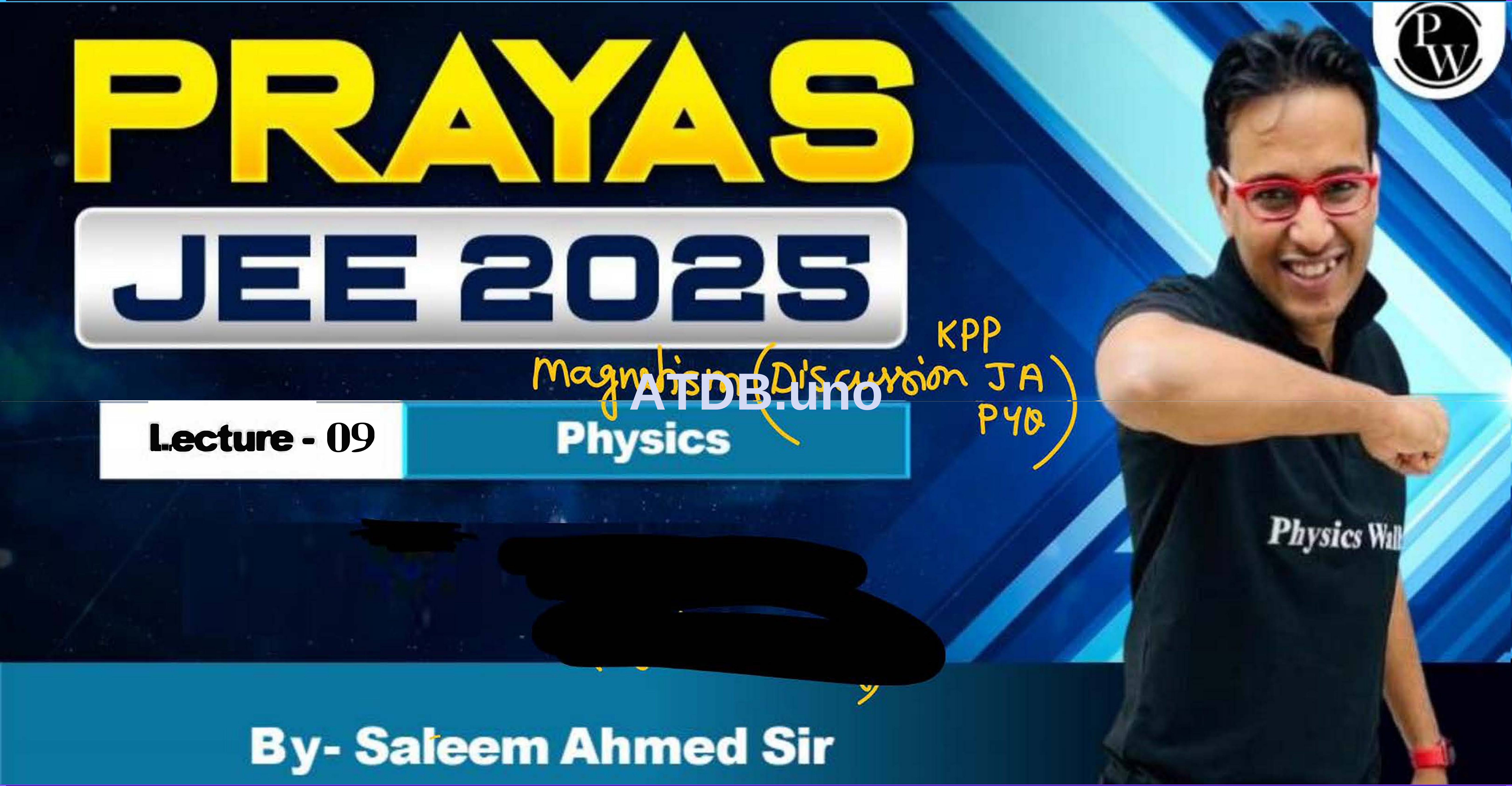
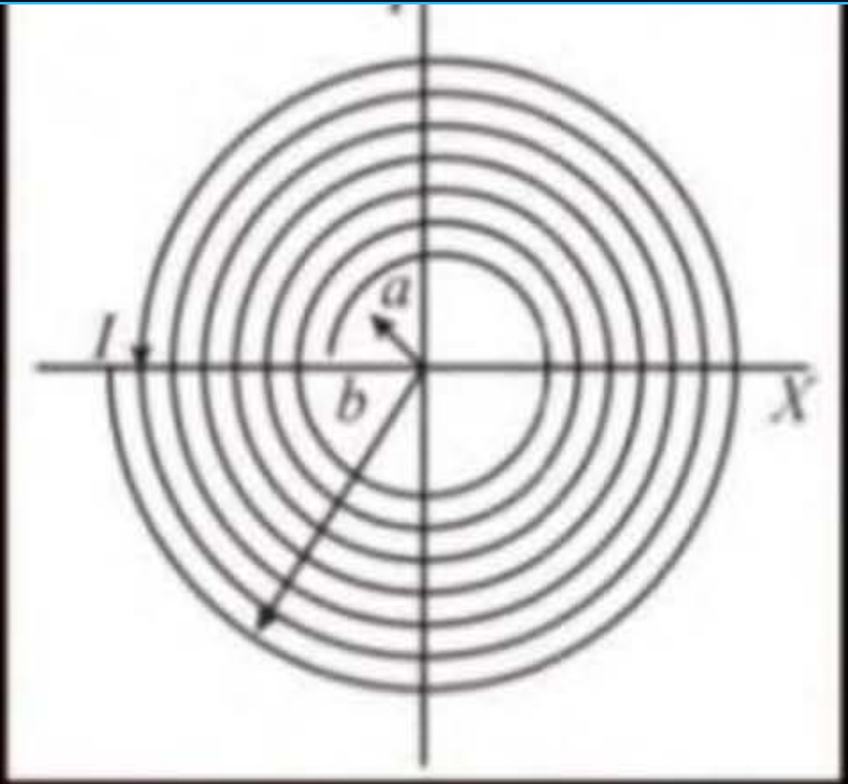

PRAYAS
JEE 2025
Magnetism (Discussion KPP JA PYQ)
Lecture - 09
Physics
[redacted]
By- Saleem Ahmed Sir

Today's Goal

KPP Discussion

1. A long insulated copper wire is closely wound as a spiral of N turns. The spiral has inner radius a and outer radius b. The spiral lies in the $X-Y$ plane and a steady current I flows through the wire. The Z-component of the magnetic field at the centre of the spiral is

(IIT-JEE 2011)



(a) $\frac{\mu_0 NI}{2(b-a)} ln\left(\frac{b}{a}\right)$ (b) $\frac{\mu_0 NI}{2(b-a)} ln\left(\frac{b+a}{b-a}\right)$

(c) $\frac{\mu_0 NI}{2b} ln\left(\frac{b}{a}\right)$ (d) $\frac{\mu_0 NI}{2b} ln\left(\frac{b+a}{b-a}\right)$

(E) Clan

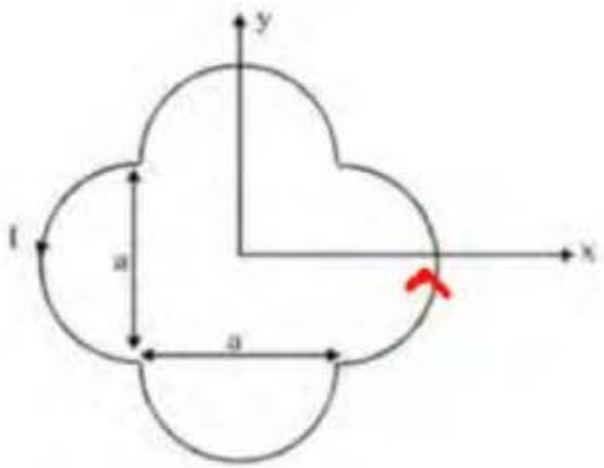
Ans : (a)

of the plane of the paper. The magnetic moment of the current loop is [JEE 2012]

चित्र में दर्शाये अनुसार एक लूप x-y तल में है और उस धारा I बह रही है। एकांक-सदिश $\hat{k}$ पृष्ठ के लम्बवत् बाहर की ओर है। लूप का चुम्बकीय आघूर्ण है

2

$\vec{m} = iA\hat{k}$



(A) $a^2I\hat{k}$ (B) $\left(\frac{\pi}{2}+1\right)a^2I\hat{k}$ (C) $-\left(\frac{\pi}{2}+1\right)a^2I\hat{k}$ (D) $(2\pi+1)a^2I\hat{k}$

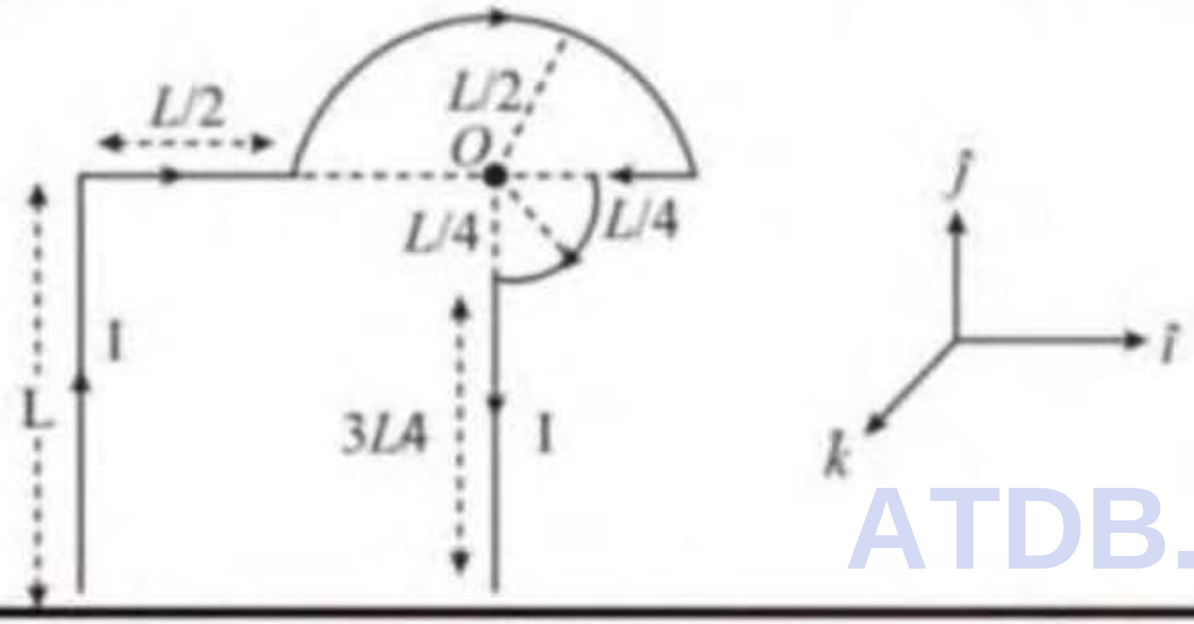
Single Correct

51. A thin flexible wire of length L is connected to two adjacent fixed points and carries a current I in the clockwise direction, as shown in the figure. When the system is put in a uniform magnetic field of strength B going into the plane of the paper, the wire takes the shape of a circle. The tension in the wire is (IIT-JEE 2010)

(a) IBL (b) $\frac{IBL}{\pi}$ (c) $\frac{IBL}{2\pi}$ (d) $\frac{IBL}{4\pi}$

4

Q. Which one of the following options represents the magnetic field $\vec{B}$ at O due to the current flowing in the given wire segments lying on the xy plane? (JEE Adv. 2022)



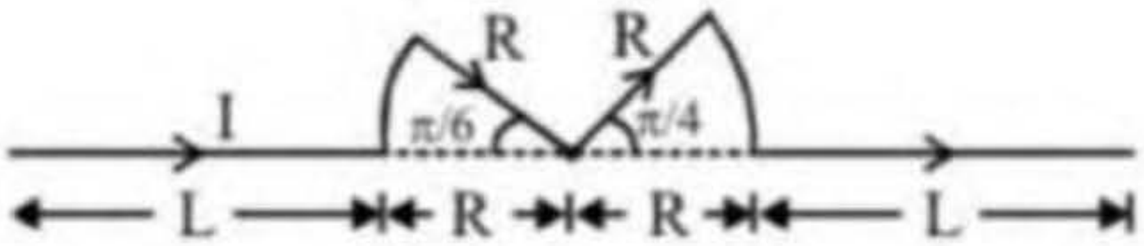
(a) $\vec{B} = \dfrac{-\mu_o I}{L}\left(\dfrac{3}{2} + \dfrac{1}{4\sqrt{2}\pi}\right)\hat{k}$ (b) $\vec{B} = -\dfrac{\mu_o I}{L}\left(\dfrac{3}{2} + \dfrac{1}{2\sqrt{2}\pi}\right)\hat{k}$

(c) $\vec{B} = \dfrac{-\mu_o I}{L}\left(1 + \dfrac{1}{4\sqrt{2}\pi}\right)\hat{k}$ (d) $\vec{B} = \dfrac{-\mu_o I}{L}\left(1 + \dfrac{1}{4\pi}\right)\hat{k}$

Ans : (c)

A conductor (shown in the figure) carrying constant current I is kept in the x-y plane in a uniform magnetic field $\vec{B}$. If F is the magnitude of the total magnetic force acting on the conductor, then the correct statement(s) is (are) **[JEE-Advanced-2015]**

5



(A) $\vec{B} = B_0 \hat{k}$

$F = i(2L+2R)B$

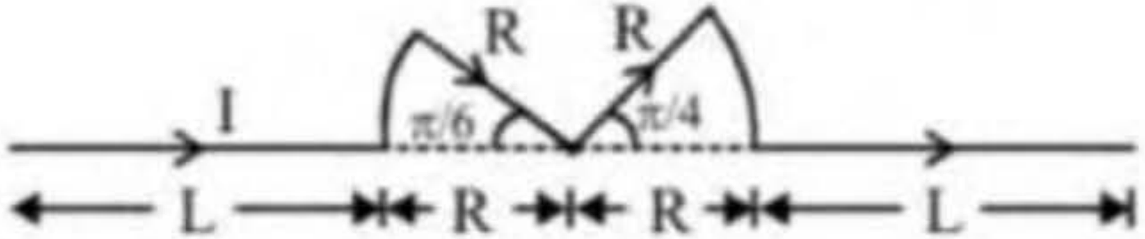
(A) If $\vec{B}$ is along $\hat{z}$, $F \propto (L+R)$

(B) If $\vec{B}$ is along $\hat{x}$, $F = 0$

(C) If $\vec{B}$ is along $\hat{y}$, $F \propto (L+R)$

(D) If $\vec{B}$ is along $\hat{z}$, $F = 0$

दर्शाये गए चित्रानुसार x-y तल में स्थित एक विद्युत I धारावाही चालक एकसमान चुंबकीय क्षेत्र $\vec{B}$ में रखा है। यदि चालक पर लगने वाले कुल चुंबकीय बल का परिमाण F है, तब सही विकल्प है (हैं) :-



(A,B,C)

(A) यदि $\vec{B}$ की दिशा $\hat{z}$ है तब $F \propto (L+R)$

(B) यदि $\vec{B}$ की दिशा $\hat{x}$ है तब $F = 0$

(C) यदि $\vec{B}$ की दिशा $\hat{y}$ है तब $F \propto (L+R)$

(D) यदि $\vec{B}$ की दिशा $\hat{z}$ है तब $F = 0$

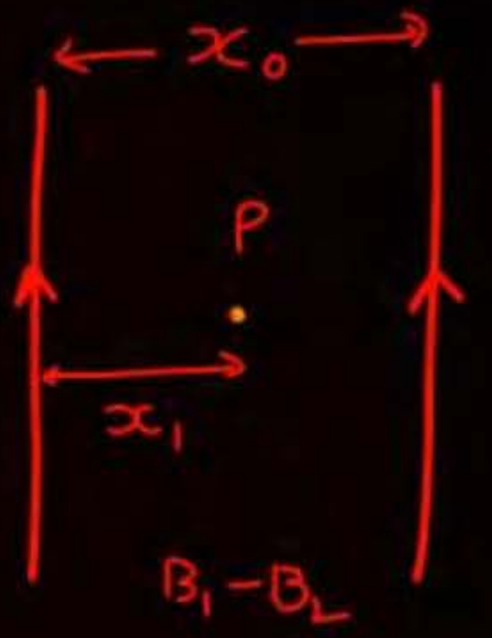
(A,B,C)

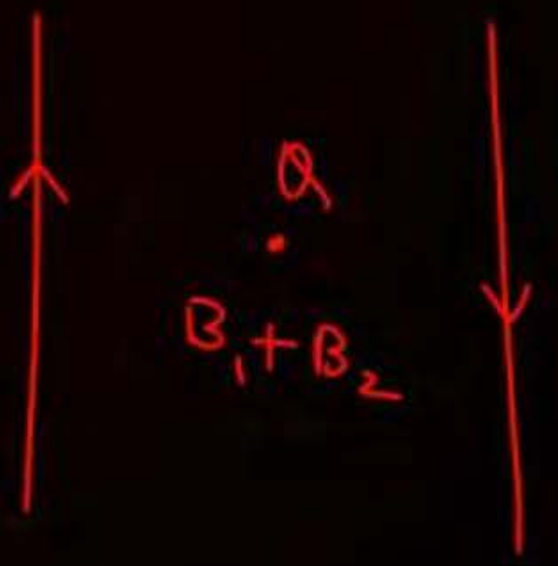
Q. 6 Two parallel wires in the plane of the paper are distance x_0 apart. A point charge is moving with speed u between the wires in the same plane at a distance x_1 from one of the wires. When the wires carry current of magnitude I in the same direction, the radius of curvature of the path of the point charge is R_1. In contrast, if the currents I in the two wires have directions opposite to each other, the radius of curvature of the path is R_2. If $\frac{x_0}{x_1} = 3$, and value of $\frac{R_1}{R_2}$ is

(JEE Adv. 2014)

$$R = \frac{mv}{qB_{net}}$$

$$\frac{R_1}{R_2} = \frac{B_1+B_2}{B_1-B_2}$$





Ans : (3)

Q. 12 (7) An electron and a proton are moving on straight parallel paths with same velocity. They enter a semi-infinite region of uniform magnetic field perpendicular to the velocity. Which of the following statement(s) is/are true? **(IIT-JEE 2011)**

(a) They will never come out of the magnetic field region

(b) They will come out travelling along parallel paths

(c) They will come out at the same time

(d) They will come out at different times

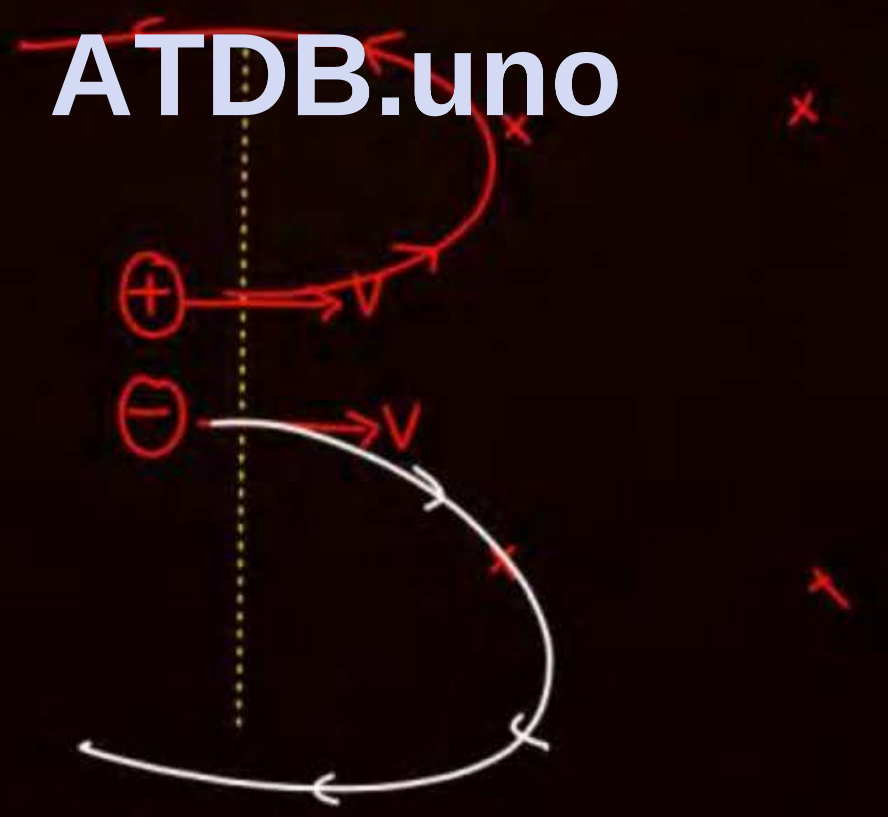
$|q| \longrightarrow$ same

$m \longrightarrow$ अलग

$m_p > m_e$

$$R = \frac{mv}{qB}$$

$$t = \frac{T}{2} = \frac{2\pi m}{qB} \propto \frac{1}{2}$$



Ans : (b, d)

Q. 1 (8) An α-particle (mass 4 amu) and a singly charged sulfur ion (mass 32 amu) are initially at rest. They are accelerated through a potential V and then allowed to pass into a region of uniform magnetic field which is normal to the velocities of the particles. Within this region, the α-particle and the sulfur ion move in circular orbits of radii r_α and r_s, respectively. The ratio (r_s/r_α) is__________.

(JEE Adv. 2021)

α — $(+2e, 4m)$

sulph — $(+e, 32m)$

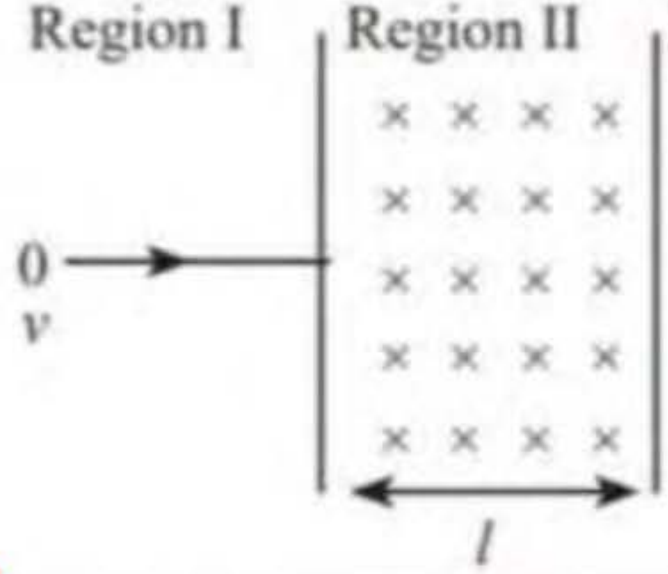
$$r = \frac{mv}{qB} = \frac{\sqrt{2m(KE)}}{qB}$$

$$r = \frac{\sqrt{2m(q\Delta V)}}{qB}$$

$$\frac{r_1}{r_2} = \sqrt{\frac{m_1}{m_2}\frac{q_1}{q_2}} \times \frac{q_2}{q_1}$$

Ans : (4)

Q. 9 A particle of mass m and charge q, moving with velocity v enters Region II normal to the boundary as shown in the figure. Region II has a uniform magnetic field B perpendicular to the plane of the paper. The length of the Region II is l. Choose the correct choice (s)



(IIT-JEE 2008)

$d < \frac{mv}{qB} \Rightarrow v > \frac{dqB}{m}$

(a) The particle enters Region III only if its velocity $v > \frac{qlB}{m}$

$d < R$

(b) The particle enters Region III only if its Velocity $v < \frac{qlB}{m}$

(c) Path length of the particle in Region II is maximum when velocity $v = qlB/m$

(d) Time spent in Region II is same for any velocity v as long as the particle returns to Region I

$d = R = \frac{mv}{qB}$

$v = \frac{qBd}{m}$

Ans : (a, c, d)

Q. 1 Consider the motion of a positive point charge in a region where there are simultaneous uniform electric and magnetic fields $E = E_0\hat{j}$ and $B = B_0\hat{j}$. At time $t = 0$, this charge has velocity v in the $x-y$ plane, making an angle θ with the x-axis. Which of the following option(s) is/are correct for time $t > 0$?

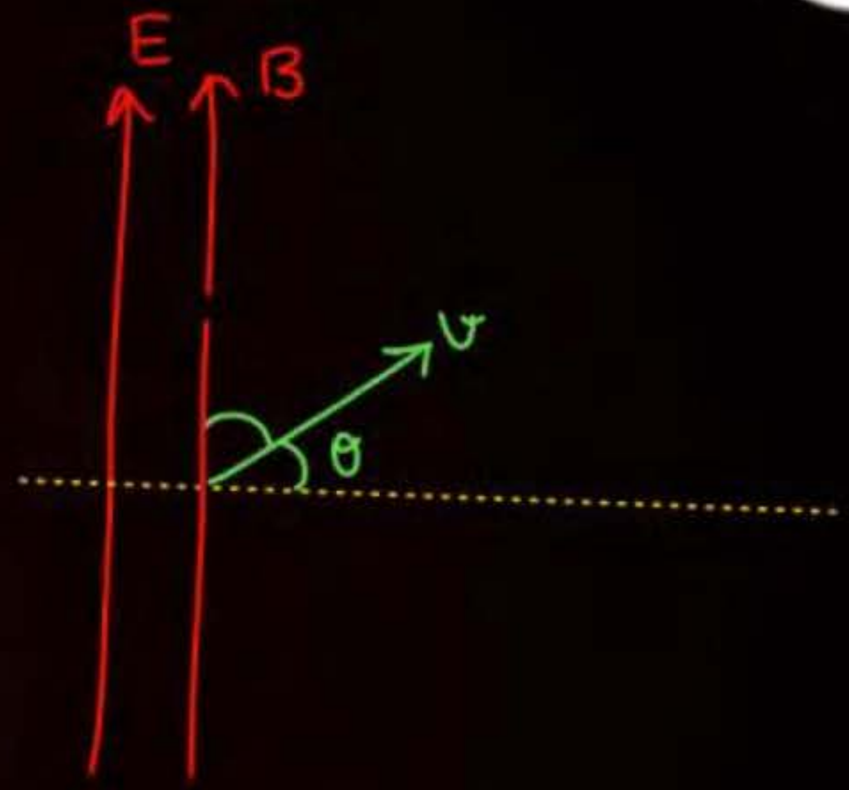
(IIT-JEE 2012)

(a) If $\theta = 0°$, the charge moves in a circular path in the $x-z$ plane

(b) If $\theta = 0°$, the charge undergoes helical motion with constant pitch along the y-axis

(c) If $\theta = 10°$, the charge undergoes helical motion with its pitch increasing with time, along the y-axis

(d) If $\theta = 90°$, the charge undergoes linear but accelerated motion along the y-axis



Ans : (c, d)


ω
θ
v

A particle of mass M and positive charge Q, moving with a constant velocity $\vec{u}_1 = 4\hat{i}\ ms^{-1}$, enters a region of uniform static magnetic field normal to the x-y plane. The region of the magnetic field extends from x = 0 to x = L from all values of y. After passing through this region, the particle emerges on the other side after 10 milliseconds with a velocity $\vec{u}_2 = 2\left(\sqrt{3}\hat{i} + \hat{j}\right)ms^{-1}$. The correct statements(s) is (are) :-

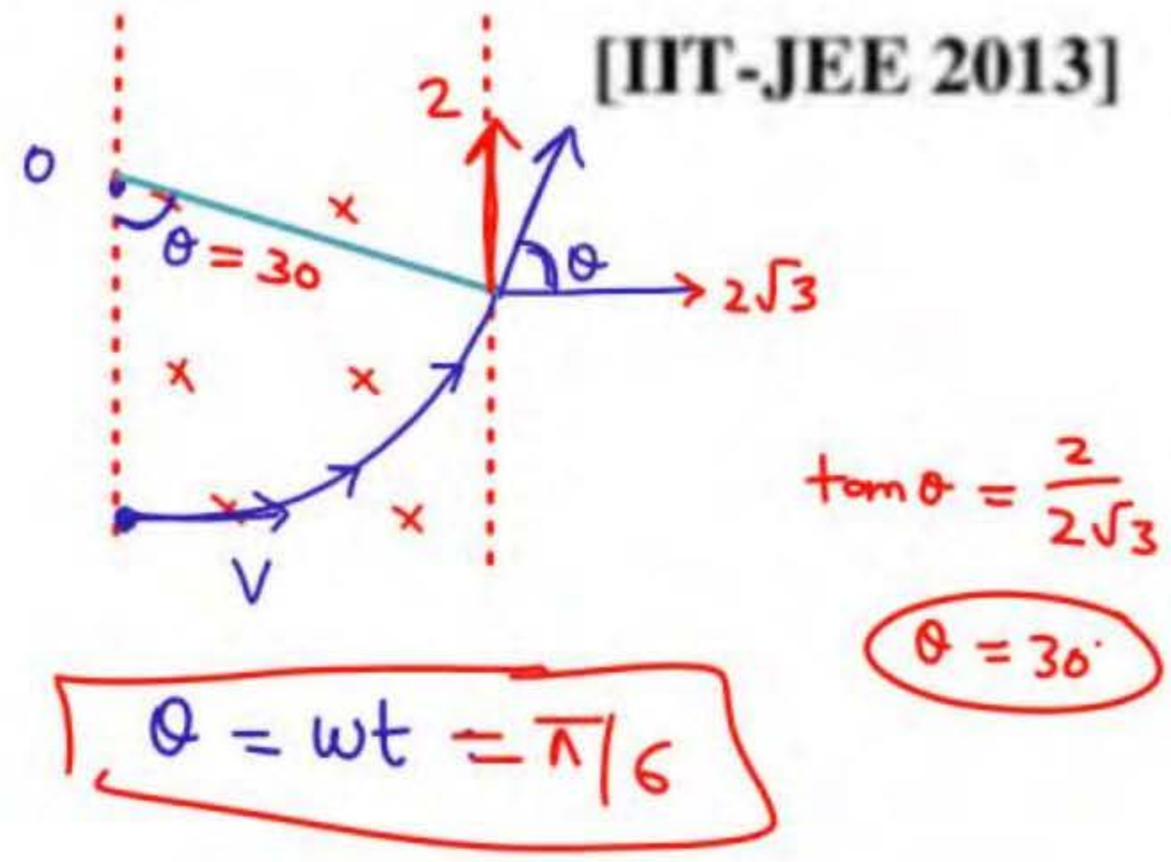
[IIT-JEE 2013]

(A) The direction of the magnetic field is –z direction.

(B) The direction of the magnetic field is +z direction.

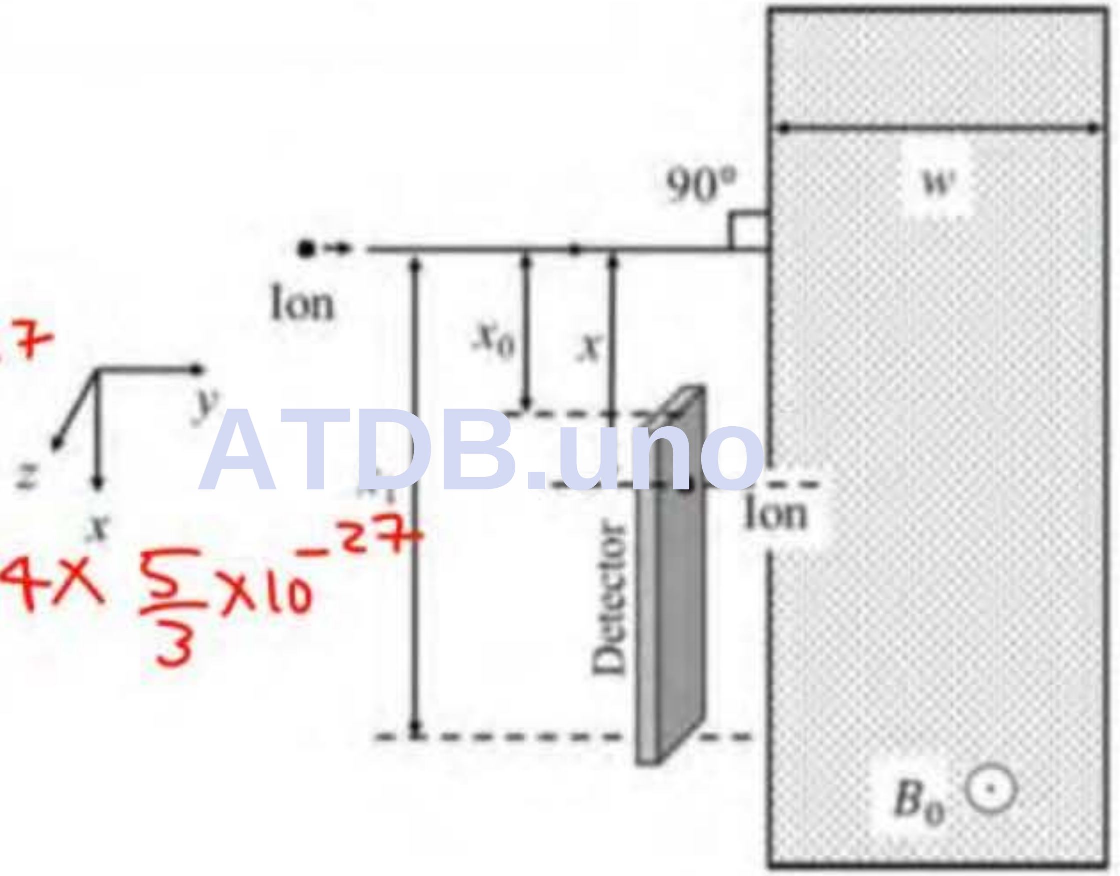
(C) The magnitude of the magnetic field $\frac{50\pi M}{3Q}$ units.

(D) The magnitude of the magnetic field is $\frac{100\pi M}{3Q}$ units.



Q.12 A positive, singly ionized atom of mass number A_M is accelerated from rest by the voltage 192 V. Thereafter, it enters a rectangular region of width w with magnetic field $\vec{B}_0 = 0.1\hat{k}$ Tesla, as shown in the figure. The ion finally hits a detector at the distance x below its starting trajectory.

[Given: Mass of neutron/proton = $(5/3) \times 10^{-27}$ kg, charge of the electron = 1.6×10^{-19} C.]



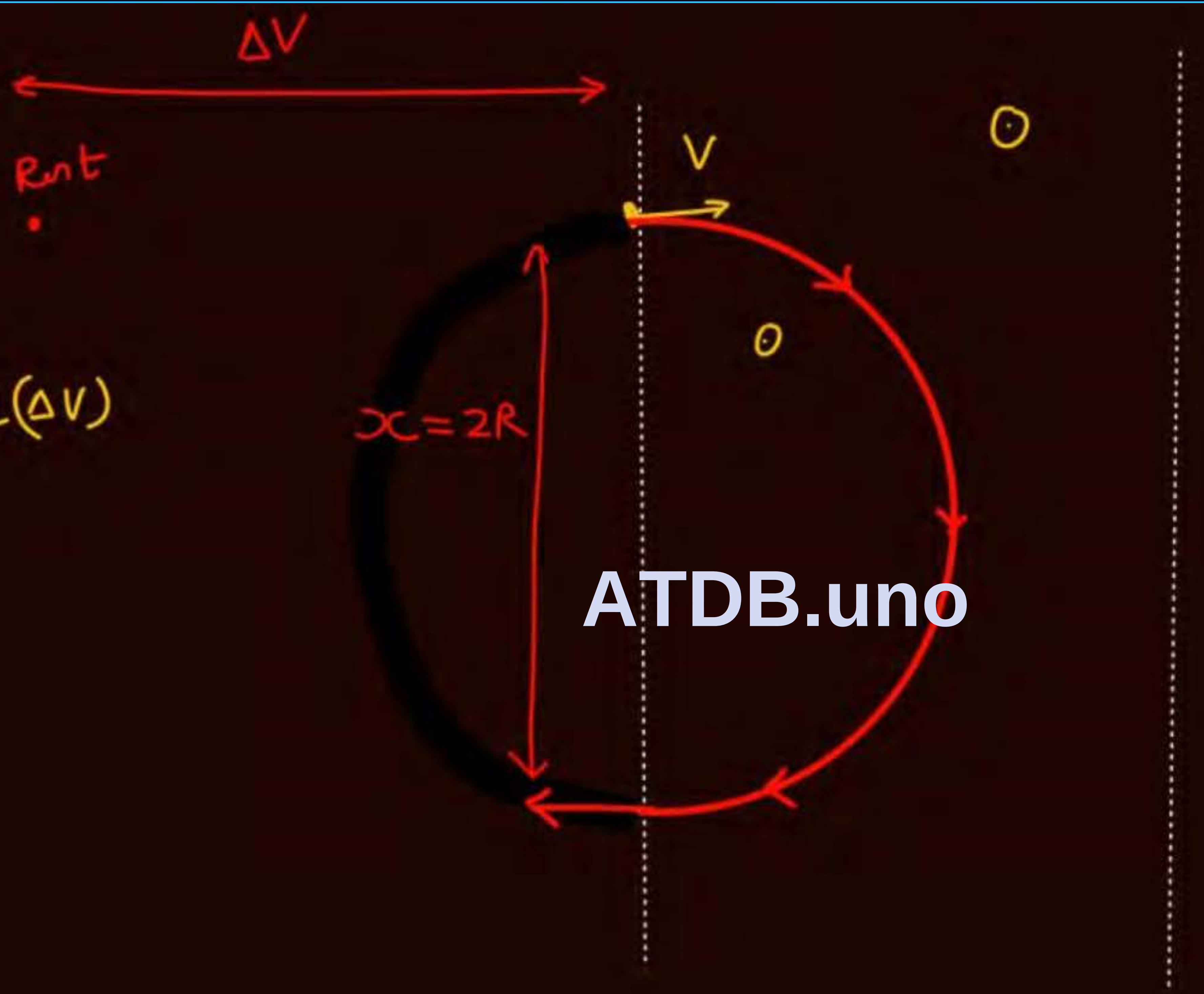
Which of the following option(s) is(are) correct?

(A) The value of x for H^+ ion is 4 cm.

(B) The value of x for an ion with $A_M = 144$ is 48 cm.

(C) For detecting ions with $1 \le A_M \le 196$, the minimum height $(x_1 - x_0)$ of the detector is 55 cm.

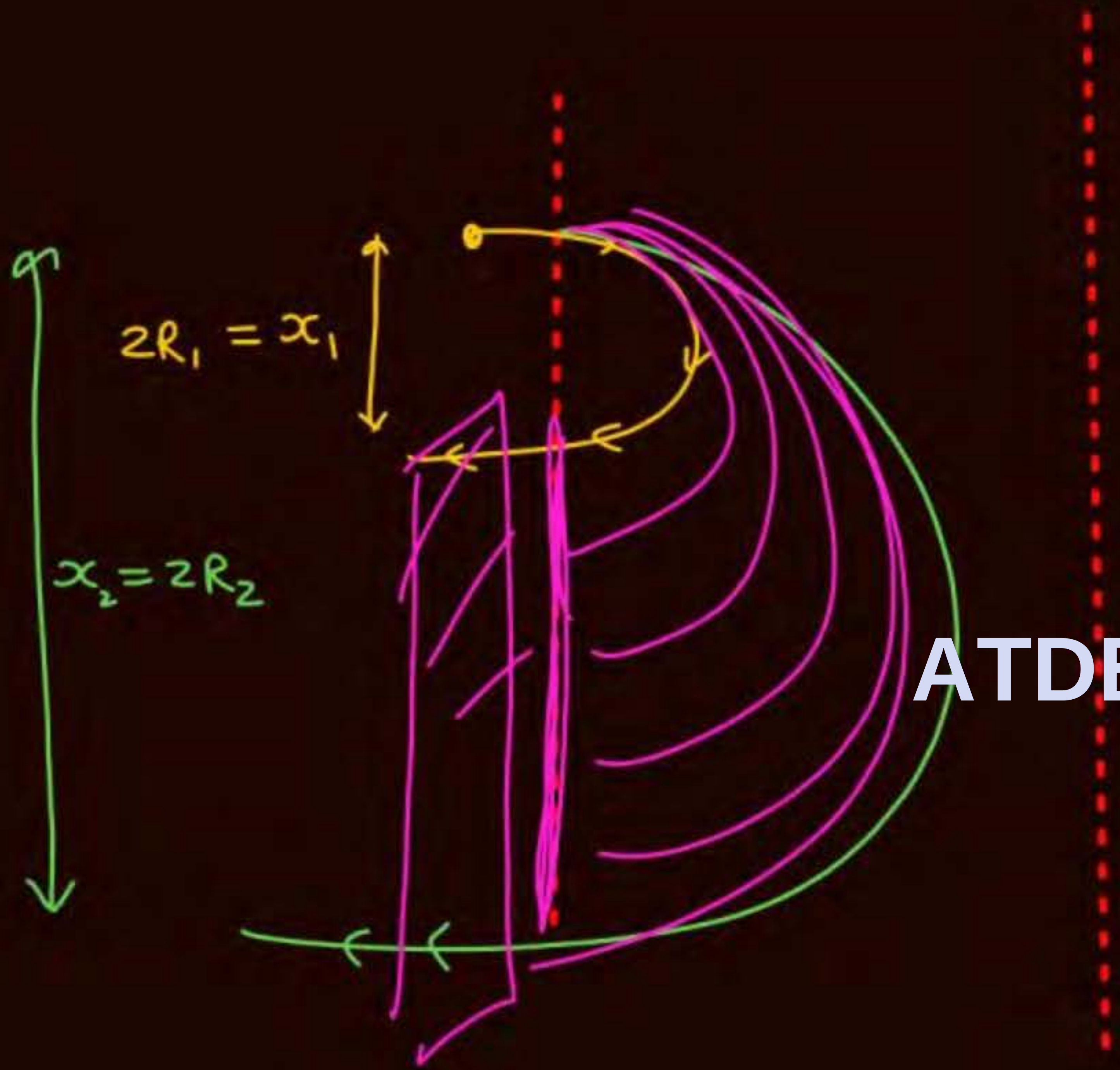
(D) The minimum width w of the region of the magnetic field for detecting ions with $A_M = 196$ is 56 cm.



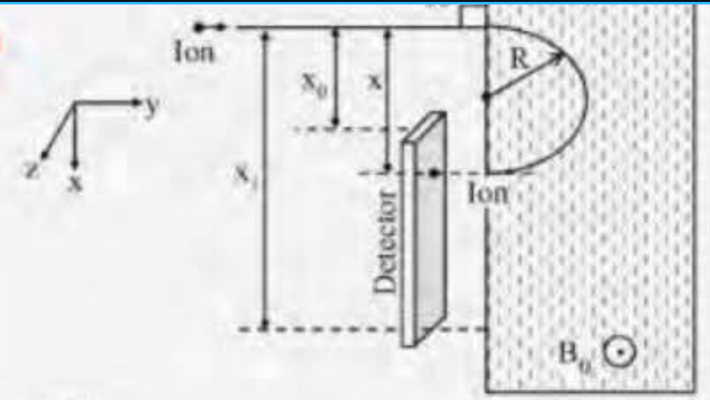
$$KE = q(\Delta V)$$

$$\text{Radius} = \frac{\sqrt{2m\cdot(q\,\Delta V)}}{qB}$$

$$\text{Radius} = \sqrt{\frac{2m(\Delta V)}{qB^2}}$$



$$x_2 - x_1 = 2R_2 - 2R_1$$
$$= 2(R_2 - R_1)$$



$x = 2R$

$$\Rightarrow x = 2\frac{P}{qB} \Rightarrow x = \frac{2\sqrt{2mqV}}{qB} \Rightarrow x = \frac{2}{B}\sqrt{\frac{2mV}{q}}$$

Option A

For $H^+ \rightarrow m = \frac{5}{3} \times 10^{-27}$ kg

$$\therefore x = \frac{2}{0.1}\sqrt{\frac{2 \times \frac{5}{3} \times 10^{-27} \times 192}{1.6 \times 10^{-19}}} = 4 \text{ cm}$$

Option B

For $A_m = 144$

$$x = \frac{2}{0.1}\sqrt{\frac{2 \times 144 \times \frac{5}{3} \times 10^{-27} \times 192}{1.6 \times 10^{-19}}} = 48 \text{ cm}$$

Option C

for $A_m = 1$

$x = 4$ cm & for $A_m = 196$

$x = 56$ cm.

so $x_0 = 4$ cm & $x_1 = 56$ cm

$\therefore x_1 - x_0 = 52$ cm.

