Moving Charges and Magnetism

Question1

If a current of 15 A passes through a solenoid of length 25 cm , radius 2 cm and number of turns 500 , then the magnetic moment of the solenoid is

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Options:

A.

$6 \mathrm{JT}^{-1}$

B.

$3 \mathrm{JT}^{-1}$

C.

$3 \pi \mathrm{JT}^{-1}$

D.

$6 \pi \mathrm{JT}^{-1}$

Answer: C

Solution:

Magnetic moment of solenoid

$$\begin{aligned} M &= NIA \\ &= 500 \times 15 \times \pi \times \left(2 \times 10^{-2}\right)^2 \\ &= 3 \pi \mathrm{JT}^{-1} \end{aligned}$$

Question2

The maximum magnetic field produced by a current of 12 A passing through a copper wire of diameter 1.2 mm is

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Options:

A.

2 mT

B.

4 mT

C.

1.5 mT

D.

8 mT

Answer: B

Solution:

$$\begin{aligned} B_{\max} &= \frac{\mu_0 I R}{2\pi R^2} = \frac{\mu_0 I}{2\pi R} \\ &= \frac{4\pi \times 10^{-7} \times 12}{2 \times 3.14 \times 0.6 \times 10^{-3}} \\ &= 4 \times 10^{-3}\ \mathrm{T} = 4\mathrm{mT} \end{aligned}$$

Question3

Two moving coil galvanometers A and B having identical springs are placed in magnetic fields of 0.25 T and 0.5 T respectively. If the number of turns in A and B are respectively 36 and 48 and the areas of the coils A and B are $2.4 \times 10^{-3}\ \mathrm{m}^2$ and $4.8 \times 10^{-3}\ \mathrm{m}^2$ respectively, then the ratio of the current sensitivities of the galvanometer A and B is

Options:

A.

3 : 16

B.

16 : 3

C.

4 : 3

D.

3 : 4

Answer: A

Solution:

Current sensitivity,

$S = \frac{NBA}{K}$

Where, $K \rightarrow$ Torsional constant

$$\Rightarrow \quad S \propto NBA$$

$$\therefore \quad \frac{S_A}{S_B} = \left(\frac{N_A}{N_B}\right)\left(\frac{B_A}{B_B}\right)\left(\frac{A_A}{A_B}\right)$$

$$= \left(\frac{36}{48}\right)\left(\frac{0.25}{0.5}\right)\left(\frac{2.4\times10^{-3}}{4.8\times10^{-3}}\right)$$

$$= \frac{3}{4} \times \frac{1}{2} \times \frac{1}{2} = \frac{3}{16}$$

$$\therefore S_A : S_B = 3 : 16$$

Question4

The magnetic field at the centre of a long solenoid having 400 turns per unit length and carrying a current ' i ' is 6.24×10^{-2} T. The magnetic field at the centre of another long solenoid having 200 turns per unit length and carrying a current $\frac{i}{2}$ is

Options:

A.

1.56×10^{-2} T

B.

2.4×10^{-2} T

C.

26×10^{-2} T

D.

2.6×10^{-2} T

Answer: A

Solution:

For the first long solenoid,

$$B_1 = \mu_0 n I$$
$$6.24 \times 10^{-2} = \mu_0 \times 400 \times I \qquad \ldots (i)$$
$$B_2 = \mu_0 n_2 i_2$$
$$B_2 = \mu_0 200 \times \frac{i}{2} \qquad \ldots (ii)$$

Dividing (ii) by (i), we get

$$\frac{B_2}{6.24 \times 10^{-2}} = \frac{200}{400} \times \frac{i/2}{i} = \frac{1}{4}$$

$$So,\ B_2 = \frac{6.24 \times 10^{-2}}{4}$$
$$= 1.56 \times 10^{-2} \text{ T}$$

Question5

If a proton of kinetic energy 8.35 MeV enters a uniform magnetic field of 10 T at right angles to the direction of the field, then the

force acting on the proton is

(Mass of proton $= 1.67 \times 10^{-27}$ kg **and Charge of proton** $= 1.6 \times 10^{-19}$C **)**

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Options:

A.

48×10^{-12} N

B.

16×10^{-12} N

C.

64×10^{-12} N

D.

32×10^{-12} N

Answer: C

Solution:

Given:

Kinetic energy of proton

$K = 8.35$ MeV

Magnetic field

$B = 10$ T

Charge of proton

$q = 1.6 \times 10^{-19}$ C

Mass of proton

$m = 1.67 \times 10^{-27}$ kg

The proton enters **at right angles** to the field.

Step 1: Get proton's velocity from its kinetic energy

$K = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2K}{m}}$

First, convert K from MeV to joules:

$K = 8.35 \times 10^6 \times 1.6 \times 10^{-19} = 1.336 \times 10^{-12}$ J

Now compute v:

$v = \sqrt{\frac{2 \times 1.336 \times 10^{-12}}{1.67 \times 10^{-27}}}$

$v = \sqrt{1.598 \times 10^{15}} = 3.998 \times 10^7$ m/s

So $v \approx 4.0 \times 10^7$ m/s.

Step 2: Magnetic force on a moving charge

At right angles,

$F = qvB$

Substituting values:

$F = (1.6 \times 10^{-19})(3.998 \times 10^7)(10)$

$F = 6.3968 \times 10^{-11}$ N

$F \approx 6.4 \times 10^{-11}$ N

Or equivalently:

$F = 64 \times 10^{-12}$ N

✅ **Final Answer:**

$\boxed{F = 64 \times 10^{-12} \text{ N}}$

Option C is correct.

Question6

Two charged particles of specific charges in the ratio 2:1 and masses in the ratio 1 : 4 moving with same kinetic energy enter a uniform magnetic field at right angles to the direction of the field. The ratio of the radii of the circular paths in which the particles move under the influence of the magnetic field is

Options:

A.

2 : 1

B.

1 : 1

C.

4 : 1

D.

8 : 1

Answer: B

Solution:

Radius of circular path in which a charged particle move when it enters a region of perpendicular uniform magnetic field is;

$$r=\frac{mv}{Bq}=\frac{\sqrt{2mK}}{Bq}$$
$$=\frac{\sqrt{2mK}}{m\cdot B\left(\frac{q}{m}\right)}=\sqrt{2}\sqrt{\frac{K}{m}}\cdot\frac{1}{B\cdot s}$$

where, $s=\frac{q}{m}=$ specific charge

Ratio of radii of the particles will be

$$\frac{r_1}{r_2}=\sqrt{\frac{m_2}{m_1}\left(\frac{s_2}{s_1}\right)^2}$$

($\therefore K_1=K_2$ and B is same for both particles.)

$$\therefore\frac{r_1}{r_2}=\sqrt{\left(\frac{m_2}{m_1}\right)\left(\frac{S_2}{S_1}\right)^2}$$
$$=\sqrt{\left(\frac{4}{1}\right)\cdot\left(\frac{1}{2}\right)^2}=1$$

Question7

The magnetic moment of an electron moving in a circular orbit of radius R with a time period T is

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Options:

A.

$\frac{2\pi Re}{T}$

B.

$\frac{\pi eR}{T}$

C.

$\frac{\pi eR^2}{T}$

D.

$\pi R^2 e^T$

Answer: C

Solution:

An electron moves in a circular orbit of

radius R

and period T.

Step 1: Find the current due to orbital motion

The charge of the electron is e (magnitude).

In one complete revolution, the charge e passes a given point once in time T.

So,

current $I = \frac{e}{T}$

Step 2: Magnetic moment due to a current loop

Magnetic moment of a current loop is given by

$\mu = I \times$ area of the loop

The area of a circular loop of radius R is

$A = \pi R^2$

Thus,

$\mu = I \times A = \frac{e}{T} \times \pi R^2 = \frac{\pi e R^2}{T}$

✅ **Correct Option:**

Option C $\rightarrow \frac{\pi e R^2}{T}$

Question8

A solenoid of one metre length and 3.55 cm inner diameter carries a current of 5 A . If the solenoid consists of five closely packed layers each with 700 turns along its length, then the magnetic field at its centre is

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Options:

A.

22 mT

B.

44 mT

C.

35 mT

D.

15 mT

Answer: A

Solution:

The solenoid has 5 closely packed layers and each layer has 700 turns.

$\therefore$ Total number of turns,

$$N = 700 \times 5 = 3500$$

$$\begin{aligned} \therefore \quad B &= \mu_0 n I \\ &= \mu_0 \times \frac{N}{L} \times I \\ &= 4\pi \times 10^{-7} \times \frac{3500}{1} \times 5 \\ &= 21.9 \times 10^{-3}\ \mathrm{T} \\ &\simeq 22 \times 10^{-3}\ \mathrm{T} \\ &\approx 22\mathrm{mT} \end{aligned}$$

Question9

If a charged particle enters a uniform magnetic field normally with certain velocity, then the time period of revolution of the particle

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Options:

A.

decreases with increase of velocity of the particle.

B.

increases with increase of radius of the orbit.

C.

increases with increase of magnetic field.

D.

decreases with increase of specific charge of the particle.

Answer: D

Solution:

When a charged particle moves into a magnetic field at a right angle (normally), it starts moving in a circle because the magnetic force keeps turning it.

The time it takes to complete one full circle (the time period T) 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 strength.

You can also write it as:

$T = \frac{2\pi}{B \cdot \left(\frac{q}{m}\right)}$

This means the time period T is inversely related to the specific charge $\left(\frac{q}{m}\right)$ (charge divided by mass).

So, if the specific charge increases, the time period decreases, and if the specific charge decreases, the time period increases.

Question10

A long straight wire of circular cross-section of radius ' a ' is carrying a steady current. The current is distributed uniformly across the cross-section of the wire. The ratio of the magnetic fields at points $0.5a$ and $1.5a$ from the centre of the wire is

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Options:

A.

1 : 1

B.

2 : 3

C.

1 : 2

D.

