CHAPTER - 5

MAGNETISM AND MATTER

5.1(a). Answer the following questions regarding earth's magnetism: A vector needs three quantities for its specification. Name the three independent quantities conventionally used to specify the earth's magnetic field.

Answer:

The three independent quantities used to specify the earth's magnetic field are:

(i) The horizontal component of Earth's magnetic field (H_E).

(ii) The magnetic declination (D): It is the angle between the geographic north and the magnetic north at a place.

(iii)The magnetic dip (I): It is the angle between the horizontal plane and the magnetic axis, as observed in the compass

5.1(b) Answer the following questions regarding earth's magnetism. The angle of dip at a location in southern India is about 18°. Would you expect a greater or smaller dip angle in Britain?

Answer:

We would expect a greater angle of dip in Britain. The angle of dip increases as the distance from equator increases.

(It is 0 at the equator and 90 degrees at the poles)

5.1 (c) Answer the following questions regarding earth's magnetism

If you made a map of magnetic field lines at Melbourne in Australia, would the lines seem to go into the ground or come out of the ground?

Answer:

The field lines go into the earth at the north magnetic pole and come out from the south magnetic pole and hence Australia being in the southern hemisphere. The magnetic field lines would come out of the ground at Melbourne.

5.1 (d) Answer the following questions regarding earth's magnetism

In which direction would a compass free to move in the vertical plane point to, if located right on the geomagnetic north or south pole?

Answer:

The magnetic field is perpendicular at the poles and the magnetic needle of the compass tends to align with the magnetic field. Therefore the compass will get aligned in the vertical direction if is held vertically at the north pole.

5.1 e) The earth's field, it is claimed, roughly approximates the field due to a dipole of magnetic moment $8 \times 10^{22}\ JT$ located at its centre. Check the order of magnitude of this number in some way.

Answer:

Magnetic field

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

substituting the values

$$R = 6.4 \times 10^6 m$$

$$\mu_0 = 4\pi \times 10^{-7}$$

$$M = 8 \times 10^{22}\ JT^{-1}$$

then

$$B = 0.3G$$

5.1 (f) Answer the following questions regarding earth's magnetism

Geologists claim that besides the main magnetic N-S poles, there are several local poles on the earth's surface oriented in different directions. How is such a thing possible at all?

Answer:

This may be possible due to the presence of minerals which are magnetic in nature.

5.2 (a) Answer the following questions

The earth's magnetic field varies from point to point in space. Does it also change with time? If so, on what time scale does it change appreciably?

Answer:

Due to the constant but slow motion of the plates and change in the core, magnetic field due to Earth may change with time too. The time scale is in centuries for appreciable change.

5.2 (b) Answer the following questions

The earth's core is known to contain iron. Yet geologists do not regard this as a source of the earth's magnetism. Why?

Answer:

The iron present in the core of the Earth is in the molten form. Hence it loses it ferromagnetism and not regarded by geologists as a source of earth's magnetism.

5.2 (c) Answer the following questions

The charged currents in the outer conducting regions of the earth's core are thought to be responsible for earth's magnetism. What might be the 'battery' (i.e., the source of energy) to sustain these currents?

Answer:

The radioactive materials might be the battery to sustain such currents.

5.2 (d) Answer the following questions

The earth may have even reversed the direction of its field several times during its history of 4 to 5 billion years. How can geologists know about the earth's field in such distant past?

Answer:

The direction of the earth's magnetic field was recorded in rocks during solidification. By studying them, geologists can tell if the direction of the field had reversed.

5.2 (e) Answer the following questions

The earth's field departs from its dipole shape substantially at large distances (greater than about 30,000 km). What agencies may be responsible for this distortion?

Answer:

The earth's field departs from its dipole shape substantially at large distances (greater than about 30,000 km) due to the presence of ions in the ionosphere. These ions in motion generate magnetic field and hence distort the shape of a magnetic dipole.

5.2 (f) Answer the following questions

Interstellar space has an extremely weak magnetic field of the order of 10^{-12}. Can such a weak field be of any significant consequence? Explain.

Answer:

This weak magnetic field can affect the motion of a charged particle in a circular motion. And a small deviation from its path in the vast interstellar space may have huge consequences.

