NCERT Solutions for Class 12 Physics

Chapter 5 – Magnetism and Matter

1. A short bar magnet placed with its axis at 30° with a uniform external magnetic field of 0.25T experiences a torque of magnitude equal to $4.5\times10^{-2}\text{J}$. What is the magnitude of magnetic moment of the magnet?

Ans: Provided in the question,

Magnetic field strength $B = 0.25\text{T}$

Torque on the bar magnet, $T = 4.5\times10^{-2}\text{J}$

Angle between the given bar magnet and the external magnetic field, $\theta = 30^\circ$

Torque is related to magnetic moment (M) as:

$$T = MB\sin(\theta)$$

$$\Rightarrow M = \frac{4.5\times10^{-2}}{0.25\times\sin30^\circ} = 0.36\text{J}/\text{T}$$

Clearly, the magnetic moment of the magnet is $0.36\text{J}/\text{T}$.

2. A short bar magnet of magnetic moment $M = 0.32\text{J}/\text{T}$ is placed in a uniform magnetic field of 0.15T. If the bar is free to rotate in the plane of the field, which orientation and would correspond to its

a) Stable?

Ans: It is provided that moment of the bar magnet, $M = 0.32\text{J}/\text{T}$. External magnetic field, $B = 0.15\text{T}$

It is considered as being in stable equilibrium, when the bar magnet is aligned along the magnetic field. Therefore, the angle θ, between the bar magnet and the magnetic field is 0°.

Potential energy of the system $= -MB\cos(\theta)$

$\Rightarrow -MB\cos(\theta) = -0.32 \times 0.15 \times \cos(0) = -4.8 \times 10^{-2}\,J$
Hence the potential energy is $= -4.8 \times 10^{-2}\,J$

b) Unstable equilibrium? What is the potential energy of the magnet in each case?

Ans: It is provided that moment of the bar magnet, $M = 0.32\,J/T$

External magnetic field, $B = 0.15T$

When the bar magnet is aligned opposite to the magnetic field, it is considered as being in unstable equilibrium, $\theta = 180^{\circ}$

Potential energy of the system is hence $= -MB\cos(\theta)$

$\Rightarrow -MB\cos(\theta) = -0.32 \times 0.15 \times \cos(180^{\circ}) = 4.8 \times 10^{-2}\,J$
Hence the potential energy is $= 4.8 \times 10^{-2}\,J$.

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

Ans: It is provided that number of turns in the solenoid, $n = 800$.

Area of cross-section, $A = 2.5 \times 10^{-4}\,m^2$

Current in the solenoid, $I = 3.0A$

A current-carrying solenoid is analogous to a bar magnet because a magnetic field develops along its axis, i.e., along its length joining the north and south poles.

The magnetic moment due to the given current-carrying solenoid is calculated as: $M = nIA = 800 \times 3 \times 2.5 \times 10^{-4} = 0.6\,J/T$

Thus, the associated magnetic moment $= 0.6\,J/T$

4. If the solenoid in Exercise 5.5 is free to turn about the vertical direction and a uniform horizontal magnetic field of $0.25T$ 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?

Ans: Given is the magnetic field strength, $B = 0.25T$

Magnetic moment, $M = 0.6/T$

The angle, θ between the axis of the turns of the solenoid and the direction of the external applied field is 30°.

Hence, the torque acting on the solenoid is given as:

$$\tau = MB\sin(\theta)$$
$$\Rightarrow \tau = 0.6 \times 0.25\sin(30^{\circ})$$
$$\Rightarrow \tau = 7.5 \times 10^{-2}\, J$$

Hence the magnitude of torque is $= 7.5 \times 10^{-2}\, J$

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

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?

