Electro Magnetism

Motion of charged particle in $\vec{B}$:-

Force acting on charge particle in $\vec{B}$ is defined by.

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

$\vec{v}$ = velocity vector of charged particle.

Magnitude of force is

$|\vec{F}| = qvB\sin\theta$ 'θ' is angle b/w $\vec{v}$ & $\vec{B}$

$|\vec{F}| = 0$ when $q = 0$

$v = 0 \Rightarrow$ Magnetic field can exert force on only moving charges.

$\theta = 0°$. $\vec{v} \uparrow\uparrow \vec{B}$

$\theta = 180°$ $\vec{v} \uparrow\downarrow \vec{B}$

Direction of force

If charge is +ve.

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

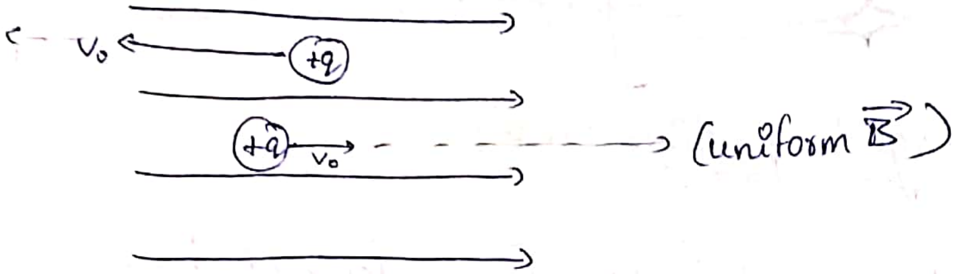
$(\vec{v} \times \vec{B}) \uparrow\uparrow \vec{F}$

If charge is -ve

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

$\vec{F} \uparrow\downarrow (\vec{v} \times \vec{B})$

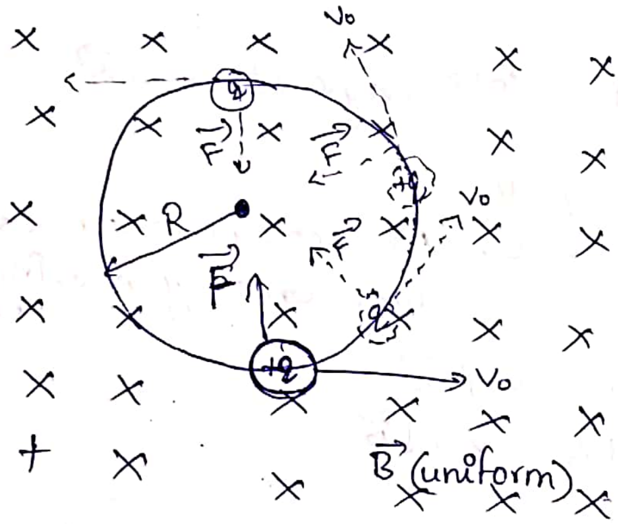
Case(i) If $\theta = 0°$, velocity of charged particle is in the direction of $\vec{B}$.



If $\theta = 0°$ (or) $180° \Rightarrow F = 0 \Rightarrow a = 0$

Path of particle is straight line.

Case(ii) If $\theta = 90°$, charged particle is projected $\perp^{ar}$ to $\vec{B}$



Force acting on the charged particle is

$F = qv_0B\sin 90°$

$F = qv_0B$

↳ acts as centripetal force

$qv_0B = \frac{mv_0^2}{R}$

$$\boxed{R = \frac{mv_0}{qB}}$$

* Time period of revolution

$T = \frac{2\pi R}{v_0} = \frac{2\pi}{\cancel{v_0}}\left(\frac{m\cancel{v_0}}{qB}\right)$

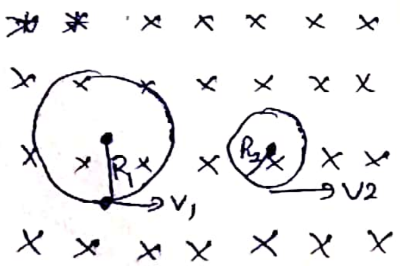
$$\boxed{T = \frac{2\pi m}{qB}}$$

↳ independent of speed

* Angular velocity of charged particle is

$\omega = \frac{2\pi}{T} \Rightarrow \boxed{\omega = \frac{qB}{m}}$

Ex:-



$v_1 > v_2$

$R_1 > R_2$

$T_1 = T_2$

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Note :- $\vec{F} \perp \vec{B}$ & $\vec{F} \perp \vec{V}$

↳ in the plane of circular motion

$\vec{F} \perp \frac{d\vec{s}}{dt}$

$\vec{F} \perp d\vec{s}$

$dw = \vec{F} \cdot d\vec{s} = 0$

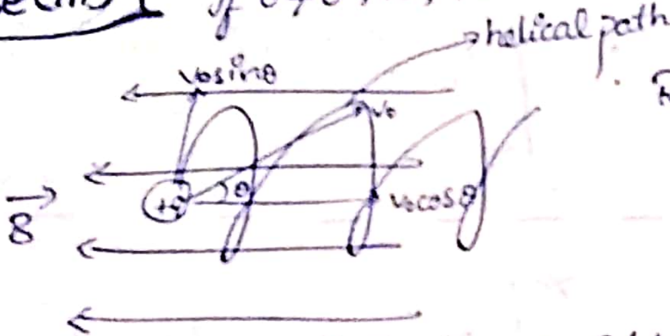
↳ change in K.E = 0

⇓

speed of the particle is constant but velocity is variable.