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

Answer:

Given,

The angle between axis of bar magnet and external magnetic field, θ = 30°

Magnetic field strength, B = 0.25 T

Torque on the bar magnet, T = 4.5 x 10^{-2}J

We know,

Torque experienced by a bar magnet placed in a uniform magnetic field is:

T = m x B = mBsin θ

$$m = \frac{T}{Bsin\theta}$$

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

∴ m = 0.36 JT^{-1}

Hence, the magnitude of the moment of the Bar magnet is 0.36 JT^{-1}.

5.4. A short bar magnet of magnetic moment $m = 32JT^{-1}$ 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?

Answer:

Given,

Magnetic moment of magnet, m = 0.32 JT^{-1}

Magnetic field strength, B = 0.15 T

(a) Stable equilibrium: When the magnetic moment is along the magnetic field i.e. θ = 0°

(b) Unstable equilibrium: When the magnetic moment is at 180° with the magnetic field i.e. θ = 180°

(c) We know that,

U = - m.B = -mBcosθ

By putting the given values:

U = (-0.32)(0.15)(cos 0°) = -0.048 J

Therefore, Potential energy of the system in stable equilibrium is -0.048 J

Similarly,

U = (-0.32)(0.15)(cos 180°) = 0.048 J

Therefore, Potential energy of the system in unstable equilibrium is 0.048J.

5.5 A closely wound solenoid of 800 turns and area of cross section $2.5 \times 10^{-4} m^2$ carries a current of 3.0 A. Explain the sense in which the solenoid acts like a bar magnet. What is its associated magnetic moment?

Answer:

In this case the magnetic field is generated along the axis / length of solenoid so it acts as a magnetic bar.

The magnetic moment is calculated as :-

$$M = N\,I\,A$$

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

or $= 0.6\,JT^{-1}$

5.6. If the solenoid in Exercise 5.5 is free to turn about the vertical direction and a uniform horizontal magnetic field of 0.25 T is applied, what is the magnitude of torque on the solenoid when its axis makes an angle of 30° with the direction of applied field?

Answer:

Given,

Magnetic field strength, B = 0.25 T

Magnetic moment, m = 0.6 JT^{-1}

The angle between the axis of the solenoid and the direction of the applied field, θ = 30°.

We know, the torque acting on the solenoid is:

τ = m x B = mBsinθ
= (0.6 JT^{-1})(0.25 T)(sin 30°)

= 0.075 J
= 7.5 x 10^{-2} J

The magnitude of torque is 7.5 x 10^{-2} J.

5.7 a)A bar magnet of magnetic moment 1.5 JT^{-1} lies aligned with the direction of a uniform magnetic field of 0.22 T.
What is the amount of work required by an external torque to turn the magnet so as to align its magnetic moment: (i) normal to the field direction

Answer:

Given.

Magnetic moment, M= 1.5 JT^{-1}

Magnetic field strength, B= 0.22 T

Now,

The initial angle between the axis and the magnetic field, θ_1= 0°

Final angle, θ_2= 90°

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

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

$$\Rightarrow W = -(1.5)(0.22)(cos90° - cos0°) = -0.33(0 - 1)$$

= 0.33 J

5.7 (a)

ii) A bar magnet of magnetic moment 1.5T JT^{-1} lies aligned with the direction of a uniform magnetic field of 0.22 T.
What is the amount of work required by an external torque to turn the magnet so as to align its magnetic moment opposite to the field direction?

Answer:

The amount of work required for the given condition will be:-

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

$$W = -MB[cos\,180° - cos\,0°$$

or $= 2MB$

or $= 2 \times 1.5 \times 0.22$

or $= 0.66\,J$

5.7 (b) A bar magnet of magnetic moment 1.5 JT^{-1} lies aligned with the direction of a uniform magnetic field of 0.22 T. What is the torque on the magnet in cases (i) and (ii)?

Answer:

For case (i):

$\theta = \theta_2 = 90°$

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

$$= (1.5)(0.22) sin\,90°$$

= 0.33 J

For case (ii):

$\theta = \theta_2 = 180°$

We know, Torque,

$$\tau = M\,B\,sin\theta$$

$$= (1.5)(0.22) sin\,180°$$

= 0

5.8 (a) A closely wound solenoid of 2000 turns 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. What is the magnetic moment associated with the solenoid?

