

Chapter 4: Moving Charges and Magnetism

NCERT · Class 12 · Physics

Questions

Question 4.13

(a) A circular coil having a radius of 8.0 cm, the number of turns as 30 and carrying a current of 6.0 A is suspended vertically in a uniform horizontal magnetic field of magnitude 1.0 T. The field lines make an angle of 60° with the normal of the coil. To prevent the coil from turning, determine the magnitude of the counter-torque that must be applied.

(b) Would your answer change, if the circular coil in (a) were replaced by a planar coil of some irregular shape that encloses the same area? (All other particulars are also unaltered.)

Answer 4.13:

(a) Number of turns on the circular coil (n) = 30

Radius of the coil (r) = 8.0 cm = 0.08 m

Area of the coil =

$$\pi r^2 = \pi (0.08)^2 = 0.0201 \text{ m}^2$$

Current flowing in the coil (I) = 6.0 A

Magnetic field strength, $B = 1 \text{ T}$

The angle between the field lines and normal with the coil surface,

$$\theta = 60^\circ$$

The coil experiences a torque in the magnetic field. Hence, it turns. The counter torque applied to prevent the coil from turning is given by the relation,

$$\tau = nIBA \sin\theta$$

=

$$30 \times 6 \times 1 \times 0.0201 \times \sin 60^\circ$$

$$= 3.133 \text{ N m}$$

(b) It can be inferred from the relation

$$\tau = nIBA \sin\theta$$

Q 4.14) Two concentric circular coils, X and Y, of radii 16 cm and 10 cm, respectively, lie in the same vertical plane containing the north-to-south direction. Coil X has 20 turns and carries a current of 16 A; coil Y has 25 turns and carries a current of 18 A. The sense of the current in X is anticlockwise and clockwise in Y for an observer looking at the coils facing west. Give the magnitude and direction of the net magnetic field due to the coils at their centre.

Solution

Radius of the coil X, $r_1 = 16 \text{ cm} = 0.16 \text{ m}$

Number of turns in coil X, $n_1 = 20$

Current in the coil X, $I_1 = 16 \text{ A}$

Radius of the coil Y, $r_2 = 10 \text{ cm} = 0.1 \text{ m}$

Number of turns in coil Y, $n_2 = 25$

Current in the coil Y, $I_2 = 18 \text{ A}$

The magnetic field due to the coil X at the centre is given as

$$B_1 = \frac{\mu_0 N_1 I_1}{2r_1}$$

Here, μ_0 is the permeability of the free space $= 4\pi \times 10^{-7} \text{ Tm/A}$

$$\begin{aligned} B_1 &= \frac{4\pi \times 10^{-7} \times 20 \times 16}{2 \times 0.16} \\ &= 4\pi \times 10^{-4} \text{ T (Towards east)} \end{aligned}$$

The magnetic field due to the coil Y at the centre is given as

$$\begin{aligned} B_2 &= \frac{\mu_0 N_2 I_2}{2r_2} \\ B_2 &= \frac{4\pi \times 10^{-7} \times 25 \times 18}{2 \times 0.10} \\ &= 9\pi \times 10^{-4} \text{ T (Towards west)} \end{aligned}$$

Therefore, the net magnetic field is given as

$$\begin{aligned} B &= B_2 - B_1 = 9\pi \times 10^{-4} \text{ T} - 4\pi \times 10^{-4} \text{ T} \\ &= 5\pi \times 10^{-4} \text{ T} \\ &= 5 \times 3.14 \times 10^{-4} \end{aligned}$$

$$= 1.57 \times 10^{-3} \text{ T (Towards west)}$$

Question 4.15

A magnetic field of 100 G ($1 \text{ G} = 10^{-4} \text{ T}$) is required, which is uniform in a region of linear dimension of about 10 cm and an area of cross-section of about 10^{-3} m^2 . The maximum current-carrying capacity of a given coil of wire is 15 A, and the number of turns per unit length that can be wound around a core is, at most, $1000 \text{ turns m}^{-1}$. Suggest some appropriate design particulars of a solenoid for the required purpose. Assume the core is not ferromagnetic.

