

Moving Charges and Magnetism

Question1

Two identical wires, carrying equal currents are bent into circular coils A and B with 2 and 3 turns respectively. The ratio of the magnetic fields at the centres of the coils A and B is

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Options:

A.

4 : 9

B.

2 : 3

C.

9 : 4

D.

3 : 2

Answer: A

Solution:

The length of the wire L is constant for both coils

For coil A , $L = N_A \times 2\pi R_A$

For coil B , $L = N_B \times 2\pi R_B$

$$N_A \times 2\pi R_A = N_B \times 2\pi R_B$$

$$N_A R_A = N_B R_B$$

$$\text{So, } \frac{R_A}{R_B} = \frac{N_B}{N_A}$$



Magnetic field at the centre of coil A

$$B_A = \frac{\mu_0 N_A I}{2R_A}$$

Magnetic field at the centre of coil B

$$B_B = \frac{\mu_0 N_B I}{2R_B}$$

The ratio is $\frac{B_A}{B_B} = \frac{\frac{\mu_0 N_A I}{2R_A}}{\frac{\mu_0 N_B I}{2R_B}}$

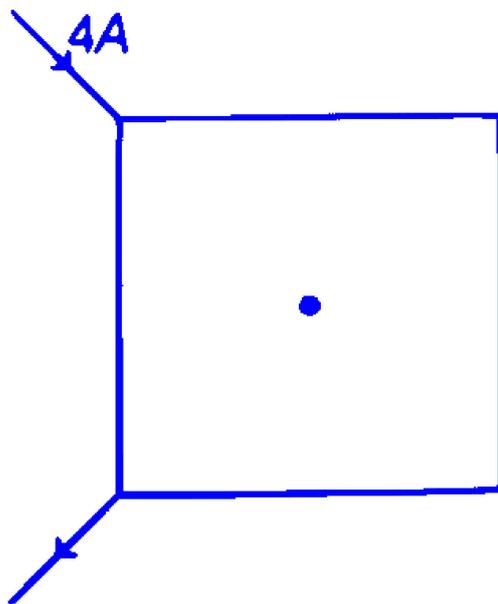
$$\frac{B_A}{B_B} = \frac{N_A}{N_B} \times \frac{R_B}{R_A} = \left(\frac{N_A}{N_B}\right) \cdot \left(\frac{N_A}{N_B}\right) = \left(\frac{N_A}{N_B}\right)^2$$

$$\frac{B_A}{B_B} = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$$

The ratio of the magnetic fields at the centres of coils A and B is 4 : 9.

Question2

A current of 4 A is passed through a square loop of side 5 cm made of a uniform manganin wire as shown in the figure. The magnetic field at the centre of the loop is



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Options:

A.

$$\frac{24\sqrt{2}}{5} \times 10^{-5} \text{ T}$$

B.

$$\frac{3\sqrt{2}}{5} \times 10^{-5} \text{ T}$$

C.

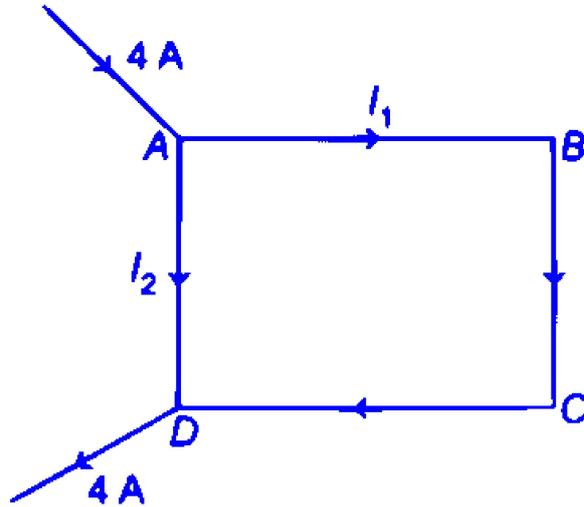
$$\frac{6\sqrt{2}}{5} \times 10^{-5} \text{ T}$$

D.

zero

Answer: D

Solution:



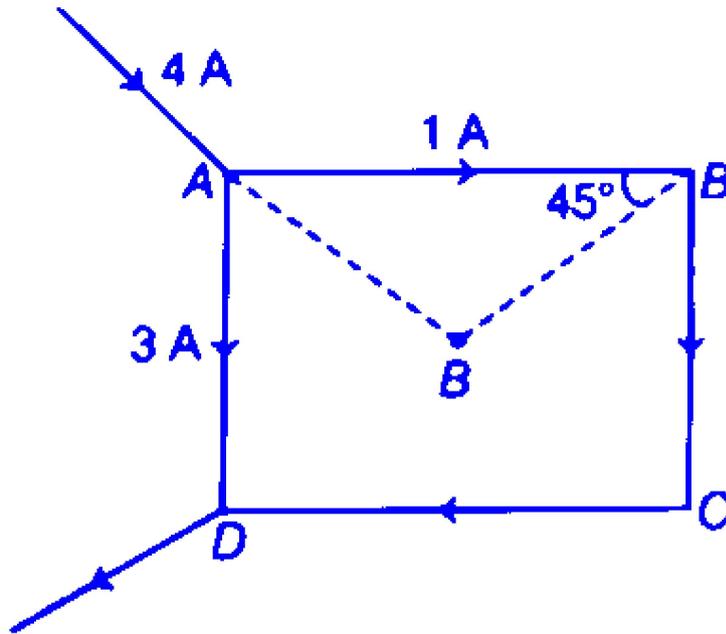
$$V_{AD} = I_1 \cdot R_{ABCD} = I_2 R_{AD}$$
$$\Rightarrow I_1 \times 3R = I_2 \times R \Rightarrow I_2 = 3I_1$$

$$\text{Also } I_1 + I_2 = 4 \text{ A} \quad (\text{given})$$

$$\Rightarrow 4I_1 = 4 \text{ A or } I_1 = 1 \text{ A}$$

So, we have following situation,





∴ Magnetic field B at centre

$$= B_{AB} + B_{BC} + B_{CD} - B_{AD}$$

Here, $B_{AB} = B_{BC} = B_{CD}$

$$= \frac{\mu_0}{4\pi} \cdot \frac{I}{r} \times 2 \sin \theta \quad [\theta = 45^\circ]$$

$$= \frac{\mu_0}{4\pi} \cdot \frac{1}{2.5 \times 10^{-2}} \times \frac{2}{\sqrt{2}}$$

$$= \frac{10^{-7} \times \sqrt{2}}{25 \times 10^{-2}} = 4\sqrt{2} \times 10^{-6} \text{ T}$$

$$\text{And } B_{AD} = 3 \times 4\sqrt{2} \times 10^{-6}$$

$$= 12\sqrt{2} \times 10^{-6} \text{ T}$$

$$\begin{aligned} \therefore B_{\text{centre}} &= 3 \times (4\sqrt{2} \times 10^{-6}) - (12\sqrt{2} \times 10^{-6}) \\ &= 0 \end{aligned}$$

Question3

A proton and an alpha particle moving with equal speeds enter normally into a uniform magnetic field. The ratio of times taken by the proton and the alpha particle to make one complete revolution in the magnetic field is

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Options:

A.

$$1 : \sqrt{2}$$

B.

$$1 : 2$$

C.

$$\sqrt{2} : 1$$

D.

$$2 : 1$$

Answer: B

Solution:

When a charged particle moves in a magnetic field, the time it takes to make one full round (the time period) is given by:

$$T = \frac{2\pi m}{Bq}$$

Here, m is the mass of the particle, q is its charge, and B is the magnetic field. This means the time period depends on the ratio of mass to charge ($\frac{m}{q}$).

To compare the time periods of a proton (T_p) and an alpha particle (T_α), use this ratio:

$$\frac{T_p}{T_\alpha} = \frac{m_p}{m_\alpha} \times \frac{q_\alpha}{q_p}$$

An alpha particle has a mass four times that of a proton ($m_\alpha = 4m_p$) and a charge twice that of a proton ($q_\alpha = 2q_p$).

Plug these values in:

$$\frac{T_p}{T_\alpha} = \frac{m_p}{4m_p} \times \frac{2q_p}{q_p} = \frac{1}{4} \times 2 = \frac{1}{2}$$

This shows that the time taken by a proton is half that of the alpha particle. So, the ratio of their times is

$$T_p : T_\alpha = 1 : 2$$

Question4

A solenoid of length 50 cm and radius 10 cm has two closely wound layers of windings 100 turns each. If a current of 2.5 A is passing

through the windings, the magnetic field (in 10^{-4} T) at a point 5 cm from the axis is

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Options:

A.

2π

B.

31.4

C.

4π

D.

zero

Answer: C

Solution:

Number of turns per unit length

$$n = \frac{N}{L} = \frac{200}{0.5} = 400 \text{ turns /m}$$

$$\therefore B = \mu_0 n I$$

$$= 4\pi \times 10^{-7} \times 400 \times 2.5$$

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

Question5

A magnetic field is applied in y -direction on an α -particle travelling along x -direction. The motion of the α -particle will be

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Options:



- A. along X -axis
- B. a circle in XZ -plane
- C. a circle in YZ -plane
- D. a circle in XY -plane

Answer: B

Solution:

Given,

The α -particle is travelling along the x -direction, $\mathbf{v} = v\hat{\mathbf{i}}$

The magnetic field is applied in the y -direction, $\mathbf{B} = B\hat{\mathbf{j}}$

