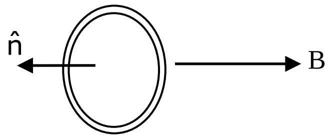
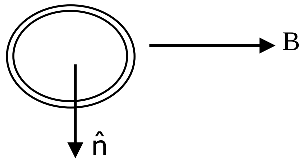
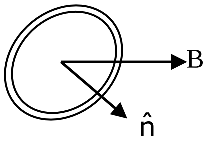
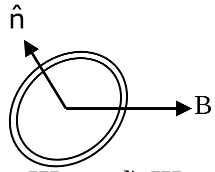
2PUC – CHAPTER 05
MAGNETISM AND MATTER

1. A current carrying loop is placed in a uniform magnetic field in four different orientations, I, II, III and IV arrange them in the decreasing order of potential energy.

I. 

II. 

III. 

IV. 

a) I > III > II > IV b) I > II > III > IV c) I > IV > II > III d) III > IV > I > II

(c)

U = -MB cosθ, where θ = Angle between normal to the plane of the coil and direction of magnetic field.

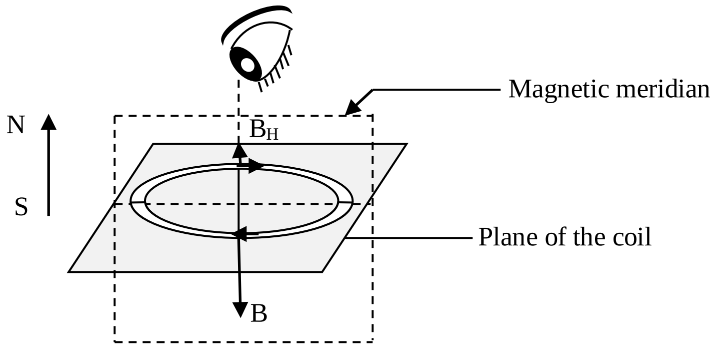
2. A neutral point is obtained at the centre of a vertical circular coil carrying current. The angle between the plane of the coil and the magnetic meridian is

a) 0 b) 45° c) 60° d) 90°

(d)

Magnetic meridian is a vertical magnetic N-S plane, the earth's magnetic field (B_H) lies in it.

To obtain neutral point at the centre of coil, magnetic field due to current (B) and B_H must cancel each other. Hence plane of the coil and magnetic meridian must be perpendicular to each other as shown



3. Rate of change of torque τ with deflection θ is maximum for a magnet suspended freely in a uniform magnetic field of induction B, when

a) θ = 0° b) θ = 45° c) θ=60° d) θ=90°

(a)

$\tau = MB_H \sin\theta$ or $\frac{d\tau}{d\theta} = MB_H \cos\theta$

This will be maximum. When θ = 0°

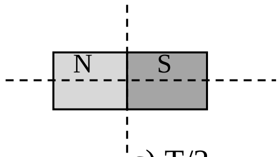
4. A magnet of magnetic moment $50\hat{i}$ A-m^2 is placed along the x-axis in a magnetic field $\vec{B} = (0.5\hat{i} + 30\hat{j})$ T. The torque acting on the magnet is

a) 175 $\hat{k}$ N-m b) 150 $\hat{k}$ N-m c) 75 $\hat{k}$ N-m d) $25\sqrt{37}\,\hat{k}$ N-m

(b)

$\vec{\tau} = \vec{M} \times \vec{B} \Rightarrow \vec{\tau} = 50\hat{i} \times (0.5\hat{i} + 3\hat{j}) = 150(\hat{i} \times \hat{j}) = 150\hat{k}$ Nm.

5. Time period for a magnet is T. If it is divided into four equal parts along its axis and perpendicular to its axis as shown, then time period for each part will be



a) 4 T b) T/4 c) T/2 d) T

(c)

When the magnet of length ℓ is cut into four parts, magnetic moment of each part is m/4

New moment of inertia I' = $\frac{(M/4)(\ell/2)^2}{12} = \frac{1}{6}\frac{M\ell^2}{12} = \frac{1}{16}I$

Time period of each part $T' = 2\pi\sqrt{\frac{I'}{m'B_H}} = 2\pi\sqrt{\frac{I/16}{(m/4)B_H}} = 2\pi\sqrt{\frac{I/16}{(m/4)B_H}} = \frac{T}{2}$

6. Moment of inertia of a magnetic needle is 40 gcm^2 has time period 3s in earth's horizontal field is 3.6×10^{-5} Wb/m^2. Its magnetic moment will be

a) 0.5 A m^2 b) 5 A m^2 c) 0.250 A m^2 d) 5×10^2 A m^2

(a)

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

$I = 40\ gcm^2 = 400 \times 10^{-8}\ kgm^2$

$\therefore 3 = 2\pi\sqrt{\frac{400 \times 10^{-8}}{36 \times 10^{-6} \times M}}$

$\Rightarrow \frac{1}{M} = \frac{9}{4\pi^2} \times \frac{36}{4} \Rightarrow M = 0.5\ Am^2$

7. A magnet is suspended in such a way that it oscillates in the horizontal plane. It makes 20 oscillations per minute at a place where dip angle is 30° and 15 oscillations per minute at a place where dip angle is 60°. The ratio of total earth's magnetic field at the two places is

a) $3\sqrt{3}:8$ b) $16:9\sqrt{3}$ c) 4:9 d) $2\sqrt{3}:9$

(b)

