Chapter 15. Magnetism and Matter

1. If θ_1 and θ_2 be the apparent angles of dip observed in two vertical planes at right angles to each other, then the true angle of dip θ is given by
(a) $\tan^2\theta = \tan^2\theta_1 + \tan^2\theta_2$
(b) $\cot^2\theta = \cot^2\theta_1 - \cot^2\theta_2$
(c) $\tan^2\theta = \tan^2\theta_1 - \tan^2\theta_2$
(d) $\cot^2\theta = \cot^2\theta_1 + \cot^2\theta_2$ *(NEET 2017)*

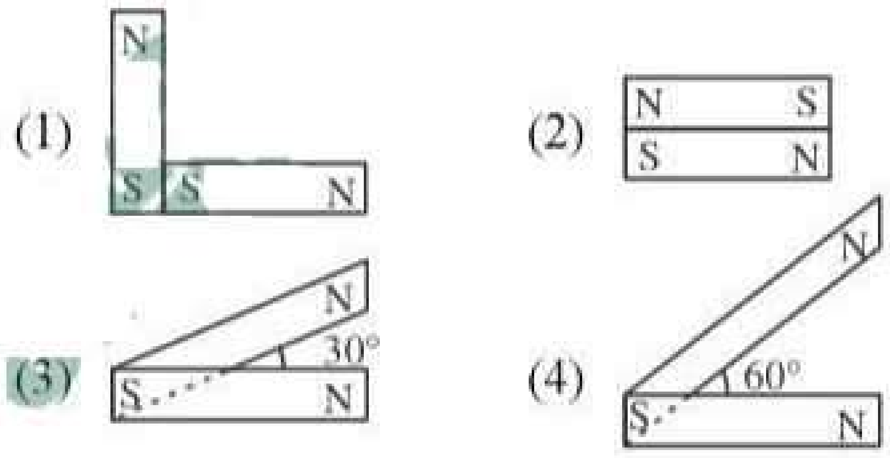
2. A 250-turn rectangular coil of length 2.1 cm and width 1.25 cm carries a current of 85 μA and subjected to a magnetic field of strength 0.85 T. Work done for rotating the coil by 180° against the torque is
(a) 4.55 μJ (b) 2.3 μJ
(c) 1.15 μJ (d) 9.1 μJ
(NEET 2017)

3. A bar magnet is hung by a thin cotton thread in a uniform horizontal magnetic field and is in equilibrium state. The energy required to rotate it by 60° is W. Now the torque required to keep the magnet in this new position is
(a) $\frac{W}{\sqrt{3}}$ (b) $\sqrt{3}W$ (c) $\frac{\sqrt{3}W}{2}$ (d) $\frac{2W}{\sqrt{3}}$
(NEET-II 2016)

4. The magnetic susceptibility is negative for
(a) ferromagnetic material only
(b) paramagnetic and ferromagnetic materials
(c) diamagnetic material only
(d) paramagnetic material only
(NEET-I 2016)

5. A rectangular coil of length 0.12 m and width 0.1 m having 50 turns of wire is suspended vertically in a uniform magnetic field of strength 0.2 Weber/m^2. The coil carries a current of 2 A. If the plane of the coil is inclined at an angle of 30° with the direction of the field, the torque required to keep the coil in stable equilibrium will be
(a) 0.24 Nm (b) 0.12 Nm
(c) 0.15 Nm (d) 0.20 Nm *(2015)*

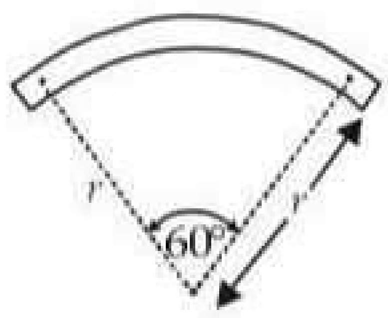
6. Following figures show the arrangement of bar magnets in different configurations. Each magnet has magnetic dipole moment $\vec{m}$. Which configuration has highest net magnetic dipole moment?