Thus, Lorentz force,

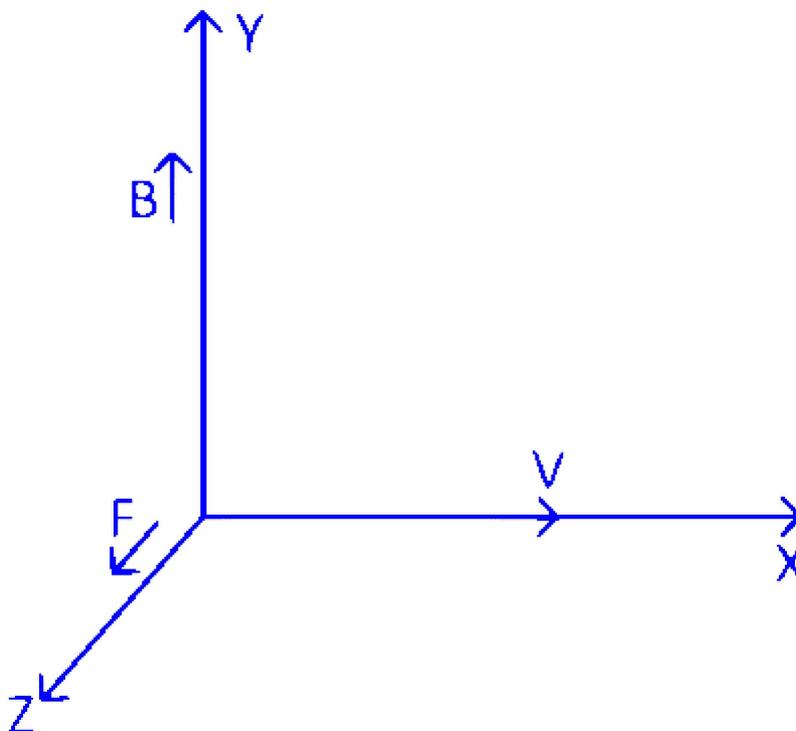
$$\mathbf{F} = q(\mathbf{v} \times \mathbf{B})$$

$$\mathbf{F} = 2 \cdot e(v\hat{\mathbf{i}}) \times (B\hat{\mathbf{j}})$$

$$\mathbf{F} = 2evB\hat{\mathbf{k}} \quad [\because \hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}}]$$

The force is acting in the $+z$ -direction.

This force is always perpendicular to both the velocity of the α -particle and the magnetic field. It will cause the α -particle to move in a circular path. Therefore, the motion of the α -particle will be a circular path in the XZ -plane, perpendicular to the direction of the magnetic field.



Question6

A straight wire carrying a current of $2\sqrt{2}$ A is making an angle of 45° with the direction of uniform magnetic field of 3 T . The force per unit length of the wire due to the magnetic field is

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Options:

A. 4Nm^{-1}

B. 8Nm^{-1}

C. 6Nm^{-1}

D. 3Nm^{-1}

Answer: C

Solution:

Given, $B = 3$ T

$$i = 2\sqrt{2} \text{ A}$$

$$\theta = 45^\circ$$

The force F on a current carrying conductor is given by,

$$F = IlB \sin \theta$$

Force per unit length,

$$\frac{F}{l} = IB \sin \theta$$

$$\frac{F}{l} = 2\sqrt{2} \times 3 \times \sin 45$$

$$\frac{F}{l} = 2\sqrt{2} \times 3 \times \frac{1}{\sqrt{2}}$$

$$\frac{F}{l} = 6\text{Nm}^{-1}$$



Question7

An electron falling freely under the influence of gravity enters a uniform magnetic field directed towards south. The electron is initially deflected towards

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Options:

- A. east
- B. west
- C. north
- D. south

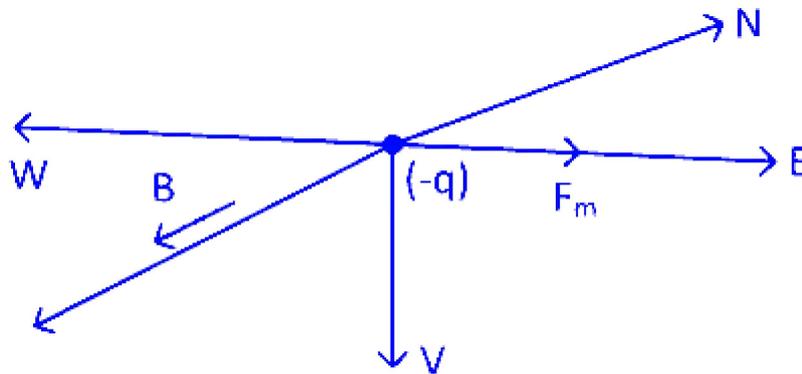
Answer: A

Solution:

Given,

Velocity of electron is downward.