↳ Magnetic field never change the speed of particle but it deflects.

Case (iii) If $\theta \neq 0°, 90°, 180°$



Radius of helical path is

$$R = \frac{m(v_\perp)}{qB}$$

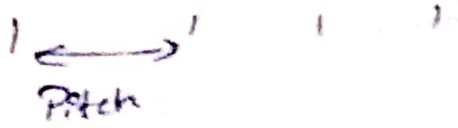
$$\boxed{R = \frac{m v_0 \sin\theta}{qB}}$$

$$R = \frac{m v_0 B \sin\theta}{qB^2}$$

$$\boxed{R = \frac{m|\vec{v} \times \vec{B}|}{qB^2}}$$

⇒ due to $v_0 \cos\theta$, path of particle is straight line.

⇒ due to $v_0 \sin\theta$, path of particle is circular.



Pitch of helical path is horizontal distance travelled by particle in one complete revolution

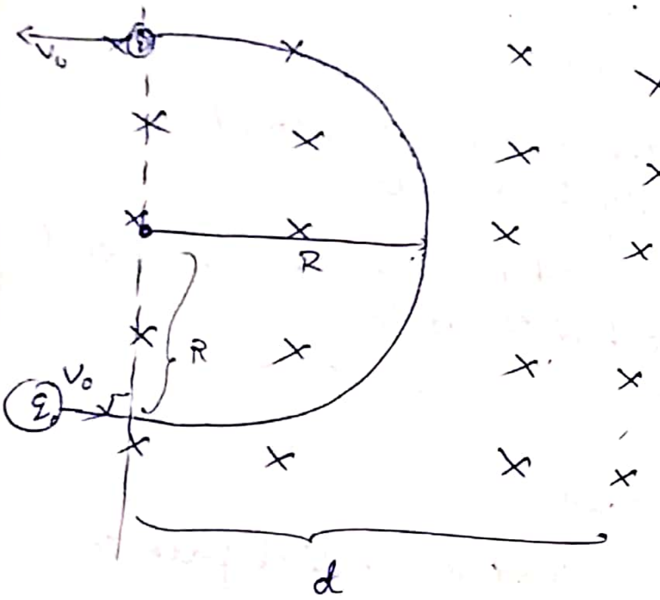
$P = (v_0 \cos\theta) T$

$P = (v_0 \cos\theta) T$

$$\boxed{P = \frac{2\pi m \, v_0 \cos\theta}{qB}}$$

Deflection of charged particle by Magnetic Field

Case (i) :- When $d > R$, then deviation produced is $180°$



$R = \frac{mv_0}{qB}$

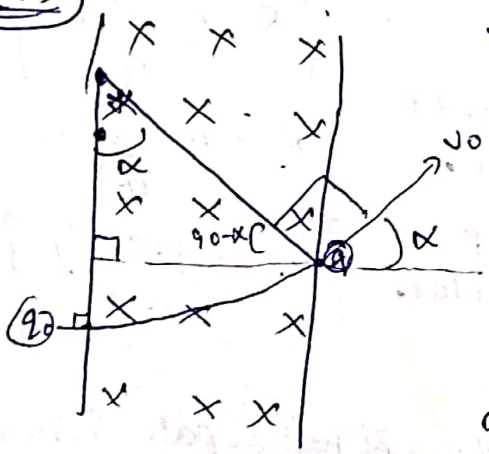
Time spent by particle in $\vec{B}$

is $\boxed{t = \frac{\pi m}{qB}}$ $\boxed{\omega = \frac{qB}{m}}$

$$\boxed{\text{time spent} = \frac{\text{angle turned in } \vec{B}}{\omega}}$$

Case (ii)

$d < R$



Angle turned in $\vec{B}$

= Deviation of charged particle

α - deviation

$\sin\alpha = \frac{d}{R}$

$\boxed{\alpha = \sin^{-1}(d/R)}$ where $R = \frac{mv_0}{qB}$

Time spent

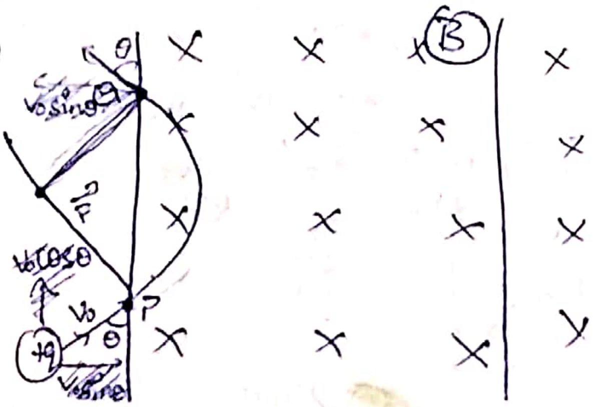
$= \frac{\alpha}{\omega}$

$\boxed{T = \frac{\alpha m}{qB}}$

If $d = R$, $\alpha = \sin^{-1}\left(\frac{R}{R}\right) = \pi/2$

$\alpha = 90°$

[Q1]

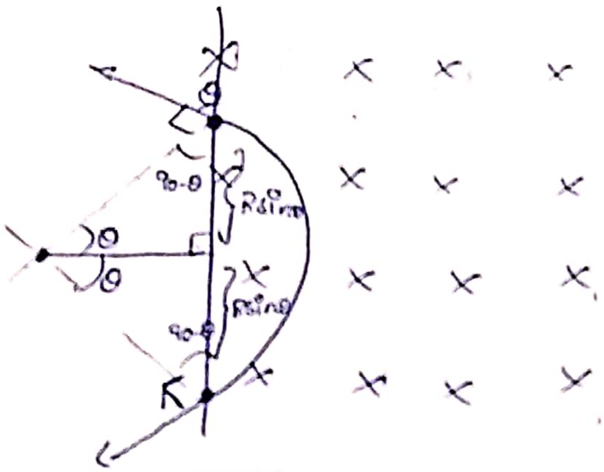


① Find the angle ~~between~~ b/w magnetic fied and particle while leaving.