Given $\nu_1 = \frac{20}{60} = \frac{1}{3}\ sec^{-1}$ and $\nu_2 = \frac{15}{60} = \frac{1}{4}\ sec^{-1}$

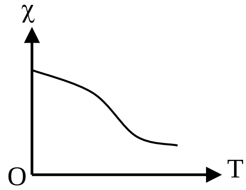
Now $\nu = \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}} = \frac{1}{2\pi}\sqrt{\frac{MB\cos\varphi}{I}}$ ($\because B_H = B\cos\varphi$)

$\therefore \frac{\nu_1}{\nu_2} = \sqrt{\frac{B_1\cos\varphi_1}{B_2\cos\varphi_2}} \Rightarrow \frac{B_1}{B_2} = \left(\frac{\nu_1}{\nu_2}\right)^2\left(\frac{\cos\varphi_2}{\cos\varphi_1}\right)^2$

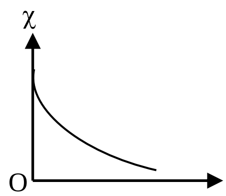
$\Rightarrow \frac{B_1}{B_2} = \left(\frac{1/3}{1/4}\right)^2 \frac{\cos 60^0}{\cos 30^0} = \frac{16}{9} \times \frac{1/2}{\sqrt{3}/2} = \frac{16}{9\sqrt{3}}$

8. The variation of magnetic susceptibility (χ) with absolute temperature T for a ferromagnetic material is

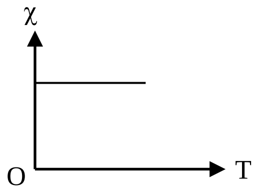
a)



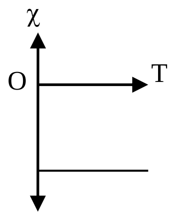
b)



c)



d)



(a)

Susceptibility of a ferromagnetic substance falls with rise of temperature $\left(\chi = \frac{C}{T - T_C}\right)$ and the substance becomes paramagnetic above Curie temperature, so magnetic susceptibility becomes very small above Curie temperature.

9. When a material is subjected to a small magnetic field H, the intensity of magnetisation is proportional to

(a) $H^{1/2}$ (b) H (c) H^2 (d) $H^{-1/2}$

(b)

The intensity of magnetisation (M) is defined as the magnetic moment per unit volume of the material. The magnitude of M depends upon the magnetisation current which is proportional to H. Hence the correct choice is (b).

10. The magnetic permeability of a paramagnetic substance is

(a) Small and positive (b) Small and negative
(c) Large and positive (d) Large and negative

(a)

11. For a paramagnetic material, the dependence of the magnetic susceptibility χ on the absolute temperature T is given by (C is a constant)

(a) $\chi = CT$ (b) $\chi = C/T$ (c) $\chi = CT^2$ (d) $\chi = CT^{-2}$

(b)

According to Curie's law, the susceptibility χ is related to temperature T as $\chi = \frac{C}{T}$ where C is curie constant. Hence the correct choice is (b).

12. The relative permeability of iron is of the order of

(a) Zero (b) 10^{-4} (c) 1 (d) 10^3

(d)

13. At a certain place on earth a magnetic needle is placed along the magnetic meridian at an angle of 60° to the horizontal. If the horizontal component of the earth's field at the place is $0.20\times10^{-4}T$, what is the magnitude of the total earth's field at the place?

(a) $0.2\times10^{-4}T$ (b) $0.4\times10^{-4}T$ (c) $0.8\times10^{-4}T$ (d) $1.6\times10^{-4}T$

(b)

$B_H = 0.20\times10^{-4}T$ and $\theta = 60^o$. We know than $B_H = B\cos\theta$, where B is the magnitude of the total earth's field. Thus, $B = \frac{B_H}{\cos\theta} = \frac{0.20\times10^{-4}}{\cos 60^o} = 0.40\times10^{-4}T$.

14. A small piece of a material is repelled by a strong magnet. The material is

(a) Paramagnetic (b) Ferromagnetic (c) Diamagnetic (d) Non-magnetic

(c)

15. A bar magnet of pole strength q and magnetic moment m is divided into two equal pieces by cutting it along its length. Then

(a) q is halved and m is doubled (b) q and m both are halved
(c) q is halved but m remains the same (d) q remains the same but m is halved

(b)

16. A sample of paramagnetic salt contains 2×10^{24} atomic dipoles, each of dipole moment $1.5\times10^{-23}JT^{-1}$. The sample is placed in a magnetic field of 0.6 T and cooled to a temperature of 4K. The degree of magnetic saturation achieved is equal to 15%. What is the total dipole moment of the sample for a magnetic field of 0.9 T and a temperature of 3K?

(a) 3 JT^{-1} (b) 6 JT^{-1} (c) 9 JT^{-1} (d) 12 JT^{-1}

(c)

Initial total magnetic moment at temperature $T_1 = 4K$ is

$M_1 = 15\%\text{ of}\left(2.0\times10^{24}\times1.5\times10^{-23}\right) = 4.5\,JT^{-1}$

Now from Curie's law, we have $\chi = C/T$

Or $\frac{I}{H} = \frac{C}{T}$ … (i)

where I is magnetization and H is the magnetizing field. If V is the volume of the sample, then by definition, $M = I/V$ and eq. (i) becomes

$M = \frac{C}{V}\left(\frac{H}{T}\right) = constant\times\left(\frac{H}{T}\right)$ … (ii)

If M_2 is the magnetic moment at temperature $T_2 = 3K$ and field $B_2 = 0.9T$, then from Eq. (ii) M_1 and M_2 are related as $\frac{M_1}{M_2} = \frac{H_1}{H_2}\cdot\frac{T_2}{T_1} = \frac{B_1}{B_2}\cdot\frac{T_2}{T_1}$

Or $M_2 = M_1\times\frac{B_2}{B_1}\times\frac{T_1}{T_2} = 4.5\times\frac{0.9}{0.6}\times\frac{4}{3} = 9$

17. A short bar magnet of length 4 cm has a magnetic moment of $4\ JT^{-1}$. What is the magnitude of the magnetic field at a distance of 2 m from the centre of the magnet on its equatorial line?

