\tan\phi}{\cos\beta}$ ...(1)

and $\tan\phi_2 = \dfrac{\tan\phi}{\cos(90-\beta)} = \dfrac{\tan\phi}{\sin\beta}$ ...(2)

From (1), $\cos\beta = \dfrac{\tan\phi}{\tan\phi_1}$

From (2), $\sin\beta = \dfrac{\tan\phi}{\tan\phi_2}$

Squaring and adding we get

$\cos^2\beta + \sin^2\beta = \tan^2\phi\left(\dfrac{1}{\tan^2\phi_1} + \dfrac{1}{\tan^2\phi_2}\right)$

$\Rightarrow \quad \cot^2\phi = \cot^2\phi_1 + \cot^2\phi_2$

Hence, the correct answer is (D).

58. $T = 2\pi\sqrt{\dfrac{I}{MB_H}}$

where moment of inertia $I = \dfrac{M_0\ell^2}{12}$, M_0 is mass of magnet

When magnet is broken into two halves then length and mass both are halved, so

I becomes $\frac{\left(\frac{m_0}{2}\right)\left(\frac{\ell}{2}\right)^2}{12} = \frac{I}{8}$ and magnetic moment is also halved.

$$\Rightarrow T' = 2\pi\sqrt{\frac{(I/8)}{(M/2)}}$$

$$\Rightarrow T' = 2\pi\frac{2\pi}{2}\sqrt{\frac{I}{MB_H}}$$

$$\Rightarrow \frac{T'}{T} = \frac{1}{2}$$

$$\Rightarrow T' = \frac{T}{2} = \frac{4}{2} = 2\text{ s}$$

Hence, the correct answer is (B).

59. Since $B \propto \frac{1}{x^3}$

$$\Rightarrow \frac{B_1}{B_2} = \left(\frac{x_2}{x_1}\right)^3 = \left(\frac{3x}{x}\right)^3 = \frac{27}{1}$$

Hence, the correct answer is (C).

60. In first case magnet oscillates under total earth's field B_e

$$\Rightarrow n = \frac{1}{2\pi}\sqrt{\frac{MB_e}{I}}$$

In second case magnet oscillates under vertical component B_V

$$\Rightarrow n' = \frac{1}{2\pi}\sqrt{\frac{MB_V}{I}}$$

Since $B_V < B_e$, hence $n' < n$

Hence, the correct answer is (C).

61. From the relation $B_V = B\sin\phi$

$$\Rightarrow B = \frac{B_V}{\sin\phi} = \frac{6\times10^{-5}}{\sin\ 40.6^\circ} = \frac{6\times10^{-5}}{0.65} = 9.2\times10^{-5}\text{ T}$$

Hence, the correct answer is (D).

62. For short bar magnet in $\tan A$-position

$$\frac{\mu_0}{4\pi}\frac{2M}{d^3} = B_H\tan\theta \quad \ldots(1)$$

In $\tan B$-position if deflection is θ', then

$$\frac{\mu_0}{4\pi}\frac{M}{d^3} = B_H\tan\theta' \quad \ldots(2)$$

$$\Rightarrow \frac{\tan\theta'}{\tan\theta} = \frac{1}{2}$$

$$\Rightarrow \tan\theta' = \frac{\tan\theta}{2} = \frac{\tan 60^\circ}{2} = \frac{\sqrt{3}}{2}$$

$$\Rightarrow \theta' = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right) = \tan^{-1}(0.866)$$

$$\Rightarrow \theta' = 40.9^\circ$$

Hence, the correct answer is (B).

63. Since, $B^2 = B_V^2 + B_H^2$

$$\Rightarrow B_V = \sqrt{B^2 - B_H^2} = \sqrt{(0.5)^2 - (0.3)^2} = 0.4$$

Also, $\tan\phi = \frac{B_V}{B_H} = \frac{0.4}{0.3} = \frac{4}{3}$

$$\Rightarrow \phi = \tan^{-1}\left(\frac{4}{3}\right)$$

Hence, the correct answer is (C).

64. Diamagnetic substances are repelled by a magnet. When a bar of diamagnetic material is kept in a magnetic field, it orients itself perpendicular to the field lines.
Hence, the correct answer is (D).

