NCERT SOLUTIONS
CLASS-XII PHYSICS
CHAPTER-5 MAGNETISM AND MATTER

Q 5.1) Answer the following:

(a) The specification of a vector requires 3 quantities. What are the three quantities that are independent and can be used conventionally to determine the earth's magnetic field?

(b) Will the dip angle be greater or smaller in Britain, if 18° is the dip angle at a location in southern India?

(c) On the off chance that you made a map of magnetic field lines at Melbourne in Australia, would the lines appear to go into the ground or leave the ground?

(d) In what direction will the compass point, if it's placed right on the geomagnetic North or the South Pole and allowed to move freely in the vertical plane?

(e) The earth's magnetic field, it is claimed, roughly approximates the field due to a dipole of the magnetic moment $8 \times 1022\ J\ T^{-1}$ located at its center. Check the order of magnitude of this number in some way.

(f) Geologists guarantee that there are many local poles oriented in different directions on the earth's surface other than the primary magnetic N-S poles. Explain.

Answer 5.1:

(a) The three independent quantities conventionally used for specifying earth's magnetic field are:

(i) Magnetic declination,

(ii) Angle of dip

(iii) Horizontal component of earth's magnetic field

(b) The angle of dip at a point depends on how far the point is located with respect to the North Pole or the South Pole So, as the location of Britain on the globe is near to the magnetic North pole, the angle of dip would be greater in Britain (About 70°) than in southern India.

(c) It is assumed that a huge bar magnet is dipped inside earth with its north pole near the geographic South Pole and its south pole near the geographic North Pole. Magnetic field lines emanate from a magnetic north pole and terminate at a magnetic south pole. Hence, in a map depicting earth's magnetic field lines, the field lines at Melbourne, Australia would seem to leave the ground.

(d) If a compass is located on the geomagnetic North Pole or the South Pole, then the compass will be free to move in the horizontal plane while earth's field is exactly vertical to the magnetic poles In such a case, the compass can point in any direction.

(e) Magnetic moment, M = $8 \times 10^{22}\ J\ T^{-1}$

Radius of earth, r = $6.4 \times 10^{6}\ m$

Magnetic field strength, B = $\frac{\mu_0 M}{4\pi r^3}$

Where,

μ_0 = Permeability of free space = $4\pi \times 10^{-7}\ TmA^{-1}$

Therefore, B = $\frac{4\pi \times 10^{-7} \times 8 \times 10^{22}}{4\pi \times (6.4 \times 10^{6})^3} = 0.3\ G$

This quantity is of the order of magnitude of the observed field on earth.

(f) Yes, there are several local poles on earth's surface oriented in different directions. A magnetized mineral deposit is an example of a local N-S pole.

Q 5.2) Answer the following:

(a) The earth's magnetic field varies from point to point in space.

Does it likewise change with time? Provided that this is true, on what time scale does it change apparently?

(b) Knowing that the earth's core contains iron, geologists do not consider it as a source of the earth's magnetism. Why?

(c) The charged currents in the external conducting regions of the earth's core are assumed to be responsible for earth's magnetism. What could be the source of energy that can sustain these currents?

(d) The earth may have even switched the course of its field a few times amid its history of 4 to 5 billion years. By what method can geologists think about the earth's field in such distant past?

(e) The earth's field departs from its dipole shape considerably at large distances (greater than about 30,000 km). What parameters may be considered and held responsible for this distortion?

(f) Interstellar space has an extremely weak magnetic field of the order of 10–12 T. Can such a weak field be of any significant consequence? Explain.

Answer 5.2:

(a) Earth's magnetic field changes with time. It takes a couple of hundred years to change by an obvious sum. The variation in earth's magnetic field with the time can't be ignored.

(b) Iron in the Earth's core cannot be considered as sources of earth's magnetism as this iron is in its molten form (Non-ferromagnetic).

(c) The radioactivity in earth's interior is the source of energy that sustains the currents in the outer conducting regions of earth's core. These charged currents are considered to be responsible for earth's magnetism.

(d) Earth reversed the direction of its field several times during its history of 4 to 5 billion years. These magnetic fields got weakly recorded in rocks during their solidification. One can get clues about the geomagnetic history from the analysis of this rock magnetism.

(e)Earth's field departs from its dipole shape substantially at large distances (greater than about 30,000 km) because of the presence of the ionosphere. In this region, earth's field gets modified because of the field of single ions. While in motion, these ions produce the magnetic field associated with them.