② Distance b/w P & Q

③ Find the time spent by the particle in $\vec{B}$?

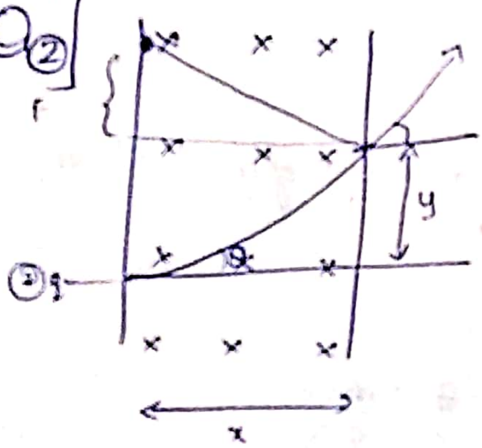
Ans ① It comes out with an angle of θ



② $PQ = 2R\sin\theta = \frac{2mv_0}{qB}\sin\theta$

③ Time spent $= \frac{2\theta m}{qB}$.

[Q2]



Find the momentum particle

$R - R\cos\theta = y$

$\frac{L}{qB}(1-\cos\theta = y$

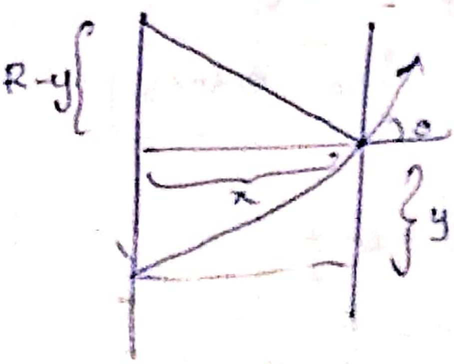
$L = \frac{yqB}{1-\cos\theta}$

$\theta = \sin^{-1}\left(\frac{x}{R}\right)$

$\sin\theta = \frac{x}{R}$

$\cos\theta = \sqrt{1-\left(\frac{x}{R}\right)^2}$

$\boxed{L = \frac{yqB}{1-\sqrt{1-\left(\frac{x}{R}\right)^2}}}$

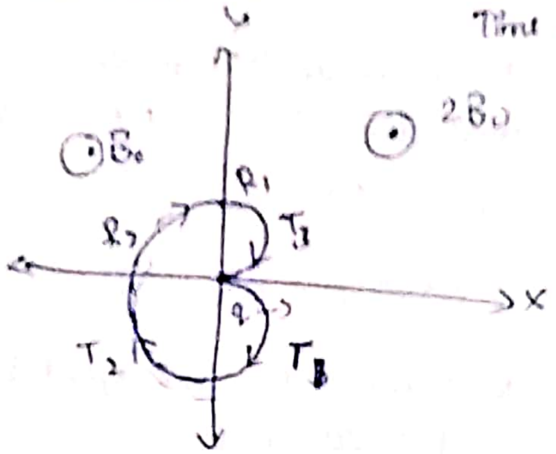


$l = x$

$\cancel{R^2} + \cancel{R^2} + y^2 - 2Ry + x^2 = \cancel{R^2} \Rightarrow R = \frac{x^2+y^2}{2y}$

$P = qB\left(\frac{x^2+y^2}{2y}\right)$

Q5



Time taken to reach origin

for $x>0$ $\vec{B} = 2B_0\hat{k}$

$x<0$ $\vec{B} = B_0\hat{k}$

$\boxed{R_1 = \frac{mv_0}{2qB_0}}$ $\boxed{R_2 = \frac{mv_0}{qB_0}}$

$\frac{\pi m}{qB}$

$\boxed{R \propto \frac{1}{B}}$

$\frac{2\pi m}{2qB_0}$ $\frac{\pi m}{qB_0}$

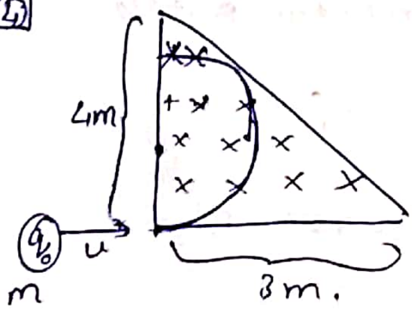
$T_1 = \frac{\pi m}{q(2B_0)}$ $T_2 = \frac{\pi m}{q(B_0)}$

