Date 31/08/21

Chapter - 5

Magnetism And Matter

Exercise

1. a) The three independent quantities conventionally used to specify earth's magnetic field are:-
- Magnetic declination
- Angle of dip.
- Horizontal component of earth's resultant magnetic field.

b) There would be a greater dip angle in Britain because it is closer to the magnetic north pole.

c) The magnetic field lines produced due to the earth's magnetic field of virtual magnet in the earth would seem to be coming out of the ground.

d) If the compass is placed right on the geomagnetic north or south poles, it can point in any directions because the compass will be able to move in a horizontal plane while the earth's magnetic field will be exactly vertical at the magnetic poles as the horizontal component of the earth's magnetic field is zero at the poles.

8) Here,
Magnetic moment of the dipole = $8 \times 10^{22} JT^{-1}$
As we know,
The radius of the earth = $6.4 \times 10^6 m$.
Now,
As the magnetic dipole is located at the

Date
Page

centre of the earth, the magnetic field will also be created at the centre of the earth.
Now,
The magnetic field at a point on the earth due to the dipole is given by-

$$B = \frac{\mu_0 m}{4\pi r^3}$$

$$= \frac{\mu_0}{4\pi} \times \frac{8 \times 10^{22}}{(6.4 \times 10^6)^3}$$

$$= 10^{-7} \times \frac{8 \times 10^{22}}{6.4 \times (6.4)^2 \times 10^{18}}$$

$$= \frac{10^{15}}{32.76 \times 10^{18}}$$

$$= 0.03 \times 10^{-3}$$

$$= 3 \times 10^{-5} T \text{ or } 0.3 G$$

Hence,
As this magnitude of the field obtained by the above evaluation is nearly equal to the actual earth's field as estimated. So it approximes the earth's field.

f) It can be possible. As the earth's field is only approximately a dipole field. Local N-S poles may arise due to, for instance, magnetised mineral deposits.

2.a) Yes, it does change with time. Time scale for appreciable change is roughly a few hundred years. But even on a much smaller scale of a few years, its variations are not completely negligible

b) Geologists donot regard this as a source of the earth's magnetism because, the molten iron which is the phase of iron at higher temperatures of the core is not ferromagnetic.

c) The radioactivity in the interior of the earth is considered responsible for the charged currents in the outer conducting region of the core & is the source of energy to sustain these currents.

~~d) Earth's magnetic field gets modified due to the field.~~

d) Earth's magnetic field gets weakly 'recorded' in certain rocks during solidification. Analysis of this rock magnetism offers clues to geomagnetic history.

e) At larger distances, the field gets modified due to the field of ions in motion in earth's ionosphere. The latter is sensitive to extra-terrestrial ~~distribution &~~ disturbances such as the solar winds.

f) From the relation $r = \frac{mv}{qB}$, an extremely minute field bends charged particles in a circle of very large radius. Over a small distance, the deflection due to the circular orbit of such large r may not be noticeable, but over the gigantic interstellar distances, the

Date
Page

deflection can significantly affect the passage of charged particles, for example, cosmic rays.

3. Given;
Angle between Axis of bar magnet & the uniform magnetic field = 30°
Magnitude of Magnetic field = 0.25 T
Torque experienced by bar magnet = 4.5×10^{-2} J
Now,
Magnitude of magnetic moment of magnet is.

$$\tau = MB\sin\theta$$

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

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

~~$= 18 \times 10^{-2}$~~

$$= \frac{450 \times 10^{-2}}{25 \times \frac{1}{2}}$$

$$= 18 \times 2 \times 10^{-2}$$

$$= 3.6 \times 10^{-1}\,JT^{-1} = 0.36\,JT^{-1}$$

4. Given;
Magnetic momentum of short bar magnet.

$$m = 0.32\,JT^{-1}$$

Magnitude of magnetic field = 0.15 T
Now,
Here, the bar magnet is free to move or rotate in the plane of the field.
Now,