(f)An extremely weak magnetic field can bend charged particles moving in a circle. This may not be noticeable for a large radius path. With reference to the gigantic interstellar space, the deflection can affect the passage of charged particles.

Q 5.3) What is the magnitude of the magnetic moment of the magnet that is placed with its axis at 30° with a uniform external magnetic field of 0.25 T experiencing a torque of magnitude equal to $4.5 \times 10^{-2}\ J$?

Answer 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, $\theta = 30^\circ$

Torque is related to magnetic moment (M) as:

$T = MBsin\theta \therefore M = \frac{T}{Bsin\theta}$

= $\frac{4.5 \times 10^{-2}}{0.25 \times sin30^\circ} = 0.36\ J\,T^{-1}$

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

Q 5.4) A small bar magnet of magnetic moment m = $0.32\ J\,T^{-1}$ is placed in a uniform magnetic field of 0.15 T. If the bar is allowed to rotate freely in the plane of the field, which orientation would correspond to its (a) stable, and (b) unstable equilibrium? Also, calculate the potential energy of the magnet in each case?

Answer 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 aligned along the magnetic field. This system is considered as being in stable equilibrium. Hence, the angle θ, between the bar magnet and the magnetic field is 0°.

Potential energy of the system = $-MBcos\theta$

= $-0.32 \times 0.15\ cos0^\circ$

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

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

Potential energy = $-MBcos\theta$

= $-0.32 \times 0.15\ cos180^\circ$

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

Q 5.5) Describe how a solenoid of cross-sectional area $5.2 \times 10^{-4}\ m^2$, carrying a current of 6.0 A acts like a bar magnet. Also, find its associated magnetic moment. (Given: No. of turns of Solenoid is 1000)

Answer 5.5:

Number of turns in the solenoid, n = 1000

Area of cross-section, A = $5.2 \times 10^{-4}\ m^2$

Current in the solenoid, I = 6.0 A

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

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

M = n I A

= $1000 \times 6 \times 5.2 \times 10^{-4}$

= $3.12\ J\,T^{-1}$

Q 5.6) By applying a uniform horizontal magnetic field of 0.5 T to a solenoid in exercise 5.5 and by allowing it to turn freely about the vertical direction, what will the magnitude of the torque on the solenoid be, if an angle of 60^0 is made with the direction of applied field by the axis of solenoid?

Answer 5.6:

Magnetic field strength, B = 0.5 T

Magnetic moment, M = 3.12 T^{-1}

The angle θ, between the axis of the solenoid and the direction of the applied field is 60°.

Therefore, the torque acting on the solenoid is given as:

$\tau = MBsin\theta$

= $3.12 \times 0.5\ sin60^{\circ}$

= 13.5×10^{-2} J

Q 5.7) A bar magnet with magnetic moment $1.5\ J\,T^{-1}$ with its axis is aligned with the direction of a uniform magnetic field of 0.22 T.

(a) How much work is required by an external torque to turn the magnet so as to align its magnetic moment: (i) perpendicular to the direction of the field, (ii) opposite to the direction of the field?

(b) Find torque on the magnet in cases (i) and (ii)?

Answer 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, $\theta_1 = 0^{\circ}$

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

= $-1.5 \times 0.22(cos90^{\circ} - cos0^{\circ}$

= – 0.33 (0 – 1)

= 0.33 J

(ii) Initial angle between the axis and the magnetic field, $\theta_1 = 0^{\circ}$

Final angle between the axis and the magnetic field, $\theta_2 = 180^{\circ}$

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

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

= $-1.5 \times 0.22(cos180^{\circ} - cos0^{\circ})$

= – 0.33 (– 1 – 1)

= 0.66 J

(b) For case (i): $\theta = \theta_2 = 90^{\circ}$

$\therefore$ Torque, $\tau = MBsin\theta$

= $MBsin90^{\circ}$

= 0.33 J

For case (ii): $\theta = \theta_2 = 180^{\circ}$

$\therefore$ Torque, $\tau = MBsin\theta$

= $MBsin180^{\circ}$

= 0 J

Q 5.8) A tightly wound solenoid of 1000 turns having area of cross-section $2 \times 10^{-4}\ m^2$ and carrying 3.0 A current, is suspended through its centre, thereby allowing it to turn in a horizontal plane.