3 : 4

Answer: D

Solution:

Magnetic field at a point inside the wire

$B_{in} = \frac{\mu_0 I r}{2\pi a^2}$

Here, $a \rightarrow$ radius of wire $r \rightarrow$ distance from centre of wire Here, $r = 0.5a$

$\therefore \quad B_{in} = \frac{\mu_0 I \cdot (0.5a)}{2\pi a^2} = \frac{\mu_0 I}{4\pi a}$

Magnetic field at a point outside the wire,

$B_{\text{out}} = \frac{\mu_0 I}{2\pi r}$

Here, $\quad r = 1.5a$

$\therefore \quad B_{\text{out}} = \frac{\mu_0 I}{2\pi(1.5a)} = \frac{\mu_0 I}{3\pi a}$

$\therefore \quad \frac{B_{\text{in}}}{B_{\text{out}}} = \frac{\frac{\mu_0 I}{4\pi a}}{\frac{\mu_0 I}{3\pi a}} = \frac{3}{4}$ or 3 : 4

Question11

In a wire of radius 1 mm a steady current of 2 A uniformly distributed across the cross-section of the wire is flowing. Then the magnetic field at a point 0.25 mm from the centre of the wire is

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Options:

A.

100μ T

B.

200μ T

C.

300μ T

D.

400μ T

Answer: A

Solution:

$$
\begin{aligned}
B & =\frac{\mu_0 I r}{2 \pi R^2} \\
& =\frac{\left(4 \pi \times 10^{-7}\right) \times 2 \times 0.25 \times 10^{-3}}{2 \pi \times\left(1 \times 10^{-3}\right)^2} \\
& =1 \times 10^{-4} \mathrm{~T}=100 \times 10^{-6} \mathrm{~T} \\
& =100 \mu \mathrm{~T}
\end{aligned}
$$

Question12

The magnetic field at the centre of a current carrying circular coil of radius R is B_c and the magnetic field at a point on its axis at a distance R from its centre is B_a. The value of $\frac{B_c}{B_a}$ is

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Options:

A.

$\sqrt{2}$

B.

$\frac{1}{2 \sqrt{2}}$

C.

$2 \sqrt{2}$

D.

$\frac{1}{\sqrt{2}}$

Answer: C

Solution:

$B_a=\frac{\mu_0 I R^2}{2\left(R^2+a^2\right)^{\frac{3}{2}}}$

Here, $a=R$

$$\therefore \quad B_a = \frac{\mu_0 I R^2}{2(R^2+R^2)^{\frac{3}{2}}} = \frac{\mu_0 I}{4\sqrt{2}R}$$

$$= \frac{\mu_0 I}{2R} \cdot \frac{1}{2\sqrt{2}}$$

$$\Rightarrow B_a = \frac{B_c}{2\sqrt{2}} \quad \left[\because B_c = \frac{\mu_0 I}{2R}\right]$$

$$\Rightarrow \frac{B_c}{B_a} = 2\sqrt{2}$$

Question13

The force per unit length on a straight wire carrying current of 8 A making an angle of 30° with a uniform magnetic field of 0.15 T is

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Options:

A.

$1.2 \mathrm{Nm}^{-1}$

B.

$1.02 \mathrm{Nm}^{-1}$

C.

$0.6 \mathrm{Nm}^{-1}$

D.

$2.4 \mathrm{Nm}^{-1}$

Answer: C

Solution:

Given:

- Current, $I = 8$ A
- Magnetic field, $B = 0.15$ T

- Angle between wire and field, $\theta = 30^\circ$

We are asked: **force per unit length** on the wire.

Formula:

$\frac{F}{L} = BI \sin\theta$

Substitution:

$\frac{F}{L} = (0.15)(8) \sin 30^\circ$

$\sin 30^\circ = \frac{1}{2}$

$\frac{F}{L} = 0.15 \times 8 \times 0.5$

$\frac{F}{L} = 0.6 \text{ N/m}$

✅ **Answer:** 0.6 N m^{-1}

Correct Option: (C)

Question14

An alpha particle moves along a circular path of radius 0.5 mm in a magnetic field of 2×10^{-2} T. The de-Broglie wavelength associated with the alpha particle is nearly (Planck's constant $= 6.63 \times 10^{-34}$ J s)

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Options:

A.

$3.1\overset{\circ}{\text{A}}$

B.

$1.1\overset{\circ}{\text{A}}$

C.

$0.1\overset{\circ}{\text{A}}$

D.

$2.1\overset{\circ}{\mathrm{A}}$

Answer: D

Solution:

$$r=\frac{mv}{Bq}$$

$$\Rightarrow \quad v=\frac{Bqr}{m}$$

and $\lambda=\frac{h}{mv}=\frac{h}{m\cdot\frac{Bqr}{m}}$

[From Eq. (i)]

$$=\frac{h}{Bqr}$$

$$=\frac{6.63\times10^{-34}}{2\times10^{-2}\times2\times1.6\times10^{-19}\times0.5\times10^{-3}}$$

$$=2.07\times10^{-10}\text{ m}=2.07\overset{\circ}{\mathrm{A}}=2.1\overset{\circ}{\mathrm{A}}$$

Question15

If a straight current carrying wire of linear density 0.12 kg m^{-1} is suspended in mid air by a uniform horizontal magnetic field of 0.5 T normal to the length of the wire, then the current through the wire is (Acceleration due to gravity $=10\text{ ms}^{-2}$, Neglect Earth's magnetic field)

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Options:

A.

2.4 A

B.

1.2 A

C.

0.6 A

D.

4.8 A

Answer: A

Solution:

- Linear mass density of wire, $\lambda = 0.12 \text{ kg/m}$
- Magnetic field, $B = 0.5 \text{ T}$
- Acceleration due to gravity, $g = 10 \text{ m/s}^2$
- The wire is suspended in air $\rightarrow$ magnetic force per unit length balances weight per unit length.

Step 1: Write force balance

For unit length of wire:

Magnetic force per unit length $=$ Weight per unit length

So,

$IB = \lambda g$

Step 2: Solve for I

$I = \frac{\lambda g}{B}$

Substitute:

$I = \frac{0.12 \times 10}{0.5}$

$I = \frac{1.2}{0.5} = 2.4 \text{ A}$

✅ **Final Answer:** $\boxed{I = 2.4 \text{ A}}$

Option A — 2.4 A

Question16

Two concentric loops A and B of same radius 2π cm are placed at right angles to each other. If the currents flowing through A and B

are 3 A and 4 A respectively, then the net magnetic field at their common centre is

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Options:

A.

0.75×10^{-5} T

B.

25×10^{-5} T

C.

5×10^{-5} T

D.

2.5×10^{-5} T

Answer: C

Solution:

Magnetic field at the centre of the loop A,

$$\begin{aligned} B_A &= \frac{\mu_0 I_A}{2r} \\ &= \frac{4\pi \times 10^{-7} \times 3}{2 \times 0.02 \times \pi} \\ &= 3 \times 10^{-5} \text{ J} \end{aligned}$$

The magnetic field at the centre of the loop B,

$$\begin{aligned} B_B &= \frac{\mu_0 I_B}{2r} = \frac{4\pi \times 10^{-7} \times 4}{2 \times 0.02 \times \pi} \\ &= 4 \times 10^{-5} \text{ T} \end{aligned}$$

Since, loops A and B are placed at right angles, thus magnetic field B_A and B_B are perpendicular to each other.

Thus, net magnetic field

$$
\begin{aligned}
B & =\sqrt{B_A^2+B_B^2} \\
& =\sqrt{\left(3 \times 10^{-5}\right)^2+\left(4 \times 10^{-5}\right)^2} \\
& =5 \times 10^{-5} \mathrm{~T}
\end{aligned}
$$

Question17

The magnetic field at a distance of 10 cm from a long straight thin wire carrying a current of 4 A is

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Options:

A.

$6 \mu \mathrm{~T}$

B.

$16 \mu \mathrm{~T}$

C.

$8 \mu \mathrm{~T}$

D.

$4 \mu T$

Answer: C

Solution:

$$
\begin{aligned}
B & =\frac{\mu_0 I}{2 \pi r} \\
& =2 \times 10^{-7} \times \frac{4}{10 \times 10^{-2}} \\
& =8 \times 10^{-6} \mathrm{~T}=8 \mu \mathrm{~T}
\end{aligned}
$$

Question18

A velocity selector is to be constructed to select ions with a velocity of $6 \mathrm{~km} \mathrm{~s}^{-1}$. If the electric field used is $400 \mathrm{~V} \mathrm{~m}^{-1}$, then the magnetic field to be used is

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Options:

A.

$\frac{11}{20} T$

B.

$\frac{2}{3} T$

C.

$\frac{1}{15} \mathrm{~T}$

D.

$\frac{2}{15} \mathrm{~T}$

Answer: C

Solution:

We have a **velocity selector** in which the electric field **E** and magnetic field **B** are perpendicular, and the particle passes undeflected when:

$qE = qvB$

so

$v = \frac{E}{B} \quad \text{or} \quad B = \frac{E}{v}$

Given values

$v = 6 \mathrm{~km/s} = 6 \times 10^3 \mathrm{~m/s}$

$E = 400 \mathrm{~V/m}$

Compute B

$B = \frac{E}{v} = \frac{400}{6 \times 10^3} = \frac{400}{6000} = \frac{4}{60} = \frac{1}{15} \mathrm{~T}$

✅ **Answer:**

$$\boxed{B = \frac{1}{15}\ \mathrm{T}}$$

Correct Option: (C) $\frac{1}{15}$ T

Question19

A closely wound solenoid of 1200 turns and area of cross-section $5\ \mathrm{cm}^2$ carries a current. If the magnetic moment of the solenoid is $1.2\mathrm{JT}^{-1}$, then the current through the solenoid is

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Options:

A.

2.5 A

B.

2 A

C.

3 A

D.

1.5 A

Answer: B

Solution:

- Number of turns, $N = 1200$
- Area of cross-section, $A = 5\ \mathrm{cm}^2 = 5 \times 10^{-4}\ \mathrm{m}^2$
- Magnetic moment, $M = 1.2\ \mathrm{J\ T}^{-1}$

We are asked to find the **current** I.

Step 1: Formula for magnetic moment of a solenoid

A solenoid with N turns, cross-sectional area A, and current I has a magnetic moment:

$M = NIA$

Step 2: Substitute given values

$1.2 = 1200 \times I \times (5 \times 10^{-4})$

Step 3: Simplify

$1.2 = 1200 \times 5 \times 10^{-4} \times I$

$1.2 = (0.6) \times I$

Step 4: Solve for I

$I = \frac{1.2}{0.6} = 2\,\text{A}$

✅ **Final Answer:**

$\boxed{I = 2\,\text{A}}$

Correct option: (B) 2 A

Question20

A charge q is spread uniformly over an isolated ring R. The ring is rotated about its natural axis with angular speed ω. The magnetic dipole moment of the ring is

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Options:

A. $\frac{q\omega R}{2}$

B. $q\omega R^2$

C. $\frac{qwR^2}{2}$

D. $\frac{q\omega}{2R}$

Answer: C

Solution:

The magnetic dipole moment μ of a rotating charged ring can be found by noting that the rotating charge constitutes a current and then multiplying by the ring's area:

Current due to rotation

The ring completes one revolution in time

$T = \frac{2\pi}{\omega}$.

