Magnetism And Matter

NCERT EXERCISE

3. 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 4.5×10^{-2} J. What is the magnitude of magnetic moment of the magnet?

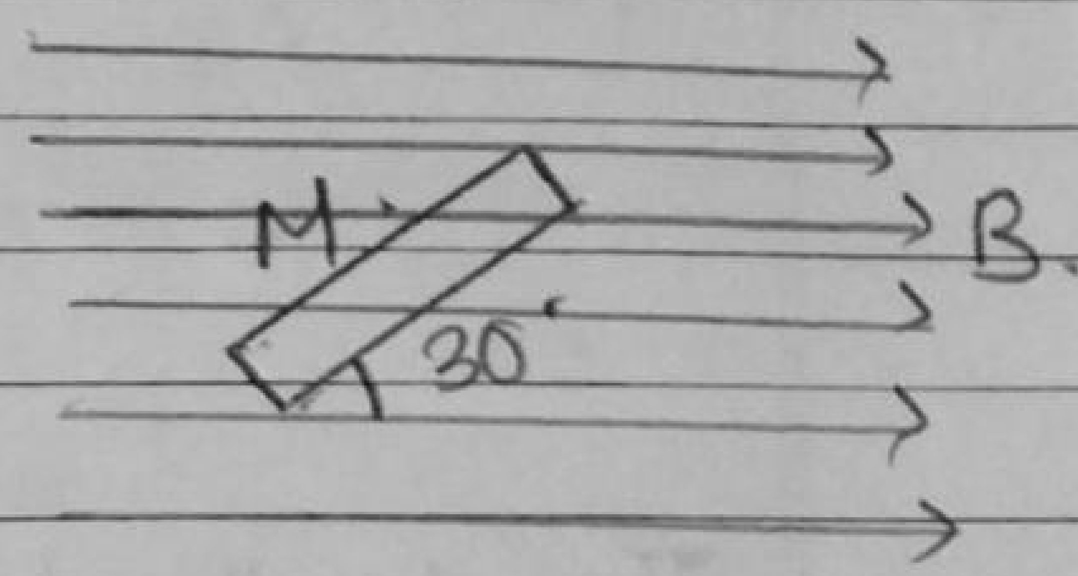
Ans Given uniform magnetic field.

$$B = 0.25T.$$

The magnitude of torque $\tau = 4.5 \times 10^{-2}$ J.

Angle between magnetic moment and magnetic field $\theta = 30°$

Torque experienced on a magnet placed in external magnetic field.



$$\tau = M \times B.$$
$$\tau = MB \sin\theta.$$

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

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

$$= \frac{4.5 \times 10^{-2} \times 2}{0.25 \times 1}$$

$$= 0.36 J/T.$$

Thus, the magnitude of magnetic moment of the magnet is 0.36J/T.

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4. A short bar magnet of magnetic moment m = 0.32 J/T is placed in a uniform magnetic field of 0.15 T. If the bar is free to rotate in the plane of the field, which orientation would correspond to its (a) stable and (b) unstable equilibrium? What is the potential energy of the magnet in each case?

Ans Given magnetic moment of magnet m = 0.32 J/T.

The magnitude of magnetic field B = 0.15 T.

(a) For stable equilibrium, the angle between magnetic moment (m) and magnetic field (B) is $\theta = 0°$

$\because$ The potential energy of the magnet.

$$U = -m \cdot B \qquad (\because A \cdot B = AB\cos\theta)$$
$$= -mB\cos\theta$$
$$= -0.32 \times 0.15 \cos 0°$$
$$= -4.8 \times 10^{-2} J.$$

Thus, for the stable equilibrium the potential energy is -4.8×10^{-2} J.