Magnetic field along south.



As from Lorentz equation,

$$\mathbf{F}_{\text{Magnetic}} = q(\mathbf{v} \times \mathbf{B})$$

Therefore the direction of \mathbf{F} will be along $(\mathbf{v} \times \mathbf{B})$.

Hence, by using right hand thumb rule for negative charge, the direction will be east.

Question8

Two long straight parallel wires A and B separated by 5 m carry currents 2 A and 6 A respectively in the same direction. The resultant magnetic field due to the two wires at a point of 2 m distance from the wire A in between the two wires is

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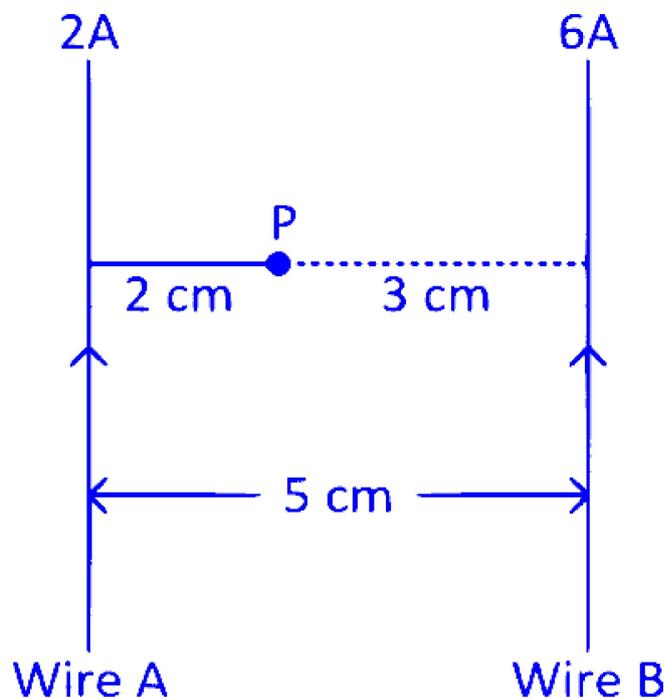
Options:

- A. $2 \times 10^{-6}\text{ T}$
- B. $2 \times 10^{-7}\text{ T}$
- C. $4 \times 10^{-7}\text{ T}$
- D. $4 \times 10^{-6}\text{ T}$

Answer: B

Solution:

Current in wire A



$$\Rightarrow I_A = 2\text{ A}$$

Current in wire B



$$I_B = 6 \text{ A}$$

We have to find net magnetic field at point P .

Magnetic field due to wire A will be inward.

Magnetic field due to wire B will be outward.

$$B_{\text{Net}} = B_B - B_A$$

Using Ampere's circuital law

$$B_A = \frac{\mu_0 i_A}{2\pi R_A}$$

$$B_A = \frac{\mu_0(2)}{2\pi(2)} = \frac{\mu_0}{2\pi}$$

$$B_B = \frac{\mu_0(6)}{2\pi \times 3} = \frac{\mu_0}{\pi}$$

$$B_{\text{Net}} = \frac{\mu_0}{\pi} - \frac{\mu_0}{2\pi} = \frac{\mu_0}{2\pi}$$

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

$$B_{\text{Net}} = \frac{4\pi \times 10^{-7}}{2\pi}$$

$$B_{\text{Net}} \text{ at point } P = 2 \times 10^{-7} \text{ T}$$

Question9

A long straight rod of diameter 4 mm carries a steady current i . The current is uniformly distributed across its cross-section. The ratio of the magnetic fields at distances 1 mm and 4 mm from the axis of the rod is

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Options:

A. 1 : 2

B. 1 : 4

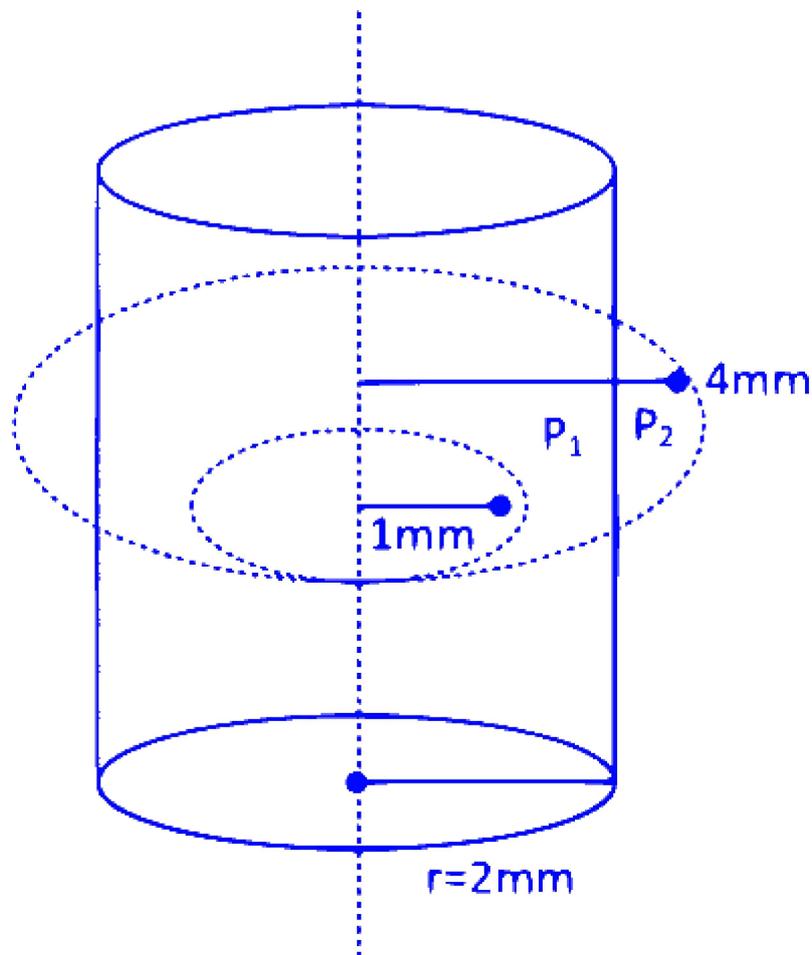
C. 4 : 1

D. 1 : 1



Answer: D

Solution:



Given,

Diameter = 4 mm

Current in wire = i

Magnetic field inside the pipe

Using Ampere's circuital law for P_1 loop

$$\oint \mathbf{B}_1 d\mathbf{L} = \mu_0 I_{\text{enclosed}}$$

$$B_1 = \frac{\mu_0 i_1}{2\pi r^2} \quad [r_1 = 1 \text{ mm}]$$

$$B_1 = \frac{\mu_0 i}{8\pi} \quad [r = 2 \text{ mm of wire}]$$

For point P_2

$$\oint \mathbf{B}_2 d\mathbf{L} = \mu_0 I_{\text{enclosed}}$$

$$B_2 = \frac{\mu_0 i}{2\pi \times (r_2)} \quad [r_2 = 4 \text{ mm}]$$

$$B_2 = \frac{\mu_0}{8\pi} i$$

From Eqs. (i) and (ii)

$$\frac{B_1}{B_2} = \frac{1}{1} = 1 : 1$$

Question10

A straight wire of length 20 cm carrying a current of $\frac{3}{\pi^2}$ A is bent in the form of a circle. The magnetic field at the centre of the circle is

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Options:

- A. 3×10^{-6} T
- B. 8×10^{-6} T
- C. 12×10^{-6} T
- D. 6×10^{-6} T

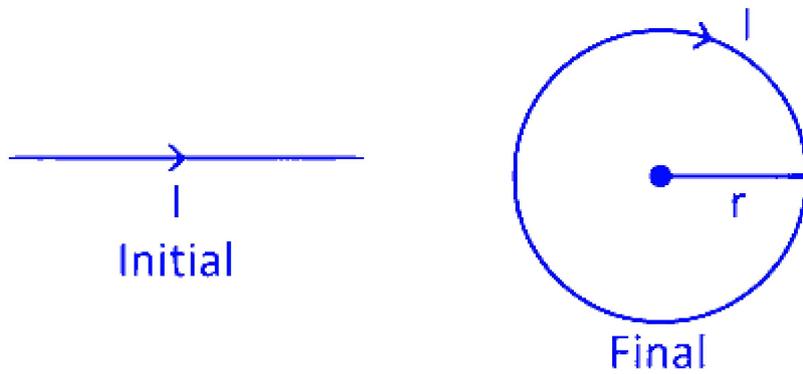
Answer: D

Solution:

Given,

Straight wire length, $l = 20$ cm

Current $I = \frac{3}{\pi^2}$ A



Length of wire = Circumference of circle

$$20 \text{ cm} = 2\pi r$$

$$r = \frac{20}{2\pi} \text{ cm or } \frac{20 \times 10^{-2}}{2\pi} \text{ m}$$

Magnetic field at the centre of circle

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

$$= \frac{4\pi \times 10^{-7} \times 3}{2 \times \frac{20 \times 10^{-2}}{2\pi} \times \pi^2}$$

$$= \frac{4\pi \times 3 \times 2\pi \times 10^{-7}}{2 \times 20 \times \pi^2 \times 10^{-2}}$$

$$= 6 \times 10^{-6} \text{ T}$$

Question11

A circular coil carrying a current of 2.5 A is free to rotate about an axis in its plane perpendicular to an external field. When the coil is made to oscillate, the time period of oscillation is T . If the current through the coil is 10 A, the time period of oscillation is

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Options:

A. $\frac{T}{2}$

B. T

C. $2T$

D. $\frac{T}{4}$

Answer: A

Solution:

Initial current in loop $I_1 = 2.5$ A

Let m is magnetic moment of loop, B is external magnetic field.