$T_3 = \frac{\pi m}{q(2B_0)}$ $\boxed{R_2 = 2R_1}$

$T_1 + T_2 + T_3 = \frac{2\pi m}{qB_0}$

$$\boxed{T = \frac{2\pi m}{qB_0}}$$

Q6

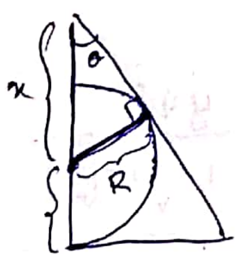


B = 2 Tesla

q = 1C

m = 1kg

Find the max value of u such th



$\sin\theta$

$\frac{3}{5} = \frac{R}{x}$

$R = \frac{3x}{5}$

$\frac{3x}{5}$

$\frac{3x}{5} = 4 - x$

$\frac{8x}{5} = 4$

$x = \frac{5}{2}$

$4 - \frac{5}{2}$

$\frac{8}{2}$

$x = \frac{5}{2}$

$\frac{3}{2} = \frac{mv_0}{qB}$

$\frac{3}{2} \times 1 \times 2 = v_0$

$\boxed{v_0 = 3\,m/s}$

$R = 4 - \frac{5}{2}$

$= \frac{3}{2}$

Ans

$4-x = R$

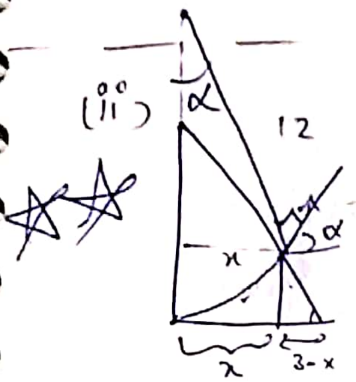
$\frac{3}{5} = \frac{R}{x} \Rightarrow R = \frac{3x}{5}$

$4-x = \frac{3x}{5} \Rightarrow x = \frac{5}{2} \Rightarrow R = \frac{3}{2}$

$\frac{mv_0}{qB} = \frac{3}{2}$

$v_0 = \frac{3}{2} \times \frac{1\times 2}{1} = 3\ m/s$

(ii)



$\mu = 24$

x^2+y^2

$\frac{4}{3} = \frac{\quad}{3-x}$

$\frac{mv_0}{qB}$

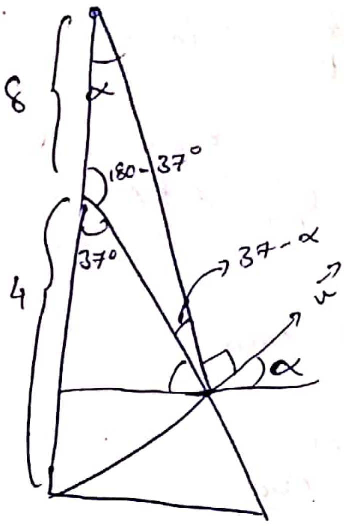
$\frac{1\times 24}{1\times 2} = 12$

$R = 12$

$\frac{12-\sqrt{144-x^2}}{3-x} = \frac{4}{3}$

$36 - 3\sqrt{144-x^2} = 12 - 4x$

$\frac{4x+24}{3} = \sqrt{144-x^2}$



Sine Rule

$\frac{8}{\sin(37-\alpha)} = \frac{12}{\sin(180-37)}$

$\frac{2}{\sin(37-\alpha)} = \frac{2}{3/5} = 5$

$\sin(37-\alpha) = \frac{2}{5}$

$37-\alpha = \sin^{-1}\left(\frac{2}{5}\right)$

$\alpha = 37^\circ - \sin^{-1}(2/5)$

[Q5] A charged particle is projected with velocity $v_0\hat{i}$ in the magnetic field $B = -B_0x\,\hat{k}$. If the particle is projected from origin Find max value of x-co-ordinate attained by particle.

Ans:- $F = q\cdot(\vec{v}\times\vec{B})$

$q\cdot(v_0\hat{i}\times -B_0x\hat{k})$

$\vec{F} = q v_0 B_0 x\,\hat{j}$

$ma = q v_0 B x\hat{j}$

$R = \frac{mv_0}{q[-B_0x]}$

$R = -\frac{mv_0}{qB_0}\frac{1}{x_0}$

$\frac{dR}{dx} = -\frac{mv_0}{qB_0}\frac{1}{x^2}$

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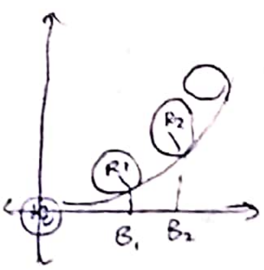
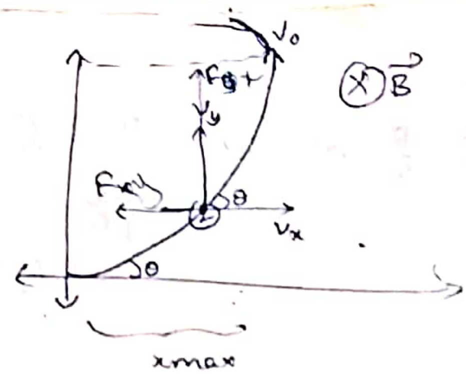