(a) (1) (b) (2)
(c) (3) (d) (4) *(2014)*

7. A current loop in a magnetic field
(a) can be in equilibrium in two orientations, both the equilibrium states are unstable.
(b) can be in equilibrium in two orientations, one stable while the other is unstable.
(c) experiences a torque whether the field is uniform or non uniform in all orientations.
(d) can be in equilibrium in one orientation.
(NEET 2013)

8. A bar magnet of length 'l' and magnetic dipole moment 'M' is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be



(a) $\frac{2}{\pi}M$
(b) $\frac{M}{2}$
(c) M
(d) $\frac{3}{\pi}M$ *(NEET 2013)*

9. A bar magnet of magnetic moment M is placed at right angles to a magnetic induction B. If a force F is experienced by each pole of the magnet, the length of the magnet will be

(a) MB/F (b) BF/M
(c) MF/B (d) F/MB
(Karnataka NEET 2013)

10. A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It
(a) will become rigid showing no movement
(b) will stay in any position
(c) will stay in north-south direction only
(d) will stay in east-west direction only *(2012)*

11. A magnetic needle suspended parallel to a magnetic field requires $\sqrt{3}$ J of work to turn it through 60°. The torque needed to maintain the needle in this position will be
(a) $2\sqrt{3}$ J (b) 3 J (c) $\sqrt{3}$ J (d) $\frac{3}{2}$ J
(Mains 2012)

12. There are four light-weight-rod samples A, B, C, D separately suspended by threads. A bar magnet is slowly brought near each sample and the following observations are noted
(i) A is feebly repelled
(ii) B is feebly attracted
(iii) C is strongly attracted
(iv) D remains unaffected
Which one of the following is true?
(a) B is of a paramagnetic material
(b) C is of a diamagnetic material
(c) D is of a ferromagnetic material
(d) A is of a non-magnetic material *(2011)*

13. A short bar magnet of magnetic moment 0.4 J T^{-1} is placed in a uniform magnetic field of 0.16 T. The magnet is in stable equilibrium when the potential energy is
(a) 0.064 J (b) – 0.064 J
(c) zero (d) – 0.082 J
(Mains 2011)

14. Electromagnets are made of soft iron because soft iron has
(a) low retentivity and high coercive force
(b) high retentivity and high coercive force
(c) low retentivity and low coercive force
(d) high retentivity and low coercive force *(2010)*

15. A vibration magnetometer placed in magnetic meridian has a small bar magnet. The magnet executes oscillations with a time period of 2 sec in earth's horizontal magnetic field of 24 microtesla. When a horizontal field of 18 microtesla is produced opposite to the earth's field by placing a current carrying wire, the new time period of magnet will be
(a) 1 s (b) 2 s
(c) 3 s (d) 4 s *(2010)*

16. The magnetic moment of a diamagnetic atom is
(a) much greater than one
(b) 1
(c) between zero and one
(d) equal to zero *(Mains 2010)*

17. Two identical bar magnets are fixed with their centres at a distance d apart. A stationary charge Q is placed at P in between the gap of the two magnets at a distance D from the centre O as shown in the figure

The force on the charge Q is
(a) zero
(b) directed along OP
(c) directed along PO
(d) directed perpendicular to the plane of paper
(Mains 2010)

18. If a diamagnetic substance is brought near the north or the south pole of a bar magnet, it is
(a) repelled by the north pole and attracted by the south pole
(b) attracted by the north pole and repelled by the south pole
(c) attracted by both the poles
(d) repelled by both the poles *(2009, 1999)*

19. A bar magnet having a magnetic moment of 2×10^4 J T^{-1} is free to rotate in a horizontal plane. A horizontal magnetic field $B = 6 \times 10^{-4}$ T exists in the space. The work done in taking the magnet slowly from a direction parallel to the field to a direction 60° from the field is
(a) 12 J (b) 6 J (c) 2 J (d) 0.6 J
(2009)

20. Curie temperature above which
(a) paramagnetic material becomes ferromagnetic material
(b) ferromagnetic material becomes diamagnetic material
(c) ferromagnetic material becomes paramagnetic material
(d) paramagnetic material becomes diamagnetic material *(2008, 2006)*

21. Nickel shows ferromagnetic property at room temperature. If the temperature is increased beyond Curie temperature, then it will show

(a) anti ferromagnetism
(b) no magnetic property
(c) diamagnetism
(d) paramagnetism. *(2007)*

22. A charged particle (charge q) is moving in a circle of radius R with uniform speed v. The associated magnetic moment μ is given by
(a) qvR^2 (b) $qvR^2/2$
(c) qvR (d) $qvR/2$. *(2007)*