Date
Page

a) The orientation for stable equilibrium will be when the magnetic field and axis of the bar magnet are parallel to each other.
i.e.,
when $\theta = 0°$ (Minimum)

$$P.E. = -MB\cos\theta$$
$$= -MB \cdot \cos 0°$$
$$= -(0.32 \times 0.15 \times 1)\ J$$
$$= -0.048\ J$$

Now,
b) The orientation for unstable equilibrium will be when the direction of magnetic field and axis of the bar magnet are antiparallel to each other. i.e.,
when $\theta = 180°$ (Maximum)

$$P.E. = -MB\cos 180°$$
$$= -MB \times -1$$
$$= (0.32 \times 0.15)\ J$$
$$= 0.048\ J$$

5. Given;
No. of turns in Solenoid = 800
Area of cross-section of solenoid = $2.5 \times 10^{-4}\ m^2$
Current in the solenoid = 3.0 A.
Now,
In a solenoid, when current is passing through its coils throughout the area of cross section of the solenoid, the North & south polarities are induced in it in each of its end like a magnet and a magnetic field is produced existing in its axis. and thus

it behaves ~~&~~ or acts like a bar magnet.

Now,

Magnetic moment associated with the solenoid is.

$\tau = NIAB$

$\Rightarrow \frac{\tau}{B} = NIA$

$\Rightarrow M = NIA$

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

$= 2400 \times \frac{25}{100} \times 10^{-4}$

$= 240 \times 25 \times 10^{-4}$

$= 6 \times 10^{3} \times 10^{-4}$

$= 0.6\ JT^{-1}$

6. Given;

No. of turns = 800

Current in solenoid = 3 A.

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

Magnitude of magnetic field = 0.25 T

Angle between the axis of the solenoid and applied magnetic field = 30°

Hence,

Magnitude of torque on solenoid is.

~~$\tau = NIAB \sin$~~

$\tau = MB \sin\theta$

$= 0.6 \times 0.25 \times \sin 30°$

$= 6 \times 25 \times 10^{-3} \times \frac{1}{2}$

$= 75 \times 10^{-3}$

$= 7.5 \times 10^{-2}\ J$

7. Given;

Magnetic moment of Bar magnet = $1.5 JT^{-1}$

Magnitude of uniform magnetic field.

$B = 0.22 T$

Intial angle between the Magnetic moment and the uniform magnetic field. $\theta_1 = 0°$

a) i) Final angle between Magnetic moment and the uniform magnetic field. $\theta_2 = 90°$

Hence,

Work done by external torque to turn the magnet is.

$W_1 = MB(\cos\theta_1 - \cos\theta_2)$

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

$= 0.33[1 - 0]$

$= 0.33 J$

ii) Final angle between Magnetic moment and the uniform magnetic field $\theta_2 = 180°$

Hence,

Work done by external torque to turn the magnet is.

$W_2 = MB[\cos\theta_1 - \cos\theta_2]$

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

$= 0.33[1 + 1]$

$= 0.33 \times 2$

$= 0.66 J$

b) The torque on the magnet in (i) case is.

$\tau_1 = MB \sin\theta$

$= (1.5 \times 0.22) \times \sin 90°$

$= 0.33 \times 1$

$= 0.33 J$

The torque on the magnet in (ii) case is.

$$\tau_2 = MB \sin\theta$$
$$= (1.5 \times 0.22) \times \sin 180^\circ$$
$$= 0.33 \times 0$$
$$= 0$$

8. Given;

No. of turns of solenoid = 2000

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

Current in the solenoid = 4.0 A

a) The Magnetic Moment associated with it is.

$$\tau = NIAB$$
$$\Rightarrow \frac{\tau}{B} = NIA$$
$$\Rightarrow M = NIA$$
$$= 2000 \times 4 \times 1.6 \times 10^{-4}$$
$$= 8 \times 10^{3} \times 1.6 \times 10^{-4}$$
$$= 12.8 \times 10^{-1}$$
$$= 1.28\ J\,T^{-1}$$

b) Magnitude of magnetic field = $7.5 \times 10^{-2}\,T$

Angle between the axis of the solenoid and the magnetic field direction = 30°

Hence,

~~Torque~~ Force on the solenoid will be zero. because, the solenoid is in uniform magnetic field so, the forces on each end of the solenoid will cancel out each others effect. and thus, the solenoid will not experience any force.