So the effective current is

$I = \frac{q}{T} = \frac{q\,\omega}{2\pi}$.

Area of the ring

$A = \pi R^2$.

Magnetic dipole moment

$\mu = I\,A = \frac{q\,\omega}{2\pi} \times \pi R^2 = \frac{q\,\omega\,R^2}{2}$.

Thus the correct choice is

Option C: $\boxed{\frac{q\,\omega\,R^2}{2}}$.

Question21

Current flows in a conductor from east to west. The direction of the magnetic field at a point below the conductor is towards

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Options:

A. north

B. south

C. east

D. west

Answer: B

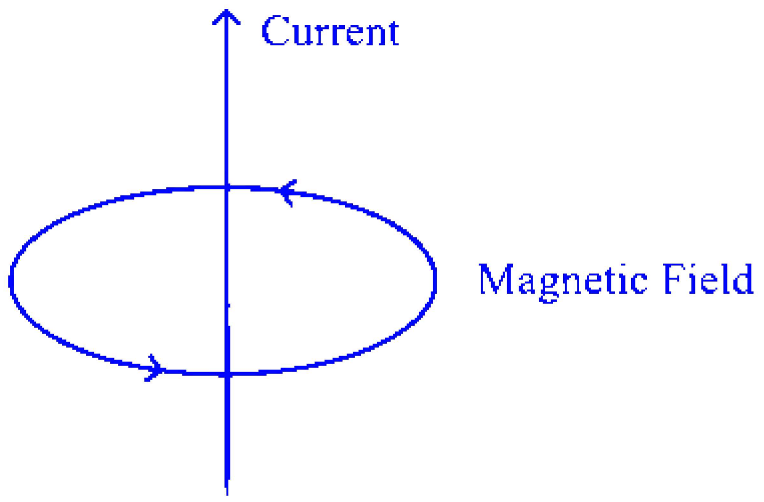
Solution:

Given,

Current flows in a conductor from to west.

According to the right-hand rule for a straight conductor, if you point your right thumb in the direction of conventional current, then your curled fingers indicate the direction of the magnetic field.

Here, thumb points in the east-west direction, then according to right-hand rule, the direction of the magnetic field at a point below the conductor is towards south.



Question22

Two infinite length wires carry currents 8 A and 6^{A} respectively and are placed along X and Y-axes respectively. Magnetic field at a point $P(0,0,C)$ will

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Options:

A. $\frac{7\mu_0}{\pi d}$

B. $\frac{10\mu_0}{\pi d}$

C. $\frac{14\mu_0}{\pi d}$

D. $\frac{5\mu}{\pi d}$

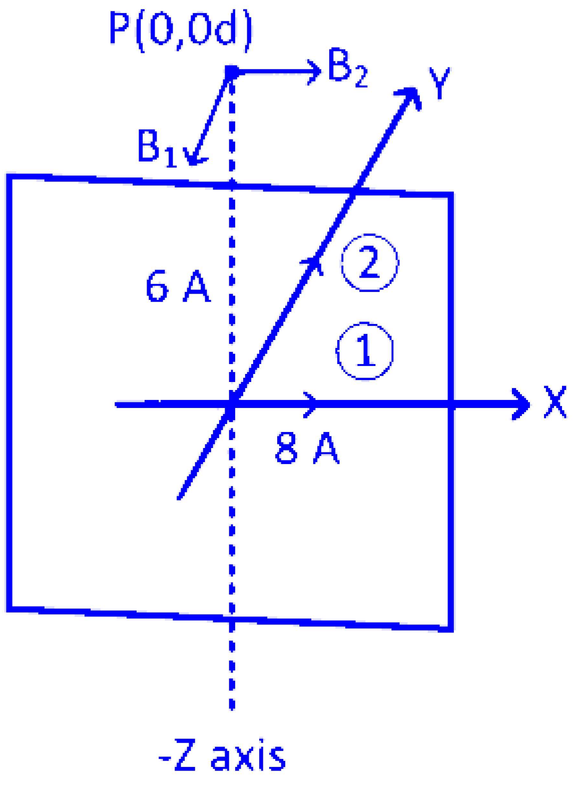
Answer: D

Solution:

We know that, The magnetic field B at a distance r from a long straight wire carrying current I is given by

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

$$\begin{aligned} Given, I_1 &= 8 \text{ A} \quad \text{(along } X\text{-axis)} \\ I_2 &= 6 \text{ A} \quad \text{(along } Y\text{-axis)} \end{aligned}$$



The direction of magnetic field due to infinite length of wire at point P is shown in figure.

Magnetic field due to wire 1 is,

$B_1 = \frac{\mu_0}{2\pi} \cdot \frac{8}{d} = \frac{\mu_0}{\pi} \cdot \frac{4}{d}$

Magnetic field due to wire 2 is,

$B_2 = \frac{\mu_0}{2\pi} \cdot \frac{6}{d} = \frac{\mu_0}{\pi} \cdot \frac{3}{d}$

Net magnetic field at point P is,

$$B_{\text{net}} = \sqrt{B_1^2 + B_2^2} = \sqrt{\left(\frac{\mu_0}{\pi} \cdot \frac{4}{d}\right)^2 + \left(\frac{\mu_0}{\pi} \cdot \frac{3}{d}\right)^2}$$
$$= \frac{\mu_0}{\pi d}\left(\sqrt{4^2 + 3^2}\right) = \frac{\mu_0}{\pi d} \cdot \sqrt{25}$$
$$B_{\text{net}} = \frac{5\mu_0}{\pi d}$$

Question23

A short magnet oscillates with a time period 0.1 s at a place where horizontal magnetic field is 24μ T. A downward current of 18 A is established in a vertical wire kept at a distance of 20 cm east of the magnet. The new time period of oscillations of the magnet is

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Options:

A. 0.1 s

B. 0.089 s

C. 0.076 s

D. 0.057 s

Answer: C

Solution:

Given the details of the problem, we start with the horizontal component of the Earth's magnetic field:

$B_H = 24 \times 10^{-6}\,\mathrm{T}$

The initial time period of oscillation for the magnet is:

$T_1 = 0.1\,\mathrm{s}$

The current flowing through the vertical wire is:

$I = 18\,\mathrm{A}$

The distance between the wire and the magnet is:

$r = 20\,\mathrm{cm} = 0.2\,\mathrm{m}$

To find the magnetic field due to the current-carrying wire, we use the formula for the magnetic field around a long straight conductor:

$B_{\text{wire}} = \frac{\mu_0}{2\pi} \cdot \frac{I}{r}$

Substituting the known values:

$B_{\text{wire}} = \frac{10^{-7} \times 2 \times 18}{0.2} = 18 \times 10^{-6}\,\mathrm{T}$

The time period of a magnetic dipole oscillating in a magnetic field is given by:

$T=2\pi\sqrt{\frac{I}{MB_H}}$

where:

I is the moment of inertia,

M is the magnetic moment.

For the initial and new conditions, we have:

$T_1=2\pi\sqrt{\frac{I}{MB_H}}$ (i)

$T_2=2\pi\sqrt{\frac{I}{M(B_H+B_{\text{wire}})}}$ (ii)

By dividing equation (i) by equation (ii), we obtain:

$\frac{T_1}{T_2}=\sqrt{\frac{B_H+B_{\text{wire}}}{B_H}}$

Substitute the given values:

$\frac{T_1}{T_2}=\sqrt{\frac{24\times10^{-6}+18\times10^{-6}}{24\times10^{-6}}}$

$\frac{0.1}{T_2}=\sqrt{\frac{42\times10^{-6}}{24\times10^{-6}}}=\frac{\sqrt{7}}{2}$

Solving further:

$T_2=\frac{0.2}{\sqrt{7}}$

Thus, the new time period of oscillation of the magnet is approximately:

$T_2=0.076\,\text{s}$

Question24

Two toroids with number of turns 400 and 200 have average radii respectively 30 cm and 60 cm . If they carry the same current, the ratio of magnetic fields in these two toroids is

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Options:

A. 2 : 1

B. 1 : 4

C. 2 : 3

D. 4 : 1

Answer: D

Solution:

Number of turns: $N_1 = 400$, $N_2 = 200$

Average radii: $r_1 = 30\,\text{cm} = 0.3\,\text{m}$, $r_2 = 60\,\text{cm} = 0.6\,\text{m}$

The magnetic field inside a toroid is given by the formula:

$B = \frac{\mu_0 NI}{2\pi R}$

where B is the magnetic field, μ_0 is the permeability of free space, N is the number of turns, I is the current, and R is the average radius of the toroid.

For the first toroid, the magnetic field B_1 is:

$B_1 = \frac{\mu_0 N_1 I}{2\pi R_1}$

For the second toroid, the magnetic field B_2 is:

$B_2 = \frac{\mu_0 N_2 I}{2\pi R_2}$

To find the ratio $\frac{B_1}{B_2}$:

$\frac{B_1}{B_2} = \frac{\mu_0 N_1 I}{2\pi R_1} \times \frac{2\pi R_2}{\mu_0 N_2 I} = \frac{N_1}{R_1} \times \frac{R_2}{N_2}$

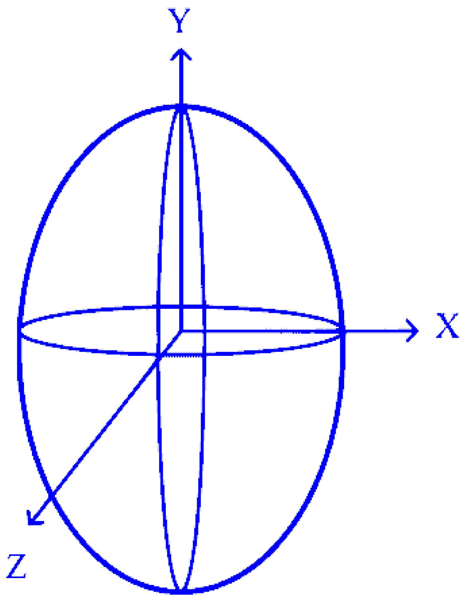
Substituting the values:

$\frac{B_1}{B_2} = \frac{400}{0.3} \times \frac{0.6}{200} = \frac{4}{1}$

Therefore, the ratio of magnetic fields in the two toroids is $B_1 : B_2 = 4 : 1$.