65. Since, $\chi \propto \frac{1}{T}$

$$\Rightarrow \chi_1 T_1 = \chi_2 T_2$$

$$\Rightarrow T_2 = \frac{1.2\times10^{-5}\times300}{1.8\times10^{-5}} = 200\text{ K}$$

Hence, the correct answer is (B).

66. Soft iron has highest susceptibility.
Hence, the correct answer is (C).

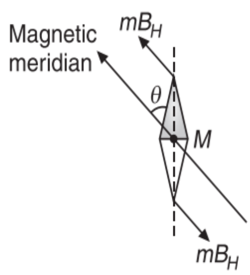
67. For null deflection, we have

$$\frac{M_1}{M_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{40}{50}\right)^3 = \frac{64}{125}$$

Hence, the correct answer is (C).

68. Magnetism of a magnet falls with rise of temperature and becomes practically zero above Curie temperature.
Hence, the correct answer is (C).

69. As the compass needle is free to rotate in a horizontal plane and points along the magnetic meridian,



So, when it is pointing along the geographic meridian, it will experience a torque due to the horizontal component of earth's magnetic field, so

$\tau = MB_H \sin\theta$, where θ is the angle between geographical and magnetic meridian also called angle of declination.

$$\Rightarrow \quad \sin\theta = \frac{1.2\times10^{-3}}{60\times40\times10^{-6}} = \frac{1}{2}$$

$$\Rightarrow \quad \theta = 30^\circ$$

Hence, the correct answer is (A).

70. Susceptibility of a paramagnetic substance is independent of magnetising field.

Hence, the correct answer is (A).

71. Since, $i = \dfrac{2RB_H}{\mu_0 N}\tan\theta$

$$\Rightarrow \quad i = \left(\frac{2\times15\times10^{-2}\times3\times10^{-5}}{4\pi\times10^{-7}\times25}\right)\tan(45^\circ)$$

$$\Rightarrow \quad i = 0.29 \text{ A}$$

Hence, the correct answer is (A).

72. Susceptibility of a ferromagnetic substance falls with rise of temperature and the substance becomes paramagnetic above Curie temperature, so magnetic susceptibility becomes very small above Curie temperature.

Hence, the correct answer is (A).

73. Curie temperature of iron is $770\ ^\circ\text{C}$, so below $770\ ^\circ\text{C}$ it is ferromagnetic and above $770\ ^\circ\text{C}$, it is paramagnetic.

Hence, the correct answer is (D).

74. Steel has the greatest retentivity. Retentivity is the property to retain magnetism after the magnet is withdrawn away from the substance to be magnetised.

Hence, the correct answer is (C).

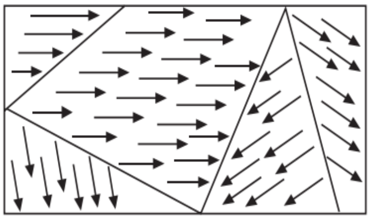
75. $i \propto \tan\theta$

$$\Rightarrow \quad \frac{i_1}{i_2} = \frac{\tan\theta_1}{\tan\theta_2}$$

$$\Rightarrow \quad \frac{0.1}{i_2} = \frac{\tan30^\circ}{\tan60^\circ} = \frac{1}{3}$$

$$\Rightarrow \quad i_2 = 0.3 \text{ A}$$

Hence, the correct answer is (B).

76. 

On heating, different domains have net magnetisation in them which are randomly distributed. Thus, the net magnetisation of the substance due to various domains decreases to minimum. Magnetisation is inversely proportional to temperature.

Hence, the correct answer is (C).

77. $M = \dfrac{CB}{T}$ is the Curie's Law.

Hence, the correct answer is (A).

78. $W = -MB(\cos\theta_2 - \cos\theta_1) = -MB(\cos60^\circ - \cos0^\circ)$

$$\Rightarrow \quad W = -MB\left(\frac{1}{2}-1\right) = \frac{MB}{2}$$

Since $|\tau| = MB\ \sin\theta = MB\ \sin60^\circ = MB\dfrac{\sqrt{3}}{2}$

$$\Rightarrow \quad \tau = \left(\frac{MB}{2}\right)\sqrt{3}$$

$$\Rightarrow \quad \tau = \sqrt{3}W$$

Hence, the correct answer is (A).