$B_2 > B_1$

$R_1 < R_2$



$F_y = q v_x B \sin 90$ $\quad F_x = q v_y B \sin 90°$

$F_y = q v_x B_0 x$ $\quad F_x = q v_y B_0 x$

$a_y = \frac{q v_x B_0 x}{m}$ $\quad a_x = -\frac{q v_y B_0 x}{m}$

$$a_y = \frac{d(v_y)}{dt} = \frac{dv_y}{dx} \cdot \frac{dx}{dt} = \frac{q v_x B_0 x}{m}$$

$$\int_0^{v_0} dv_y = \frac{q B_0}{m} \int_0^{x_{max}} x\,dx$$

$$v_0 = \frac{q B_0}{m} \frac{x_{max}^2}{2}$$

$$\boxed{x_{max} = \sqrt{\frac{2 m v_0}{q B_0}}}$$

Motion of charged particle in $\vec{E}$ and $\vec{B}$

Case (i) Net force acting on the charge particle is

$$\vec{F}_{net} = \vec{F}_e + \vec{F}_m$$

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

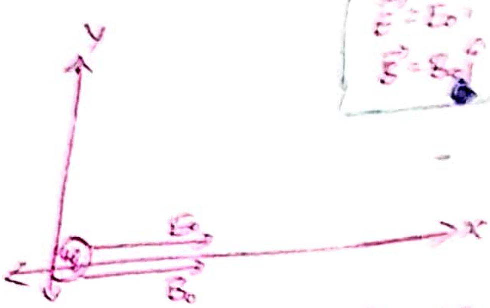
$$\boxed{\vec{F}_{net} = q(\vec{E} + \vec{v} \times \vec{B})}$$

Lorentz force

Case (ii)

$\vec{E} = E_0 \hat{i}$
$\vec{B} = B_0 \hat{i}$

If charged particle is released from rest at origin.



E_0 and B are in same direction
So, Force due to magnetic field is zero.
So, Force due to electric field and it
Force is only due to electric field and accelerations with constant acceleration

$F_{net} = \vec{E}q + 0$

$ma = qE_0$

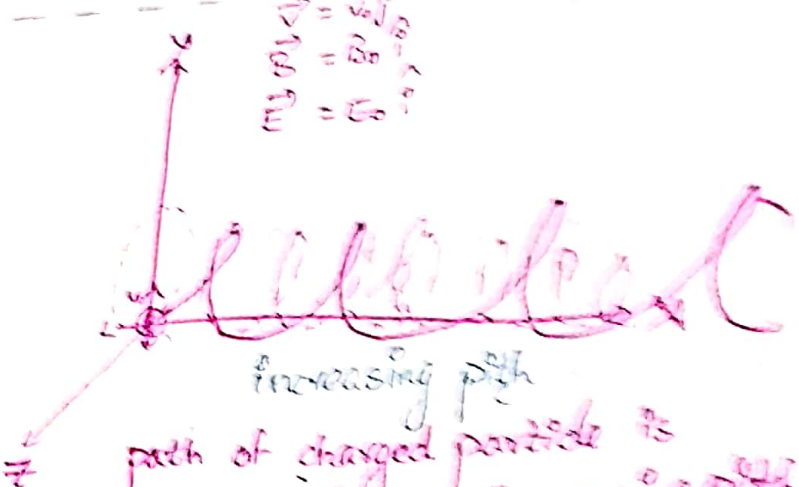
$\boxed{a = \frac{qE_0}{m}}$

$V_x = 0 + \left(\frac{qE_0}{m}\right)t \Rightarrow \boxed{V_x = \frac{qE_0 t}{m}}$

So $x = 0 + \frac{1}{2}\left(\frac{qE_0}{m}\right)t^2 \Rightarrow \boxed{x = \frac{qE_0}{2m} t^2}$

Case (iii)

$\vec{v} = v_0 \hat{j}$
$\vec{B} = B_0 \hat{i}$
$\vec{E} = E_0 \hat{i}$

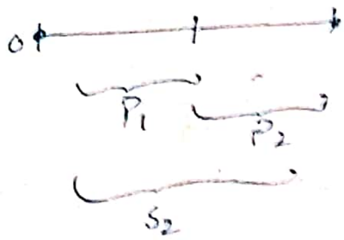


path of charged particle is helical path with increasing pitch

$P_1 = s = ut + \frac{1}{2}at^2$

$P_1 = 0 \times T + \frac{1}{2}\left(\frac{qE}{m}\right)T^2$

$P_1 = \frac{qE}{2m} T^2$



$S_2 = u_x t + \frac{1}{2} a_x t^2$

$S_2 = 0(2T) + \frac{1}{2}\left(\frac{qE}{m}\right)(2T)^2$

$S_2 = \frac{qE}{2m} 4T^2$ $P_2 = S_2 - P_1 = \frac{qE}{2m} 3T^2$

$P_3 = \frac{qE}{2m}(9T^2 - 4T^2)$

$P_3 = \frac{qE}{2m}(5T^2)$

$P_1 : P_2 : P_3 = 1 : 3 : 5$

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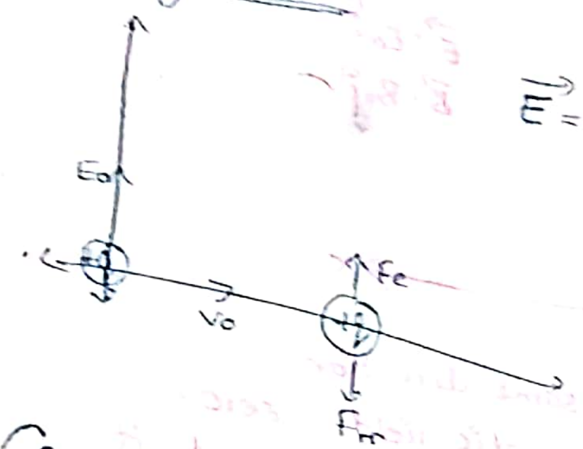
Velocity selector