Question25

Three rings, each with equal radius r are placed mutually perpendicular to each other and each having centre at the origin of coordinate system. I is current passing through each ring. The magnetic field value at the common centre is



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Options:

A. zero

B. $(\sqrt{3}-1)\frac{\mu_0 I}{2\pi r}$

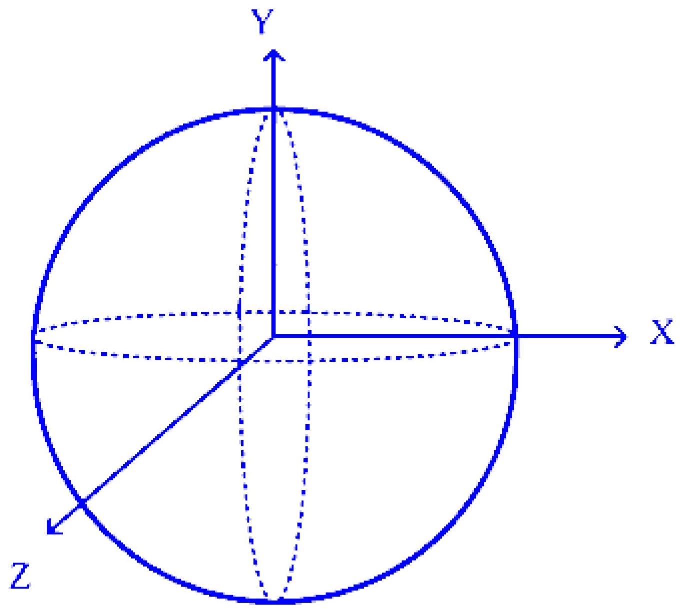
C. $\sqrt{3}\frac{\mu_0 dl}{2r}$

D. $\sqrt{2}\frac{\mu_0 l}{2r}$

Answer: C

Solution:

There are three ring having equal radius r, they are perpendicular to each other



Current flowing in each ring $= I$ Magnetic field at the common centre is

$\mathbf{B} = \frac{\mu_0 I}{2r}(\pm\hat{\mathbf{i}}) + \frac{\mu_0 I}{2r}(\pm\hat{\mathbf{j}}) + \frac{\mu_0 I}{2r}(\pm\hat{\mathbf{k}})$

Thus, $|\mathbf{B}| = \frac{\mu_0 I}{2r}\sqrt{3}$ or $|\mathbf{B}| = \frac{\sqrt{3}\mu_0 I}{2r}$

Question26

A proton and an alpha particle moving with energies in the ratio $1:4$ enter a uniform magnetic field of 3 T at right angles to the direction of magnetic field. The ratio of the magnetic forces acting on the proton and the alpha particle is

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Options:

A. $1:2$

B. $1:4$

C. $2:3$

D. $1:3$

Answer: A

Solution:

To determine the ratio of the magnetic forces acting on the proton and the alpha particle, we have the following information:

Ratio of kinetic energy: $(\mathrm{KE})_p : (\mathrm{KE})_\alpha = 1:4$

Magnetic field strength: $B = 3\,\mathrm{T}$

Angle with the magnetic field: $\theta = 90^\circ$

Definitions:

q is the charge of the particle.

v is the velocity of the particle.

F is the magnetic force acting on the particle.

Using the Lorentz Force Equation:

The magnetic force (F) on a charged particle moving in a magnetic field is given by:

$F = qvB\sin\theta$

Since $\theta = 90^\circ$, $\sin 90^\circ = 1$, so:

$F = qvB$

Given that the ratio of kinetic energy (KE) is:

$\frac{(\mathrm{KE})_p}{(\mathrm{KE})_\alpha} = \frac{1}{4}$

The kinetic energy (KE) is defined as:

$\mathrm{KE} = \frac{1}{2}mv^2$

Thus, we have:

$\frac{\frac{1}{2}m_p v_p^2}{\frac{1}{2}m_\alpha v_\alpha^2} = \frac{1}{4}$

Since the mass of the alpha particle (m_α) is four times that of the proton (m_p), i.e., $m_\alpha = 4m_p$, the equation simplifies to:

$\frac{v_p}{v_\alpha} = 1 \implies v_p = v_\alpha$

Calculating the Ratio of Forces:

From the equation $F = qvB$, the forces on the proton and alpha particle are:

For the proton: $F_p = q_p v_p B$

For the alpha particle: $F_\alpha = q_\alpha v_\alpha B$

The charge of the proton is $q_p = e$ and the charge of the alpha particle is $q_\alpha = 2e$. Therefore, we find the ratio of the forces:

$\frac{F_p}{F_\alpha} = \frac{q_p v_p B}{q_\alpha v_\alpha B} = \frac{e}{2e} = \frac{1}{2}$

Thus, the ratio of the magnetic force acting on the proton to that on the alpha particle is $1:2$.

Question27

A charged particle moving along a straight line path enters a uniform magnetic field of 4 mT at right angles to the direction of the magnetic field. If the specific charge of the charged particle is $8 \times 10^7 \mathrm{Ckg}^{-1}$. The angular velocity of the particle in the magnetic field is

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Options:

A. $64 \times 10^4 \mathrm{rads}^{-1}$

B. $32 \times 10^4 \mathrm{rads}^{-1}$

C. $16 \times 10^4 \mathrm{rads}^{-1}$

D. $48 \times 10^4 \mathrm{rads}^{-1}$

Answer: B

Solution:

Given:

Magnetic field, $B = 4\,\mathrm{mT} = 4 \times 10^{-3}\,\mathrm{T}$

Specific charge (charge-to-mass ratio), $\frac{q}{m} = 8 \times 10^7\,\mathrm{C/kg}$

When a particle moves in a circular path in an external magnetic field perpendicular to its velocity, the magnetic force acting on it is given by:

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

Also, the relationship between velocity, radius, and angular velocity is:

$v = r\omega$

Thus, the equation becomes:

$qvB = m\omega^2 r$

Rearranging terms, we find:

$qvB = m(r\omega)\omega$

$qvB = mv\omega$

Considering the specific charge, we derive the formula for angular velocity, ω:

$\omega = \frac{qB}{m}$

Substituting the given values:

$\omega = 8 \times 10^7 \times 4 \times 10^{-3}$
$\omega = 32 \times 10^4$ rad/s

Question28

When an electron placed in a uniform magnetic field is accelerated from rest through a potential difference V_1. It experiences a force F. If the potential difference is changed to V_2, the force experienced by the electron in same magnetic field is $2F$, then the ratio of potential differences $\frac{V_2}{V_1}$ is

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Options:

A. 2 : 1

B. 1 : 4

C. 4 : 1

D. 1 : 2

Answer: C

Solution:

To find the ratio of the potential differences $\frac{V_2}{V_1}$, we start by considering the kinetic energy relationship for an electron:

$K = \frac{1}{2}mv^2 = eV$

From this equation, we can solve for v:

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

The force F exerted by the magnetic field on an electron moving with velocity v is given by:

$F = ev \times B$

Substituting the expression for v into the force equation:

$$F = e \cdot \sqrt{\frac{2eV}{m}} \times B$$

We are given:

When the potential difference is V_1, the force is $F_1 = F$.

When the potential difference is V_2, the force doubles, $F_2 = 2F$.

According to the problem, we set up the force ratio:

$$\frac{F_1}{F_2} = \frac{e \cdot \sqrt{\frac{2eV_1}{m}} \times B}{e \cdot \sqrt{\frac{2eV_2}{m}} \times B}$$

Simplifying, we have:

$$\frac{F}{2F} = \sqrt{\frac{V_1}{V_2}}$$

This simplifies to:

$$\frac{1}{2} = \sqrt{\frac{V_1}{V_2}}$$

Squaring both sides gives:

$$\frac{V_1}{V_2} = \frac{1}{4}$$

This means:

$$\frac{V_2}{V_1} = \frac{4}{1}$$

Thus, the ratio $V_2 : V_1$ is 4 : 1.

Question29

A rectangular loop of sides 25 cm and 10 cm carrying a current of 10 A is placed with its longer side parallel to a long straight conductor 10 cm apart carrying current 25 A . The net force on the loop is

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Options:

A. 6.25×10^{-5} N

B. 5.5×10^{-5} N

C. 3.75×10^{-5} N

D. 8.75×10^{-11} N

Answer: A

Solution:

A rectangular loop $PQRS$ is positioned near a long straight wire as shown.

Dimensions and Parameters:

Length of PQ and RS: $l = 25\,\text{cm} = 0.25\,\text{m}$

Length of QR and PS: $b = 10\,\text{cm} = 0.10\,\text{m}$

Distance from PQ to wire XY: $r_1 = 10\,\text{cm} = 0.1\,\text{m}$

Distance from RS to wire XY: $r_2 = 20\,\text{cm} = 0.2\,\text{m}$

Calculating Forces:

Force on PQ:

Current in PQ is antiparallel to the current in XY, causing repulsion. The repulsive force is calculated by:

$F_1 = \frac{\mu_0}{2\pi} \cdot \frac{I_1 I_2}{r_1} \cdot l$

Substituting values:

$F_1 = \frac{2\times10^{-7}\times25\times10\times0.25}{0.1} = 1250 \times 10^{-7} = 1.25 \times 10^{-4}\,\text{N}$

Force on RS:

Current in RS is parallel to the current in XY, causing attraction. The attractive force is:

$F_2 = \frac{\mu_0}{2\pi} \cdot \frac{I_1 I_2}{r_2} \cdot l$

Substituting values:

$F_2 = \frac{2\times10^{-7}\times10\times25\times0.25}{0.2} = 625 \times 10^{-7} = 0.625 \times 10^{-4}\,\text{N}$

Forces on PS and QR:

The forces due to currents in PS and QR are equal in magnitude and opposite, cancelling each other out.

Net Force on the Loop:

The net force is the difference between F_1 and F_2:

$F_{\text{net}} = F_1 - F_2$

$F_{\text{net}} = 1.25 \times 10^{-4} - 0.625 \times 10^{-4}$

$F_{\text{net}} = 0.625 \times 10^{-4} = 6.25 \times 10^{-5}\,\text{N}$

The net force is directed away from the long wire XY.