Solution

Magnetic field strength, $B = 100 \text{ G} = 100 \times 10^{-4} \text{ T}$

Number of turns per unit length, $N = 1000 \text{ turns/m}$

Current carrying capacity of the coil = 15 A

Permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ TmA}^{-1}$

The magnetic field is given as

$$B = \mu_0 NI$$

$$\Rightarrow NI = B/\mu_0$$

$$= (100 \times 10^{-4})/(4\pi \times 10^{-7})$$

$$NI = 7961$$

Now, we can consider a possible combination. Let the current, $I = 10 \text{ A}$ and the length of the solenoid, $l = 0.5 \text{ m}$

So we get

$$(N \times 10)/0.5 = 7961$$

$$N = 398 \text{ turns} \approx 400 \text{ turns}$$

Length about 50 cm, number of turns about 400, current about 10 A. These particulars are not unique. Some adjustment with limits is possible.

Question 4.16

For a circular coil of radius R and N turns carrying current I , the magnitude of the magnetic field at a point on its axis at a distance x from its centre is given by,

$$B = \frac{\mu_0 I R^2 N}{2(x^2 + R^2)^{3/2}}$$

(a) Show that this reduces to the familiar result for the field at the centre of the coil.

(b) Consider two parallel co-axial circular coils of equal radius R and number of turns N , carrying equal currents in the same direction, and separated by a distance R . Show that the field on the axis around the mid-point between the coils is uniform over a distance that is small as compared to R , and is given by,

$$B = 0.72 \frac{\mu_0 N I}{R}$$

, approximately.

[Such an arrangement to produce a nearly uniform magnetic field over a small region is known as Helmholtz coils.]

Solution

(a) Given,

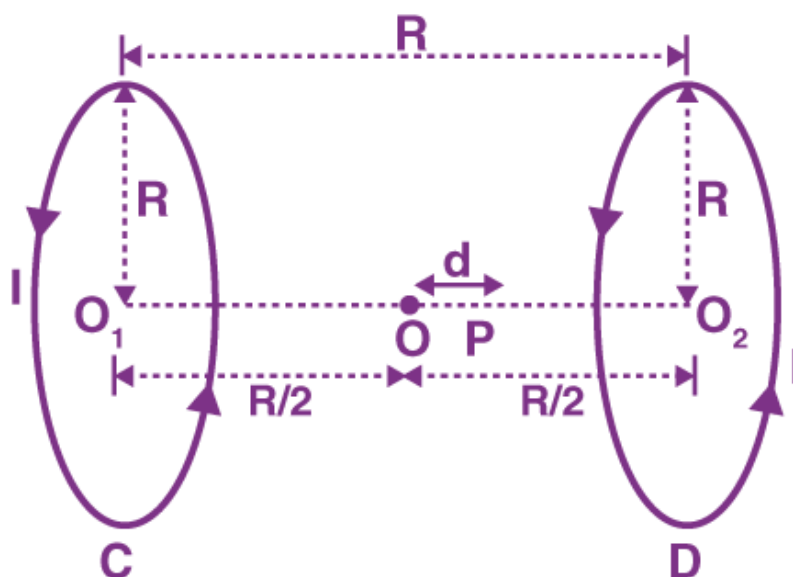
$$B = \frac{\mu_0 I R^2 N}{2(x^2 + R^2)^{3/2}}$$

At the centre of the coil, $x = 0$

Therefore, the magnetic field at the centre is

$$B = \frac{\mu_0 I R^2 N}{2R^3}$$

$$B = \frac{\mu_0 I N}{2R}$$



(b) Let the small distance between the points P and O be d.

For the coil C, the distance $O_1P = x_1 = (R/2) + d$

For the coil d, the distance $O_2P = x_2 = (R/2) - d$

The magnetic field on the axis at a distance x from the centre of the circular coil having a radius a, with n number of turns and having a current I is given by

$$B = \frac{\mu_0}{4\pi} \frac{2\pi n I a^2}{(x^2 + a^2)^{3/2}}$$

$$B = \frac{\mu_0}{2} \frac{n I a^2}{(x^2 + a^2)^{3/2}}$$

The magnetic field at P due to coil C

$$B_1 = \frac{\mu_0}{2} \frac{N I R^2}{(x_1^2 + R^2)^{3/2}}$$

$$B_1 = \frac{\mu_0}{2} \frac{N I R^2}{\left(\left(\frac{R}{2} + d\right)^2 + R^2\right)^{3/2}}$$

$$B_1 = \frac{\mu_0}{2} \frac{N I R^2}{\left(\left(\frac{R^2}{4} + d^2 + R d\right) + R^2\right)^{3/2}}$$

d^2 can be neglected when compared to R^2

$$B_1 = \frac{\mu_0 N I R^2}{2} \frac{1}{\left(\frac{5R^2}{4}\right)^{3/2}} \left[\left(1 + \frac{4d}{5R}\right)^{-3/2} \right]$$