(b) For the unstable equilibrium the ~~potential energy~~ angle between the magnetic moment and magnetic field is 180°. ($\because$ In this position it will be in a direction perpendicular to magnetic field thus maximum torque will act on it.)

$$\theta = 180°.$$

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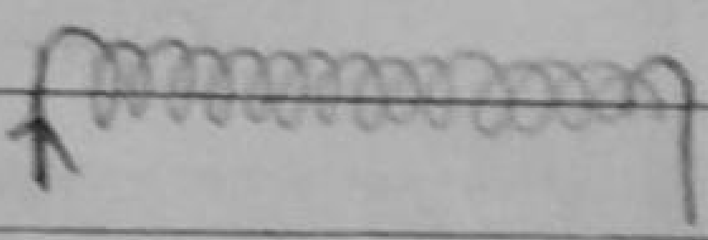
Potential energy of the magnet.

$$U = -mB\cos 180^\circ$$
$$= -0.32 \times 0.15\,(-1)$$
$$= 4.8 \times 10^{-2}\,J.$$

Thus, for the unstable equilibrium the potential energy is $4.8 \times 10^{-2}\,J$.

5. 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 act like a bar magnet. What is its associated magnetic moment?

Ans Given, number of turns $n = 800$.



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

Current through Solenoid $I = 3A$.

As a current passes through a solenoid, a magnetic field is produced. By the use of maxwell's right hand grip rule. the magnetic field is along the axis of the Solenoid. Using the formula of magnetic moment.

$$M = nIA.$$
$$M = nIA.$$
$$= 800 \times 3 \times 2.5 \times 10^{-4}.$$
$$= 0.6\,J/T$$ along the axis of the Solenoid.

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8. A closely wound solenoid of 2000 turns ~~each~~ and area of cross section $1.6 \times 10^{-4} m^2$, 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 are the force and torque on the Solenoid, If a uniform horizontal magnetic field of 7.5×10^{-2} T is set up at an angle of 30° with the axis of Solenoid?

Ans Given number of turns $n = 2000$

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

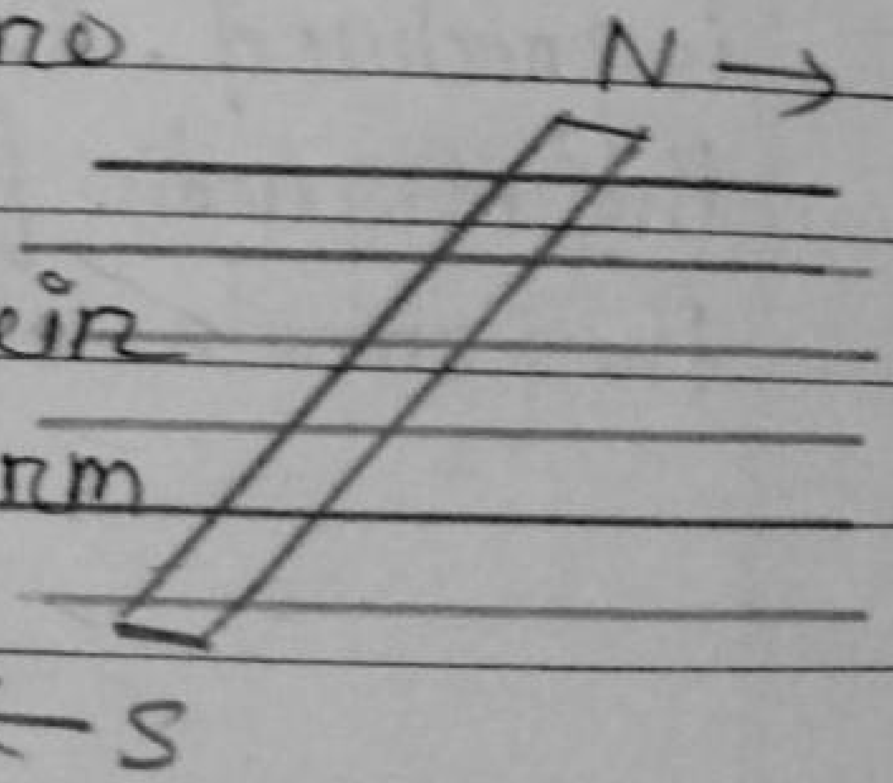
Current $I = 4 A$.

(a) Magnetic moment associated with Solenoid.

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

$= 1.28 \, J/T$.

(b) The force (net) on the Solenoid is zero because two equal and opposite forces (on each of its poles) are acting, but their lines of action are parallel so they form a couple thus a torque (no force) is applied on it.



Torque on the Solenoid $\tau = MB \sin\theta$.