Answer:

Given,

Number of turns, N = 2000

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

Current in the solenoid, I = 4 A

We know, The magnetic moment along the axis of the solenoid is:

m = NIA

= (2000)(4 A)(1.6 x 10^{-4} m^2)

= 1.28 Am^2

5.8 (b) A closely wound solenoid of 2000 turns 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.

(b) What is the force and torque on the solenoid if a uniform horizontal magnetic field of $7.5 \times 10^{-2} T$ is set up at an angle of 30° with the axis of the solenoid?

Answer:

Now,

Magnetic field strength, B = $7.5 \times 10^{-2} T$

The angle between the magnetic field and the axis of the solenoid, θ = 30°

Now, As the Magnetic field is uniform, the Force is zero

Also, we know,

τ = mxB = mBsinθ

= (1.28 JT^{-1})($7.5 \times 10^{-2} T$)(sin 30°)

= 4.8 x 10^{-2} J

Therefore, Force on the solenoid = 0 and torque on the solenoid = 4.8 x 10^{-2} J

5.9.A circular coil of 16 turns and radius 10 cm carrying a current of 0.75 A rests with its plane normal to an external field of magnitude 5.0×10^{-2} The coil is free to turn about an axis in its plane perpendicular to the field direction. 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:

Given,

Number of turns, N = 16

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

Current in the coil, I = 0.75 A

Magnetic field strength, B = 5.0 x 10^{-2} T

Frequency of oscillations of the coil, f = 2.0 s^{-1}

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

We know, Magnetic moment, m = NIA

= (16)(0.75 A)($\pi \times (0.1)^2 m^2$)

= 0.377 JT^{-1}

We know, frequency of oscillation in a magnetic field is:

$f = 1/2\pi\sqrt{\frac{MB}{I}}$ (I = Moment of Inertia of the coil)

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

$\Rightarrow I = \frac{0.377\times5\times10^{-2}}{4\pi^2 2^2}$

$$I = 1.19 \times 10^{-4}\ kgm^2$$

The moment of inertia of the coil about its axis of rotation is $1.19 \times 10^{-4}\ kgm^2$

5.10. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip pointing down at 22° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.35 G. Determine the magnitude of the earth's magnetic field at the place.

Answer:

Given,

The horizontal component of earth's magnetic field, B_H = 0.35 G

Angle made by the needle with the horizontal plane at the place = Angle of dip = δ = 22°

We know, B_H = B cosδ, where B is earth's magnetic field

B = B_H/cosδ = 0.35/(cos22°) = 0.377 G

The earth's magnetic field strength at the place is 0.377 G.

5.11. At a certain location 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. 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.

Answer:

Given,

The horizontal component of earth's magnetic field, B_H = 0.16 G

The angle of declination, θ = 12°

The angle of dip, δ = 60°

We know, B_H = B cosδ , where B is Earth's magnetic field

B = B_H/cosδ = 0.16/(cos 60°) = 0.32 G

Earth's magnetic field is 0.32 G in magnitude lying in the vertical plane, 12° west of the geographic meridian and 60° above the horizontal.

5.12 (a). A short bar magnet has a magnetic moment of $0.48\ JT^{-1}$. Give the direction and magnitude of the magnetic field produced by the magnet at a distance of 10 cm from the centre of the magnet on the axis,

Answer:

Given,

The magnetic moment of the bar magnet, m = 0.48 JT^{-1}

Distance from the centre, d = 10 cm = 0.1 m

We know, The magnetic field at distance d, from the centre of the magnet on the axis is:

$$B = \frac{\mu_0 m}{2\pi r^3}$$

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

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

Therefore, the magnetic field on the axis, B = 0.96 G

Note: The magnetic field is along the S–N direction (like a dipole!).

5. 12 (b). A short bar magnet has a magnetic moment of 0.48 JT^{-1} Give the direction and magnitude of the magnetic field produced by the magnet at a distance of 10 cm from the centre of the magnet on the equatorial lines (normal bisector) of the magnet.

Answer:

On the equatorial axis,

Distance,d = 10cm = 0.1 m

We know, the magnetic field due to a bar magnet along the equator is:

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

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

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

Therefore, the magnetic field on the equatorial axis, B = 0.48 G

The negative sign implies that the magnetic field is along the N–S direction.