(a) $10^{-7}T$ (b) $5\times10^{-8}T$ (c) $10^{-6}T$ (d) $5\times10^{-5}T$

(b)

Here $2a = 4cm$, $m = 4\,JT^{-1}$ and $r = 2m$.

Since $a << r$, the magnetic field at a distance r on the equatorial line is

$B_m = \frac{\mu_0 M}{4\pi r^3} = \frac{4\pi\times10^{-7}\times4}{4\pi\times(2)^3} = 5\times10^{-8}T$.

18. Electromagnets are made of soft iron because, soft iron has

a) low susceptibility and low retentivity b) high susceptibility and low retentivity

c) high susceptibility and high retentivity d) low susceptibility and high retentivity

(b)

19. Material of permanent magnet has

a) high retentivity and high coercivity b) low retentivity and high coercivity

c) low retentivity and low coercivity d) high retentivity and low coercivity

(a)

20. The magnetic properties of a magnet is lost at it's

a) Melting pointing b) Boiling point c) Curie point d) Triple point

(c)

21. The correct definition of Meissner effect is

a) The phenomenon of perfect paramagnetism in super conductors

b) The phenomenon of perfect diamagnetism in superconductors

c) The phenomenon of perfect diamagnetism in semiconductors

d) The phenomenon of ferromagnetism in metals

(b)

22. At certain place, the horizontal component of earth's magnetic field is 3.0 G and the angle dip at the place is 30°. The magnetic field of earth at that location

a) 4.5 G b) 5.1 G c) 3.5 G d) 6.0 G

(c)

Solution: B_H = 3.0G, θ = 30°

$B_H = B\cos\theta$

$B = \frac{B_H}{\cos\theta} = \frac{3}{\cos(30^\circ)}$ = 3.5 G.

23. At a certain place on earth a magnetic needle is placed along the magnetic meridian at an angle of 60° to the horizontal. If the horizontal component of the earth's field at the place of 0.20×10^{-4} T, what is the magnitude of the total earth's field at that place?

a) 0.2×10^{-4} T b) 0.4×10^{-4} T c) 0.8×10^{-4} T d) 1.6×10^{-4} T

(b)

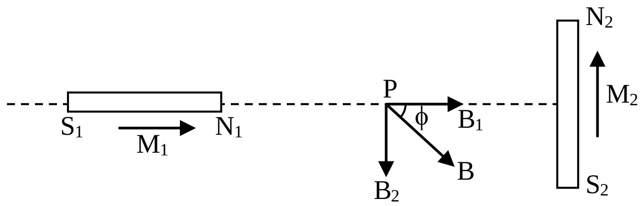
$B_H = 0.20 \times 10^{-4}$ T and $\theta = 60^o$. We know that $B_H = B\cos\theta$, where B is the magnetic of the total earth's field. Thus,

$$B = \frac{B_H}{\cos\theta} = \frac{0.20 x 10^{-4}}{\cos 60^o} = 0.40 x 10^{-4} T$$

24. Two identical magnetic dipoles of magnetic moment 2 A m^2 are placed at a separation of 2 m with their axis perpendicular to each other in air. The resultant magnetic field at a midpoint between the dipole is

a) $4\sqrt{5} \times 10^{-5}$ T b) $2\sqrt{5} \times 10^{-5}$ T c) $4\sqrt{5} \times 10^{-7}$ T d) $2\sqrt{5} \times 10^{-7}$ T

(d)



Let point P be a midpoint between the dipoles. The point P will be in end-on position with respect to one dipole and in broad side on position with respect to the other.

$\therefore$ $$B_1 = \frac{\mu_0}{4\pi}\frac{2M_1}{r_1^3} = \frac{10^{-7} \times 2 \times 2}{(1)^3} = 4 \times 10^{-7} \text{ T}$$

and $$B_2 = \frac{\mu_0}{4\pi}\frac{M_2}{r_2^3} = \frac{10^{-7} \times 2}{(1)^3} = 2 \times 10^{-7} \text{ T}$$

As B_1 and B_2 are perpendicular to each other, therefore the resultant magnetic field at point P is

$$B = \sqrt{B_1^2 + B_2^2} = \sqrt{(4 \times 10^{-7})^2 + (2 \times 10^{-7})^2} = 2\sqrt{5} \times 10^{-7} \text{ T}$$

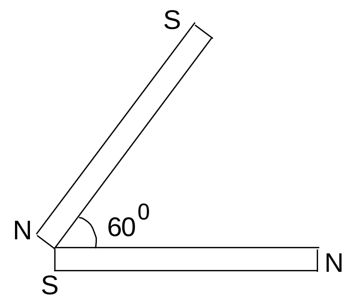
25. Two magnets of equal magnetic moments M each are placed as shown in figure. The resultant magnetic moment is

a) M

b) $\sqrt{3}$ M

c) $\sqrt{2}$ M

d) M/2



(a)

As, magnetic moments are directed along SN, angle between $\vec{M}$ and $\vec{M}$ is $\theta = 120^o$.