It acts along PO_2

The magnetic field at P is given by

$$B_2 = \frac{\mu_0}{2} \frac{NIa^2}{(x_2^2 + R^2)^{3/2}}$$

$$B_2 = \frac{\mu_0}{2} \frac{NIR^2}{\left(\left(\frac{R}{2} - d\right)^2 + R^2\right)^{3/2}}$$

$$B_2 = \frac{\mu_0 NIR^2}{2} \frac{1}{\left(\frac{5R^2}{4}\right)^{3/2}} \left[\left(1 - \frac{4d}{5R}\right)^{-3/2} \right]$$

It acts along PO_2

The total Magnetic field at the point P due to the current through the coils $B = B_1 + B_2$

$$B = \frac{\mu_0 NIR^2}{2} \frac{1}{\left(\frac{5R^2}{4}\right)^{3/2}} \left[\left(1 + \frac{4d}{5R}\right)^{-3/2} + \left(1 - \frac{4d}{5R}\right)^{-3/2} \right]$$

$$B = \frac{\mu_0 NIR^2}{2\left(\frac{5R^2}{4}\right)^{3/2}} \left[1 - \frac{6d}{5R} + 1 + \frac{6d}{5R} \right]$$

$$B = \frac{\mu_0 NIR^2}{2\left(\frac{5R^2}{4}\right)^{3/2}} \times 2$$

$$B = \frac{\mu_0 NI}{R} \left(\frac{4}{5}\right)^{3/2}$$

$$B = (0.72) \frac{\mu_0 NI}{R}$$

Question 4.17

A toroid has a core (non-ferromagnetic) of inner radius 25 cm and outer radius 26 cm, around which 3500 turns of a wire are wound. If the current in the wire is 11 A, what is the magnetic field?

(a) outside the toroid, (b) inside the core of the toroid, and (c) in the empty space surrounded by the toroid.

Solution

The inner radius of the core, $r_1 = 25 \text{ cm} = 0.25 \text{ m}$

The outer radius of the core, $r_2 = 26 \text{ cm} = 0.26 \text{ m}$

Number of turns of the wire, $N = 3500$ turns

Current in the wire, $I = 11 \text{ A}$

(a) The magnetic field outside the toroid is zero.

(b) Inside the core of the toroid, the magnetic field induction is

$$B = \mu_0 NI / l$$

Mean length of the toroid,

$$l = 2\pi\left(\frac{r_1 + r_2}{2}\right) \\ = \pi(r_1 + r_2) = \pi(0.25 + 0.26) = \pi \times 0.51$$

So, $B = \mu_0 NI / l$

$$B = \frac{(4\pi \times 10^{-7}) \times 3500 \times 11}{\pi \times 0.51} = 3.02 \times 10^{-2} T$$

(c) The magnetic field in the empty space surrounded by the toroid is zero.

Question 4.18

Answer the following questions:

- (a) A magnetic field that varies in magnitude from point to point but has a constant direction (east to west) is set up in a chamber. A charged particle enters the chamber and travels undeflected along a straight path with constant speed. What can you say about the initial velocity of the particle?
- (b) A charged particle enters an environment of a strong and non-uniform magnetic field varying from point to point both in magnitude and direction and comes out of it following a complicated trajectory. Would its final speed equal the initial speed if it suffered no collisions with the environment?
- (c) An electron travelling west to east enters a chamber having a uniform electrostatic field in the north-to-south direction. Specify the direction in which a uniform magnetic field should be set up to prevent the electron from deflecting from its straight-line path.

Solution

- (a) Initial velocity is either parallel or antiparallel to the magnetic field. There is no magnetic force acting on the particle when it is parallel or antiparallel, and it moves undeflected.
- (b) Yes, because magnetic force can change the direction of velocity but not its magnitude.
- (c) Magnetic field should be in a vertically downward direction.

Question 4.19

An electron emitted by a heated cathode and accelerated through a potential difference of 2.0 kV enters a region with a uniform magnetic field of 0.15 T. Determine the trajectory of the electron if the field (a) is transverse to its initial velocity, (b) makes an angle of 30° with the initial velocity.

Solution

Magnetic field, $B = 0.15 \text{ T}$

Potential difference, $V = 2.0 \text{ kV}$

An electron gains kinetic energy, which is given by

$$E = (1/2) mv^2$$

$$eV = (1/2) mv^2$$

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

$$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^3}{9.1 \times 10^{-31}}} = 2.652 \times 10^7 \text{ m/s}$$

(a) When the field applied is transverse to the initial velocity, the force F_1 acting on the electron is perpendicular to the direction of the magnetic field and the direction of motion of the electron. The perpendicular force provides the centripetal force F_2 to the electron and makes it move in a circular path.