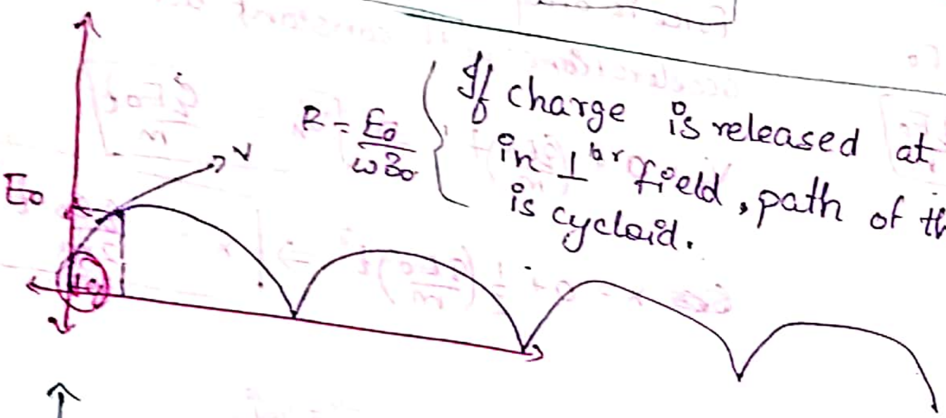
$\vec{E} = E_0\hat{j}$, $\vec{B} = B_0\hat{k}$, $\vec{V} = V_0\hat{i}$

If $F_m = F_E$, then no deflection occurs.

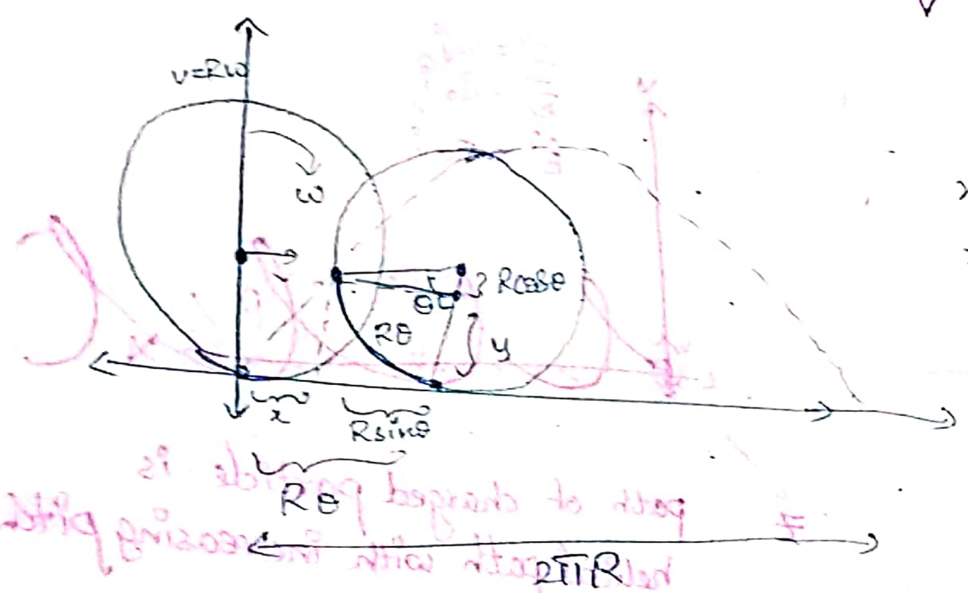
$$V B_0 \cancel{q} = \cancel{q} E_0$$

$$\boxed{V = \frac{E_0}{B_0}}$$

Case (iii)



$R = \frac{E_0}{\omega B_0}$ } If charge is released at origin in $\perp^{ar}$ field, path of the particle is cycloid.



$x = R\theta - R\sin\theta$

$x = R(\omega t - \sin\omega t)$

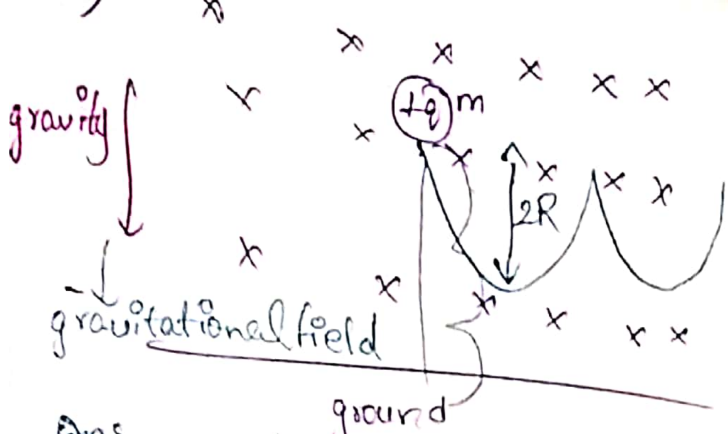
$y = R - R\cos\theta$

$y = R(1 - \cos\omega t)$

$$x = \frac{E_0}{\omega B_0}(\omega t - \sin\omega t)$$

$$y = \frac{E_0}{\omega B_0}(1 - \cos\omega t)$$

$y_{max} = 2R = \frac{2E_0}{\omega B_0}$



If the charged particle released from rest at height. Find the h_{min} so that charged particle should not hit the ground.