$\therefore$ Resultant magnetic moment = $\sqrt{M^2 + M^2 + 2M\cos 120^0} = \sqrt{M^2 + M^2 + 2M^2(-1/2)} = M$

26. A circular current loop of magnetic moment M is in an arbitrary orientation in an external magnetic field B. The work done to rotate the loop by 30^o about an axis perpendicular to its plane is

a) MB b) $\sqrt{3}\,\frac{MB}{2}$ c) $\frac{MB}{2}$ d) zero

(d)

Let magnetic moment M of current loop be making an angle α with the direction of B. When a circular current loop is rotated in a magnetic field by 30° about an axis perpendicular to its plane, there is no change in the angle α between magnetic moment M and magnetic field B. Therefore, $\theta_1 = \alpha$, $\theta_2 = \alpha$

Work done, $W = MB(\cos\theta_1 - \cos\theta_2) = MB(\cos\alpha - \cos\alpha) = 0$

27. The time period of vibration of two magnets in sum position in 3s. When polarity of weaker magnet is reversed, the combination makes 12 oscillations per minute. The ratio of magnetic moments of two magnets is

a) $\frac{16}{17}$ b) $\frac{17}{8}$ c) $\frac{3}{5}$ d) $\frac{4}{5}$

(b)

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

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

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

28. A paramagnetic sample shows a net magnetisation of 8 Am^{-1} when placed in an external magnetic field of 0.6T at a temperature of 4K. When the same sample is placed in an external magnetic field of 0.2 T at a temperature of 16K, the magnetisation will be

a) $\frac{32}{3}$ Am^{-1} b) $\frac{2}{3}$ Am^{-1} c) 6 Am^{-1} d) 2.4 Am^{-1}

(b)

As Curie law explains, we can deduce a formula for the relation between magnetic field induction, temperature and magnetization

$M = \chi H$

$\chi \propto \frac{1}{T}$; $H \propto B$

i.e., $M(\text{magnetisation}) \propto \frac{B(\text{magnetic field induction})}{T(\text{temperature in kelvin})} \Rightarrow \frac{M_2}{M_1} = \frac{B_2}{B_1} \times \frac{T_1}{T_2}$

Let us suppose, here $M_1 = 8\,Am^{-1}$, $B_1 = 0.6T, T_1 = 4K$

$B_2 = 0.2T, T_2 = 16K$

$I_2 = ?$

$\Rightarrow \frac{0.2}{0.6} \times \frac{4}{16} = \frac{M_2}{8} \Rightarrow M_2 = 8 \times \frac{1}{12} = \frac{2}{3} Am^{-1}$

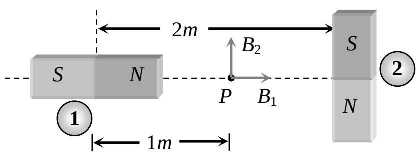
29. Two identical magnetic dipoles of magnetic moments 1.0 $A\text{-}m^2$ each, placed at a separation of 2m with their axis perpendicular to each other. The resultant magnetic field at a point midway between the dipoles is

(a) $5 \times 10^{-7} T$ (b) $\sqrt{5} \times 10^{-7} T$

(c) $10^{-7} T$ (d) None of these

(b)

With respect to 1st magnet, P lies in end side-on position $\therefore B_1 = \frac{\mu_0}{4\pi}\left(\frac{2M}{d^3}\right)$ (RHS)



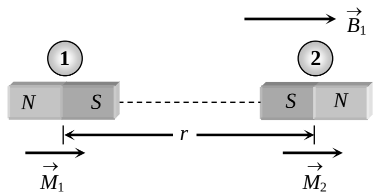
With respect to 2nd magnet. P lies in broad side on position. $\therefore B_2 = \frac{\mu_0}{4\pi}\left(\frac{M}{d^3}\right)$ (Upward)

$B_1 = 10^{-7} \times \frac{2 \times 1}{1} = 2 \times 10^{-7} T$, $B_2 = \frac{B_1}{2} = 10^{-7} T$

As B_1 and B_2 are mutually perpendicular, hence the resultant magnetic field

$B_R = \sqrt{B_1^2 + B_2^2} = \sqrt{(2 \times 10^{-7})^2 + (10^{-7})^2} = \sqrt{5} \times 10^{-7} T$

30. Two short magnets placed along the same axis with their like poles facing each other repel each other with a force which varies inversely as
(a) Square of the distance
(b) Cube of the distance
(c) Distance
(d) Fourth power of the distance
(d)



Both the magnets are placed in the field of one another, hence potential energy of dipole (2) is

$$U_2 = -M_2B_1\cos 0 = -M_2B_1 = M_2 \times \frac{\mu_0}{4\pi}.\frac{2M_1}{r^3}$$

By using $F = -\frac{dU}{dr}$, Force on magnet (2) is

$$F_2 = -\frac{dU_2}{dr} = -\frac{d}{dr}\left(\frac{\mu_0}{4\pi}.\frac{2M_1M_2}{r^3}\right) = -\frac{\mu_0}{4\pi}.6\frac{M_1M_2}{r^4}$$