Now,
Torque on the solenoid will be:

$\tau = MB \sin\theta$
$= 1.28 \times 7.5 \times 10^{-2} \times \sin 30^\circ$
$= 9.6 \times 10^{-2} \times \frac{1}{2}$
$= 4.8 \times 10^{-2}$ J

9. Given;
No. of turns of circular coil = 16
Radius of the circular coil = 10 cm.
Current in the circular coil = 0.75 A
Magnitude of the external magnetic field
$B = 5.0 \times 10^{-2}$ T
Angle between plane of the coil & the magnetic field is = 90°
Now,
Magnetic moment of the circular coil is.

$\tau = NIAB$
$\Rightarrow \frac{\tau}{B} = NIA$
$\Rightarrow M = NIA$
$= 16 \times 0.75 \times \pi r^2$
$= 12 \times \pi \times 10^{-2}$
$= 12\pi \times 10^{-2}$ JT^{-1}

Now,
Frequency of oscillation of the circular coil is.
$f = 2.0\ s^{-1}$
∴ Time period of oscillation is.
$T = \frac{1}{f} = \frac{1}{2} = 0.5$ s

Hence,
The Moment of inertia of the coil about the axis of rotation is:

~~$T = 2\pi\sqrt{\frac{MB}{I}}$~~

$$T = 2\pi\sqrt{\frac{I_m}{MB}}$$

$$\Rightarrow I_m = \frac{T^2 \times MB}{4\pi^2}$$

$$\Rightarrow I_m = \frac{(0.5)^2 \times 12\pi \times 10^{-2} \times 5.0 \times 10^{-2}}{4\pi^2}$$

$$= \frac{25 \times 10^{-2} \times 5 \times 10^{-2} \times 3 \times 10^{-2}}{\pi}$$

$$= \frac{375 \times 10^{-6}}{\pi}$$

$$= \frac{3.75 \times 10^{-4}}{3.14}$$

$$= 1.2 \times 10^{-4}\ J s^2/Kg\ m^2$$

10. Given;
Horizontal Component of the earth's Magnetic field, $H = 0.35G$
Angle between the noth tip of the magnetic needle & the horizontal plane of the earth.
i.e., Angle of dip $\delta = 22^\circ$
Now,
The Magnitude of the earth's magnetic field at the place will be:

$$H = 0.35$$

$$\Rightarrow R_B \cos\delta = 0.35$$

$$\Rightarrow R_B \cos 22^\circ = 0.35$$

Date
Page

$\Rightarrow R_B = \frac{0.35}{\cos 22^\circ}$

$= \frac{0.35}{0.92} = 0.38\,G$

11. Given;

Angle between the north tip of magnetic ~~field~~ needle & the horizontal of the earth is.

$\delta = 60^\circ$

Horizontal component of the earth magnetic field

$H = 0.16\,G$

Hence,

The Magnitude of earth's magnetic field is.

$H = 0.16$

$\Rightarrow R_B \cos \delta = 0.16$

$\Rightarrow R_B \cos 60^\circ = 0.16$

$\Rightarrow R_B = \frac{0.16}{\cos 60^\circ}$

$= 2 \times 0.16 = 0.32\,G$

Here,

The earth's magnetic field lies in the vertical plane 12° west of the geographic north making angle of 60° upwards with the horizontal. ~~From~~ and its direction is from magnetic South to magnetic north.

12. Given,

Magnetic moment of a short bar magnet is.

$m = 0.48\,JT^{-1}$

Separation distance between the centre of the magnet & the point where the magnetic field is created is 10 cm.