79. When a diamagnetic substance is placed in a non-uniform strong magnetic field, it always aligns itself perpendicular to the lines of induction, hence repulsion. Magnetisation, hence susceptibility is negative.

Hence, the correct answer is (D).

80. For a temporary magnet, the hysteresis loop should be long and narrow.

Hence, the correct answer is (D).

81. When magnet of length ℓ is cut into four equal parts, then we have

$$m' = \frac{m}{2} \text{ and } l' = \frac{l}{2}$$

$$\Rightarrow \quad M' = \frac{m}{2}\times\frac{l}{2} = \frac{ml}{4} = \frac{M}{4}$$

New moment of inertia, if w is mass of original magnet is

$$I' = \frac{wl^2}{12} = \frac{\frac{w}{4}\left(\frac{1}{2}\right)^2}{12} = \frac{1}{16}\frac{wl^2}{12}$$

$$\Rightarrow \quad I' = \frac{I}{16}$$

Time period of each part is given by

$$T' = 2\pi\sqrt{\frac{I'}{M'B_H}}$$

$$\Rightarrow \quad T' = 2\pi\sqrt{\frac{\frac{I}{16}}{\left(\frac{M}{4}\right)B_H}} = 2\pi\sqrt{\frac{I}{4MB_H}} = \frac{T}{2}$$

Hence, the correct answer is (C).

82. The bar magnet has coercivity 4×10^3 Am^{-1} i.e. it requires a magnetic intensity $H = 4\times10^3$ Am^{-1} to get demagnetised. Let i be the current carried by solenoid having n number of turns per metre length, then by definition

$$H = ni$$

Here $H = 4\times10^3$ Amp turn metre^{-1}

$$n = \frac{N}{\ell} = \frac{60}{0.12} = 500 \text{ turn metre}^{-1}$$

$$\Rightarrow \quad i = \frac{H}{n} = \frac{4\times10^3}{500} = 8.0 \text{ A}$$

Hence, the correct answer is (D).

83. Since, $\mu_r = 1 + \chi_m$

$$\Rightarrow \quad \mu_r = 1 + \frac{I}{H}$$

$$\Rightarrow \quad I = (\mu_r - 1)H$$

For a solenoid of n-turns per unit length and current i, we have $B = \mu_0 ni$

$$\Rightarrow \quad H = \frac{B}{\mu_0} = ni$$

$$\Rightarrow \quad I = (\mu_r - 1)ni = (1000-1)\times500\times0.5$$

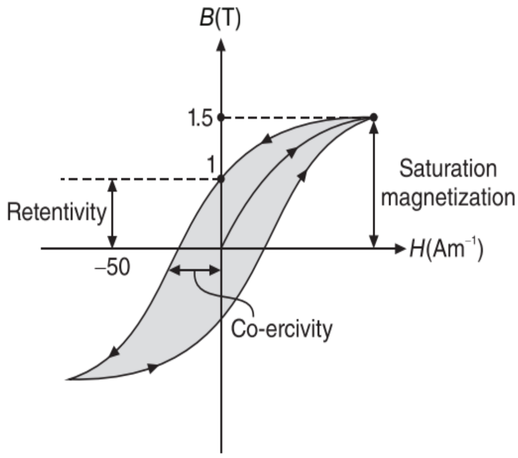
$$\Rightarrow \quad I = 2.5\times10^5 \text{ Am}^{-1}$$

Magnetic moment is given by $M = IV$

$$\Rightarrow \quad M = 2.5\times10^5\times10^{-4} = 25 \text{ Am}$$

Hence, the correct answer is (D).

84.



Retentivity $= 1.0$ T

Co-ercivity $= 50$ Am^{-1}

Saturation $= 1.5$ T

Hence, the correct answer is (B).