Option D

Minimum width = R

for $A_M = 196$

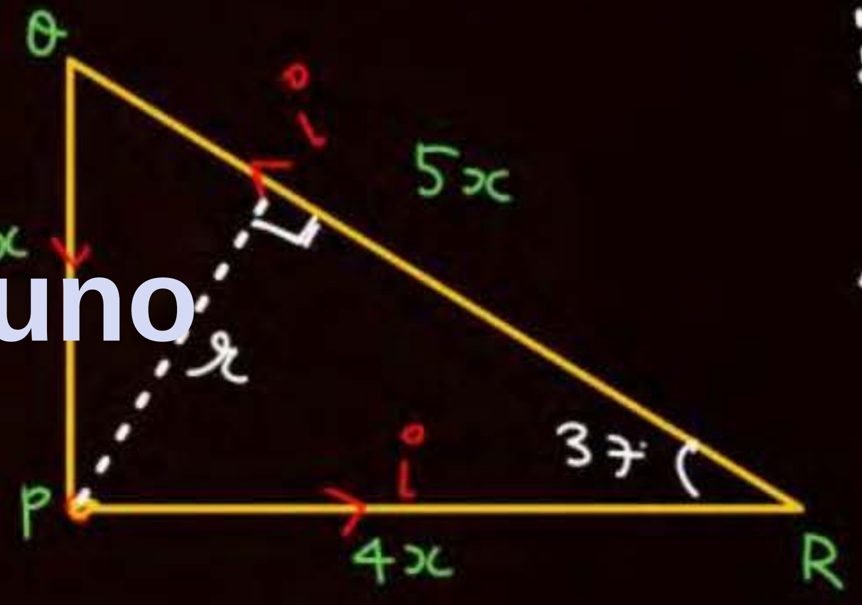
$$R = \frac{P}{qB} = \frac{\sqrt{2mqV}}{qB}$$

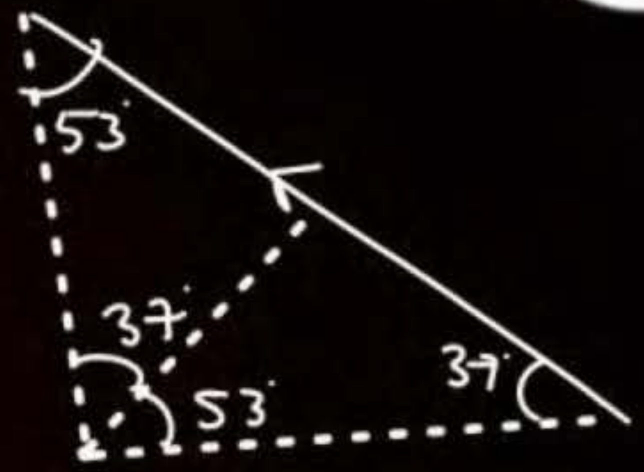
$$R = \frac{1}{B}\sqrt{\frac{2mV}{q}}$$

$$w_{min} = R = \frac{1}{0.1}\sqrt{\frac{2 \times 196 \times \frac{5}{3} \times 10^{-27} \times 192}{1.6 \times 10^{-19}}} = 28 \text{ cm}$$

Q. 13 A steady current I goes through a wire loop PQR having shape of a right angle triangle with $PQ = 3x$, $PR = 4x$ and $QR = 5x$. If the magnitude of the magnetic field at P due to this loop is $k\left(\frac{\mu_0 I}{48\pi x}\right)$, find the value of k **(IIT-JEE 2009)**

$$0 + 0 + \frac{Ki}{r}\left(\frac{3}{5} + \frac{4}{5}\right)$$





Ans : (7)

14. ... shown in the schematic figure, its two ends are connected to two wires and it is hanging by those wires with its plane being vertical. The wires are connected to a capacitor with charge Q through a switch. The coil is in a horizontal uniform magnetic field B parallel to the plane of the coil. When the switch is closed, the capacitor gets discharged through the coil in a very short time. By the time the capacitor is discharged fully, magnitude of the angular momentum gained by the coil will be (assume that the discharge time is so short that the coil has hardly rotated during this time)

C-15.91 W-28.13 UA-55.96 PC-0 **(JEE Adv. 2020)**

$\Delta P = \int F\,dt$

$\int L = \int \tau\,dt$

$i = \frac{dq}{dt}$

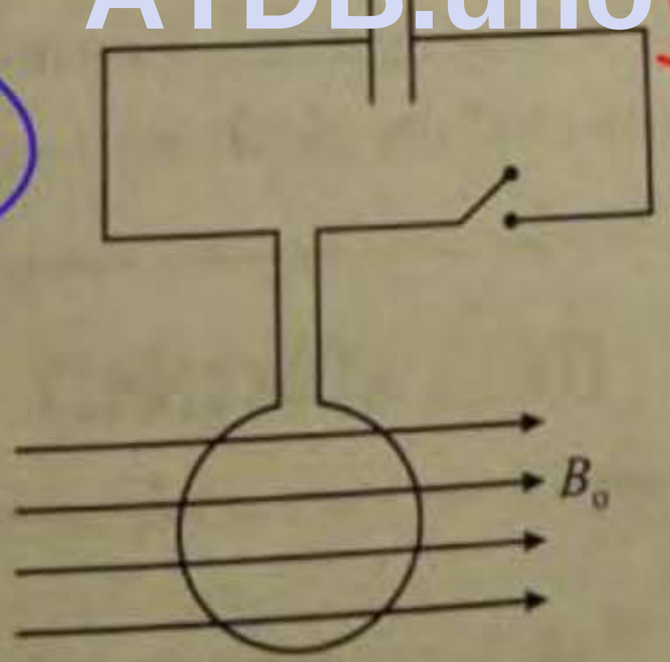
$\vec{\tau} = \frac{d\vec{L}}{dt}$

$\Delta Q = \int i\,dt$

$\int dL = \int NIBA\,dt$

$\Delta L = NBA \int i\,dt$ → total chg flow

$NB\pi R^2 Q$



(a) $\frac{\pi}{\cdots}NQB_0R^2$ (b) πNQB_0R^2 (c) $2\pi NQB_0R^2$ (d) $4\pi NQB_0R^2$

(b)

15. A thin stiff insulated metal wire is bent into a circular loop with its two ends extending tangentially from the same point of the loop. The wire loop has mass m and radius r and it is in a uniform vertical magnetic field B_0, as shown in the figure. Initially, it hangs vertically downwards, because of acceleration due to gravity g, on two conducting supports at P and Q. When a current I is passed through the loop, the loop turns about the line PQ by an angle θ given by

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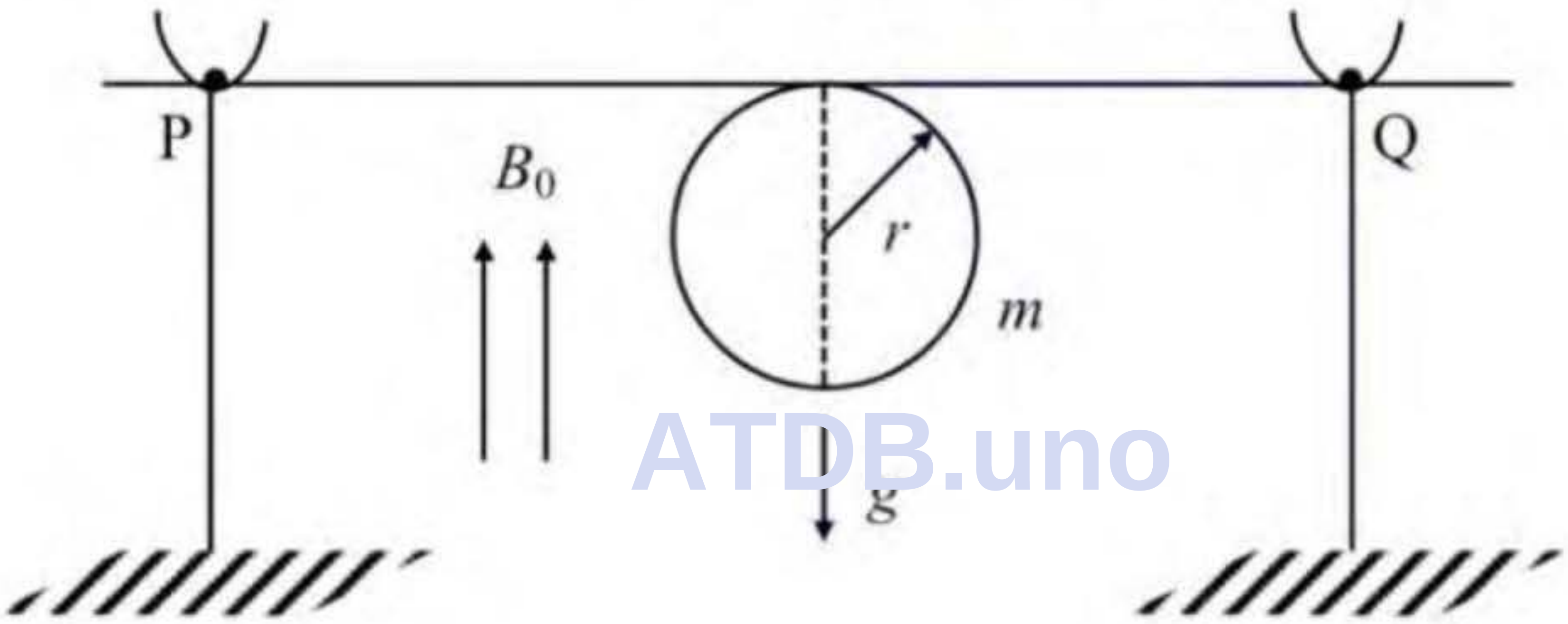

(A) $\tan\theta = \pi r I B_0/(mg)$

(B) $\tan\theta = 2\pi r I B_0/(mg)$

(C) $\tan\theta = \pi r I B_0/(2mg)$

(D) $\tan\theta = mg/(\pi r I B_0)$

Ans. (A)

Sol.

(15) A thin stiff insulated metal wire is bent into a circular loop with its two ends extending tangentially from the same point of the loop. The wire loop has mass m and radius r and it is in a uniform vertical magnetic field B_0, as shown in the figure. Initially, it hangs vertically downwards, because of acceleration due to gravity g, on two conducting supports at P and Q. When a current I is passed through the loop, the loop turns about the line PQ by an angle θ given by

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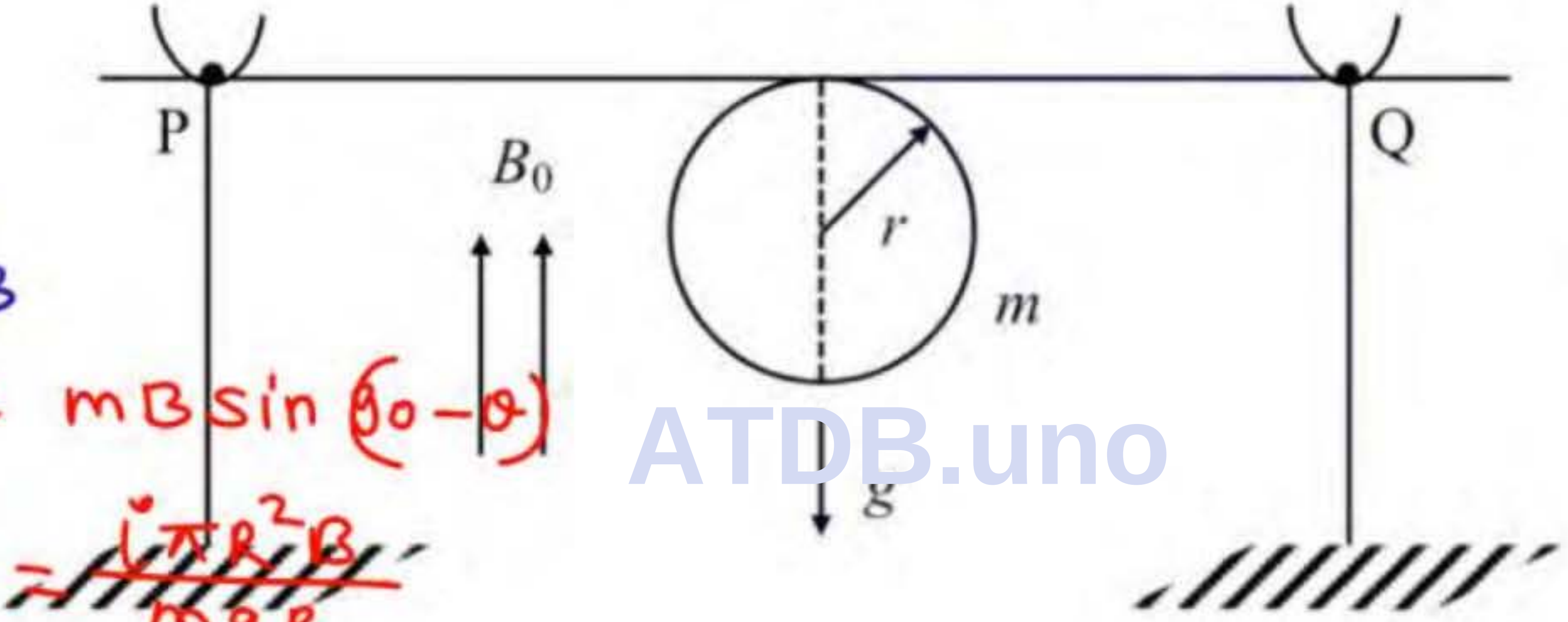
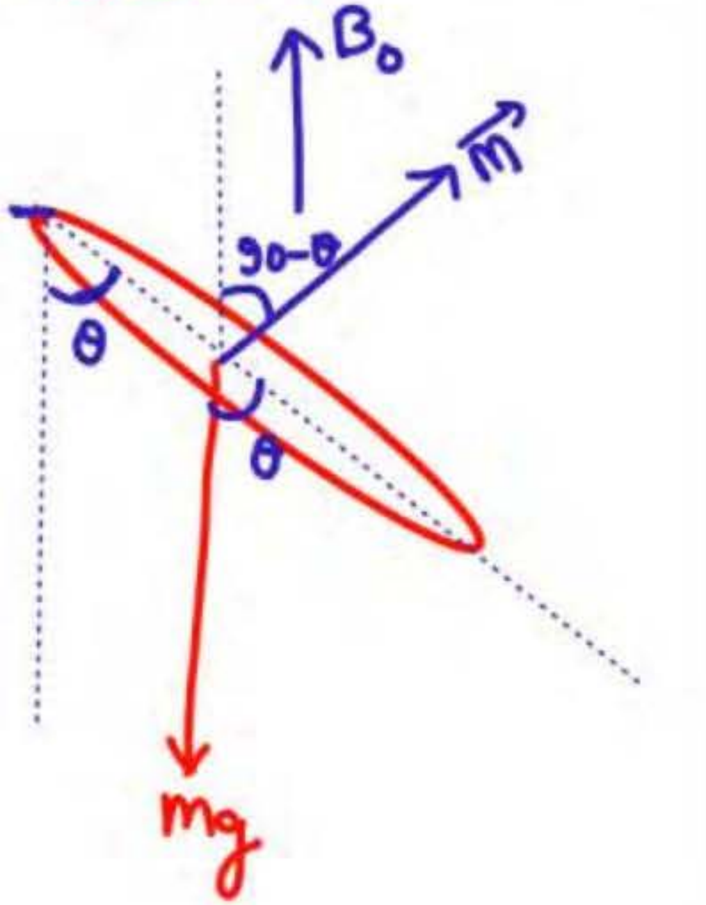
Equilibrium

$\tau_{mg} = \tau_B$

$mg\sin\theta \cdot R = mB\sin(90-\theta)$

$\tan\theta = \frac{mB}{mgR} = \frac{i\pi R^2 B}{mgR}$





(A) $\tan\theta = \pi r I B_0/(mg)$

(B) $\tan\theta = 2\pi r I B_0/(mg)$

(C) $\tan\theta = \pi r I B_0/(2mg)$

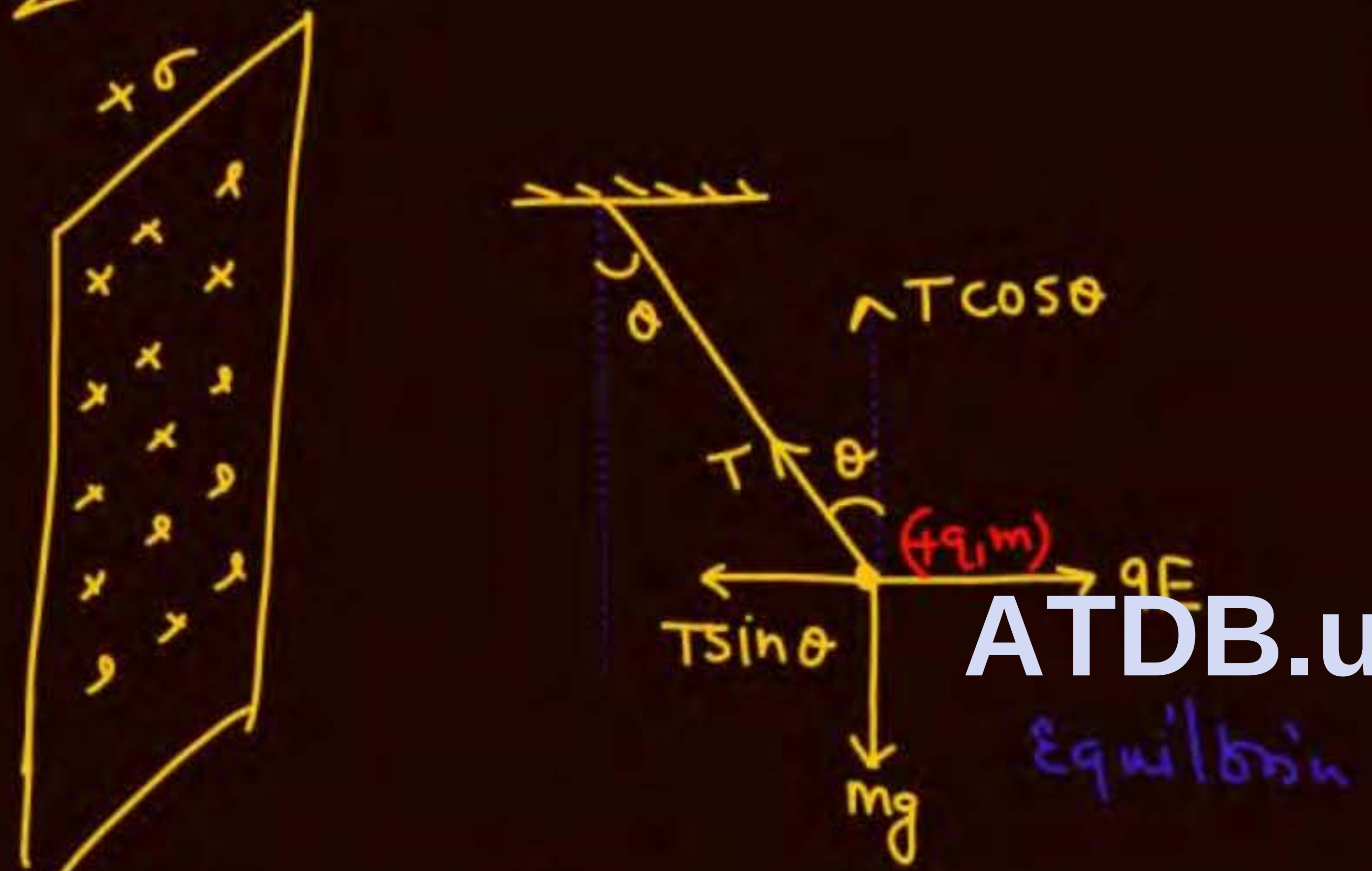
(D) $\tan\theta = mg/(\pi r I B_0)$

$\theta = \tan^{-1}(\quad)$

Ans. (A)

Sol.

Q

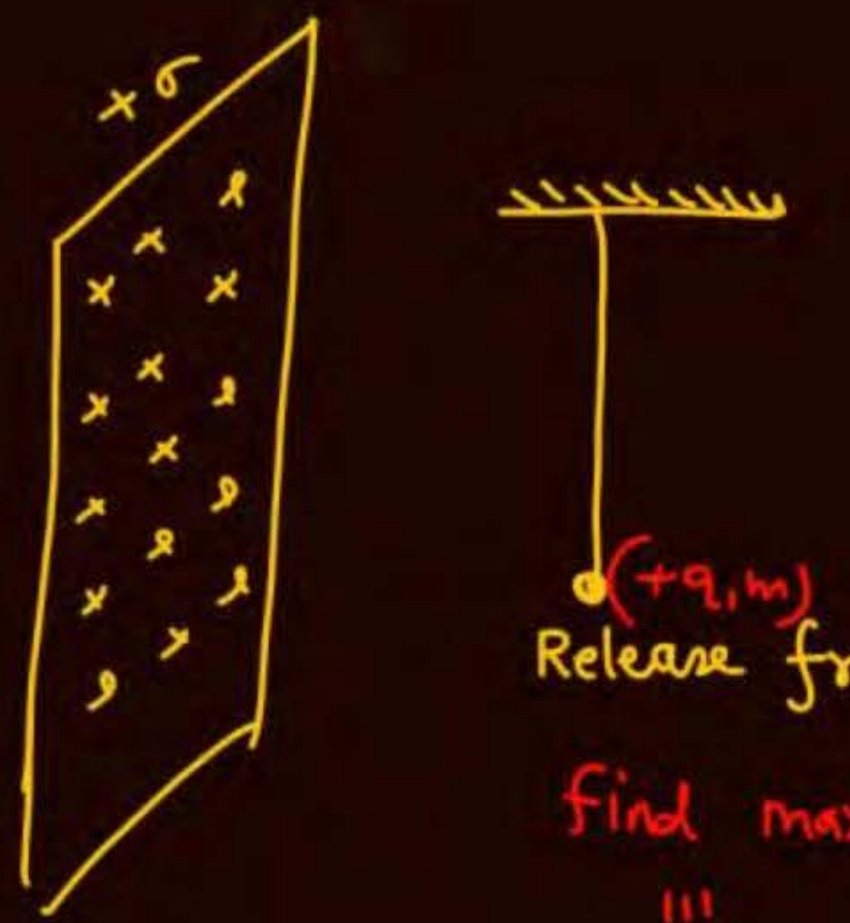


$$T\sin\theta = qE$$
$$T\cos\theta = mg$$

$$\tan\theta = \frac{qE}{mg}$$

$$\theta = \tan^{-1}\left(\frac{qE}{mg}\right)$$

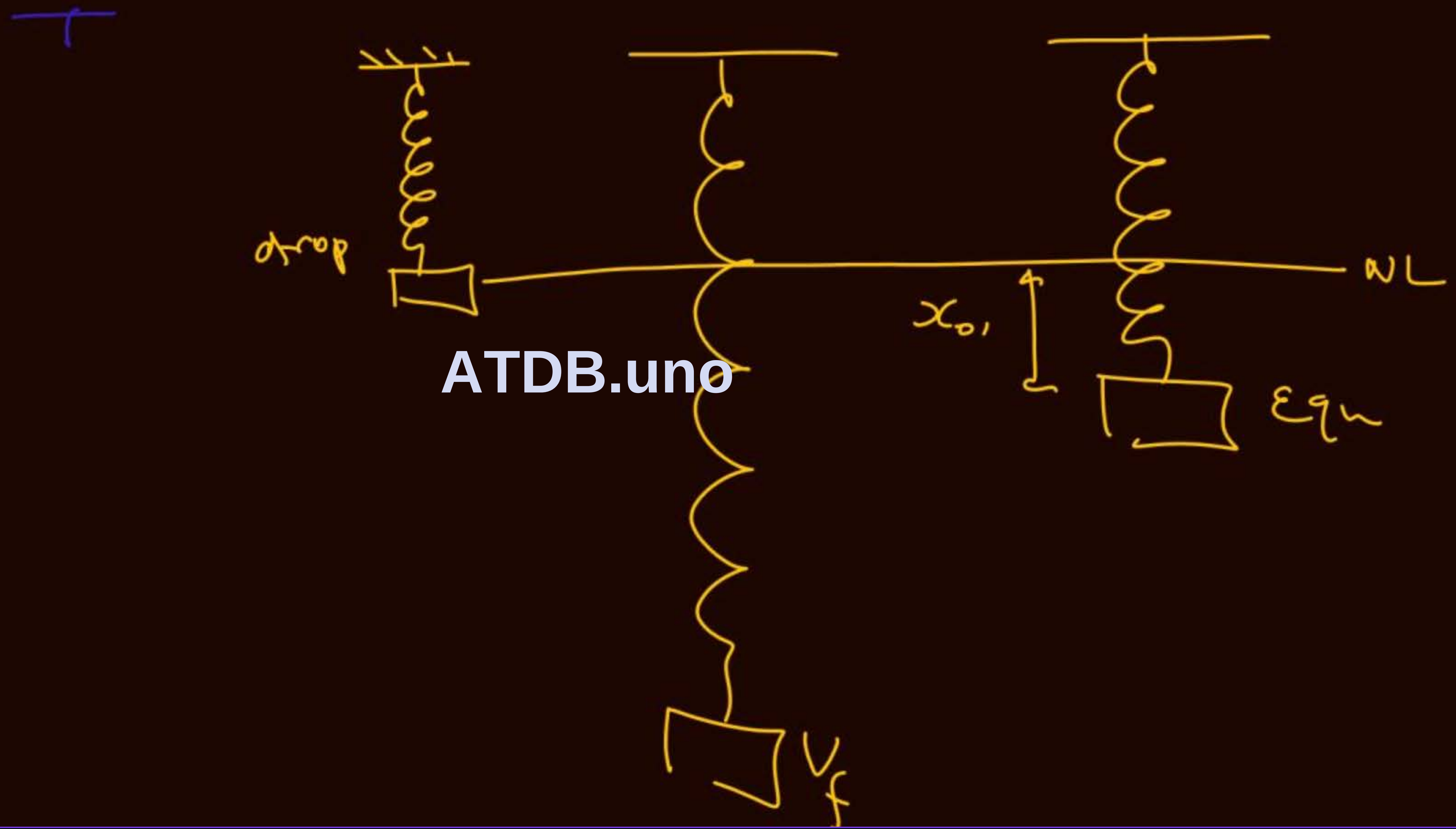
Q



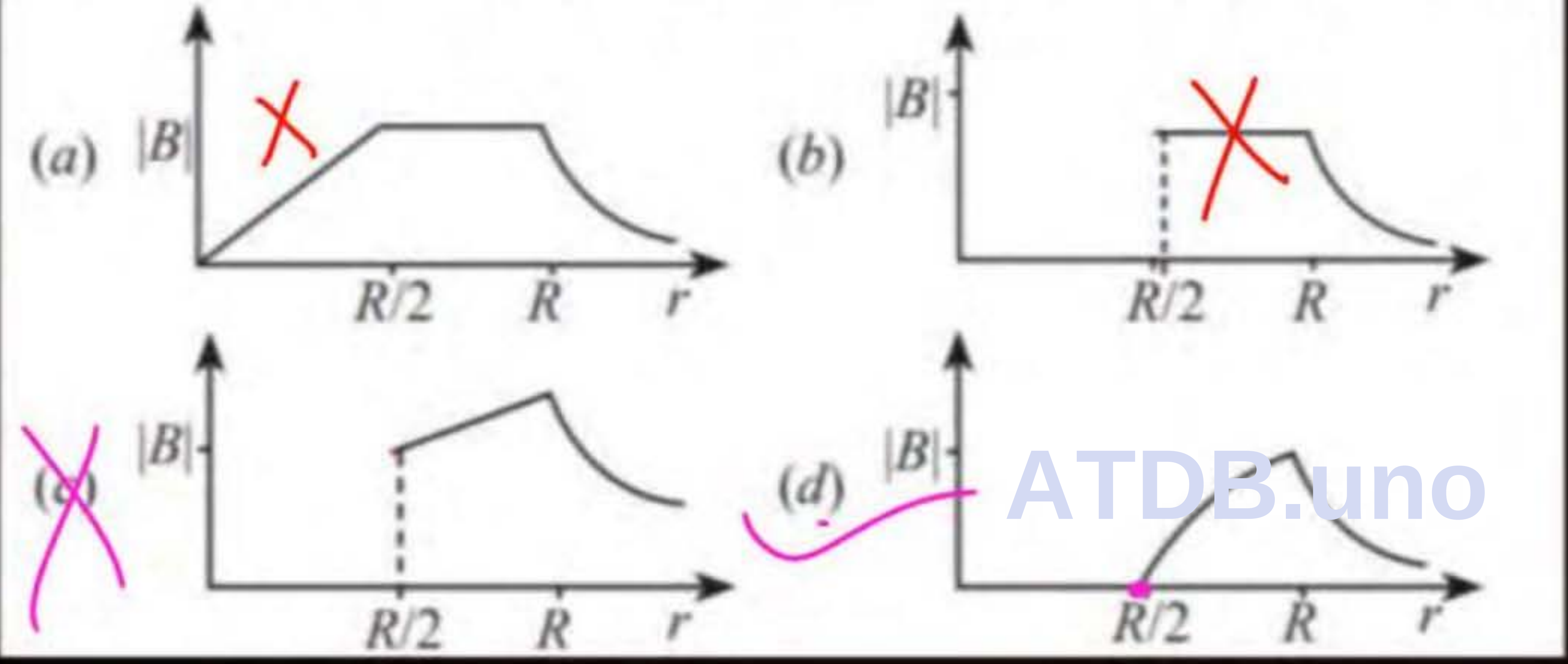
Release from rest

find max deflection

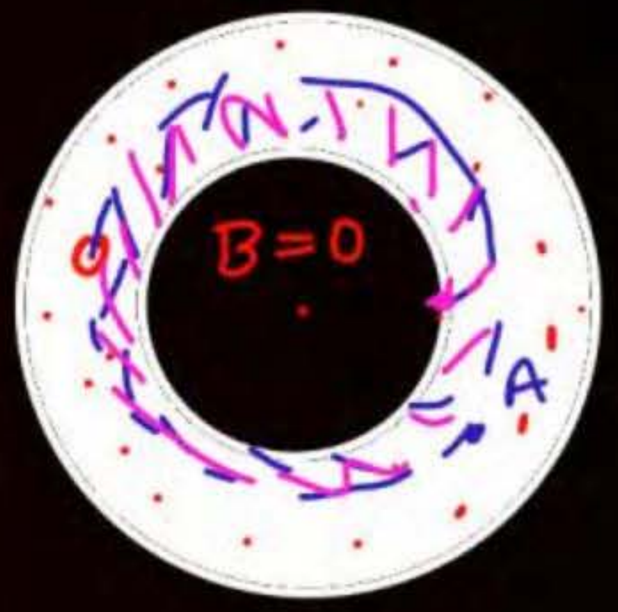
$$\theta_{max} = 2\theta$$


drop
WL
x_0,
Eqn
V_f

Q. 16 An infinitely long hollow conducting cylinder with inner radius $R/2$ and outer radius R carries a uniform current density along its length. The magnitude of the magnetic field, $|B|$ as a function of the radial distance r from the axis is best represented by **(IIT-JEE 2012)**



Top view



$B = \frac{2ki}{r}$

$B\, 2\pi r = \mu_0 J \pi\left[r^2 - (R/2)^2\right]$

Ans : (d)

the cylinder and the cavity are infinitely long. A uniform current density J flows along the length. If

17

the magnitude of the magnetic field at the point P is given by $\frac{N}{12}\mu_0 aJ$, then the value of N is :

[IIT-JEE 2012]

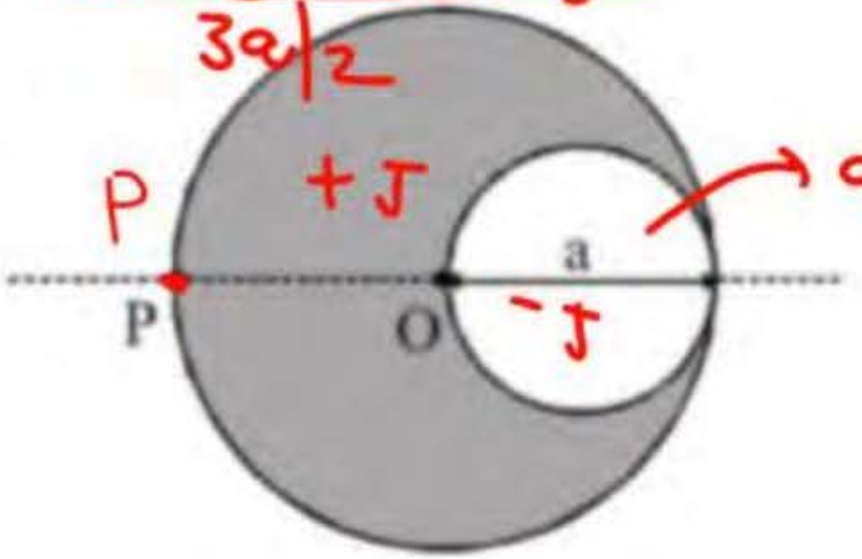
व्यास 2a के एक बेलन में, त्रिज्या a का एक खोखला बेलनीय-कोश है (चित्र देखिये) और दोनों अपरिमित लम्बे हैं। इनकी लम्बाई की दिशा में इनमें एकसमान धारा-घनत्व J है। यदि बिंदु P पर चुम्बकीय क्षेत्र का मान $\frac{N}{12}\mu_0 aJ$ है, तब N का मान क्या है?

$B_1 = \frac{\mu_0 J a}{2}$

$B_2 = \frac{2ki}{r} = \frac{2k\left[J\pi(a/2)^2\right]}{3a/2}$

$\frac{2ki}{r}, \frac{2ki}{R}, \frac{\mu_0 \vec{J} \times \vec{r}}{2}$

$B_1 - B_2$



(18,19)
20

at the origin ($x = 0, y = 0, z = 0$) with a given initial velocity v. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity v, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in columns I, II and III, respectively. The quantities E_0, B_0, are positive in magnitude

(JEE Adv. 2017)

Column-I		Column-II		Column-III	
(I)	Electron with $v = 2\frac{E_0}{B_0}\hat{x}$	(i)	$\vec{E} = E_0\hat{z}$	(P)	$\vec{B} = -B_0\hat{x}$
(II)	Election with $v = \frac{E_0}{B_0}\hat{y}$	(ii)	$\vec{E} = -E_0\hat{y}$	(Q)	$\vec{B} = B_0\hat{x}$
(III)	Proton with $v = 0$	(iii)	$\vec{E} = -E_0\hat{x}$	(R)	$\vec{B} = B_0\hat{y}$
(IV)	Proton with $v = 2\frac{E_0}{B_0}\hat{x}$	(iv)	$\vec{E} = E_0\hat{x}$	(S)	$\vec{B} = B_0\hat{z}$

Q. 31 31. In which case would the particle move in a straight line along the negative direction of Y-axis (i.e. move along $-y$)?

(a) (II) (iii) (S) (b) (III) (iii) (P)
(c) (IV) (i) (S) (d) (III) (ii) (R)

Ans : (c)

Q. 32 32. In which case will the particle move in a straight line with constant velocity?

(a) (II) (iii) (S) (b) (III) (iii) (P)
(c) (IV) (i) (S) (d) (III) (ii) (R)

initial velocity $\vec{v}$. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity $\vec{v}$, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in column 1, 2 and 3, respectively. The quantities E_0, B_0 are positive in magnitude. **[JEE-Advanced-2017]**

Column-1	**Column-2**	**Column-3**
(I) Electron with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(i) $\vec{E} = E_0\hat{z}$	(P) $\vec{B} = -B_0\hat{x}$
(II) Electron with $\vec{v} = \frac{E_0}{B_0}\hat{y}$	(ii) $\vec{E} = -E_0\hat{y}$	(Q) $\vec{B} = B_0\hat{x}$
(III) Proton with $\vec{v} = 0$	(iii) $\vec{E} = -E_0\hat{x}$	(R) $\vec{B} = B_0\hat{y}$
(IV) Proton with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(iv) $\vec{E} = E_0\hat{x}$	(S) $\vec{B} = B_0\hat{z}$

(18) किस स्थिति में कण अचल गति से सीधी रेखा में चलन करता है ?

(A) (II) (iii) (S) (B) (IV) (i) (S) (C) (III) (ii) (R) (D) (III) (iii) (P)

Ans. (A)

$$\vec{F} = q\vec{E} + q\,\vec{v}\times\vec{B} = 0$$

$$\vec{E} = -(\vec{v}\times\vec{B})$$

(19) **8.** In which case will the particle describe a helical path with axis along the positive z-direction ?

किस स्थिति में कण +z-अक्ष अनुदिश कुंडलित पथ (helical path along the positive z-axis) का अनुसरण करेगा ?

(A) (II) (ii) (R) (B) (IV) (ii) (R) (C) (IV) (i) (S) (D) (III) (iii) (P)

Ans. (C)

(20) **9.** In which case would the particle move in a straight line along the negative direction of y-axis (i.e., move along $-\hat{y}$) ?

किस स्थिति में कण सीधी रेखा में ऋणात्मक y-अक्ष (negative y-axis) की दिशा में चलेगा ?

(A) (IV) (ii) (S) (B) (III) (ii) (P) (C) (II) (iii) (Q) (D) (III) (ii) (R)

$E = h\nu$

↳ Energy

$$i = \frac{dq}{dt}$$

$$F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$$

$$\epsilon_0 = \frac{q_1 q_2}{4\pi F r^2}$$

$$\rightarrow \frac{AT\,AT}{MLT^{-2}L^2} = M^{-1}L^{-3}T^{4}A^{2}$$

Dimentional formula of $q \Rightarrow [AT]$

" " $\epsilon_0 = [M^{-1}L^{-3}T^4A^2]$

" " $\mu_0 = [MLT^{-2}A^{-2}]$

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

$$F = qvB$$

→ Dimentionally

$$F = \frac{qv\mu_0 i}{2R}$$

$$\mu_0 = \frac{FR}{qvi} = \frac{MLT^{-2}\cdot L}{AT\,LT^{-1}\,A} = [MLT^{-2}A^{-2}]$$

In a particular system of units, a physical quantity can be expressed in terms of the electric charge e, electron mass m_e, Planck's constant h, and Coulomb's constant $k = \frac{1}{4\pi \epsilon_0}$, where ϵ_0 is the permittivity of vacuum. In terms of these physical constants, the dimension of the magnetic field is $[B] = [e]^{\alpha} [m_e]^{\beta} [h]^{\gamma} [k]^{\delta}$. The value of $\alpha + \beta + \gamma + \delta$ is ________.

एक विशेष मात्राक पद्धति निकाय (system of units) में, एक भौतिकी राशि को इलेक्ट्रॉनिक आवेश e, इलेक्ट्रॉन द्रव्यमान m_e, प्लांक नियतांक (Planck's constant) h और कुलाम्ब नियतांक $k = \frac{1}{4\pi \epsilon_0}$ के रूप में निरूपित किया जाता है, जहाँ ϵ_0 निर्वात का परावेधुतांक (permittivity) है। इन भौतिकीय नियतांको के रूप में, चुम्बकीय क्षेत्र की विमा (dimension) $[B] = [e]^{\alpha} [m_e]^{\beta} [h]^{\gamma} [k]^{\delta}$ है। $\alpha + \beta + \gamma + \delta$ का मान ________ है। **[JEE-Advance-2022]**

Ans. (4)

Q. 22 JEE Adv. 2024

A dimensionless quantity is constructed in terms of electronic charge e, permittivity of free space ε_0, Planck's constant h, and speed of light c. If the dimensionless quantity is written as $e^{\alpha}\varepsilon_0^{\beta}h^{\gamma}c^{\delta}$ and n is a non-zero integer, then $(\alpha, \beta, \gamma, \delta)$ is given by

(A) $(2n, -n, -n, -n)$
(B) $(n, -n, -2n, -n)$
(C) $(n, -n, -n, -2n)$
(D) $(2n, -n, -2n, -2n)$

Answer: (A)

$E = h\nu$

$$e^{\alpha}\varepsilon_0^{\beta}h^{\gamma}c^{\delta} = 1$$

$$(AT)^{\alpha}(M^{-1}L^{-3}T^{4}A^{2})^{\beta}(ML^{2}T^{-1})^{\gamma}(LT^{-1})^{\delta} = 1$$

$$M^{-\beta+\gamma}L^{-3\beta+2\gamma+\delta}T^{\alpha+4\beta-\gamma-\delta}A^{\alpha+2\beta} = 1$$

$\gamma = \beta = x$

$\alpha = 2\beta$

$\alpha = 2x$

Q 23 An infinitely long wire, located on the z-axis, carries a current I along the $+z$-direction and produces the magnetic field $\vec{B}$. The magnitude of the line integral $\int \vec{B} \cdot \vec{dl}$ along a straight line from the point $(-\sqrt{3}a, a, 0)$ to $(a, a, 0)$ is given by

JEE Adv 2024

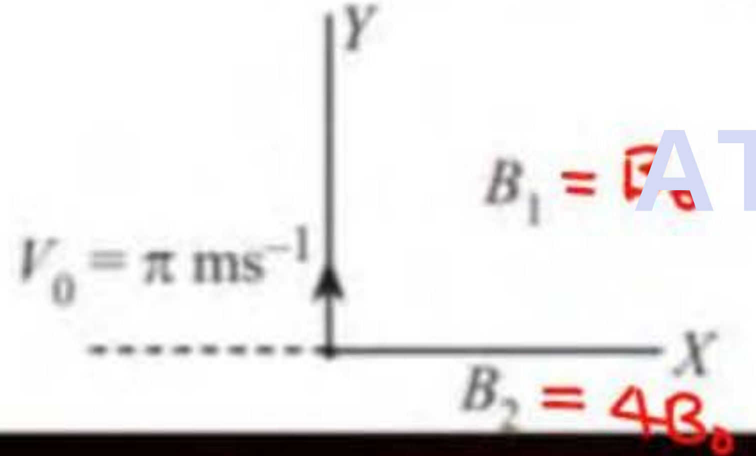
[μ_0 is the magnetic permeability of free space.]

(A) $7\mu_0 I/24$ (B) $7\mu_0 I/12$ (C) $\mu_0 I/8$ (D) $\mu_0 I/6$

I will Discuss Article Remaining in class

Answer: (A)

Q. (24) In the xy-plane, the region $y > 0$ has a uniform magnetic field $B_1\hat{k}$ and the region $y < 0$ has another uniform magnetic field $B_2\hat{k}$. A positively charged particle is projected from the origin along the positive Y-axis with speed $v_0 = \pi ms^{-1}$ at $t = 0$, as shown in figure. Neglect gravity in this problem. Let $t = T$ be the time when the particle crosses the X-axis from below for the time when the particle crosses the X-axis from below for the first time. If $B_2 = 4B_1$, the average speed of the particle, in ms^{-1}, along the X-axis in the time interval T is… **(JEE Adv. 2018)**



$B_1 = B_0$

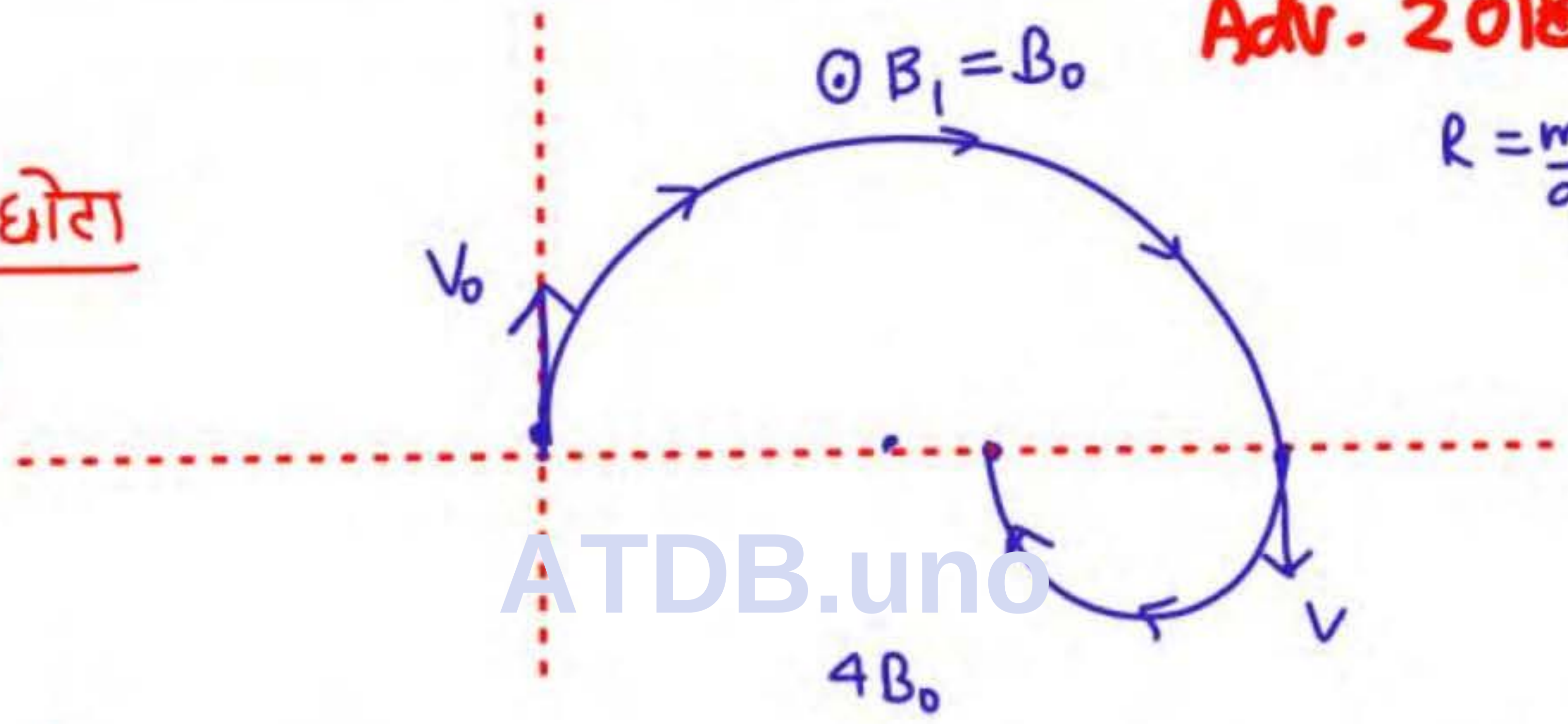
$B_2 = 4B_0$

Ans : (2)

25. uniform magnetic field $B_2\hat{k}$. A positively charged particle is projected from the origin along the positive y-axis with speed $v_0 = \pi\, ms^{-1}$ at $t = 0$, as shown in the figure. Neglect gravity in this problem. Let $t = T$ be the time when the particle crosses the x-axis from below for the first time. If $B_2 = 4B_1$, the average speed of the particle, in ms^{-1}, along the x-axis in the time interval T is ______.

