CHAPTER 5

# MAGNETISM AND MATTER

CLASS 12TH

## NCERT EXERCISE AND SOLUTIONS - PHYSICS



**5.1 A short bar magnet placed with its axis at 30° with a uniform external magnetic field of 0.25 T experiences a torque of magnitude equal to $4.5 \times 10^{-2}$ J. What is the magnitude of magnetic moment of the magnet?**

**SOLUTION:**

Given – Angle (θ) =30°, Magnetic field (B) = 0.25 T, Torque (τ) = $4.5 \times 10^{-2}$ J.

Need to find – Magnetic moment (M) of the magnet.

Magnetic moment (M) of the magnet is given by,

$$\tau = MB\,\text{Sin}\theta$$

$$M = \frac{\tau}{B\sin\theta}$$

$$M = \frac{4.5\times10^{-2}}{0.25\times\sin 30^{\circ}} = 0.36\text{J/T}$$

Therefore, the magnetic moment of the magnet is 0.36 J/T.

**5.2 A short bar magnet of magnetic moment m = 0.32 J/T is placed in a uniform magnetic field of 0.15 T. If the bar is free to rotate in the plane of the field, which orientation would correspond to its (a) stable, and (b) unstable equilibrium? What is the potential energy of the magnet in each case?**

**SOLUTION:**

Given – Magnetic moment (m) = 0.32 J/T, External magnetic field (B) = 0.15 T.

Need to find – Orientation of bar in stable and unstable equilibrium and potential energy in each case.

(a) In stable equilibrium: Angle (θ) = 0° i.e., bar magnet is oriented to 0° to the magnetic field. Potential energy of the system is given by,

$$U = -MB\,\text{Cos}\theta$$

$$U = -(0.32)(0.15) \times \text{Cos}0^{\circ} = -(0.32) \times (0.15)$$

$$U = -4.8 \times 10^{-2}\ \text{J}$$

(b) In unstable equilibrium: Angle (θ) = 180° i.e., bar magnet is oriented to 180° to the magnetic field. Potential energy of the system is given by,

$$U = -MB\,\text{Cos}\theta$$

$$U = -(0.32) \times (0.15) \times \cos 180° = +(0.32) \times (0.15)$$
$$U = +4.8 \times 10^{-2}\ J$$

Therefore, potential energy in stable equilibrium and unstable equilibrium is $-4.810^{-2}$ J and $4.8 \times 10^{-2}$ J respectively.

**5.3 A closely wound solenoid of 800 turns and area of cross section $2.5 \times 10^{-4}\ m^2$ carries a current of 3.0 A. Explain the sense in which the solenoid acts like a bar magnet. What is its associated magnetic moment?**

**SOLUTION:**

Given – Number of turns (n) = 800, Area of cross-section (A) = $2.5 \times 10^{-4}\ m^2$, Current (I) = 3 A,

Need to find – Magnetic moment associated with solenoid.

A current-carrying solenoid behaves like a bar magnet because it generates a magnetic field along its axis, i.e., along its length.

The magnetic moment associated with the solenoid is given by,

$$M = nIA$$
$$M = (800) \times (3) \times (2.5 \times 10^{-4})$$
$$M = 0.6\ J/T$$

Therefore, the magnetic moment associated with solenoid is 0.6 J/T.

**5.4 If the solenoid in Exercise 5.5 is free to turn about the vertical direction and a uniform horizontal magnetic field of 0.25 T is applied, what is the magnitude of torque on the solenoid when its axis makes an angle of 30° with the direction of applied field?**

**SOLUTION:**

Given – Horizontal magnetic field (B) = 0.25 T, Angle (θ) = 30°.

Need to find – Torque (τ) on the solenoid.

Torque on the solenoid is given by,

$$\tau = MB\sin\theta$$
$$\tau = (0.6)\times(0.25)\times\sin 30^{\circ}$$
$$\tau = (0.6)\times(0.25)\times\frac{1}{2} = 7.5\times10^{-2} J$$

Therefore, the torque on the solenoid is $7.5\times10^{-2} J$.