Ans

$2R = h_{min}$

$2R \cdot h_{min}$

$h_{min} = \frac{2mg}{\omega B_0 q}$

$= \frac{2g}{\left(\frac{qB_0}{m}\right)\omega}$

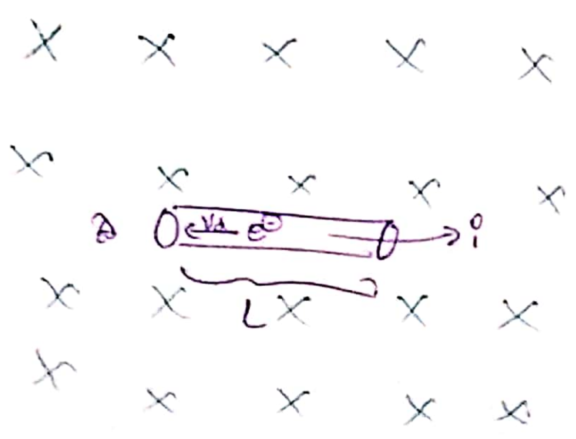
$\boxed{h_{min} = \frac{2g}{\omega^2}}$

$qE_0 = mg$

$E_0 = \frac{mg}{q}$

Q) Force acting on Current carrying wire in $\vec{B}$:-

A :- Area of cross-section



Force acting on each e^- is

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

$\vec{F_e} = -e(\vec{v_d} \times \vec{B})$

Net force acting on the wire is

$\vec{F_{net}} = (\text{no. of } e^-)(\vec{F_e})$

$\vec{F_{net}} = (n.AL)[-e(\vec{v_d} \times \vec{B})]$

$\vec{F_{net}} = -neAL(\vec{v_d} \times \vec{B})$

$\vec{F_{net}} = neAv_d(\vec{l} \times \vec{B})$

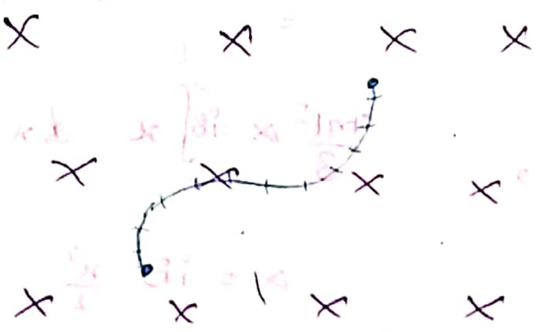
$$\boxed{\vec{F}_{net} = i(\vec{l} \times \vec{B})}^{*}$$

valid for straight line

$\vec{l}$ is in the direction of $-\vec{v_d}$.

$\rightarrow$ $\vec{l}$ should be taken in the direction of current.

Force acting on Curved conductor:-



$\vec{dF_1} = i(\vec{dl_1} \times \vec{B})$

$\vec{dF_2} = i(\vec{dl_2} \times \vec{B})$

$\vdots$

$\vec{dF_n} = i(\vec{dl_n} \times \vec{B})$

Net force acting on the wire.

$\vec{F}_{net} = i(\vec{dl_1} + \vec{dl_2} + \vec{dl_n}) \times \vec{B}$

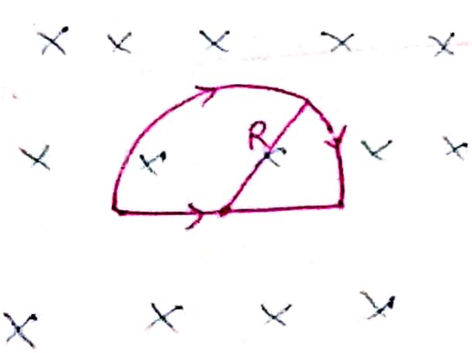
$\vec{F}_{net} = i(\vec{AB} \times \vec{B})$

$\hookrightarrow$ length vector drawn from one end to the other end in the current sense.

Force acting in closed conductor is zero.

$\vec{AB} = 0$ $\quad \vec{F} = 0$.

Q)



$2\vec{F}$

$2\, i\, 2RB$

It is not a closed loop as direction of current is not same.

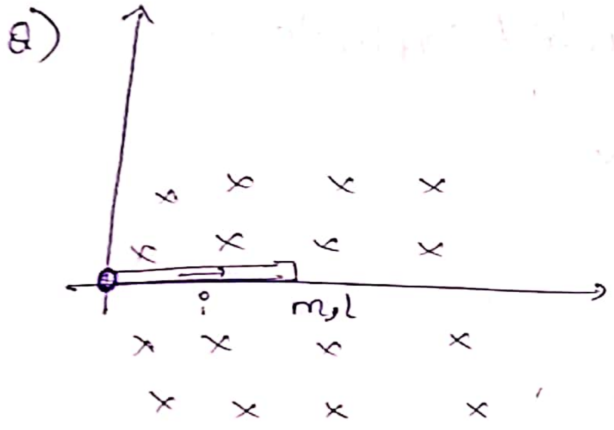
Find net force acting on the loop?

$\vec{F}_{net} = 2\vec{F} = 2\,i(\vec{l}\times\vec{B})$

$= 2\,i \cdot 2R\,B\sin 90$

$\vec{F}_{Net} = 4\,iRB$

Q)



$B = B_0 x$

If rod is left free from shown position Find initial angular acceleration.

