The vertical component of earth's magnetic field is given as:

H_v = Hsinδ

= 0.39 sin 35° = 0.22 G

The angle made by the field with its horizontal component is given as:

$$\theta = \tan^{-1}\frac{H_v}{H_h}$$

$$= \tan^{-1}\frac{0.22}{0.12} = 61.39°$$

The resultant field at the point is given as:

$$H_1 = \sqrt{(H_v)^2 + (H_h)^2}$$

$$= \sqrt{(0.22)^2 + (0.12)^2} = 0.25 \text{ G}$$

For a point 4 cm above the cable:

Horizontal component of earth's magnetic field:

H_h = Hcosδ + B

= 0.39 cos 35° + 0.2 = 0.52 G

Vertical component of earth's magnetic field:

H_v = Hsinδ

= 0.39 sin 35° = 0.22 G

Angle, $\theta = \tan^{-1}\frac{H_v}{H_h} = \tan^{-1}\frac{0.22}{0.52}$ = 22.9°

And resultant field:

$$H_2 = \sqrt{(H_v)^2 + (H_h)^2}$$

$$= \sqrt{(0.22)^2 + (0.52)^2} = 0.56 \text{ T}$$

Question 5.20:

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 45º with the magnetic meridian. When the current in the coil is 0.35 A, the needle points west to east.

(a) Determine the horizontal component of the earth's magnetic field at the location.

(b) The current in the coil is reversed, and the coil is rotated about its vertical axis by an angle of 90º in the anticlockwise sense looking from above. Predict the direction of the needle. Take the magnetic declination at the places to be zero.

Answer

Number of turns in the circular coil, $N = 30$

Radius of the circular coil, $r = 12$ cm $= 0.12$ m

Current in the coil, $I = 0.35$ A

Angle of dip, $\delta = 45°$

(a) The magnetic field due to current I, at a distance r, is given as:

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

Where,

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

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

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

The compass needle points from West to East. Hence, the horizontal component of earth's magnetic field is given as:

$B_H = B\sin\delta$

$= 5.49 \times 10^{-5} \sin 45° = 3.88 \times 10^{-5}$ T $= 0.388$ G

(b) When the current in the coil is reversed and the coil is rotated about its vertical axis by an angle of 90 º, the needle will reverse its original direction. In this case, the needle will point from East to West.

Question 5.21:

A magnetic dipole is under the influence of two magnetic fields. The angle between the field directions is 60º, 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 15º with this field, what is the magnitude of the other field?

Answer

Magnitude of one of the magnetic fields, $B_1 = 1.2 \times 10^{-2}$ T

Magnitude of the other magnetic field $= B_2$

Angle between the two fields, $\theta = 60°$

At stable equilibrium, the angle between the dipole and field B_1, $\theta_1 = 15°$

Angle between the dipole and field B_2, $\theta_2 = \theta - \theta_1 = 60° - 15° = 45°$

At rotational equilibrium, the torques between both the fields must balance each other

∴Torque due to field B_1 = Torque due to field B_2

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

Where,

M = Magnetic moment of the dipole

$$\therefore B_2 = \frac{B_1 \sin\theta_1}{\sin\theta_2}$$

$$= \frac{1.2 \times 10^{-2} \times \sin 15°}{\sin 45°} = 4.39 \times 10^{-3} \text{ T}$$

Hence, the magnitude of the other magnetic field is 4.39×10^{-3} T.

Question 5.22:

A monoenergetic (18 keV) electron beam initially in the horizontal direction is subjecte to a horizontal magnetic field of 0.04 G normal to the initial direction. Estimate the up down deflection of the beam over a distance of 30 cm (m_e= 9.11×10^{-19} C). [**Note:** *Data* in this exercise are so chosen that the answer will give you an idea of the effect c earth's magnetic field on the motion of the electron beam from the electron gun to the screen in a TV set.]