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

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$= 1.28 \times 7.5 \times 10^{-2} \times \frac{1}{2}$

$= 4.8 \times 10^{-2}$ N·m.

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

Ans Given, number of turns of circular coil $n = 16$.

Radius of circular coil $r = 10$ cm $= 0.1$ m

Current $I = 0.75$ A.

Magnetic field $B = 5.0 \times 10^{-2}$ T.

frequency $f = 2/s$.

Magnetic moment of the coil $M = nIA = 16 \times 0.75 \times \pi (0.1)^2$

$= 16 \times 0.75 \times 3.14 \times 0.1 \times 0.1$

$= 0.377$ J/T.

frequency of oscillation of the coil

$$f = \frac{1}{2\pi}\sqrt{\frac{M \times B}{I}}$$

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Where I = moment of interdia of the coil.

Squaring on both the sides, we get.

$$f^2 = \frac{1}{4\pi^2} \cdot \frac{MB}{I}$$

$$I = \frac{MB}{4\pi^2 f^2} = \frac{0.377 \times 5 \times 10^{-2}}{4 \times 3.14 \times 3.14 \times 2 \times 2}$$

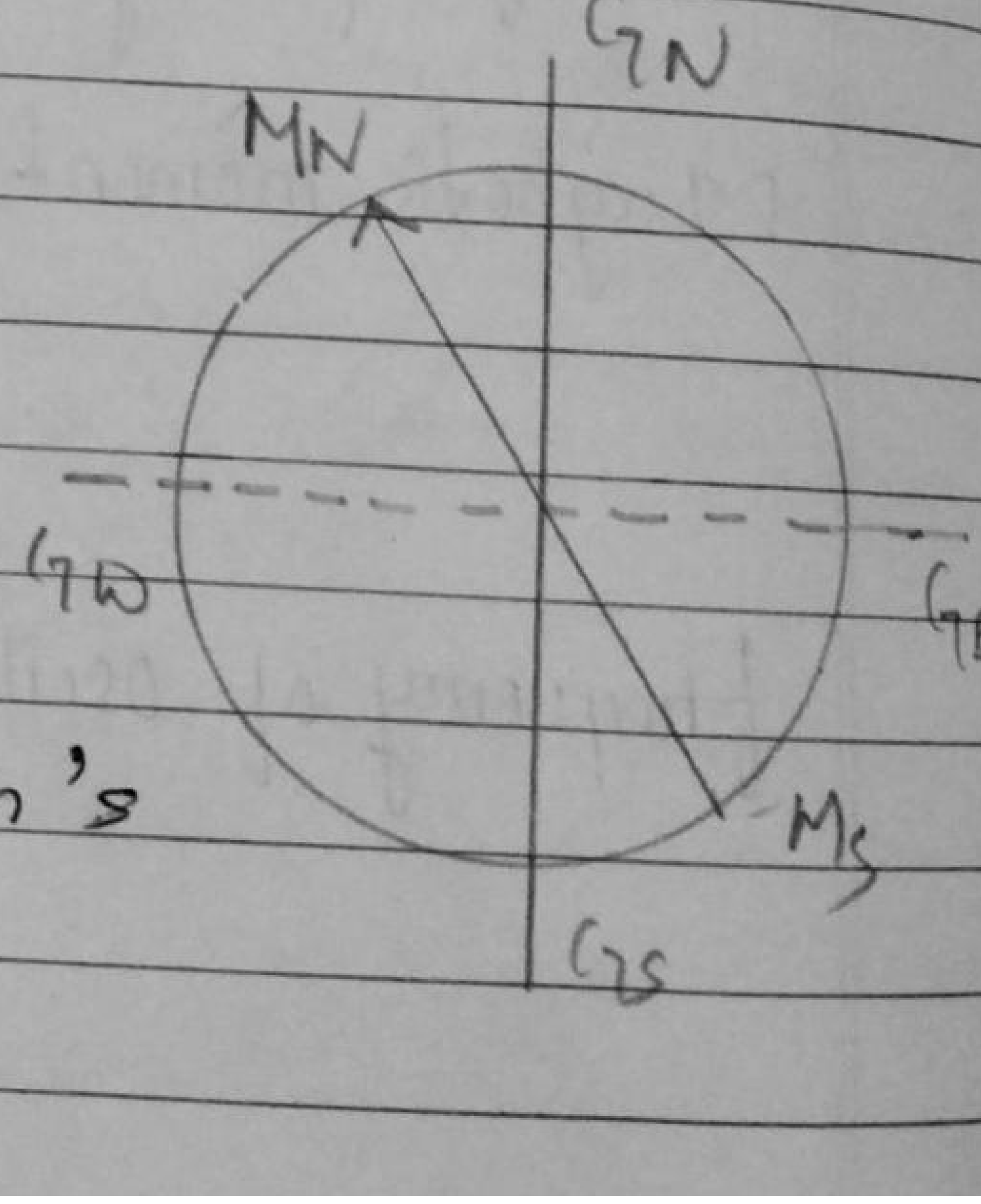
$$= 1.2 \times 10^{-4}\ kg \cdot m^2$$

Thus, the moment of inendia of the coil is 1.2×10^{-4} kg-m^2

11. At a certain location in Africa, a compass points 12° west of the geographical 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.

Ans Given, angle of declination.

$$\theta = 12^\circ \text{ west}$$



Angle of dip $\delta = 60°$

Horizontal Component of earth's magnetic field

$$H = 0.16\ G$$

Let the magnitude of earth's magnetic field at that place is R.