Now,

a) The Magnitude of magnetic field produced by magnet on the axis is.

$$B_{axis} = \frac{\mu_0 2m}{4\pi x^3}$$

$$= \frac{\mu_0}{4\pi} \times \frac{2 \times 0.48}{(0.1)^3}$$

$$= 10^{-7} \times \frac{0.96}{10^{-3}}$$

$$= 0.96 \times 10^{-4}$$

$$= 9.6 \times 10^{-5} \text{ T}$$

The direction of magnetic field is along the direction of magnetic moment i.e., along South-North direction.

Now,

b) The Magnitude of magnetic field produced by the magnet on the equatorial line is.

$$B_{equator} = \frac{\mu_0 m}{4\pi y^3}$$

$$= \frac{\mu_0}{4\pi} \times \frac{0.48}{(0.1)^3}$$

$$= 10^{-7} \times \frac{0.48}{10^{-3}}$$

$$= 0.48 \times 10^{-4} \text{ T}$$

The direction of magnetic field is along the direction from North to South i.e., antiparallel with the direction of the magnetic moment.

13. Given,
Distance between the Null points and centre of the bar magnet = 14 cm.
As the angle of dip, $\delta = 0°$
The bar magnet is in the equator of the earth.
So, horizontal component of magnetic field is

$$H_E = 0.36 G$$

Here,
The magnetic field produced by the magnet on it's axis is = 0.36 G
Now,
Magnetic momment of the bar magnet is.

$$B_A = \frac{\mu_0 2m}{4\pi x^3}$$

$$\Rightarrow m = \frac{B \times x^3}{2 \times 10^{-7}}$$

$$= \frac{0.36 \times 10^{-4} \times (14 \times 10^{-2})^3}{2 \times 10^{-7}}$$

$$= \frac{0.18 \times 10^{-4} \times 2744 \times 10^{-6}}{10^{-7}}$$

$$= 493.92 \times 10^{-3} JT^{-1}$$

~~4.93 × 10~~

~~= 0.49 JT⁻¹~~

Now,
Magnetic field on the null point at the same distance from centre of magnet in the equatorial line is.

$$B_E = \frac{\mu_0 m}{4\pi y^3} \qquad (x = y)$$

$$= \frac{\mu_0}{4\pi} \times \frac{493.92 \times 10^{-3}}{(14 \times 10^{-2})^3}$$

$$= 10^{-7} \times \frac{493.92 \times 10^{-3}}{2744 \times 10^{-6}}$$

$$= 0.18 \times 10^{-4} T$$

$$= 0.18 G$$

Hence,
The ~~tototal~~ total magnetic field on the normal bisector of magnet is.

$$B_{net} = B_A + B_E$$

$$= (0.36 + 0.18) G$$

$$= 0.54 G$$

The direction of magnetic field on the normal bisector ~~is~~ of the magnet is ~~alon~~ in the direction of earth's magnetic field.

14. Given;
The bar magnet is turned around by 180°.
Let the ~~new~~ null point from the centre of the magnet be. l cm.
As we know,
Magnetic field before the magnet is turned is. equal ~~B~~ to the magnetic field produced after the magnet is turned.
Now,
Magnetic field on the null point of 14 cm.

$$B_1 = \frac{\mu_0 \, 2m}{4\pi x^3}$$

$(B_1 = H)$ .... (1)

Magnetic field on the null point of l cm.

$$B_2 = \frac{\mu_0 m}{4\pi l^3}$$

$(B_2 = H)$ .... (2)

Now,
On dividing both the equation, we get..

$$1 = \frac{2}{x^3} \times l^3$$

$$\Rightarrow \frac{2}{x^3} = \frac{1}{l^3}$$

$$\Rightarrow l^3 = \frac{(14)^3}{2}$$

$$\Rightarrow l^3 = \frac{2744}{2}$$

$$\Rightarrow l = \frac{14}{\sqrt[3]{2}}$$

$$= \frac{14}{1.25} = 11.2 \text{ cm.}$$

Hence,
The new null point will be located 11.2 cm from the centre of the magnet on the normal bisector.