Ans: Provided that,

Magnetic moment, $M = 1.5J/T$

Magnetic field strength, $B = 0.22T$

(i) Initial angle between the magnetic field and the axis is, $\theta_1 = 0^{\circ}$

Final angle between the magnetic field and the axis is, $\theta_2 = 90^{\circ}$

The work that would be required to make the magnetic moment perpendicular to the direction of magnetic field would be:

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

$\Rightarrow W = -1.5 \times 0.22(\cos 90^\circ - \cos 0^\circ)$

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

$\Rightarrow W = 0.33J$

(ii) Initial angle between the magnetic field and the axis, $\theta_1 = 0^\circ$

Final angle between the magnetic field and the axis, $\theta_2 = 180^\circ$

The work that would be required to make the magnetic moment opposite (180 degrees) to the direction of magnetic field is given as:

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

$\Rightarrow W = -1.5 \times 0.22(\cos 180^\circ - \cos 0^\circ)$

$\Rightarrow W = -0.33(-1-1)$

$\Rightarrow W = 0.66J$

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

Ans: For the first (i) case, $\theta = \theta_1 = 90^\circ$

Hence the Torque, $\vec{\tau} = \vec{M} \times B$

And its magnitude is:

$\tau = MB\sin(\theta)$

$\Rightarrow \tau = 1.5 \times 0.22\sin(90^\circ)$

$\Rightarrow \tau = 0.33Nm$

Hence the torque involved is $= 0.33Nm$

For the second-(ii) case:

$\theta = \theta_1 = 180^\circ$

And its magnitude of the torque is:

$\tau = MB\sin(\theta)$

$\Rightarrow \tau = 1.5 \times 0.22 \sin(180^\circ)$

$\Rightarrow \tau = 0 \text{Nm}$

Hence the torque is zero.

6. A closely wound solenoid of 2000 turns and area of cross-section $1.6 \times 10^{-4} \text{m}^2$, carrying a current of 4.0A, is suspended through its center allowing it to turn in a horizontal plane.

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

Ans: Given is the number of turns on the solenoid, $n = 2000$

Area of cross-section of the solenoid, $A = 1.6 \times 10^{-4} \text{m}^2$

Current in the solenoid, $I = 4\text{A}$

The magnetic moment inside the solenoid at the axis is calculated as:

$M = nAI = 2000 \times 1.6 \times 10^{-4} \times 4 = 1.28 \text{Am}^2$

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

Ans: Provided that,

Magnetic field, $B = 7.5 \times 10^{-2}\text{T}$

Angle between the axis and the magnetic field of the solenoid, $\theta = 30^\circ$

Torque, $\tau = MB\sin(\theta)$

$\Rightarrow \tau = 1.28 \times 7.5 \times 10^{-2} \sin(30^\circ)$

$\Rightarrow \tau = 4.8 \times 10^{-2} \text{Nm}$

Given the magnetic field is uniform, and the force on the solenoid is zero. The torque on the solenoid is $4.8 \times 10^{-2} \text{Nm}$.

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 center of the magnet on

a) the axis,

Ans: Provided that the magnetic moment of the given bar magnet, M is $0.48 J/T$

Given distance, $d = 10 cm = 0.1 m$
The magnetic field at d-distance, from the centre of the magnet on the axis is given by the relation:

$$B = \frac{\mu_0}{4\pi}\frac{2M}{d^3}$$

here, μ_0 = Permeability of free space $= 4\pi \times 10^{-7} Tm/A$

Substituting these values, B becomes as follows:

$$\Rightarrow B = \frac{4\pi \times 10^{-7}}{4\pi}\frac{2 \times 0.48}{0.1^3}$$
$$\Rightarrow B = 0.96 \times 10^{-4} T = 0.96 G$$

The magnetic field is 0.96G along the South-North direction.

b) the equatorial lines (normal bisector) of the magnet.

Ans: The magnetic field at a point which is $d = 10 cm = 0.1 m$ away on the equatorial of the magnet is given as:

$$B = \frac{\mu_0}{4\pi}\frac{M}{d^3}$$
$$\Rightarrow B = \frac{4\pi \times 10^{-7}}{4\pi}\frac{0.48}{0.1^3}$$
$$\Rightarrow B = 0.48 \times 10^{-4} T = 0.48 G$$

The magnetic field is 0.48G along the North-South direction.