(a) Find out the magnetic moment associated with the solenoid?

(b) Also find the force and torque on the solenoid if a uniform horizontal magnetic field of $5.5 \times 10^{-2}\ T$ is set up at an angle of 30^0 with the axis of the solenoid?

Answer 5.8:

Number of turns on the solenoid, n = 1000

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

Current in the solenoid, I = 3.0 A

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

M = nAI

= $1000 \times 2 \times 10^{-4} \times 3$

= 0.6 Am^2

= 0.6 Am

(b) Magnetic field, B = $5.5 \times 10^{-2}\ T$

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

Torque, $\tau = MBsin\theta$

= $0.6 \times 5.5 \times 10^{-2}\ sin30^\circ$

= $1.65 \times 10^{-2}\ Nm$

Since the magnetic field is uniform, the force on the solenoid is zero. The torque on the solenoid is $1.65 \times 10^{-2}\ Nm$.

Q 5.9) A circular coil having 16 turns and radius 10 cm carrying a current of 0.75 A rests with its plane perpendicular to an external field having magnitude $5.0 \times 10^{-2}\ T$. The coil is allowed to turn freely about an axis in its plane perpendicular to the direction of field. When the coil is turned slightly and released, it oscillates about its stable equilibrium with a frequency of $2.0\ s^{-1}$. What is the moment of inertia of the coil about its axis of rotation?

Answer 5.9:

Number of turns in the circular coil, N = 16

Radius of the coil, r = 10 cm = 0.1 m

Cross-section of the coil, A = $\pi r^2 = n \times (0.1)^2\ m^2$

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 moment, M = NIA = $NI\pi r^2$

= $16 \times 0.75 \times n \times (0.1)^2$

= $0.377\ J\,T^{-1}$

Frequency is given by the relation:

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

Where,

I = Moment of inertia of the coil

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

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

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

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

Q 5.10) A magnetic needle allowed to turn freely in a vertical plane parallel to the magnetic meridian has its north tip indicating down at 22° with the horizontal. Determine the magnitude of the earth's magnetic field at the place with its horizontal component measured as 0.35 G.

Answer 5.10:

Horizontal component of earth's magnetic field, $B_H = 0.35\ G$

Angle made by the needle with the horizontal plane = Angle of dip = $\delta = 22^\circ$

Earth's magnetic field strength = B

We can relate B and B_H as:

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

= $\frac{0.35}{cos\ 22^\circ}$ = 0.377 G

Hence, the strength of earth's magnetic field at the given location is 0.377 G.

Q 5.11) At a particular place in Africa, a compass points 12° west of the geographic north. The north tip of the magnetic needle of a dip circle placed in the plane of magnetic meridian points 60° above the horizontal. Find the magnitude and direction of the earth's field at the particular place with its horizontal component measured as 0.16 G.

Answer 5.11:

Angle of declination, $\theta = 12^\circ$

Angle of dip, $\delta = 60^\circ$

Horizontal component of earth's magnetic field, $B_H = 0.16\ G$

Earth's magnetic field at the given location = B

We can relate B and B_H as:

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

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

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.

Q 5.12) Find the magnitude and direction of the magnetic field produced by the magnet with magnetic moment $0.48\ J\,T^{-1}$ which is 10 cm away from the centre of the magnet on (a) the axis, (b) the equatorial lines (normal bisector) of the magnet.

Answer 5.12:

Magnetic moment of the bar magnet, M = $0.48\ J\,T^{-1}$

(a) Distance, d = 10 cm = 0.1 m

The magnetic field at distance d, from the centre of the magnet on the axis is given by the relation:

$B = \frac{\mu_0\ 2M}{4\pi d^3}$

Where,

μ_0 = Permeability of free space = $4\pi \times 10^{-7}\ TmA^{-1}$

$\therefore B = \frac{4\pi \times 10^{-7} \times 2 \times 0.48}{4\pi \times (0.1)^3}$

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

The magnetic field is along the S-N direction.

(b) The magnetic field at a distance of 10 cm (i.e., d = 0.1 m) on the equatorial line of the magnet is given as:

$B = \frac{\mu_0 \times M}{4\pi \times d^3}$

= $\frac{4\pi \times 10^{-7} \times 0.48}{4\pi (0.1)^3}$

= 0.48 G

The magnetic field is along the N – S direction.