15. Given;
Magnetic moment of a short bar magnet is.

$$M = 5.25 \times 10^{-2} \text{ J T}^{-1}$$

Magnitude of earth's magnetic field is.

$$B_E = 0.42 \text{ G}$$

a) Let the distance resultant field from the centre of the magnet on normal bisector be x cm.
When resultant field is inclined at 45° with the earth's field; $\tan\theta = \frac{B_1}{B_E}$ $(\theta = 45°)$

Date
Page

$$\Rightarrow \tan 45^\circ = \frac{B_1}{B_E}$$

$$\Rightarrow B_1 = B_E \times 1.$$

$$\Rightarrow B_1 = B_E = 0.42\ G$$

Now,
The distance from the centre of the magnet on the normal bisector is.

$$B_1 = \frac{\mu_0 m}{4\pi y^3}$$

~~$\Rightarrow y^3 = \frac{B_1}{10^{-7}}$~~

$$\Rightarrow y^3 = \frac{10^{-7} \times m}{B_1}$$

$$= \frac{10^{-7} \times 5.25 \times 10^{-2}}{0.42 \times 10^{-4}}$$

$$= 12.5 \times 10^{-5}$$

$$\Rightarrow y = \sqrt[3]{125 \times 10^{-6}}$$

$$= 5 \times 10^{-2}\ m$$

$$= 5\ cm.$$

b) Let, the distance of resultant field from the centre of the magnet on the axis of the magnet be x cm.
When resultant field is inclined at 45° with the earth's field

$$\tan\theta = \frac{B_2}{B_E} \qquad (\theta = 45^\circ)$$

$$\Rightarrow \tan 45^\circ = \frac{B_2}{B_E}$$

$$\Rightarrow B_2 = B_E \times 1$$

$$\Rightarrow B_2 = B_E = 0.42\ G$$

~~Now~~ ..

Hence,
The distance from the centre of the magnet on its axis is.

$$B_2 = \frac{\mu_0}{4\pi} \frac{2m}{x^3}$$

$$\Rightarrow x^3 = \frac{10^{-7} \times 2m}{B_2}$$

$$= \frac{10^{-7} \times 2 \times 5.25 \times 10^{-2}}{0.42 \times 10^{-4}}$$

$$= \frac{10.5}{0.42} \times 10^{-5}$$

$$= 25 \times 10^{-5}$$

$$\Rightarrow x = \sqrt[3]{25 \times 10^{-5}}$$

$$= \sqrt[3]{250 \times 10^{-6}}$$

$$= 5\sqrt[3]{2} \times 10^{-2}$$

$$= 6.3 \times 10^{-2}$$

$$= 6.3 \text{ cm}$$

16 a) The tendency to disrupt the alligement of dipoles with the magnetising field arising from random thermal motion is reduced at lower temperature. That is why the paramagnetic sample display greater magnetisation when cooled.

b) The induced dipole moment in a diamagnetic substance is always oppocite to the magnetising field. Hence, the internal motion of the atoms which is related to temperature does not affect the diamagnetism of material.

c) The field in the core of the toroid will be slightly less because bismuth is diamagnetic in nature.

~~d) No, the permeability of a ferromagnetic material is not independent of the magnetic field~~

d) No, the permeability of a ferromagnetic material is not independent of the magnetic field. It is greater for a lower field.

e) The permeability (μ) of a ferromagnetic material is not less than one. It is always greater than one ($\mu >> 1$). Hence, magnetic field lines are always nearly normal to the surface of such material at every point.

f) Yes, the maximum possible magnetisation of a paramagnetic sample can be of the same order of magnitude as the magnetisation of a ferromagnet. But this requires high magnetising field.

17.a) From the hysteresis curve of a ferromagnetic material.
It can be observed that magnetisation persists even when the external field is removed. This reflects the irreversibility of a ferromagnet.

Date
Page

b) Carbon steel piece will dissipate greater heat energy because heat lost per cycle is proportional to the area of hysteresis loop.

c) The value of magnetisation is memory or record of hysterisis loop cycles of magnetisation. These bits of information corresponds to the cycle of magnetisation. Haysteresis loops can be used for storing information.

d) Ceramic is the ferromagnetic material used for coating magnetic tapes in a cassette player & for building memory stores in a morden computer.

e) A certain region of space can be shielded from magnetic fields if it is surrounded by soft iron rings. In such arrangments, the magnetic lines are drawn out of the region.