23. If the magnetic dipole moment of an atom of diamagnetic material, paramagnetic material and ferromagnetic material are denoted by μ_d, μ_p and μ_f respectively, then
(a) $\mu_d = 0$ and $\mu_p \neq 0$
(b) $\mu_d \neq 0$ and $\mu_p = 0$
(c) $\mu_p = 0$ and $\mu_f \neq 0$
(d) $\mu_d \neq 0$ and $\mu_f \neq 0$. *(2005)*

24. A coil in the shape of an equilateral triangle of side l is suspended between the pole pieces of a permanent magnet such that $\vec{B}$ is in plane of the coil. If due to a current i in the triangle a torque τ acts on it, the side l of the triangle is
(a) $\frac{2}{\sqrt{3}}\left(\frac{\tau}{Bi}\right)$ (b) $2\left(\frac{\tau}{\sqrt{3}Bi}\right)^{1/2}$
(c) $\frac{2}{\sqrt{3}}\left(\frac{\tau}{Bi}\right)^{1/2}$ (d) $\frac{1}{\sqrt{3}}\frac{\tau}{Bi}$ *(2005)*

25. A diamagnetic material in a magnetic field moves
(a) from stronger to the weaker parts of the field
(b) from weaker to the stronger parts of the field
(c) perpendicular to the field
(d) in none of the above directions *(2003)*

26. According to Curie's law, the magnetic susceptibility of a substance at an absolute temperature T is proportional to
(a) $1/T$ (b) T
(c) $1/T^2$ (d) T^2 *(2003)*

27. A bar magnet is oscillating in the Earth's magnetic field with a period T. What happens to its period and motion if its mass is quadrupled ?
(a) motion remains simple harmonic with time period = $T/2$
(b) motion remains S.H.M with time period = $2T$
(c) motion remains S.H.M with time period = $4T$
(d) motion remains S.H.M and period remains nearly constant *(2003, 1994)*

28. Two bar magnets having same geometry with magnetic moments M and $2M$, are firstly placed in such a way that their similar poles are same side then its time period of oscillation is T_1. Now the polarity of one of the magnet is reversed then time period of oscillation is T_2, then
(a) $T_1 < T_2$ (b) $T_1 = T_2$
(c) $T_1 > T_2$ (d) $T_2 = \infty$. *(2002)*

29. Among which the magnetic susceptibility does not depend on the temperature?
(a) diamagnetism (b) paramagnetism
(c) ferromagnetism (d) ferrite. *(2001)*

30. Tangent galvanometer is used to measure
(a) potential difference (b) current
(c) resistance (d) charge. *(2001)*

31. A bar magnet of magnetic moment $\overline{M}$, is placed in a magnetic field of induction $\overline{B}$. The torque exerted on it is
(a) $\overline{M} \times \overline{B}$ (b) $-\overline{M}\cdot\overline{B}$
(c) $\overline{M}\cdot\overline{B}$ (d) $-\overline{B}\times\overline{M}$ *(1999)*

32. For protecting a sensitive equipment from the external magnetic field, it should be
(a) surrounded with fine copper sheet
(b) placed inside an iron can
(c) wrapped with insulation around it when passing current through it
(d) placed inside an aluminium can. *(1998)*

33. A bar magnet of magnetic moment M is cut into two parts of equal length. The magnetic moment of each part will be
(a) M (b) $2M$ (c) zero (d) $0.5\ M$. *(1997)*

34. The work done in turning a magnet of magnetic moment M by an angle of 90° from the meridian, is n times the corresponding work done to turn it through an angle of 60°. The value of n is given by
(a) 1/2 (b) 1/4 (c) 2 (d) 1. *(1995)*

Answer Key

1.	(d)	**2.**	(d)	**3.**	(b)	**4.**	(c)	**5.**	(d)	**6.**	(c)	**7.**	(b)	**8.**	(d)	**9.**	(a)	**10.**	(b)
11.	(b)	**12.**	(a)	**13.**	(b)	**14.**	(c)	**15.**	(d)	**16.**	(d)	**17.**	(a)	**18.**	(d)	**19.**	(b)	**20.**	(c)
21.	(d)	**22.**	(d)	**23.**	(a)	**24.**	(b)	**25.**	(a)	**26.**	(a)	**27.**	(b)	**28.**	(a)	**29.**	(a)	**30.**	(b)
31.	(a, d)	**32.**	(b)	**33.**	(d)	**34.**	(c)												