$B_2 = 4B_1$

Adv. 2018



$R = \frac{mv}{qB}$

Ans $= \dfrac{2R_{बड़ा} + 2R_{छोटा}}{\frac{T_1}{2} + \frac{T_2}{2}}$

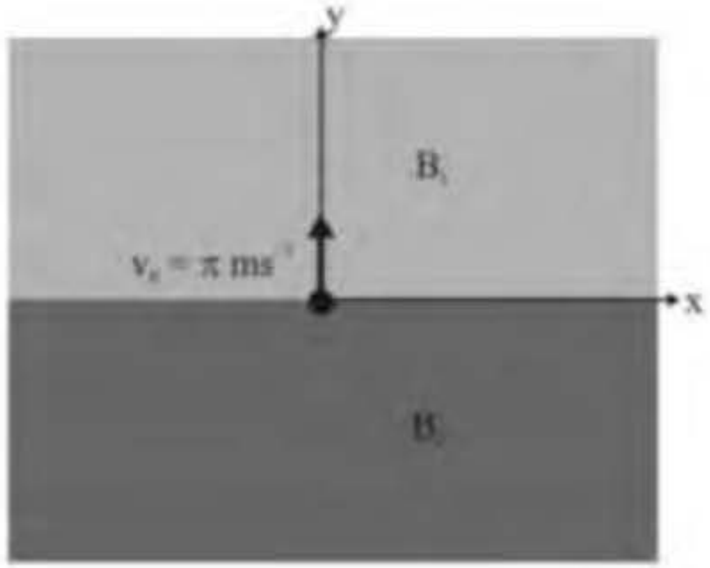
$R_{बड़ा} = \frac{mv}{qB_1}$

$R_{छोटा} = \frac{mv}{qB_2}$

$T_1 = \frac{2\pi m}{qB_1}$

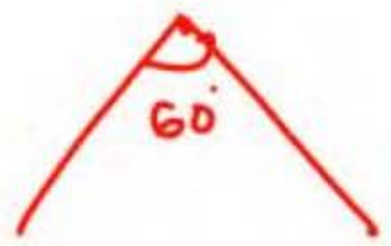
$T_2 = \frac{2\pi m}{qB}$

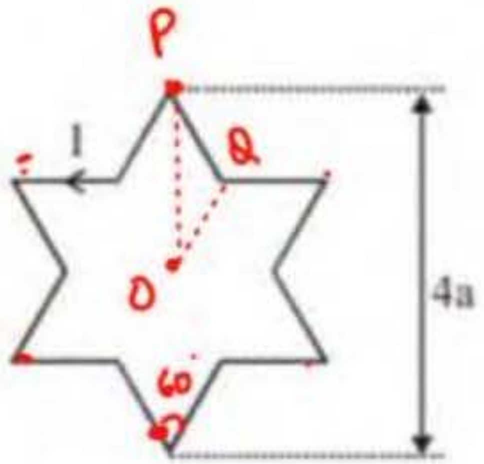
[JEE-Advanced-2018]

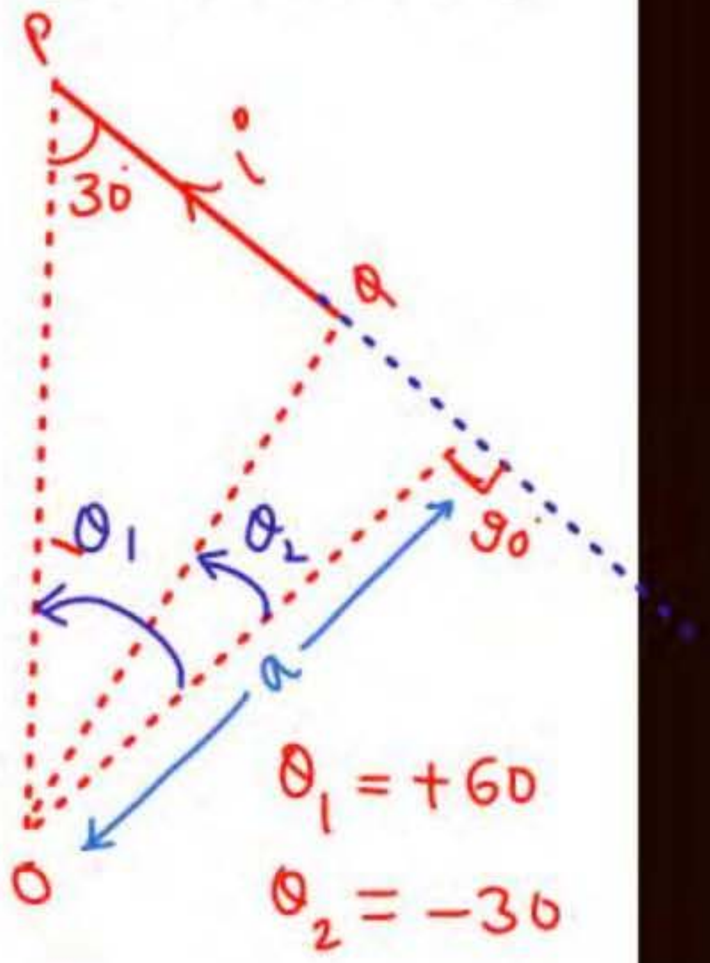


26 figure. The distance between the diametrically opposite vertices of the star is 4a. The magnitude of the magnetic field at the center of the loop is :

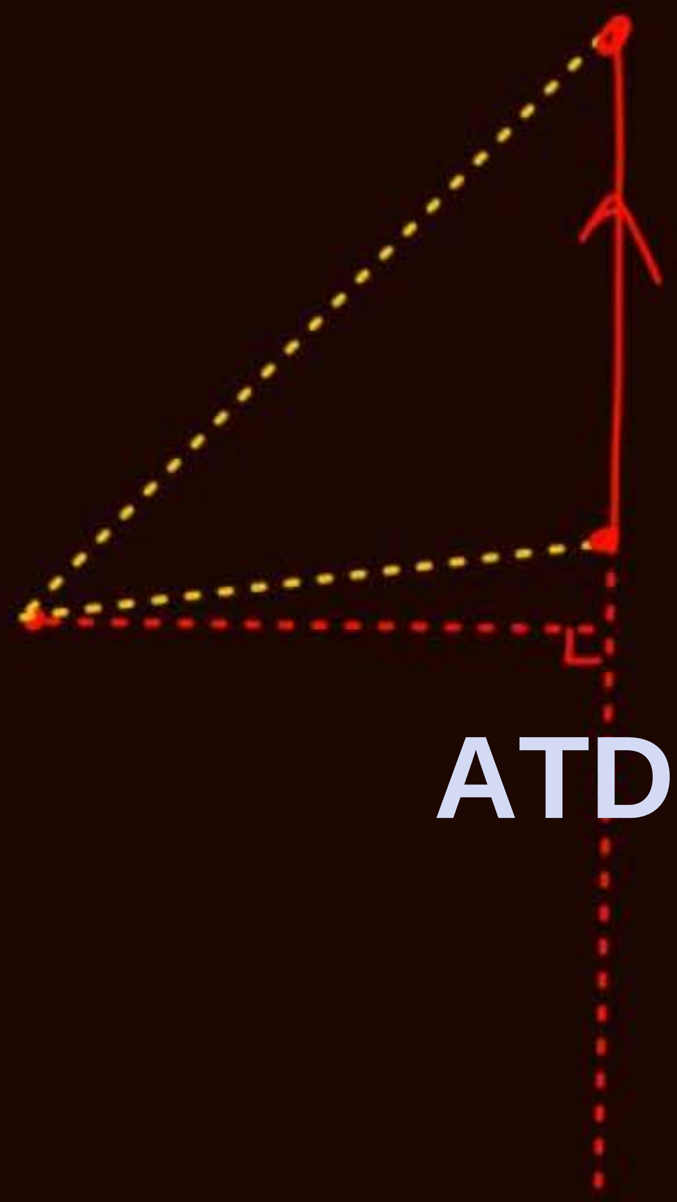
जैसे कि चित्रित किया गया है, एक सम्मित तारे (symmetric star) के आकार के चालक में अपरिवर्तित धारा I बह रही है। यहाँ विपरीत शीर्षों (diametrically opposite vertices) के बीच की दूरी 4a है। चालक के केन्द्र पर चुम्बकीय क्षेत्र का मान होगा : **[JEE-Advanced-2017]**







(A) $\frac{\mu_0 I}{4\pi a}3\left[\sqrt{3}-1\right]$ (B) $\frac{\mu_0 I}{4\pi a}6\left[\sqrt{3}-1\right]$ (C) $\frac{\mu_0 I}{4\pi a}6\left[\sqrt{3}+1\right]$ (D) $\frac{\mu_0 I}{4\pi a}3\left[2-\sqrt{3}\right]$



27

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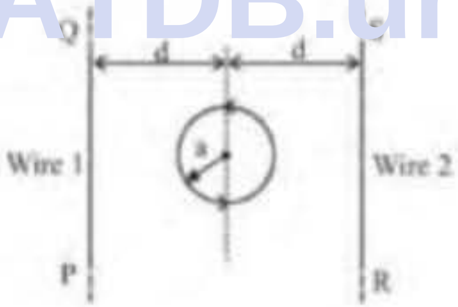
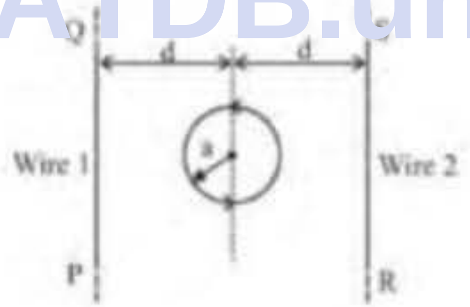
plane of the paper. The distance of each wire from the centre of the loop is d. The loop and the wires are carrying the same current I. The current in the loop is in the counterclockwise direction if seen from above. **[JEE-Advanced-2014]**



16. When d ≈ a but wires are not touching the loop, it is found that the net magnetic field on the axis of the loop is zero at a height h above the loop. In that case
(A) current in wire 1 and wire 2 is the direction PQ and RS, respectively and h ≈ a
(B) current in wire 1 and wire 2 is the direction PQ and SR, respectively and h ≈ a
(C) current in wire 1 and wire 2 is the direction PQ and SR, respectively and h ≈ 1.2 a
(D) current in wire 1 and wire 2 is the direction PQ and RS, respectively and h ≈ 1.2 a
जब d ≈ a लेकिन तार पाश को स्पर्श नही कर रहे हैं तब वृत्तीय पाश के अक्ष पर h ऊँचाई पर परिणामी चुम्बकीय क्षेत्र शून्य मिलने की स्थिति में
(A) तार 1 तथा तार 2 में धारा की दिशा क्रमशः PQ तथा RS है और h ≈ a
(B) तार 1 तथा तार 2 में धारा की दिशा क्रमशः PQ तथा SR है और h ≈ a
(C) तार 1 तथा तार 2 में धारा की दिशा क्रमशः PQ तथा SR है और h ≈ 1.2 a

27
28

plane of the paper. The distance of each wire from the centre of the loop is d. The loop and the wires are carrying the same current I. The current in the loop is in the counterclockwise direction if seen from above. **[JEE-Advanced-2014]**



16. When d ≈ a but wires are not touching the loop, it is found that the net magnetic field on the axis of the loop is zero at a height h above the loop. In that case

(A) current in wire 1 and wire 2 is the direction PQ and RS, respectively and h ≈ a

(B) current in wire 1 and wire 2 is the direction PQ and SR, respectively and h ≈ a

(C) current in wire 1 and wire 2 is the direction PQ and SR, respectively and h ≈ 1.2 a

(D) current in wire 1 and wire 2 is the direction PQ and RS, respectively and h ≈ 1.2 a

जब d ≈ a लेकिन तार पाश को स्पर्श नही कर रहे हैं तब वृत्तीय पाश के अक्ष पर h ऊँचाई पर परिणामी चुम्बकीय क्षेत्र शून्य मिलने की स्थिति में

(A) तार 1 तथा तार 2 में धारा की दिशा क्रमशः PQ तथा RS है और h ≈ a

(B) तार 1 तथा तार 2 में धारा की दिशा क्रमशः PQ तथा SR है और h ≈ a

(C) तार 1 तथा तार 2 में धारा की दिशा क्रमशः PQ तथा SR है और h ≈ 1.2 a

28. Consider d >> a, and the loop is rotated about its diameter parallel to the wires by 30° from the position shown in the figure. If the currents in the wires are in the opposite directions, the torque on the loop at its new position will be (assume that the net field due to the wires is constant over the loop)

Paragraph from (Q 27)

[JEE-Advanced-2014]

मान लीजिए d >> a तथा पाश को चित्र में दिखाई गई अवस्था से तारों के समान्तर तथा पाश के व्यास के परित: 30° से घुमाया जाता है। यदि तारों में विद्युत धारा की दिशा एक-दूसरे के विपरीत दिशा में हो तो पाश की नई अवस्था में उस पर लगने वाला बल आघूर्ण होगा (मान लीजिए कि तारों के कारण वृत्तीय पाश पर चुम्बकीय क्षेत्र स्थिर है।)

(A) $\frac{\mu_0 I^2 a^2}{d}$ (B) $\frac{\mu_0 I^2 a^2}{2d}$ (C) $\frac{\sqrt{3}\mu_0 I^2 a^2}{d}$ (D) $\frac{\sqrt{3}\mu_0 I^2 a^2}{2d}$

Ans. (B)

29

conductor of radius R. This cylinder is placed coaxially inside an infinite solenoid of radius $2R$. The solenoid has n turns per unit length and carries a steady current I. Consider a point P at a distance r from the common axis. The correct statements (is/are)

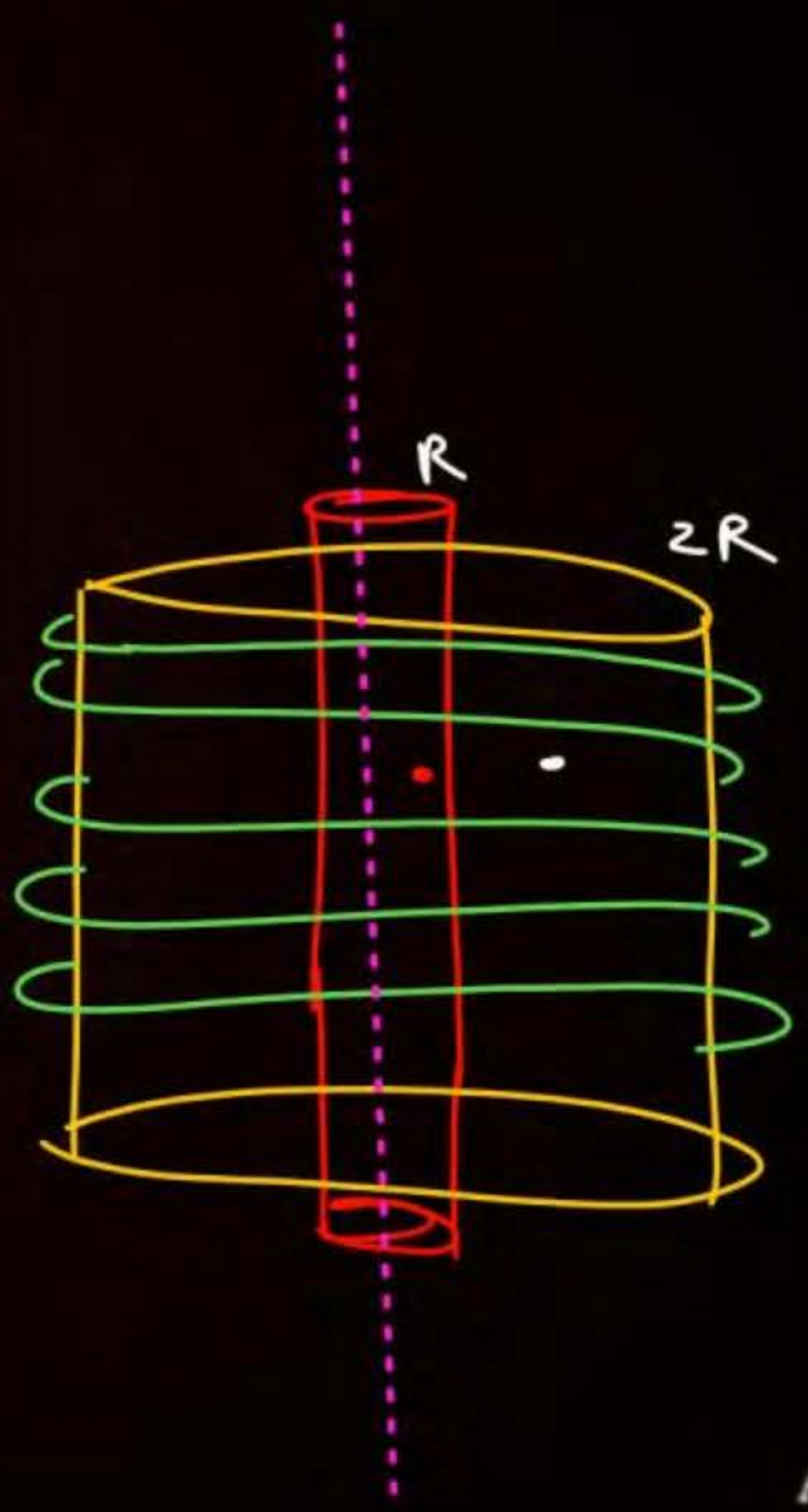
(JEE Adv. 2013)

(a) In the region $0 < r < R$, the magnetic field is non-zero

(b) In the region $R < r < 2R$, the magnetic field is along the common axis

(c) In the region $R < r < 2R$, the magnetic field is tangential to the circle of radius r, centered on the axis

(d) In the region $r > 2R$, the magnetic field is non-zero



Ans : (a, d)

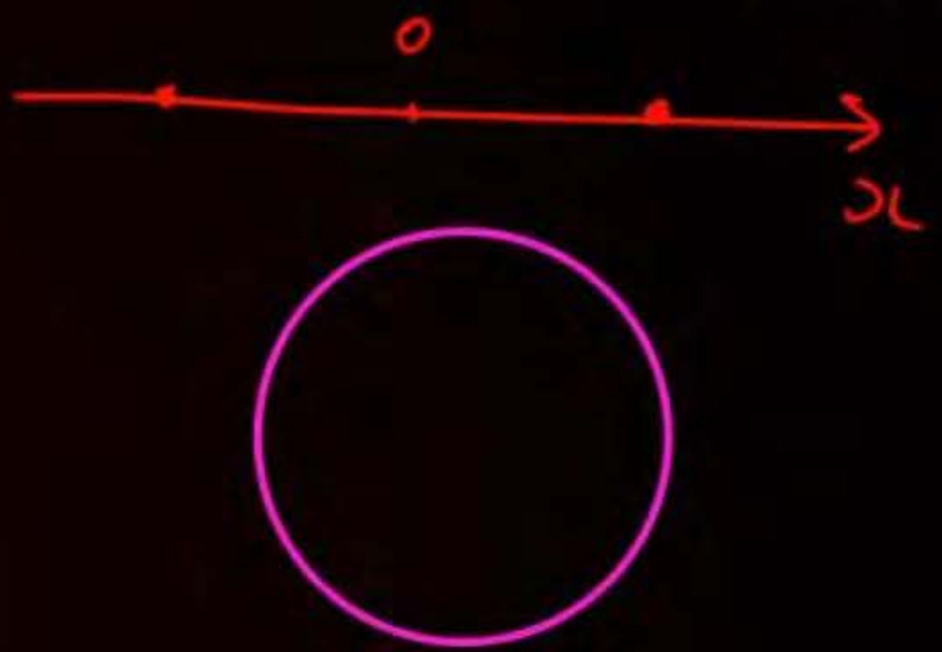
Q. Two infinitely long straight wires lie in the *xy*-plane along the lines $x = \pm R$. The wire located at $x = +R$ carries a constant current I_1 and the wire located at $x = -R$ carries a constant current I_2. A circular loop of radius R is suspended with its center at $\left(0, 0, \sqrt{3}R\right)$ and in a plane parallel to the *xy*-plane. This loop carries a constant current I in the clockwise direction as seen from above the loop. The current in the wire is taken to be positive, if it is in the $+\hat{j}$-direction. Which of the following statements regarding the magnetic field B is/are true? **(JEE Adv. 2018)**

(a) If $I_1 = I_2$, then B cannot be equal to zero at the origin (0, 0, 0)

(b) If $I_1 > 0$ and $I_2 < 0$, then B can be equal to zero at the origin (0, 0, 0)

(c) If $I_1 < 0$ and $I_2 > 0$, then B can be equal to zero at the origin (0, 0, 0)

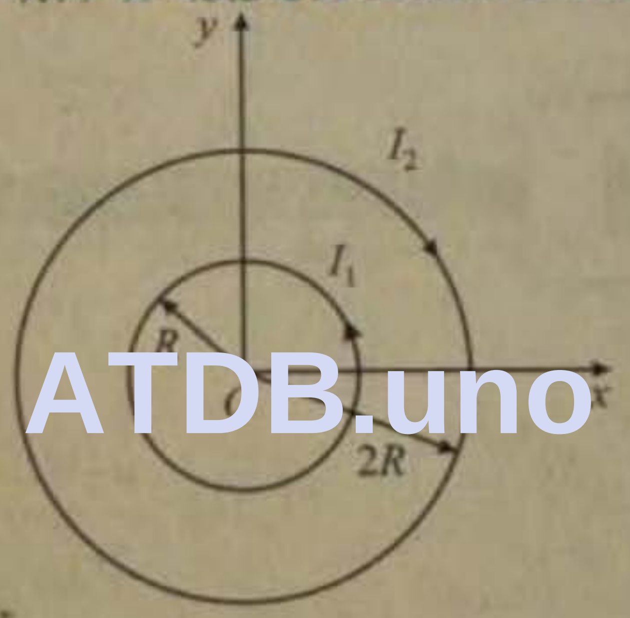
(d) If $I_1 = I_2$, then the z-component of the magnetic field at the center of the loop is $\left(-\frac{\mu_0 I}{2R}\right)$



Ans : (a, b, d)

31. Two concentric circular loops, one of radius R and the other of radius $2R$, lie in the xy-plane with the origin as their common center, as shown in the figure. The smaller loop carries current I_1 in the anti-clockwise direction and the larger loop carries current I_2 in the clockwise direction, with $I_2 > 2I_1$. $\vec{B}(x, y)$ denotes the magnetic field at a point (x, y) in the xy-plane. Which of the following statement(s) is/are correct?

C-7.77 W-43.5 UA-30.62 PC-18.12 (JEE Adv. 2021)



(a) $\vec{B}(x,y)$ is perpendicular to the xy-plane at any point in the plane.

(b) $|\vec{B}(x,y)|$ depends on x and y only through the radial distance $r=\sqrt{x^2+y^2}$.

(c) $|\vec{B}(x,y)|$ is non-zero at all points for $r < R$.

(d) $\vec{B}(x,y)$ points normally outward from the plane for all the points between the two loops.

11.

12

23. A uniform magnetic field B exists in the region between $x = 0$ and $x = \frac{3R}{2}$ (region 2 in the figure) pointing normally into the plane of the paper. A particle with charge +Q and momentum p directed along x-axis enters region 2 from region 1 at point $P_1 (y = -R)$. Which of the following options(s) is/are correct ? **[JEE-Advanced-2017]**

(A) For $B = \frac{8}{13}\frac{p}{QR}$, the particle will enter region 3 through the point P_2 on x-axis

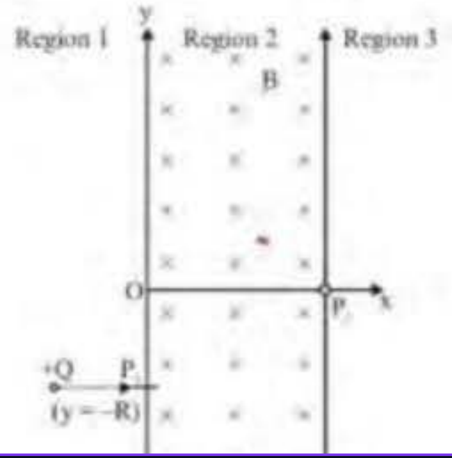
(B) For $B > \frac{2}{3}\frac{p}{QR}$, the particle will re-enter region 1

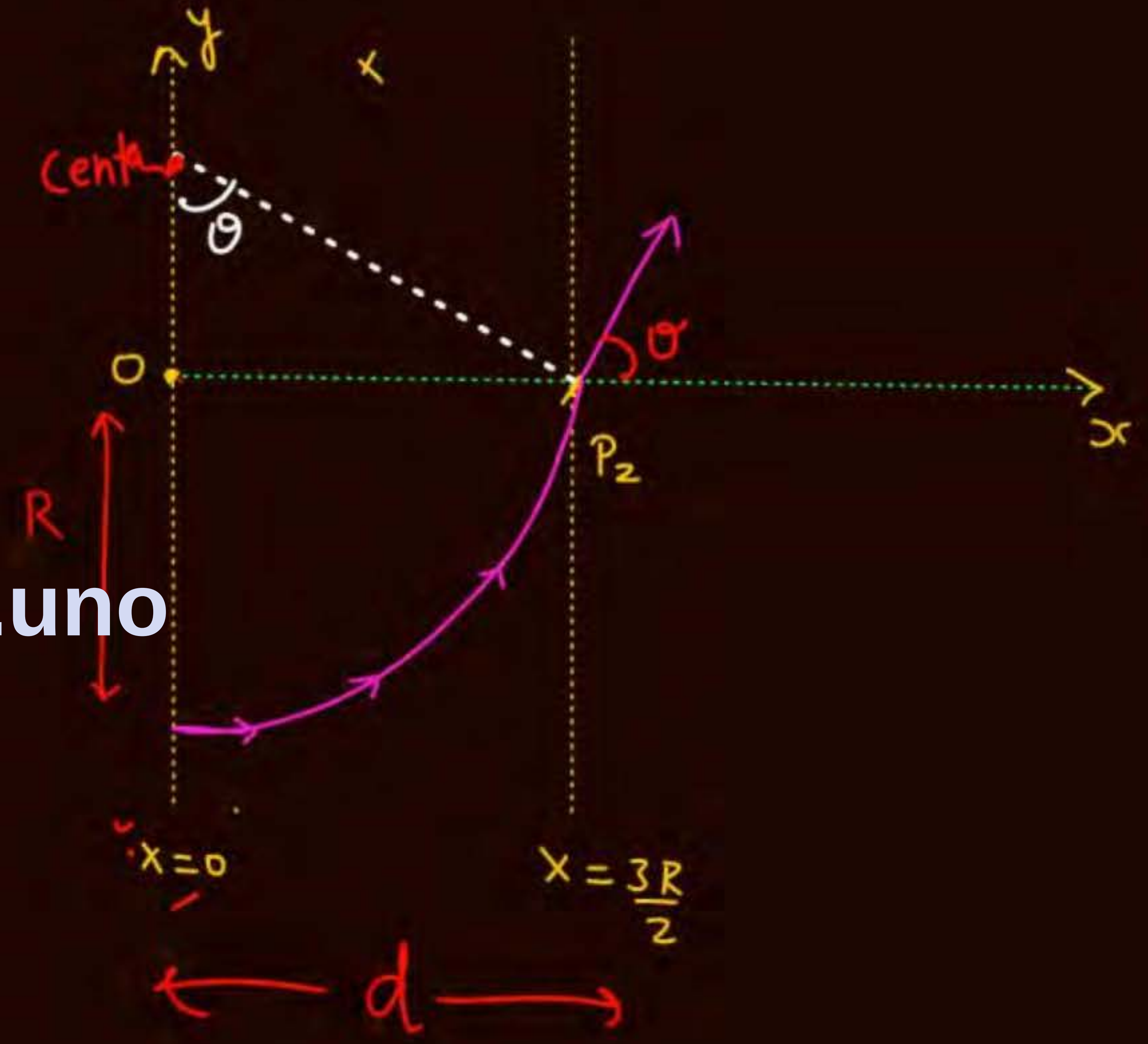
(C) For a fixed B, particle of same charge Q and same velocity v, the distance between the point P_1 and the point of re-entry into region 1 is inversely proportional to the mass of the particle.

(D) When the particle re-enters region 1 through the longest possible path in region 2, the magnitude of the chage in its linear momentum between point P_1 and the farthest point from y-axis is $\frac{p}{\sqrt{2}}$.

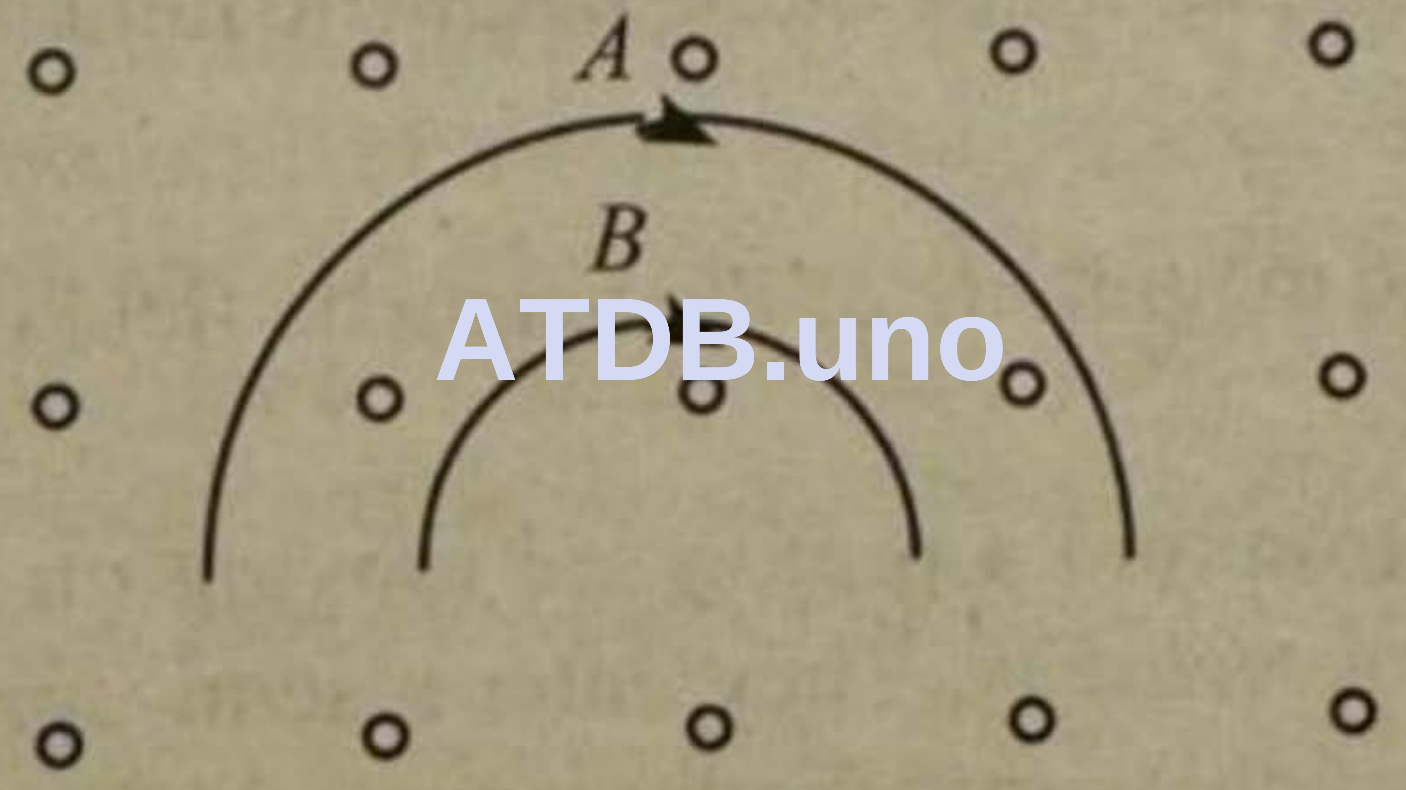
(B) $d > \frac{mv}{qB}$; $d = \frac{3R}{2}$

$\frac{3R}{2} > \frac{p}{qB}$





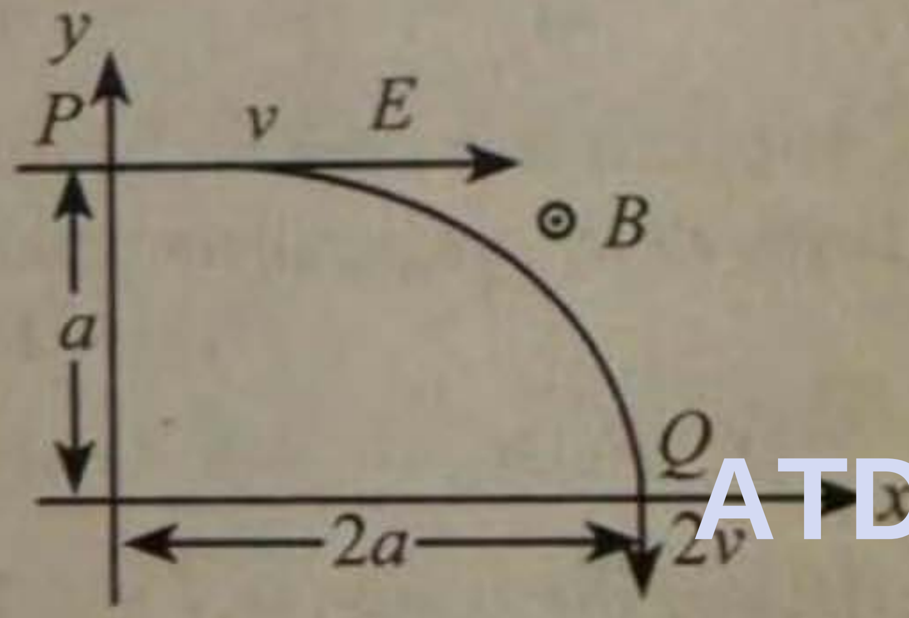
21. (32) Two particles A and B of masses mA and mB respectively and having the same charge are moving in a plane. A uniform magnetic field exists perpendicular to this plane. The speeds of the particles are vA and vB, respectively and the trajectories are as shown in the figure. Then **(IIT-JEE 2001)**



(a) $m_A v_A < m_B v_B$ (b) $m_A v_A > m_B v_B$

(c) $m_A < m_B$ and $v_A < v_B$ (d) $m_A = m_B$ and $v_A = v_B$ (b)

(33) A particle of charge $+q$ and mass m moving under the influence of a uniform electric field $E\hat{i}$ and uniform magnetic field $B\hat{k}$ follows a trajectory from P to Q as shown in figure. The velocities at P and Q are $v\hat{i}$ and $-2v\hat{j}$. Which of the following statement(s) is/are correct?



Jm-2022

(IIT-JEE 1991)

(a) $E = \frac{3}{4}\left[\frac{mv^2}{qa}\right]$

(b) Rate of work done by the electric field at P is $\frac{3}{4}\left[\frac{mv^3}{a}\right]$

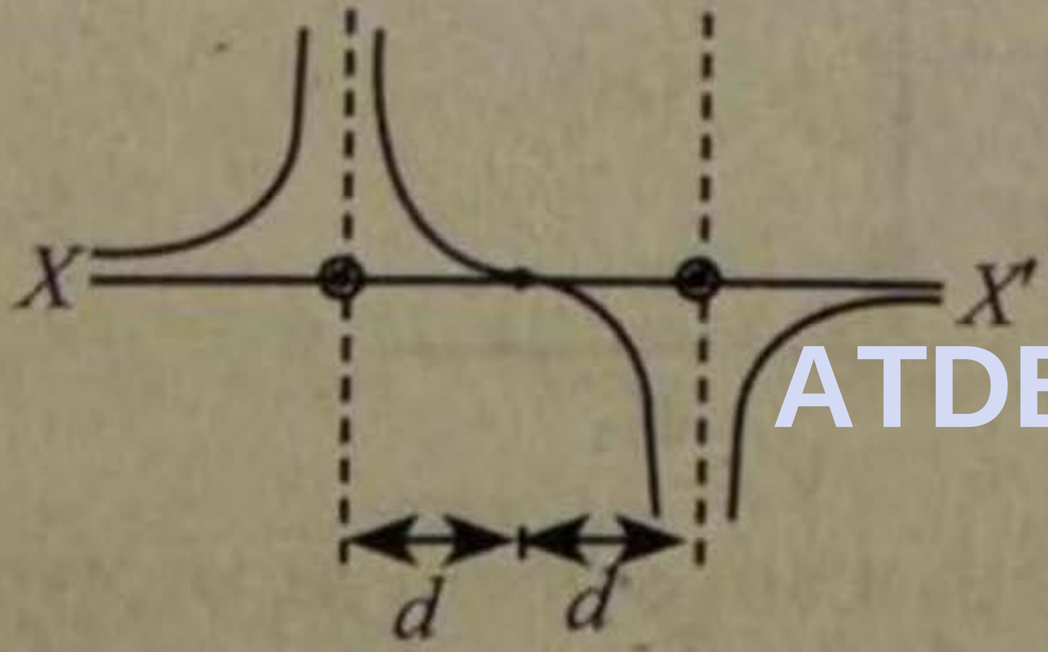
(c) Rate of work done by the electric field at P is zero

(d) Rate of work done by both the fields at Q is zero (abd)

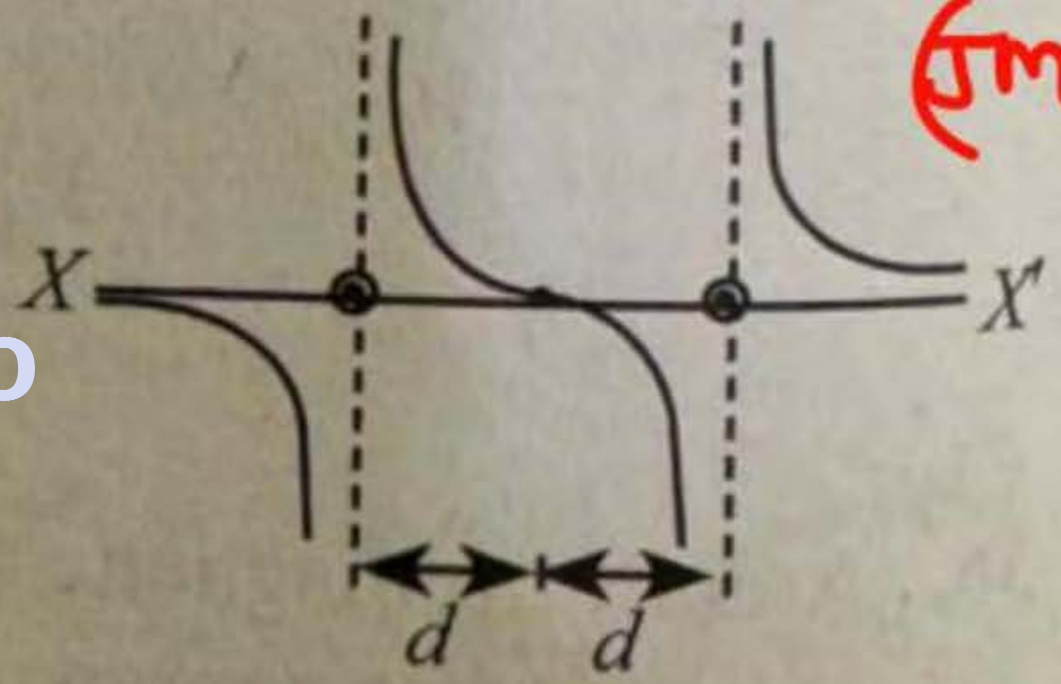
Two long parallel wires are at a distance $2d$ apart. They carry steady equal currents flowing out of the plane of the paper as shown. The variation of the magnetic field B along the line XX' is given by

(IIT-JEE 2000)

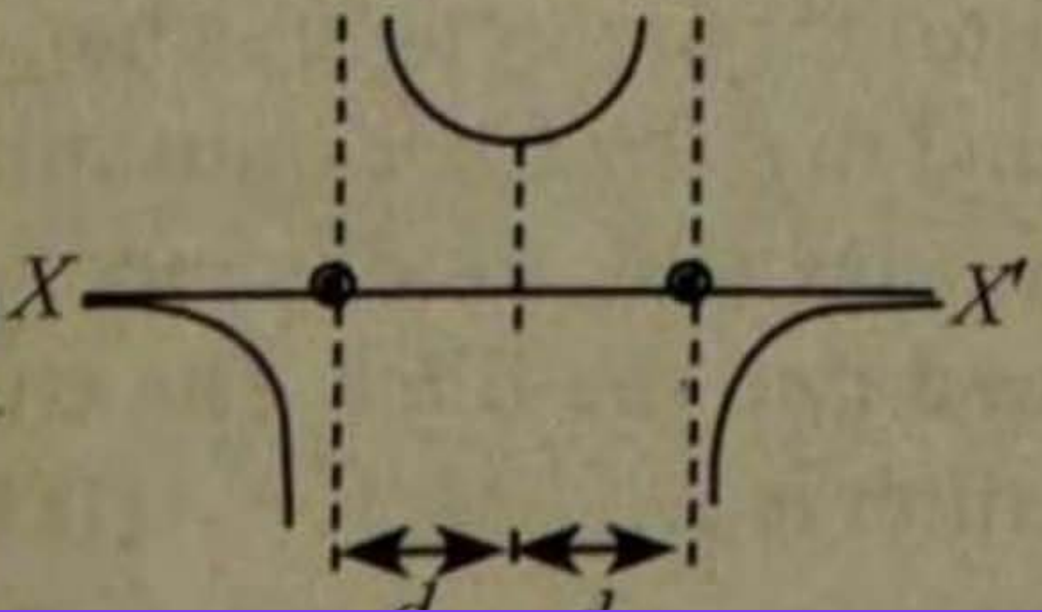
(a)



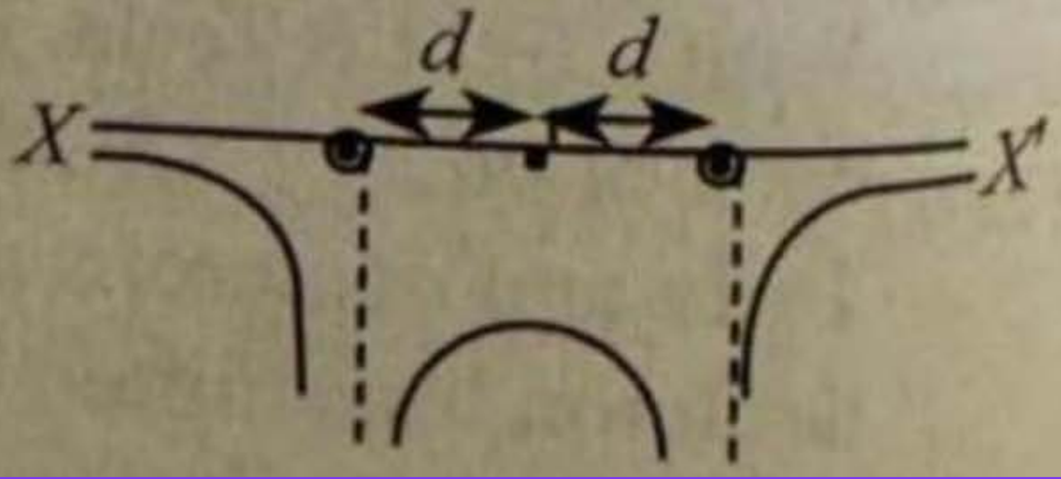
(b)



(c)

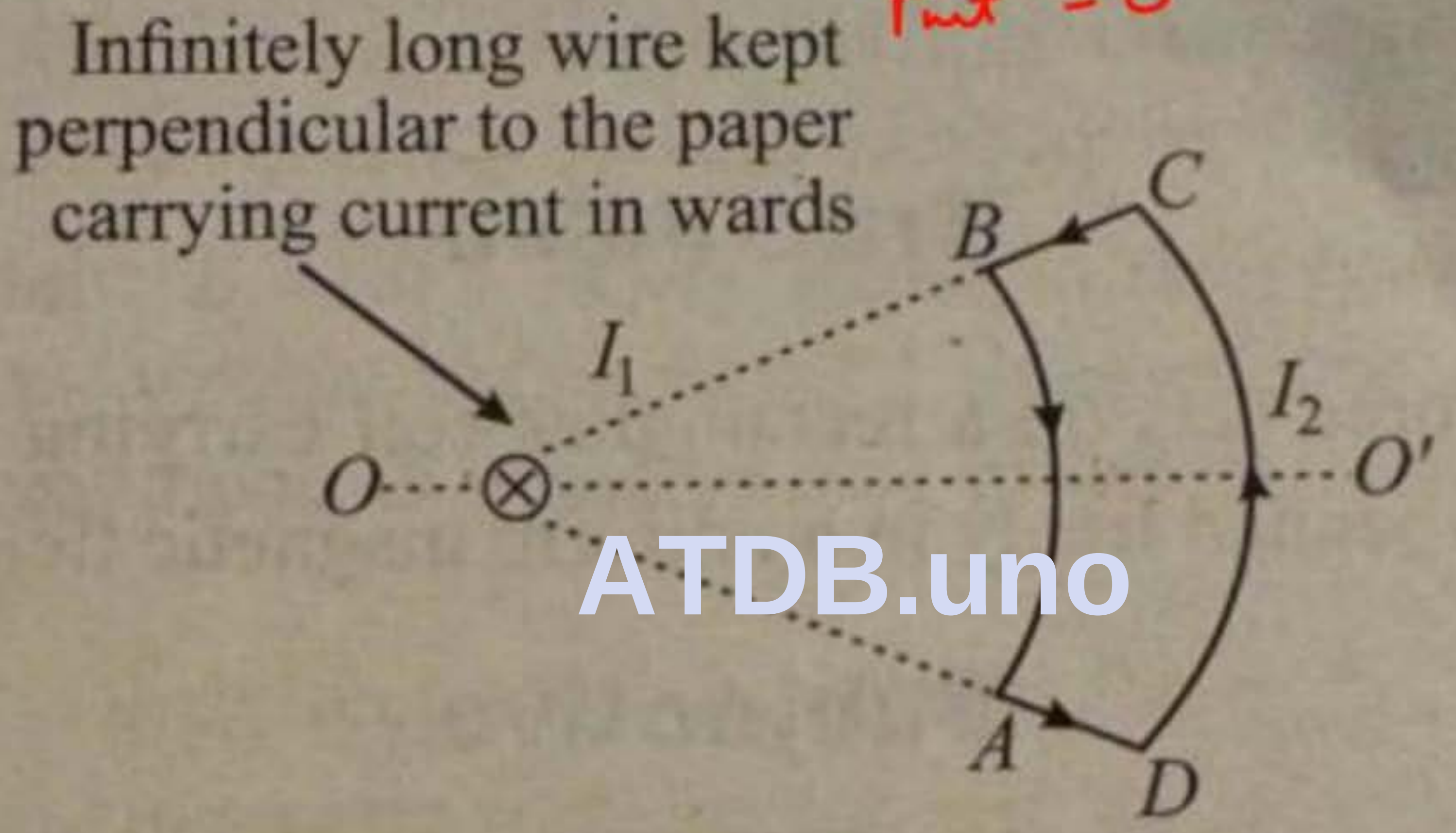


(d)



60. Which of the following statement is/are correct in the given figure?

(IIT-JEE 2006)



(a) Net force on the loop is zero

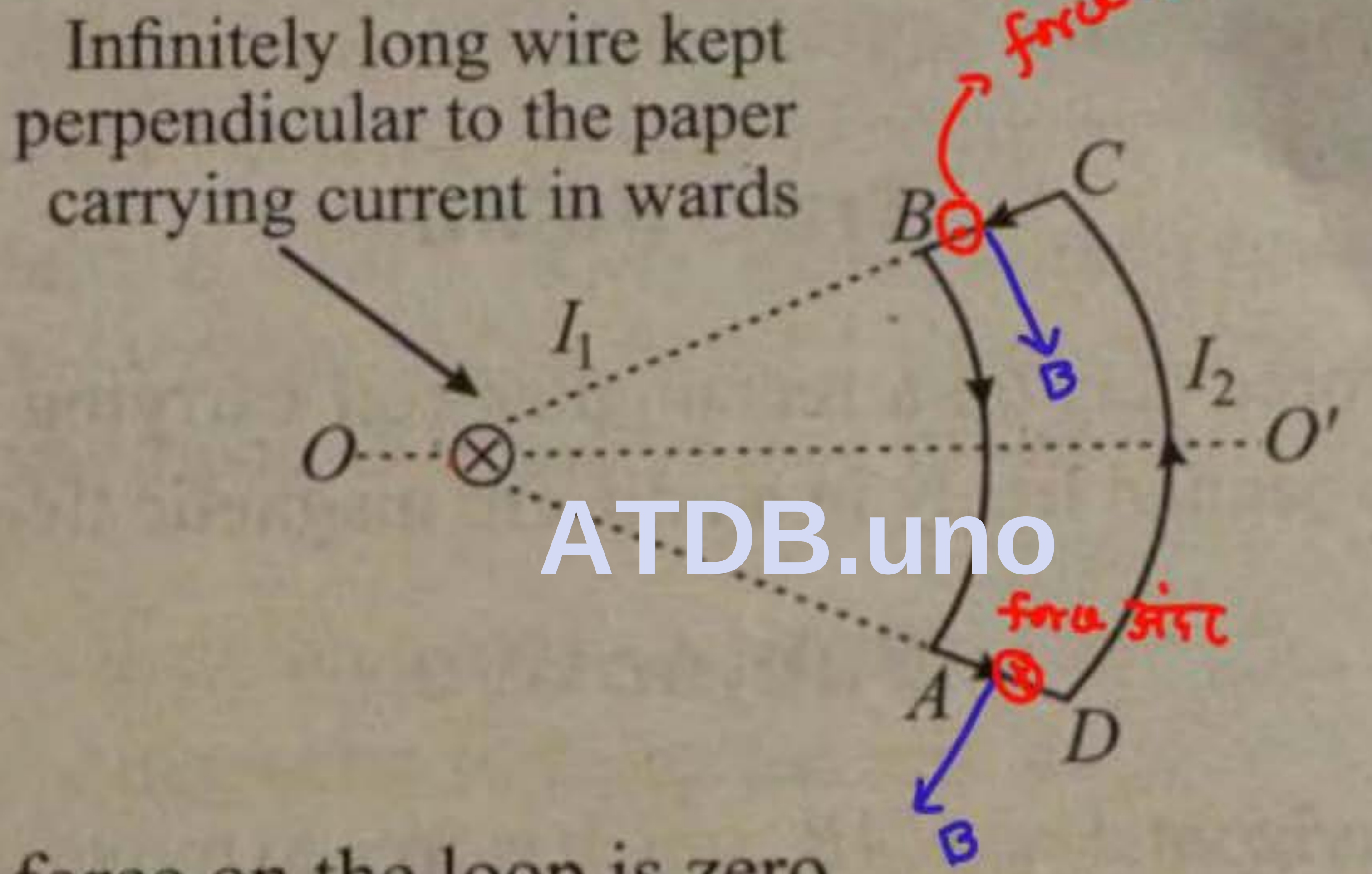
(b) Net torque on the loop is zero

(c) Loop will rotate clockwise about axis OO' when seen from O

(d) Loop will rotate anticlockwise about OO' when seen from O

60. Which of the following statement is/are correct in the given figure?

(IIT-JEE 2006)



(a) Net force on the loop is zero

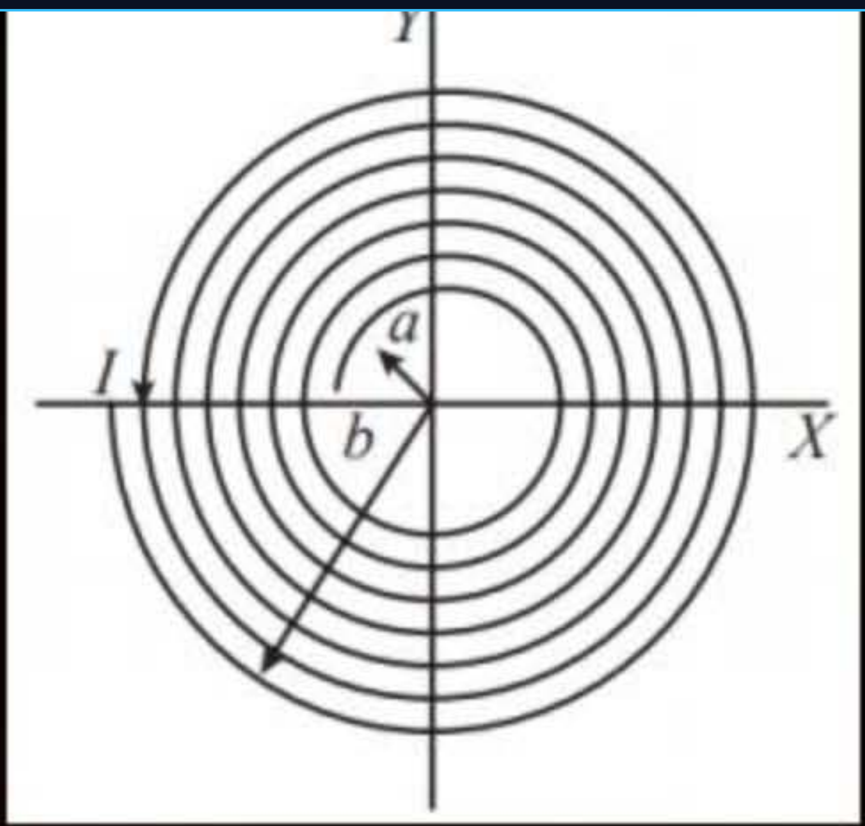
(b) Net torque on the loop is zero

(c) Loop will rotate clockwise about axis OO' when seen from O

(d) Loop will rotate anticlockwise about OO' when seen from O

Q. 1 A long insulated copper wire is closely wound as a spiral of N turns. The spiral has inner radius a and outer radius b. The spiral lies in the $X-Y$ plane and a steady current I flows through the wire. The Z-component of the magnetic field at the centre of the spiral is

(IIT-JEE 2011)



(a) $\frac{\mu_0 NI}{2(b-a)} ln\left(\frac{b}{a}\right)$

(b) $\frac{\mu_0 NI}{2(b-a)} ln\left(\frac{b+a}{b-a}\right)$

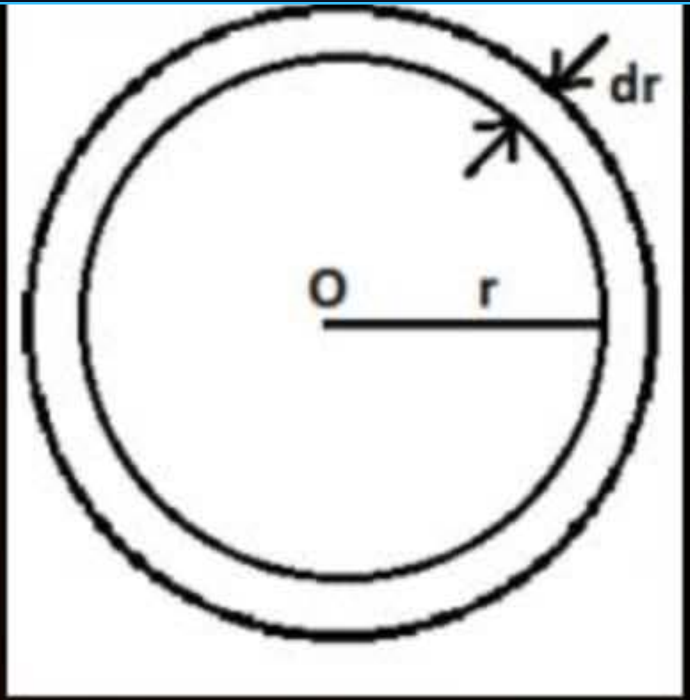
(c) $\frac{\mu_0 NI}{2b} ln\left(\frac{b}{a}\right)$

(d) $\frac{\mu_0 NI}{2b} ln\left(\frac{b+a}{b-a}\right)$

Ans : (a)

Solution 1

Let us consider an elementary ring of radius r and thickness dr in which current I is flowing.