85. Since, $B_H = B\cos\phi$ and $B_V = B\sin\phi$

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

$$\Rightarrow \quad B_V = B_H \tan\phi$$

$$\Rightarrow \quad B_V = 0.36\times10^{-4}\times\tan60^\circ = 0.623\times10^{-4} \text{ Wbm}^{-2}$$

Hence, the correct answer is (D).

86. Iron is ferromagnetic and is strongly attracted by the magnetic field.
Hence, the correct answer is (A).

87. On passing current through the coil. It acts as a magnetic dipole. Torque acting on magnetic dipole should be counter balanced by the moment of additional weight about position O. Torque acting on a magnetic dipole is

$$\tau = MB\sin\theta = (NiA)B\sin90^\circ = NiAB$$

Also, torque due to additional weight about O is

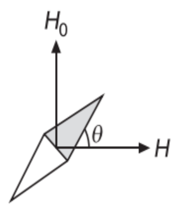
$$\tau = (\Delta m)gl$$

$$\Rightarrow \quad NiAB = (\Delta m)gl$$

$$\Rightarrow \quad B = \frac{(\Delta m)gl}{NiA} = \frac{60\times10^{-3}\times9.8\times30\times10^{-2}}{200\times22\times10^{-3}\times1\times10^{-4}} = 0.4 \text{ T}$$

Hence, the correct answer is (A).

88. In given case, H and H_0 are perpendicular to each other as shown in Figure.



$\Rightarrow \quad \tan\theta = \dfrac{H_0}{H}$

$\Rightarrow \quad \theta = \tan^{-1}\left(\dfrac{H_0}{H}\right)$

Hence, the correct answer is (A).

89. The bar magnet coercivity is 4×10^3 Am^{-1} i.e., it requires a magnetic intensity $H = 4\times10^3$ Am^{-1} to get demagnetized.

Let i be the current carried by solenoid having n number of turns per metre length, then, we have

$H = ni$, where $H = 4\times10^3$ Am^{-1}

Since, $n = \dfrac{N}{l} = \dfrac{60}{0.12} = 500$ turn m^{-1}

$\Rightarrow \quad i = \dfrac{H}{n} = \dfrac{4\times10^3}{500} = 8.0$ A

Hence, the correct answer is (D).

90. Since, $I = \dfrac{M}{V} = \dfrac{M}{\text{mass/density}}$,

Given that mass $= 1\text{ g} = 10^{-3}$ kg and

$$\rho = 5\text{ gcm}^{-3} = \frac{5\times10^{-3}\text{ kg}}{(10^{-2})\text{ m}^3} = 5\times10^3\text{ kgm}^{-3}$$

$\Rightarrow \quad I = \dfrac{6\times10^{-7}\times5\times10^3}{10^{-3}} = 3$

Hence, the correct answer is (B).

91. Since $T = 2\pi\sqrt{\dfrac{I}{MB_H}}$

$\Rightarrow \quad \dfrac{T_A}{T_B} = \sqrt{\dfrac{(B_H)_B}{(B_H)_A}}$

$\Rightarrow \quad \dfrac{\frac{60}{10}}{\frac{60}{20}} = \sqrt{\dfrac{(B_H)_B}{36\times10^{-6}}}$

$\Rightarrow \quad (B_H)_B = 144\times10^{-6}$ T

Hence, the correct answer is (C).

92. When a paramagnetic substance is placed in a non-uniform magnetic field, the substance always aligns along the field lines, because by aligning along the lines of induction, magnetisation is maximum.

Hence, the correct answer is (A).

93. Assume the length of magnet to be l, mass be w and magnetic moment be M. When cut in six equal parts length each part becomes $\dfrac{l}{6}$, mass becomes $\dfrac{w}{6}$ and magnetic moment also becomes $\dfrac{M}{6}$. Moment of inertia of each part is

$$I' = \frac{1}{12}w'L'^2 = \frac{1}{12}\left(\frac{w}{6}\right)\left(\frac{L}{6}\right)^2 = \frac{I}{6^3}$$

Initially, $T = 2\pi\sqrt{\dfrac{I}{MB_H}}$

For the arrangement shown,

$$I_{net} = 6I' = \frac{I}{6^2}$$

$$M_{net} = \frac{4M}{6} - \frac{2M}{6} = \frac{M}{3}$$

Time period of the arrangement is

$$T_{net} = \sqrt{\frac{\frac{I}{6^2}}{\left(\frac{M}{3}\right)B_H}} = \frac{T}{\sqrt{12}} = \frac{T}{2\sqrt{3}}$$

Hence, the correct answer is (C).