Question30

Two long straight parallel conductors A and B carrying currents 4.5 A and 8 A respectively, are separated by 25 cm in air. The resultant magnetic field at a point which is at a distance of 15 cm from conductor A and 20 cm from conductor B is

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Options:

A. 2×10^{-5} N

B. 2×10^{-4} N

C. 10^{-5} N

D. 10^{-4} N

Answer: C

Solution:

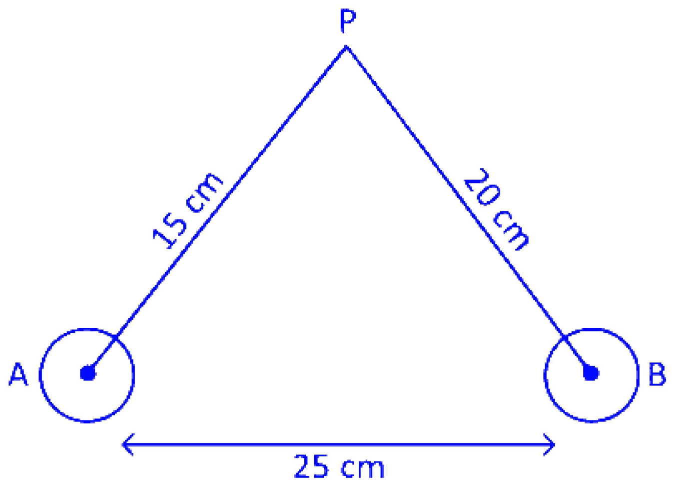
Given, current in conductor $A, i_A = 4.5$ A

current in conductor $B, i_B = 8$ A distance between two conductors,

$d = 25 \text{ cm} = 25 \times 10^{-2}$ m

Let $\odot$ represent the wire. Thus, magnetic field due to a conductor is given by

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



$\therefore$ Magnetic field due to wire A

$B_A = \frac{\mu_0 \times 4.5}{2 \times 314 \times 15 \times 10^{-2}}$

Magnetic field due to wire B,

$$\begin{aligned} B_B &= \frac{\mu_0 \times 8}{2 \times 314 \times 20 \times 10^{-2}} \\ B_{\text{net}} &= \sqrt{B_A^2 + B_B^2 + 2B_A B_A \cos\theta} \end{aligned}$$

From $\triangle APB, \cos\theta = 0 \quad (\because \theta = 90^\circ)$

$$\begin{aligned} \Rightarrow \quad B_{\text{net}} &= \sqrt{B_A^2 + B_B^2} \\ &= \frac{\mu_0}{10^{-2} \times 2\pi} \sqrt{\left(\frac{4.5}{15}\right)^2 + \left(\frac{8}{20}\right)^2} \\ &= \frac{\mu_0}{2\pi \times 10^{-2}} \times \sqrt{(0.3)^2 + (0.4)^2} \\ &= \frac{\mu_0}{2\pi \times 10^{-2}} \times (0.5) \\ &= 1 \times 10^{-5}\ \mathrm{N} \end{aligned}$$

Question31

Two concentric thin circular rings of radii 50 cm and 40 cm , each carry a current of 3.5 A in opposite directions. If the two rings are coplanar, the net magnetic field due to the rings at their centre is

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Options:

A. 11×10^{-7} T

B. 17×10^{-7} T

C. 22×10^{-7} T

D. #VALUE!

Answer: A

Solution:

Given:

Radius of the first ring, $R_1 = 40\,\mathrm{cm} = 0.4\,\mathrm{m}$

Radius of the second ring, $R_2 = 50\,\mathrm{cm} = 0.5\,\mathrm{m}$

Current carried by each ring, $I = 3.5\,\mathrm{A}$

The magnetic field at the center of a circular coil is given by:

$B_1 = \frac{\mu_0 I}{2R_1}$

For the second coil:

$B_2 = \frac{\mu_0 I}{2R_2}$

Since the currents are in opposite directions, the net magnetic field at the center is:

$$
\begin{aligned}
B_{\text{net}} &= B_1 - B_2 = \frac{\mu_0 I}{2}\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \\
&= \frac{\mu_0 I}{2}\left[\frac{1}{0.4} - \frac{1}{0.5}\right] \\
&= \frac{4\pi \times 10^{-7} \times 3.5}{2}\left[\frac{1}{0.4} - \frac{1}{0.5}\right] \\
&= 1.1 \times 10^{-6}\,\mathrm{T} \\
&= 11 \times 10^{-7}\,\mathrm{T}
\end{aligned}
$$

Question32

In hydrogen atom an electron is making $6.6 \times 10^{15} \mathrm{rev/s}$ around the nucleus of radius $0.47 \overset{o}{A}$. The magnetic field induction produced at the centre of the orbit is nearly.

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Options:

A. 0.14 Wb m^{-2}

B. 1.4 Wb m^{-2}

C. 14 Wb m^{-2}

D. 140 Wb m^{-2}

Answer: C

Solution:

To find the magnetic field induction produced at the center of an electron orbiting a hydrogen nucleus, we start by considering the electron as equivalent to a current loop.

The current (I) generated by the electron can be calculated using the formula:

$I = \frac{q}{t} = q \cdot f$

where:

$q = 1.6 \times 10^{-19}\,\text{C}$ (charge of an electron),

$f = 6.6 \times 10^{15}\,\text{Hz}$ (frequency, since the electron completes 6.6×10^{15} revolutions per second).

Calculating the current:

$I = 1.6 \times 10^{-19}\,\text{C} \times 6.6 \times 10^{15}\,\text{Hz} = 1.056 \times 10^{-3}\,\text{A} \approx 1\,\text{mA}$

The electron orbits a nucleus with a radius of $0.47\,\mathring{A} = 0.47 \times 10^{-10}\,\text{m}$.

The magnetic field induction (B) at the center of the orbit is given by:

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

where:

$\mu_0 = 4\pi \times 10^{-7}\,\text{T} \cdot \text{m/A}$ (permeability of free space),

$r = 0.47 \times 10^{-10}\,\text{m}$.

Plugging in the values:

$B = \frac{4\pi \times 10^{-7} \times 10^{-3}}{2 \times 0.47 \times 10^{-10}}$

This simplifies to:

$B = \frac{4\pi}{2 \times 0.47} \times 10^{7}$

Calculating further:

$B = 1336\,\text{Wb/m}^2 \approx 14\,\text{Wb/m}^2$

Therefore, the magnetic field induction at the center of the electron's orbit is approximately $14 \mathrm{~Wb/m^2}$.

Question33

When two coaxial coils having same current in same direction are brought to each other, then the value of current in both the coils

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Options:

A. increases

B. decreases

C. remains same

D. increases in one coil and decreases in other coil

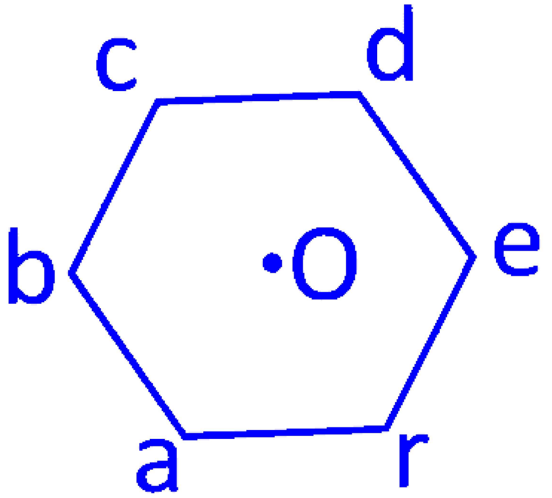
Answer: B

Solution:

When two coils are brought near to each other, then magnetic flux linked with both the coils changes, due to which an induce current produces. So, the current in both the coils decreases because induce current opposes the main current.

Question34

A wire shaped in a regular hexagon of side 2 cm carries a current of 4 A . The magnetic field at the centre of hexagon is



Options:

A. $4\sqrt{3} \times 10^{-5}$ T

B. $8\sqrt{3} \times 10^{-5}$ T

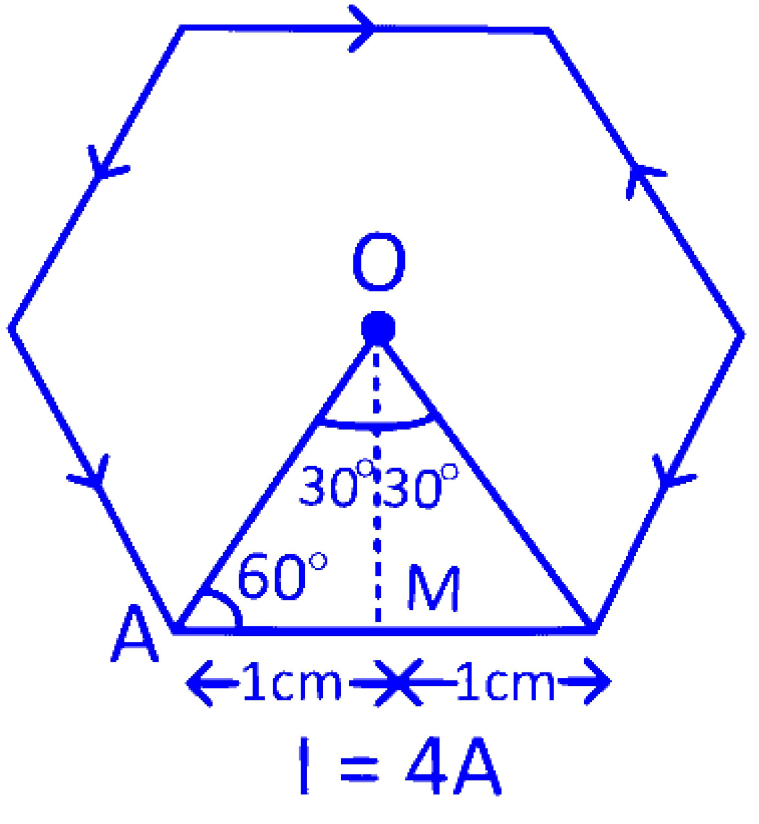
C. $\sqrt{3} \times 10^{-5}$ T

D. $6\sqrt{3} \times 10^{-5}$ T

Answer: B

Solution:

The given situation is shown below.



$$\frac{OM}{AM} = \tan 60^\circ$$
$$OM = AM \tan 60^\circ$$
$$= 1 \times \sqrt{3} \text{ cm} = \sqrt{3} \text{ cm}$$
$$OM = \sqrt{3} \times 10^{-2} \text{ m}$$

$\therefore$ Magnetic field at the centre,

$$B = 6 \times \frac{\mu_0}{4\pi} \frac{I}{(OM)} (\sin 30^\circ + \sin 30^\circ)$$
$$= 6 \times 10^{-7} \times \frac{4}{\sqrt{3} \times 10^{-2}} \left(\frac{1}{2} + \frac{1}{2}\right)$$
$$= 8\sqrt{3} \times 10^{-5} \text{ T}$$

Question35

A tightly wound coil of 200 turns and of radius 20 cm carrying current 5 A . Magnetic field at the centre of the coil is

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Options:

A. 3.14×10^{-3} T

B. 3.14×10^{-2} T

C. 628×10^{-4} T

D. 628×10^{-3} T

Answer: A

Solution:

To calculate the magnetic field at the center of a tightly wound coil, we use the formula:

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

μ_0 is the permeability of free space, approximately $4 \pi \times 10^{-7}$ T m/A.