The forces F_1 and F_2 are equal

$$F_1 = evB$$

$$F_2 = mv^2/2r$$

$$F_1 = F_2$$

$$evB = mv^2/2r$$

$$\Rightarrow r = mv/eB$$

$$r = \frac{9.1 \times 10^{-31} \times 2.652 \times 10^7}{0.15 \times 1.6 \times 10^{-19}}$$

$$= 10^{-3} \text{ m} = 1 \text{ mm}$$

The electron will move in a circular path with a radius of 1 mm in the direction perpendicular to the magnetic field.

(b) The applied force is inclined to the initial velocity. The velocity of the electron is resolved into two components, $V \cos \theta$ and $V \sin \theta$. $V \cos \theta$ is along the direction of the field, and it causes the electron to move in a straight line. $V \sin \theta$ is along the normal, and it causes the electron to move in a circular path. Therefore, the electron moves in a helical path. The radius of the helical path is given as,

$$r = mV \sin \theta / Be$$

$$r = \frac{9.1 \times 10^{-31} \times 2.652 \times 10^7 \times \sin 30^\circ}{0.15 \times 1.6 \times 10^{-19}}$$

$$= 50.25 \times 10^{-5} \text{ m}$$

$$r = 0.5 \text{ mm}$$

The helical trajectory of radius 0.5 mm along the direction of the magnetic field.

Question 4.20

A magnetic field set up using Helmholtz coils (described in Exercise 4.16) is uniform in a small region and has a magnitude of 0.75 T. In the same region, a uniform electrostatic field is maintained in a direction normal to the common axis of the coils. A narrow beam of (single species) charged particles, all accelerated through 15 kV, enters this region in a direction perpendicular to both the axis of the coils and the electrostatic field. If the beam remains undeflected when the electrostatic field is $9.0 \times 10^{-5} \text{ V m}^{-1}$, make a simple guess as to what the beam contains. Why is the answer not unique?

Solution

Magnetic field, $B = 0.75 \text{ T}$

Accelerating voltage, $V = 15 \text{ kV} = 15 \times 10^3 \text{ V}$

Electrostatic field, $E = 9.0 \times 10^{-5} \text{ V m}^{-1}$

Kinetic energy of the electron, $E = (1/2) mv^2$

$$eV = (1/2) mv^2$$

$$\text{Therefore, } (e/m) = (v^2/2V)$$

Here,

Mass of the electron = m

Charge of the electron = e

The velocity of the electron = v

The particles are not deflected by the electric field and the magnetic field. So the force on the particle due to the electric field is balanced by force due to the magnetic field.

$$eE = evB$$

$$\Rightarrow v = E/B$$

Therefore, $(1/2) m(E/B)^2 = eV$

$$e/m = E^2/2VB^2$$

$$= \frac{(9.0 \times 10^5)^2}{2 \times 15000 \times (0.75)^2} = 4.8 \times 10^7 C/kg$$

The beam contains Deuterium ions or deuterons

The answer is not unique because only the ratio of charge to mass is determined. Other possible answers are He^{++} , Li^{++} , etc.

Question 4.21

A straight horizontal conducting rod of length 0.45 m and mass 60 g is suspended by two vertical wires at its ends. A current of 5.0 A is set up in the rod through the wires.

(a) What magnetic field should be set up normal to the conductor in order that the tension in the wires is zero?

(b) What will be the total tension in the wires if the direction of the current is reversed, keeping the magnetic field the same as before?

(Ignore the mass of the wires.) $g = 9.8 \text{ m s}^{-2}$.

Solution

Length of the rod, $l = 0.45 \text{ m}$

Mass suspended, $m = 60 \text{ g} = 60 \times 10^{-3} \text{ Kg}$

Current, $I = 5 \text{ A}$

(a) Tension in the wire is zero if the force on the current-carrying wire due to the magnetic field is equal and opposite to the weight on the wire.

$$BIl = mg$$

$$B = mg/Il$$

$$= \frac{60 \times 10^{-3} \times 9.8}{5 \times 0.45}$$

The magnetic field set up normal to the conductor is 0.26133 T

(b) When the direction of the current is reversed, BIl and mg will act vertically downwards; the effective tension in the wire is

$$T = BIl + mg$$

$$= (0.26133 \times 5.0 \times 0.45) + (60 \times 10^{-3} \times 9.8) = 0.587 + (0.588) = 1.176 \text{ N}$$

Total tension in the wire = 1.176 N

Question 4.22

The wires which connect the battery of an automobile to its starting motor carry a current of 300 A (for a short time). What is the force per unit length between the wires if they are 70 cm long and 1.5 cm apart? Is the force attractive or repulsive?

