CHAPTER 5

Magnetism and Matter

5.2 The Bar Magnet

1. 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

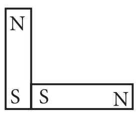
(a) 4.55 μJ (b) 2.3 μJ
(c) 1.15 μJ (d) 9.1 μJ *(NEET 2017)*

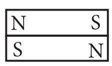
2. A bar magnet is hung by a thin cotton thread in a uniform horizontal magnetic field and is in equilibrium state. The energy required to rotate it by 60° is W. Now the torque required to keep the magnet in this new position is

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

(NEET-II 2016)

3. 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?

(1)


(2)


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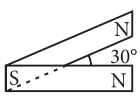

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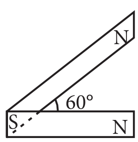
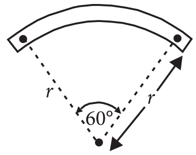


(a) (1) (b) (2)
(c) (3) (d) (4) *(2014)*

4. 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)

5. 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)

6. 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)

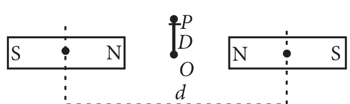
7. A short bar magnet of magnetic moment 0.4 J T^{-1} is placed in a uniform magnetic field of 0.16 T. The magnet is in stable equilibrium when the potential energy is

(a) 0.064 J (b) –0.064 J
(c) zero (d) –0.082 J *(Mains 2011)*

8. 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)*

9. 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)

10. A closely wound solenoid of 2000 turns and area of cross-section 1.5×10^{-4} m^2 carries a current of 2.0 A. It is suspended through its centre and perpendicular to its length, allowing it to turn in a horizontal plane in a uniform magnetic field 5×10^{-2} tesla making an angle of 30° with the axis of the solenoid. The torque on the solenoid will be
(a) 3×10^{-3} N m (b) 1.5×10^{-3} N m
(c) 1.5×10^{-2} N m (d) 3×10^{-2} N m
(Mains 2010)

11. 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)*

12. 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)*

13. Two bar magnets having same geometry with magnetic moments M and $2M$, are firstly placed in such a way that their similar poles are in 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)*

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

15. 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) $0.5M$ *(1997)*

16. 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)*

5.4 The Earth's Magnetism

17. At a point A on the earth's surface the angle of dip, $\delta = +25°$. At a point B on the earth's surface the angle of dip, $\delta = -25°$. We can interpret that
(a) A and B are both located in the southern hemisphere.
(b) A and B are both located in the northern hemisphere.
(c) A is located in the southern hemisphere and B is located in the northern hemisphere.
(d) A is located in the northern hemisphere and B is located in the southern hemisphere.
(NEET 2019)

18. 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)*

19. 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)*

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

5.5 Magnetisation and Magnetic Intensity

21. An iron rod of susceptibility 599 is subjected to a magnetising field of 1200 A m^{-1}. The permeability of the material of the rod is ($\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1})
(a) $2.4\pi \times 10^{-4}$ T m A^{-1} (b) 8.0×10^{-5} T m A^{-1}
(c) $2.4\pi \times 10^{-5}$ T m A^{-1} (d) $2.4\pi \times 10^{-7}$ T m A^{-1}
(NEET 2020)

5.6 Magnetic Properties of Materials

22. A thin diamagnetic rod is placed vertically between the poles of an electromagnet. When the current in the electromagnet is switched on, then the diamagnetic rod is pushed up, out of the horizontal magnetic field. Hence the rod gains gravitational potential energy. The work required to do this comes from
(a) the current source (b) the magnetic field
(c) the lattice structure of the material of the rod
(d) the induced electric field due to the changing magnetic field *(NEET 2018)*

23. 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)*

24. 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)*

25. 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)*

26. 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)*

27. 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)*

28. 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)*

29. 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)*

30. 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)*

31. 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)*

32. Among which the magnetic susceptibility does not depend on the temperature?
(a) Diamagnetism (b) Paramagnetism
(c) Ferromagnetism (d) Ferrite. *(2001)*

33. 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)*

5.7 Permanent Magnets and Electromagnets

34. 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)*

ANSWER KEY

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

Hints & Explanations

1. (d) : Work done in a coil
$W = mB(\cos\theta_1 - \cos\theta_2)$
When it is rotated by angle 180° then
$W = 2mB = 2(NIA)B$ ...(i)
Given: $N = 250$, $I = 85\ \mu A = 85 \times 10^{-6}$ A
$A = 1.25 \times 2.1 \times 10^{-4}\ m^2 \approx 2.6 \times 10^{-4}\ m^2$
$B = 0.85$ T
Putting these values in eqn. (i), we get
$W = 2 \times 250 \times 85 \times 10^{-6} \times 2.6 \times 10^{-4} \times 0.85$
$\approx 9.1 \times 10^{-6}\ J = 9.1\ \mu J$