5.13).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 at the place is 0.36 G and the angle 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 points, field due to a magnet is equal and opposite to the horizontal component of earth's magnetic field.)

Answer:

Earth's magnetic field at the given place, B = 0.36 G

The magnetic field at a distance d from the centre of the magnet on its **axis** is:

$$B = \mu_0 m/2\pi d^3$$

And the magnetic field at a distance d' from the centre of the magnet on the **normal bisector** is:

$$B' = \mu_0 m/4\pi d^3$$

= B/2 (since d' = d, i.e same distance of null points.)

Hence the total magnetic field is B + B' = B + B/2 = (0.36 + 0.18) G = 0.54 G

Therefore, the magnetic field in the direction of earth's magnetic field is 0.54 G.

5.14. If the bar magnet in exercise 5.13 is turned around by 180°, where will the new null points be located?

Answer:

Given, d = 14 cm

The magnetic field at a distance d from the centre of the magnet on its **axis**:

$$B = \mu_0 m/2\pi d^3$$

If the bar magnet is turned through 180°, then the neutral point will lie on the equatorial (perpendicular bisector) line.

The magnetic field at a distance d' from the centre of the magnet on the normal bisector is:

$$B = \mu_0 m/4\pi d'^3$$

Equating these two, we get:

$$\frac{1}{2d^3} = 1/4d'^3$$

$$\Rightarrow \frac{d'^3}{d^3} = \frac{1}{2}$$

d' = 14 x 0.794 = 11.1cm

The new null points will be at a distance of 11.1 cm on the normal bisector.

5.15 (a). A short bar magnet of magnetic movement $5.25 \times 10^{-2}\ JT^{-1}$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 its normal bisector

Answer:

Given,

The magnetic moment of the bar magnet, $m = 5.25 \times 10^{-2}\ JT^{-1}$

The magnitude of earth's magnetic field at a place, $H = 0.42G = 0.42 \times 10^{-4}T$

The magnetic field at a distance R from the centre of the magnet on the normal bisector is:

$$B = \mu_0 m/4\pi R^3$$

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

$$B = H = 0.42 \times 10^{-4}T$$

$$R^3 = \mu_0 m/4\pi B = 4\pi \times 10^{-7} \times 5.25 \times 10^{-2}/4\pi \times 0.42 \times 10^{-4}$$

Therefore, R = 0.05 m = 5 cm

5.15 (b).A short bar magnet of magnetic movement $5.25 \times 10^{-2}\ JT^{-1}$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 its axis. The magnitude of the earth's field at the place is given to be 0.42 G. Ignore the length of the magnet in comparison to the distances involved.

Answer:

The magnetic field at a distance R from the centre of the magnet on its **axis**:

$$B = \mu_0 m/2\pi R^3$$

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

$$R^3 = \mu_0 m/2\pi B = 4\pi \times 10^{-7} \times 10^{-2}/2\pi \times 0.42 \times 10^{-4} = 25 \times 10^{-5} m^3$$

Therefore, R = 0.063 m = 6.3 cm

5.16 Answer the following questions

(a). Why does a paramagnetic sample display greater magnetisation (for the same magnetising field) when cooled?

Answer:

At high temperatures, alignment of dipoles gets disturbed due to the random thermal motion of molecules in a paramagnetic sample. But when cooled, this random thermal motion reduces. Hence, a paramagnetic sample displays greater magnetization when cooled.

5.16 Answer the following questions

(b). Why is diamagnetism, in contrast, almost independent of temperature?

Answer:

The magnetism in a diamagnetic substance is due to induced dipole moment. So the random thermal motion of the atoms does not affect it which is dependent on temperature. Hence diamagnetism is almost independent of temperature.

5.16 Answer the following questions

(c). If a toroid uses bismuth for its core, will the field in the core be (slightly) greater or (slightly) less than when the core is empty?

Answer:

A toroid using bismuth for its core will have slightly greater magnetic field than a toroid with an empty core because bismuth is a diamagnetic substance.

5. 16 (d). Is the permeability of a ferromagnetic material independent of the magnetic field? If not, is it more for lower or higher fields?