Number of turns in this elementary ring $dN = \frac{N}{b-a}dr$

Thus magnetic field at the centre O due to this ring $dB = \frac{\mu_0 I dN}{2r}$

We get $dB = \frac{\mu_0 I N dr}{2(b-a)r}$

Net magnetic field at centre of spiral $B = \int_a^b \frac{\mu_0 I N}{2(b-a)} \frac{dr}{r}$

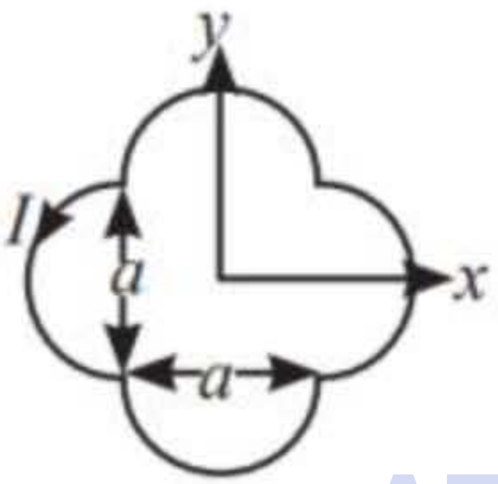
$\therefore B = \frac{\mu_0 I N}{2(b-a)} \int_a^b \frac{dr}{r}$

Or $B = \frac{\mu_0 I N}{2(b-a)} \times \ln r \Big|_a^b$

Or $B = \frac{\mu_0 I N}{2(b-a)} \ln \frac{b}{a}$

Q. 2 A loop carrying current I lies in the x-y plane as shown in the figure. The unit vector $\hat{k}$ is coming out of the plane of the paper. The magnetic moment of the current loop is

(IIT-JEE 2012)



(a) $a^2 I \hat{k}$

(b) $\left(\frac{\pi}{2}+1\right) a^2 I \hat{k}$

(c) $-\left(\frac{\pi}{2}+1\right) a^2 I \hat{k}$

(d) $(2\pi+1) a^2 I \hat{k}$

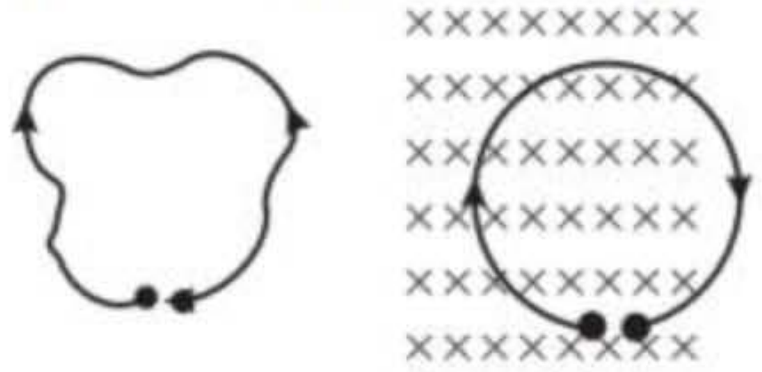
Ans : (b)

Solution 2

Area of the loop: $A = a^2 + 4 \times \frac{\pi\left(\frac{a}{2}\right)^2}{2} = a^2 + \frac{\pi a^2}{2}$

$$\vec{\mu} = IA\hat{k} = I\left(a^2 + \frac{\pi a^2}{2}\right)\hat{k} = Ia^2\left(1 + \frac{\pi}{2}\right)\hat{k}$$

Q. 3 A thin flexible wire of length L is connected to two adjacent fixed points and carries a current I in the clockwise direction, as shown in the figure. When the system is put in a uniform magnetic field of strength B going into the plane of the paper, the wire takes the shape of a circle. The tension in the wire is **(IIT-JEE 2010)**



(a) IBL (b) $\frac{IBL}{\pi}$ (c) $\frac{IBL}{2\pi}$ (d) $\frac{IBL}{4\pi}$

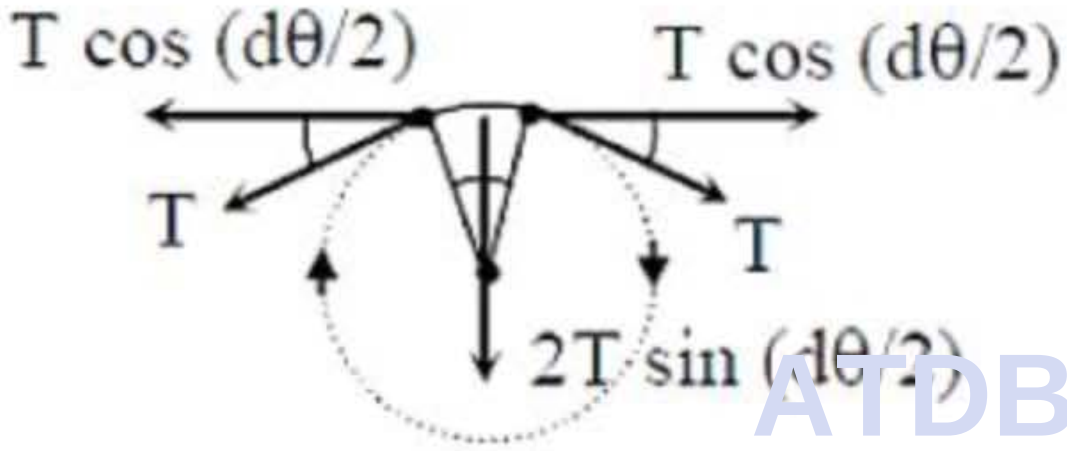
Ans : (b)

Solution 3

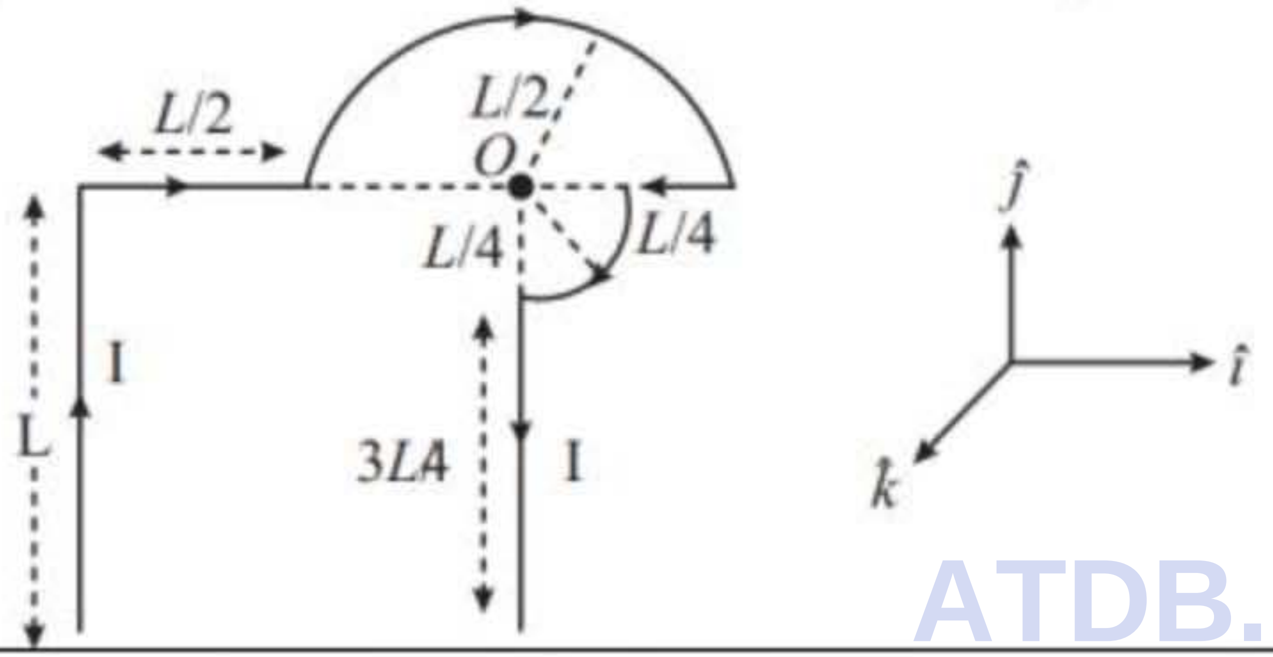
$$2T\sin\frac{d\theta}{2} = BiRd\theta$$

$$Td\theta = BiRd\theta \text{ (for } \theta \text{ small)}$$

$$T = BiR = \frac{BiL}{2\pi}$$



Q. 4 Which one of the following options represents the magnetic field $\vec{B}$ at O due to the current flowing in the given wire segments lying on the xy plane? **(JEE Adv. 2022)**



(a) $\vec{B} = \frac{-\mu_o I}{L}\left(\frac{3}{2} + \frac{1}{4\sqrt{2}\pi}\right)\hat{k}$ (b) $\vec{B} = -\frac{\mu_o I}{L}\left(\frac{3}{2} + \frac{1}{2\sqrt{2}\pi}\right)\hat{k}$

(c) $\vec{B} = \frac{-\mu_o I}{L}\left(1 + \frac{1}{4\sqrt{2}\pi}\right)\hat{k}$ (d) $\vec{B} = \frac{-\mu_o I}{L}\left(1 + \frac{1}{4\pi}\right)\hat{k}$

Ans : (c)

Solution 4

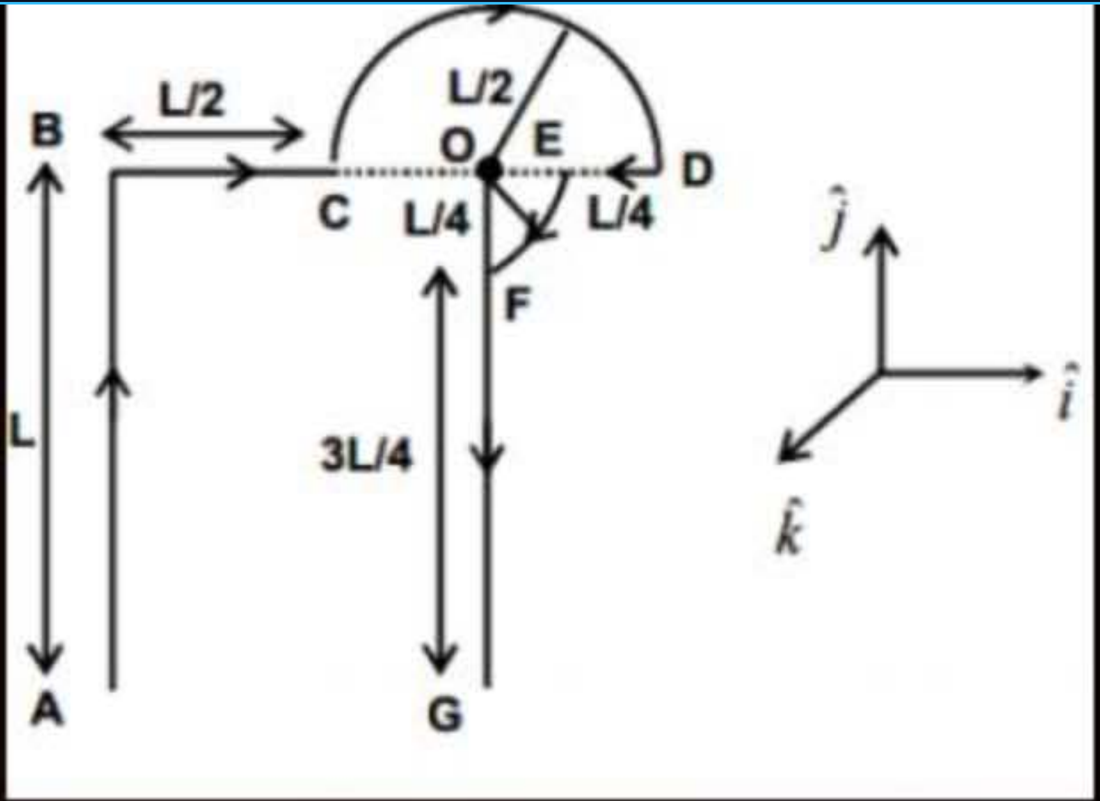
$$\vec{B}_{Net} = \vec{B}_{AB} + \vec{B}_{BC} + \vec{B}_{CD} + \vec{B}_{DE} + \vec{B}_{EF} + \vec{B}_{FG}$$

$$\vec{B}_{AB} = \vec{B}_{DE} = \vec{B}_{FG} = 0$$

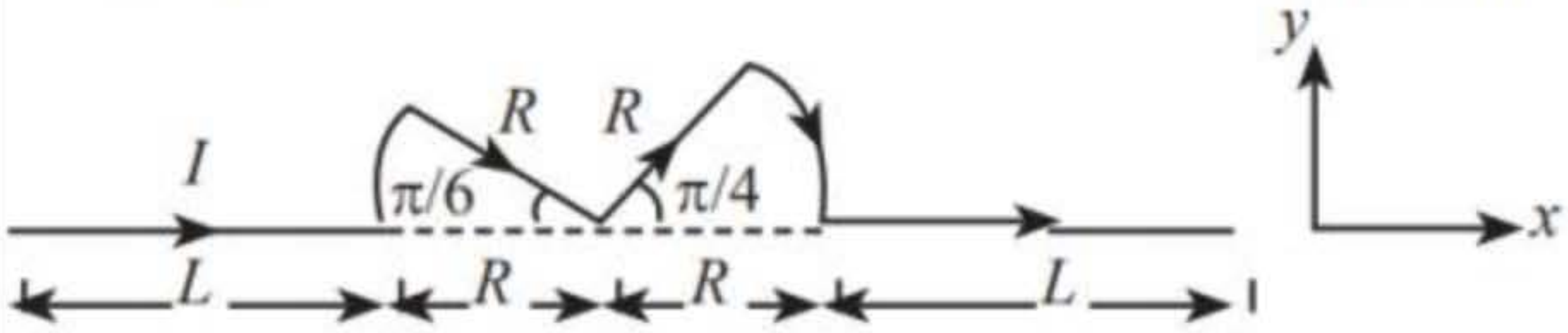
$$\vec{B}_{AB} = \frac{\mu_0 I}{4\pi L}\sin 45^\circ\left[-\hat{k}\right]$$

$$\vec{B}_{CD} = \frac{\mu_0 I}{4\left(\frac{L}{2}\right)}\left[-\hat{k}\right]$$

$$\vec{B}_{EF} = \frac{\mu_0 I}{8\left(\frac{L}{4}\right)}\left[-\hat{k}\right] \Rightarrow (C)$$



Q. 5 A conductor (shown in the figure) carrying constant current I is kept in the x–y plane in a uniform magnetic field B. If F is the magnitude of the total magnetic force acting on the conductor, then the correct statements is/are **(JEE Adv. 2015)**



(a) If B is along $\hat{z}$, $F \propto (L + R)$

(b) If B is along $\hat{x}$, $F = 0$

(c) If B is along $\hat{y}$, $F \propto (L + R)$

(d) If B is along $\hat{z}$, F = 0

Ans : (a, b, c)

Solution 5

The vector sum of all current element in wires not parallel to x axis will lead to resultant current element of length R and current along x axis. Total length of current element:

$dl = 2(L + R)\hat{x}$

$\vec{F} = i(2(L + R)\hat{x}) \times \vec{B}$

If $\vec{B}$ along $\hat{z}$ then F will be along $-\hat{y}$ and will be propotional to (L+R)

If $\vec{B}$ along $\hat{x}$ then F = 0 since vector product is zero.

If $\vec{B}$ along $\hat{y}$ then F will be along $\hat{z}$ and will be prop to (L+R)

If $\vec{B}$ along $\hat{z}$ then F will be along $-\hat{y}$ and will not be equal to 0.

Q. 6 Two parallel wires in the plane of the paper are distance x_0 apart. A point charge is moving with speed u between the wires in the same plane at a distance x_1 from one of the wires. When the wires carry current of magnitude I in the same direction, the radius of curvature of the path of the point charge is R_1. In contrast, if the currents I in the two wires have directions opposite to each other, the radius of curvature of the path is R_2. If $\frac{x_0}{x_1} = 3$, and value of $\frac{R_1}{R_2}$ is

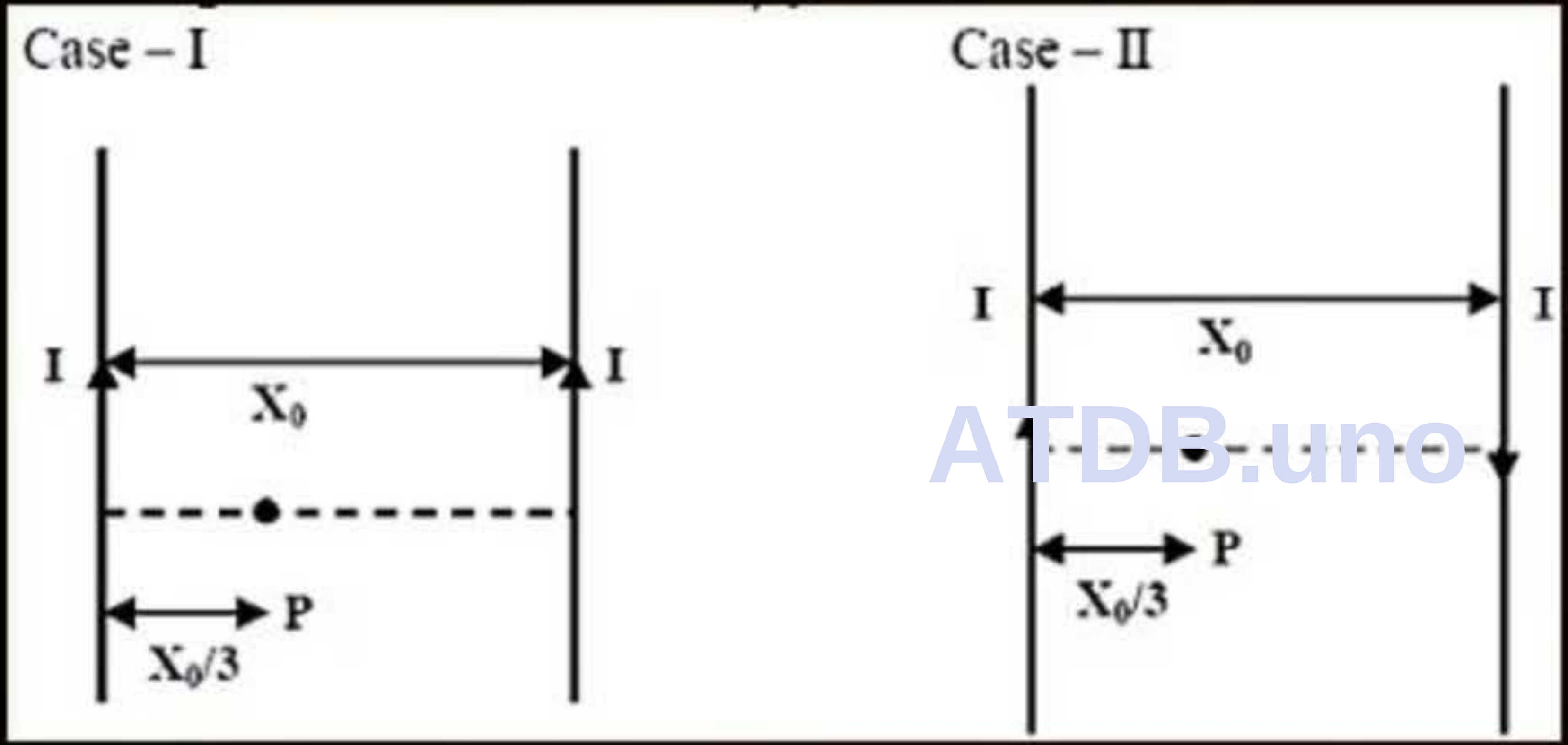
(JEE Adv. 2014)

Ans : (3)

Solution 6

$$B_1 = \frac{1}{2}\left(\frac{\mu_0}{2\pi}\right)\left(\frac{3I}{x_0}\right) \quad R_2 = \frac{mv}{qB_2}$$

$$R_1 = \frac{mv}{qB_1} \Rightarrow \frac{R_1}{R_2} = \frac{B_2}{B_1} = \frac{1/3}{1/9} = 3$$



Q. 7 An electron and a proton are moving on straight parallel paths with same velocity. They enter a semi-infinite region of uniform magnetic field perpendicular to the velocity. Which of the following statement(s) is/are true? **(IIT-JEE 2011)**

(*a*) They will never come out of the magnetic field region

(*b*) They will come out travelling along parallel paths

(*c*) They will come out at the same time

(*d*) They will come out at different times

Ans : (b, d)

Solution 7

By diagram B is true

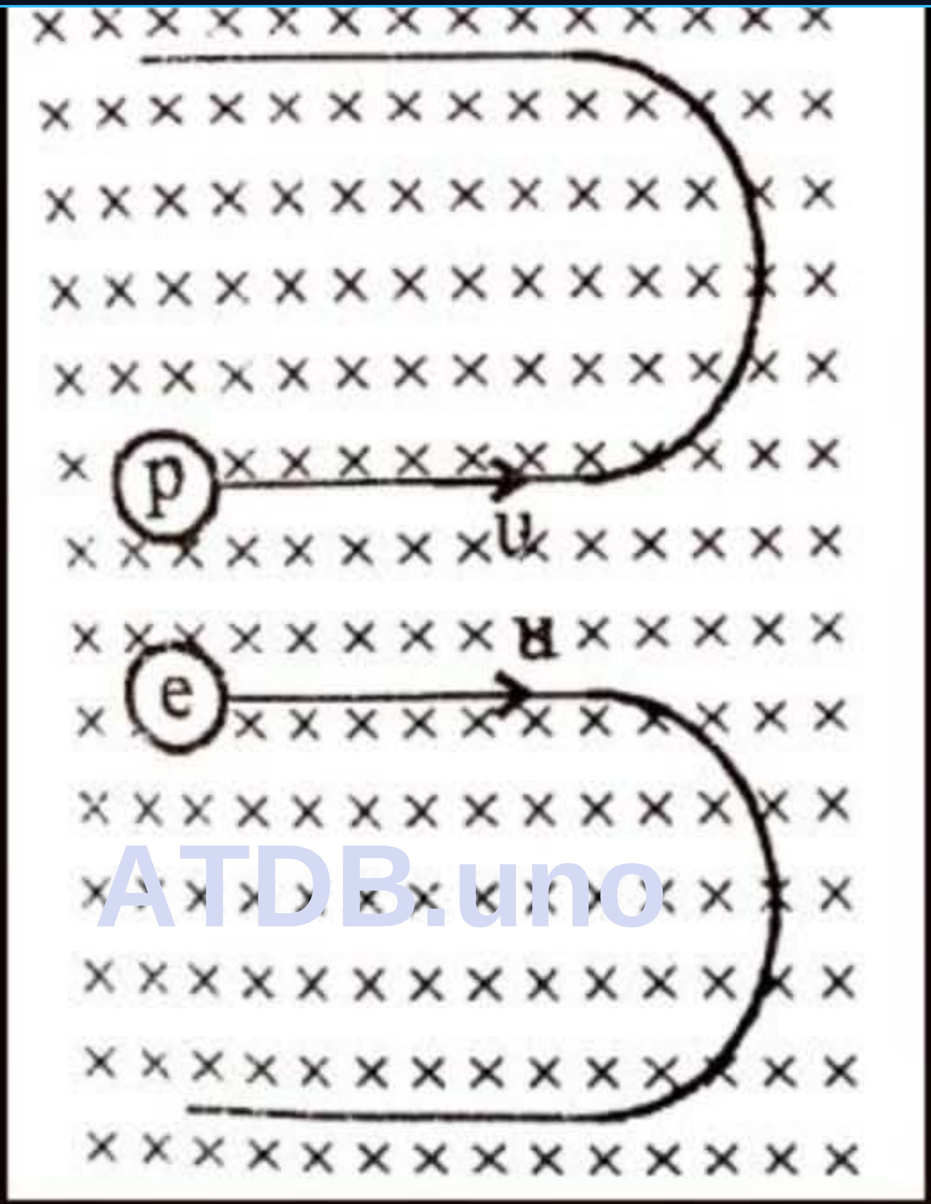
$$T = \frac{2\pi m}{qB}$$

$$t \propto m$$

$$m_p > m_e$$

$$T_p > T_e$$

So, D is also true



Q. 8 Ail α-particle (mass 4 amu) and a singly charged sulfur ion (mass 32 amu) are initially at rest. They are accelerated through a potential V and then allowed to pass into a region of uniform magnetic field which is normal to the velocities of the particles. Within this region, the α-particle and the sulfur ion move in circular orbits of radii r_α and r_s, respectively. The ratio (r_s/r_α) is_________.

(JEE Adv. 2021)

Ans : (4)

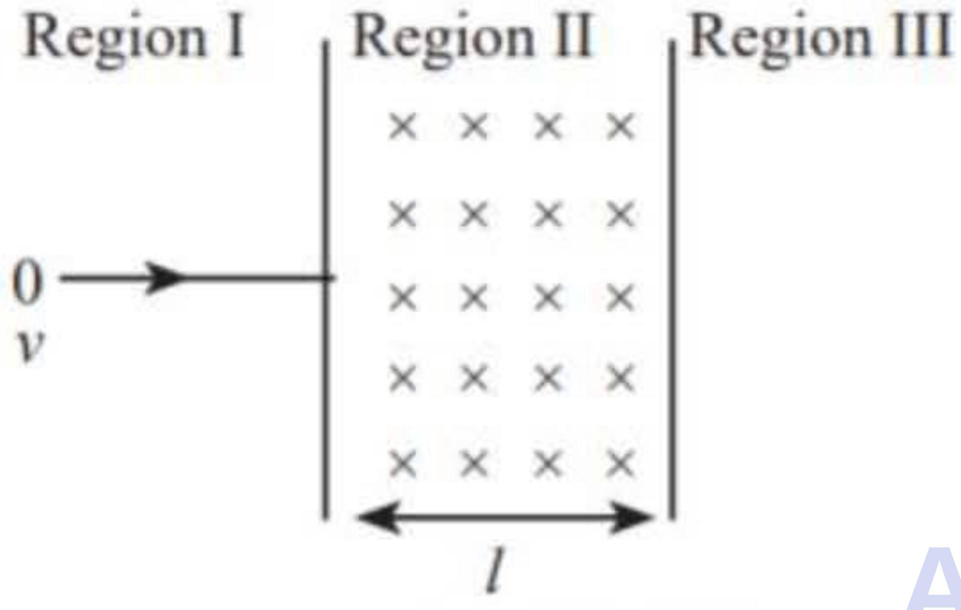
Solution 8

For a charged particle projected into uniform magnetic field, radius of path is given by

$$r = \frac{\sqrt{2mqV}}{qB} \Rightarrow r \propto \sqrt{\frac{m}{q}}$$

$$\Rightarrow \frac{r_s}{r_\alpha} = \sqrt{\frac{m_s}{m_\alpha}\left(\frac{q_\alpha}{q_s}\right)} = \sqrt{\frac{32(2)}{4(1)}} = 4$$

Q. 9 A particle of mass m and charge q, moving with velocity v enters Region II normal to the boundary as shown in the figure. Region II has a uniform magnetic field B perpendicular to the plane of the paper. The length of the Region II is l. Choose the correct choice (s)



(IIT-JEE 2008)

(a) The particle enters Region III only if its velocity $v > \frac{qlB}{m}$

(b) The particle enters Region III only if its Velocity $v < \frac{qlB}{m}$

(c) Path length of the particle in Region II is maximum when velocity $v = qlB/m$

(d) Time spent in Region II is same for any velocity v as long as the particle returns to Region I

Ans : (a, c, d)

Solution 9

As the particle enters region II, it will have a portion of circular path in this region.

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

If the width of the region l is less than r, the particle will enter region III.

$$\therefore \frac{mv}{qB} > l$$

$$\Rightarrow v > \frac{qBl}{m}$$

∴ the path length of the particle in region II will be maximum

when $l = r$ i.e $v = \dfrac{qlB}{m}$

when $r = l$, time spent in the region II is $\dfrac{T}{2} = \dfrac{1}{2}\dfrac{2\pi m}{qB} = \dfrac{\pi m}{qB}$.

Time is independent of speed

Q. 10 Consider the motion of a positive point charge in a region where there are simultaneous uniform electric and magnetic fields $E = E_0\hat{j}$ and $B = B_0\hat{j}$. At time $t = 0$, this charge has velocity v in the $x - y$ plane, making an angle θ with the x-axis. Which of the following option(s) is/are correct for time $t > 0$?

(IIT-JEE 2012)

(*a*) If θ = 0°, the charge moves in a circular path in the $x - z$ plane

(*b*) If θ = 0°, the charge undergoes helical motion with constant pitch along the y-axis

(*c*) If θ = 10°, the charge undergoes helical motion with its pitch increasing with time, along the y-axis

(*d*) If θ = 90°, the charge undergoes linear but accelerated motion along the y-axis

Ans : (c, d)

Solution 10

Correct Answer - C::D

Here, $\vec{E} = E_0\hat{j}$ and $\vec{B} = B_0\hat{j}$.

Let m, q be the mass and charge of the positive point charge which is moving with velocity $\vec{v}$ in the electric and magnetic fields acting along Y-axis.

Resolving $\vec{v}$ into two rectangular components we have, $v\cos\theta$ along X-axis and $v\sin\theta$ acts along Y-axis.

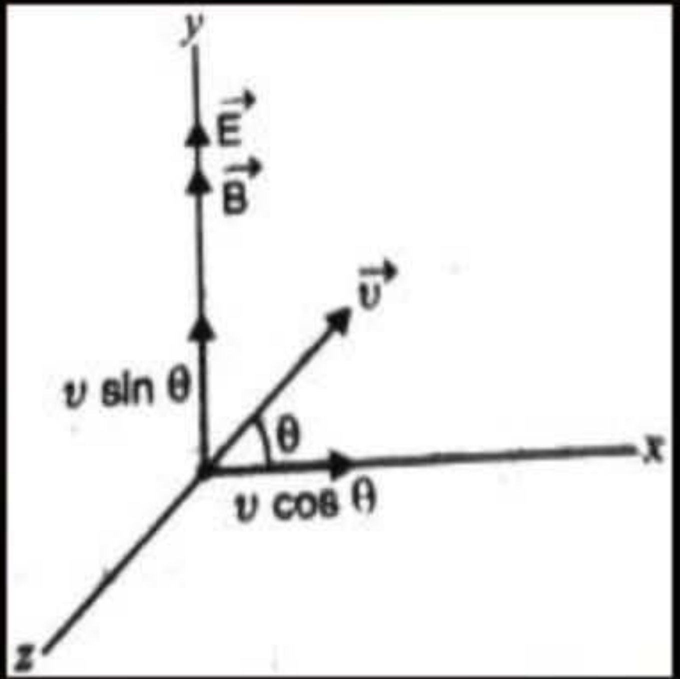
Due to component velocity $v\sin\theta$, the charged particle is accelerated due to electric field with acceleration, $a_y = E_0 q / m$ along Y-axis.

The particle does not experience any force due to magnetic field.

Due to component velocity $v\cos\theta$, the particle is accelerated due to electric field with acceleration $a_y = E_0 q / m$ along Y-axis.

The particle experiences maximum force due to magnetic field and describes a circular path with time period, $T = 2\pi m / Bq$ which is independent of r and v.

Due to combined electric and magnetic fields along Y-axis, when $\theta = 10^\circ$, the particle will describe a helical path whose pitch increases with time along the Y-axis (i.e., option (c) is true). When $\theta = 90^\circ$, the particle does not experience any force due to magnetic field. Hence it is accelerated along y-axis due to electric field alone. Thus option (d) is true.



Q. 11 A particle of mass M and positive charge Q, moving with a constant velocity $u_1 = 4\hat{i}\ \text{ms}^{-1}$, enters a region of uniform static magnetic field normal to the $x-y$ plane. The region of the magnetic field extends from $x = 0$ to $x = L$ for all values of y. After passing through this region, the particle emerges on the other side after 10 milliseconds with a velocity $u_2 = 2\left(\sqrt{3}\hat{i} + \hat{j}\right)\text{ms}^{-1}$. The correct statement(s) is/are **(JEE Adv. 2013)**

(a) The direction of the magnetic field is $-z$ direction.

(b) The direction of the magnetic field is $+z$ direction

(c) The magnitude of the magnetic field is $\frac{50\pi M}{3Q}$ units

(d) The magnitude of the magnetic field is $\frac{100\pi M}{3Q}$ units

Ans : (a, c)

Solution 11

Correct Answer - A::C

Refer to figure, component of final velocity of particle is in positive y-direction. The centre of circular path of particle in magnetic field is present on positive y-direction So magnetic field is present in negative z-direction.

If θ is the angle of deviation of the particle with x-axis while emerging from magnetic field, then

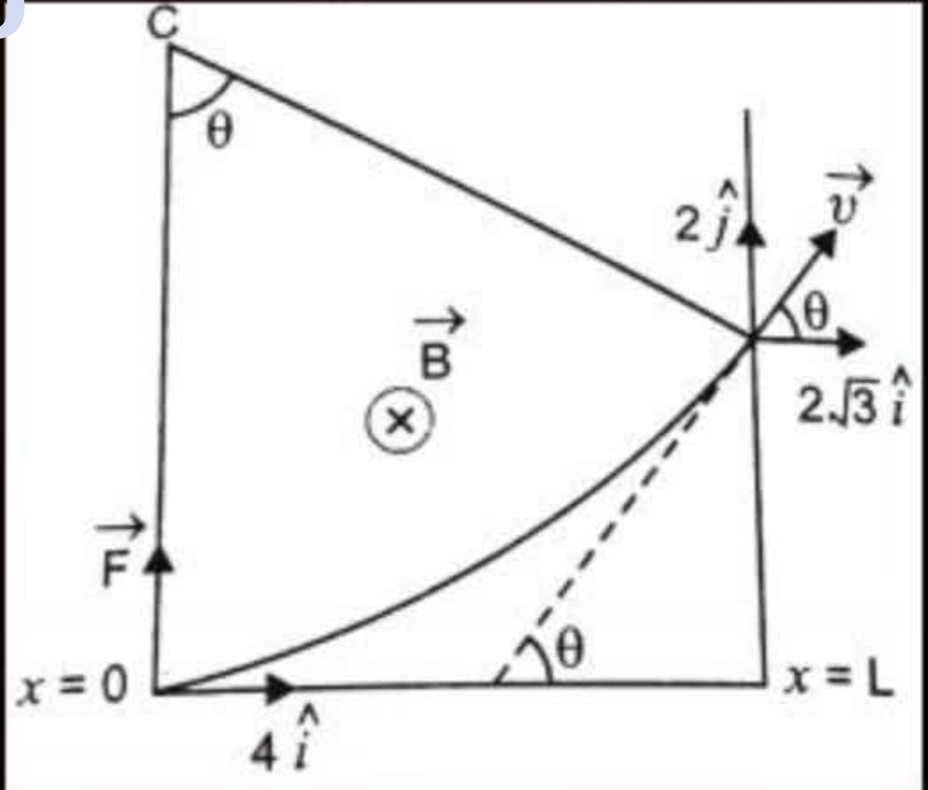
$$\tan\theta = \frac{v_y}{v_x} = \frac{2}{2\sqrt{3}} = \frac{1}{\sqrt{3}} = \frac{\tan\pi}{6} \text{ or } \theta = \frac{\pi}{6}$$

Angular velocity of rotation of particle in magnetic field, $\omega = \frac{QB}{M}$

Time taken by particle to cross the magnetic field is

$$t = \frac{\theta}{\omega} = \frac{\pi/6}{QB/M} = \frac{M\pi}{6QB}$$

$$\text{or } B = \frac{M\pi}{6Qt} = \frac{M\pi}{6Q \times (10 \times 10^{-3})} = \frac{50M\pi}{3Q}$$

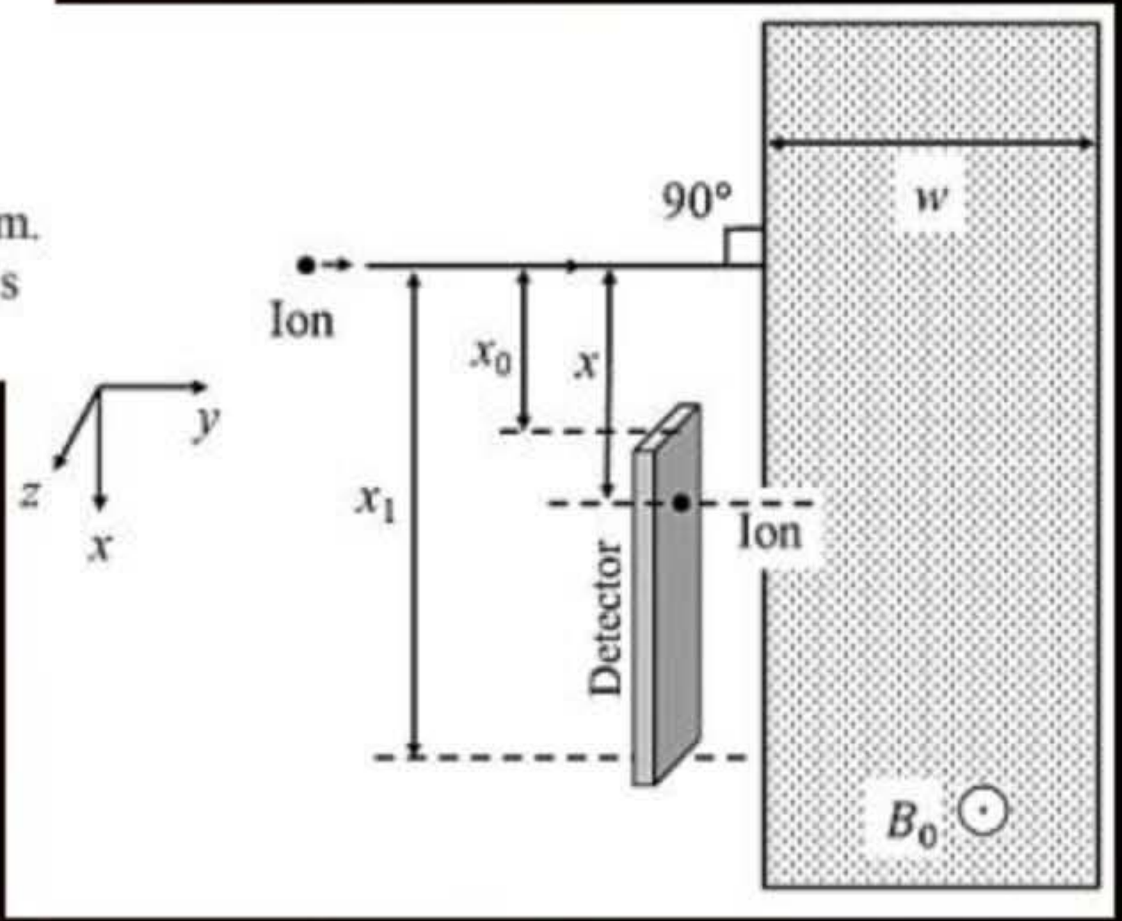


Q. 12 A positive, singly ionized atom of mass number A_M is accelerated from rest by the voltage 192 V. Thereafter, it enters a rectangular region of width w with magnetic field $\vec{B}_0 = 0.1\hat{k}$ Tesla, as shown in the figure. The ion finally hits a detector at the distance x below its starting trajectory.

[Given: Mass of neutron/proton = $(5/3) \times 10^{-27}$ kg, charge of the electron = 1.6×10^{-19} C.]

Which of the following option(s) is(are) correct?

(A) The value of x for H^+ ion is 4 cm.
(B) The value of x for an ion with $A_M = 144$ is 48 cm.
(C) For detecting ions with $1 \leq A_M \leq 196$, the minimum height $(x_1 - x_0)$ of the detector is 55 cm.
(D) The minimum width w of the region of the magnetic field for detecting ions with $A_M = 196$ is 56 cm.