N is the number of turns in the coil, which is 200.

I is the current passing through the coil, which is 5 A.

r is the radius of the coil in meters, given as 20 cm or 0.2 m.

Substituting these values into the formula:

$B=\frac{4 \pi \times 10^{-7} \times 200 \times 5}{2 \times 0.2}$

Solving this, we get:

$B=3.14 \times 10^{-3}$ T

Thus, the magnetic field at the center of the coil is 3.14×10^{-3} T.

Question36

A current carrying coil experiences a torque due to a magnetic field. The value of the torque is 80% of the maximum possible torque. The angle between the magnetic field and the normal to the plane of the coil is

AP EAPCET 2024 - 18th May Morning Shift

Options:

A. 30°

B. 45°

C. $\tan^{-1}\left(\frac{3}{4}\right)$

D. $\tan^{-1}\left(\frac{4}{3}\right)$

Answer: D

Solution:

A coil carrying a current experiences a torque when placed in a magnetic field. This torque is quantified by the following relation:

$\tau = N \cdot I \cdot A \cdot B \cdot \sin\theta$

where N is the number of turns in the coil, I is the current flowing through the coil, A is the area of the coil, B is the magnetic field strength, and θ is the angle between the magnetic field and the normal to the plane of the coil.

The torque is at its maximum when $\sin\theta = 1$, which occurs at $\theta = 90^{\circ}$. Thus, the maximum torque $\tau_{\max}$ can be expressed as:

$\tau_{\max} = N \cdot I \cdot A \cdot B \quad \ldots(\text{i})$

According to the problem, the experienced torque is 80% of this maximum:

$N \cdot I \cdot A \cdot B \cdot \sin\theta = 0.8 \cdot \tau_{\max}$

Substituting $\tau_{\max}$ from equation (i):

$N \cdot I \cdot A \cdot B \cdot \sin\theta = \frac{80}{100} \cdot (N \cdot I \cdot A \cdot B)$

This simplifies to:

$\sin\theta = \frac{4}{5}$

We know that:

$\cos\theta = \sqrt{1 - \sin^2\theta} = \frac{3}{5}$

Thus, the tangent of the angle θ becomes:

$\tan\theta = \frac{\sin\theta}{\cos\theta} = \frac{4/5}{3/5} = \frac{4}{3}$

Therefore, the angle θ is:

$\theta = \tan^{-1}\left(\frac{4}{3}\right)$

Question37

An electron in moving with a velocity $\left[\mathrm{i} + 3\hat{\mathrm{j}}\ \mathrm{ms}^{-1}\right.$ in an electric field $(\hat{\mathrm{i}} + 6\hat{\mathrm{j}} + 2\hat{\mathrm{k}})\mathrm{Vm}^{-1}$ and a magnetic field of $(\Omega\mathrm{j} + 3\mathrm{k})$ T. Then, the magnitude and direction (with X-axis) of the Lorentz force

acting on the electron is

AP EAPCET 2024 - 18th May Morning Shift

Options:

A. 96×10^{-11} N, $8 = \cos^{-1}\left(\frac{2}{\sqrt{5}}\right)$

B. 96×10^{-19} N, $\theta = \cos^{-1}\left(\frac{5}{\sqrt{2}}\right)$

C. 215×10^{-18} N, . $\theta = \cos^{-1}\left(\frac{2}{\sqrt{5}}\right)$

D. 2.15×10^{-14} N, $\theta = \cos^{-1}\left(\frac{5}{\sqrt{2}}\right)$

Answer: C

Solution:

Given:

Velocity of the electron: $\mathbf{v} = (2\hat{\mathbf{i}} + 3\hat{\mathbf{j}})$ m/s

Electric field: $\mathbf{E} = (3\hat{\mathbf{i}} + 6\hat{\mathbf{j}} + 2\hat{\mathbf{k}})$ V/m

Magnetic field: $\mathbf{B} = (2\hat{\mathbf{j}} + 3\hat{\mathbf{k}})$ T

The Lorentz force is calculated using the formula:

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

First, solve for $\mathbf{v} \times \mathbf{B}$:

$$\mathbf{v} \times \mathbf{B} = \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 2 & 3 & 0 \\ 0 & 2 & 3 \end{vmatrix} = (9\hat{\mathbf{i}} - 6\hat{\mathbf{j}} + 4\hat{\mathbf{k}})$$

Now, find the total force $\mathbf{F}$:

$$\mathbf{F} = q\left[(3\hat{\mathbf{i}} + 6\hat{\mathbf{j}} + 2\hat{\mathbf{k}}) + (9\hat{\mathbf{i}} - 6\hat{\mathbf{j}} + 4\hat{\mathbf{k}})\right] = q[12\hat{\mathbf{i}} + 6\hat{\mathbf{k}}]$$

For an electron, $q = 1.6 \times 10^{-19}$ C:

$$\mathbf{F} = 1.6 \times 10^{-19} \times [12\hat{\mathbf{i}} + 6\hat{\mathbf{k}}]$$
$$|\mathbf{F}| = 1.6 \times 10^{-19} \times \sqrt{12^2 + 6^2}$$
$$|\mathbf{F}| = 1.6 \times 10^{-19} \times \sqrt{180}$$
$$|\mathbf{F}| = 2.15 \times 10^{-18} \text{ N}$$

To determine the direction of $\mathbf{F}$ with respect to the X-axis:

$$\theta = \tan^{-1}\left(\frac{6}{12}\right) = \tan^{-1}\left(\frac{1}{2}\right)$$

Thus, we have:

$$\cos\theta = \frac{2}{\sqrt{5}} \quad \Rightarrow \quad \theta = \cos^{-1}\left(\frac{2}{\sqrt{5}}\right)$$

Question38

An electron having kinetic energy of 100 eV circulates in a path of radius 10 cm in a magnetic field. The magnitude of magnetic field $|\mathbf{B}|$ is approximately[Mass of electron $= 0.5 \text{ MeVc}^{-2}$, where c is the velocity of light].

AP EAPCET 2022 - 5th July Morning Shift

Options:

A. 3.3×10^{-4} T

B. 2.6×10^{-4} T

C. 1.70×10^{-4} T

D. 4.3×10^{-4} T

Answer: A

Solution:

Kinetic energy of electron,

$$K = 100\text{eV}$$
$$= 100 \times 1.6 \times 10^{-19} \text{ J} = 1.6 \times 10^{-17} \text{ J}$$

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

Mass of electron, $m = 0.5 \text{ MeVc}^{-2}$

$$= \frac{0.5\text{MeV}}{c^2} = \frac{0.5 \times 10^6 \times 1.6 \times 10^{-19}}{3 \times 10^8 \times 3 \times 10^8} \text{ kg}$$
$$= 8.89 \times 10^{-31} \text{ kg}$$

$\because$ Radius of circular path of electron in magnetic field B in terms of kinetic energy (K) is given as

$$r = \frac{\sqrt{2mK}}{Bq}$$

$$\Rightarrow B = \frac{\sqrt{2mK}}{rq} = \frac{\sqrt{2 \times 8.89 \times 10^{-31} \times 1.6 \times 10^{-17}}}{0.1 \times 1.6 \times 10^{-19}}$$
$$= 3.3 \times 10^{-4} \text{ T}$$

Question39

A particle of mass 2.2×10^{-30} kg and charge 1.6×10^{-19}C is moving at a speed of 10 km s^{-1} in a circular path of radius 2.8 cm inside a solenoid. The solenoid has $25 \frac{\text{turns}}{\text{cm}}$ and its magnetic field is perpendicular to the plane of the particle's path. The current in the solenoid is

(Take, $\mu_0 = 4\pi \times 10^{-7} \text{ Hm}^{-1}$)

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Options:

A. 1.25 mA

B. 10.20 mA

C. 2.50 mA

D. 1.56 mA

Answer: D

Solution:

Given :

Mass of the particle, $m = 2.2 \times 10^{-30}$ kg

Charge, $q = 1.6 \times 10^{-19}$ C

Velocity, $v = 10\,\text{km/s} = 10^4\,\text{m/s}$

Radius of the circular path, $r = 2.8\,\text{cm} = 2.8 \times 10^{-2}\,\text{m}$

Turn density, $n = 25\,\text{turns/cm} = 2500\,\text{turns/m}$

Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\,\text{H/m}$

The radius of the circular path is given by the equation :

$r = \frac{mv}{Bq} \quad \text{(i)}$

The magnetic field inside the solenoid is given by :

$B = \mu_0 n I \quad \text{(ii)}$

Combining equations (i) and (ii), we get :

$$r = \frac{mv}{(\mu_0 n I) q}$$

$$\Rightarrow I = \frac{mv}{\mu_0 n q r}$$

$$= \frac{2.2 \times 10^{-30} \times 10^4}{4\pi \times 10^{-7} \times 2500 \times 1.6 \times 10^{-19} \times 2.8 \times 10^{-2}}$$

$$= 1.56 \times 10^{-3}\,\text{A} = 1.56\,\text{mA}$$

Question40

A toroid has a non ferromagnetic core of inner radius 24 cm and outer radius 25 cm , around which 4900 turns of a wire are wound. If the current in the wire is 12 A , the magnetic field inside the core of the toroid is

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Options:

A. 56 mT

B. 54 mT

C. 42 mT

D. 48 mT

Answer: D

Solution:

For a toroid,

Inner radius, $r_1 = 24$ cm

Outer radius, $r_2 = 25$ cm

Current, $I = 12$ A

$\because$ Length of toroid,

$$\begin{aligned} l &= 2\pi \frac{(r_1 + r_2)}{2} \\ &= \pi (r_1 + r_2) \\ &= \pi(24 + 25) \\ &= 0.49\pi \mathrm{m} \end{aligned}$$

$\because$ no. of turns per unit length in toroid,

$$\begin{aligned} n &= \frac{N}{l} \\ &= \frac{4900}{0.49\pi} = \frac{10^4}{\pi} \end{aligned}$$

$\because$ Magnetic field inside the core of toroid

$$\begin{aligned} B &= \mu_0 n I \\ &= 4\pi \times 10^{-7} \times \frac{10^4}{\pi} \times 12 \\ &= 48 \times 10^{-3}\ \mathrm{T} = 48\mathrm{mT} \end{aligned}$$

Question41

Two infinitely long wires each carrying the same current and pointing in $+y$ direction are placed in the xy-plane, at $x = -2$ cm and $x = 1$ cm. An electron is fired with speed u from the origin making an angle of $+45^\circ$ from the X-axis. The force on the electron at the instant it is fired is

[B_0 is the magnitude of the field at origin due to the wire at $x = 1$ cm alone].