2. (b) : At equilibrium, potential energy of dipole
$U_i = -MB_H$

Final potential energy of dipole,

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

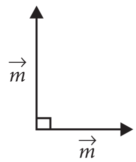
$$W = U_f - U_i = -\frac{MB_H}{2} - (-MB_H) = \frac{MB_H}{2} \qquad \text{...(i)}$$

$$\tau = MB_H \sin 60° = 2W \times \frac{\sqrt{3}}{2} \qquad \text{[Using eqn. (i)]}$$

$$= \sqrt{3}W$$

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

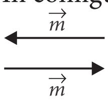
In configuration (1),



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

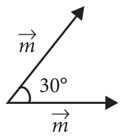
$$= \sqrt{m^2 + m^2} = m\sqrt{2}$$

In configuration (2),



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

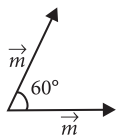
In configuration (3),



$$m_{net} = \sqrt{m^2 + m^2 + 2mm\cos 30°}$$

$$= \sqrt{2m^2 + 2m^2\left(\frac{\sqrt{3}}{2}\right)} = m\sqrt{2+\sqrt{3}}$$

In configuration (4),



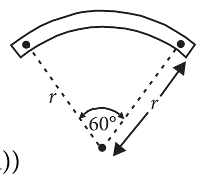
$$m_{net} = \sqrt{m^2 + m^2 + 2mm\cos 60°}$$

$$= \sqrt{2m^2 + 2m^2\left(\frac{1}{2}\right)} = m\sqrt{3}$$

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

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

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



$$l = \frac{\pi}{3} \times r = \frac{\pi r}{3} \quad \text{or} \quad r = \frac{3l}{\pi}$$

New magnetic dipole moment

$$M' = m \times 2r \sin 30°$$

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

5. (a)

6. (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

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

7. (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

8. (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 and M remain 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,

$B_1 = 24\ \mu$T, $B_2 = 24\ \mu\text{T} - 18\ \mu\text{T} = 6\ \mu$T, $T_1 = 2$ s

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

9. (a) : Magnetic field due to bar magnets exerts force on moving charges only. Since the charge is at rest, no force acts on it.

10. (c) : Magnetic moment of the loop

$M = NIA = 2000 \times 2 \times 1.5 \times 10^{-4} = 0.6$ J/T

Torque $\tau = MB\sin 30°$

$$= 0.6 \times 5 \times 10^{-2} \times \frac{1}{2} = 1.5 \times 10^{-2}\text{ Nm}$$

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

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

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

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

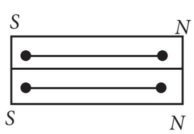
12. (b) : Initial mass of the magnet $(m_1) = m$ and final mass of the magnet $(m_2) = 4m$.

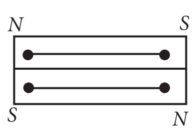
$$\text{The time period, } T = 2\pi\sqrt{\frac{I}{MB}} = 2\pi\sqrt{\frac{mk^2}{MB}} \propto \sqrt{m}$$

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

or $T_2 = 2T_1 = 2T$

13. (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.

For sum position

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

For difference position.

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

$$\therefore \quad \frac{T_1}{T_2} = \sqrt{\frac{M}{3M}} = \frac{1}{\sqrt{3}} < 1 \quad \text{or} \quad T_1 < T_2$$

14. (a, d) : Option (a) and (d) has equal magnitude.

15. (d) : Magnetic moment = pole strength × length
$\therefore \quad M' = M/2 = 0.5M$

16. (c) : Angle of magnet (θ) = 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 $n = 2$

17. (d) : At a point A, the angle of dip is positive and the earth's magnetic north pole is in northern hemisphere. So, point A is located in the northern hemisphere and B is located in the southern hemisphere.

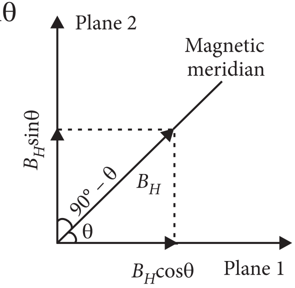
18. (d) : Let B_H and B_V be the horizontal and vertical components of earth's magnetic field $\vec{B}$. Since θ is the angle of dip

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

Suppose planes 1 and 2 are two mutually perpendicular planes and respectively make angles θ and 90°– θ 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

$B_1 = B_H \cos\theta$ and $B_2 = B_H \sin\theta$

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



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

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

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

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

From eqns. (ii) and (iii)

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

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

19. (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.

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

21. (a) : Given, $X_m = 599$
Relative permeability of the material, $\mu_r = 1 + X_m$
or $\mu_r = 1 + 599 = 600$
$\therefore \quad \mu = \mu_r\mu_0 = 600 \times (4\pi \times 10^{-7}) = 24\pi \times 10^{-5}$ T m A^{-1}

22. (a) : Energy of current source will be converted into gravitational potential energy of the rod.

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

24. (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.

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

26. (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.

27. (c) : Above Curie temperature, there is a change from ferromagnetic to paramagnetic behaviour.

28. (d)

29. (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.
$\mu_d = 0, \mu_p \neq 0.$

30. (a)

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

32. (a) **33. (b)**

34. (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.