Solution

Current in the wires, $I = 300 \text{ A}$

Distance between the wires, $d = 1.5 \text{ cm} = 0.015 \text{ m}$

Length of the wires, $l = 70 \text{ cm} = 0.7 \text{ m}$

The force between the two wires, $F = \mu_0 I^2 / 2\pi d$

Here,

μ_0 = permeability of the free space = $4\pi \times 10^{-7} \text{ Tm/A}$

$$F = \frac{4\pi \times 10^{-7} \times (300)^2}{2\pi \times 0.015} = 1.2 \text{ N/m}$$

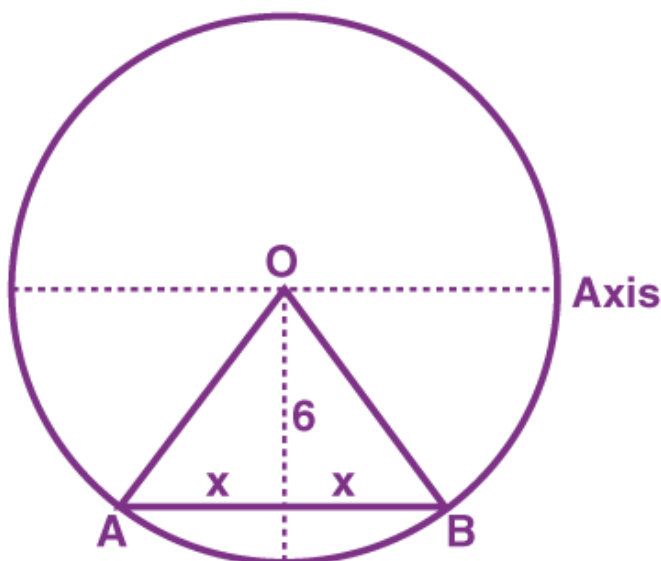
Since the direction of the wires is opposite, the force will be repulsive.

Question 4.23

A uniform magnetic field of 1.5 T exists in a cylindrical region of a radius of 10.0 cm, its direction parallel to the axis along east to west. A wire carrying a current of 7.0 A in the north-to-south direction passes through this region. What is the magnitude and direction of the force on the wire if,

- (a) the wire intersects the axis,
- (b) the wire is turned from N-S to the northeast-northwest direction
- (c) the wire in the N-S direction is lowered from the axis by a distance of 6.0 cm?

Solution



(a) Magnetic field, $B = 1.5 \text{ T}$

Current in the wire, $I = 7.0 \text{ A}$

Radius, $r = 10 \text{ cm} = 0.1 \text{ m}$

Diameter, $l = 2 \times r = 0.2 \text{ m}$

A force 2.1 N acts vertically downward on the wire

(a) The wire intersects the axis, $\theta = 90^\circ$

$$F = BI/\sin\theta = 1.5 \times 7 \times 0.20 \times \sin 90^\circ$$

$$= 2.1 \text{ N}$$

(b) The wire is turned from N-S to the northeast-northwest direction

$$F = BI/l_1 \sin \theta$$

The length of the wire after turning to the northeast-northwest direction is $l_1 = l/\sin\theta$