Answer:

We know that the permeability of ferromagnetic materials is inversely proportional to the applied magnetic field. Therefore it is more for a lower field.

5. 16 (e). Magnetic field lines are always nearly normal to the surface of a ferromagnet at every point. (This fact is analogous to the static electric field lines being normal to the surface of a conductor at every point.) Why?

Answer:

Since the permeability of ferromagnetic material is always greater than one, the magnetic field lines are always nearly normal to the surface of ferromagnetic materials at every point.

5.16 (f). Would the maximum possible magnetisation of a paramagnetic sample be of the same order of magnitude as the magnetisation of a ferromagnet?

Answer:

Yes, the maximum possible magnetisation of a paramagnetic sample will be of the same order of magnitude as the magnetisation of a ferromagnet for very strong magnetic fields.

5.17 (a). Explain qualitatively on the basis of domain picture the irreversibility in the magnetisation curve of a ferromagnet.

Answer:

According to the graph between B (external magnetic field) and H (magnetic intensity) in ferromagnetic materials, magnetization persists even when the external field is removed. This shows the irreversibility of magnetization in a ferromagnet.

5.17 (b). The hysteresis loop of a soft iron piece has a much smaller area than that of a carbon steel piece. If the material is to go through repeated cycles of magnetisation, which piece will dissipate greater heat energy?

Answer:

Material that has a greater area of hysteresis loop will dissipate more heat energy. Hence after going through repeated cycles of magnetization, a carbon steel piece dissipates greater heat energy than a soft iron piece, as the carbon steel piece has a greater hysteresis curve area.

5.17 (c)'A system displaying a hysteresis loop such as a ferromagnet, is a device for storing memory?' Explain the meaning of this statement.

Answer:

Ferromagnets have a record of memory of the magnetisation cycle. Hence it can be used to store memories.

5.17 (d). What kind of ferromagnetic material is used for coating magnetic tapes in a cassette player, or for building 'memory stores' in a modern computer?

Answer:

Ceramic, a ferromagnetic material is used for coating magnetic tapes in a cassette player, or for building 'memory stores' in a modern computer.

5.17(e).A certain region of space is to be shielded from magnetic fields. Suggest a method.

Answer:

The region can be surrounded by a coil made of soft iron to shield from magnetic fields.

5.18. 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 geographic 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 points (ignore the thickness of the cable)? (At neutral points, magnetic field due to a current-carrying cable is equal and opposite to the horizontal component of earth's magnetic field.)

Answer:

Given,

Current in the cable, I = 2.5 A

Earth's magnetic field at the location, H = 0.33 G = 0.33×10^{-4}T

The angle of dip, $\delta = 0$

Let the distance of the line of the neutral point from the horizontal cable = r m.

The magnetic field at the neutral point due to current carrying cable is:

$H_n = \mu_0 I/2\pi r$,

We know, Horizontal component of earth's magnetic field, $H_E = H\ cos\ \delta$

Also, at neutral points, $H_E = H_n$

$$\Rightarrow H\ cos\delta = \mu_0 I/2\pi r$$

$$\Rightarrow 0.33 \times 10^{-4} T\ cos\ 0° = \frac{4\pi \times 10^{-7} \times 2.5}{2\pi r}$$

$\Rightarrow r = 1.515\ cm$

Required distance is 1.515 cm.

5.19 A telephone cable at a place has four long straight horizontal wires carrying a current of 1.0 A in the same direction east to west. The earth's magnetic field at the place is 0.39 G, and the angle of dip is 35°. The magnetic declination is nearly zero. What are the resultant magnetic fields at points 4.0 cm below the cable?

Answer:

Number of long straight horizontal wires = 4

The current carried by each wire = 1A

earth's magnetic field at the place = 0.39 G

the angle of dip = 35^0

magnetic field due to infinite current-carrying straight wire

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

r=4cm =0.04 m

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

magnetic field due to such 4 wiresi8

$$B = 4 \times \frac{4\pi \times 10^{-7} \times 1}{2\pi \times 4 \times 10^{-2}} = 2 \times 10^{-5} T$$