Then time period of oscillation,

$$T = \frac{1}{2\pi} \sqrt{\frac{mB}{I}}$$

or

$$T = \frac{1}{2\pi} \sqrt{\frac{mB}{2.5}}$$

Now, when current is 10 A

$$T' = \frac{1}{2\pi} \sqrt{\frac{mB}{10}}$$

or

$$\frac{1}{2\pi} \sqrt{\frac{mB}{4 \times 2.5}}$$

or

$$\frac{1}{2} \times \frac{1}{2\pi} \sqrt{\frac{mB}{2.5}}$$

Hence, $T' = T/2$

Question12

Two points A and B on the axis of a circular current loop are at distances of 4 cm and $3\sqrt{3}$ cm from the centre of the loop. If the ratio of the induced magnetic fields at points A and B is 216 : 125, then radius of the loop is

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Options:

A. 3 cm

B. 4 cm



C. 5 cm

D. 6 cm

Answer: A

Solution:

The magnetic field B in the circular coil is given as

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

Given, $x_1 = 4$ cm and $x_2 = 3\sqrt{3}$ cm

According to question,

$$B_1 = \frac{\mu_0 I r^2}{2(r^2 + 4^2)^{3/2}} \quad \dots \text{(i)}$$

$$B_2 = \frac{\mu_0 I r^2}{2[r^2 + (3\sqrt{3})^2]^{3/2}} \quad \dots \text{(ii)}$$

On dividing Eqs. (i) by (ii), we get

$$\therefore \frac{216}{125} = \frac{\mu_0 I r^2}{2(r^2 + 16)^{3/2}} \times \frac{2(r^2 + 27)^{3/2}}{\mu_0 I r^2}$$

$$\Rightarrow \left(\frac{6}{5}\right)^3 = \frac{(r^2 + 27)^{3/2}}{(r^2 + 16)^{3/2}}$$

$$\Rightarrow \left(\frac{6}{5}\right) = \frac{(r^2 + 27)^{\frac{1}{2}}}{(r^2 + 16)^{\frac{1}{2}}}$$

$$\Rightarrow \frac{36}{25} = \frac{r^2 + 27}{r^2 + 16}$$

$$\Rightarrow 36(r^2 + 16) = 25(r^2 + 27)$$

$$\Rightarrow 36r^2 + 576 = 25r^2 + 675$$

$$\Rightarrow 11r^2 = 99$$

$$\Rightarrow r^2 = 9$$

$$\Rightarrow r = 3 \text{ cm}$$

Question13

Two charged particles A and B of masses m and $2m$, charges $2q$ and $3q$ respectively moving with same velocity enter a uniform magnetic field such that both the particles make same angle ($< 90^\circ$) with the direction of the magnetic field. Then, the ratio of pitches of the helical paths of the particles A and B is

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Options:

A. 4 : 3

B. 3 : 2

C. 3 : 4

D. 2 : 3

Answer: C

Solution:

The pitch of a charged particle having charge q and mass m is given by

$$r = \frac{2\pi m \times v \sin \theta}{qB}$$

$$\therefore \frac{r_1}{r_2} = \frac{2\pi m_1 \times v \sin \theta}{q_1 B} \times \frac{q_2 B}{2\pi m_2 v \sin \theta}$$

$$= \frac{q_2 m_1}{q_1 m_2}$$

$$= \frac{3q \times m}{2q \times 2m} \Rightarrow \frac{3}{4}$$



Question14

A particle of charge 2 C is moving with a velocity of $(3\hat{i} + 4\hat{j})\text{ms}^{-1}$ in the presence of magnetic and electric fields. If the magnetic field is $(\hat{i} + 2\hat{j} + 3\hat{k})\text{T}$ and the electric field is $(-2\hat{k})\text{NC}^{-1}$, then the Lorentz force on the particle is

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Options:

- A. 50 N
- B. 20 N
- C. 30 N
- D. 40 N

Answer: C

Solution:

Charge, $q = 2\text{C}$

Velocity,

$$v = (3\hat{i} + 4\hat{j})\text{m/s}$$

Magnetic field,

$$\mathbf{B} = (\hat{i} + 2\hat{j} + 3\hat{k})\text{T}$$

Electric field,

$$\mathbf{E} = (-2\hat{k})\text{NC}^{-1}$$

Lorentz force is given by

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

$$\mathbf{v} \times \mathbf{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 4 & 0 \\ 1 & 2 & 3 \end{vmatrix}$$



$$= (12 - 0)\hat{i} - (9 - 0)\hat{j} + (6 - 4)\hat{k}$$

$$\mathbf{v} \times \mathbf{B} = 12\hat{i} - 9\hat{j} + 2\hat{k}$$

$$\text{Thus, } \mathbf{F} = 2(-2\hat{k}) + 2(12\hat{i} - 9\hat{j} + 2\hat{k})$$

F

$$= 24\hat{i} - 18\hat{j} + (4 - 4)\hat{k}$$

F

Magnitude of Lorentz force,

$$|\mathbf{F}| = \sqrt{(24)^2 + (-18)^2}$$

$$= \sqrt{576 + 324}$$

$$= \sqrt{900}$$

$$|\mathbf{F}| = 30 \text{ N}$$

Question15

A rectangular coil of 400 turns and 10^{-2} m^2 area, carrying a current of 0.5 A is placed in a uniform magnetic field of IT such that the plane of the coil makes an angle of 60° with the direction of the magnetic field. The initial moment of force acting on the coil in $\text{N} - \text{m}$ is

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Options:

A. $\sqrt{3}$

B. $1/\sqrt{3}$

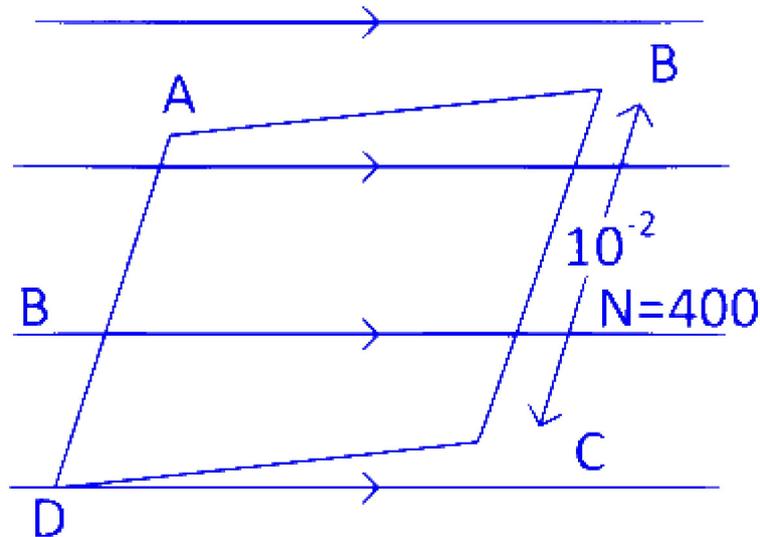
C. 1



D. $\sqrt{3}/2$

Answer: C

Solution:



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

$$A = 10^{-2} \text{ m}^2, I = 0.5 \text{ A}$$

$$B = 1 \text{ T}, \theta = (90^\circ - 60^\circ) = 30^\circ$$

As we know, $\tau = NIBA \sin \theta$

$$\tau = 400 \times 0.5 \times 1 \times 10^{-2} \times \sin 30^\circ$$

$$\tau = 400 \times 0.5 \times 10^{-2} \times \frac{1}{2}$$

$$\tau = 200 \times 0.5 \times 10^{-2}$$

$$= 20 \times 5 \times 10^{-2} = 100 \times 10^{-2}$$

$$\tau \cong 1 \text{ N - m}$$

The initial moment of force acting on the coil in Nm is 1.

Question16

The magnetic field at a perpendicular distance of one metre from a wire carrying current of 1 A is

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Options:

A. 2×10^{-7} T

B. 2×10^{-8} T

C. 2×10^{-6} T

D. 2×10^{-9} T

Answer: A

Solution:

To determine the magnetic field at a distance of one meter from a wire carrying a current of 1 ampere, we apply the Biot-Savart law.

Given:

Distance, $r = 1$ m

Current, $I = 1$ A

The magnetic field at a perpendicular distance from a straight current-carrying wire can be calculated using the formula derived from Biot-Savart's Law:

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

where $\mu_0 = 4\pi \times 10^{-7}$ H/m is the permeability of free space.

Calculation:

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

Therefore, the magnetic field at a distance of one meter from the wire is 2×10^{-7} T.