18. Given,
Current in the Cable = 2.5A
Earth's magnetic field (B_E) = 0.33G.
Angle of dip = 0°
so, as it is in the equator of earth.
The horizontal component of earth's magnetic field will be.

$$H = B_E \cos \delta$$
$$= B_E \cos 0° = 0.33G$$

Now,
As it is mentioned that ~~the~~ at neutral points,

The magnetic field due to a current carrying cable is equal & opposite to the horizontal component of earth's magnetic field.

i.e., $B_I = H$.

Hence,

The distance between the cable and the neutral point is.

$$B_I = \frac{\mu_0 I}{2\pi r}$$

$$\Rightarrow r = \frac{\mu_0 I}{B_I \times 2\pi}$$

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

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

$$= \frac{5}{0.33} \times 10^{-3}$$

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

$$= 1.5\ cm.$$

The neutral point is parallel to and above the cable at a distance of 1.5 cm.

19. Given;

Current in each of four straight long horizontal wire $= 1.0 A$

Earth's magnetic field $= 0.39 G$

Angle of dip $= 35°$

Distance between the resultant field and the cable $= 4.0$ cm.

The Magnetic declination ≈ 0.

i.e., $\theta \approx 0$.

It means, the magnetic meridian & geographic meridian, are in the same position. Coinciding with each other.

Now,

Magnetic field due to the current carrying telephone cables is.

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

$$= \frac{4\pi \times 10^{-7} \times 1 \times 4}{2\pi \times 4 \times 10^{-2}}$$

$$= 2 \times 10^{-5}$$

~~[illegible]~~

~~$= 0.2 \times 10^{-4}$ T~~

~~$= 0.05$ G~~

$$= 0.2 \times 10^{-4} \text{ T}$$

$$\Rightarrow B = 0.2 \text{ G}$$

Now,

The horizontal component of magnetic field of earth is

$$H = R\cos\delta - B$$

$$= 0.39 \times \cos 35^\circ - 0.2$$

$$= (0.39 \times 0.819) - 0.2$$

$$= 0.32 - 0.2$$

$$= 0.12 \text{ G}$$

The vertical component of earth's magnetic field will be:

$$V = R\sin\delta$$

$$= 0.39 \times \sin 35$$

$$= 0.39 \times 0.57$$

$$= 0.22 \text{ G}$$

Now,

The resultant magnetic field at points 4.0 cm below the cable will be:

$$B_{net} = \sqrt{H^2 + V^2}$$
$$= \sqrt{(0.12)^2 + (0.22)^2}$$
$$= \sqrt{144 \times 10^{-4} + 484 \times 10^{-4}}$$
$$= \sqrt{628 \times 10^{-4}}$$
$$= 25.05 \times 10^{-2}$$
$$= 0.25\ G$$

30. Given;

No. of turns of circular coil = 30

Radius of the circular coil = 12 cm.

Angle between the coil & the magnetic meridian of earth is = 45°

Current in the circular coil = 0.35 A.

a) The magnetic field due to the circular coils

$$B = \frac{\mu_0 N I}{2r}$$
$$= \frac{4\pi \times 10^{-7} \times 30 \times 0.35}{2 \times 12 \times 10^{-2}}$$
$$= \frac{10.5 \times \pi \times 10^{-7}}{6 \times 10^{-2}}$$
$$= \frac{10.5 \times 3.14 \times 10^{-5}}{6}$$
$$= \frac{32.97 \times 10^{-5}}{6}$$
$$= 5.49 \times 10^{-5}\ T$$
$$= 0.54\ G$$

As we know,

The Angle of dip, $\delta = 45°$

The ho
magne

b) If the
Coil is
angle
Then t
to c

21. Given
Angle
Field
Magn

Let
Noc
As p