The horizontal component of the earth's magnetic field

$$H = 0.39 \times 10^{-4} \cos 35 = 0.319 \times 10^{-4} T = 3.19 \times 10^{-5} T$$

the horizontal component of the earth's magnetic field

$$V = 0.39 \times 10^{-4} \sin 35 = 0.22 \times 10^{-4} T = 2.2 \times 10^{-5} T$$

At the point below the cable

$$H' = H - B = 3.19 \times 10^{-5} - 2 \times 10^{-5} = 1.19 \times 10^{-5} T$$

The resulting field is

$$\sqrt{H^2 + V^2} = \sqrt{(1.19 \times 10^{-5})^2 + (2.2 \times 10^{-5})^2} = 2.5 \times 10^{-5} T = 0.25 G$$

5.20(a). A compass needle free to turn in a horizontal plane is placed at the centre of circular coil of 30 turns and radius 12 cm. The coil is in a vertical plane making an angle of 45° with the magnetic meridian. When the current in the coil is 0.35 A, the needle points west to east. Determine the horizontal component of the earth's magnetic field at the location.

Answer:

Given,

Number of turns in the coil, n = 30

Radius of coil, r = 12cm = 0.12m

Current in the coil, I = 0.35A

The angle of dip, δ = 45°

We know, Magnetic fields due to current carrying coils, B = $\mu_0 nI/2r$

$$B = 4\pi \times 10^{-7} \times 30 \times \frac{0.35}{2} \times 0.12$$

$$= 5.49 \times 10^{-5} T$$

Now, Horizontal component of the earth's magnetic field = Bsin δ

$$= 5.49 \times 10^{-} T \sin 45°$$

$= 3.88 \times 10^{-5}$ (Hint: Take sin45° as 0.7)

$$= 0.388G$$

5.20 (b).A compass needle free to turn in a horizontal plane is placed at the centre of circular coil of 30 turns and radius 12 cm. The coil is in a vertical plane making an angle of 45° with the magnetic meridian. When the current in the coil is 0.35 A, the needle points west to east. The current in the coil is reversed, and the coil is rotated about its vertical axis by an angle of 90° in the anticlockwise sense looking from above. Predict the direction of the needle. Take the magnetic declination at the places to be zero.

Answer:

When the current in the coil is reversed and the coil is rotated about its vertical axis by an angle of 90° in the anticlockwise sense looking from above, then the needle will reverse its direction. The new direction will be from east to west.

5.21. A magnetic dipole is under the influence of two magnetic fields. The angle between the field directions is 60°, and one of the fields has a magnitude of 1.2×10^{-2} T. If the dipole comes to stable equilibrium at an angle of 15° with this field, what is the magnitude of the other field?

Answer:

Given,

The magnitude of the first magnetic field, $B_1 = 1.2 \times 10^{-2}$ T

The angle between the magnetic field directions, $\theta = 60°$

The angle between the dipole and the magnetic field B_1 is $\theta_1 = 15°$

Let B_2 be the magnitude of the second magnetic field and M be the magnetic dipole moment

Therefore, the angle between the dipole and the magnetic field B_2 is $\theta_2 = \theta - \theta_1 = 45°$

Now, at rotational equilibrium,

The torque due to field B_1 = Torque due to field B_2

$$MB_1 sin\,\theta_1 = MB_2 sin\theta_2$$

$$B_2 = \frac{MB_1\,sin\,\theta_1}{M\,sin\,\theta_2} = \frac{1.2\times10^{-2}\times sin15°}{sin\,45°}$$

$$= 4.39 \times 10^{-3} T$$

Hence the magnitude of the second magnetic field $4.39 \times 10^{-3} T$

5.22) A monoenergetic (18 keV) electron beam initially in the horizontal direction is subjected to a horizontal magnetic field of 0.04 G normal to the initial direction. Estimate the up or down deflection of the beam over a distance of 30 cm ($m_e = 9.11 \times 10^{-31} Kg$). [Note: Data in this exercise are so chosen that the answer will give you an idea of the effect of earth's magnetic field on the motion of the electron beam from the electron gun to the screen in a TV set.]