Question17

A circular coil of area 2 cm^2 has 1000 turns. If the current through the coil is 1 A, then its magnetic moment is

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Options:

A. $4 \text{ A} \cdot \text{m}^2$

B. $0.2 \text{ A} \cdot \text{m}^2$

C. $0.4 \text{ A} \cdot \text{m}^2$

D. $2 \text{ A} \cdot \text{m}^2$

Answer: B

Solution:

Given:

Number of turns, $N = 1000$

Area of the coil, $A = 2 \text{ cm}^2$ or $2 \times 10^{-4} \text{ m}^2$

Current through the coil, $I = 1 \text{ A}$

The magnetic moment (M) of a coil is calculated using the formula:

$$M = N \times I \times A$$

Substitute the given values:

$$M = 1000 \times 1 \times 2 \times 10^{-4}$$

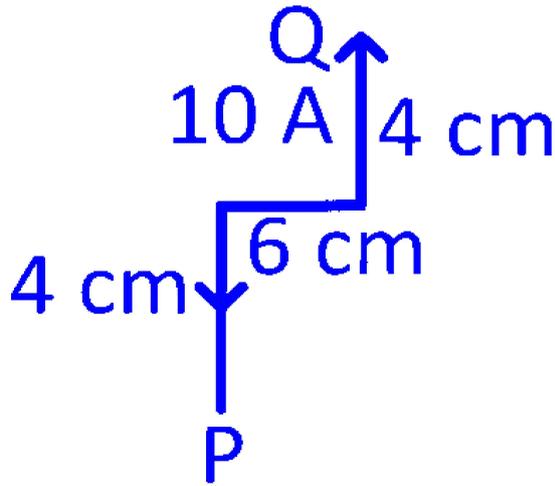
$$M = 0.2 \text{ A} \cdot \text{m}^2$$

Therefore, the magnetic moment of the coil is $0.2 \text{ A} \cdot \text{m}^2$.



Question18

A contjuncting wire PQ carries a current 10 A as shown in the figure. ft is placed in a uniform magnetic field 5 T which is acting normally outside from the paper. Then, the net force experienced by it is



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Options:

- A. 0
- B. 5 N
- C. 30 N
- D. 20 N

Answer: B

Solution:

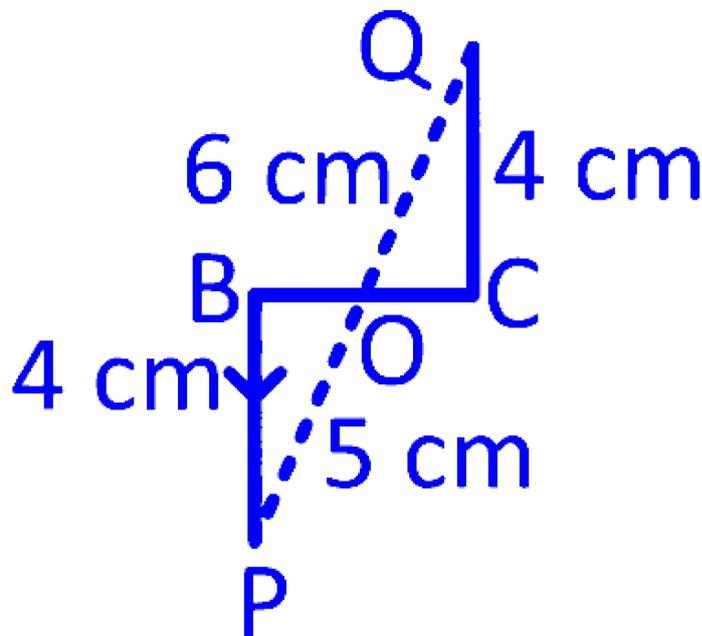
Given,

Wire PQ carries current = 10 A

Magnetic field (uniform) = 5 T

Which is normal to plane of paper.

Let PQ be a straight wire, then



$$[\triangle PBO, PO^2 = PB^2 + BV^2]$$

$$\text{Length of } PQ = PO + OQ \\ = 5 + 5 = 10 \text{ cm}$$

Force experienced by wire in uniform magnetic field is given by

$$F = BIL \sin \theta$$

$$\text{Here, } \theta = 90^\circ$$

[Plane and outward (normal) to plane]

$$F = 5 \times 10 \times \sin 90^\circ \times (0.1 \text{ m}) \\ \Rightarrow F = 5 \text{ N}$$

Question19

A long straight wire carries a current of 18 A . The magnitude of the magnetic field at a point 12 cm from it is

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Options:

A. $1.5 \times 10^{-5} \text{ T}$

B. $2 \times 10^{-5} \text{ T}$

C. $3 \times 10^{-5} \text{ T}$

D. $1.8 \times 10^{-5} \text{ T}$

Answer: C

Solution:

Given:

Current in the long straight wire, $I = 18 \text{ A}$

Distance from the wire where the magnetic field is measured, $r = 12 \text{ cm} = 0.12 \text{ m}$

To find the magnetic field using Ampere's law for a long straight wire:

$$\oint B \cdot dl = \mu_0 I$$

This simplifies to:

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

Substituting the known values into the equation:

$$B = \frac{(4\pi \times 10^{-7}) \times 18}{2\pi \times 0.12}$$

Simplifying, we get:

$$B = 3 \times 10^{-5} \text{ T}$$

The magnitude of the magnetic field at a point 12 cm from the wire is $3 \times 10^{-5} \text{ T}$.