Ans : (A, B)

Solution 12

$x = 2R$ & $R = \frac{MV}{qB}$

$M = A_M \times M$

m → mass of neutron/proton

By Energy conservation

$$\frac{1}{2mv^2} = q(\Delta V)$$

$$\Rightarrow v = \sqrt{\frac{2q(\Delta V)}{M}}$$

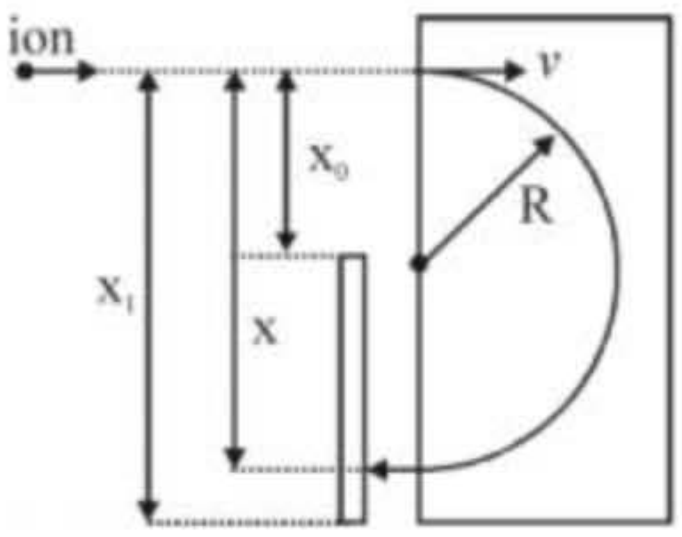
Thus $x = \frac{2M}{qB} \times \sqrt{\frac{2q(\Delta v)}{M}}$

also put $M = A_M \times M$

On Simlifying we get $x = \sqrt{\frac{8mA_M(\Delta V)}{qB^2}}$

In this only A_m is varying in different parts of question

$$\Rightarrow x = \sqrt{\frac{8m\Delta V}{qB^2}} \times \sqrt{A_M} = C\sqrt{A_M}$$



From Diagram

(A) For H^+, $x = C = \sqrt{\frac{8 \times \frac{5}{3} \times 10^{-27} \times 192}{1.6 \times 10^{-19} \times 10^{-2}}} = 4cm$

(B) For $A_M = 144, x = 4 \times \sqrt{144} = 48cm$

(C) For $A_M = 196, x = x_1 = 4 \times \sqrt{196} = 56cm$ & $A_M = 1$ $x = x_0 = 4cm$ $x_1 = x_0 = 52cm$

(D) Min width = Radius of path = $\frac{x}{2}$, For $A_M = 196, R = \frac{x}{2} = \frac{56}{2} = 28cm$

Q. 13 A steady current I goes through a wire loop PQR having shape of a right angle triangle with $PQ = 3x$, $PR = 4x$ and $QR = 5x$. If the magnitude of the magnetic field at P due to this loop is $k\left(\frac{\mu_0 I}{48\pi x}\right)$, find the value of k **(IIT-JEE 2009)**

Ans : (7)

Solution 13

Using the concept of area of triangle

$$\frac{1}{2} \times PD \times 5x = \frac{1}{2} \times 3x \times 4x$$

$$\therefore PD = \frac{12x}{5}$$

$$QD = \sqrt{(PQ)^2 - (PQ)^2} = \sqrt{9x^2 - \frac{144x^2}{25}} = \frac{9x}{5}$$

$$\text{and } DR = 5x - \frac{9x}{5} = \frac{16x}{5}$$

Magnetic field at P due to current elements PQ and PR is zero as the point P is on the conductor. Therefore, magnetic field at P due to current element QR is

$$B = \frac{\mu_0 I}{4\pi PD}(\sin\phi_1 + \sin\phi_2)$$

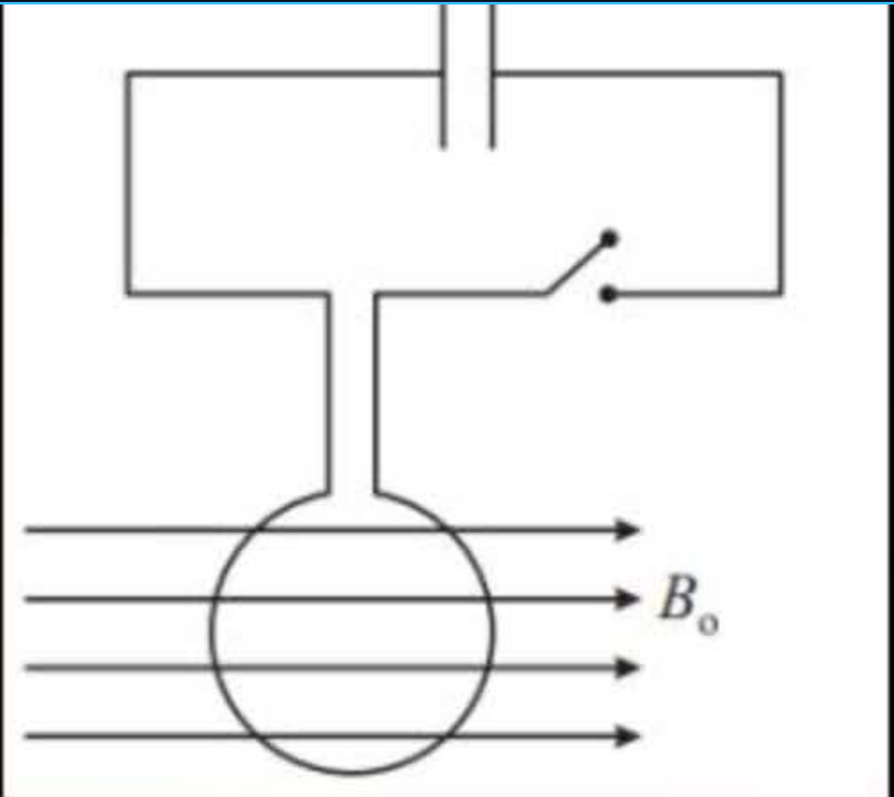
$$B = \frac{\mu_0 I \times 5}{4\pi \times 12x}\left(\frac{(9x/5)}{3x} + \frac{(16x/5)}{4x}\right)$$

$$B = \frac{\mu_0 I 5}{48\pi x}\left(\frac{3}{5} + \frac{4}{5}\right)$$

$$B = \frac{7\mu_0 I}{48\pi x} \therefore k = 7$$

Q. 14 A circular coil of radius R and N turns has negligible resistance. As shown in the schematic figure, its two ends are connected to two wires and it is hanging by those wires with its plane being vertical. The wires are connected to a capacitor with charge Q through a switch. The coil is in a horizontal uniform magnetic field B parallel to the plane of the coil. When the switch is closed, the capacitor gets discharged through the coil in a very short time. By the time the capacitor is discharged fully, magnitude of the angular momentum gained by the coil will be (assume that the discharge time is so short that the coil has hardly rotated during this time)

(JEE Adv. 2020)



(a) $\frac{\pi}{2}NQB_0R^2$ (b) πNQB_0R^2 (c) $2\pi NQB_0R^2$ (d) $4\pi NQB_0R^2$

Ans : (b)

Solution 14

Correct option is B. πNQB_0R^2

correct answer is

$(B)\pi NQB_0R^2$

Torque experienced by ciruclar loop $= \vec{M} \times \vec{B}$

where $= \vec{M}$ is magnetic moment

$= \vec{B}$ is magneti field.

$\therefore \tau = i\pi R^2 NB_0$ [at the instant shown $\theta = \pi/2$]

$\therefore \vec{\tau}dt = d\vec{L} = i\pi R^2 NB_0 dt = Q\pi R^2 NB_0\,[idt = Q]$

Q. 15 A thin stiff insulated metal wire is bent into a circular loop with its two ends extending tangentially from the same point of the loop. The wire loop has mass m and radius r and it is in a uniform vertical magnetic field B_0, as shown in the figure. Initially, it hangs vertically downwards, because of acceleration due to gravity g, on two conducting supports at P and Q. When a current I is passed through the loop, the loop turns about the line PQ by an angle θ given by

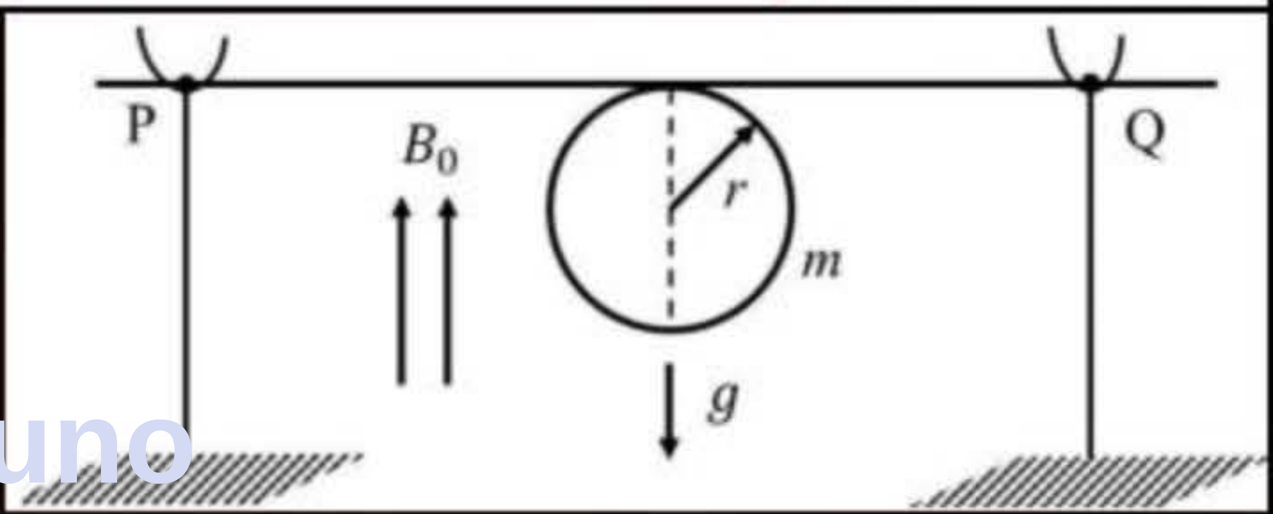
JEE Adv 2024

(A) $\tan\theta = \pi r I B_0 / (mg)$

(B) $\tan\theta = 2\pi r I B_0 / (mg)$

(C) $\tan\theta = \pi r I B_0 / (2mg)$

(D) $\tan\theta = mg / (\pi r I B_0)$



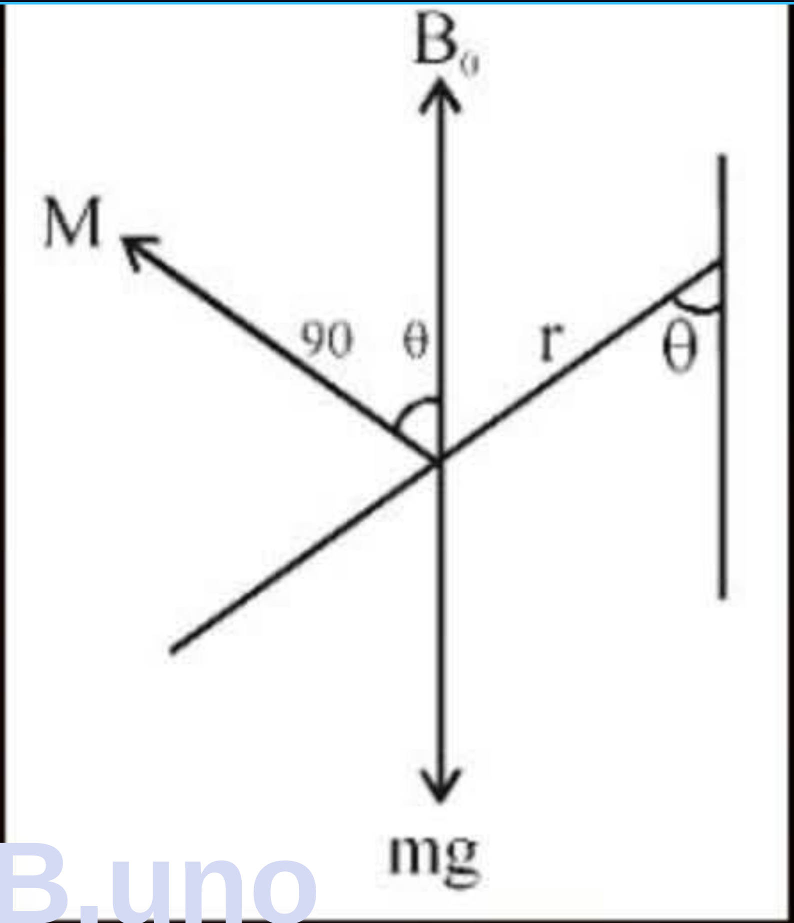
Ans : (A)

Solution 15

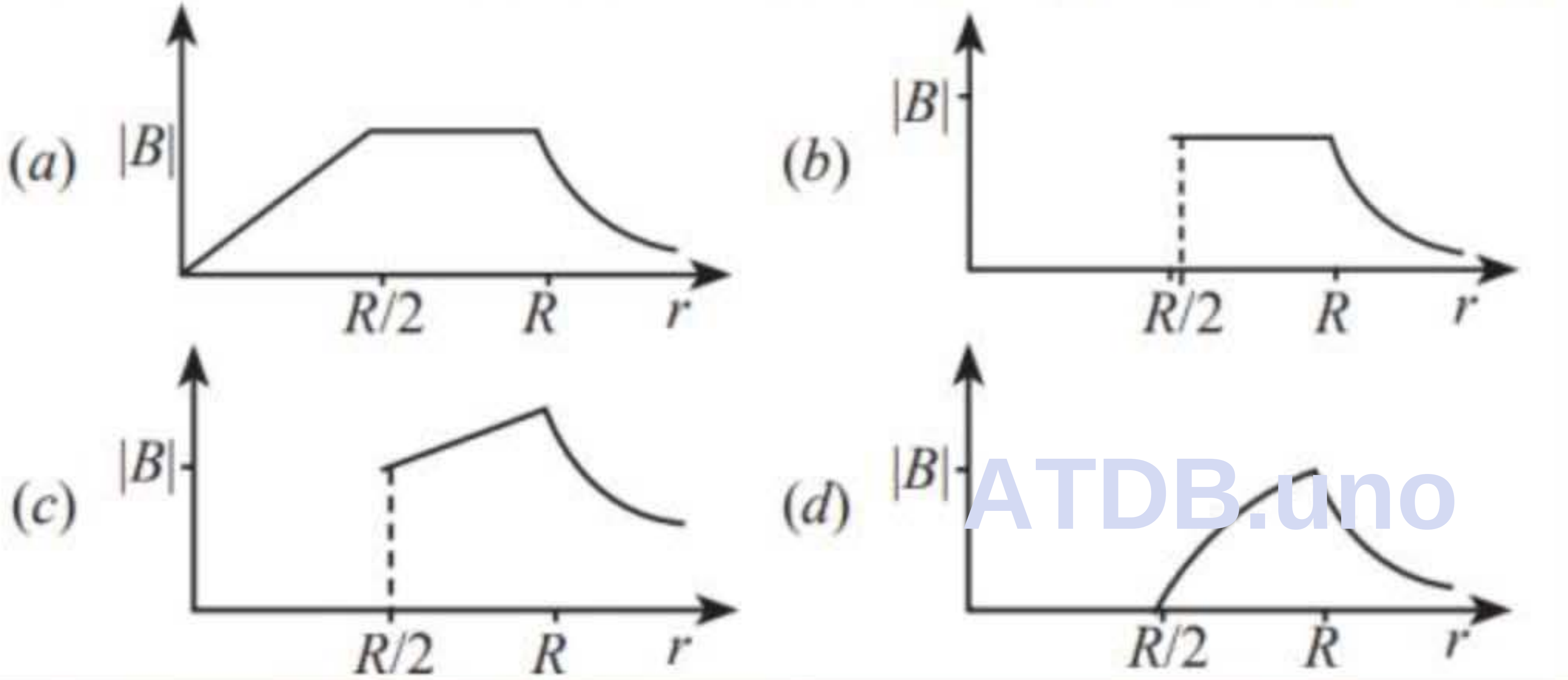
$$Z = MB\sin(90 - \theta)$$

$$mgr\sin\theta = i(\pi r^2)B_0(0)\theta$$

$$\tan\theta = \pi rIB_0 / (mg)$$



Q. 16 An infinitely long hollow conducting cylinder with inner radius $R/2$ and outer radius R carries a uniform current density along its length. The magnitude of the magnetic field, $|B|$ as a function of the radial distance r from the axis is best represented by **(IIT-JEE 2012)**



Ans : (d)

Solution 16

inside the cavity, for $x < (R/2)$, $B = 0$ (1)

For,

$(R/2) < x < R$

$\int B \cdot d\ell = \mu_0 I$

Putting $I = JA$

$\therefore$ $|B|\, 2\pi x = \mu_0 [\pi x^2 - \pi(R/2)^2]J$

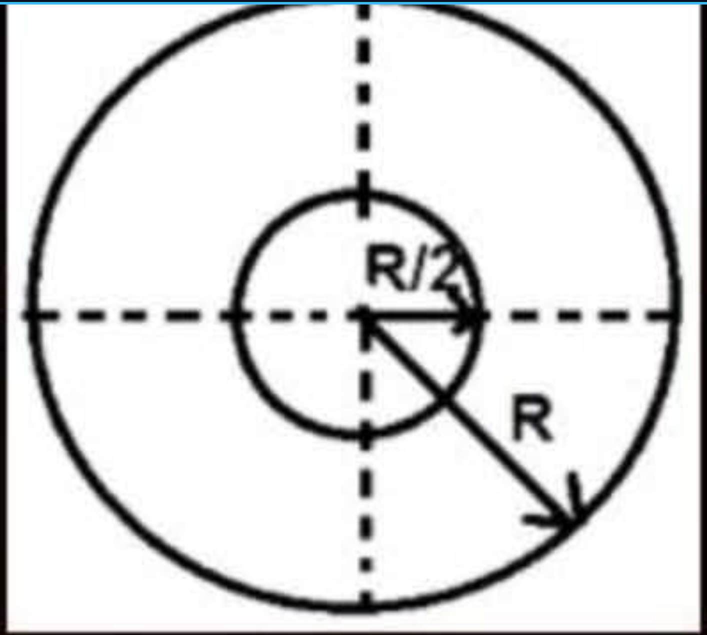
$|B| = [(\mu_0 J \times \pi)/(2\pi x)][x^2 - (R^2/4)]$

$|B| = [(\mu_0 J)/2x][x^2 - (R^2/4)]$ (2)

For $x \geq R$,

$\int \vec{B} \cdot d\vec{\ell} = \mu_0 I$

$|B| \cdot 2\pi x = \mu_0 [(\pi R^2 - \pi(R/2)^2]J$



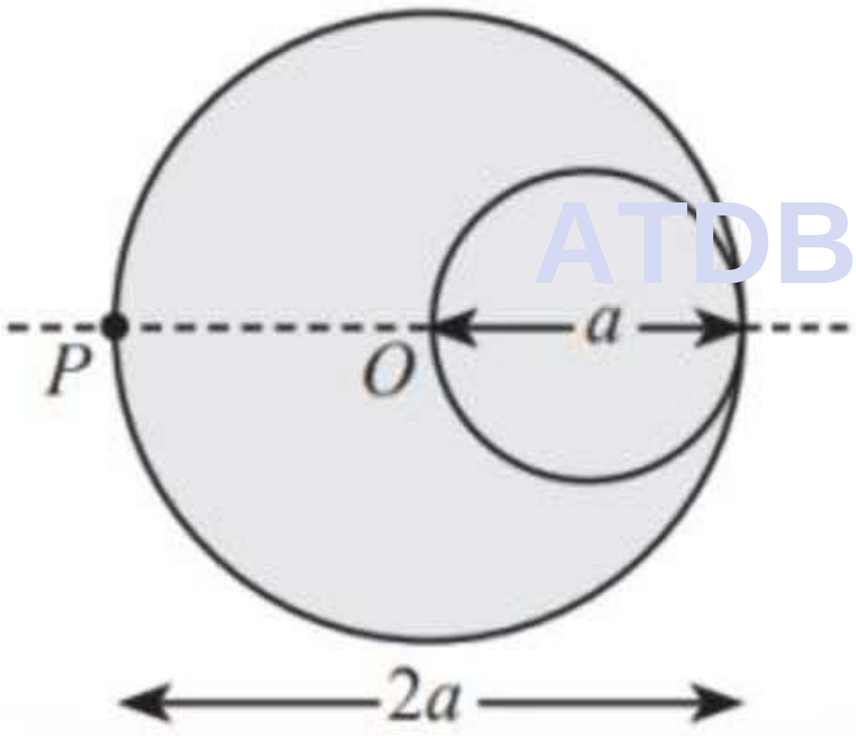
$|B| = [(\mu_0 J)/2x][(3/4)R^2]$ (3)

From (1), (2), (3) graph (d)

Q. 17 A cylindrical cavity of diameter a exists inside a cylinder of diameter $2a$ as shown in the figure. Both the cylinder and the cavity are infinitely long. A uniform current density J flows along the length.

If the magnitude of the magnetic field at the point P is given by $\frac{N}{12}\mu_0 a.J$, then the value of N is

(IIT-JEE 2012)



Ans : (5)

Solution 17

The magnetic field for an infinitely long cylinder is given by,

$$B_{in} = \frac{\mu_o J r}{2}$$

$$B_{out} = \frac{\mu_o J R^2}{2r}$$

r = distance from the axis of the cylinder.

R = Radius of the cylinder.

Assuming the bigger cylinder to carry a positive current density and the smaller cylinder carry a negative current density of magnitude J each.

$\therefore$ Magnetic field at point P = $B = B_1 + B_2$

$$B_1 = \frac{\mu_o J a}{2}$$

$$B_2 = \frac{-\mu_o J \left(\frac{a}{2}\right)^2}{2\frac{3a}{2}}$$

$$\therefore B_2 = \frac{-\mu_o J a}{12}$$

$$\therefore B = \frac{5\mu_o J a}{12}. \qquad \therefore N = 5$$

Q. 18 at the origin ($x = 0, y = 0, z = 0$) with a given initial velocity v. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity v, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in columns I, II and III, respectively. The quantities E_0, B_0, are positive in magnitude

(JEE Adv. 2017)

Column-I		Column-II		Column-III	
(I)	Electron with $v = 2\frac{E_0}{B_0}\hat{x}$	(*i*)	$\vec{E} = E_0\hat{z}$	(P)	$\vec{B} = -B\ \hat{x}$
(II)	Election with $v = \frac{E_0}{B_0}\hat{y}$	(*ii*)	$\vec{E} = -E_0\hat{y}$	(Q)	$\vec{B} = B_0\hat{x}$
(III)	Proton with $v = 0$	(*iii*)	$\vec{E} = -E_0\hat{x}$	(R)	$\vec{B} = B_0\hat{y}$
(IV)	Proton with $\overline{v} = 2\frac{E_0}{B_0}\hat{x}$	(*iv*)	$\vec{E} = E_0\hat{x}$	(S)	$\vec{B} - = B_0\hat{z}$

In which case will the particle move in a straight line with constant velocity?

(*a*) (II) (*iii*) (S)　　(*b*) (III) (*iii*) (P)

(*c*) (IV) (*i*) (S)　　(*d*) (III) (ii) (R)

Ans : (a)

Solution 18

The correct option is A (II)(iii)(S)

$F_{net} = F_e + F_B$

$\Rightarrow F = qE + qv \times B$

For particle to move in a straight line, F_{net} = zero

Hence $qE + qv \times B = 0$

Q. 19

at the origin ($x = 0, y = 0, z = 0$) with a given initial velocity v. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity v, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in columns I, II and III, respectively. The quantities E_0, B_0, are positive in magnitude

(JEE Adv. 2017)

Column-I		Column-II		Column-III	
(I)	Electron with $v = 2\frac{E_0}{B_0}\hat{x}$	(*i*)	$\vec{E} = E_0\hat{z}$	(P)	$\vec{B} = -B\ \hat{x}$
(II)	Election with $v = \frac{E_0}{B_0}\hat{y}$	(*ii*)	$\vec{E} = -E_0\hat{y}$	(Q)	$\vec{B} = B_0\hat{x}$
(III)	Proton with $v = 0$	(*iii*)	$\vec{E} = -E_0\hat{x}$	(R)	$\vec{B} = B_0\hat{y}$
(IV)	Proton with $\overline{v} = 2\frac{E_0}{B_0}\hat{x}$	(*iv*)	$\vec{E} = E_0\hat{x}$	(S)	$\vec{B} - = B_0\hat{z}$

In which case will the particle describe a helical path with axis along the positive z-direction?

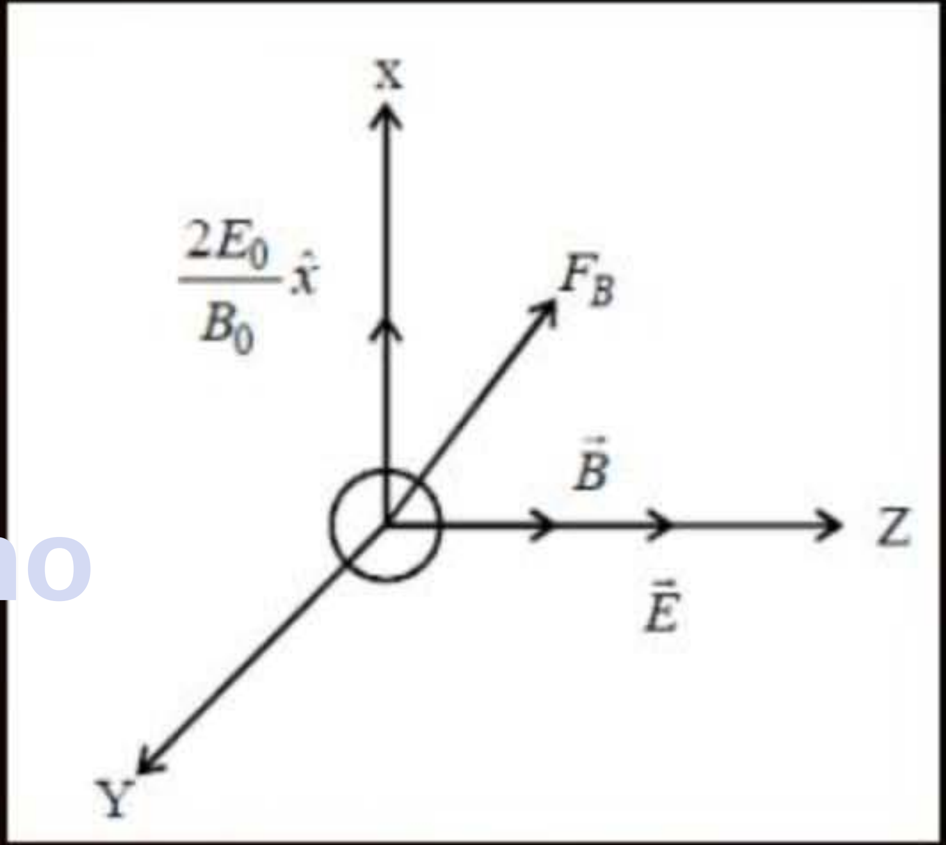
(*a*) (II) (*ii*) (R) (*b*) (III) (*iii*) (P)

(*c*) (IV) (*i*) (S) (*d*) (IV) (*ii*) (R)

Ans : (c)

Solution 19

The force due to magnetic field FB will provide the necessary centripetal force for circular motion which will be in X-Y plane. The force due to electric field will accelerate proton in Z-direction. Thus the path will be helical with increasing pitch.



Q. 20 A charged particle (electron or proton) is introduced at the origin ($x = 0, y = 0, z = 0$) with a given initial velocity v. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity v, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in columns I, II and III, respectively. The quantities E_0, B_0, are positive in magnitude

(JEE Adv. 2017)

Column-I		Column-II		Column-III	
(I)	Electron with $v = 2\frac{E_0}{B_0}\hat{x}$	(*i*)	$\vec{E} = E_0\hat{z}$	(P)	$\vec{B} = -B\ \hat{x}$
(II)	Election with $v = \frac{E_0}{B_0}\hat{y}$	(*ii*)	$\vec{E} = -E_0\hat{y}$	(Q)	$\vec{B} = B_0\hat{x}$
(III)	Proton with $v = 0$	(*iii*)	$\vec{E} = -E_0\hat{x}$	(R)	$\vec{B} = B_0\hat{y}$
(IV)	Proton with $\overline{v} = 2\frac{E_0}{B_0}\hat{x}$	(*iv*)	$\vec{E} = E_0\hat{x}$	(S)	$\vec{B} - = B_0\hat{z}$

In which case would the particle move in a straight line along the negative direction of Y-axis (i.e. move along $-y$)?

(*a*) (II) (*iii*) (S) (*b*) (III) (*iii*) (P)

(*c*) (IV) (*i*) (S) (*d*) (III) (*ii*) (R)

Ans : (d)

ATDB.uno

Solution 20

For particle to move in -ve y-direction, either its velocity must be in –ve y-direction (if initial velocity is not equal to zero) & force should be parallel to velocity or it must experience a net force in –ve y-direction only (if initial velocity = 0)

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Q. 21 In a particular system of units, a physical quantity can be expressed in terms of the electric charge e, electron mass m_e, Planck's constant h, and Coulomb's constant k $= \frac{1}{4\pi\varepsilon_0}$, where ε_0 is the permittivity of vacuum. In terms of these physical constants, the dimension of the magnetic field is $[B] = [e]^{\alpha} [m_e]^{\beta} [h]^{\gamma} [k]^{\delta}$. The value of $\alpha + \beta + \gamma + \delta$ is ________. [JEE-Advance-2022]

Ans : (4)

Solution 21

$$[B] = [e]^{\alpha} [M_e]^{\beta} [h]^{\gamma} [K]^{\delta}$$

$$[B] = MT^{-2}I^{-1}$$

$$[e] = I^{T}$$

$$[h] = ML^{2} T^{-1}$$

$$[K] = ML^{3} T^{-4} I^{-2}$$

$$MT^{-2}I^{-1} = [IT]^{\alpha} [M]^{\beta}$$

$$[ML^{2}T^{-1}]^{\gamma} [ML^{3}T^{-4}I^{-2}]^{\delta}$$

$$1 = \beta + \gamma + \delta \qquad (1)$$

$$-2 = \alpha - \gamma - 4\delta \qquad (2)$$

$$-1 = \alpha - 2\delta \qquad (3)$$

$$0 = 2\gamma + 3\delta \qquad (4)$$

On solving equation (1), (2), (3) and (4), we get

$$\alpha = 3$$

$$\gamma = -3$$

$$\delta = 2$$

$$\beta = 2$$

$$\alpha + \beta + \gamma + \delta = 4$$

Q. 22 A dimensionless quantity is constructed in terms of electronic charge e, permittivity of free space ε_0, Planck's constant h, and speed of light c. If the dimensionless quantity is written as $e^{\alpha}\varepsilon_0^{\beta}h^{\gamma}c^{\delta}$ and n is a non-zero integer, then $(\alpha, \beta, \gamma, \delta)$ is given by

JEE Adv. 2024

(A) (2n, -n, -n, -n)

(B) (n, -n, -2n, -n)

(C) (n, -n, -n, -2n)

(D) (2n, -n, -2n, -2n)

Ans : (A)

Solution 22

For the quantity to be dimensionless

$$e^{\alpha}\varepsilon_0^{\beta}h^{\gamma}c^{d} = M^0\,L^0\,T^0\,A^0$$

$$\Rightarrow (AT)^{\alpha}\left(M^{-1}\,L^{-3}\,T^{4}\,A^{2}\right)^{\beta}\left(ML^{2}\,T^{-1}\right)^{\gamma}\left(LT^{-1}\right)^{\delta} = A^0M^0\,L^0\,T^0$$

$$\therefore \alpha + 2\beta = 0, \alpha + 4\beta - \gamma - \delta = 0, -\beta + \gamma = 0 \& -3\beta + 2\gamma + \delta = 0$$

$$\therefore \alpha = -2\beta, \beta = \gamma \;\&\; \gamma = \delta$$

Option (A) satisfies the given condition.

Q. 23 An infinitely long wire, located on the z-axis, carries a current I along the +z-direction and produces the magnetic field $\vec{B}$. The magnitude of the line integral $\int \vec{B} \cdot \overrightarrow{dl}$ along a straight line from the point $(-\sqrt{3}a, a, 0)$ to $(a, a, 0)$ is given by

[μ_0 is the magnetic permeability of free space.]

JEE Adv. 2024

(A) $7\mu_0 I/24$

(B) $7\mu_0 I/12$

(C) $\mu_0 I/8$

(D) $\mu_0 I/6$

Ans : (A)

Solution 23

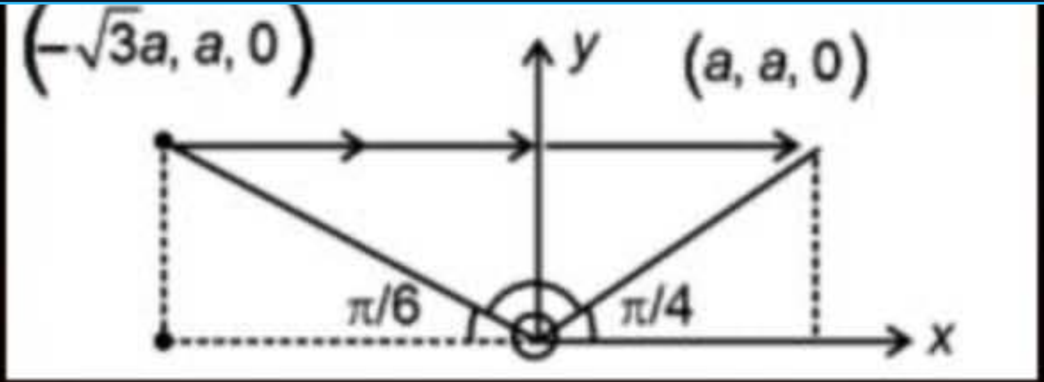
$$\theta = \pi - \frac{\pi}{4} - \frac{\pi}{6}$$

$$\Rightarrow \theta = \frac{12\pi - 3\pi - 2\pi}{12} = \frac{7\pi}{12}$$

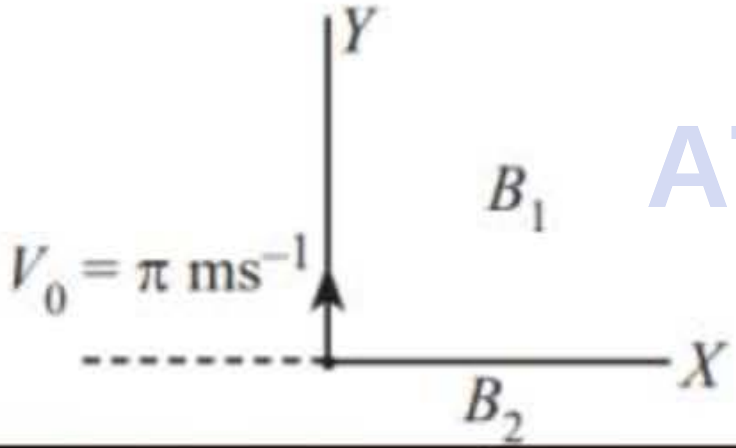
So, $\int \vec{B} \cdot \overrightarrow{dl}$ along the line is

$$\int \vec{B} \cdot \vec{d} = -\frac{\mu_0(I)}{2\pi} \cdot \theta = \frac{\mu_0 I}{2\pi} \cdot \frac{7\pi}{12}$$

$$\Rightarrow \left|\int \vec{B} \cdot \overrightarrow{dl}\right| = \frac{7\mu_0 I}{24}$$



Q. 24 In the xy-plane, the region $y > 0$ has a uniform magnetic field $B_1\hat{k}$ and the region $y < 0$ has another uniform magnetic field $B_2\hat{k}$. A positively charged particle is projected from the origin along the positive Y-axis with speed $v_0 = \pi ms^{-1}$ at $t = 0$, as shown in figure. Neglect gravity in this problem. Let $t = T$ be the time when the particle crosses the X-axis from below for the time when the particle crosses the X-axis from below for the first time. If $B_2 = 4B_1$, the average speed of the particle, in ms^{-1}, along the X-axis in the time interval T is… **(JEE Adv. 2018)**



Ans : (2)

Solution 24

Average speed along the x-axis

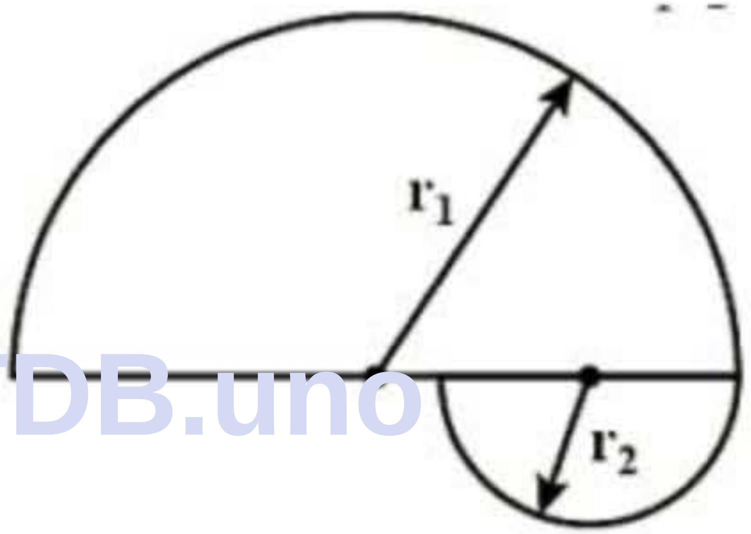
$$(V_x) = \frac{\int |\vec{V}_x| dt}{\int dt} = \frac{d_1 + d_2}{t_1 + t_2} \rightarrow (1)$$

We also have,

$$r_1 = \frac{mv}{qB_1}, r_2 = \frac{mv}{qB_2}$$

since $B_1 = \frac{B_2}{4}$

$$\therefore r_1 = 4r_2 \rightarrow (2)$$



Time in $B_1 \Rightarrow \frac{\pi B}{qB_1} = t_1$

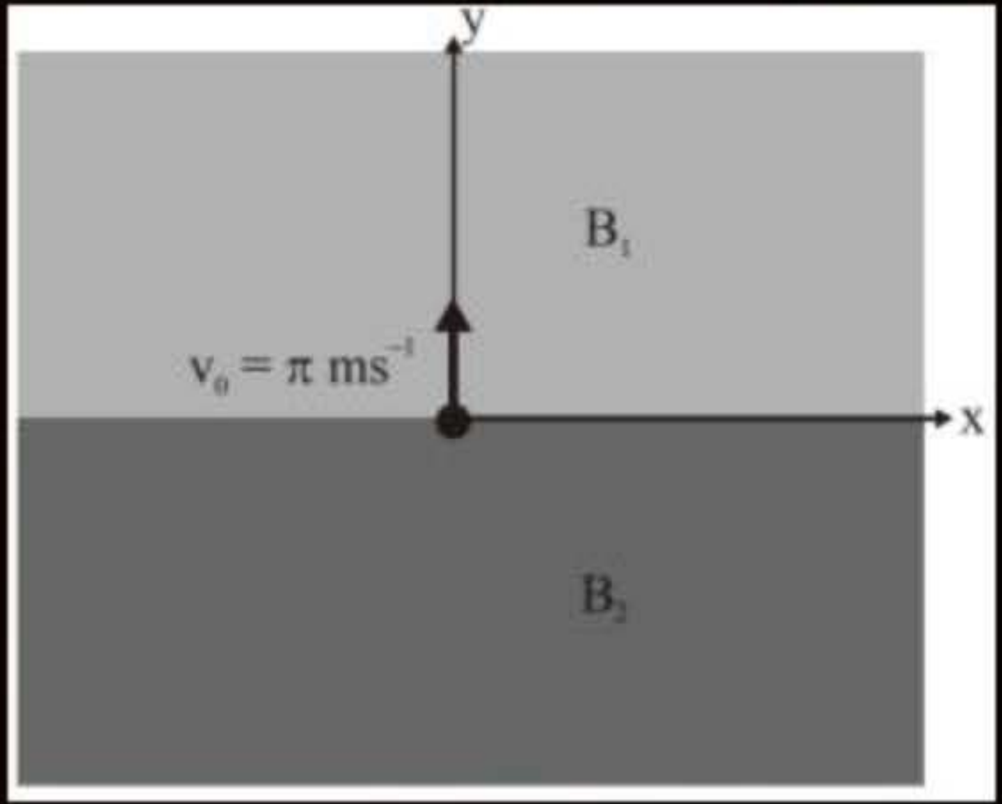
Time in $B_2 \Rightarrow \frac{\pi B}{qB_2} = t_2$

Total distance along x-axis $d_1 + d_2 = 2r_1 + 2r_2 = 2(r_1 + r_2) = 2(5r_2)$

Total time $T = t_1 + t_2 = 5t_2$

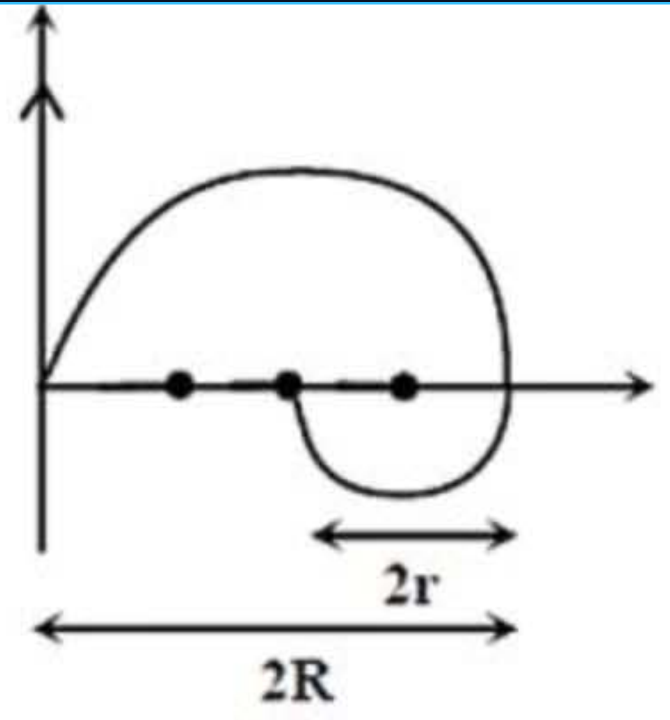
$$\therefore \text{Average speed} = \frac{10r_2}{5t_2} = 2\frac{mv}{qB_2} \times \frac{qB_2}{\pi m} = 2$$

Q. 25 In the x-y-plane, the region y > 0 has a uniform magnetic field $B_1\hat{k}$ and the region y < 0 has a another uniform magnetic field $B_2\hat{k}$. A positively charged particle is projected from the origin along the positive y-axis with speed $v_0 = \pi ms^{-1}$ at t = 0, as shown in the figure. Neglect gravity in this problem. Let t = T be the time when the particle crosses the x-axis from below for the first time. If $B_2 = 4B_1$, the average speed of the particle, in ms^{-1}, along the x-axis in the time interval T is _______. **[JEE-Advanced-2018]**



Ans : 2 [1.99, 2.01]

Solution 25



Avg. speed along x-axis

$$= \frac{\text{total distance travelled along x-axis}}{\text{total time taken}}$$

$$= \frac{2R + 2r}{\frac{\pi R}{V_0} + \frac{\pi r}{V_0}} = \frac{2V_0}{\pi} = 2m/s$$

Q. 26 A symmetric star shaped conducting wire loop is carrying a steady state current I as shown in the figure. The distance between the diametrically opposite vertices of the star is 4a. The magnitude of the magnetic field at the center of the loop is

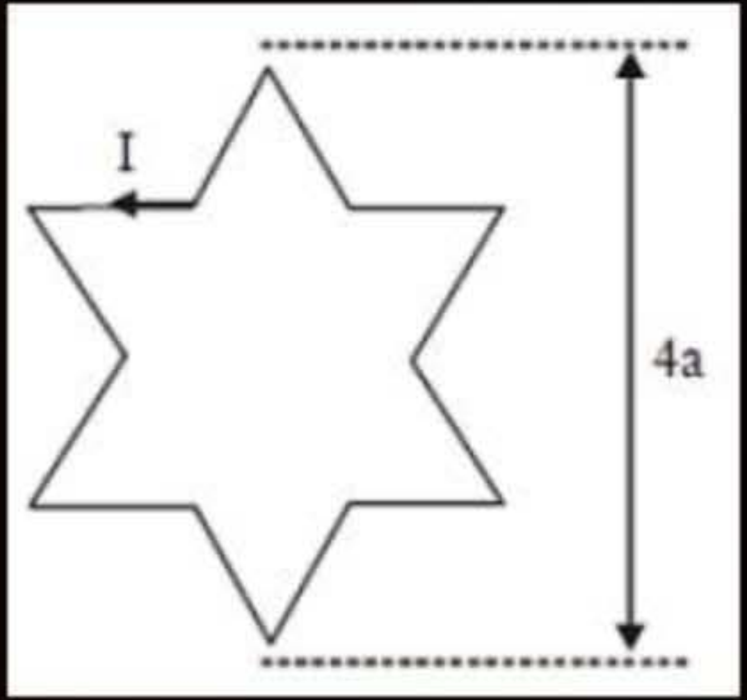
[JEE-Advanced-2017]

(A) $\frac{\mu_0 I}{4\pi a}6[\sqrt{3}-1]$

(B) $\frac{\mu_0 I}{4\pi a}6[\sqrt{3}+1]$

(C) $\frac{\mu_0 I}{4\pi a}3[\sqrt{3}-1]$

(D) $\frac{\mu_0 I}{4\pi a}3[2-\sqrt{3}]$



Ans : (A)

Solution 26

In Δ OAC $\quad \cos 60^\circ = \frac{OC}{OA}$

$$\therefore OC = 2a \times \frac{1}{2} = a$$

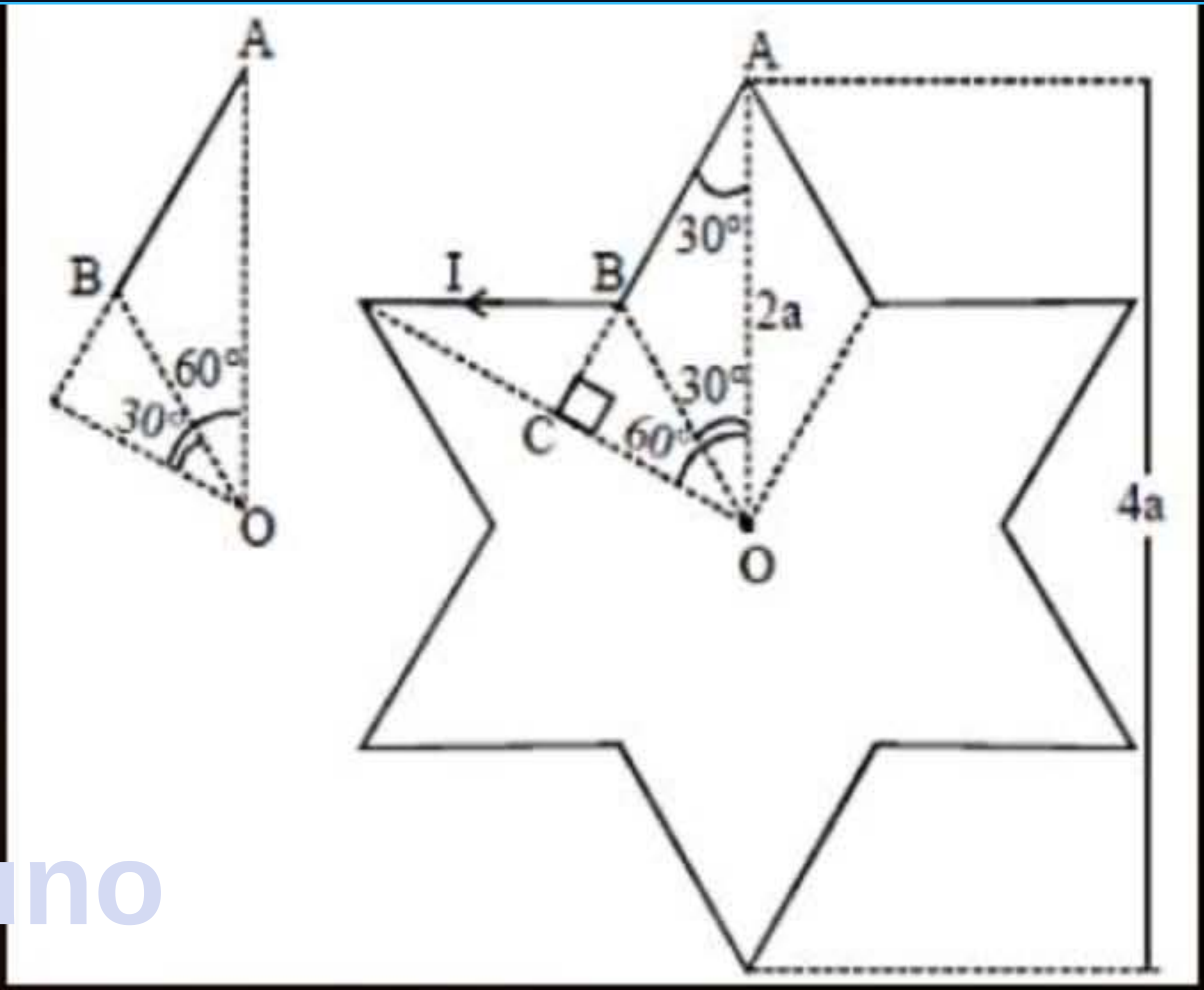
The magnetic field at 'O' due to

$$AB = \frac{\mu_0}{4\pi}\frac{I}{a}[\sin 60^\circ - \sin 30^\circ]$$

$$= \frac{\mu_0}{4\pi}\frac{I}{a}\left[\frac{\sqrt{3}}{2} - \frac{1}{2}\right] = \frac{\mu_0 I}{4\pi a} \times \frac{1}{2}(\sqrt{3} - 1)$$

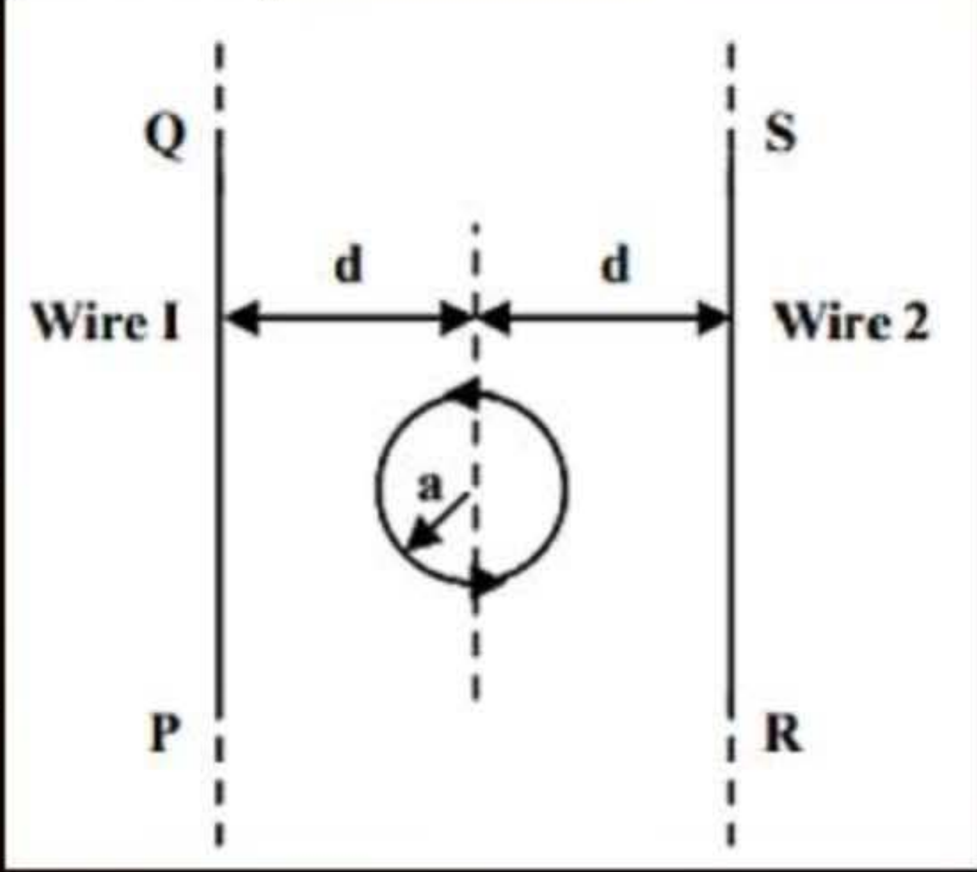
The total magnetic field due to all the straight segments of the star is

$$= \left[\frac{\mu_0}{4\pi}\frac{I}{a} \times \frac{1}{2}(\sqrt{3} - 1)\right] \times 12 = \frac{\mu_0}{4\pi}\frac{I}{a} \times 6(\sqrt{3} - 1)$$



Q. 27 The figure shows a circular loop of radius a with two long parallel wires (numbered 1 and 2) all in the plane of the paper. The distance of each wire from the center of the loop is d. The loop and the wires are carrying the same current I. The current in the loop is in the counterclockwise direction if seen from above. [JEE-Advanced-2014]

When d ≈ a but wires are not touching the loop, it is found that the net magnetic field on the axis of the loop is zero at a height h above the loop. In that case



(A) current in wire 1 and wire 2 is the direction PQ and RS, respectively and $h \approx a$

(B) current in wire 1 and wire 2 is the direction PQ and SR, respectively and $h \approx a$

(C) current in wire 1 and wire 2 is the direction PQ and SR, respectively and $h \approx 1.2a$

(D) current in wire 1 and wire 2 is the direction PQ and RS, respectively and $h \approx 1.2a$

Ans : (C)

Solution 27

The net magnetic field at the given point will be zero if.

$$\left|\vec{B}_{wires}\right| = \left|\vec{B}_{loop}\right|$$

$$\Rightarrow 2\frac{\mu_0 I}{2\pi\sqrt{a^2+h^2}} \times \frac{a}{\sqrt{a^2+h^2}}$$

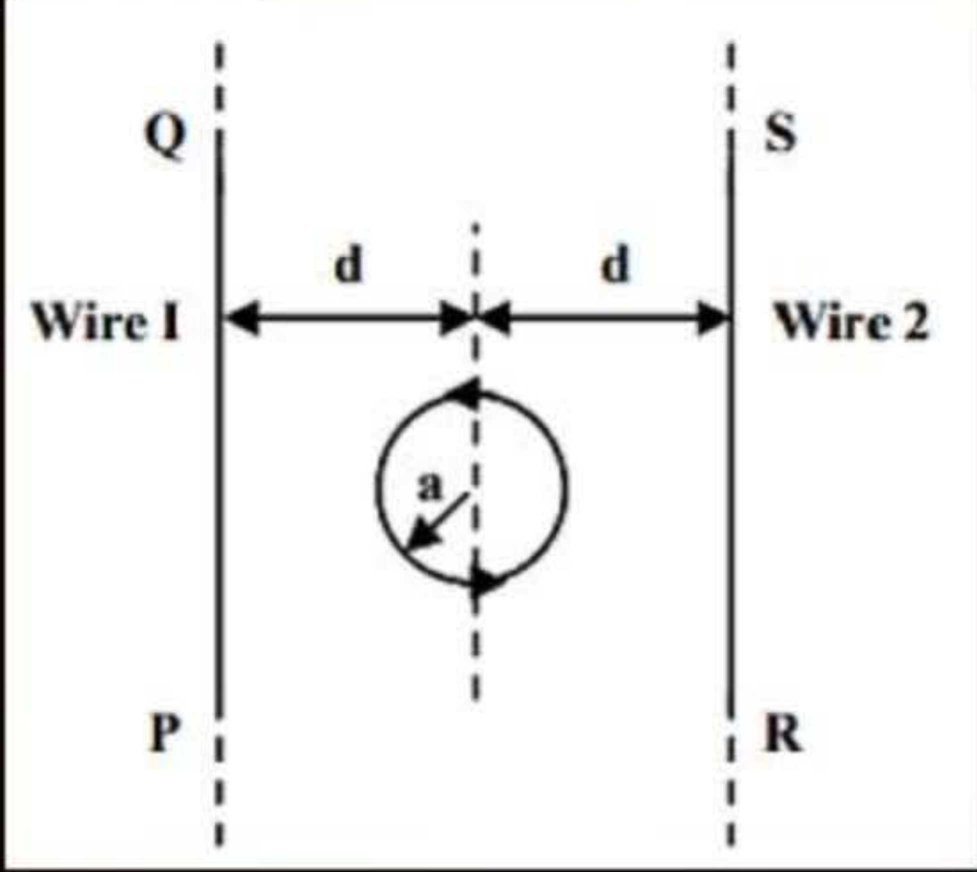
$$= \frac{\mu_0 I a^2}{2(a^2+h^2)^{3/2}}$$

$$\Rightarrow h \approx 1.2\,a$$

The direction of magnetic field at the given point due to the loop is normally out of the plane. Therefore, the net magnetic field due the both wires should be into the plane. For this current in wire I should be along PQ and that in wire RS should be along SR.