Options:

A. $\frac{-euB_0}{2\sqrt{2}}(\hat{\boldsymbol{i}}-\hat{\boldsymbol{j}})$

B. $\frac{-euB_0}{2}(\hat{\boldsymbol{i}}-\hat{\boldsymbol{j}})$

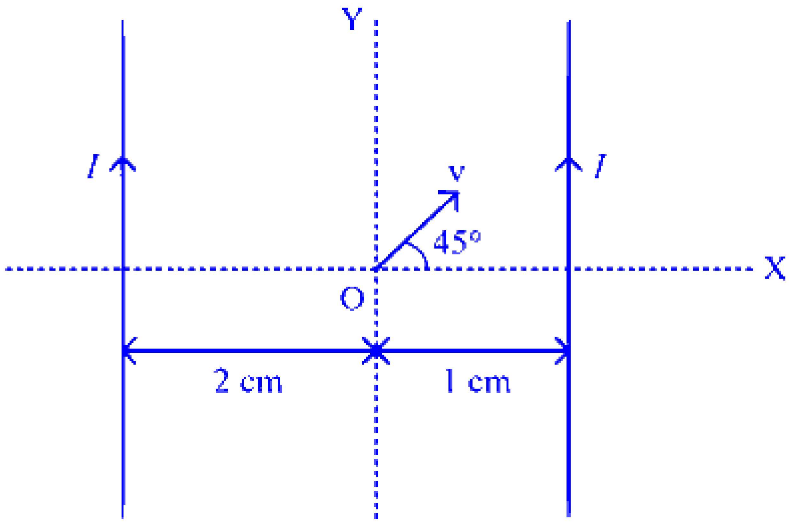
C. $\frac{-euB_0}{\sqrt{2}}(\hat{\boldsymbol{i}}-\hat{\boldsymbol{j}})$

D. $-\mathrm{euB}_0(\hat{\boldsymbol{i}}-\hat{\boldsymbol{j}})$

Answer: A

Solution:

The given situation is shown below



Magnetic field intensity at point O due to wire 1

$\mathbf{B}_0=\frac{\mu_0}{2\pi}\times\frac{\mathbf{I}}{r_1}\hat{k}$

$\Rightarrow \quad \mathbf{B}_0=\frac{\mu_0}{2\pi}\times\frac{\mathbf{I}}{1\times10^{-2}}\hat{k} \quad$ ... (i)

Similarly, magnetic field at point O due wire 2

$$\mathbf{B}' = \frac{\mu_0}{2\pi}\hat{k}\frac{I}{r_2} = \frac{\mu_0}{2\pi} \cdot \frac{I}{2 \times 10^{-2}}(-\hat{k})$$

$\Rightarrow$

$$\mathbf{B}' = \frac{1}{2}\left[\frac{\mu_0}{2\pi}\frac{I}{10^{-2}}\right](\hat{k})$$

$$= \frac{1}{2} \times B_0(-\hat{k}) \quad \text{[Form Eq. (i)]}$$

$$= \frac{B_0}{2}(-\hat{k}) = -\frac{B_0}{2}$$

Net magnetic field at point O.

$$\mathbf{B}_{\text{net}} = \mathbf{B}_0 + \mathbf{B}' = \mathbf{B}_0 + \mathbf{B}'$$

$$= B_0 - \frac{B_0}{2} = \frac{B_0}{2}$$

$$\mathbf{B}_{\text{net}} = \frac{1}{2} \cdot \frac{\mu_0}{2\pi} \cdot \frac{1}{1 \times 10^{-2}}\hat{k} \quad \text{[From Eq. (i)]}$$

$$= \frac{\mathbf{B}_0}{2}\hat{k}$$

force on the electron,

$$\mathbf{F} = -e\left(\mathbf{u} \times \mathbf{B}_{\text{net}}\right)$$

$$= -e\left[\mathbf{u}\left(\cos 45\hat{i} + \sin 45^\circ\hat{j}\right) \times \mathbf{B}_{\text{net}}\right]$$

$$= -e\left[\frac{\mathbf{u}}{\sqrt{2}}(\hat{i} + \hat{j}) \times \frac{B_0}{2}\hat{k}\right] = \frac{-euB_0}{2\sqrt{2}}[\hat{i} \times \hat{k} + \hat{j} \times \hat{k}]$$

$$= \frac{-euB_0}{2\sqrt{2}}[-\hat{j} + \hat{i}] = -\frac{-euB_0}{2\sqrt{2}}(\hat{i} - \hat{j})$$

Question42

Two electrons, e_1 and e_2 of mass m and charge q are injected into the perpendicular direction of the magnetic field B such that the kinetic energy of e_1 is double than that of e_2. The relation of their frequencies of rotation, f_1 and f_2 is

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Options:

A. $f_1 = f_2$

B. $f_1 = 2f_2$

C. $2 f_1=f_2$

D. $4 f_1=f_2$

Answer: A

Solution:

If v_1 and v_2 be the velocities of electron e_1 and e_2. Then according to given condition.

$$K_1=2 K_2$$
$$\frac{1}{2} m v_1^2=2\left(\frac{1}{2} m v_2^2\right)$$
$$\Rightarrow \quad v_1^2=2 v_2^2 \Rightarrow v_1=\sqrt{2} v_2$$

Since, frequency of rotation of electrons in magnetic field is given as,

$f=\frac{2 \pi m}{B q} \Rightarrow f \propto \frac{m}{q}$

Since m and q are same for both electrons e_1 and e_2 an f does not depend on the velocity of moving electron.

Hence, $f_1=f_2$

Question43

Torque required to hold a small circular coil of 10 turns, area of $2 \times 10^{-4} \mathrm{~m}^2$ area of carrying 0.5 A current in the middle of a long solenoid of 10^3 turns per metre carrying $3 \mathrm{~A}$ current, with its axis perpendicular to the axis of the solenoid is

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Options:

A. $12 \pi \times 10^{-7} \mathrm{Nm}$

B. $6 \pi \times 10^{-7} \mathrm{Nm}$

C. $4 \pi \times 10^{-7} \mathrm{Nm}$

D. $2 \pi \times 10^{-7} \mathrm{Nm}$

Answer: A

Solution:

Given, number of turns for coil, $N_1 = 10$

Coil area, $A_1 = 2 \times 10^{-4} \text{ m}^2$

Coil current, $I_1 = 0.5 \text{ A}$

and number of turns per metre of solenoid, $n_2 = 1000$

Current through solenoid, $I_2 = 3 \text{ A}$

Since, Torque (τ) = magnetic moment $(M) \times$ magnetic field

$$\Rightarrow \tau = I_1 N_1 A_1 \times n_2 \mu_0 I_2$$
$$\Rightarrow \tau = \frac{5}{10} \times 10 \times 2 \times 10^{-4} \times 10^3 \times 4\pi \times 10^{-7} \times 3$$
$$= 12\pi \times 10^{-7} \text{ N} - \text{m}$$

Question44

Two concentric coils each of radius equal to 4π cm are placed at right angles to each other. If 10 A and 24 A are the currents flowing through the coils respectively, then the magnetic induction at the centre of the coils will be

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Options:

A. 13×10^{-5} T

B. 12×10^{-5} T

C. 7×10^{-5} T

D. 5×10^{-5} T

Answer: A

Solution:

Given, radius of coil, $R = 4\pi \times 10^{-2}$ m

Current through coils $I_1 = 10$ A, $I_2 = 24$ A

Let, B_1, B_2 is the magnetic induction due to coil 1 and 2

$B_1 = \frac{1}{2}\frac{\mu_0 I_1}{R} \Rightarrow B_1 = \frac{1}{2} \times \frac{4\pi\times10^{-7}\times10}{4\pi\times10^{-2}} = 5 \times 10^{-5}$ T

Similarly,

$$\begin{aligned} B_2 &= \frac{1}{2}\frac{4\pi \times 10^{-7} \times 24}{4\pi \times 10^{-2}} = 12 \times 10^{-5} \text{ T} \\ \therefore \quad B_{\text{net}} &= \sqrt{B_1^2 + B_2^2} = 10^{-5}\sqrt{5^2 + 12^2} \\ &= 10^{-5}\sqrt{25 + 144} = 13 \times 10^{-5} \text{ T} \end{aligned}$$

Question45

A wire of length L metre carrying a current I ampere is bent in the form of a circle. Magnitude of its magnetic moment is

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Options:

A. $\frac{L^2 I^2}{4\pi}$

B. $\frac{L^2 I}{4\pi}$

C. $\frac{LI}{4\pi}$

D. $\frac{LI^2}{4\pi}$

Answer: B

Solution:

Given,

Length of wire $= L$

Current through wire $= I$

$\because$ Magnetic moment, $m = \text{Current } (I) \times \text{Area}(A)$ ..... (i)

and since circle of radius r is made of wire of length L

$\therefore \quad 2\pi r = L \Rightarrow r = \frac{L}{2\pi}$

So, area, $A = \pi r^2$

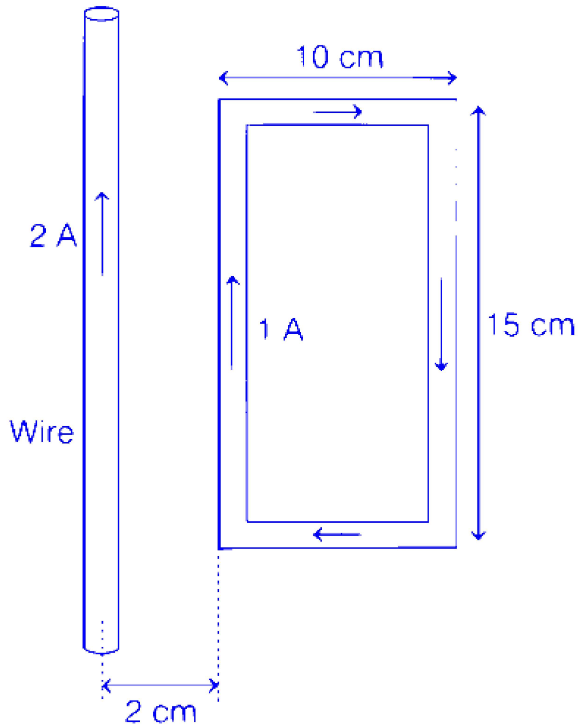
$= \pi\left(\frac{L}{2\pi}\right)^2 = \frac{L^2}{4\pi}$

Put this value in Eq. (i), we get

$m = \frac{IL^2}{4\pi}$

Question46

What is the net force on the square coil?