$$\text{Therefore, } l = l_1 \sin \theta$$

$$F = BI/l$$

$$= 1.5 \times 7 \times 0.20 = 2.1 \text{ N}$$

A force 2.1 N acts vertically downward on the wire

(c) When the wire is lowered by 6 cm, then

Then,

$$x = \sqrt{(10)^2 - (6^2)} = \sqrt{64} = 8 \text{ cm}$$

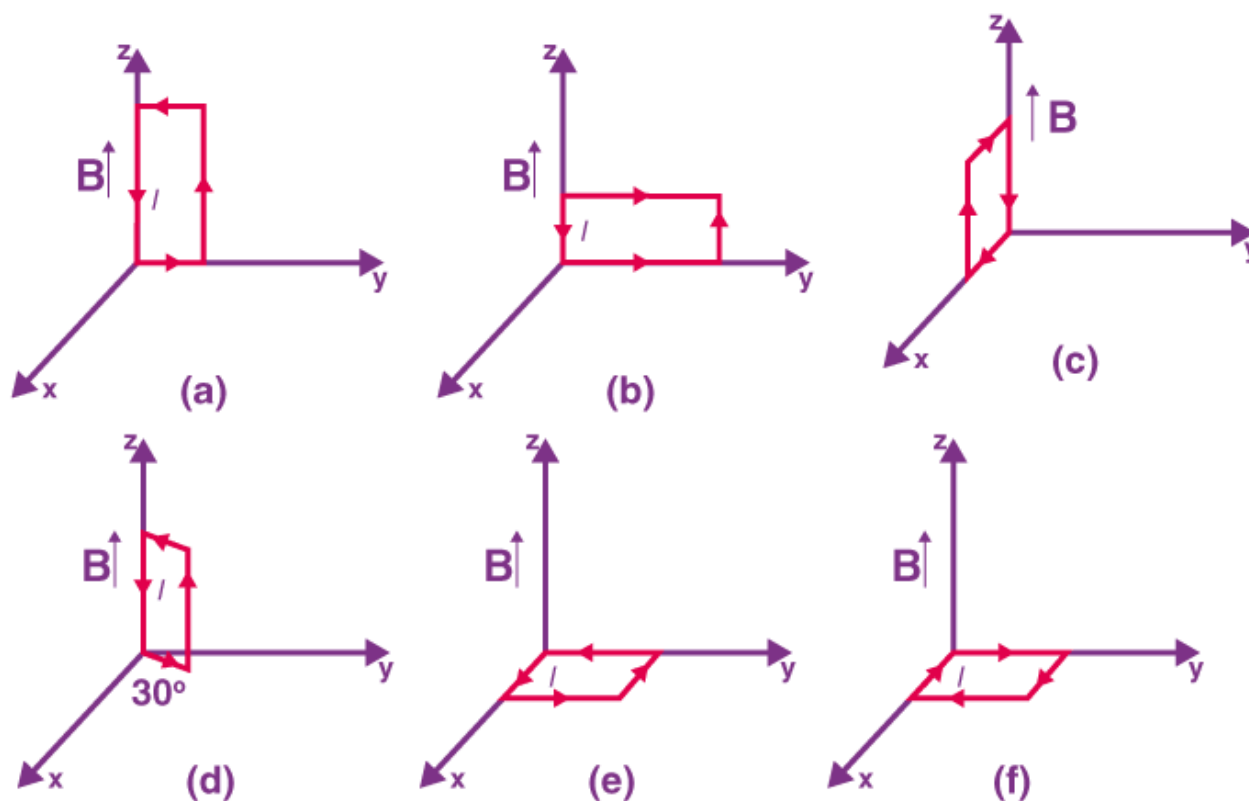
$$2x = l_2 = 16 \text{ cm}$$

$$F_2 = BI l_2 = 1.5 \times 7 \times 0.16 = 1.68 \text{ N}$$

The force is directed vertically downwards.

Question 4.24

A uniform magnetic field of 3000 G is established along the positive z-direction. A rectangular loop of sides 10 cm and 5 cm carries a current of 12 A. What is the torque on the loop in the different cases shown in the figure? What is the force in each case? Which case corresponds to stable equilibrium?



Solution

Magnetic field strength, $B = 3000 \text{ G} = 0.3 \text{ T}$

Area of the loop, $A = 10 \times 5 = 50 \text{ cm}^2 = 50 \times 10^{-4} \text{ m}^2$

Current in the loop, $I = 12 \text{ A}$

(a) Torque,

$$\vec{\tau} = I \vec{A} \times \vec{B}$$

$\vec{A}$ is normal to the y - z plane, and $\vec{B}$ is directed along the z -axis

$$\vec{A} = 50 \times 10^{-4} \hat{i}$$

$$\vec{B} = 0.3 \hat{k}$$

$$\vec{\tau} = 12 \times (50 \times 10^{-4}) \hat{i} \times 0.3 \hat{k}$$

$$= -1.8 \times 10^{-2} \hat{j} \text{ Nm}$$

The torque is $1.8 \times 10^{-2} \text{ N m}$ along the negative y -direction. The net force on the loop is zero since the opposite forces acting on the two ends of the loop will cancel each other.

(b) This is the same as (a). Therefore, the torque is $1.8 \times 10^{-2} \text{ N m}$ along the negative y-direction. The net force is zero.

(c) A is normal to the x-z plane, and B is along the z-axis

$$\vec{A} = -50 \times 10^{-4} \hat{j}$$

$$\vec{B} = 0.3 \hat{k}$$

$$\vec{\tau} = 12 \times (-50 \times 10^{-4}) \hat{j} \times 0.3 \hat{k}$$

$$= -1.8 \times 10^{-2} \hat{i} \text{ Nm}$$

Therefore, the torque is $1.8 \times 10^{-2} \text{ N m}$ along the negative x-direction. The net force is zero.