**5.5 A bar magnet of magnetic moment 1.5 J/T lies aligned with the direction of a uniform magnetic field of 0.22 T.**

**(a) What is the amount of work required by an external torque to turn the magnet so as to align its magnetic moment: (i) normal to the field direction, (ii) opposite to the field direction?**

**(b) What is the torque on the magnet in cases (i) and (ii)?**

**SOLUTION:**

Given – Magnetic moment (M) = 1.5 J/T, Magnetic field (B) = 0.22 T.

(a) Initial angle between the axis and the magnetic field: $\theta_1 = 0°$

Final angle between the axis and the magnetic field: $\theta_2 = 90°$

The work required to make the magnetic moment normal to the direction of magnetic field is given by,

$$W = MB(\cos\theta_1 - \cos\theta_2) = 1.5 \times 0.22(\cos 0^\circ - \cos 90^\circ)$$

$$W = 0.33\ (1 - 0) = 0.33\ J$$

Initial angle between the axis and the magnetic field: $\theta_1 = 0°$

Final angle between the axis and the magnetic field: $\theta_2 = 180°$

The work required to make the magnetic moment normal to the direction of magnetic field is given by,

$$W = MB(\cos\theta_1 - \cos\theta_2) = 1.5 \times 0.22(\cos 0^\circ - \cos 180^\circ)$$

$$W = 0.33[1 - (-1)] = 0.66\ J$$

Therefore, the work done in normal and opposite directions is 0.33 J and 0.66 J, respectively.

(b) For first case: $\theta = 90°$

Torque on the magnet is given by,

$$\tau = MB\sin\theta$$

$$\tau = 1.5 \times 0.22 \sin 90^\circ = 0.33J$$

For second case: $\theta = 180°$

Torque on the magnet is given by,

$$\tau = MB\sin\theta$$

$$\tau = 1.5 \times 0.22 \sin 180^\circ = 0$$

Therefore, the torque in normal and opposite directions is 0.33 J and 0 J, respectively.

5.6 **A closely wound solenoid of 2000 turns and area of cross-section $1.6 \times 10^{-4}$ m², carrying a current of 4.0 A, is suspended through its centre allowing it to turn in a horizontal plane.**

**(a) What is the magnetic moment associated with the solenoid?**

**(b) What is the force and torque on the solenoid if a uniform horizontal magnetic field of $7.5 \times 10^{-2}$ T is set up at an angle of 30° with the axis of the solenoid?**

**SOLUTION:**

Given – Number of turns (n) = 2000, Area of cross-section (A) = $1.6 \times 10^{-4}$ m², Current (I) = 4 A.

(a) The magnetic moment along the axis of the solenoid is given by,

$$M = nIA$$

$$M = (2000) \times (4) \times (1.6 \times 10^{-4})$$

$$M = 1.28\ A - m^2$$

(b) Magnetic field (b) = $7.5 \times 10^{-2}$ T, Angle ($\theta$) = 30°.

Torque on the solenoid is given by,

$$\tau = MB\ \sin\theta$$

$$\tau = (1.28)\times\left(7.5\times10^{-2}\right)\times\sin 30^{\circ} = (1.28)\times\left(7.5\times10^{-2}\right)\times\frac{1}{2}$$

$$\tau = 4.8\times10^{-2}\,\text{N}-\text{m}$$

Since the magnetic field is uniform that means the force on the solenoid is zero.

Therefore, the torque on the solenoid is $4.8\times10^{-2}\,\text{N}-\text{m}$ and the force is zero.

**5.7 A short bar magnet has a magnetic moment of 0.48 J/T. Give the direction and magnitude of the magnetic field produced by the magnet at a distance of 10 cm from the centre of the magnet on (a) the axis, (b) the equatorial lines (normal bisector) of the magnet.**

**SOLUTION:**

Given – Magnetic moment (M) = 0.48 J/T, Distance from the centre (r) = 10 cm = 0.1 m.