Answer

Energy of an electron beam, $E = 18$ keV $= 18 \times 10^3$ eV

Charge on an electron, $e = 1.6 \times 10^{-19}$ C

$E = 18 \times 10^3 \times 1.6 \times 10^{-19}$ J

Magnetic field, $B = 0.04$ G

Mass of an electron, $m_e = 9.11 \times 10^{-19}$ kg

Distance up to which the electron beam travels, $d = 30$ cm $= 0.3$ m

We can write the kinetic energy of the electron beam as:

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

$$v = \sqrt{\frac{2E}{m}}$$

$$= \sqrt{\frac{2 \times 18 \times 10^3 \times 1.6 \times 10^{-19} \times 10^{-15}}{9.11 \times 10^{-31}}} = 0.795 \times 10^8 \text{ m/s}$$

The electron beam deflects along a circular path of radius, *r*.

The force due to the magnetic field balances the centripetal force of the path.

$$BeV = \frac{mv^2}{r}$$

$$\therefore r = \frac{mv}{Be}$$

$$= \frac{9.11 \times 10^{-31} \times 0.795 \times 10^8}{0.4 \times 10^{-4} \times 1.6 \times 10^{-19}} = 11.3 \text{ m}$$

Let the up and down deflection of the electron beam be $x = r(1 - \cos\theta)$

Where,

θ = Angle of declination

$$\sin\theta = \frac{d}{r}$$

$$= \frac{0.3}{11.3}$$

$$\theta = \sin^{-1}\frac{0.3}{11.3} = 1.521°$$

$$\text{And } x = 11.3(1 - \cos 1.521°)$$

$$= 0.0039 \text{ m} = 3.9 \text{ mm}$$

Therefore, the up and down deflection of the beam is 3.9 mm.

Question 5.23:

A sample of paramagnetic salt contains 2.0×10^{24} atomic dipoles each of dipole moment 1.5×10^{-23} J T^{-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

Number of atomic dipoles, $n = 2.0 \times 10^{24}$

Dipole moment of each atomic dipole, $M = 1.5 \times 10^{-23}$ J T^{-1}

When the magnetic field, $B_1 = 0.64$ T

The sample is cooled to a temperature, $T_1 = 4.2°$K

Total dipole moment of the atomic dipole, $M_{tot} = n \times M$

$= 2 \times 10^{24} \times 1.5 \times 10^{-23}$

$= 30$ J T^{-1}

Magnetic saturation is achieved at 15%.

Hence, effective dipole moment, $M_1 = \frac{15}{100} \times 30 = 4.5 \text{ J T}^{-1}$

When the magnetic field, $B_2 = 0.98$ T

Temperature, $T_2 = 2.8°$K

Its total dipole moment = M_2

According to Curie's law, we have the ratio of two magnetic dipoles as:

$$\frac{M_2}{M_1} = \frac{B_2}{B_1} \times \frac{T_1}{T_2}$$

$$\therefore M_2 = \frac{B_2 T_1 M_1}{B_1 T_2}$$

$$= \frac{0.98 \times 4.2 \times 4.5}{2.8 \times 0.64} = 10.336 \text{ J T}^{-1}$$

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

Question 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

Mean radius of a Rowland ring, r = 15 cm = 0.15 m

Number of turns on a ferromagnetic core, N = 3500

Relative permeability of the core material, $\mu_r = 800$

Magnetising current, I = 1.2 A

The magnetic field is given by the relation:

$$B = \frac{\mu_r \mu_0 IN}{2\pi r}$$

Where,

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

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

Therefore, the magnetic field in the core is 4.48 T.

Question 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

The magnetic moment associated with the intrinsic spin angular momentum ( ) is given as

The magnetic moment associated with the orbital angular momentum ( ) is given as

For current *i* and area of cross-section *A*, we have the relation:

Where,

e = Charge of the electron

r = Radius of the circular orbit

T = Time taken to complete one rotation around the circular orbit of radius *r*

Angular momentum, *l* = *mvr*

Where,

m = Mass of the electron

v = Velocity of the electron

Dividing equation (1) by equation (2), we get:

Therefore, of the two relations, is in accordance with classical physics.

*********** END **********