EXPLANATIONS

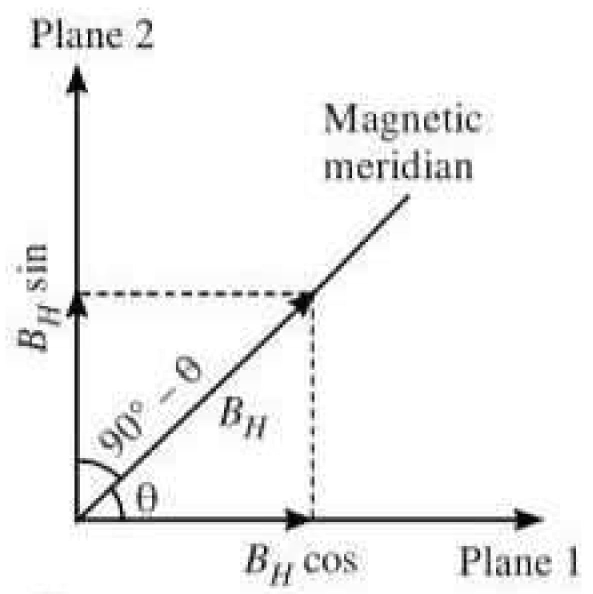
1. **(d)** : Let B_H and B_V be the horizonal and vertical components of earth's magnetic field $\vec{B}$. Since θ is the angle of dip

$$\therefore \quad \tan\theta = \frac{B_V}{B_H} \text{ or } \cot\theta = \frac{B_H}{B_V} \quad \text{...(i)}$$

Suppose planes 1 and 2 are two mutually perpendicular planes and respectively make angles θ and $90° - \theta$ with the magnetic meridian. The vertical components of earth's magnetic field remain same in the two planes but the effective horizontal components in the planes will be

$$B_1 = B_H \cos\theta \text{ and } B_2 = B_H \sin\theta$$

The angles of dip θ_1 and θ_2 in the two planes are given by



$$\tan\theta_1 = \frac{B_V}{B_1}$$

$$\tan\theta_1 = \frac{B_V}{B_H \cos\theta}$$

$$\text{or} \quad \cot\theta_1 = \frac{B_H \sin\theta}{B_V} \quad \text{...(ii)}$$

$$\text{Similarly, } \cot\theta_2 = \frac{B_H \sin\theta}{B_V} \quad \text{...(iii)}$$

From eqns. (ii) and (iii)

$$\cot^2\theta_1 + \cot^2\theta_2 = \frac{B_H^2}{B_V^2}(\cos^2\theta + \sin^2\theta) = \frac{B_H^2}{B_V^2}$$

$$\therefore \quad \cot^2\theta_1 + \cot^2\theta_2 = \cot^2\theta \quad \text{[from eqn. (i)]}$$

2. **(d)** : Work done in a coil

$$W = mB(\cos\theta_1 - \cos\theta_2)$$

When it is rotated by angle 180° then

$$W = 2mB = 2(NIA)B \quad \text{...(i)}$$

Given: $N = 250$, $I = 85\ \mu\text{A} = 85 \times 10^{-6}$ A

$A = 1.25 \times 2.1 \times 10^{-4}\ \text{m}^2 \approx 2.5 \times 10^{-4}\ \text{m}^2$

$B = 0.85$ T

Putting these values in eqn. (i), we get

$$W = 2 \times 250 \times 85 \times 10^{-6} \times 2.5 \times 10^{-4} \times 0.85$$
$$\approx 9.1 \times 10^{-6}\ \text{J} = 9.1\ \mu\text{J}$$

3. **(b)** : At equilibrium, potential energy of dipole

$$U_i = -MB_H$$

Final potential energy of dipole,

$$U_f = -MB_H \cos 60° = -\frac{MB_H}{2}$$

$$W = U_f - U_i = -\frac{MB_H}{2} - (-MB_H) = \frac{MB_H}{2} \quad \text{...(i)}$$

Required torque, $\tau = MB_H \sin 60°$

$$\tau = 2W \times \frac{\sqrt{3}}{2} \quad \text{[Using eqn. (i)]}$$
$$= \sqrt{3}W$$

4. **(c)** : Magnetic susceptibility is negative for diamagnetic material only.