It can be proved $|F_1| = |F_2| = F = \frac{\mu_0}{4\pi}.\frac{6M_1M_2}{r^4}$

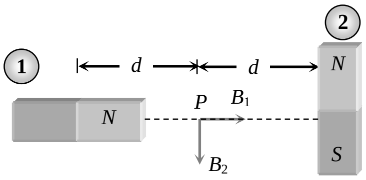
$$\Rightarrow F \propto \frac{1}{r^4}$$

31. Two identical short bar magnets, each having magnetic moment M, are placed a distance of 2d apart with axes perpendicular to each other in a horizontal plane. The magnetic induction at a point midway between them is

(a) $\frac{\mu_0}{4\pi}(\sqrt{2})\frac{M}{d^3}$ (b) $\frac{\mu_0}{4\pi}(\sqrt{3})\frac{M}{d^3}$
(c) $\left(\frac{2\mu_0}{\pi}\right)\frac{M}{d^3}$ (d) $\frac{\mu_0}{4\pi}(\sqrt{5})\frac{M}{d^3}$
(d)

At point P net magnetic field $B_{net} = \sqrt{B_1^2 + B_2^2}$ where $B_1 = \frac{\mu_0}{4\pi}.\frac{2M}{d^3}$ and $B_2 = \frac{\mu_0}{4\pi}.\frac{M}{d^3}$

$$\Rightarrow B_{net} = \frac{\mu_0}{4\pi}.\frac{\sqrt{5}M}{d^3}$$



32. If a magnet is suspended at an angle 30° to the magnetic meridian, it makes an angle of 45° with the horizontal. The real dip is
(a) $\tan^{-1}(\sqrt{3}/2)$ (b) $\tan^{-1}(\sqrt{3})$
(c) $\tan^{-1}(\sqrt{3/2})$ (d) $\tan^{-1}(2/\sqrt{3})$
(a)

Let the real dip be ϕ, then $\tan\phi = \frac{B_V}{B_H}$

For apparent dip, $\tan\phi' = \frac{B_V}{B_H\cos\beta} = \frac{B_V}{B_H\cos 30^o} = \frac{2B_V}{\sqrt{3}B_H}$

or $\tan 45^o = \frac{2}{\sqrt{3}}.\tan\phi$ or $\phi = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

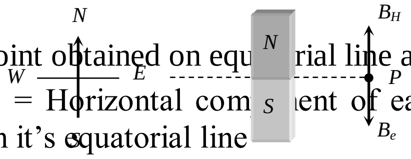
33. A short bar magnet with its north pole facing north forms a neutral point at P in the horizontal plane. If the magnet is rotated by 90° in the horizontal plane, the net magnetic induction at P is (Horizontal component of earth's magnetic field = B_H)

(a) 0 (b) 2 B_H

(c) $\frac{\sqrt{5}}{2} B_H$ (d) $\sqrt{5}\, B_H$

(d)

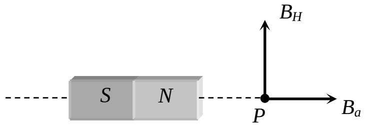
Initially



Neutral point obtained on equatorial line and at neutral point $|B_H| = |B_e|$

where B_H = Horizontal component of earth's magnetic field, B_e = Magnetic field due to bar magnet on it's equatorial line

Finally



Point P comes on axial line of the magnet and at P, net magnetic field $B = \sqrt{B_a^2 + B_H^2}$

$= \sqrt{(2B_e)^2 + (B_H)^2} = \sqrt{(2B_H)^2 + B_H^2} = \sqrt{5}\ B_H$

34. The true value of angle of dip at a place is 60°, the apparent dip in a plane inclined at an angle of 30° with magnetic meridian is

(a) $\tan^{-1}\frac{1}{2}$ (b) $\tan^{-1}(2)$

(c) $\tan^{-1}\left(\frac{2}{3}\right)$ (d) None of these

(b)

$\tan\phi' = \frac{\tan\phi}{\cos\beta}$; where ϕ' =Apparent angle of dip,

ϕ = True angle of dip, β =Angle made by vertical plane with magnetic meridian.

$\Rightarrow \tan\phi' = \frac{\tan 60^o}{\cos 30^o} = 2 \Rightarrow \phi' = \tan^{-1}(2)$

35. A vibration magnetometer consists of two identical bar magnets placed one over the other such that they are perpendicular and bisect each other. The time period of oscillation in a horizontal magnetic field is $2^{5/4}$ second. One of the magnets is removed and if the other magnet oscillates in the same field, then the time period in seconds is

(a) $2^{1/4}$ (b) $2^{1/2}$

(c) 2 (d) $2^{3/4}$

(c)

Initially magnetic moment of system $M_1 = \sqrt{M^2 + M^2} = 2M$ and moment of inertia $I_1 = I + I = 2I.$

Finally when one of the magnet is removed then $M_2 = M$ and $I_2 = I$

So $T = 2\pi\sqrt{\frac{I}{M\ B_H}}$

$$\frac{T_1}{T_2} = \sqrt{\frac{I_1}{I_2} \times \frac{M_2}{M_1}} = \sqrt{\frac{2I}{I} \times \frac{M}{\sqrt{2}M}} \Rightarrow T_2 = \frac{2^{5/4}}{2^{1/4}} = 2\,s$$

36. In a vibration magnetometer, the time period of a bar magnet oscillating in horizontal component of earth's magnetic field is 2s. When a magnet is brought near and parallel to it, the time period reduces to 1s. The ratio H/F of the horizontal component H and the field F due to magnet will be

