Chapter - 5

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# Magnestium and Matter

5.3 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 is related to magnetic moment (M) as

$$\Rightarrow T = MB \sin \theta$$

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

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

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

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

a) The bar magnet is alligned along the magnetic field. This system is considered as being in stable equilibrium. Hence, the angle $\theta$, between the bar magnet and the magnetic field is $0°$.

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

$$= -0.32 \times 0.15 \cos 0°$$

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

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

$\theta = 180°$

Potential Energy $= -MB\cos\theta$

$= -0.32 \times 0.15 \cos 180°$

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

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 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:-

$M = nIA$

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

$= 0.6 J T^{-1}$

5.7 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, $\theta_1 = 0°$

~~the cross~~ Final angle between the axis and the

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magnetic field, $\theta_2 = 90°$

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

$$W = -MB(\cos\theta_2 - \cos\theta_1)$$
$$= -1.5 \times 0.22 (\cos 90° - \cos 0°)$$
$$= -0.33(0-1)$$
$$= 0.33 J$$

ii) 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 opposite to the direction of magnetic field is given as:-

$$W = -MB(\cos\theta_2 - \cos\theta_1)$$
$$= -1.5 \times 0.22 (\cos 180 - \cos 0°)$$
$$= -0.33(-1-1)$$
$$= 0.66 J$$

(b) For case (i) :- $\theta = \theta_2 = 90°$

$\therefore$ Torque, $\tau = MB \sin\theta$
$$= 1.5 \times 0.22 \times \sin 90°$$
$$= 0.33 J$$

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For case (ii) :- $\theta = \theta_2 = 180°$

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

$= MB\sin 180° = 0\,J$

5.8 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 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, $\theta = 30°$

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

$$= 1.28 \times 7.5 \times 10^{-2} \sin 30°$$
$$= 4.8 \times 10^{-2}\,Nm$$

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

5.9 Number of turns in the circular coil, $N = 16$
Radius of the coil, $r = 10\,cm = 0.1\,m$

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Cross-section 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, $v = 2.0 s^{-1}$

$\therefore$ Magnetic ~~field~~ moment, $M = NIA = NIr^2\pi$

$$= 16 \times 0.75 \times \pi \times (0.1)^2$$
$$= 0.377 JT^{-1}$$

Frequency is given by the relation:

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

where,
I = Moment of inertia of the coil

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

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

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

5.11 Angle of declination, $\theta = 12°$
Angle of dip, $\delta = 60°$
Horizontal component of earth's magnetic field, $B_H = 0.16 G$

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Earth's magnetic field at the given location = B

We can relate B and $B_H$ as:

$$B_H = B\cos\delta$$

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

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

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

5.13 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:-

$$B_1 = \frac{\mu_0}{4\pi}\frac{2M}{d^2} = H \qquad \text{—— (1)}$$

where,
$\mu_0$ = 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:

$$B_2 = \frac{\mu_0 M}{4\pi d^3} = H/2 \quad [\text{using Eq}^n \text{ (1)}]$$

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Total magnetic field, $B = B_1 + B_2$

$= H + H/2$

$= 0.36 + 0.18$

$= 0.54G$

Hence, the magnetic field is 0.54G in the dir^n of earth's magnetic field.

5.18. Current in the wire, $I = 2.5A$

Angle of dip at the given location on earth, $\delta = 0°$

Earth's magnetic field, $H = 0.33G = 0.33 \times 10^{-4}T$

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

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

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

$= 1.51cm$

Hence, a set of neutral point parallel to and above the cable are located at a ~~p~~ normal distance of 1.51 cm.