Need to find – Magnetic field due to magnet at axis and equatorial lines.

(a) The magnetic field at distance r, from the centre of the magnet on the axis is given by,

$$B = \frac{\mu_0}{4\pi}\frac{2M}{r^3} \qquad (\mu_0 = 4\pi\times10^{-7}\ Tm/A)$$

$$B = \frac{4\pi\times10^{-7}\times2\times0.48}{4\pi\times(0.1)^3}$$

$$B = 0.96\times10^{-4}\,\text{T} = 0.96\,\text{G}$$

The magnetic field is along the S – N direction.

(b) The magnetic field at distance r, from the centre of the magnet on the equatorial line is given by,

$$B = \frac{\mu_0}{4\pi}\frac{M}{r^3} \qquad (\mu_0 = 4\pi\times10^{-7}\ Tm/A)$$

$$B = \frac{4\pi\times10^{-7}\times0.48}{4\pi\times(0.1)^3}$$

$$B = 0.48\times10^{-4}\,\text{T} = 0.48\,\text{G}$$

The magnetic field is along the N – S direction.

Therefore, the magnetic field at axial and equatorial positions is 0.96 G and 0.48 G, respectively.

**5.8 A short bar magnet placed in a horizontal plane has its axis aligned along the magnetic north-south direction. Null points are found on the axis of the magnet at 14 cm from the centre of the magnet. The earth's magnetic field at the place is 0.36 G and the angle of dip is zero. What is the total magnetic field on the normal bisector of the magnet at the same distance as the null–point (i.e., 14 cm) from the centre of the magnet? (At null points, field due to a magnet is equal and opposite to the horizontal component of earth's magnetic field.)**

**SOLUTION:**

Given – Null point from the centre at distance (r) = 14 cm = 0.14 m, Earth's magnetic field (H) = 0.36 G, Angle of dip (θ) = 0.

Need to find – Magnetic field (B).

The magnetic field ($B_1$) at a distance r, on the axis of the magnet is given by,

$$B_1 = \frac{\mu_0}{4\pi}\frac{2M}{r^3} = H \qquad (\mu_0 = 4\pi \times 10^{-7}\, Tm/A)$$

The magnetic field at the same distance r, on the equatorial line of the magnet is given by,

$$B_2 = \frac{\mu_0 M}{4\pi r^3} = \frac{H}{2}$$

Total magnetic field (B) = $B_1 + B_2$

$$B = H + \frac{H}{2} = 0.36 + 0.18 = 0.54 \text{ G}$$

Therefore, the magnetic field in the direction of earth's magnetic field is 0.54 G.

**5.9 If the bar magnet in exercise 5.8 is turned around by 180°, where will the new null points be located?**

## SOLUTION:

Given – Bar magnet turned around by θ = 180°

Need to find – Location of new null point.

If the bar magnet is turned through 180°, then the neutral point will lie on the equatorial line.

The magnetic field ($B_1$) at a distance $r_1$ (= 14 cm = 0.14 m) on the axis of the magnet is given by,

$$B_1 = \frac{\mu_0}{4\pi}\frac{2M}{r_1^3} = H \text{ ......... (i)} \qquad (\mu_0 = 4\pi \times 10^{-7}\, Tm/A)$$

The magnetic field at distance $r_2$, on the equatorial line of the magnet is given by,

$$B_2 = \frac{\mu_0 M}{4\pi r_2^3} = H \text{ .......... (ii)}$$

From equation (i) and (ii) we get,

$$\frac{2}{(r_1)^3} = \frac{1}{(r_2)^3} \quad \left(\frac{r_2}{r_1}\right)^3 = \frac{1}{2}$$

$$r_2 = r_1 \times \left(\frac{1}{2}\right)^{\frac{1}{3}} = 14 \times \left(\frac{1}{2}\right)^{\frac{1}{3}}$$

$$r_2 = 11.1 \text{ cm}$$

Therefore, the new null points will be located 11.1 cm on the normal bisector.