Q. 28 The figure shows a circular loop of radius a with two long parallel wires (numbered 1 and 2) all in the plane of the paper. The distance of each wire from the center of the loop is d. The loop and the wires are carrying the same current I. The current in the loop is in the counterclockwise direction if seen from above. [JEE-Advanced-2014]

Consider d >> a, and the loop is rotated about its diameter parallel to the wires by 30° from the position shown in the figure. If the currents in the wires are in the opposite directions, the torque on the loop at its new position will be (assume that the net field due to the wires is constant over the loop)



(A) $\mu_0 I^2 a^2/d$

(B) $\mu_0 I^2 a^2/2d$

(C) $\sqrt{3}\mu_0 I^2 a^2/d$

(D) $\sqrt{3}\mu_0 I^2 a^2/2d$

Ans : (B)

Solution 28

(B) $\mu_0 I^2 a^2/2d$

$$\tau = MB\sin\theta$$

$$= I\pi a^2 \times 2 \times \frac{\mu_0 I}{2\pi d}\sin 30^\circ$$

$$= \frac{\mu_0 I^2 a^2}{2d}$$

Q. 29 A steady current I flows along an infinitely long hollow cylindrical conductor of radius R. This cylinder is placed coaxially inside an infinite solenoid of radius $2R$. The solenoid has n turns per unit length and carries a steady current I. Consider a point P at a distance r from the common axis. The correct statements (is/are)

(JEE Adv. 2013)

(*a*) In the region $0 < r < R$, the magnetic field is non-zero

(*b*) In the region $R < r < 2R$, the magnetic field is along the common axis

(*c*) In the region $R < r < 2R$, the magnetic field is tangential to the circle of radius r, centered on the axis

(*d*) In the region $r > 2R$, the magnetic field is non-zero

Ans : (a, d)

Solution 29

Correct Answer - A::D

Let B_C and B_S be the magnetic field due to current in cylinder C and solenoid S respectively at point P, distance r from the common axis.

(a) For $\theta < r < R$,

$B = B_S = \mu_0 n I \neq 0$ hence correct.

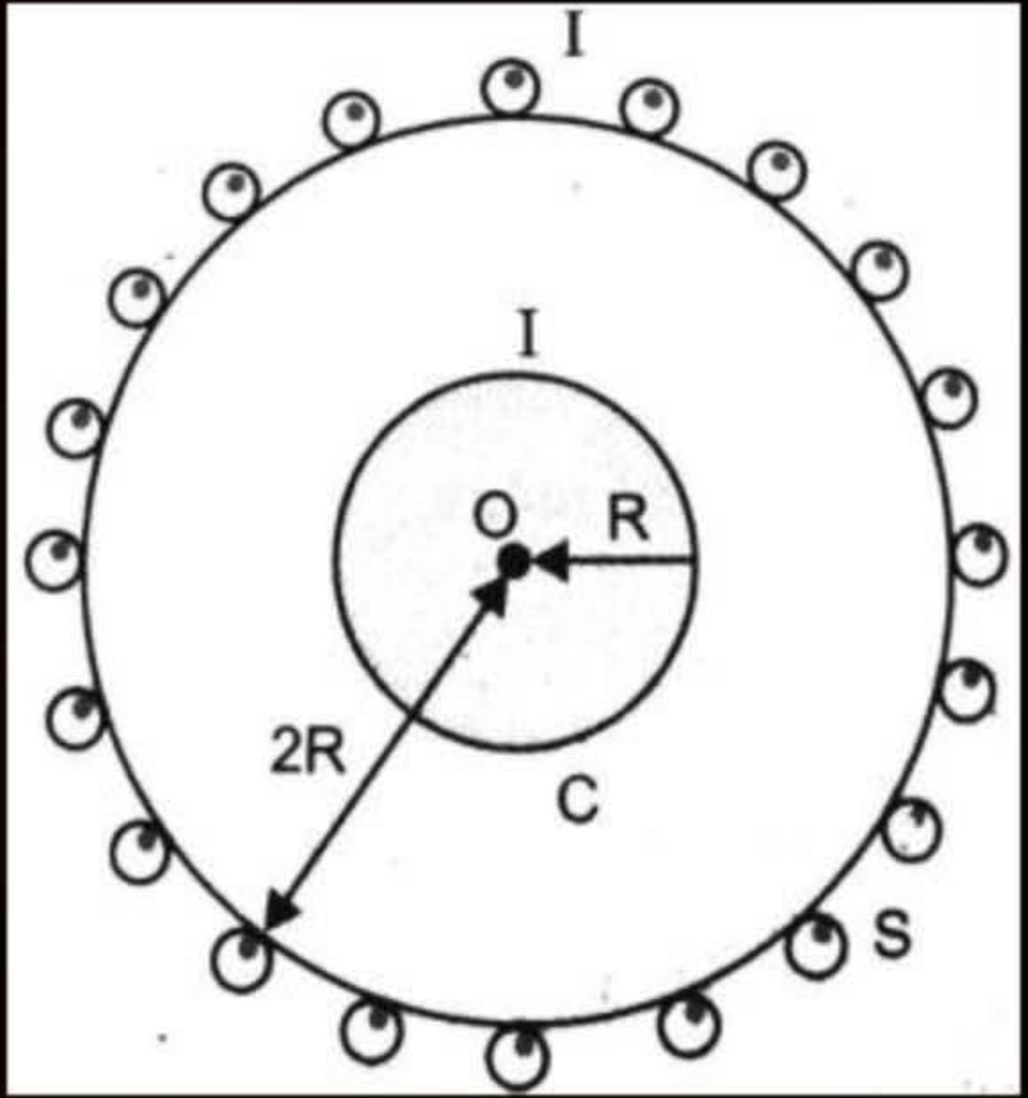
(b) For $R < r < 2R$

$B = \sqrt{B_S^2 + B_C^2}$

It is not acting along the axis of cylinder, hence wrong.

(c) For $R < r < 2R$, B is not in the plane of circle, hence wrong.

(d) For $r > 2R$, $B \neq 0$, hence correct.



Q. 30 Two infinitely long straight wires lie in the xy-plane along the lines $x = \pm R$. The wire located at $x = \pm R$ carries a constant current I_1 and the wire located at $x = -R$ carries a constant current I_2. A circular loop of radius R is suspended with its center at $\left(0, 0, \sqrt{3}R\right)$ and in a plane parallel to the xy-plane. This loop carries a constant current I in the clockwise direction as seen from above the loop. The current in the wire is taken to be positive, if it is in the $+\hat{j}$ -direction. Which of the following statements regarding the magnetic field B is/are true? **(JEE Adv. 2018)**

(a) If $I_1 = I_2$, then B cannot be equal to zero at the origin (0, 0, 0)

(b) If $I_1 > 0$ and $I_2 < 0$, then B can be equal to zero at the origin (0, 0, 0)

(c) If $I_1 < 0$ and $I_2 > 0$, then B can be equal to zero at the origin (0, 0, 0)

(d) If $I_1 = I_2$, then the z-component of the magnetic field at the center of the loop is $\left(-\frac{\mu_0 I}{2R}\right)$

Ans : (a, b, d)

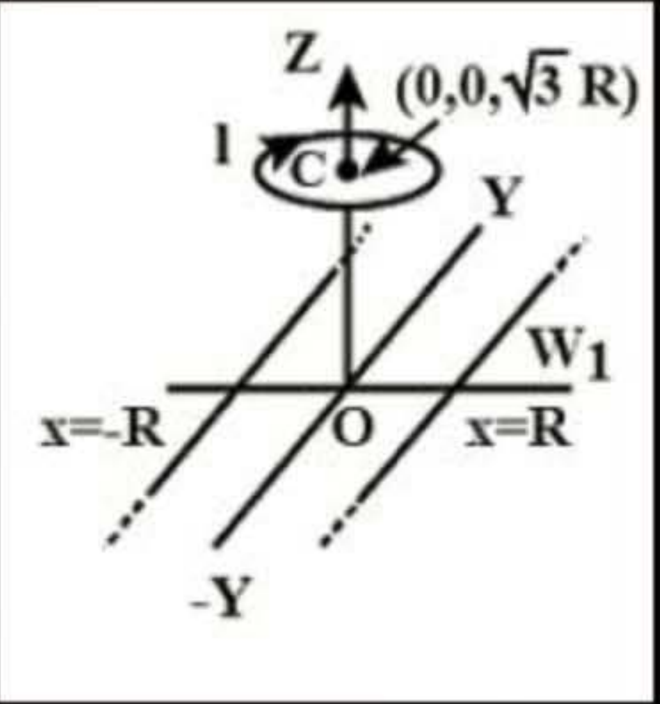
Solution 30

The correct options are

A If $I_1 = I_2$, then $\vec{B}$ cannot be equal to zero at the origin (0, 0, 0)

B If $I_1 > 0$ and $I_2 < 0$, then $\vec{B}$ can be equal to zero at the origin (0, 0, 0)

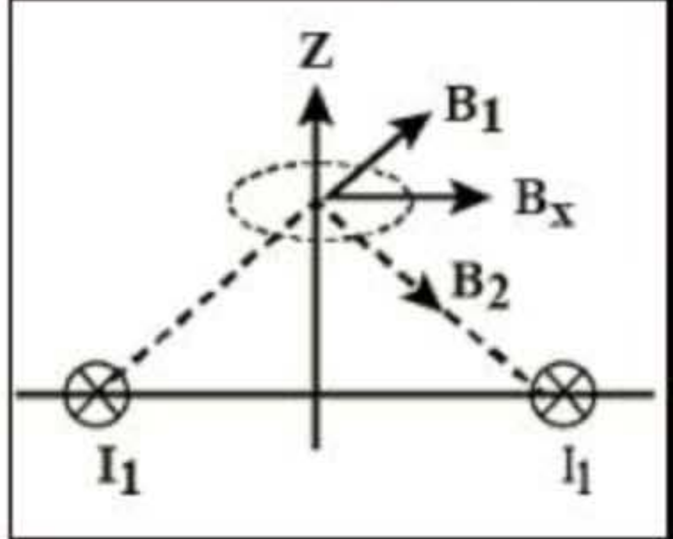
D If $I_1 = I_2$, then the z-component of the magnetic field at the centre of the loop is $\left(-\frac{\mu_0 I}{2R}\right)$



(A) At origin, $\vec{B} = 0$ due to two wires if $I_1 = I_2$ (they cancel each other) hence $(\vec{B}_{net})$ at origin is equal to $\vec{B}$ due to ring, which is non-zero.

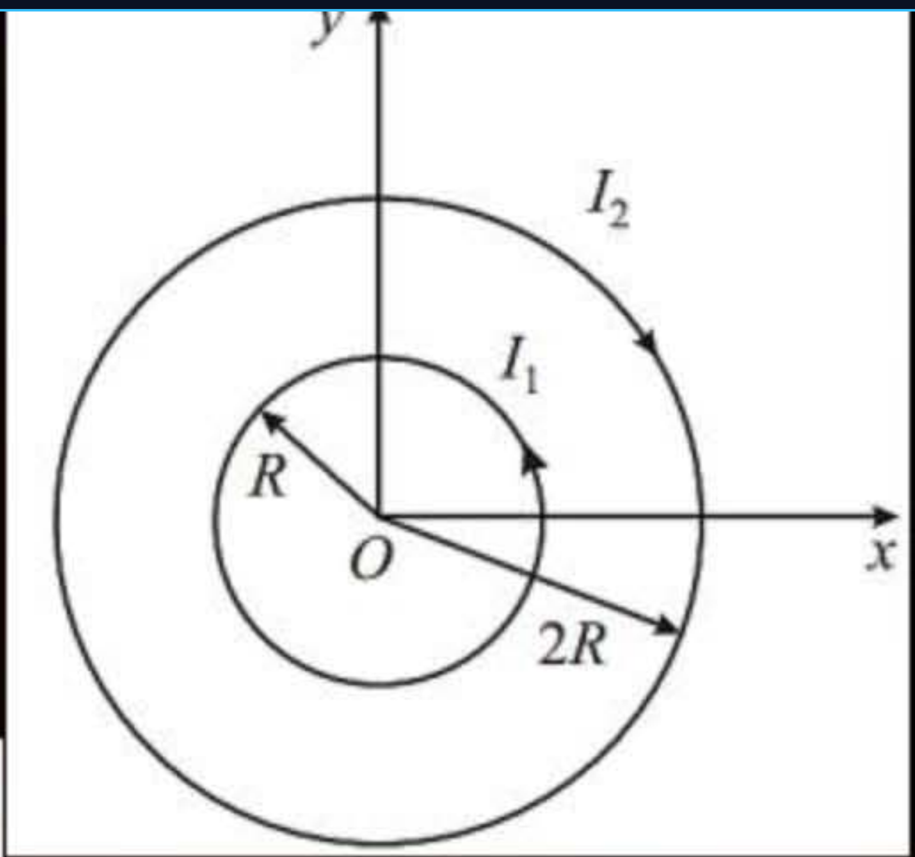
(B) If $I_1 > 0$ and $I_2 < 0$, $\vec{B}$ at origin due to wires will be along $+\hat{k}$ direction and $\vec{B}$ due to ring is along $-\hat{k}$ direction and hence $\vec{B}$ can be zero at origin.

(C) If $I_1 < 0$ and $I_2 > 0$, $\vec{B}$ at origin due to wires is along $-\hat{k}$ and also along $-\hat{k}$ due to ring, hence $\vec{B}$ cannot be zero.



(D) (ref. image 2) At centre of ring, $\vec{B}$ due to wires is along x-axis, hence z-component is only because of ring which $\vec{B} = \frac{\mu_0 I}{2R}(-\hat{K})$

Q. 31 Two concentric circular loops, one of radius R and the other of radius $2R$, lie in the xy-plane with the origin as their common center, as shown in the figure. The smaller loop carries current I_1 in the anti-clockwise direction and the larger loop carries current I_2 in the clockwise direction, with $I_2 > 2I_1$. $\vec{B}(x, y)$ denotes the magnetic field at a point (x, y) in the xy-plane. Which of the following statement(s) is/are correct?



(JEE Adv. 2021)

(a) $\vec{B}(x,y)$ is perpendicular to the xy-plane at any point in the plane.

(b) $|\vec{B}(x,y)|$ depends on x and y only through the radial distance $r = \sqrt{x^2 + y^2}$.

(c) $|\vec{B}(x,y)|$ is non-zero at all points for $r < R$.

(d) $\vec{B}(x,y)$ points normally outward from the plane for all the points between the two loops.

Ans : (a, b)

Solution 31

Consider a circular loop of radius r in $x-y$ plane and having centre at origin

$$\oint \vec{B} \cdot \overrightarrow{d\ell} = 0$$

$$B \oint d\ell \cos\theta = 0$$

$\because B \neq 0$ for given r

$$\Rightarrow \cos\theta = 0$$

$$\theta = 90^\circ$$

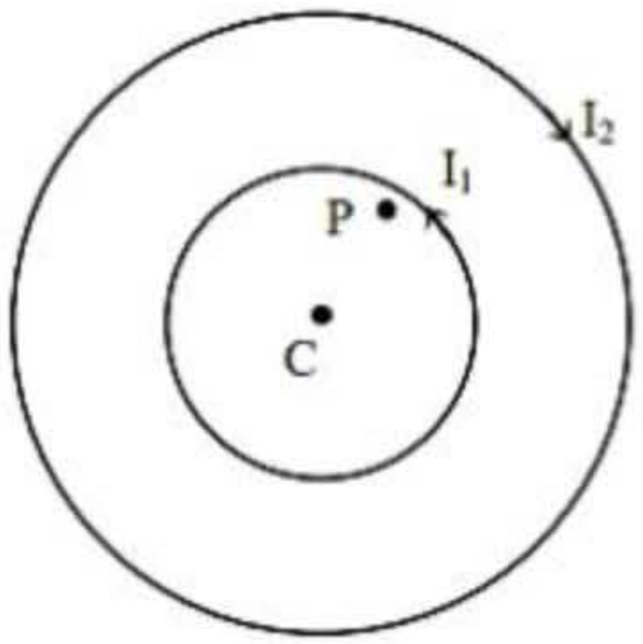
Here $d\ell$ is in xy plane $\Rightarrow$ B is normal to plane (B can't be in xy plane as its magnetic lines would have been in radial direction)

Also, for given r, B must be same in magnitude for all points on loop of radius r.

At centre $B = \left(\frac{\mu_0 i_1}{2R} - \frac{\mu_0 i_2}{4R}\right)$

(inwards)

For point P, Let field of inner loop increases x_1 times and that of outer loop increases x_2 times



$\Rightarrow$ magnetic field at P

$B_P = \left(x_1 \frac{\mu_0 i_1}{2R} - x_2 \frac{\mu_0 i_2}{4R}\right)$

For $B_P = 0, i_2 = \left(\frac{x_1}{x_2}\right) \cdot (2i_1)$

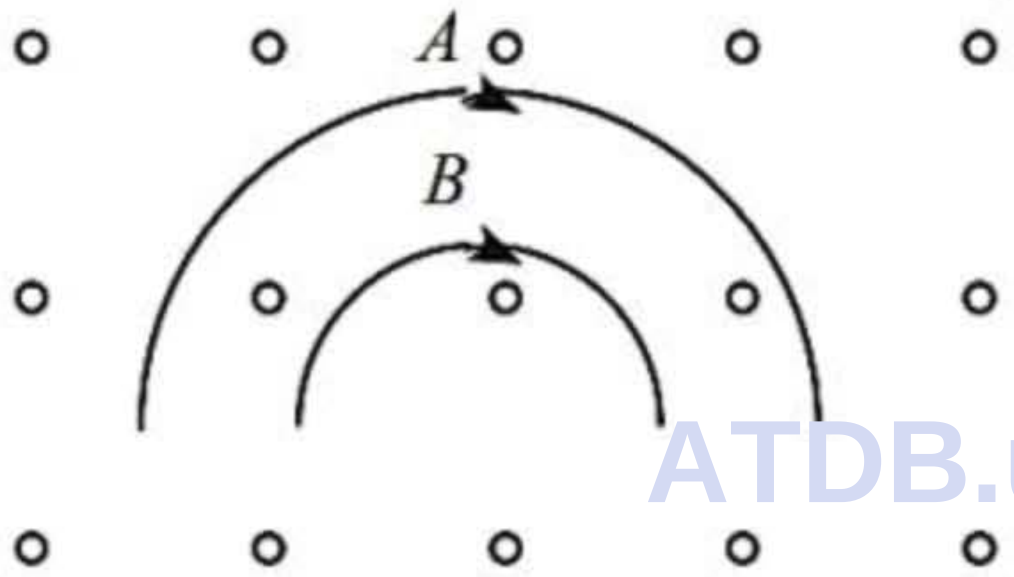
$\because B$ changes more rapidly as point P come closer to circumference.

$\Rightarrow x_1 > x_2$

Or $i_2 > 2i_1$ (which is given condition)

So, there are points inside inner loop where magnetic field will be zero.

Q. 32 Two particles A and B of masses mA and mB respectively and having the same charge are moving in a plane. A uniform magnetic field exists perpendicular to this plane. The speeds of the particles are vA and vB, respectively and the trajectories are as shown in the figure. Then **(IIT-JEE 2001)**



(a) $m_A v_A < m_B v_B$

(b) $m_A v_A > m_B v_B$

(c) $m_A < m_B$ and $v_A < v_B$

(d) $m_A = m_B$ and $v_A = v_B$

Ans : (b)

Solution 32

Radius of the circle = mv/Bq

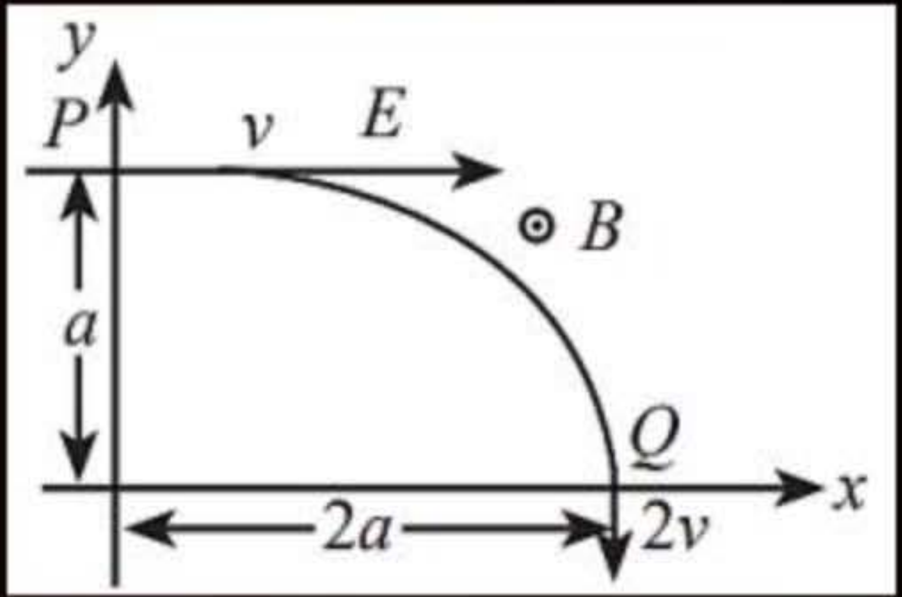
or radius $\propto$ mv if B and q are same.

$(\text{Radius})_A > (\text{Radius})_B$; therefore $m_A v_A > m_B v_B$

Q. 33 A particle of charge $+q$ and mass m moving under the influence of a uniform electric field $E\hat{i}$ and uniform magnetic field $B\hat{k}$ follows a trajectory from P to Q as shown in figure. The velocities at P and Q are $v\hat{i}$ and $-2v\hat{j}$. Which of the following statement(s) is/are correct?

JM-2022

(IIT-JEE 1991)



(a) $E = \frac{3}{4}\left[\frac{mv^2}{qa}\right]$

(b) Rate of work done by the electric field at P is $\frac{3}{4}\left[\frac{mv^3}{a}\right]$

(c) Rate of work done by the electric field at P is zero

(d) Rate of work done by both the fields at Q is zero

Ans : (a, b, d)

Solution 33

Magnetic force does not do work. From work-energy theorem:

$$\vec{W}_{Fe} = \Delta KE \text{ or } (qE)(2a) = \frac{1}{2}m[4v^2 - v^2]$$

$$\text{or } E = \frac{3}{4}\left(\frac{mv^2}{qa}\right)$$

$\therefore$ Correct option is (a)

At P, rate of work done by electric field

$$= \vec{F}_e \cdot \vec{v} = (qE)(v)\cos 0°$$

$$= q\left(\frac{3}{4}\frac{mv^2}{qa}\right)v = \frac{3}{4}\left(\frac{mv^3}{a}\right)$$

Therefore, option (b) is also correct. Rate of work done at Q:

of electric field $= \vec{F}_e \cdot \vec{v} = (qE)(2v)\cos 90° = 0$

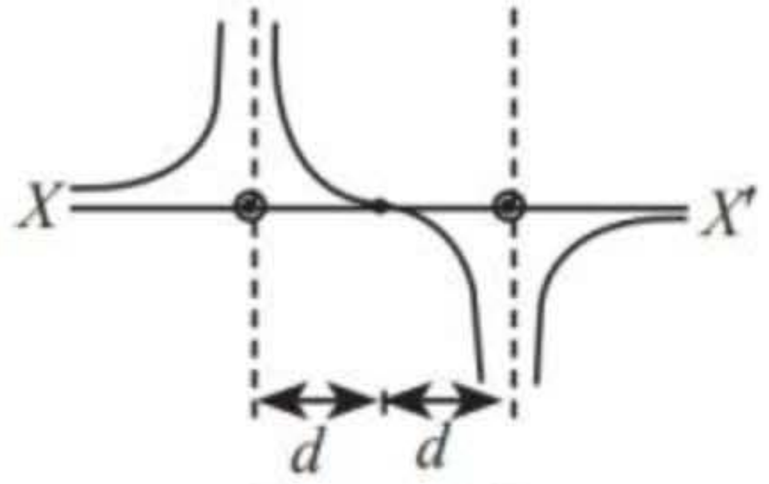
and of magnetic field is always zero. Therefore, option (d) is also correct.

Note that $\vec{F}_e = qE\hat{i}$

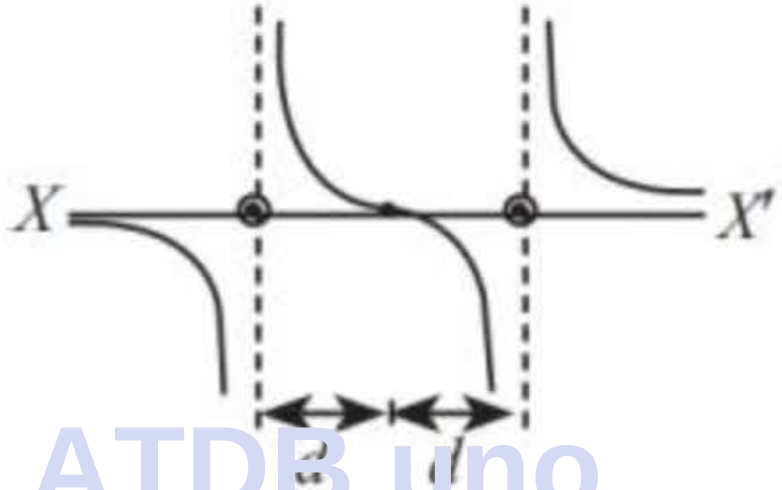
Q. 34 Two long parallel wires are at a distance $2d$ apart. They carry steady equal currents flowing out of the plane of the paper as shown. The variation of the magnetic field B along the line XX' is given by

(IIT-JEE 2000)

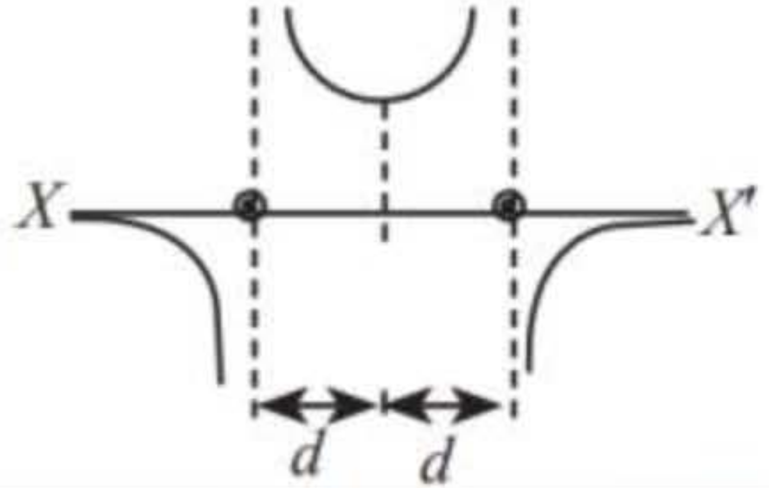
(a)



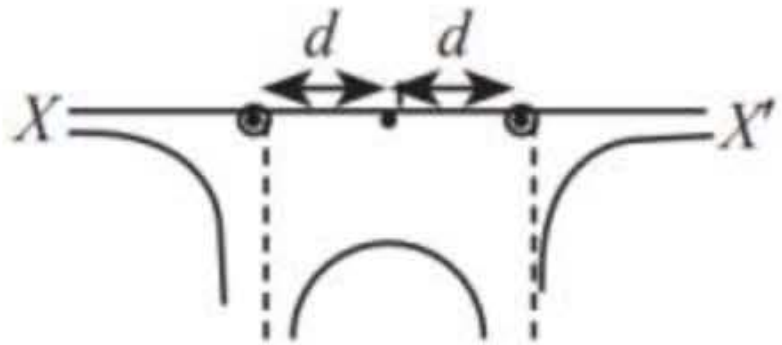
(b)



(c)



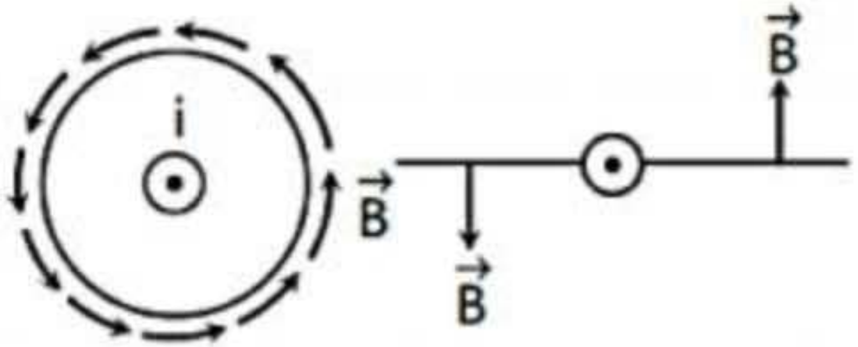
(d)



Ans : (b)

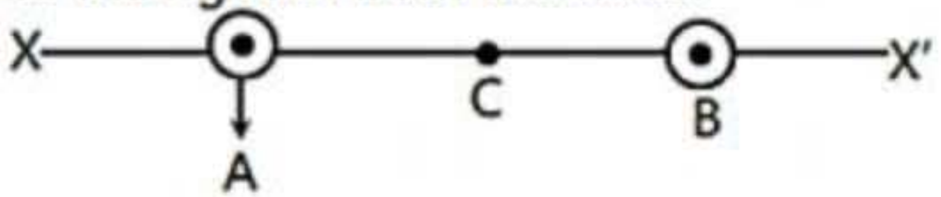
Solution 34

If the current flows out of the paper, the magnetic field at points to the right of the wire will be upwards and to the left will be downwards as shown in figure.



Now, let us come to the problem.
Magnetic field at C = 0

Magnetic field in region BX′ will be upwards (+ve) because all points lying in this region are to the right of both the wires.

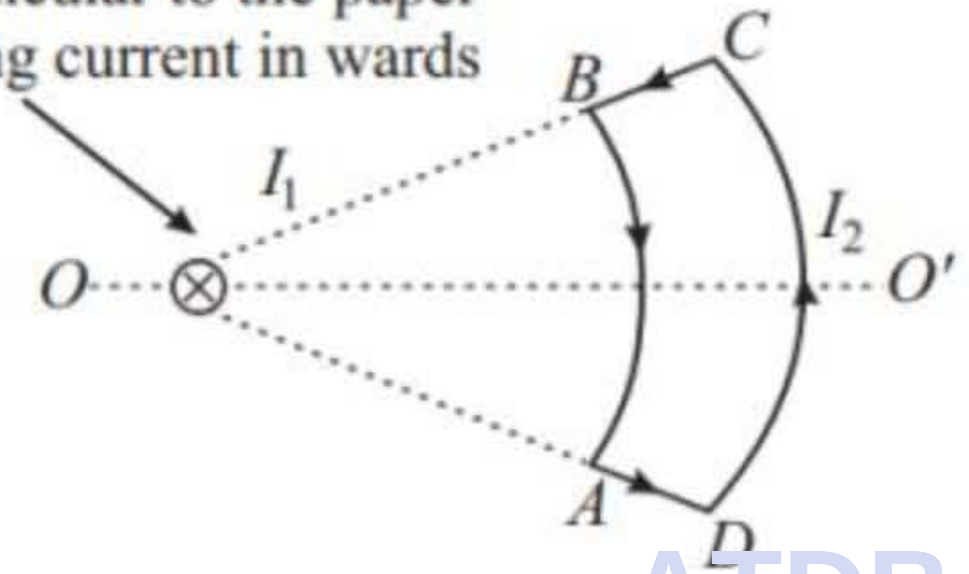


Magnetic field in region AC will be upwards (+ve), because points are closer to A, compared to B. Similarly magnetic field in region BC will be downwards (–ve).

Graph (b) satisfies all these conditions. Therefore, correct answer is (b).

Q. 35 Which of the following statement is/are correct in the given figure?

(IIT-JEE 2006)



(a) Net force on the loop is zero

(b) Net torque on the loop is zero

(c) Loop will rotate clockwise about axis OO' when seen from O

(d) Loop will rotate anticlockwise about OO' when seen from O

Ans : (a, c)

Solution 35

The correct option is **C** Loop will rotate clockwise about axis OO′ when seen from O

From the figure, we can conclude that, $\vec{F}_{BA}$&$\vec{F}_{CD}$ are zero .

Because, magnetic fields due to long straight wire are parallel to wires BA & CD respectively.

Also, that $\vec{F}_{BC}$ is out of plane and $\vec{F}_{AD}$ is inwards to the plane .

Thus, $\vec{F}_{BC} + \vec{F}_{AD} = 0 \Rightarrow \vec{F}_{net} = 0$

Option (a) is correct.

To find the net torque due to the forces $\vec{F}_{BC}$ and $\vec{F}_{AD}$

As the forces are equal and opposite in nature, they form a couple.

So, the net torque acting on the loop would be non-zero.

Sense of rotation of loop is clockwise as seen from O due to the fact that , $\vec{F}_{BC}$ is out of plane and $\vec{F}_{AD}$ is inwards to the plane .

Note :- A pseudo vector is a type of vector whose sense of rotation differs with the position of observer.

Q. 36 A proton moving with a constant velocity passes through a region of space without any change in its velocity. If E and B represent the electric and magnetic fields respectively. Then, this region of space may have **(IIT-JEE 1985)**

(a) $E = 0, B = 0$ (b) $E = 0, B \neq 0$

(c) $E \neq 0, B = 0$ (d) $E \neq 0, B \neq 0$

Ans : (a, b, d)

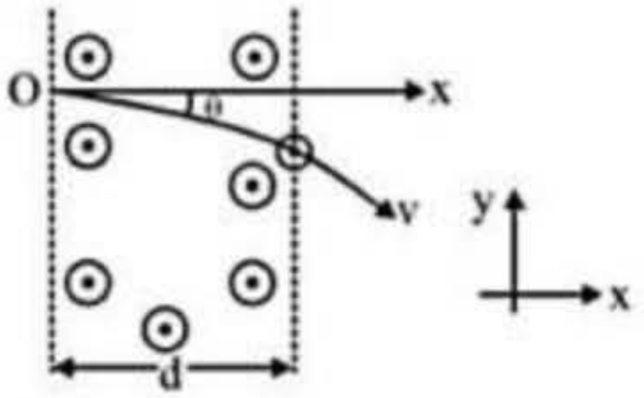
Solution 36

If both E and B are zero, then vector F_e and vector F_m both are zero. Hence, velocity may remain constant. Therefore, option (a) is correct.

If $E = 0$, $B \neq 0$ but velocity is parallel or antiparallel to magnetic field, then also vector F_e and vector F_m both are zero. Hence, option (b) is also correct.

If $E \neq 0$, $B \neq 0$ but vector $(F_e + F_m)$ then also velocity may remain constant or option (d) is also correct.

Q. 37 A particle of charge q is projected with a momentum $\vec{P} = P\hat{i}$ in the given region of magnetic field $\vec{B} = B\hat{k}$. It emerges from the magnetic field after deviating through an angle $\theta = 30°$.



(A) The value of $\vec{p}$ is 2qBd

(B) The value of $\vec{p}$ is qBd

(C) Maximum change in momentum takes place for $d \geq \frac{P}{qB}$

(D) Maximum change in momentum takes place for $d \geq \frac{P}{2qB}$

Ans : (A, C)

Solution 37 (A), (C)

Q. 38 A charge particle is moving inside both electric field and magnetic field without any acceleration. Electric field is $10^3\hat{i}\frac{N}{C}$ and magnetic field is $2 \times 10^{-2}\hat{j}T$. The velocity of charge particle is-

a. $5 \times 10^{+4}\hat{k}$

b. $2 \times 10^3\hat{k}$

c. $4 \times 10^4(-\hat{k})$

d. May be both $5 \times 10^{-4}\hat{k}$ and $5 \times 10^{-4}(-\hat{k})$ depend on nature of charge

Ans : (A)

Solution 38 (A)

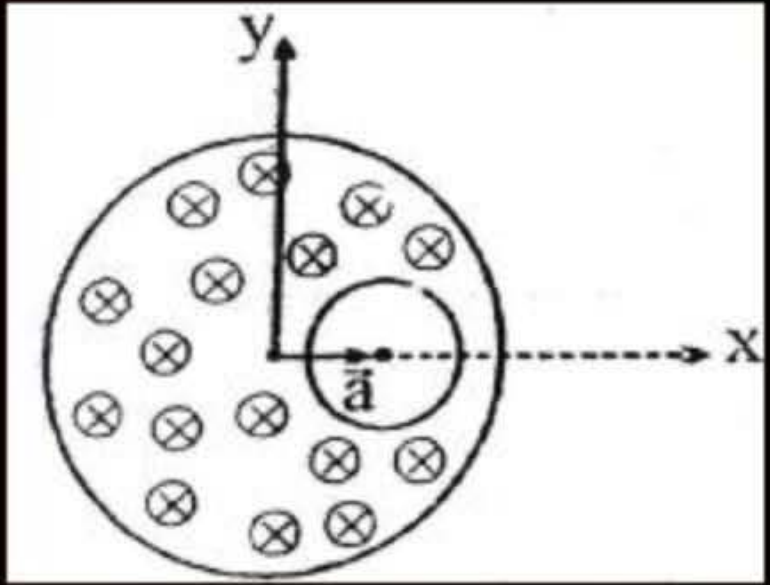
Q. 39 Figure shows crosssection view of a infinite cylindrical wire with a cavity, current density is uniform $\vec{j} = -j_0\hat{k}$ as shown in figure

A. magnetic field inside cavity is uniform

B. magnetic field inside cavity is along $\vec{a}$

C. magnetic field inside cavity is perpendicular to $\vec{a}$

D. If an electron is projected with velocity $v_0\hat{j}$ inside the cavity it will move undeviated.



Ans : (A, C, D)

Solution 39

Correct Answer - A::C::D

Magnetic field is given by $\vec{B} = \frac{\mu_0 \left(\vec{j} \times \vec{a}\right)}{2}$

Q. 40 A tightly-wound, long solenoid carries a current of 2.00A. An electron is found to execute a uniform circular motion inside the solenoid with a frequency of 1.00×10^8 rev/s. Find the number of turns per metre in the solenoid.

Ans : (1421)

Solution 40

$i = 2a$, $f = 10^8$ rev/sec, $n = ?$, $m_e = 9.1 \times 10^{-31}$ kg,

$q_e = 1.6 \times 10^{-19}$ c, $B = \mu_0 n i \Rightarrow n = \dfrac{B}{\mu_0 i}$

$$f = \frac{qB}{2\pi m_e} \Rightarrow B = \frac{f 2\pi m_e}{q_e} \Rightarrow n = \frac{B}{\mu_0 i} = \frac{f 2\pi m_e}{q_e \mu_0 i}$$

$$= \frac{10^8 \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 2 \times 10^{-7} \times 2} = 1421 \text{ turns/m}$$

Q. 44 A charged particle with some initial velocity is projected in a region where uniform electric and/or magnetic fields are present. In Column-I information about the existence of electric and/or magnetic field and direction of initial velocity of charged particle are given, while in column-II the possible paths of charged particle is mentioned. Match the entries of Column I with the entries of Column-II.

Column–I	Column–II
(A) $\vec{E}=0, \vec{B}\neq 0$ and initial velocity is at an unknown angle with $\vec{B}$	(P) Straight line
(B) $\vec{E}\neq 0, \vec{B}=0$ and initial velocity is at an unknown angle with $\vec{E}$	(Q) Parabola
(C) $\vec{E}\neq 0, \vec{B}\neq 0, \vec{E}\parallel\vec{B}$ and initial velocity is perpendicular to $\vec{E}$	(R) Circular
(D) $\vec{E}\neq\vec{B}, B\neq 0, \vec{E}$ perpendicular $\vec{B}$ and initial velocity is perpendicular to both $\vec{E}$ and $\vec{B}$	(S) Helical path with nonuniform pitch
	(T) Helical path with uniform pitch

Ans. (A) → (P,R, T) ; (B) → (P,Q) ; (C) → (S) ; (D) → (P)

Solution 44 Ans. (A) → (P,R, T) ; (B) → (P,Q) ; (C) → (S) ; (D) → (P)

Q. 46 A particle of specific charge (charge/mass) α starts moving from the origin under the action of an electric field $\vec{E} = E_0\hat{i}$ and magnetic field $\vec{B} = B_0\hat{k}$ Its velocity at $(x_0, y_0.0)$ is $(4\hat{i} + 3\hat{j})$ The value of x_0 is

A. $\frac{13\alpha E_0}{2B_0}$

B. $\frac{16\alpha B_0}{E_0}$

C. $\frac{25}{2\alpha E_0}$

D. $\frac{5\alpha}{2B_0}$

Ans : (C)

Solution 46

Work done electric field $= \Delta K$

$$qE_0X_0 = \frac{1}{2}mv^2$$

$$x_0 = \frac{1}{2}\frac{mv^2}{qE_0}$$

$$\vec{V} = 4\hat{i} + 3\hat{j} \Rightarrow V = 5$$

From (1) and (2) $x_0 = \dfrac{25}{2\alpha E_0}$.