(d) Torque,

$$\vec{\tau} = I \vec{A} \times \vec{B}$$

From the given figure, it can be observed that A is normal to the coil. Since the coil makes an angle of -30° with the y-axis, A will make an angle of 30° with the positive x-axis in the negative y-direction, and B will be directed along the z-axis. The angle between A and B is $\theta = 90^\circ$. Therefore,

Accordingly, the magnitude of torque will be,

$$\tau = 12 \times 50 \times 10^{-4} \times 0.3$$

$$= 1.8 \times 10^{-2} \text{ N m}$$

The direction of the torque is $(90^\circ + 30^\circ)$ from the negative x-axis or $360^\circ - 120^\circ = 240^\circ$ from the positive x-axis. The net force on the loop is zero.

(e) From the given figure, we can see that A is normal to the x-y plane in the positive z-direction and B is directed along the z-axis.

$$\vec{A} = 50 \times 10^{-4} \hat{k}$$

$$\vec{B} = 0.3 \hat{k}$$

Accordingly,

$$\vec{\tau} = 12 \times (50 \times 10^{-4}) \hat{k} \times 0.3 \hat{k}$$

$$= 0$$

Hence, the torque is zero. The force is also zero.

(f) From the given figure, we can see that A is normal to the x-y plane in the negative z-direction and B is directed along the z-axis. The angle between A and B is $\theta = 180^\circ$. Therefore,

$$\vec{A} = -50 \times 10^{-4} \hat{k}$$

$$\begin{aligned}\vec{B} &= 0.3\hat{k} \\ \vec{\tau} &= 12 \times (-50 \times 10^{-4})\hat{k} \times 0.3\hat{k} \\ &= 0\end{aligned}$$

Therefore, torque and force is zero.

Case (e) corresponds to stable, and case (f) corresponds to unstable equilibrium.

Question 4.25

A circular coil of 20 turns and a radius of 10 cm is placed in a uniform magnetic field of 0.10 T normal to the plane of the coil. If the current in the coil is 5.0 A, what is

- (a) the total torque on the coil
- (b) the total force on the coil
- (c) the average force on each electron in the coil due to the magnetic field? (The coil is made of copper wire of a cross-sectional area of 10^{-5} m^2 , and the free electron density in copper is about 10^{29} m^{-3} .)

Solution

Number of turns, $n = 20$ turns

Radius of the coil, $r = 10 \text{ cm} = 0.1 \text{ m}$

Current in the coil, $I = 5 \text{ A}$

Magnetic field strength, $B = 0.10 \text{ T}$

The cross-sectional area of the wire, $a = 10^{-5} \text{ m}^2$

The angle between

$$\begin{aligned}\vec{A} \\ \vec{B}\end{aligned}$$

- (a) Total torque on the coil

$$\begin{aligned}\vec{\tau} &= NI\vec{A} \times \vec{B} \\ \Rightarrow \tau &= NIAB \sin 0 = 0\end{aligned}$$

Therefore, the torque is zero.

- (b) Equal and opposite forces act on opposite sides of the coil. Therefore, the total force on the coil is zero.

(c) Average force on the moving electron

$$F = B e v_d$$

v_d is the drift velocity of the electrons

$$v_d = I / N e A$$

Therefore, $F = B e I / N e a$

$$F = B I / n a$$

=

$$\frac{0.1 \times 5}{10^{29} \times 10^{-5}} = 5 \times 10^{-25} N$$

The average force on each electron is $5 \times 10^{-25} N$

Question 4.26

A solenoid 60 cm long and of radius 4.0 cm has 3 layers of windings of 300 turns each. A 2.0 cm long wire of mass 2.5 g lies inside the solenoid (near its centre) normal to its axis; both the wire and the axis of the solenoid are in the horizontal plane. The wire is connected through two leads parallel to the axis of the solenoid to an external battery which supplies a current of 6.0 A in the wire. What value of current (with an appropriate sense of circulation) in the windings of the solenoid can support the weight of the wire? $g = 9.8 \text{ m s}^{-2}$?