Using the formula, $H = R\cos\delta$

$$R = \frac{H}{\cos\delta} = \frac{0.16}{\cos 60} = \frac{0.16 \times 2}{1}$$

$$= 0.32\ G = 0.32 \times 10^{-4}\ T.$$

The earth's magnetic field lies in a vertical plane 12° west of geographical meridian at an angle 60° above the horizontal.

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 ~~on the normal~~ at the plane is 0.36 G and the angle ~~is~~ 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 point, field due to a magnet is ~~[illegible]~~ equal and opposite to the horizontal component of earth's magnetic field).

Ans Distance of the null point from the Centre of magnet

$d = 14 cm = 0.14 m$.

The earth's magnetic field where the angle of dip is zero, is the horizontal component of earth's magnetic field.

$H = 0.36 G$.

Initially the null points are on the axis of the magnet, we use the formula of magnetic field on axial line (consider that the magnet is short in length).

$$B_1 = \frac{\mu_0}{4\pi} \cdot \frac{2m}{d^3}$$

This magnetic field is equal to the horizontal component of earth's magnetic field.

$$B_1 = \frac{\mu_0}{4\pi} \cdot \frac{m}{d^3} = H \quad \text{—(i)}.$$

On the equitorial line of magnet at same distance (d) magnetic field due to the magnet.

$$B_2 = \frac{\mu_0}{4\pi} \cdot \frac{m}{d^3} = \frac{B_1}{2} = \frac{H}{2} \quad \text{—(ii)}$$

The total magnetic field on equitorial line at this point (as given in question).

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$$B = B_2 + H = \frac{H}{2} + H.$$

