



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

Answer

(a) Magnetic moment, $M = 1.5 \text{ J T}^{-1}$

Magnetic field strength, $B = 0.22 \text{ T}$

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

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

The work required to make the magnetic moment normal to the direction of magnetic field is given as:

$$\begin{aligned} W &= -MB(\cos \theta_2 - \cos \theta_1) \\ &= -1.5 \times 0.22(\cos 90^\circ - \cos 0^\circ) \\ &= -0.33(0 - 1) \\ &= 0.33 \text{ J} \end{aligned}$$

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

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

The work required to make the magnetic moment opposite to the direction of magnetic field is given as:

$$\begin{aligned} W &= -MB(\cos \theta_2 - \cos \theta_1) \\ &= -1.5 \times 0.22(\cos 180^\circ - \cos 0^\circ) \\ &= -0.33(-1 - 1) \\ &= 0.66 \text{ J} \end{aligned}$$

(b) For case (i): $\theta = \theta_2 = 90^\circ$

∴ Torque, $\tau = MB \sin \theta$

$$\begin{aligned} &= 1.5 \times 0.22 \sin 90^\circ \\ &= 0.33 \text{ J} \end{aligned}$$

For case (ii): $\theta = \theta_2 = 180^\circ$

$$\therefore \text{Torque, } \tau = MB \sin \theta$$

$$= MB \sin 180^\circ = 0 \text{ J}$$

Question 5.8:

A closely wound solenoid of 2000 turns and area of cross-section $1.6 \times 10^{-4} \text{ m}^2$, carrying a current of 4.0 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 $7.5 \times 10^{-2} \text{ T}$ is set up at an angle of 30° with the axis of the solenoid?

Answer

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, $I = 4 \text{ A}$

(a) The magnetic moment along the axis of the solenoid is calculated as:

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

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

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

$$\text{Torque, } \tau = MB \sin \theta$$

$$\begin{aligned} &= 1.28 \times 7.5 \times 10^{-2} \sin 30^\circ \\ &= 4.8 \times 10^{-3} \text{ Nm} \end{aligned}$$

Since the magnetic field is uniform, the force on the solenoid is zero. The torque on the solenoid is $4.8 \times 10^{-3} \text{ Nm}$.

Question 5.9:

A circular coil of 16 turns and radius 10 cm carrying a current of 0.75 A rests with its plane normal to an external field of magnitude $5.0 \times 10^{-2} \text{ T}$. The coil is free to turn about an axis in its plane perpendicular to the field direction. When the coil is turned slightly and released, it oscillates about its stable equilibrium with a frequency of 2.0 s^{-1} . What is the moment of inertia of the coil about its axis of rotation?

Answer

Number of turns in the circular coil, $N = 16$

Radius of the coil, $r = 10 \text{ cm} = 0.1 \text{ m}$

Cross-section of the coil, $A = \pi r^2 = \pi \times (0.1)^2 \text{ m}^2$

Current in the coil, $I = 0.75 \text{ A}$

Magnetic field strength, $B = 5.0 \times 10^{-2} \text{ T}$

Frequency of oscillations of the coil, $\nu = 2.0 \text{ s}^{-1}$

$$\therefore \text{Magnetic moment, } M = NIA = N\pi r^2$$

$$\begin{aligned} &= 16 \times 0.75 \times \pi \times (0.1)^2 \\ &= 0.377 \text{ J T}^{-1} \end{aligned}$$

Frequency is given by the relation:

$$\nu = \frac{1}{2\pi} \sqrt{\frac{MB}{I}}$$

Where,

I = Moment of inertia of the coil

$$\therefore I = \frac{MB}{4\pi^2 \nu^2}$$

$$= \frac{0.377 \times 5 \times 10^{-2}}{4\pi^2 \times (2)^2}$$

$$= 1.19 \times 10^{-4} \text{ kg m}^2$$

Hence, the moment of inertia of the coil about its axis of rotation is $1.19 \times 10^{-4} \text{ kg m}^2$.

Question 5.10:

A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip pointing down at 22° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.35 G. Determine the magnitude of the earth's magnetic field at the place.

Answer

Horizontal component of earth's magnetic field, $B_H = 0.35 \text{ G}$

Angle made by the needle with the horizontal plane = Angle of dip = $\delta = 22^\circ$

Earth's magnetic field strength = B

We can relate B and B_H as:

$$B_H = B \cos \theta$$

$$\therefore B = \frac{B_H}{\cos \delta}$$

$$= \frac{0.35}{\cos 22^\circ} = 0.377 \text{ G}$$

Hence, the strength of earth's magnetic field at the given location is 0.377 G.

Question 5.11:

At a certain location in Africa, a compass points 12° west of the geographic north. The north tip of the magnetic needle of a dip circle placed in the plane of magnetic meridian points 60° above the horizontal. The horizontal component of the earth's field is measured to be 0.16 G. Specify the direction and magnitude of the earth's field at the location.

Answer

Angle of declination, $\theta = 12^\circ$

Angle of dip, $\delta = 60^\circ$

Horizontal component of earth's magnetic field, $B_H = 0.16 \text{ G}$

Earth's magnetic field at the given location = B

We can relate B and B_H as:

$$B_H = B \cos \delta$$

$$\therefore B = \frac{B_H}{\cos \delta}$$

$$= \frac{0.16}{\cos 60^\circ} = 0.32 \text{ G}$$

Earth's magnetic field lies in the vertical plane, 12° West of the geographic meridian, making an angle of 60° (upward) with the horizontal direction. Its magnitude is 0.32 G.

Question 5.12:

A short bar magnet has a magnetic moment of 0.48 J T^{-1} . 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.

Answer

Magnetic moment of the bar magnet, $M = 0.48 \text{ J T}^{-1}$

(a) Distance, $d = 10 \text{ cm} = 0.1 \text{ m}$

The magnetic field at distance d , from the centre of the magnet on the axis is given by the relation:

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

Where,

$$\mu_0 = \text{Permeability of free space} = 4\pi \times 10^{-7} \text{ Tm A}^{-1}$$

$$\therefore B = \frac{4\pi \times 10^{-7} \times 2 \times 0.48}{4\pi \times (0.1)^3}$$

$$= 0.96 \times 10^{-4} \text{ T} = 0.96 \text{ G}$$

The magnetic field is along the S – N direction.

(b) The magnetic field at a distance of 10 cm (i.e., $d = 0.1 \text{ m}$) on the equatorial line of the magnet is given as:

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

$$= \frac{4\pi \times 10^{-7} \times 0.48}{4\pi (0.1)^3}$$

$$= 0.48 \text{ G}$$

The magnetic field is along the N – S direction.

Question 5.13:

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.)

Answer

Earth's magnetic field at the given place, $H = 0.36 \text{ G}$

The magnetic field at a distance d , on the axis of the magnet is given as:

$$B_1 = \frac{\mu_0}{4\pi} \frac{2M}{d^3} = H \quad \dots (i)$$

Where,

μ_0 = Permeability of free space

M = Magnetic moment

The magnetic field at the same distance d , on the equatorial line of the magnet is given as:

$$B_2 = \frac{\mu_0 M}{4\pi d^3} = \frac{H}{2} \quad [\text{Using equation (i)}]$$

Total magnetic field, $B = B_1 + B_2$

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