(a) 3 (b) 1/3

(c) $\sqrt{3}$ (d) $1/\sqrt{3}$

(b)

$T \propto \frac{1}{\sqrt{H}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{H_2}{H_1}} \Rightarrow \frac{2}{1} = \sqrt{\frac{H+F}{H}} \Rightarrow F = 3H$

or $\frac{H}{F} = \frac{1}{3}$

37. A cylindrical rod magnet has a length of 5 cm and a diameter of 1 cm. It has a uniform magnetisation of 5.30×10^3 Amp/m^3. What its magnetic dipole moment

(a) $1 \times 10^{-2}\ J/T$ (b) $2.08 \times 10^{-2}\ J/T$

(c) $3.08 \times 10^{-2}\ J/T$ (d) $1.52 \times 10^{-2}\ J/T$

(b)

Relation for dipole moment is, $M = I \times V$.

Volume of the cylinder $V = \pi r^2 l$, where r is the radius and ℓ is the length of the cylinder, then dipole moment, $M = I\pi r^2 l = (5.30 \times 10^3) \times \frac{22}{7} \times (0.5 \times 10^{-2})^2 (5 \times 10^{-2}) = 2.08 \times 10^{-2}\ J/T$

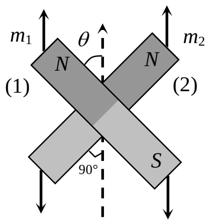
38. Two magnets of equal mass are joined at right angles to each other as shown the magnet 1 has a magnetic moment 3 times that of magnet 2. This arrangement is pivoted so that it is free to rotate in the horizontal plane. In equilibrium what angle will the magnet 1 subtend with the magnetic meridian?

(a) $\tan^{-1}\left(\frac{1}{2}\right)$

(b) $\tan^{-1}\left(\frac{1}{3}\right)$

(c) $\tan^{-1}(1)$

(d) 0°



(b)

For equilibrium of the system torques on M_1 and M_2 due to B_H must counter balance each other i.e. $M_1 \times B_H = M_2 \times B_H$. If θ is the angle between M_1 and B_H will be $(90 - \theta)$; so $M_1 B_H \sin\theta = M_2 B_H \sin(90 - \theta)$

$\Rightarrow \tan\theta = \frac{M_2}{M_1} = \frac{M}{3M} = \frac{1}{3} \Rightarrow \theta = \tan^{-1}\left(\frac{1}{3}\right)$

39. The dipole moment of each molecule of a paramagnetic gas is 1.5×10^{-23} amp × m^2. The temperature of gas is 27°C and the number of molecules per unit volume in it is 2×10^{26} m^{-3}. The maximum possible intensity of magnetisation in the gas will be

(a) 3×10^3 amp/m (b) 4×10^{-3} amp/m

(c) 5×10^5 amp/m (d) 6×10^{-4} amp/m

(a)

$I = \frac{M}{V} = \frac{\mu N}{V} = \frac{1.5 \times 10^{-23} \times 2 \times 10^{26}}{1} = 3 \times 10^3\ Amp/m$

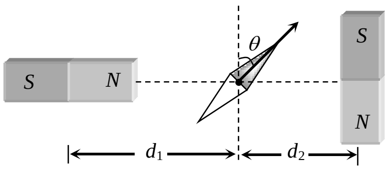
40. Two magnets A and B are identical and these are arranged as shown in the figure. Their length is negligible in comparison to the separation between them. A magnetic needle is placed between the magnets at point P which gets deflected through an angle θ under the influence of magnets. The ratio of distance d_1 and d_2 will be

(a) $(2\tan\theta)^{1/3}$

(b) $(2\tan\theta)^{-1/3}$

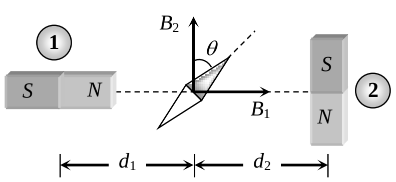
(c) $(2\cot\theta)^{1/3}$

(d) $(2\cot\theta)^{-1/3}$



(c)

In equilibrium $B_1 = B_2 \tan\theta$



$\Rightarrow \frac{\mu_0}{4\pi} \cdot \frac{2M}{d_1^3} = \frac{\mu_0}{4\pi} \cdot \frac{M}{d_2^3} \tan\theta$

$\Rightarrow \frac{d_1}{d_2} = (2\cot\theta)^{1/3}$

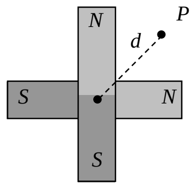
41. Two short magnets of equal dipole moments M are fastened perpendicularly at their centre (figure). The magnitude of the magnetic field at a distance d from the centre on the bisector of the right angle is

(a) $\frac{\mu_0}{4\pi}\frac{M}{d^3}$

(b) $\frac{\mu_0}{4\pi}\frac{M\sqrt{2}}{d^3}$

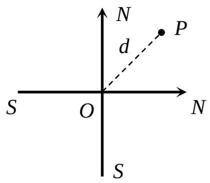
(c) $\frac{\mu_0}{4\pi}\frac{2\sqrt{2}M}{d^3}$

(d) $\frac{\mu_0}{4\pi}\frac{2M}{d^3}$



(c)

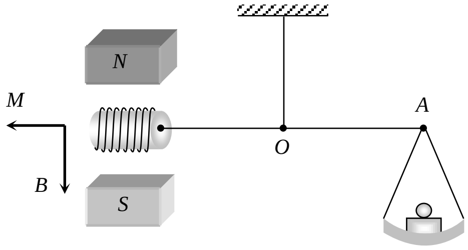
Resultant magnetic moment of the two magnets is $M_{net} = \sqrt{M^2 + M^2} = \sqrt{2}M$



Imagine a short magnet lying along OP with magnetic moment equal to $M\sqrt{2}$. Thus point P lies on the axial line of the magnet.

