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Ch - 5
Magnetism and Matter

NCERT Exercises

(Qn: 3, 4, 5, 7, 8, 9, 11, 13, 18).

(3) Magnetic field strength, $B = 0.25\ T$
Torque on the bar magnet, $T = 4.5 \times 10^{-2}\ J$
Angle between the bar magnet and the external magnetic field, $\theta = 30°$.
~~Torque~~ Torque is related to magnetic moment (M) as $T = MB \sin\theta$

$$\Rightarrow M = \frac{T}{B \sin\theta}$$

$$= \frac{4.5 \times 10^{-2}}{0.25 \times \sin 30°} = 0.36\ J\,T^{-1}$$

$\therefore$ Hence, the magnetic moment of the magnet is $0.36\ J\,T^{-1}$.

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(4) Moment of the bar magnet, $M = 0.32\ J\,T^{-1}$
External magnetic field, $B = 0.15\ T$

(a) The bar magnet is aligned along the magnetic field. This system is considered as being in a stable equilibrium.
So, the angle between the bar magnet and the magnetic field $= 0°$.
potential energy of the system $= -MB\cos\theta$

$$= -0.32 \times 0.15 \cos 0°$$

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

(b) The bar magnet is oriented $180°$ to the magnetic field. Hence, it is in unstable equilibrium.
$\theta = 180°$.

potential energy $= -MB\cos\theta$

$= -0.32 \times 0.15 \cos 180^\circ$

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

(5) Number of turns in the solenoid, $n = 800$

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

current in the solenoid, $I = 3.0$ A

A current carrying solenoid behaves as a bar magnet because a magnetic field develops along its axis, i.e., along its length.

The magnetic moment associated with the given current-carrying solenoid is calculated as:

$M = n I A$

$= 800 \times 3 \times 2.5 \times 10^{-4}$

$= 0.6$ J T^{-1}

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

Magnetic field strength, $B = 0.22$ 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:

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

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

$= -0.33 (0-1)$

$= 0.33$ J

(ii) $\theta_1 = 0^\circ$, $\theta_2 = 180^\circ$

work required to make the magnetic moment

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opposite to the direction of magnetic field:

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

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

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

$= 0.66\ J$

(b) For case (i),

$\theta = \theta_2 = 90^\circ$.

$\therefore$ Torque, $\tau = MB\sin\theta$

$= 1.5 \times 0.22 \sin 90^\circ$

$= 0.33\ J$

For case (ii),

$\theta = \theta_2 = 180^\circ$

$\therefore$ Torque, $\tau = MB\sin\theta$

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

$= 0\ J$

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(8) Number of turns on the solenoid, $n = 2000$

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

current in the solenoid, $I = 4A$.

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

$M = nAI$

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

$= 1.28\ Am^2$

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

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

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

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$= 1.28 \times 7.5 \times 10^{-2} \sin 30°$

$= 4.8 \times 10^{-2}$ Nm.

Since the magnetic field is uniform, the force on the solenoid is zero. The torque on the solenoid is 4.8×10^{-2} Nm.

(9) Number of turns in the circular coil, N = 16.
Radius of the coil, $r = 10$ cm $= 0.1$ m.
cross-section area of the coil, $A = \pi r^2$
$= \pi \times (0.1)^2 \ m^2$
current in the coil, $I = 0.75$ A
Magnetic field strength, $B = 5.0 \times 10^{-2}$ T
Frequency of oscillations of the coil, $\nu = 2.0 s^{-1}$
$\therefore$ Magnetic moment, $M = NIA = NI\pi r^2$
$= 16 \times 0.75 \times \pi \times (0.1)^2$
$= 0.377 \ J T^{-1}$
Frequency is given by the relation:

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

where, I = moment of inertia of the coil.

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

$$= \frac{0.377 \times 5 \times 10^{-2}}{4\pi^2 \times (2)^2} = 1.19 \times 10^{-4} \ kg \ m^2$$

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

(11) Angle of declination, $\theta = 12°$.
Angle of dip, $\delta = 60°$.
Horizontal component of earth's magnetic field,

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$B_H = 0.16\,G$

Earth's magnetic field at the given location $= B$

We can relate B and B_H as:

$B_H = B \cos \delta$

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

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

$\therefore$ Earth's magnetic field ~~lines~~ lies in the vertical plane, 12° west of the geographic meridian, making an angle of 60° (upward) with the horizontal direction. It's magnitude is $0.32\,G$

(13) Earth's magnetic field at the given place;

$H = 0.36\,G$

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

$B_1 = \frac{\mu_0}{4\pi} \frac{2M}{d^3} = H$ ——— (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:

$B_2 = \frac{\mu_0 M}{4\pi d^3} = \frac{H}{2}$ (using eq. (i))

Total magnetic field, $B = B_1 + B_2$

$= H + \frac{H}{2} = 0.36 + 0.18$

$= \boxed{0.54\,G}$

$\therefore$ The magnetic field is $0.54\,G$ in the direction of earth's magnetic field.

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Additional exercises

(18) Current in the wire, $I = 2.5\ A$
Angle of dip at the given location on earth, $\delta = 0°$

Earth's magnetic field, $H = 0.33\ G = 0.33 \times 10^{-4} T$
The horizontal component of earth's magnetic field is given as:

$$H_H = H \cos \delta$$
$$= 0.33 \times 10^{-4} \times \cos 0°$$
$$= 0.33 \times 10^{-4}\ T.$$

The magnetic field at the neutral point at a distance R from the cable is given by the relation:

$$H_H = \frac{\mu_0 I}{2\pi R}$$

where, μ_0 = permeability of free space
$= 4\pi \times 10^{-7}\ T\,m\,A^{-1}$

$$\Rightarrow R = \frac{\mu_0 I}{2\pi H_H}$$

$$= \frac{4\pi \times 10^{-7} \times 2.5}{2\pi \times 0.33 \times 10^{-4}} = 15.15 \times 10^{-3}\ m$$
$$= 1.51\ cm.$$

$\therefore$ Hence, a set of neutral points parallel to and above the cable are located at a normal distance of 1.51 cm.

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