Q 5.13) A bar magnet is aligned along the magnetic N-S direction which is placed in a horizontal plane. From the centre of the magnet at exactly 28 cm the null points are found on the axis of the magnet. 0.72 G is the earth's magnetic field at the place with zero being the angle of dip. Find the total magnetic field on the perpendicular bisector of the magnet at the same distance as the null-point (i.e., 28 cm) from the mid-point of the magnet? (The horizontal component of earth's magnetic field is equal to field occurred due to a magnet at null point.)

Answer 5.13:

Earth's magnetic field at the given place, H = 0.72 G

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

$B_1 = \frac{\mu_0 2M}{4\pi d^3} = H \qquad \ldots (i)$

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:

$B_2 = \frac{\mu_0 M}{4\pi d^3} = \frac{H}{2} \qquad [Using\ equation\ (i)]$

Total magnetic field, B = $B_1 + B_2$

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

= 0.72 + 0.28 = 1.00 G

Hence, the magnetic field is 1.00 G in the direction of earth's magnetic field.

Q 5.14) Determine the location of new null points that will be obtained when the bar magnet in exercise 5.13 is turned around by 180°.

Answer 5.14:

The magnetic field on the axis of the magnet at a distance d_1 = 14 cm, can be written as:

$B_1 = \frac{\mu_0 2M}{4\pi (d_1)^3} = H \qquad \ldots (1)$

Where,

M = Magnetic moment

μ_0 = Permeability of free space

H = Horizontal component of the magnetic field at d_1

If the bar magnet is turned through , then the neutral point will lie on the equatorial line.

Hence, the magnetic field at a distance d_2, on the equatorial line of the magnet can be written as:

$$B_1 = \frac{\mu_0 2M}{4\pi (d_1)^3} = H \qquad \ldots (2)$$

Equating equations (1) and (2), we get:

$$\frac{2}{(d_1)^3} = \frac{1}{(d_2)^3} \left[\frac{d_2}{d_1}\right]^3 = \frac{1}{2} \therefore d_2 = d_1 \times \left(\frac{1}{2}\right)^{\frac{1}{3}}$$

= $14 \times 0.794 = 11.1 cm$

The new null points will be locked 11.1 cm on the normal bisector.

Q 5.15) A bar magnet of magnetic moment $6.45 \times 10^{-2}\ J\,T^{-1}$ is placed with its axis perpendicular to the earth's field direction. At what distance from the centre of the magnet, the resultant field is inclined at 45° with earth's field on

(a) its ordinary bisector and (b) its axis. 0.62 G is given as the magnitude of the earth's field at the place. Neglect the length of the magnet in contrast to the distances involved.

Answer 5.15:

Magnetic moment of the bar magnet, M = $6.45 \times 10^{-2}\ J\,T^{-1}$

Magnitude of earth's magnetic field at a place, H = 0.62 G = $0.62 \times 10^{-4}\ T$

(a) The magnetic field at a distance R from the centre of the magnet on the ordinary bisector is given by:

$$B = \frac{\mu_0 M}{4\pi R^3}$$

Where,

μ_0 = Permeability of free space = $4\pi \times 10^{-7} TmA^{-1}$

When the resultant field is inclined at 45° with earth's field, B = H

$$\therefore \frac{\mu_0 M}{4\pi R^3} = H = 0.62 \times 10^{-4}\ R^3 = \frac{\mu_0 M}{0.62 \times 10^{-4} \times 4\pi}$$

= $R^3 = \frac{4\pi \times 10^{-7} \times 6.45 \times 10^{-2}}{4\pi \times 0.62 \times 10^{-4}}$

= 10.40×10^{-5}

$\therefore R = 0.047\ m = 4.7\ cm$

(b) The magnetic field at a distanced 'R' from the centre of the magnet on its axis is given as:

$$B' = \frac{\mu_0 2M}{4\pi R^3}$$

The resultant field is inclined at 45° with the earth's field.

$$\therefore B' = H\ \frac{\mu_0 2M}{4\pi (R')^3} = H\ (R')^3 = \frac{\mu_0\ 2M}{4\pi \times H}$$

= $\frac{4\pi \times 10^{-7} \times 2 \times 6.45 \times 10^{-2}}{4\pi \times 0.62 \times 10^{-4}} = 20.806 \times 10^{-5}$

$\therefore R = 0.0592\ m = 5.92\ cm$