$\therefore$ Magnitude of magnetic field at P is given by $B = \frac{\mu_0}{4\pi}.\frac{2\sqrt{2}M}{d^3}$

42. A small coil C with N = 200 turns is mounted on one end of a balance beam and introduced between the poles of an electromagnet as shown in figure. The cross sectional area of coil is A= 1.0 cm^2, length of arm OA of the balance beam is $l = 30\ cm$. When there is no current in the coil the balance is in equilibrium. On passing a current I = 22 mA through the coil the equilibrium is restored by putting the additional counter weight of mass $\Delta m = 60\ mg$ on the balance pan. Find the magnetic induction at the spot where coil is located.



(a) 0.4 T (b) 0.3 T

(c) 0.2 T (d) 0.1 T

(a)

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

Torque acting on a magnetic dipole $\tau = MB\sin\theta = (NiA)B\sin 90^o = NiAB$.

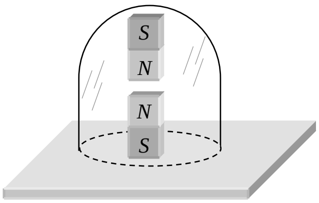
Again $\tau = Force \times Lever\ arm = \Delta mg \times l$

$\Rightarrow NiAB = \Delta mgl$

$\Rightarrow B = \frac{\Delta mgl}{NiA} = \frac{60 \times 10^{-3} \times 9.8 \times 30 \times 10^{-2}}{200 \times 22 \times 10^{-3} \times 1 \times 10^{-4}}$ = 0.4 T

43. Two identical bar magnets with a length 10 cm and weight 50 gm-weight are arranged freely with their like poles facing in a inverted vertical glass tube. The upper magnet hangs in the air above the lower one so that the distance between the nearest pole of the magnet is 3mm. Pole strength of the poles of each magnet will be (g = 9.8 m/s^2)

(a) 6.64 amp × m
(b) 2 amp × m
(c) 10.25 amp × m
(d) None of these



(a)

The weight of upper magnet should be balanced by the repulsion between the two magnet

$$\therefore \frac{\mu}{4\pi}.\frac{m^2}{r^2} = 50\text{gm} - \text{wt}$$

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

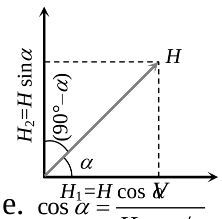
$$\Rightarrow m = 6.64\text{Am}$$

44. If ϕ_1 and ϕ_2 be the angles of dip observed in two vertical planes at right angles to each other and ϕ be the true angle of dip, then

(a) $\cos^2\phi = \cos^2\phi_1 + \cos^2\phi_2$
(b) $\sec^2\phi = \sec^2\phi_1 + \sec^2\phi_2$
(c) $\tan^2\phi = \tan^2\phi_1 + \tan^2\phi_2$
(d) $\cot^2\phi = \cot^2\phi_1 + \cot^2\phi_2$

(d)

Let α be the angle which one of the planes make with the magnetic meridian the other plane makes an angle $(90^o - \alpha)$ with it. The components of H in these planes will be $H\cos\alpha$ and $H\sin\alpha$ respectively. If ϕ_1 and ϕ_2 are the apparent dips in these two planes, then



$\tan\phi_1 = \frac{V}{H\cos\alpha}$ i.e. $\cos\alpha = \frac{V}{H\tan\phi_1}$ ..... (i)

$\tan\phi_2 = \frac{V}{H\sin\alpha}$ i.e. $\sin\alpha = \frac{V}{H\tan\phi_2}$ ..... (ii)

Squaring and adding (i) and (ii), we get

$$\cos^2\alpha + \sin^2\alpha = \left(\frac{V}{H}\right)^2\left(\frac{1}{\tan^2\phi_1} + \frac{1}{\tan^2\phi_2}\right)$$

i.e. $1 = \frac{V^2}{H^2}\left(\cot^2\phi_1 + \cot^2\phi_2\right)$

or $\frac{H^2}{V^2} = \cot^2\phi_1 + \cot^2\phi_2$ i.e. $\cot^2\phi = \cot^2\phi_1 + \cot^2\phi_2$

This is the required result.

45. Each atom of an iron bar $(5\,cm \times 1\,cm \times 1\,cm)$ has a magnetic moment $1.8\times 10^{-23}\ Am^2$. Knowing that the density of iron is $7.78\times 10^3\ kg^{-3}m$, atomic weight is 56 and Avogadro's number is 6.02×10^{23} the magnetic moment of bar in the state of magnetic saturation will be

(a) $4.75\ Am^2$ (b) $5.74\ Am^2$
(c) $7.54\ Am^2$ (d) $75.4\ Am^2$

(c)

The number of atoms per unit volume in a specimen, $n = \frac{\rho N_A}{A}$

For iron, $\rho = 7.8\times10^{-3}\, kgm^{-3}$,

$N_A = 6.02\times10^{26}\ /kgmol$, A=56

$\Rightarrow n = \dfrac{7.8\times10^{3}\times6.02\times10^{26}}{56} = 8.38\times10^{28}\, m^{-3}$