$$= \frac{3}{2} H = \frac{3}{2} \times 0.36$$

$$= 0.54 \text{ G}$$

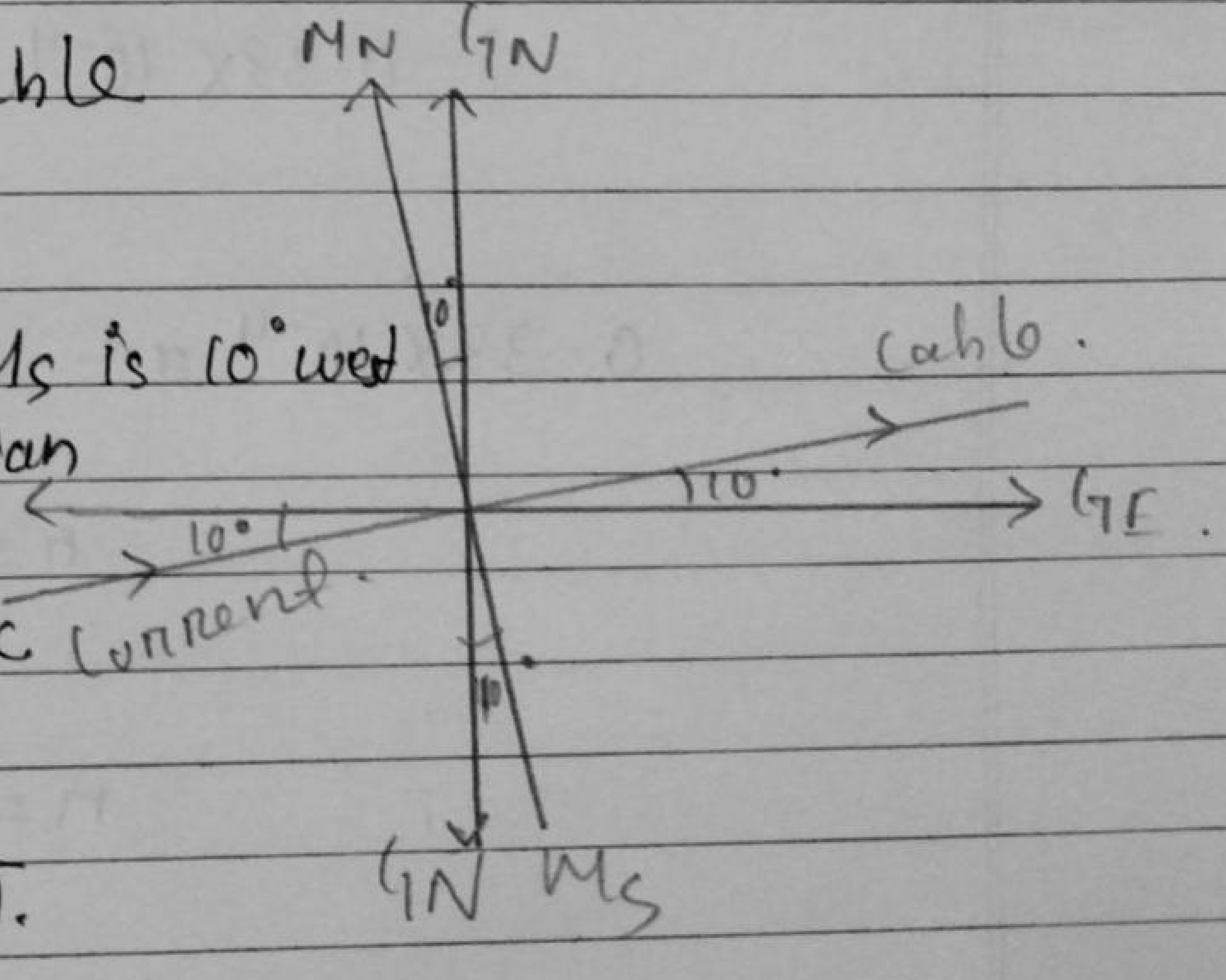
The direction of magnetic field is in the direction of earth's field.

18. A long straight horizontal cable carries a current of 2.5 A. in the direction 10° south of west to 10° north of east. The magnetic meridian of the place happens to be 10° west of the geographical meridian. The earth's magnetic field at the location is 0.33 G and the angle of dip is zero. locate the line of neutral point (ignore the thickness of the cable) (At neutral point, magnetic field due to a current-carrying cable is equal and opposite to the horizontal component of earth's magnetic field.).

Ans Given current in the cable

$$I = 2.5 A.$$

Magnetic meridian $M_N M_S$ is 10° west of geographical meridian



$G_N G_S$ earth magnetic field $R = 0.33$ G

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

Angle of dip $\delta = 0°$

The neutral point is the point where the magnetic field due to the current carrying cable is equal to the horizontal component's of earth's magnetic field.

Horizontal component of earth's magnetic field.

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

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

Using the formula of magnetic field at distance r due to an infinite long current carrying conductor.

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2I}{r}$$

$$H = B.$$

At neutral point.

$$0.33 \times 10^{-4} = \frac{\mu_0}{4\pi} \cdot \frac{2I}{r}$$

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

$$r = \frac{5 \times 10^{-7}}{0.33 \times 10^{-4}}$$

$$r = 1.5 \times 10^{-2} m$$

$$= 1.5 cm$$

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