Answer:

The energy of electron beam = 18 eV

We can write:-

$$E = \frac{1}{2}mv^2$$

so $$v = \sqrt{\frac{2E}{M}}$$

We are given horizontal magentic field : B = 0.40 G

Also, $$Bev = \frac{mv^2}{r}$$

We obtain, $$r = \frac{1}{B_e}\sqrt{2EM}$$

or $$r = 11.3\ m$$

Using geometry, we can write :-

$$sin\ \theta = \frac{x}{r} = \frac{0.3}{11.3}$$

and $$y = r - r\ cos\theta$$

or $$= r - cos\ \theta$$

or $$y \approx 4mm$$

5.23. A sample of paramagnetic salt contains 2.0×10^{24}atomic dipoles each of dipole moment $1.5 \times 10^{-23}\ JT^{-1}$ The sample is placed under a homogeneous magnetic field of 0.64 T, and cooled to a temperature of 4.2 K. The degree of magnetic saturation achieved is equal to 15%. What is the total dipole moment of the sample for a magnetic field of 0.98 T and a temperature of 2.8 K? (Assume Curie's law)

Answer:

Given,

Magnetic field, B_1 = 0.64 T

Temperature, θ_1 = 4.2K

And, saturation = 15%

Hence, Effective dipole moment, M_1 = 15% of Total dipole moment

M_1 = 0.15 x (no. of atomic dipole × individual dipole moment)

$$M_1 = 0.15 \times 2 \times 10^{24} \times 1.5 \times 10^{-23} = 4.5\ JT^{-1}$$

Now, Magnetic field, B_2 = 0.98 T and Temperature, θ_1 = 2.8 K

Let M_2 be the new dipole moment.

We know that according to Curie's Law, $M \propto \frac{B}{\theta}$

∴ The ratio of magnetic dipole moments

$\frac{M_2}{M_1} = \frac{B_2 \times \theta_1}{B_1 \times \theta_1}$

$$\Rightarrow M_2 = \frac{B_2 \times \theta_1}{B_1 \times \theta_1} \times M_1$$

$$\Rightarrow M_2 = \frac{098T \times 4.2K}{0.64T \times 2.8K} \times 4.5\, JT^{-1}$$

$$= 10.336\, JT^{-1}$$

Therefore, the total dipole moment of the sample for a magnetic field of 0.98 T and a temperature of 2.8 K = 10.336 JT^{-1}

5.24. A Rowland ring of mean radius 15 cm has 3500 turns of wire wound on a ferromagnetic core of relative permeability 800. What is the magnetic field B in the core for a magnetising current of 1.2 A?

Answer:

Given,

Radius of ring, r = 15cm = 0.15m

Number of turns in the ring, n = 3500

Relative permeability of the ferromagnetic core, μ_r = 800

Current in the Rowland ring, I = 1.2A

We know,

Magnetic Field due to a circular coil, B $= \frac{\mu_r \mu_0 nI}{2\pi r}$

∴ B = $\frac{4\pi \times 10^{-7} \times 800 \times 3500 \times 1.2}{2\pi \times 0.15}$ = 4.48T

Therefore, the magnetic field B in the core for a magnetising current is 4.48 T

5.25) The magnetic moment vectors μ_s and μ_l associated with the intrinsic spin angular momentum S and orbital angular momentum l, respectively, of an electron, are predicted by quantum theory (and verified experimentally to a high accuracy) to be given by:

$$\mu_s = -(e/m)S$$

$$\mu_l = -(e/2m)l$$

Which of these relations is in accordance with the result expected classically? Outline the derivation of the classical result.

Answer:

We know,

$\mu_l = -\left(\frac{e}{2m}\right) l$

∴ $\mu_l = -\left(\frac{e}{2m}\right) l$ is in expected from classical physics.

Now, Magnetic moment associated with the orbital motion of the electron is:

μ_l = Current x Area covered by orbit = I x A

$$= \left(\frac{e}{T}\right)\pi r^2$$

And, l = angular momentum = mvr

$$= m\left(\frac{2\pi r}{T}\right)r$$

(m is the mass of the electron having charge (-e), r is the radius of the orbit of by the electron around the nucleus and T is the time period.)

Dividing these two equations:

$$\frac{\mu_l}{l} = -\frac{e}{T}\pi r^2 \times \frac{T}{m \times 2\pi r^2} = \frac{e}{2m}$$

$\mu_l = \left(-\frac{e}{2m}\right) l$, which is the same result predicted by quantum theory.

The negative sign implies that μ_l and l are anti-parallel.