ARCHIVE: JEE MAIN

1. According to Curie's Law,

$$\chi \propto \frac{1}{T}$$

$\Rightarrow \quad \chi_1 T_1 = \chi_2 T_2$

$\Rightarrow \quad \chi_2 = \dfrac{2.8\times350}{300}\times10^{-4} = 3.267\times10^{-4}$

Hence, the correct answer is (D).

2. Magnetic intensity (M) is

$$M = \chi H$$

$\Rightarrow \quad \chi = \dfrac{20\times10^{-6}}{60\times10^3\times10^{-6}}$

$\Rightarrow \quad \chi = 3.3\times10^{-4}$

Hence, the correct answer is (C).

3. Time period of hoop is

$$T_h = 2\pi\sqrt{\frac{I_h}{M_h B}}$$

Time period of cylinder is

$$T_c = 2\pi\sqrt{\frac{I_c}{M_c B}}$$

$$\Rightarrow \frac{T_h}{T_c} = \sqrt{\frac{I_h M_c}{I_c M_h}}$$

Since $M_h = 2M_c$

$$\Rightarrow \frac{T_h}{T_c} = \sqrt{\frac{(mR^2)(M_c)}{\left(\frac{mR^2}{2}\right)(2M_c)}} = 1$$

$$\Rightarrow T_h = T_c$$

Hence, the correct answer is (B).

4. Since, $\frac{B_v}{B_H} = \tan(45°)$

$$\Rightarrow B_v = B_H = 18\times10^{-6}\ \text{T}$$

Torque due to vertical component of field is

$$\tau_{B_v} = MB_v$$

where $M = m(2l)$

$$\Rightarrow \tau_{B_v} = [(18\times10^{-6})(1.8)(0.12)]$$

Torque due to vertical force about centre is

$$\tau_f = F\left(\frac{0.12}{2}\right)$$

Equating both torques, we get

$$F = (18)(1.8\times10^{-6})(2)$$

$$\Rightarrow F \simeq 6.5\times10^{-5}\ \text{N}$$

Hence, the correct answer is (C).

5. Since $\theta = \omega t$

$$\Rightarrow \theta = 0.125\ \text{rad}$$

$$\Rightarrow \theta = \frac{1}{8}\ \text{radian}$$

Initial and final potential energy are given by

$$U_i = -MB\cos\left(\frac{1}{8}\right)$$

$$U_f = MB\cos\left(\frac{1}{8}\right)$$

$$\Rightarrow W = 2MB\cos\left(\frac{1}{8}\right) = 0.0198\ \text{J}$$

*No given option is correct.

6. Coercivity of ferromagnet is $H = 100\ \text{Am}^{-1}$

Since $H = ni = 100$

$$\Rightarrow i = \frac{100}{10^5} = 1\ \text{mA}$$

Hence, the correct answer is (A).

7. Time period of magnetic needle oscillating simple harmonically is given by

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

$$\Rightarrow T = 2\pi\sqrt{\frac{7.5\times10^{-6}}{6.7\times10^{-2}\times0.01}}$$

$$\Rightarrow T = \frac{2\pi}{10}\times1.05\ \text{s}$$

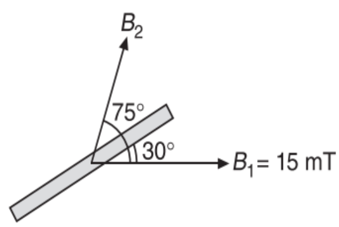
For 10 oscillations, total time taken

$$T' = 10T = 2\pi\times1.05 \approx 6.65\ \text{s}$$

Hence, the correct answer is (A).

8. For both, the electromagnet and transformer, the magnetic field changes with time. Hence the energy losses must be less in both devices. Hysteresis loop represented in B has less area which means it dissipates less energy.
Hence, the correct answer is (D).

