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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:-

$$T = MB\sin\theta$$

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

$$= \frac{4.5 \times 10^{-2}}{0.25 \times \sin 30°}$$

$$= 0.36\ J/T.$$

Hence, the magnetic moment of the magnet is $0.36\ J/T$.

5.4) Moment of the bar magnet, $M = 0.32\ J/T$.
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. Hence, the angle θ, between the bar magnet and the magnetic field is $0°$.

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

$$= -0.32 \times 0.15 \cos 0°$$

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

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

$\theta = 180^\circ$

Potential energy $= -MB\cos\theta$
$= -0.32 \times 0.15 \cos 180^\circ$
$= 4.8 \times 10^{-2}$ J.

5.5) No. of turns in the solenoid, $n = 800$
Area of cross-section, $A = 2.5 \times 10^{-4}\ m^2$
Current in the solenoid, $I = 3A$.

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.

5.7) a) Magnetic moment, $M = 1.5$ J/T.
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:-

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

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

$= -0.33(-1)$

$= 0.33\ J.$

ii) Initial angle, $\theta_1 = 0°$
Final angle, $\theta_2 = 180°$

Work required, $W = -MB(\cos\theta_2 - \cos\theta_1)$

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

$= -0.33(-1-1)$

$= 0.66\ J.$

b) For case - 1 :-

$\theta = \theta_2 = 90°$

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

$= 1.5 \times 0.22 \sin 90°$

$= 0.33\ J.$

For case - 2 :-

$\theta = \theta_2 = 180°$

$\therefore$ Torque, $\tau = mB\sin\theta$
$= mB\sin 180°$
$= 0\,J$.

5.8) No. 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:-

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

b) Magnetic field, $B = 7.5 \times 10^{-2}\ T$.
Angle b/w the magnetic field and the axis of the solenoid, $\theta = 30°$
Torque, $\tau = mB\sin\theta$
$= 1.28 \times 7.5 \times 10^{-2} \times \sin 30°$
$= 4.8 \times 10^{-2}\ Nm$.

Since, the magnetic field is uniform, the force on the solenoid is 0. The torque on the solenoid is 4.8×10^{-2} Nm.

5.9) No. of turns in the circular coil, $N = 16$
Radius of the coil, $r = 10cm$
$= 0.1\ m$.
Cross-section of the coil, $A = \pi r^2$
$= \pi \times (0.1)^2\ m^2$.
Current in the coil, $I = 0.75A$
Magnetic field strength, $B = 5 \times 10^{-2}\ T$
frequency of oscillations of the coil, $\nu = 2\,s^{-1}$

$\therefore$ Magnetic moment, $m = NIA$
$= nI\pi r^2$
$= 16 \times 0.75 \times \pi \times (0.1)^2$
$= 0.377\ J/T$.

~~Freq~~ 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, $B_H = 0.16\ G$
Earth's magnetic field at the given location = B

~~We ca~~ Now,
$B_H = B\cos\delta$

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

$$= \frac{0.16}{\cos 60°} = 0.32\ G.$$

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

5. B) 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 :-

$$B_1 = \frac{\mu_0}{4\pi}\frac{2M}{d^3} = H \quad \text{— (1)}$$

where,

μ_0 = Permittivity of free space
M = magnetic moment

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

$$B_2 = \frac{\mu_0}{4\pi}\frac{M}{d^3} = \frac{H}{2} \quad [\because \text{Using eq. (1)}]$$

Total magnetic field, $B = B_1 + B_2$

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

$$= 0.36 + 0.18$$

$$= 0.54\ G.$$

Hence, the magnetic field is 0.54 G in the direction of Earth's magnetic field.

5.18) 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:-

$$H_H = H \cos \delta$$

$$= 0.33 \times 10^{-4} \times \cos 0°$$

$$= 0.33 \times 10^{-4} \text{ T}.$$

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 = Permittivity of free space $= 4\pi \times 10^{-7}$ TmA^{-1}

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

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

$$= 15.15 \times 10^{-3} \text{ m}$$

$$= 1.51 \text{ cm}.$$

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