Total number of atoms in the bar is $N_0 = nV = 8.38\times10^{28}\times(5\times10^{-2}\times1\times10^{-2}\times1\times10^{-2})$

$N_0 = 4.19\times10^{23}$

The saturated magnetic moment of bar $= 4.19\times10^{23}\times1.8\times10^{-23} = 7.54\ Am^2$

46. An iron rod of volume $10^{-4}m^3$ and relative permeability 1000 is placed inside a long solenoid wound with 5 turns/cm. If a current of 0.5 A is passed through the solenoid, then the magnetic moment of the rod is

(a) $10\ Am^2$ (b) $15\ Am^2$

(c) $20\ Am^2$ (d) $25\ Am^2$

(d)

We have, $B = \mu_0 H + \mu_0 I$

or $I = \dfrac{B-\mu_0 H}{\mu_0}$ or $I = \dfrac{\mu H - \mu_0 H}{\mu_0} = \left(\dfrac{\mu}{\mu_0} - 1\right)H$

$I = (\mu_r - 1)H$

For a solenoid of n-turns per unit length and current i is H = ni

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

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

$\therefore$ Magnetic moment M=IV

$M = 2.5\times10^{5}\times10^{-4}$ = 25 Am^2

47. A bar magnet has coercivity $4\times10^{3}\ Am^{-1}$. It is desired to demagnetise it by inserting it inside a solenoid 12 cm long and having 60 turns. The current that should be sent through the solenoid is

(a) 2 A (b) 4 A

(c) 6 A (d) 8 A

(d)

The bar magnet coercivity $4\times10^{3}\ Am^{-1}$ 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 $metre^{-1}$

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

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

48. A magnet is suspended in the magnetic meridian with an untwisted wire. The upper end of wire is rotated through 180^o to deflect the magnet by 30^o from magnetic meridian. When this magnet is replaced by another magnet, the upper end of wire is rotated through 270^o to deflect the magnet 30^o from magnetic meridian. The ratio of magnetic moments of magnets is

(a) 1 : 5 (b) 1 : 8

(c) 5 : 8 (d) 8 : 5

(c)

Let M_1 and M_2 be the magnetic moments of magnets and H the horizontal component of earth's field.

We have $\tau = MH\sin\theta$. If ϕ is the twist of wire, then $\tau = C\phi$, C being restoring couple per unit twist of wire $\Rightarrow C\phi = MH\sin\theta$

Here $\phi_1 = (180^o - 30^o) = 150^o = 150\times\dfrac{\pi}{180}$ rad

$\phi_2 = (270^o - 30^o) = 240^o = 240\times\dfrac{\pi}{180}$ rad

So, $C\phi_1 = M_1 H\sin\theta$ (For deflection $\theta = 30^o$ of I magnet)

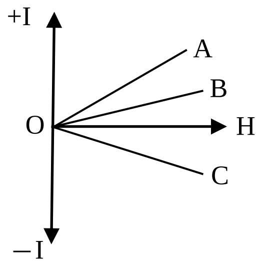
$C\phi_2 = M_2 H\sin\theta$ (For deflection $\theta = 30^o$ of II magnet)

Dividing $\dfrac{\phi_1}{\phi_2} = \dfrac{M_1}{M_2}$

$$\Rightarrow \frac{M_1}{M_2} = \frac{\phi_1}{\phi_2} = \frac{150 \times \left(\frac{\pi}{180}\right)}{240 \times \left(\frac{\pi}{180}\right)} = \frac{15}{24} = \frac{5}{8}$$

$\Rightarrow M_1 : M_2 = 5 : 8$

49. The given figure shows the variation of intensity of magnetization (I) versus the applied magnetic field intensity (H) for 3 magnetic materials A, B and C. Name the diamagnetic (D), ferromagnetic (F) and paramagnetic (P) material amongst A, B and C.



a) [A – F, B – D, C – P]
b) [A – F, B – P, C – D]
c) [A – P, B – D, C – F]
d) [A – D, B – F, C – P]

(b)

The slope of the graph of I versus H gives the susceptibility $\left(\chi = \frac{I}{H}\right)$.

∴ For C, χ is small but –ve, hence it is diamagnetic.

For B, χ is small but +ve, it may be paramagnetic.

The slope of A is +ve and its value is more than that of B.

∴ $\chi_B > \chi_A$ and it is +ve.

A will be ferromagnetic.

Thus correct option is [A – F, B – P, C – D]

50. Two magnets A and B having the same mass and length are suspended and made to oscillate freely with time periods T_A and T_B. If the moment of inertia of A is one fourth that of B, the ratio of T_B to T_A is

a) 2 : 1 b) 1 : 4 c) 4 : 1 d) 1 : 2

(a)

The time period of oscillation of a magnet in a magnetic field B is $T = 2\pi\sqrt{\frac{I}{MB}}$

where I and M are the moment of inertia and the magnetic moment of the magnet respectively.

As M and B are the same for both magnets A and B,

∴ $\frac{T_A}{T_B} = \sqrt{\frac{I_A}{I_B}}$; But $I_A = \frac{1}{4} I_B$ (given)

∴ $\frac{T_A}{T_B} = \sqrt{\frac{1}{4}} = \frac{1}{2}$ or $\frac{T_B}{T_A} = \frac{2}{1}$ or $T_B : T_A = 2 : 1$