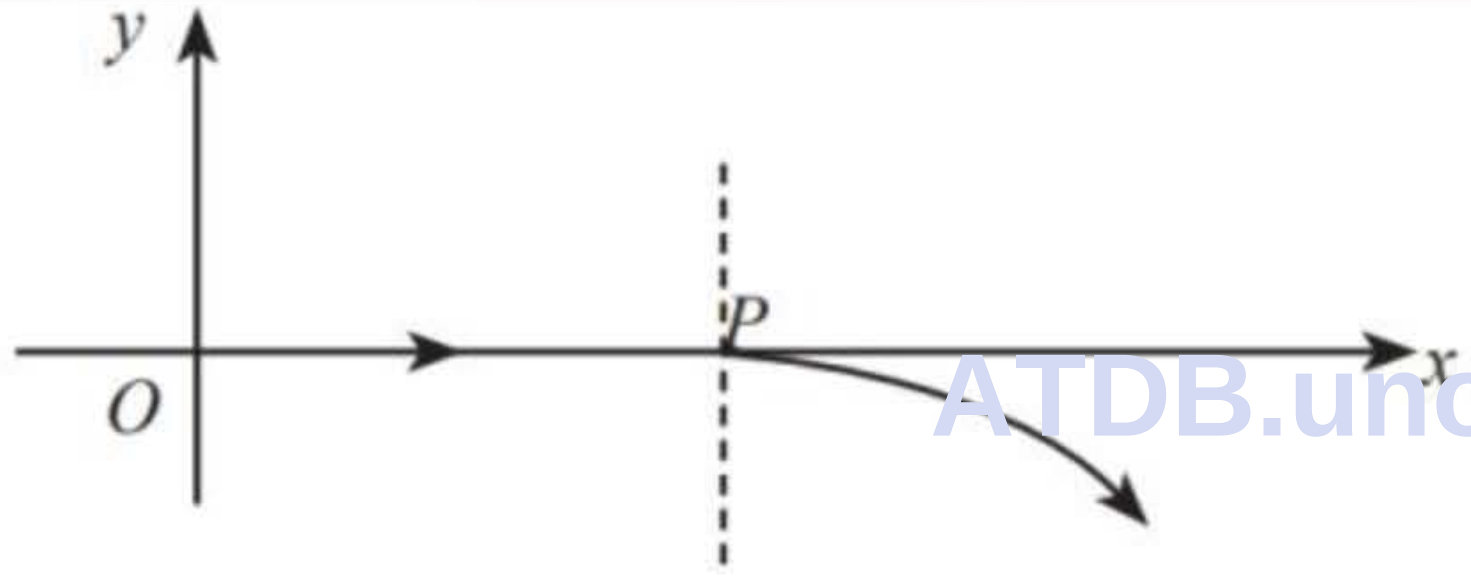
Q. 48

Column-I (Magnetic moment of)		Column-II
(A)	a uniformly charged ring rotating uniformly about its axis	(p) $\frac{q\omega r^2}{5}$
(B)	a charged particle rotating uniformly about a point	(q) $\frac{q\omega r^2}{4}$
(C)	a uniformly charged disk rotating uniformly about its axis	(r) $\frac{q\omega r^2}{3}$
(D)	a uniformly charged spherical shell rotating uniformly about one of its diameter	(s) $\frac{q\omega r^2}{2}$
(E)	a uniformly charged sphere rotating	(t) $q\omega r^2$

Ans. (A)-s; (B)-s; (C)-q; (D)-r; (E)-p

Solution 48 Ans. (A)-s; (B)-s; (C)-q; (D)-r; (E)-p

Q. 49 For a positively charged particle moving in a $x-y$ plane initially along the x-axis, there is a sudden change in its path due to the presence of electric and/or magnetic fields beyond P. The curved path is shown in the $x-y$ plane and is found to be non-circular) Which one of the following combinations is possible? **(IIT-JEE 2003)**



(a) $E = 0; B = b\hat{j} + c\hat{k}$ (b) $E = a\hat{i}; B = c\hat{k} + a\hat{i}$

(c) $E = 0; B = c\hat{j} + b\hat{k}$ (d) $E = a\hat{i}; B = c\hat{k} + b\hat{j}$

Ans : (b)

Solution 49

Electric field can deviate the path of the particle in the shown direction only when it is along negative y-direction. In the given options vector E is either zero or along x-direction. Hence, it is the magnetic field which is really responsible for its curved path. Options (a) and (c) cannot be accepted as the path will be circular in that case. Option (d) is wrong because in that case component of net force on the particle also

comes in $\hat{k}$ direction which is not acceptable as the particle is moving in x-y plane. Only in option (b) the particle can move in x-y plane.

In option (d) $\vec{F}_{net} = q\vec{E} + q(\vec{v} \times \vec{B})$

Initial velocity is along x-direction. So, let

$$\vec{v} = v\hat{i}$$

$$\vec{F}_{net} = qa\hat{i} + q[(v\hat{i}) \times (c\hat{k} + b\hat{j})]$$

$$= qa\hat{i} - qvc\hat{j} + qvb\hat{k}$$

In option (b) $\vec{F}_{net} = q(a\hat{i}) + q[(v\hat{i}) \times (c\hat{k} + a\hat{i})] = qa\hat{i} - qvc\hat{j}$

Q. 50 An electron makes 3×10^5 revolutions per second in a circle of radius 0.5 angstrom. Find the magnetic field B at the centre of the circle.

(A) 6×10^{-10} T (B) 12×10^{-10} T (C) 18×10^{-10} T (D) 24×10^{-10} T

Ans : (A)

Solution 50

3×10^5 revolutions in 1sec.

1 revolutions in $\frac{1}{3 \times 10^5}$ sec

$$i = \frac{q}{t} = \frac{1.6 \times 10^{-19}}{\left(\frac{1}{3 \times 10^5}\right)} \text{ A}$$

$$B = \frac{\mu_0 i}{2r} = \frac{4\pi \times 10^{-7} . 16 \times 10^{-19} 3 \times 10^5}{2 \times 0.5 \times 10^{-10}} \quad \frac{2\pi \times 1.6 \times 3}{0.5} \times 10^{-11}$$

$= 6.028 \times 10^{-10} \approx 6 \times 10^{-10}$T

Q. 51 Two moving coil meters M_1 and M_2 have the following particulars:

$R_1 = 10\Omega, N_1 = 30, A_1 = 3 \cdot 6 \times 10^{-3} m^2, B_1 = 0 \cdot 25T,$

$R_2 = 14\Omega, N_2 = 42, A_2 = 1 \cdot 8 \times 10^{-3} m^2, B_2 = 0 \cdot 50T$

(The spring constants are identical for the two metres).

Determine the ratio of (a) current sensitivity and (b) voltage sensitivity of M_2 and M_1. *(NCERT)*

Ans : (a) 1.4; (b) 1

Solution 51

For meter M_1, $R_1 = 10\Omega$, $N_1 = 30$, $A_1 = 3 \cdot 6 \times 10^{-3} m^2$,

$B_1 = 0 \cdot 25T$, $k_1 = k$

For meter M_2, $R_2 = 14\Omega$, $N_2 = 42$, $A_2 = 1 \cdot 8 \times 10^{-3} m^2$,

$B_2 = 0 \cdot 50T$ $k_2 = k$.

As, current sensitivity $I_s = NBA/k$.

(a) So,

$$\frac{I_{s_2}}{I_{s_1}} = \frac{N_2 B_2 A_2 / k_2}{N_1 B_1 A_1 / k_1} = \frac{42 \times 0 \cdot 50 \times 1 \cdot 8 \times 10^{-3} / k}{30 \times 0 \cdot 25 \times 3 \cdot 6 \times 10^{-3} / k} = 1 \cdot 4$$

(b) Voltage sensitivity $V_s = \dfrac{NBA}{kR}$

So,

$$\frac{V_{s_2}}{V_{s_1}} = \frac{N_2 B_2 A_2 / (k_2 R_2)}{N_1 B_1 A_1 / (k_1 R_1)} = \frac{N_2 B_2 A_2 R_1 k_1}{N_1 B_1 A_1 R_2 k_2}$$

$$= \frac{42 \times 0.50 \times \left(1 \cdot 8 \times 10^{-3}\right) \times 10 \times k}{30 \times 0 \cdot 25 \times \left(3 \cdot 6 \times 10^{-3}\right) \times 14 \times k} = 1$$

Q. 52 A square current carrying loop made of thin wire and having a mass m=10g can rotate without friction with respect to the vertical axis OO_1, passing through the center of the loop at right angles to two opposite sides of the loop. The loop is placed in a uniform magnetic field with an induction $B=10^{-1}T$ directed at right angles to the plane of the drawing. A current I=2A is flowing in the loop. Find the period of small oscillations that the loop performs about its position of stable equilibrium.

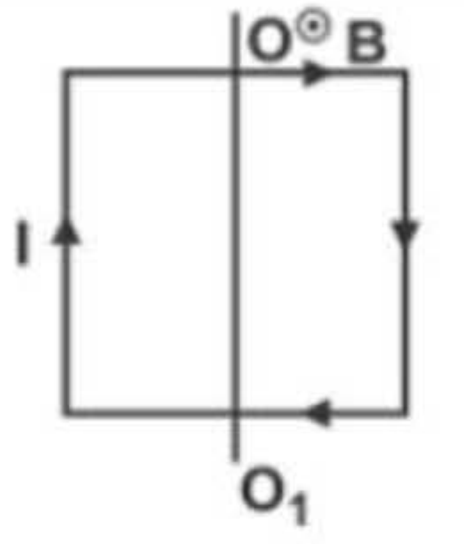
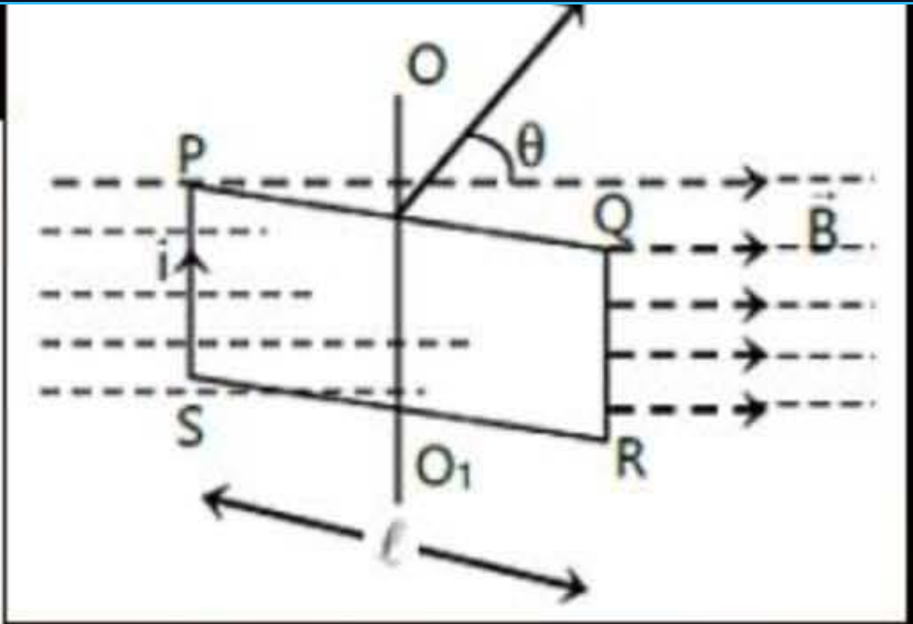


Figure 21.115

Ans : 0.57 sec.

Solution 52



Consider a loop PQRS placed in uniform magnetic field B in such a way that the normal to coil subtends an angle to the direction of B when a current I flows through the loop clockwise.

The sides PQ and RS are perpendicular to the field and equal and opposite forces of magnitude I and B act upwards and downwards respectively. Equal and opposite forces act on sides QR and PS towards right and left of coil. The resultant force is zero but resultant torque is not zero. The forces on sides PQ and RS produce a torque due to a single turn which is given by

$\tau = I\ell^2 B\sin\theta$

for small θ, $\sin\theta \approx \theta$

$\tau = I\ell^2 B\theta \qquad ...(1)$

$\tau = I\alpha$

$= \left(\frac{m}{4}\frac{\ell^2}{12}\times 2 + \frac{m}{4}\frac{\ell^2}{4}\times 2\right)\alpha$

$= m\ell^2\left[\frac{1}{24}+\frac{1}{8}\right]\alpha = \frac{m\ell^2}{8}\left[\frac{4}{3}\right] = \frac{m\ell^2}{6} \qquad ...(2)$

By (1) and (2)

$I\ell^2 B\theta = \frac{m\ell^2}{6}\alpha$

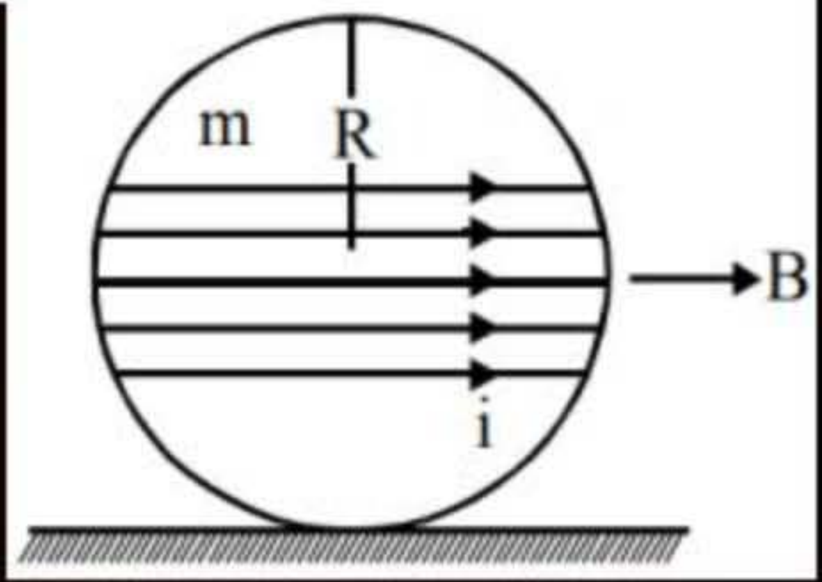
$\alpha = \frac{6IB}{m}\theta$

$\omega^2 = \frac{6IB}{m}$

$\text{Time period} = 2\pi\sqrt{\frac{m}{6IB}} = 2\pi\sqrt{\frac{10^{-2}}{6\times 2\times 10^{-1}}}$

$= 2\pi\sqrt{\frac{1}{120}} = 0.57 \text{ sec}$

Q. 56 A wire is wrapped $N = 10$ times over a solid sphere of mass $m = 5kg$, current $I = 2A$, which is placed on a smooth horizontal surface. A horizontal magnetic field of induction $|\vec{B}| = 10T$ is present. Find the angular acceleration experienced by the sphere. Assume that the mass of the wire is negligible compared to the mass of the sphere. If answer is $20n\pi$. Write value of n.



Ans : 5

Solution 56 5

Q. 59 A particle of charge q and mass m starts moving from the origin under the action of an electric field $\vec{E} = E_0\hat{i}$ and $\vec{B} = B_0\hat{i}$ with a velocity $\vec{v} = v_0\hat{j}$. The speed of the particle will become $2v_0$ after a time.

(A) $t = \frac{2mv_0}{qE}$ (B) $t = \frac{2Bq}{mv_0}$ (C) $t = \frac{\sqrt{3}\,Bq}{mv_0}$ (D) $t = \frac{\sqrt{3}\,mv_0}{qE}$

Ans : (D)

Solution 59

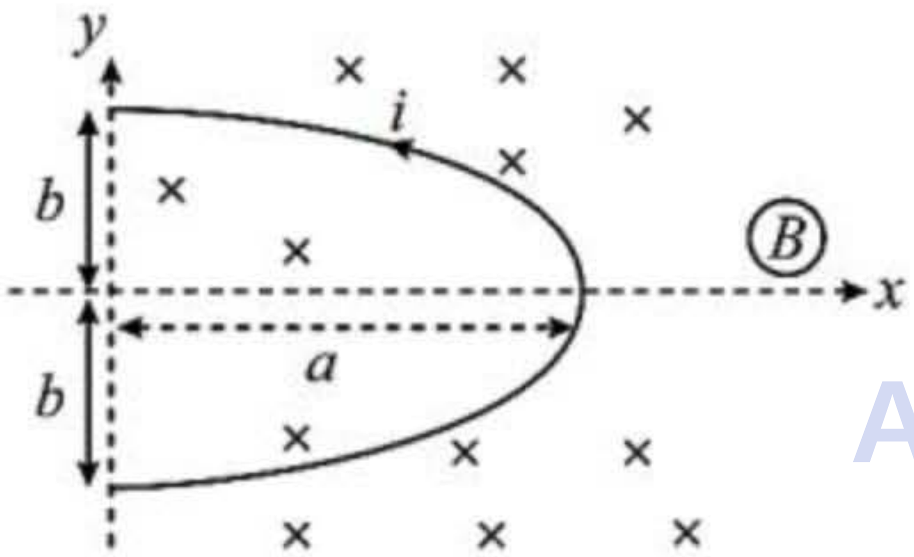
Final velocity of the particle

$$= v = \sqrt{v_0^2 + \left(\frac{qEt}{m}\right)^2} = 2v_0$$

$$v_0^2 + \left(\frac{qEt}{m}\right)^2 = 4v_0^2$$

$$\left(\frac{qEt}{m}\right)^2 = 3v_0^2 \qquad \Rightarrow t = \frac{\sqrt{3}mv_0}{qE}$$

Q. 62 In the figure, there is a conducting wire having current i and which has a shape of half ellipse $\left[\frac{x^2}{a^2}+\frac{y^2}{b^2}=1\right]$ is kept in a uniform magnetic field B as shown. If the mass of wire is m, the acceleration of wire will be



(a) $\frac{ibB}{m}$ (b) $\frac{iaB}{m}$ (c) $\frac{2iaB}{m}$ (d) $\frac{2ibB}{m}$

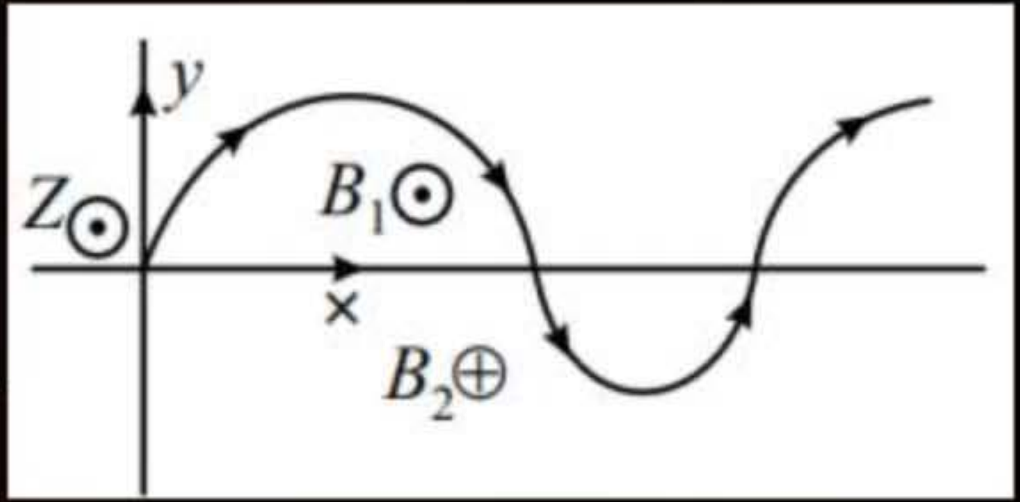
(JEE Lakshya Physics M-2 XII)

Ans : (d)

Solution 62

(d) $\frac{2ibB}{m}$

Q. 64 At $t = 0$ a charge q is at the origin and moving in the y-direction with velocity $\vec{v} = v\hat{j}$. The charge moves in a magnetic field that is for $y > 0$ out of page and given by $B_1\hat{z}$ and for $y < 0$ into the page and given $-B_2\hat{z}$. The charge's subsequent trajectory is shown in the sketch. From this information, we can deduce that



(a) $q > 0$ and $|B_1| < |B_2|$

(b) $q < 0$ and $|B_1| < |B_2|$

(c) $q > 0$ and $|B_1| > |B_2|$

(d) $q < 0$ and $|B_1| > |B_2|$

Ans : (a)

Solution 64

$$\vec{F} = q\left(\vec{V} \times \vec{B}\right)$$

$$B = B_1\hat{k}$$

$$V = V\hat{j}$$

Force at origin is along x axis.

$\hat{j} \times \hat{k} = \hat{i}$ so q should be positive.

$$r = \frac{mV}{qB}$$

$$\because r_2 < r_1$$

$$\therefore |B_2| > |B_1|$$

Q. 67 A current I flows along a thin wire shaped as a regular polygon with n sides which can be inscribed into a circle of radius R. Find the magnetic induction at the centre of the polygon. Analyse the obtained expression at $n \to \infty$.

Ans. $B = n \propto_0 I \tan(\pi n)/2\pi R$, for $n \to \infty$ $B = \propto_0 I/2R$

Solution 67

As $\angle AOB = \frac{2\pi}{n}$, OC or perpendicular distance of any segment from centre equals Rcos π/n. Now magnetic induction at O, due to die right current carrying element AB

$$= \frac{\mu_0}{4\pi} \frac{i}{R\cos\frac{\pi}{n}} 2\sin\frac{\pi}{n}$$

(From Biot- Savart's law, the magnetic field at O due to any section such as AB is perpendicular to the plane of the figure and has the magnitude.)

$$B = \int \frac{\mu_0}{4\pi} i \frac{dx}{r^2}\cos\theta$$

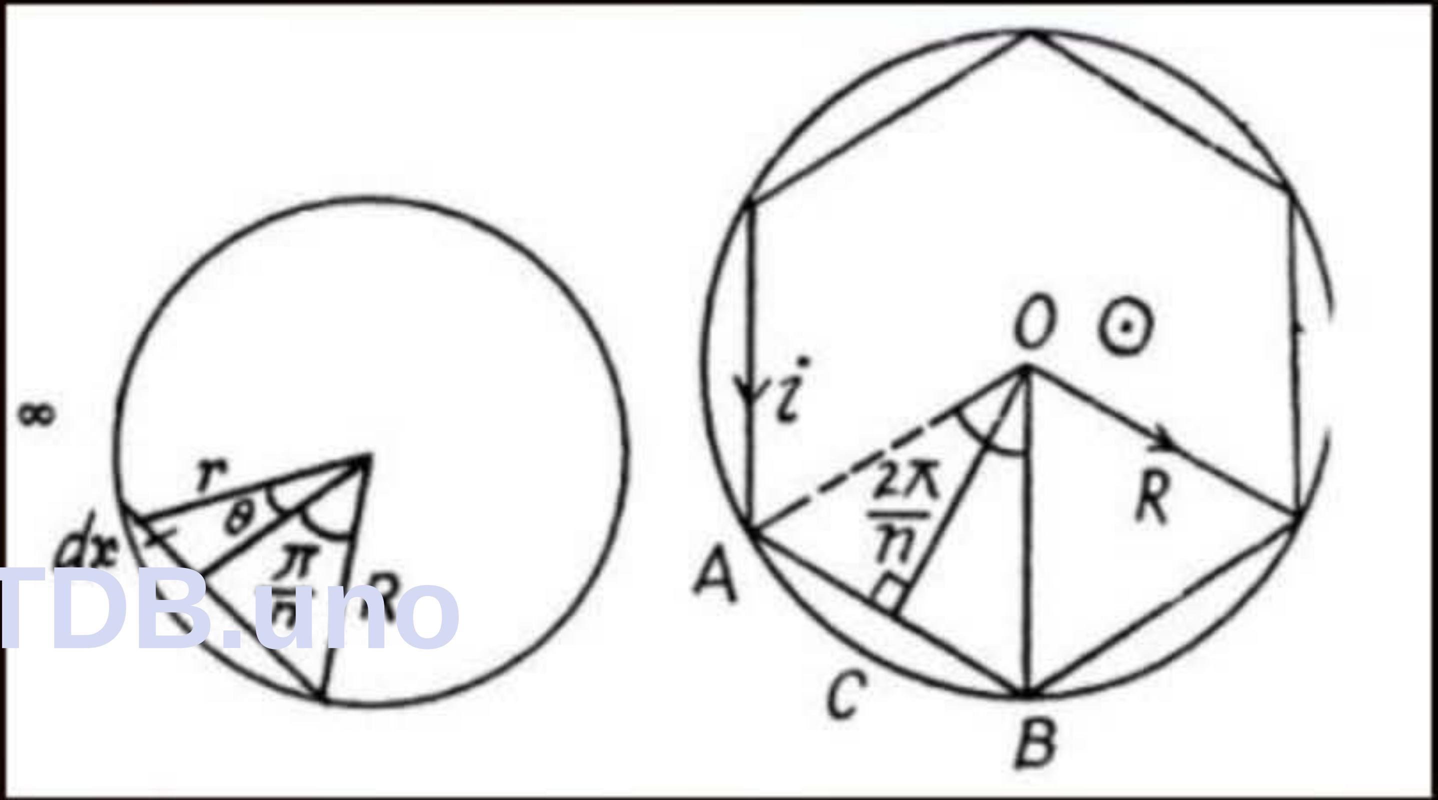
$$= \int_{-\frac{\pi}{n}}^{\frac{\pi}{n}} \frac{\mu_0 i}{4\pi} \frac{R\cos\frac{\pi}{n}\sec^2\theta d\theta}{R^2\cos\frac{2\pi}{n}\sec^2\theta}\cos\theta \qquad = \frac{\mu_0 i}{4\pi}\frac{1}{R\cos\frac{\pi}{n}} 2\sin\frac{\pi}{n}$$

As there are n number of sides and magnetic induction vectors, due to each side at O, are equal in magnitude and direction. So,

$$B_0 = \frac{\mu_0}{4\pi} \frac{ni}{R\cos\frac{\pi}{n}} 2\sin\frac{\pi}{n} \cdot n$$

$$= \frac{\mu_0}{2\pi} \frac{ni}{R} \tan\frac{\pi}{n} \quad \text{and for } n \to \infty$$

$$B_0 = \frac{\mu_0}{2} \frac{i}{R} \underset{n\to\infty}{Lt} \left(\frac{\tan\frac{\pi}{n}}{\pi/n} \right) = \frac{\mu_0}{2} \frac{i}{R}$$



Q. 68 Find the magnetic induction at the centre of a rectangular wire frame whose diagonal is equal to $d = 16$ cm and the angle between the diagonals is equal to $\phi = 30Y$; the current flowing in the frame equals $I = 5.0$ A.

Ans. $B = 4\propto_0 I/\pi d \sin\phi = 0.10$ mT.

Solution 68

We know that magnetic induction due to a straight current carrying wire at any point, at a perpendicular distance from it is given by,

$$B = \frac{\mu_0 i}{4\pi r}(\sin\theta_1 + \sin\theta_2),$$

where r is the perpendicular distance of the wire from the point, considered, and θ_1 is the angle between the line, joining the upper point of straight wire to the considered point and the perpendicular drawn to the wire and θ_2 that from the lower point of the straight wire.

$$\text{Here, } B_1 = B_3 = \frac{\mu_0}{4\pi}\frac{i}{\left(\frac{d}{2}\right)\sin\frac{\varphi}{2}}\left\{\cos\frac{\varphi}{2} + \cos\frac{\varphi}{2}\right\}$$

$$\text{and } B_2 = B_4 = \frac{\mu_0}{4\pi}\frac{i}{\left(\frac{d}{2}\right)\cos\frac{\varphi}{2}}\left\{\sin\frac{\varphi}{2} + \sin\frac{\varphi}{2}\right\}$$

Hence, the magnitude of total magnetic induction at O,

$$B_o = B_1 + B_2 + B_3 + B_4$$

$$= \frac{\mu_0}{4\pi}\frac{4i}{d}\left[\frac{\cos\frac{\varphi}{2}}{\sin\frac{\varphi}{2}} + \frac{\sin\frac{\varphi}{2}}{\cos\frac{\varphi}{2}}\right] \qquad = \frac{4\mu_0 i}{\pi d\sin\varphi} = 0.10\ \text{mT}$$

Q. 69 A current $I = 5.0$ A flows along a thin wire shaped as shown in Fig. 3.59. The radius of a curved part of the wire is equal to $R = 120$ mm, the angle $2\phi = 90$Υ. Find the magnetic induction of the field at the point O.

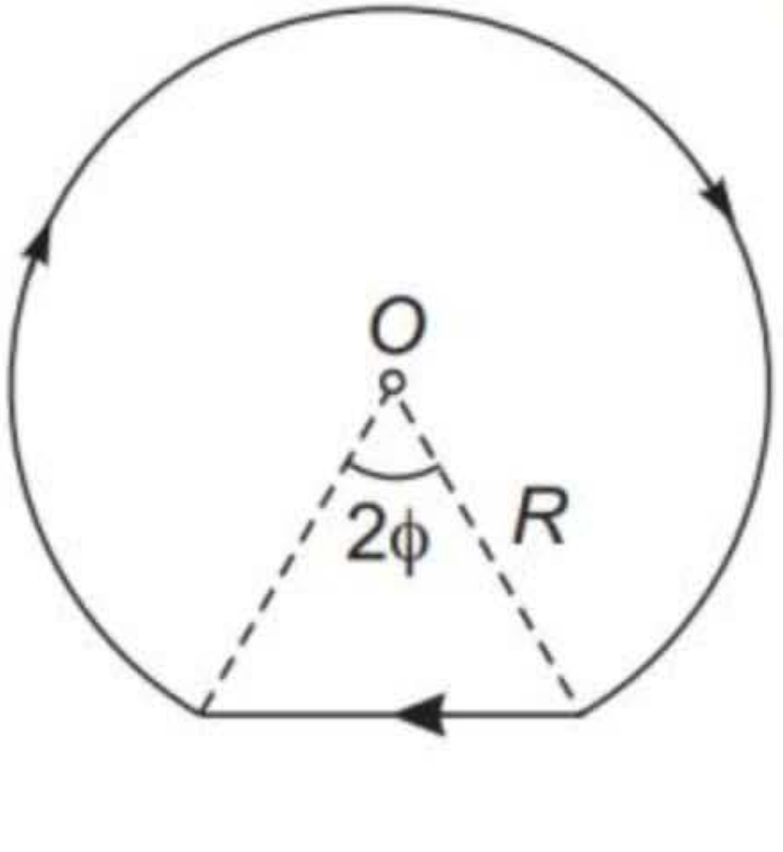


Fig. 3.59

Ans. $B = (\pi - \phi + \tan\phi)\propto_0 I/2\pi R = 28 \propto T.$

Solution 69

Magnetic induction due to the arc segment at O,

$$B_{arc} = \frac{\mu_0 i}{4\pi R}(2\pi - 2\varphi)$$

and magnetic induction due to the line segment at O,

$$B_{line} = \frac{\mu_0 i}{4\pi R\cos\varphi}[2\sin\varphi]$$

So, total magnetic induction at O,

$$B_o = B_{arc} + B_{line} = \frac{\mu_0 i}{2\pi R}[\pi - \varphi + \tan\varphi] = 28\ \mu T$$

Q. 70 Find the magnetic induction of the field at the point O of a loop with current I, whose shape is illustrated.

(a) In Fig. 3.60a, the radii a and b, as well as the angle ϕ are known;

(b) in Fig. 3.60b, the radius a and the side b are known.

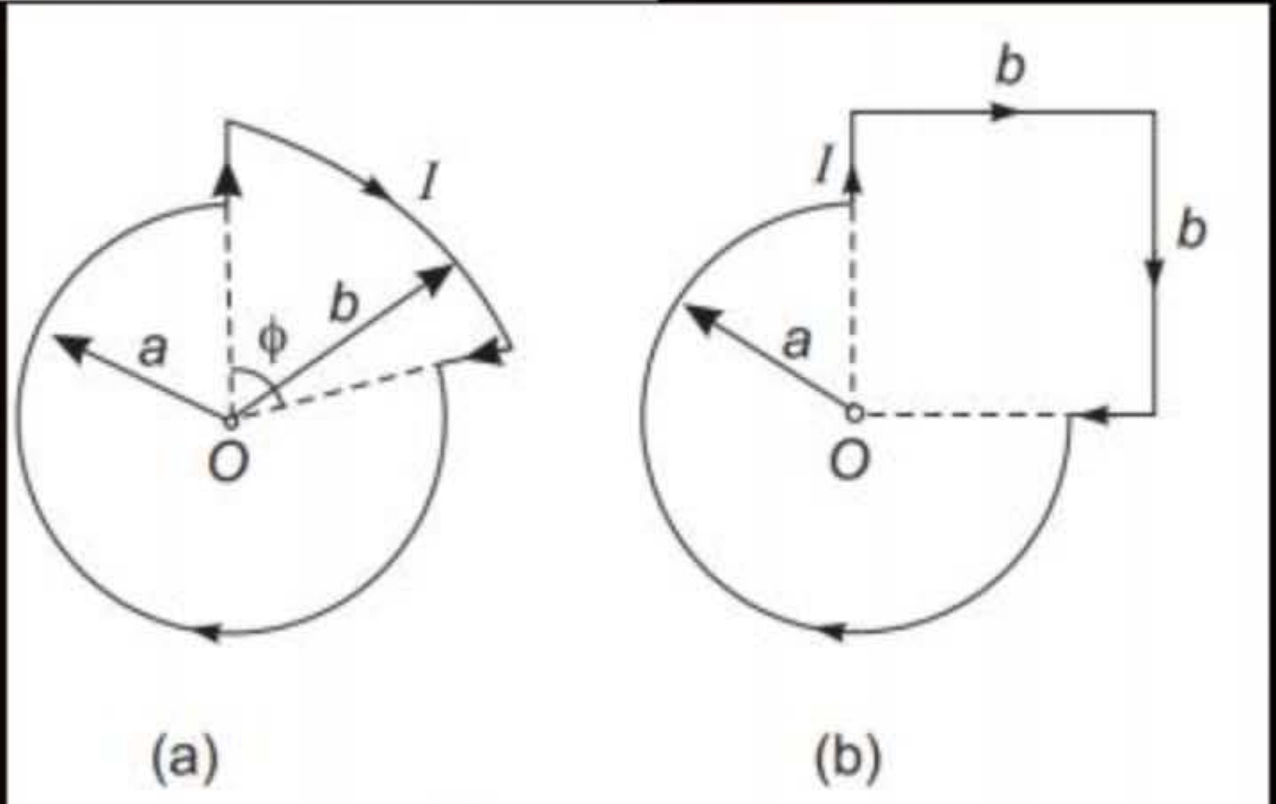


Fig. 3.60

Ans. (a) $B = \frac{\mu_0 I}{4\pi}\left(\frac{2\pi - \phi}{a} + \frac{\phi}{b}\right)$; (b) $B = \frac{\mu_0 I}{4\pi}\left(\frac{3\pi}{4a} + \frac{\sqrt{2}}{b}\right)$.

Solution 70

(a) From the Biot-Savart law,

$$dB = \frac{\mu_0}{4\pi} i \frac{(\vec{dl} \times \vec{r})}{r^3}$$

So, magnetic field induction due to the segment 1 at O,

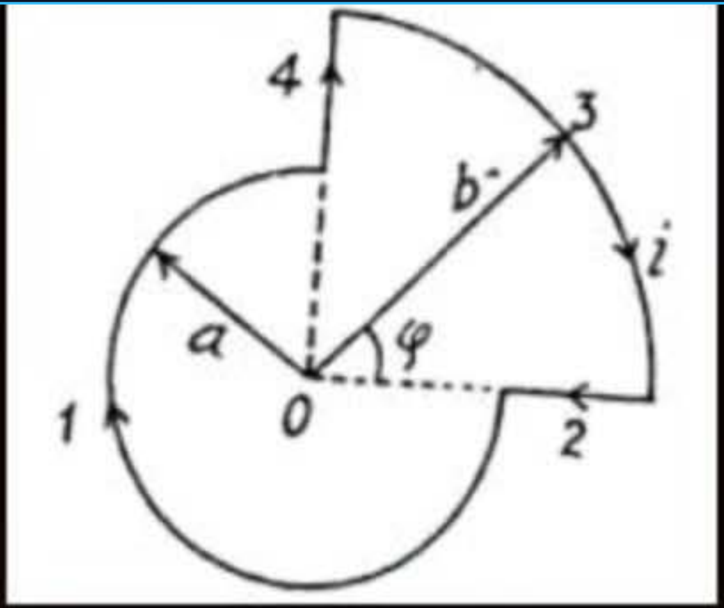
$$B_1 = \frac{\mu_0}{4\pi} \frac{i}{a} (2\pi - \varphi)$$

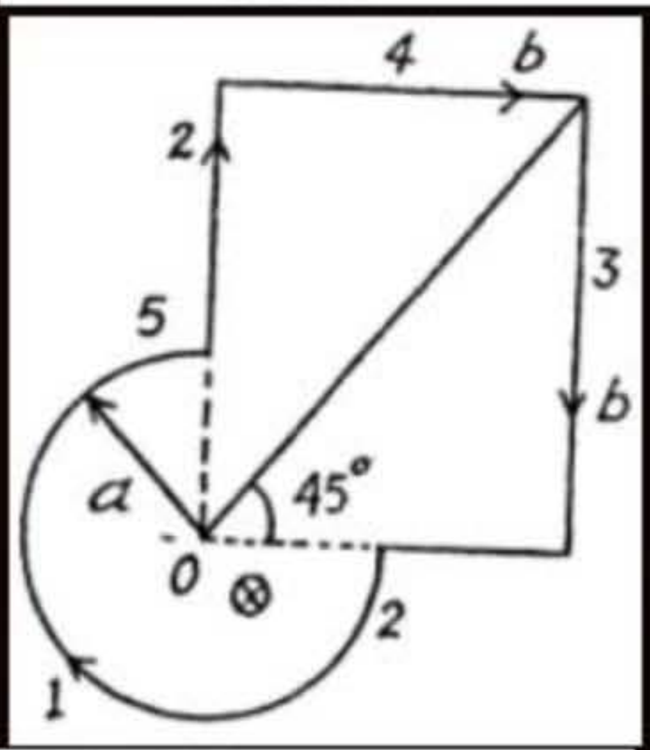
also $B_2 = B_4 = 0$, as $\vec{dl} \uparrow\uparrow \vec{r}$

and $B_3 = \frac{\mu_0}{4\pi} \frac{i}{b} \varphi$

Hence, $B_0 = B_1 + B_2 + B_3 + B_4$

$$= \frac{\mu_0}{4\pi} i \left[\frac{2\pi - \varphi}{a} + \frac{\varphi}{b} \right],$$





(b) Here, $B_1 = \frac{\mu_0}{4\pi} \frac{i}{a} \frac{3\pi}{a}$, $\vec{B_2} = 0$,

$$B_3 = \frac{\mu_0}{4\pi} \frac{i}{b} \sin 45°,$$

$$B_4 = \frac{\mu_0}{4\pi} \frac{i}{b} \sin 45°,$$

and $B_5 = 0$

So, $B_0 = B_1 + B_2 + B_3 + B_4 + B_5$

$$= \frac{\mu_0}{4\pi} \frac{i}{a} \frac{3\pi}{2} + 0 + \frac{\mu_0}{4\pi} \frac{i}{b} \sin 45° + \frac{\mu_0}{4\pi} \frac{i}{b} \sin 45° + 0$$

$$= \frac{\mu_0}{4\pi} i \left[\frac{3\pi}{2a} + \frac{\sqrt{2}}{b} \right]$$

Q. 71 A current I flows in a long straight wire with cross-section having the form of a thin half-ring of radius R (Fig. 3.61). Find the induction of the magnetic field at the point O.

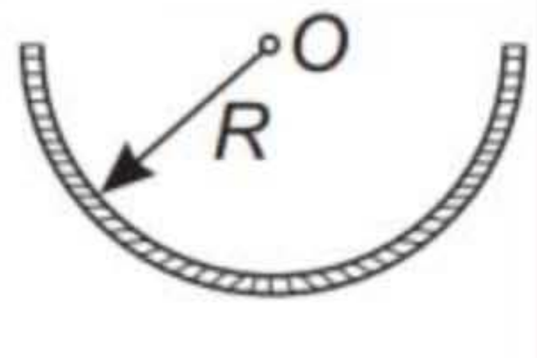


Fig. 3.61

Ans. $B = \mu_0 I / \pi^2 R.$

Solution 71

First of all let us find out the direction of vector $\overrightarrow{B}$ at point O. For this purpose, we divide the entire conductor into elementary fragments with current di. It is obvious that the sum of any two symmetric fragments gives a resultant along $\overrightarrow{B}$ shown in the figure below and consequently, vector $\overrightarrow{B}$ will also be directed as shown

So, $|\overrightarrow{B}| = \int dB \sin\varphi$ (1)

$$= \int \frac{\mu_o}{2\pi R} di \sin\varphi$$

$$= \int_o^{\pi} \frac{\mu_o}{2\pi^2 R} i \sin\varphi d\varphi, \ \left(\text{as } di = \frac{i}{\pi} d\varphi\right)$$

Hence $B = \dfrac{\mu_o i}{\pi^2 R}$

Q. 72 Find the magnetic induction of the field at the point O if a current-carrying wire has the shape shown in Fig. 3.62a, b, c. The radius of the curved part of the wire is R, the linear parts are assumed to be very long.

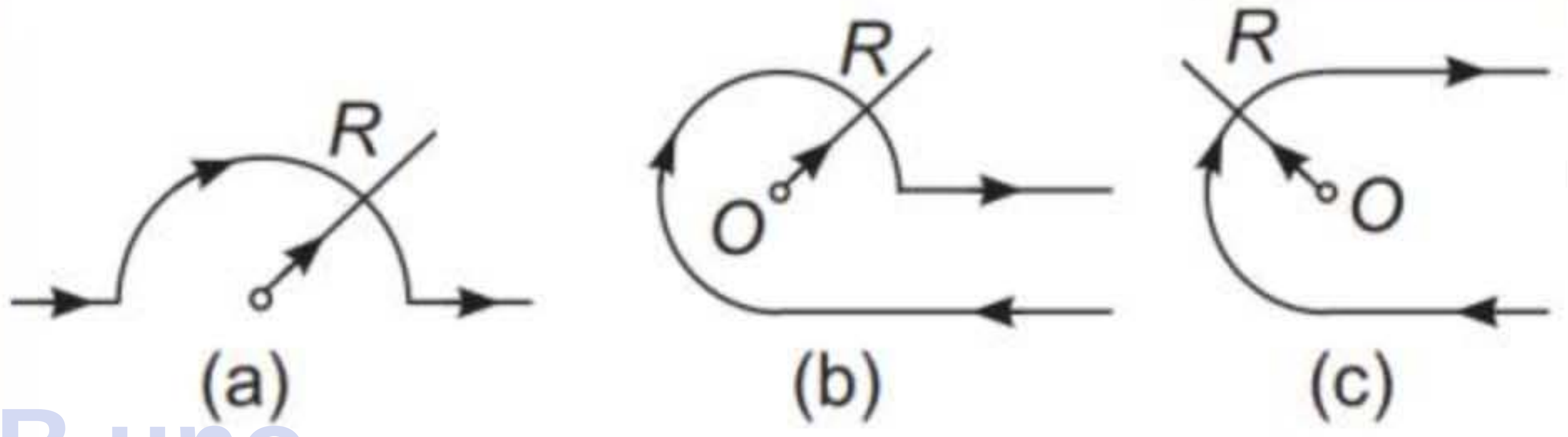


Fig. 3.62

Ans. (a) $B = (\propto_0/4\pi)(\pi I/R)$; (b) $B = (\propto_0/4\pi)(1 + 3\pi/2)\, I/R$;

Solution 72

(a) From symmetry

$$B_0 = B_1 + B_2 + B_3$$

$$= 0 + \frac{\mu_0}{4\pi}\frac{i}{R}\pi + 0 = \frac{\mu_0}{4}\frac{i}{R}$$

(b) From symmetry

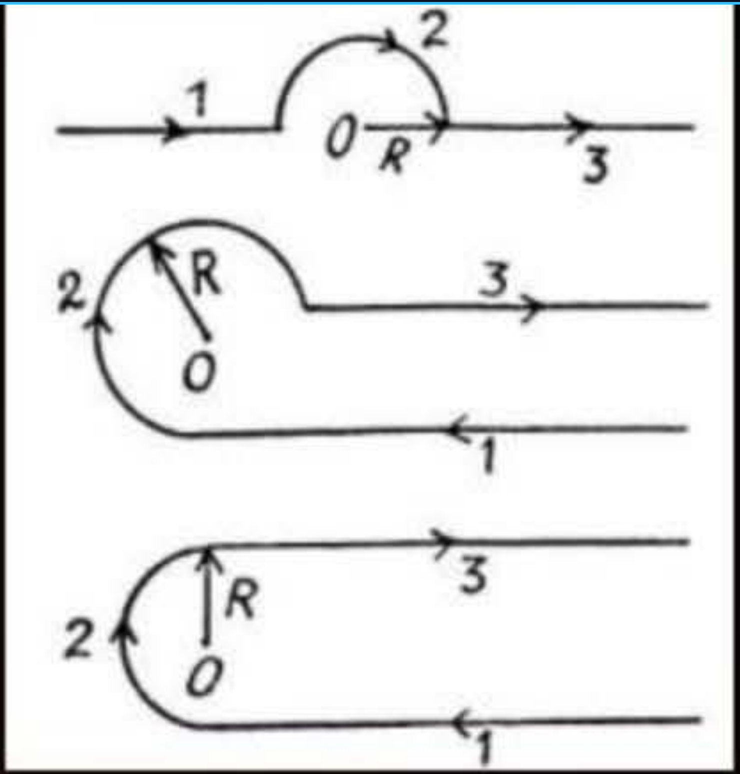
$$B_0 = B_1 + B_2 + B_3$$

$$= \frac{\mu_0}{4\pi}\frac{i}{R} + \frac{\mu_0}{2\pi}\frac{i}{R}\frac{3\pi}{2} + 0 = \frac{\mu_0}{4\pi}\frac{i}{R}\left[1 + \frac{3\pi}{2}\right]$$

(c) From symmetry

$$B_0 = B_1 + B_2 + B_3$$

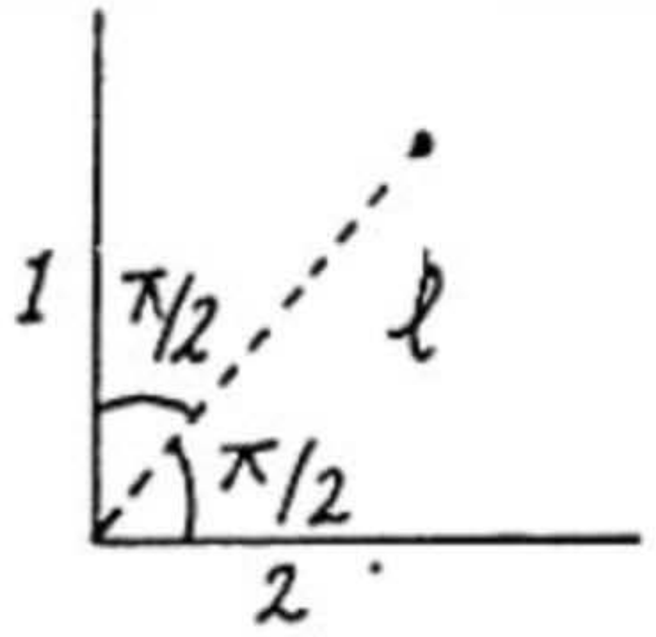
$$= \frac{\mu_0}{4\pi}\frac{i}{R} + \frac{\mu_0}{4\pi}\frac{i}{R}\pi + \frac{\mu_0}{4\pi}\frac{i}{R} = \frac{\mu_0}{4\pi}\frac{i}{R}(2 + \pi).$$



Q. 73 A very long wire carrying a current $I = 5.0$ A is bent at right angles. Find the magnetic induction at a point lying on a perpendicular to the wire, drawn through the point of bending, at a distance $l = 35$ cm from it.