Solution

Length of the solenoid, $l = 60 \text{ cm}$

Layers of windings = 3

Each layer has 300 turns

Number of turns per unit length, $n = (3 \times 300) / 0.6 = 1500 \text{ m}^{-1}$

The magnetic field inside the solenoid is given by, $B = \mu_0 n I$

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

$$B = (4\pi \times 10^{-7}) \times 1500 \times I$$

$$= 6\pi \times 10^{-4} l \text{ ————— (1)}$$

Force due to magnetic field, $F = I'B/l$

I' = Current in the wire = 6 A

l = length of the wire = 2 cm

The windings of the solenoid would support the weight of the wire when the force due to the magnetic field inside the solenoid balances the weight of the wire.

$$I'B/l = mg$$

m = mass of the wire = 2.5 g

$$B = mg/I'l$$

From equation (1), we get

$$6\pi \times 10^{-4} l = mg/I'l$$

$$\Rightarrow I = mg/(6\pi \times 10^{-4}) l'$$

$$I = \frac{2.5 \times 10^{-3} \times 9.8}{6 \times 0.02 \times 4\pi \times 10^{-7} \times 1500} = 108.37 \text{ A}$$

A current of 108.37 A will support the wire.

Question 4.27

A galvanometer coil has a resistance of 12 Ω , and the metre shows full-scale deflection for a current of 3 mA. How will you convert the metre into a voltmeter of range 0 to 18 V?

Solution

Resistance of the galvanometer coil, $G = 12 \Omega$

Current for which there is full-scale deflection, $I = 3\text{mA}$

A resistor with a resistance R is connected in series with the galvanometer to convert it into a voltmeter. The resistance R is given as

$$R = (V/I_g) - G$$

=

$$\frac{18}{3 \times 10^{-3}} - 12 = 6000 - 12 = 5988 \Omega$$

A galvanometer can be converted into a voltmeter by connecting a resistor of 5988 Ω .

Question 4.28

A galvanometer coil has a resistance of 15 Ω , and the metre shows full-scale deflection for a current of 4 mA. How will you convert the metre into an ammeter of range 0 to 6 A?

Solution

Resistance of the galvanometer, $G = 15 \Omega$

Current through the galvanometer, $I_g = 4 \text{ mA} = 4 \times 10^{-3} \text{ A}$

Ammeter range = 0 to 6 A

$$S = \frac{I_g G}{I - I_g}$$

Therefore, $S =$

$$S = \frac{4 \times 10^{-3} \times 15}{6 - 0.004}$$

$$= 10 \times 10^{-3} \text{ A}$$

$S = 10 \text{ mA}$

A 10 mA resistor must be connected in parallel to the galvanometer.

NCERT Class 12 Solutions PDF for Moving Charges and Magnetism provided here has answers to textbook questions and Class 12 Physics Chapter 4 important questions from previous year question papers, exercises and worksheets. These solutions will help you prepare Chapter 4 Physics Class 12 notes, which can be kept handy when the exam nears.

Class 12 Physics NCERT Solutions for Moving Charges and Magnetism

Chapter 4 Moving Charges and Magnetism of Class 12 Physics, is prepared as per the latest CBSE Syllabus 2023-24. The NCERT Solutions of Chapter 4 given here can help the students to clear all their doubts instantly. The **NCERT Solutions** of this chapter comprise diagrams, graphs, illustrations and day-to-day examples that make your study interesting and help you remember the concepts for a longer period.

The direct derivations of topics like forces between two current-carrying wires and ampere circuital law are frequently asked in exams. Numerical problems are also asked in this chapter. The working and figure of the cyclotron should be studied intensively.

Subtopics of NCERT Class 12 Physics Chapter 4 Moving Charges and Magnetism

Section Number	Topic
4.1	Introduction
4.2	Magnetic Force
4.2.1	Sources and Fields
4.2.2	Magnetic Field, Lorentz Force
4.2.3	Magnetic Force on a current-carrying Conductor
4.3	Motion in a Magnetic Field
4.4	Motion in Combined Electric and Magnetic Fields
4.4.1	Velocity Selector
4.4.2	Cyclotron
4.5	Magnetic Field Due to a Current Element, Biot-Savart Law
4.6	Magnetic Field on the Axis of a Circular Current Loop
4.7	Ampere's Circuital Law
4.8	The Solenoid and the Toroid
4.8.1	The Solenoid
4.8.2	The Toroid
4.9	Force between Two Parallel Currents, The Ampere
4.10	Torque on Current Loop, Magnetic Dipole
4.10.1	Torque on a Rectangular Current Loop in a Uniform Magnetic Field
4.10.2	Circular Current Loop as a Magnetic Dipole
4.10.3	The Magnetic Dipole Moment of a Revolving Electron

4.11	The Moving Coil Galvanometer
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