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Options:

A. 25×10^{-7} N moving towards wire

B. 25×10^{-7} N moving away from wire

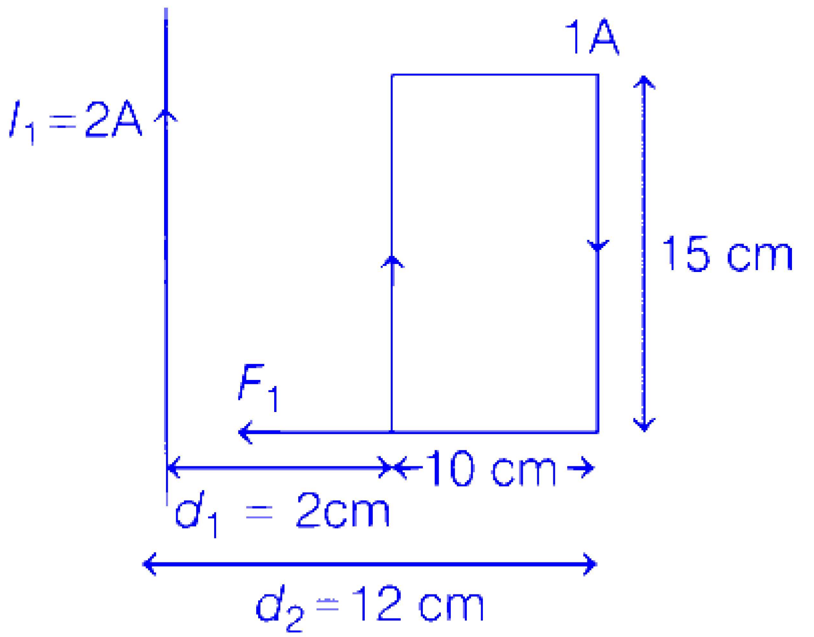
C. 35×10^{-7} N moving towards wire

D. 35×10^{-7} N moving away from wire

Answer: A

Solution:

According to given diagram,



As we know that, $F = \frac{\propto_0}{2\pi} \cdot \frac{I_1 I_2}{d} l$

where, F is force, $\propto_0$ is $4\pi \times 10^{-7}$, I_1 and I_2 are currents in conductors, l is length of conductor and d is separation between two wires. As same sense of current, attract whereas opposite sense, repel.

$$\therefore \text{ Net force, } F_{\text{net}} = \left(\frac{\alpha_0}{2\pi} \frac{I_1 I_2}{d_1} - \frac{\alpha_0}{2\pi} \frac{I_1 \cdot I_2}{d_2}\right) l$$

$$= \frac{\alpha_0}{2\pi} \cdot \left(\frac{2 \times 1}{2 \times 10^{-2}} - \frac{2 \times 1}{12 \times 10^{-2}}\right) 15 \times 10^{-2}$$

$= 25 \times 10^{-7}$ N, towards wire

Question47

In a co-axial, straight cable, the central conductor and the outer conductor carry equal currents in opposite directions. The magnetic field is zero

Options:

A. outside the cable

B. inside the inner conductor

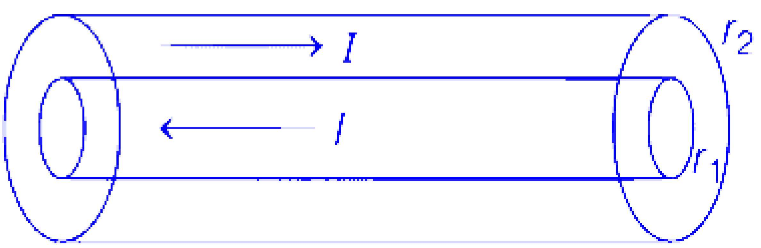
C. inside the outer conductor

D. in between the two conductors

Answer: A

Solution:

According to question, construction of currentand conductor is



$\because$ Magnetic field due to straight conductor,

$(B)=\frac{1}{2\pi}\frac{\mu_0 I}{R}$

Let B_{net} , B_1 and B_2 are net magnetic field, magnetic field due to conductor 1 and 2, respectively.

$\therefore B_{\text{net}} \ =B_1-B_2=\frac{\mu_0 I}{2\pi}\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$

$\because r_2>r_1$

$\therefore B_{net}$ will only zero outside conductor or cable.

Question48

The magnetic field, of a given length of wirefor single turn coil, at its centre is B, then itsvalue for two turns coil for the same wire is

Options:

A. B/4

B. B/2

C. 4B

D. 2B

Answer: C

Solution:

Given, initial magnetic field at centre of single turn coil $= B$

Final number of turn, $n_2 = 2$

Let final magnetic field be B'

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

where, μ_0 is permeability,

I is current,

R is radius,

But length l of conductor is same.

$\Rightarrow \quad l = 2\pi R = 2 \times 2\pi R' \Rightarrow R' = R/2$

$$\text{Now,} \quad B \propto \frac{n}{R}$$

$$\therefore \quad \frac{B'}{B} = \frac{2}{\frac{R}{2}} \times \frac{R}{1} = 4 \Rightarrow B' = 4B$$

Question49

In which of the following case no forceexerted by a magnetic field on a charge?

Options:

A. Moving with constant velocity

B. Moving in a circle

C. At rest

D. Moving along a curved path

Answer: C

Solution:

As, we know that, force on a moving chargeparticle.

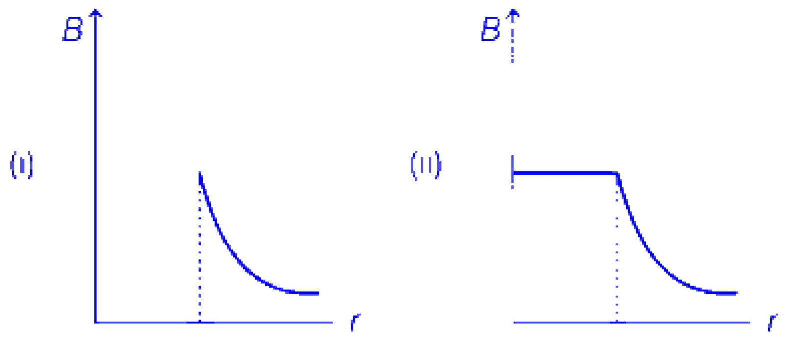
$\therefore F = Bqv \sin\theta$

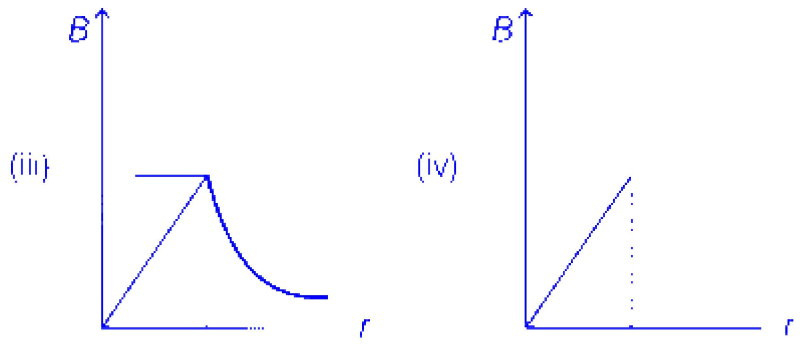
Hence, F will be zero, if any of the parameter ofabove formula equals zero.

$\therefore$ Force on a charge at rest will be zero.

Question50

A long thin hollow metallic cylinder of radiusR has a current i ampere. The magneticinduction B away from the axis at a distance rfrom the axis varies as shown in





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Options:

A. (i)

B. (ii)

C. (iii)

D. (iv)

Answer: A

Solution:

Given, radius of hollow cylinder = R

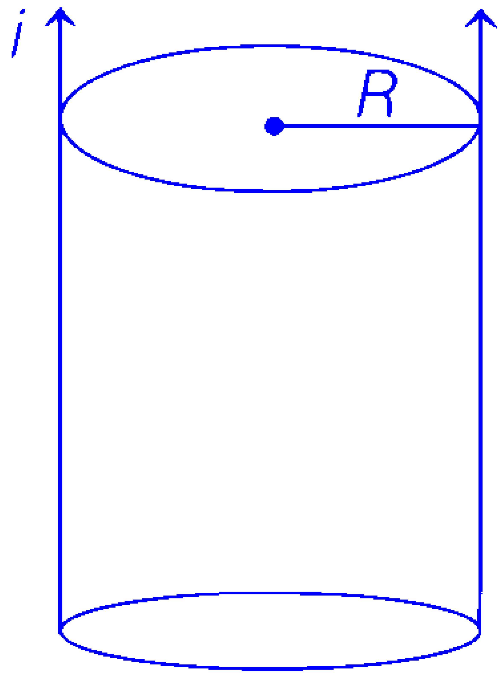
Current = i

Distance from axis = r

Let magnetic field be B.

∵ No current is passing through region r < R

and magnetic field $(B) = \frac{1}{2\pi} \frac{\propto_0 I}{r}$



So,

$$B(r < R) = 0$$

$$B(r = R) = \frac{1}{2\pi} \frac{\propto_0 I}{R}$$

and

$$B(r > R) = \frac{1}{2\pi} \frac{\propto_0 I}{r}$$

So, these variations are correctly shown as below.