Ans. $B = (\propto_0/4\pi)I\sqrt{2}/l = 2.0\ \propto\text{T}.$

Solution 73



$$\vec{B}_0 = \vec{B}_1 + \vec{B}_2$$

$$B = \frac{\mu_0}{4\pi}\frac{i}{r}(\sin\theta_1 + \sin\theta_2),$$

using above equation

$$\text{or, } |\vec{B}_0| = \frac{\mu_0 i}{4\pi l}\sqrt{2} = 2{\cdot}0\ \mu\text{T},$$

Q. 74 Find the magnetic induction at the point O if the wire carrying a current $I = 8.0$ A has the shape shown in Fig. 3.63a, b, c.
The radius of the curved part of the wire is $R = 100$ mm, the linear parts of the wire are very long

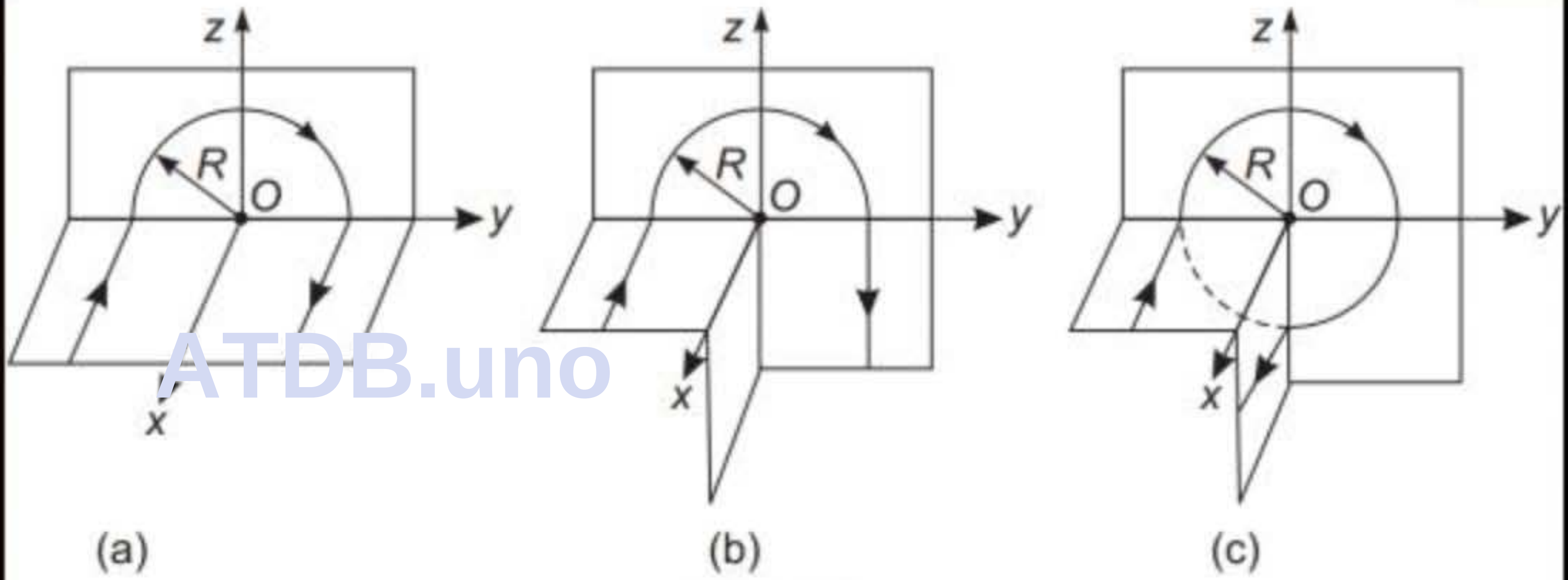


Fig. 3.63

Ans.

(a) $B = (\propto_0/4\pi)\sqrt{4 + \pi^2}\ I/R = 0.30\ \propto T$;

(b) $B = (\propto_0/4\pi) \times \sqrt{2 + 2\pi + \pi^2} I/R = 0.34\ \propto T$;

(c) [illegible]

Solution 74

(a) $\vec{B}_0 = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$

$$= \frac{\mu_0}{4\pi}\frac{i}{R}(-\vec{k}) + \frac{\mu_0}{4\pi}\frac{i}{R}\pi(-\vec{i}) + \frac{\mu_0}{4\pi}\frac{i}{R}(-\vec{k})$$

$$= -\frac{\mu_0}{4\pi}\frac{i}{R}[2\vec{k} + \pi\vec{i}]$$

So, $|\vec{B}_0| = \frac{\mu_0}{4\pi}\frac{i}{R}\sqrt{\pi^2 + 4} = 0{\cdot}30\ \mu T$

(b) $\vec{B}_0 = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$

$$= \frac{\mu_0}{4\pi}\frac{i}{R}(-\vec{k}) + \frac{\mu_0}{4\pi}\frac{i}{R}\pi(-\vec{i}) + \frac{\mu_0}{4\pi}\frac{i}{R}(-\vec{i})$$

$$= -\frac{\mu_0}{4\pi}\frac{i}{R}[\vec{k} + (\pi + 1)\vec{i}]$$

So,

$$|\vec{B}_0| = \frac{\mu_0}{4\pi}\frac{i}{R}\sqrt{1 + (\pi + 1)^2} = 0{\cdot}34\ \mu T$$

(c) Here using the law of parallel resistances

$i_1 + i_2 = i$ and $\frac{i_1}{i_2} = \frac{1}{3}$,

So, $\frac{i_1 + i_2}{i_2} = \frac{4}{3}$

Hence $i_2 = \frac{3}{4}i$, and $i_1 = \frac{1}{4}i$

Thus $\vec{B}_0 = \frac{\mu_0}{4\pi}\frac{i}{R}(-\vec{k}) + \frac{\mu_0}{4\pi}\frac{i}{R}(-\vec{j})$

$$+\left[\frac{\mu_0}{4\pi}\left(\frac{3\pi}{2}\right)\frac{i_1}{R}(-\vec{i}) + \frac{\mu_0}{4\pi}\frac{(\pi/2)\,i_2}{R}\vec{i}\right]$$

$$= \frac{-\mu_0}{4\pi}\frac{i}{R}(\vec{j} + \vec{k}) + 0$$

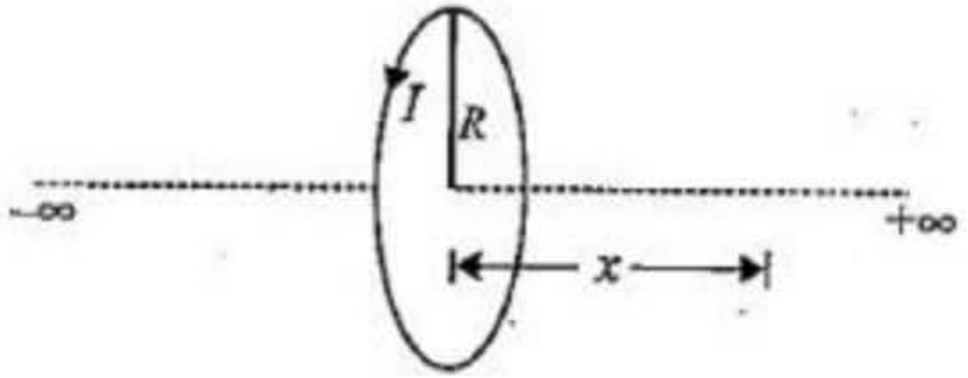
Thus, $|\vec{B}_0| = \frac{\mu_0}{4\pi}\frac{\sqrt{2}\,i}{R} = 0{\cdot}11\ \mu T$

Q. 75 A current I flows along a round loop. Find the integral $\int \mathbf{B}\, d\mathbf{r}$ along the axis of the loop within the range from $-\infty$ to $+\infty$. Explain the result obtained.

Ans. The given integral is equal to $\propto_0 I$.

Solution 75

The magnetic field at point P on the axis of a coil at a distance x from the center of the coil is: $B_x = \dfrac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}}$



The axis of the loop taken along the x-axis:

$$\int_{-\infty}^{+\infty} \vec{B} \cdot d\vec{r} = \int_{-\infty}^{+\infty} B_x dx = \frac{\mu_0 I R^2}{2} \int_{-\infty}^{+\infty} \frac{dx}{(R^2 + x^2)^{3/2}}$$

$$= \frac{\mu_0 I R^2}{2} \int_{-\pi/2}^{+\pi/2} \frac{R \sec^2\theta}{R^3 \sec^3\theta} = \frac{\mu_0 I}{2} \int_{-\pi/2}^{+\pi/2} \cos\theta d\theta = \mu_0 I$$

The integral on the LHS cab be thought of as the line integral of B over a closed path (a straight line from −∞ to +∞ and a semicircle of infinite radius where hte magnetic field vanishes). Then as per Ampere's law, this must be μ_0 times the current enclosed by the path which is I.

Q. 76 A direct current of density **j** flows along a round uniform straight wire with cross-section radius R. Find the magnetic induction vector of this current at the point whose position relative to the axis of the wire is defined by a radius vector **r**. The magnetic permeability is assumed to be equal to unity throughout all the space.

Ans.

$$B = \begin{cases} 1/2 \propto_0 [jr] & \text{for } r \le R, \\ 1/2 \propto_0 [jr]\, R^2/r^2 & \text{for } r \ge R. \end{cases}$$

Solution 76

By circulation theorem inside the conductor

$$B_\varphi 2\pi r = \mu_0 j_z \pi r^2$$

or, $B_\varphi = \mu_0 j_z r/2$

i.e., $\vec{B} = \frac{1}{2}\mu_0 \vec{j} \times \vec{r}$

Similarly outside the conductor,

$$B_\varphi 2\pi r = \mu_0 j_z \pi R^2$$

or, $B_\varphi = \frac{1}{2}\mu_0 j_z \frac{R^2}{r}$

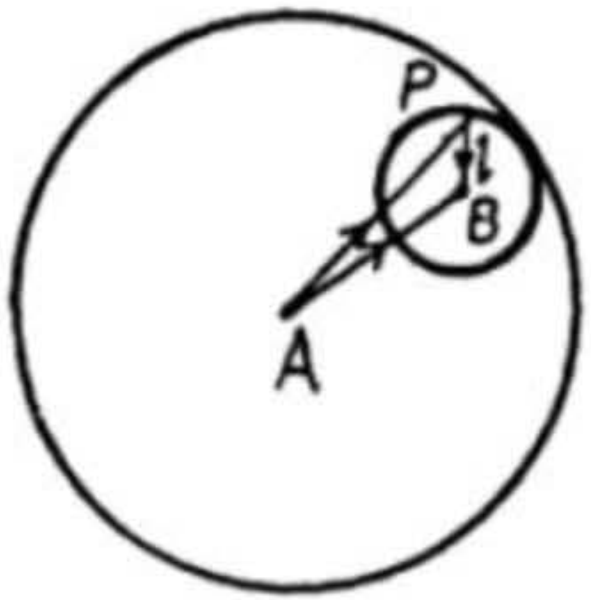
So, $\vec{B} = \frac{1}{2}\mu_0 (\vec{j} \times \vec{r}) \frac{R^2}{r^2}$

Q. 77 Inside a long straight uniform wire of round cross-section there is a long round cylindrical cavity whose axis is parallel to the axis of the wire and displaced from the latter by a distance l. A direct current of density **j** flows along the wire. Find the magnetic induction inside the cavity. Consider, in particular, the case $l = 0$.

Ans. $\mathbf{B} = 1/2 \propto_0 [\mathbf{jl}]$, *i.e.*, field inside the cavity is uniform.

Solution 77

We can think of the given current which will be assumed uniform, as arising due to a negative current, flowing in the cavity, superimposed on the true current, everywhere including the cavity. Then from the previous problem, by superposition.



$$\vec{B} = \frac{1}{2}\mu_0 \vec{j} \times (A\vec{P} - B\vec{P}) = \frac{1}{2}\mu_0 \vec{j} \times \vec{l}$$

If vector l vanishes so that the cavity is concentric with the conductor, there is no magnetic field in the cavity.

Q. 79 A uniform current of density j flows inside an infinite plate of thickness $2d$ parallel to its surface. Find the magnetic induction induced by this current as a function of the distance x from the median plane of the plate. The magnetic permeability is assumed to be equal to unity both inside and outside the plate.

Ans. $B = \begin{cases} \propto_0 jx \text{ inside the plate,} \\ \propto_0 jd \text{ outside the plate.} \end{cases}$

Solution 79

We assume that the current flows perpendicular to the plane of the paper, by circulation theorem,

$2Bdl = \mu_o(2xdl)j$

or, $B = \mu_o xj, |x| \leq d$

Outside, $2Bdl = \mu_o(2d * dl)j$

or, $B = \mu_o dj, |x| \geq d$

Q. 80 Find the magnetic moment of a thin round loop with current if the radius of the loop is equal to $R = 100$ mm and the magnetic induction at its centre is equal to $B = 6.0 \propto T$.

Ans. $p_m = 2\pi R^2 B/\propto_0 = 30\ \text{mA} \cdot \text{m}^2.$

Solution 80

Magnetic moment of a current loop is given by $p_m = niS$ (where n is the number of turns and S, the cross sectional area.) In our problem, $n = 1$, $S = \pi R^2$ and $B = \frac{\mu_0}{2}\frac{i}{R}$

$$\text{So, } p_m = \frac{2BR}{\mu_0}\pi R^2 = \frac{2\pi BR^3}{\mu_0} = 30 \times 10^{-3} A - m^2$$

Q. 81 A thin insulated wire forms a plane spiral of $N = 100$ tight turns carrying a current $I = 8$ mA. The radii of inside and outside turns (Fig. 3.67) are equal to $a = 50$ mm and $5 = 100$ mm. Find:

(a) the magnetic induction at the centre of the spiral;

(b) the magnetic moment of the spiral with a given current.

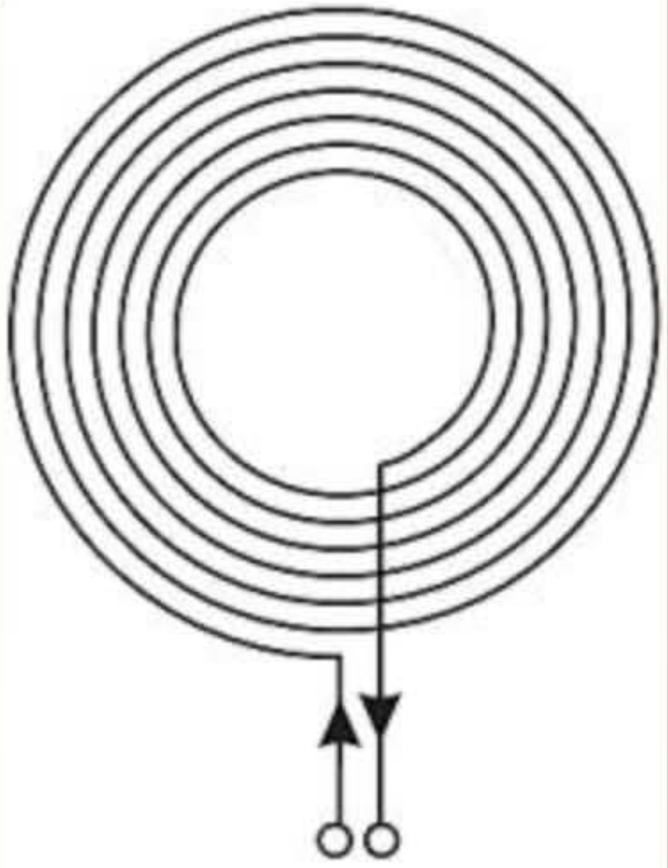


Fig. 3.67

Ans. (a) $B = \frac{\propto_0 IN \ln(b/a)}{2(b-a)} = 7 \propto\text{T}$; (b) $p_m = 1/3\, \pi I N(a^2 + ab + b^2) = 15\ \text{mA} \cdot \text{m}^2$.

Solution 81

carrying wire loop at its centre is given by,

$$B_r = \frac{\mu_0}{2r} i$$

The plane spiral is made up of concentric circular loops, having different radii, varying from a to b. Therefore, the total magnetic induction at the centre,

$$B_0 = \int \frac{\mu_0}{2r} dN \qquad (1)$$

where $\frac{\mu_0}{2r} i$ is the contribution of one turn of radius r and dN is the number of turns in the interval (r, r + dr)

i.e. $dN = \frac{N}{b-a} dr$

Substituting in equation (1) and integrating the result over r between a and b, we obtain,

$$B_0 = \int_a^b \frac{\mu_0 i}{2r} \frac{N}{(b-a)} dr = \frac{\mu_0 i N}{2(b-a)} \ln \frac{b}{a}$$

(b) The magnetic moment of a turn of radius r is $p_m = i\pi r^2$ and of all turns,

$$p = \int p_m \, dN = \int_a^b i\pi r^2 \frac{N}{b-a} dr$$

$$= \frac{\pi i N (b^3 - a^2)}{3(b-a)}$$

Q. 82 A non-conducting thin disc of radius R charged uniformly over one side with surface density σ rotates about its axis with an angular velocity ω. Find:

(a) the magnetic induction at the centre of the disc;

(b) the magnetic moment of the disc.

Ans. (a) $B = 1/2 \propto_0 \sigma\omega R$; (b) $p_m = 1/4\ \pi\sigma\omega R^4$.

Solution 82

(a) Let us a ring element of radius r and thickness dr, then charge on the ring element.,

$d\rho = \sigma\, 2\pi\, r\, dr$

and current, due to this element,

$di = \frac{(\sigma 2\pi r dr)\omega}{2\pi} = \pi\, \omega\, r\, dr$

So, magnetic induction at the center, due to this element :

$dB = \frac{\mu_0}{2}\frac{di}{r}$

$B = \int dB$

$\int_0^R \frac{\mu_0 \sigma \omega r dr}{r}$ $

$\frac{\mu_0}{2}\sigma\omega R$

and hence, from symmetry :

(b) Magnetic moment of the element, considered,

$dp_m = (di)\pi r^2 = \sigma\omega dr \pi r^2$

$= \sigma\pi\omega r^3\, dr$

Hence, the sought magnetic moment,

$P_m = \int dp_m$

$= \int_0^R \sigma\pi\omega r^3 dr$

$= \sigma\omega\pi\frac{R^4}{4}$

Q. 83 Find the magnetic moment of a thin round loop with current if the radius of the loop is equal to $R = 100$ mm and the magnetic induction at its centre is equal to $B = 6.0 \propto T$.

Ans. $p_m = 2\pi R^2 B/\propto_0 = 30 \text{ mA} \cdot \text{m}^2$.

Solution 83

Magnetic moment of a current loop is given by $p_m = niS$ (where n is the number of turns and S, the cross sectional area.) In our problem, $n = 1$,

$S = \pi R^2$ and $B = \dfrac{\mu_0 \ i}{2 \ R}$

$$\text{So, } p_m = \frac{2BR}{\mu_0}\pi R^2 = \frac{2\pi BR^3}{\mu_0} = 30 \times 10^{-3} \text{A} - \text{m}^2$$

Q. 84 A copper wire with cross-sectional area $S = 2.5\ \text{mm}^2$ bent to make three sides a square can turn about a horizontal axis OO' (Fig. 3.69). The wire is located in uniform vertical magnetic field. Find the magnetic induction if on passing a current $I = 16$ A through the wire the latter deflects by an angle $\theta = 20Y$.

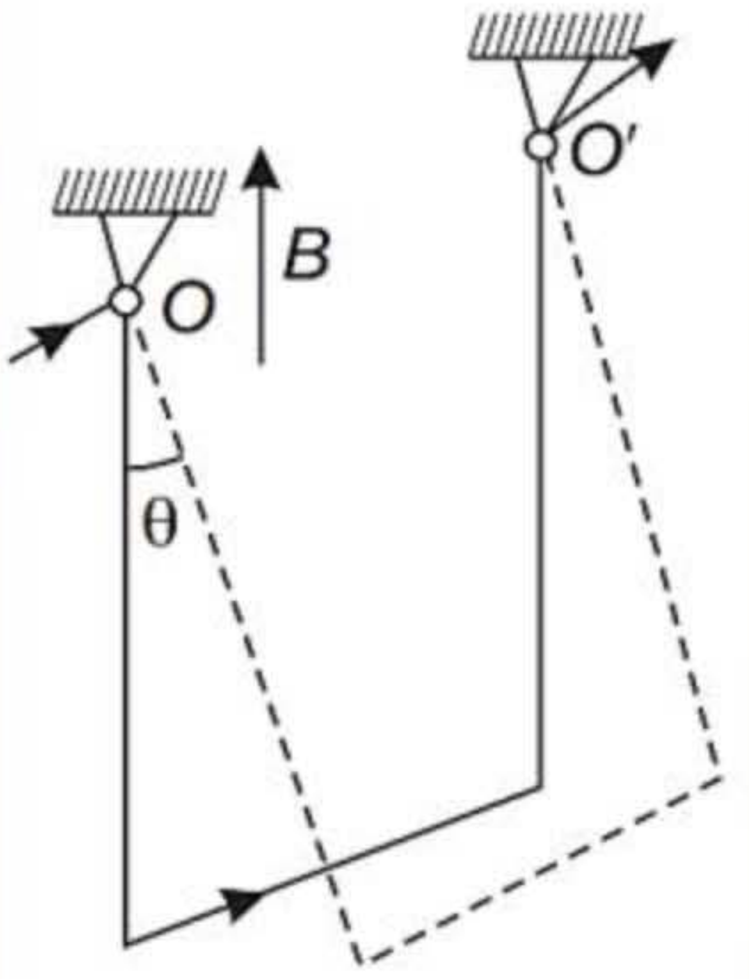


Fig. 3.69

Ans. $B = (2\rho g S / I) \tan\theta = 10$ mT, where ρ is the density of copper.

Solution 84

The Ampere forces on the sides OP and O′P′ are directed along the same line, in opposite directions and have equal values, hence the net force as well as the net torque of these forces about the axis OO′ is zero. The Ampere-force on the segment PP′ is effective and is deflecting in nature.

In equilibrium (in the dotted position) the deflecting torque must be equal to the restoring torque, developed due to the weight of the shape.

Let, the length of each side be l and ρ be the density of the material then,

$$ilB(l\cos\theta) = (Sl\rho)g\frac{l}{2}\sin\theta + (Sl\rho)g\frac{l}{2}\sin\theta + (Sl\rho)gl\sin\theta$$

or, $il^2B\cos\theta = 2S\rho gl^2\sin\theta$

Hence, $B = \frac{2S\rho g}{i}\tan\theta$

Q. 85 Two long thin parallel conductors of the shape shown in Fig. 3.71 carry direct currents I_1 and I_2. The separation between the conductors is a, the width of the right-hand conductor is equal to b. With both conductors lying in one plane, find the magnetic interaction force between them reduced to a unit of their length.

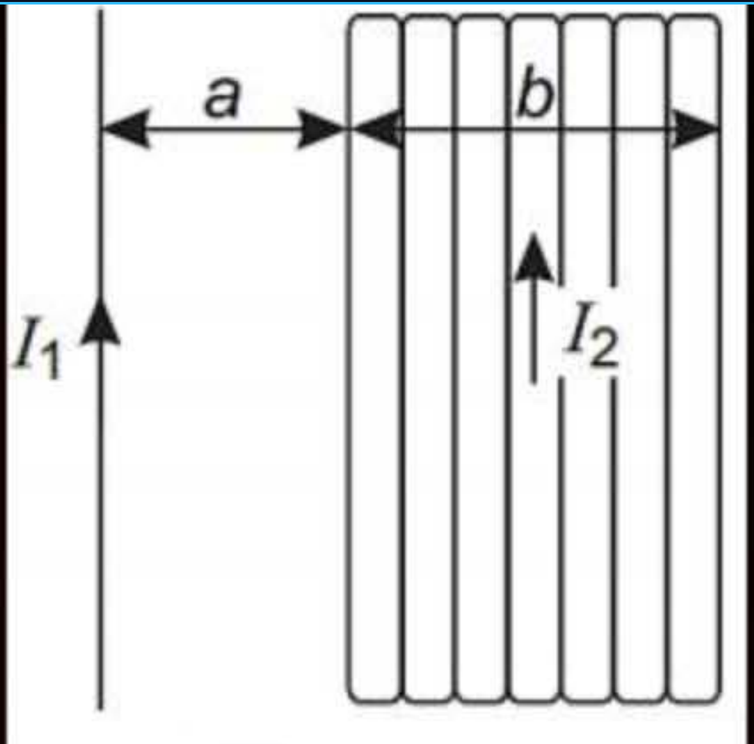


Fig. 3.71

Ans. $F_1 = \frac{\propto_0}{4\pi}\frac{2I_1I_2}{b}\ln(1 + b/a).$

Solution 85

We know that Ampere's force per unit length on a wire element in a magnetic field is given by.

$d\vec{F}_n = i(\hat{n} \times \hat{B})$ where $\hat{n}$ is the unit vector along the direction of current. (1)

Now, let us take an element of the conductor i_2, as shown in the figure. This wire element is in the magnetic field, produced by the current i_1, which is directed normally into the sheet of the paper and its magnitude is given by,

$$|\vec{B}| = \frac{\mu_0 I_1}{2\pi r} \qquad (2)$$

From Eqs. (1) and (2)

$$d\vec{F}_n = \frac{I_2}{b} dr\,(\hat{n} \times \vec{B}),$$

(because the current through the element equals $\frac{I_2}{b} dr$)

So, $d\vec{F}_n = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{b} \frac{dr}{r}$, towards left (as $\hat{n} \perp^r \vec{B}$).

Hence the magnetic force on the conductor :

$$\vec{F}_n = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{b}\int_a^{a+b}\frac{dr}{r}$$

$$\text{(towards left)} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{b}\ln\frac{a+b}{a}\text{ (towards left).}$$

Then according to the Newton's third law the magnitude of sought magnetic interaction force

$$= \frac{\mu_0 I_1 I_2}{2\pi b}\ln\frac{a+b}{a}$$

Q. 86 A direct current I flows in a long straight conductor whose cross-section has the form of a thin half-ring of radius R. The same current flows in the opposite direction along a thin conductor located on the "axis" of the first conductor (point O in Fig. 3.61). Find the magnetic interaction force between the given conductor reduced to a unit of their length.

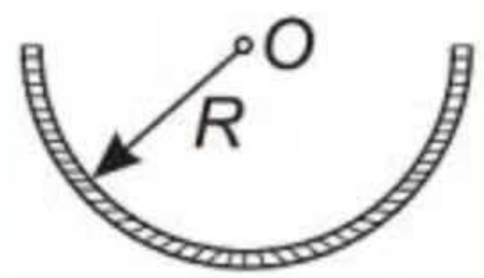


Fig. 3.61

Ans. $F_1 = \propto_0 I^2/\pi^2 R.$

Solution 86

$$|\vec{B}| = \int dB \sin\varphi \qquad (1)$$

The magnetic field due to the conductor with semicircular cross section is

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

Then $\frac{\partial F}{\partial l} = BI = \frac{\mu_0 I^2}{\pi^2 R}$

Q. 87 A wire, carrying a current i, is kept in the x–y plane along the curve $y = A\sin\left(\frac{2\pi}{\lambda}x\right)$. A magnetic field B exists in the z-direction. Find the magnitude of the magnetic force on the portion of the wire between $x = 0$ and $x = \lambda$.

Ans. $i\lambda B$

Solution 87

Given:

Electric current flowing through the wire = i

The wire is kept in the x–y plane along the curve, $y = A\sin\left(\frac{2\pi}{\lambda}x\right)$

Magnetic field (B) exists in the z direction.

We have to find the magnetic force on the portion of the wire between x = 0 and x = λ.

Magnetic force is given by

$$\vec{F} = i\vec{l} \times \vec{B}$$

For a small element dl,

$$d\vec{F} = i\left(\mathrm{d}l \times \vec{B}\right)$$

The effective force on the whole wire is equivalent to the force on a starlight wire of length λ placed along the x axis.

So,

$$F = iB\int_0^{\lambda} dl$$

$$\Rightarrow F = i\lambda B$$

Q. 88 A rigid wire consists of a semicircular portion of radius R and two straight sections (figure 34-E6). The wire is partially immersed in a perpendicular magnetic field B as shown in the figure. Find the magnetic force on the wire if it carries a current i.

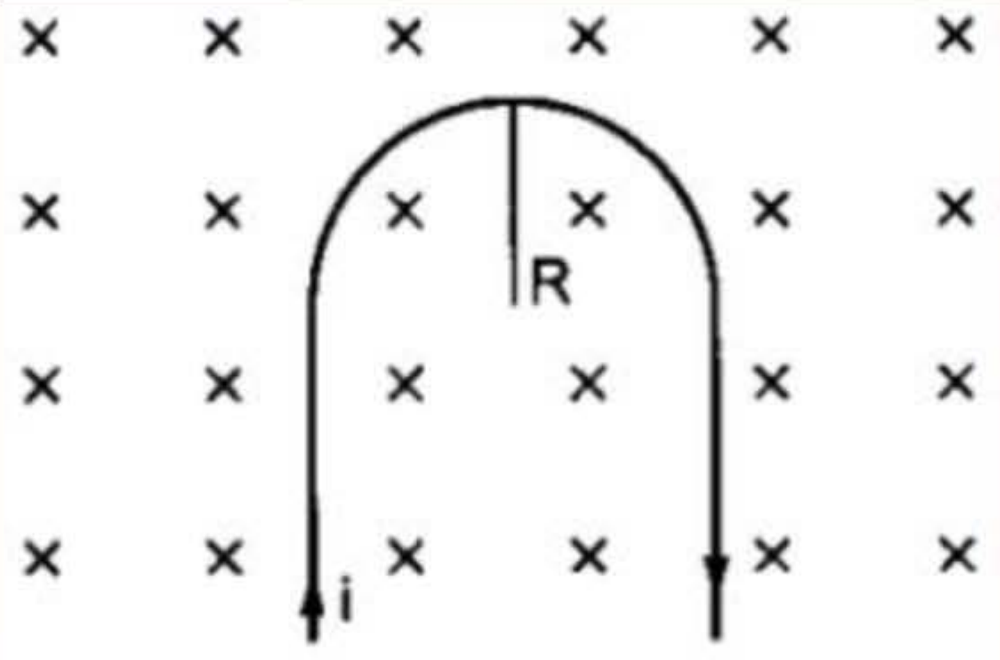


Figure 34-E6

Ans. $2iRB$, upward in the figure

Solution 88

The directions of forces F_1, F_2 and F_3 is marked as per the Fleming's Left hand rule.

Since force F_1 and F_2 are acting in opposite directions and are equal in magnitude, they cancel each other's effect.

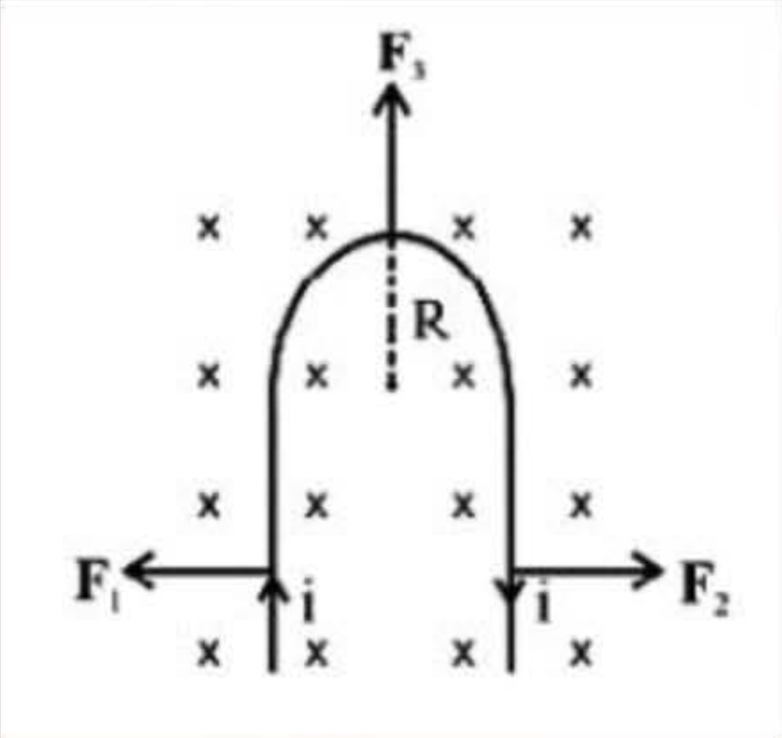
Hence the total force on the given loop is due to the semi circular portion,

which is equal to

$$\mathbf{F}_3 = i\boldsymbol{\ell} \times \mathbf{B}$$

$$\therefore \quad |\mathbf{F}_3| = i(2R)B\sin 90^0$$

= 2iRB acting upward on the given loop.



Q. 89 A straight horizontal wire of mass 10 mg and length 1·0 m carries a current of 2·0 A. What minimum magnetic field B should be applied in the region so that the magnetic force on the wire may balance its weight ?

Ans. $4{\cdot}9 \times 10^{-5}$ T

Solution 89

mass = 10 mg = 10^{-5} Kg

length = 1 m, i = 2A, B = ?

Now, mg = ilB

$\Rightarrow B = mg/il = 4.9 \times 10^{-5}$ T

Q. 90 A straight wire of length l can slide on two parallel plastic rails kept in a horizontal plane with a separation d. The coefficient of friction between the wire and the rails is μ. If the wire carries a current i, what minimum magnetic field should exist in the space in order to slide the wire on the rails.

Ans. $\frac{\mu m g}{i l}$

Solution 90

Mass= m

lengths = I

Current =i

Magnetic field = B= ?

Friction coefficient =μ

$$iBl = \mu mg$$

$$\Rightarrow B = \frac{\mu mg}{il}$$

Q. 91 Figure (34-E10) shows a circular wire-loop of radius a, carrying a current i, placed in a perpendicular magnetic field B. (a) Consider a small part dl of the wire. Find the force on this part of the wire exerted by the magnetic field. (b) Find the force of compression in the wire.

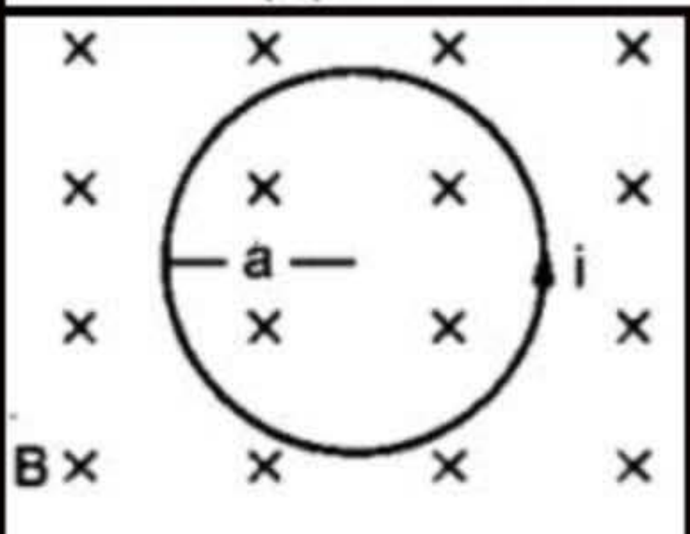


Figure 34-E10

Ans. (a) $idlB$ towards the centre (b) iaB

Solution 91

(a) $F\,dl = i \times dl \times B$ towards centre. (By cross product rule)

(b) Let the length of subtends an small angle of 2θ at the centre

Here,

$2T \sin\theta = i \times dl \times B$

$2T\theta = i \times a \times 2\theta \times B$ [As $\theta \to 0, \sin\theta \approx 0$]

$T = i \times a \times B$

$T = a\,i\,B$

Force of compression on the wire = iaB

Q. 92 Figure (34-E10) shows a circular wire-loop of radius a, carrying a current i, placed in a perpendicular magnetic field B. (a) Consider a small part dl of the wire. Find the force on this part of the wire exerted by the magnetic field. (b) Find the force of compression in the wire.

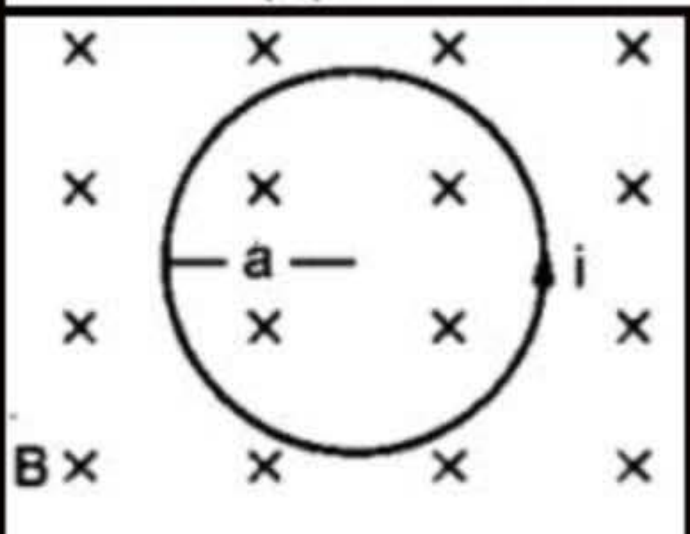


Figure 34-E10

Ans. (a) $idlB$ towards the centre (b) iaB

Solution 92

(a) $F\,dl = i \times dl \times B$ towards centre. (By cross product rule)

(b) Let the length of subtends an small angle of 2θ at the centre

Here,

$2T\sin\theta = i \times dl \times B$

$2T\theta = i \times a \times 2\theta \times B$ [As $\theta \to 0, \sin\theta \approx 0$]

$T = i \times a \times B$

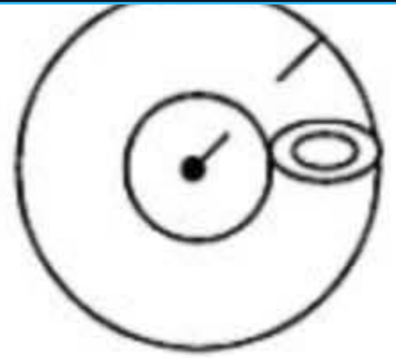
$T = a\,i\,B$

Force of compression on the wire = iaB

Q. 93 Suppose that the radius of cross section of the wire used in the previous problem is r. Find the increase in the radius of the loop if the magnetic field is switched off. The Young modulus of the material of the wire is Y.

Ans. $\frac{ia^2B}{\pi r^2Y}$

Solution 93



Y = stress/strain = $(F/\pi r^2)/(dl/L)$

$$\Rightarrow \frac{dl}{L} Y = \frac{F}{\pi r^2} \Rightarrow dl = \frac{F}{\pi r^2} \times \frac{L}{Y}$$

$$= \frac{iaB}{\pi r^2} \times \frac{2\pi a}{Y} = \frac{2\pi a^2 iB}{\pi r^2 Y}$$

So, $dp = \frac{2\pi a^2 iB}{\pi r^2 Y}$ (for small cross sectional circle)

$$dr = \frac{2\pi a^2 iB}{\pi r^2 Y} \times \frac{1}{2\pi} = \frac{a^2 iB}{\pi r^2 Y}$$

Q. 95 A particle having mass m and charge q is released from the origin in a region in which electric field and magnetic field are given by

$$\vec{B} = -B_0\vec{j} \text{ and } \vec{E} = E_0\vec{k}.$$

Find the speed of the particle as a function of its z-coordinate.

Ans. $\sqrt{\frac{2qE_0 z}{m}}$

Solution 95

Velocity will be along x - $zpla \neq -\bar{B}$

$= -\bar{B}_0\bar{J}, \bar{E} = E_0\bar{K}$

$F = q(E + V \times B)$

$= qE_0K - qV_xB_0K + qV_xB_0I$

Since $V_x = 0, F_2 = qE_0$

so $a = \dfrac{qE_0}{m}$

$\therefore V^2 = u^2 + 2as = 2\dfrac{qE_0}{m}z$

$so, v = \sqrt{\dfrac{2qE_0z}{m}}$

[dist along z - direction be z].

Q. 96 An electron is emitted with negligible speed from the negative plate of a parallel plate capacitor charged to a potential difference V. The separation between the plates is d and a magnetic field B exists in the space as shown in figure (34-E20). Show that the electron will fail to strike the upper plate if

$$d > \left(\frac{2m_e V}{eB_0^2}\right)^{\frac{1}{2}}.$$

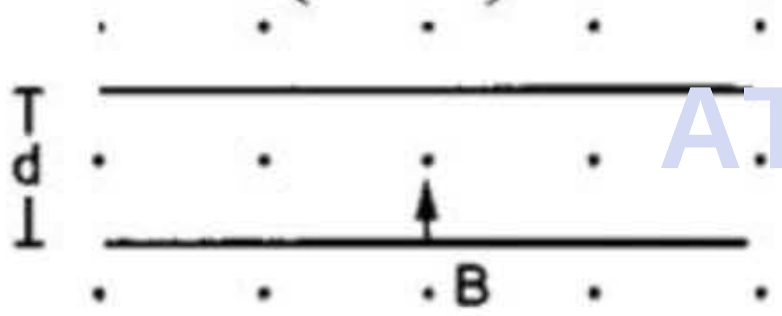


Figure 34-E20

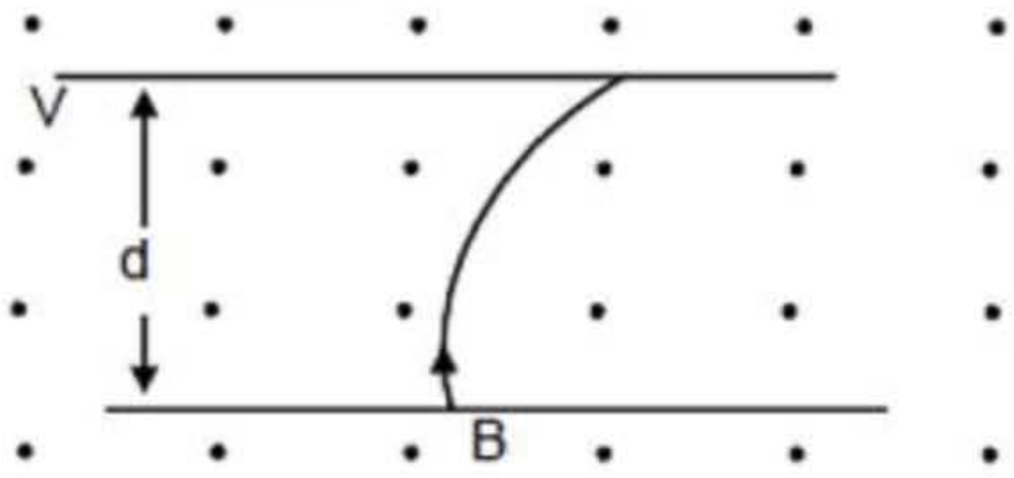
Ans. (*)

Solution 96

The force experienced first is due to the electric field due to the capacitor

$E = V/d \quad F = eE$

$a = eE/m_e$ [Where e→ charge of electron m_e → mass of electron]



$$\upsilon^2 = u^2 + 2as \Rightarrow \upsilon^2 = 2 \times \frac{eE}{m_e} \times d = \frac{2 \times e \times V \times d}{dm_e}$$

$$\text{or } \upsilon = \sqrt{\frac{2eV}{m_e}}$$

Now, The electron will fail to strike the upper plate only when d is greater than radius of the are thus formed.

$$\text{or, } d > \frac{m_e \times \sqrt{\frac{2eV}{m_e}}}{eB} \Rightarrow d > \frac{\sqrt{2m_eV}}{eB^2}$$

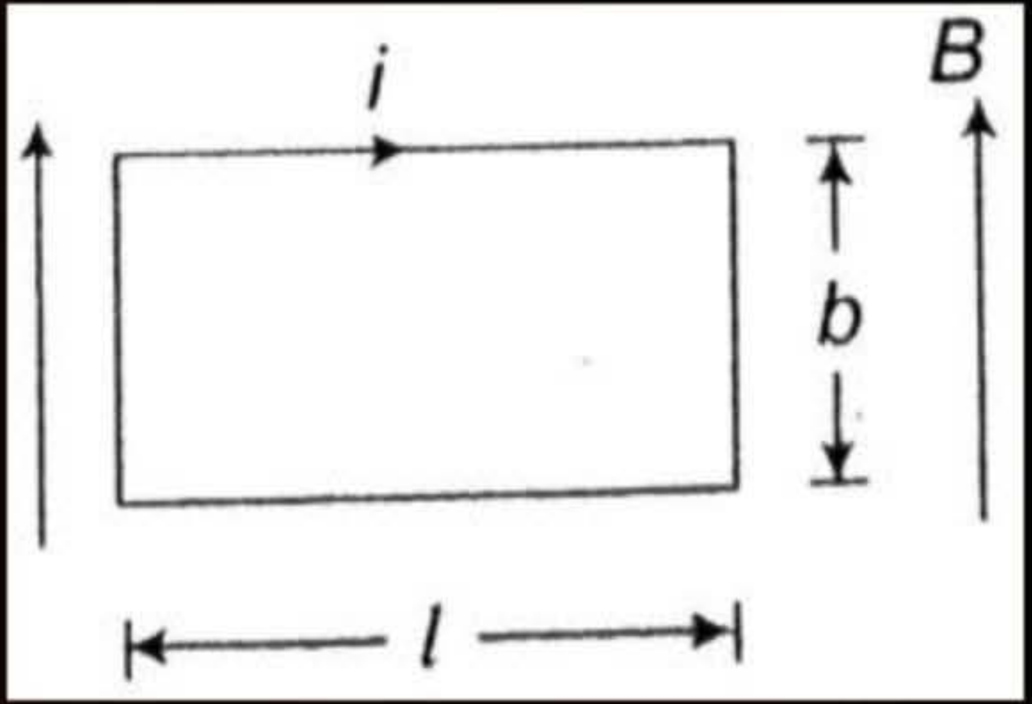
Q. 97 A rectangular coil of 100 turns has length 5 cm and width 4 cm. It is placed with its plane parallel to a uniform magnetic field and a current of 2 A is sent through the coil. Find the magnitude of the magnetic field B, if the torque acting on the coil is $0 \cdot 2$ N m^{-1}.

Ans. 0.5 T

Solution 97

$$\tau = |\vec{\tau}| = MB\sin\theta = NiAB\sin 90^\circ = NiAB = NilbB$$

$$B = \frac{\tau}{Nilb} = \frac{0.2}{100 \times 2 \times 5 \times 4 \times 10^{-4}} = 0.5T$$



Q. 98 A 50-turn circular coil of radius 2·0 cm carrying a current of 5·0 A is rotated in a magnetic field of strength 0·20 T. (a) What is the maximum torque that acts on the coil ? (b) In a particular position of the coil, the torque acting on it is half of this maximum. What is the angle between the magnetic field and the plane of the coil ?

Ans. (a) $6{\cdot}3 \times 10^{-2}$ N m (b) 60°

Solution 98

$n = 50, r = 0.02m$

$A = \pi \times (0.02)^2, B = 0.02T$

$i = 5A, \mu = niA = 50 \times 5 \times \pi \times 4 \times 10^{-4}$

τ is max. when $\theta = 90°$

$\tau = \mu \times B = \mu B Sin90° = \mu B = 50 \times 5 \times 3.14 \times 4 \times 10^{-4} \times 2 \times 10^{-1} = 6.28 \times 10^{-2}$N-M

Given $\tau = (1/2)\tau_{max}$

=> $Sin\theta = (1/2)$

or, $\theta = 30°$ = Angle between area vector & magnetic field.

=> Angle between magnetic field and the plane of the coil = $90° - 30° = 60°$


THANK
YOU
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