5. **(d)** : The required torque is $\tau = NIAB\sin\theta$ where N is the number of turns in the coil, I is the current through the coil, B is the uniform magnetic field, A is the area of the coil and θ is the angle between the direction of the magnetic field and normal to the plane of the coil.

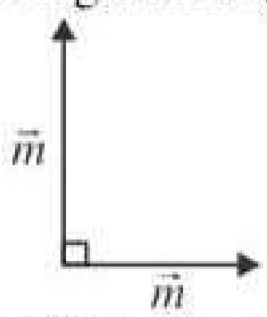
Here, $N = 50$, $I = 2$ A, $A = 0.12\ \text{m} \times 0.1\ \text{m} = 0.012\ \text{m}^2$

$B = 0.2\ \text{Wb/m}^2$ and $\theta = 90° - 30° = 60°$

$$\therefore \quad \tau = (50)(2\ \text{A})(0.012\ \text{m}^2)(0.2\ \text{Wb/m}^2)\sin 60°$$
$$= 0.20\ \text{N m}$$

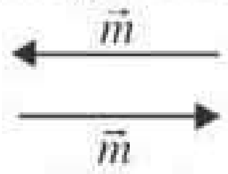
6. **(c)** : The direction of magnetic dipole moment is from south to north pole of the magnet.

In configuration (1),



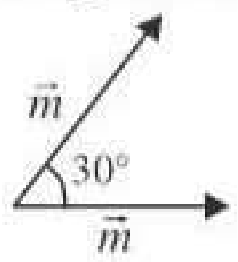
$$m_{\text{net}} = \sqrt{m^2 + m^2 + 2mm\cos 90°}$$
$$= \sqrt{m^2 + m^2} = 2\sqrt{m}$$

In configuration (2),



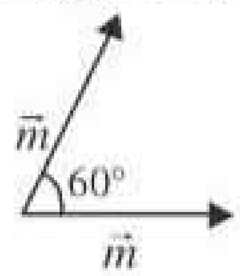
$$m_{\text{net}} = m - m = 0$$

In configuration (3),



$$m_{\text{net}} = \sqrt{m^2 + m^2 + 2mm\cos 30°}$$
$$= \sqrt{2m^2 + 2m^2\left(\frac{\sqrt{3}}{2}\right)} = m\sqrt{2 + \sqrt{3}}$$

In configuration (4),



$$m_{\text{net}} = \sqrt{m^2 + m^2 + 2mm\cos 60°}$$
$$= \sqrt{2m^2 + 2m^2\left(\frac{1}{2}\right)} = m\sqrt{3}$$

7. **(b) :** When a current loop is placed in a magnetic field it experiences a torque. It is given by

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

where, $\vec{M}$ is the magnetic moment of the loop and $\vec{B}$ is the magnetic field.

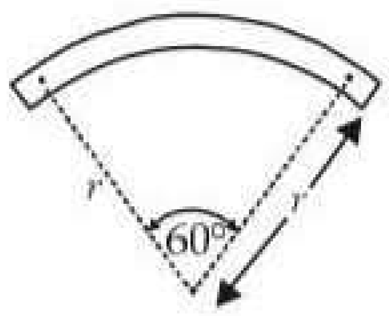
or $\quad \tau = MB \sin\theta$ where θ is angle between M and B

When $\vec{M}$ and $\vec{B}$ are parallel (*i.e.* $\theta = 0°$) the equilibrium is stable and when they are antiparallel (*i.e.* $\theta = \pi$) the equilibrium is unstable.

8. **(d) :** Let m be strength of each pole of bar magnet of length l. Then

$M = m \times l \qquad$ ...(i)

When the bar magnet is bent in the form of an arc as shown in figure



Then

$$l = \frac{\pi}{3} \times r = \frac{\pi r}{3}$$

or $\quad r = \dfrac{3l}{\pi}$

New magnetic dipole moment

$M' = m \times 2r \sin 30°$

$$= m \times 2 \times \frac{3l}{\pi} \times \frac{1}{2} = \frac{3ml}{\pi} = \frac{3M}{\pi} \qquad \text{(Using (i))}$$

9. **(a)**

10. **(b) :** A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It will stay in any position as the horizontal component of earth's magnetic field becomes zero at the geomagnetic pole.