9. The magnetic dipole attains stable equilibrium under the influence of these two fields making an angle $\theta_1 = 30°$ with B_1 and $\theta_2 = 75° - 30° = 45°$ with B_2 as shown in Figure.



For stable equilibrium, net torque acting on dipole must be zero.

$$\Rightarrow \vec{\tau}_1 + \vec{\tau}_2 = 0$$

$$\Rightarrow \tau_1 = \tau_2$$

$$\Rightarrow MB_1\sin\theta_1 = MB_2\sin\theta_2$$

$$\Rightarrow B_2 = B_1\frac{\sin\theta_1}{\sin\theta_2} = (15\ \text{mT})\left(\frac{\sin 30°}{\sin 45°}\right)$$

$$\Rightarrow B_2 = (15\ \text{mT})\left(\frac{1}{2}\right)\sqrt{2} = 10.6\ \text{mT} \approx 11\ \text{mT}$$

Hence, the correct answer is (B).

CHAPTER 2

10. $\ell = 25$ cm , $r = 2$ cm , $N = 500$, $i = 15$ A

Since, $|\vec{M}| = \dfrac{\text{Magnetic moment}}{\text{Volume}} = \dfrac{NiA}{A\ell} = \dfrac{Ni}{\ell}$

$\Rightarrow \quad |\vec{M}| = \dfrac{15 \times 500}{25 \times 10^{-2}} = 30000 \text{ Am}^{-1}$

Hence, the correct answer is (B).

11. At 30 cm from the magnet on its equatorial plane for the neutral point, we get

$$\left|\vec{B}_{\text{magnet}}\right| = \left|\vec{B}_H\right|$$

$\Rightarrow \quad \dfrac{\mu_0}{4\pi}\dfrac{M}{r^3} = 3.6 \times 10^{-5}$

$\Rightarrow \quad \dfrac{10^{-7} \times M}{(0.3)^3} = 3.6 \times 10^{-5}$

$\Rightarrow \quad M = 3.6 \times 0.027 \times 10^2 = 9.7 \text{ Am}^2$

Hence, the correct answer is (A).

12. Given that $\dfrac{B}{\mu_0} = 3 \times 10^3 \text{ Am}^{-1}$

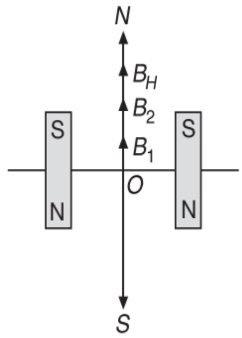
$$L = 10 \text{ cm} = 0.1 \text{ m}, \ N = 100, \ i = ?$$

Since, $B = \mu_0 ni = \mu_0 \dfrac{N}{L} i$

$\Rightarrow \quad i = \dfrac{B}{\mu_0} \times \dfrac{L}{N} = 3 \times 10^3 \times \dfrac{0.1}{100} = 3 \text{ A}$

Hence, the correct answer is (D).

13. The situation is shown in Figure.



As the point O lies on broad-side position with respect to both the magnets. Therefore, the net magnetic field at point O is

$$B_{net} = B_1 + B_2 + B_H$$

$\Rightarrow \quad B_{\text{net}} = \dfrac{\mu_0}{4\pi}\dfrac{M_1}{r^3} + \dfrac{\mu_0}{4\pi}\dfrac{M_2}{r^3} + B_H$

$\Rightarrow \quad B_{\text{net}} = \dfrac{\mu_0}{4\pi r^3}(M_1 + M_2) + B_H$

Substituting the given values, we get

$$B_{net} = \frac{4\pi \times 10^{-7}}{4\pi \times \left(10 \times 10^{-2}\right)^3}(1.2 + 1) + 3.6 \times 10^{-5}$$

$$B_{\text{net}} = \left(\frac{10^{-7}}{10^{-3}}\right)(2.2) + 3.6 \times 10^{-5}$$

$\Rightarrow \quad B_{\text{net}} = 2.2 \times 10^{-4} + 0.36 \times 10^{-4}$

$\Rightarrow \quad B_{\text{net}} = 2.56 \times 10^{-4} \text{ Wbm}^{-2}$

Hence, the correct answer is (C).