11. **(b) :** Work done in changing the orientation of a magnetic needle of magnetic moment M in a magnetic field B from position θ_1 to θ_2 is given by

$W = MB(\cos\theta_1 - \cos\theta_2)$

Here, $\theta_1 = 0°$, $\theta_2 = 60°$

$$= MB\left(1 - \frac{1}{2}\right) = \frac{MB}{2} \qquad \text{...(i)}$$

The torque on the needle is

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

In magnitude,

$$\tau = MB\sin\theta = MB\sin 60° = \frac{\sqrt{3}}{2}MB \qquad \text{...(ii)}$$

Dividing (ii) by (i), we get

$$\frac{\tau}{W} = \sqrt{3}$$

$$\tau = \sqrt{3}W = \sqrt{3} \times \sqrt{3}\ \text{J} = 3\ \text{J}$$

12. **(a) :** Diamagnetic will be feebly repelled.
Paramagnetic will be feebly attracted.
Ferromagnetic will be strongly attracted.
Therefore, A is of diamagnetic material. B is of paramagnetic material. C is of ferromagnetic material. D is of non-magnetic material.

13. **(b) :** Here, Magnetic moment, $M = 0.4\ \text{J T}^{-1}$

Magnetic field, $B = 0.16$ T

When a bar magnet of magnetic moment is placed in a uniform magnetic field , its potential energy is

$$U = -\vec{M} \cdot \vec{B} = -MB\cos\theta$$

For stable equilibrium, $\theta = 0°$

$\therefore \quad U = -MB = -(0.4\ \text{J T}^{-1})(0.16\ \text{T}) = -0.064$ J

14. **(c) :** Electromagnets are made of soft iron because soft iron has low retentivity and low coercive force or low coercivity. Soft iron is a soft magnetic material.

15. **(d) :** The time period T of oscillation of a magnet is given by

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

where,

I = Moment of inertia of the magnet about the axis of rotation

M = Magnetic moment of the magnet

B = Uniform magnetic field

As I, B remains the same

$$\therefore \quad T \propto \frac{1}{\sqrt{B}} \quad \text{or} \quad \frac{T_2}{T_1} = \sqrt{\frac{B_1}{B_2}}$$

According to given problem,

$B_1 = 24\ \mu\text{T}$

$B_2 = 24\ \mu\text{T} - 18\ \mu\text{T} = 6\ \mu\text{T}$

$T_1 = 2$ s

$$\therefore \quad T_2 = (2\ \text{s})\sqrt{\frac{(24\ \mu\text{T})}{(6\ \mu\text{T})}} = 4\ \text{s}$$

16. **(d) :** The magnetic moment of a diamagnetic atom is equal to zero.

17. **(a) :** Magnetic field due to bar magnets exerts force on moving charges only. Since the charge is at rest, zero force acts on it.

18. **(d) :** A diamagnet is always repelled by a magnetic field. Therefore it is repelled by both the north pole as well as the south pole.

19. **(b) :** Here, $M = 2 \times 10^4\ \text{J T}^{-1}$

$B = 6 \times 10^{-4}$ T, $\theta_1 = 0°$, $\theta_2 = 60°$

$$W = MB(\cos\theta_1 - \cos\theta_2) = MB(1 - \cos 60°)$$

$$W = 2 \times 10^4 \times 6 \times 10^{-4}\left(1-\frac{1}{2}\right) = 6 \text{ J.}$$

20. (c) : At Curie temperature, there is a change from ferromagnetic to paramagnetic behaviour. Above this temperature, the paramagnetic substance obeys Curie Weiss law, even those resistances which are not ferromagnetic but only paramagnetic also obey Curie Weiss law above the Curie temperature only.

21. (d) : Above Curie temperature, ferromagnetic material become paramagnetic.

22. (d) : Magnetic moment $\mu = IA$

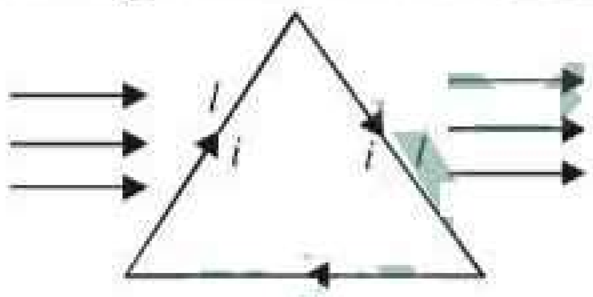
Since $T = \dfrac{2\pi R}{v}$ Also, $I = \dfrac{q}{T} = \dfrac{qv}{2\pi R}$

$$\therefore \quad \mu = \left(\frac{qv}{2\pi R}\right)(\pi R^2) = \frac{qvR}{2}.$$

23. (a) : Materials with no unpaired, or isolated electrons are considered diamagnetic. Diamagnetic substances do not have magnetic dipole moments and have negative susceptibilities. However, materials having unpaired electrons whose spins do not cancel each other are called paramagnetic. These substances have positive magnetic moments and susceptibilities.

$\mu_d = 0,\ \mu_p \neq 0.$

24. (b) : The current flowing clockwise in the equilateral triangle has a magnetic field in the direction $\hat{k}$



$$\tau = BiNA\sin\theta = B\,iA\sin 90°$$

$$\tau = Bi \times \frac{\sqrt{3}}{4}l^2 \quad \text{(area of equilateral triangle}$$

$$= \frac{\sqrt{3}}{4}l^2) \quad \text{(as it appears that } N = 1)$$

$$\left(\frac{4\tau}{\sqrt{3}Bi}\right) = l^2 \Rightarrow l = 2\left(\frac{\tau}{Bi\sqrt{3}}\right)^{1/2}.$$

25. (a)

26. (a) : According to Curie's law $\chi \propto \dfrac{1}{T}$

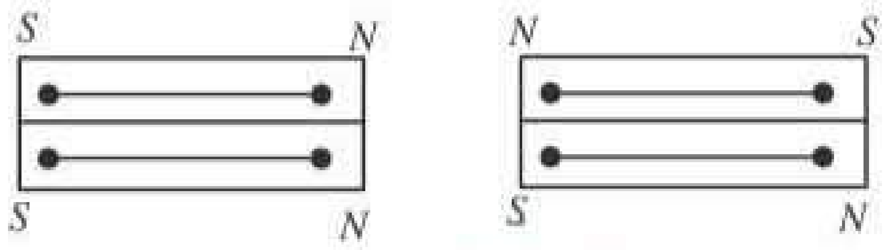
27. (b) : Initial mass of the magnet $(m_1) = m$ and final mass of the magnet $(m_2) = 4\ m$. The time period

$$(T) = 2\pi\sqrt{\frac{I}{MB}} = 2\pi\sqrt{\frac{mk^2}{MB}} \propto \sqrt{m}.$$

Therefore $\dfrac{T_1}{T_2} = \dfrac{\sqrt{m_1}}{\sqrt{m_2}} = \dfrac{\sqrt{m}}{\sqrt{4m}} = \dfrac{1}{2}$

or $T_2 = 2T_1 = 2T.$

28. (a) :



(i) $M = M_1 + M_2$ (ii) $M = M_1 - M_2$

$I = I_1 + I_2$ $I = I_1 + I_2$

(i) Similar poles are placed at the same side (sum position)

(ii) Opposite poles are placed at the same side (difference position)

I_1 and I_2 are the moments of inertia of the magnets and M_1 and M_2 are the moments of the magnets.

Here $M_1 = M$ and $M_2 = 2M$, $I_1 = I_2 = I$ (say), for same geometry.

$$\therefore \quad T_1 = 2\pi\sqrt{\frac{I_1 + I_2}{(M_1 + M_2)H}} = 2\pi\sqrt{\frac{2I}{(M + 2M)H}}$$

for same position.

$$\text{and } T_2 = 2\pi\sqrt{\frac{I_1 + I_2}{(M_2 - M_1)H}} = 2\pi\sqrt{\frac{2I}{(2M - M)H}}$$

for difference position.

$$\therefore \quad \frac{T_1}{T_2} = \sqrt{\frac{M}{3M}} = \frac{1}{\sqrt{3}} < 1, \quad \therefore \quad T_1 < T_2.$$

29. (a)

30. (b) : $I = K \tan\theta$

31. (a, d)

32. (b)

33. (d) : Magnetic moment = pole strength × length

$\therefore \quad M' = M/2 = 0.5\ M.$

34. (c) : Angle of magnet $(\theta) = 90°$ and $60°$. Work done in turning the magnet through $90°$.

$$(W_1) = MB(\cos 0° - \cos 90°) = MB(1 - 0) = MB.$$

Similarly

$$W_2 = MB(\cos 0° - \cos 60°) = MB\left(1-\frac{1}{2}\right)$$

$$= \frac{MB}{2}.$$

Therefore $W_1 = 2W_2$ or $n = 2.$