$F = i(\vec{l}\times\vec{B})$

$=$

$\frac{ml^2}{3}\alpha = iB\int_0^l x\,dx$

$\alpha = \cancel{iB\frac{x^2}{2}}$

$\tau = I\alpha$

$F = i(dx\,Bx)$

$F = i\,B_0\,x\,dx$

$d\tau = xF$

$\int_0^\tau d\tau = iB_0\int x^2 dx$

$\tau = iB_0\frac{l^3}{3}$

$\frac{ml^2}{3}\alpha = iB_0\frac{l^3}{3}$

$\boxed{\alpha = \frac{iB_0 l}{m}}$

Q)

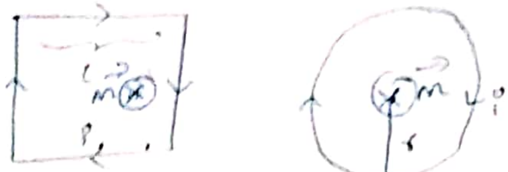
Magnetic Dipole

every carrying closed loop will act as magnetic dipole

Magnetic Dipole Moment ($\vec{m}$)

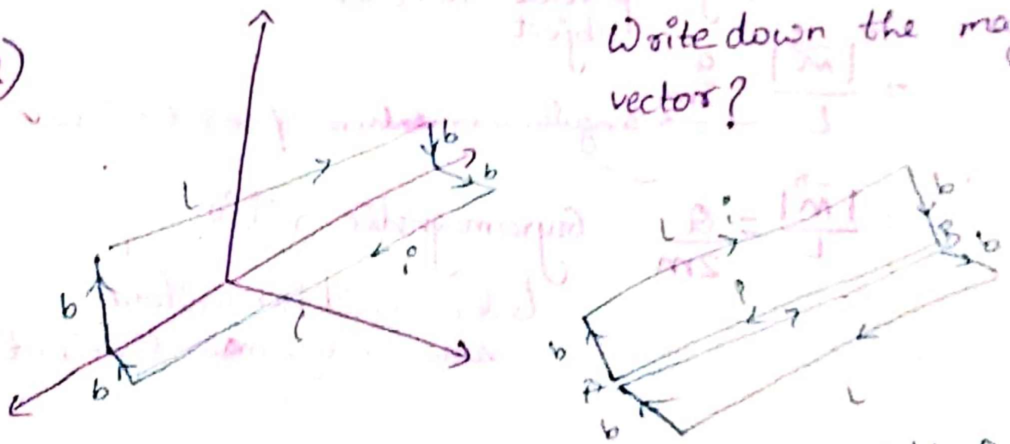
$|\vec{m}| = $ (current)(area of loop)

Direction of $\vec{m}$ is defined by right hand thumb rule.



$|\vec{m}| = i(l^2)$ $\quad$ $|\vec{m}| = i\pi r^2$

Q) Write down the magnetic moment vector?

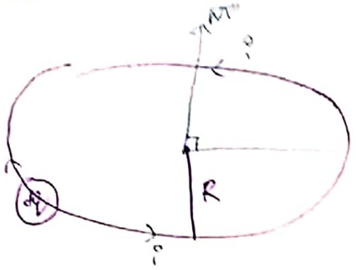


Net current b/w A and B is zero.

$\vec{m} = i(Lb)(-\hat{i}) + i(b)(-\hat{j})$

$\vec{m} = -ilb(\hat{i}+\hat{j})$

$|\vec{m}| = \sqrt{2}\, ilb$.



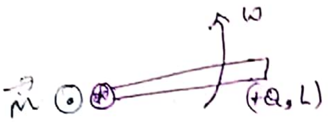
q charge circulates with angular velocity ω. Find the magnetic dipole moment of charge.

$$i = \frac{q}{T} = \frac{q\omega}{2\pi}$$

$$|\vec{M}| = \frac{q\omega}{2\pi} \times \pi R^2 = \frac{q\omega R^2}{2}.$$

---

a)



$$|\vec{M}| = \frac{\omega}{2\pi}\frac{Q\,dx}{l}\,\pi x^2$$

$$|\vec{M}| = \frac{Q\omega}{2l}\int_0^l x^2\,dx$$

$$= \frac{Q\omega}{2l}\frac{l^3}{3}$$

$$|\vec{M}| = \frac{Q\omega l^2}{6}$$

Note :- When charged ~~particle~~ object revolves

$$= \frac{|\vec{M}|}{L} = \frac{Q}{2m}$$

$L \rightarrow$ angular momentum of object $= I\omega$

$$\boxed{\frac{|\vec{M}|}{L} = \frac{Q}{2m}}$$ Gyromagnetic ratio

↳ It is valid for uniform ~~same~~ charge/mass distribution

---

method-2

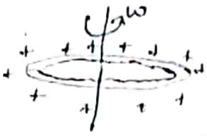
$$|\vec{M}| = \frac{Q(I\omega)}{2m}$$

$$= \frac{q}{2}\left(\frac{ml^2}{3}\frac{\omega}{m}\right)$$

$$|\vec{M}| = \frac{q\omega L^2}{6}.$$

gular velocity
le moment

Ring



$\frac{M}{L} = \frac{Q}{2m}$

$M = \frac{Q\, mR^2\omega}{2m}$

$\vec{M} = \frac{QR^2\omega}{2}$

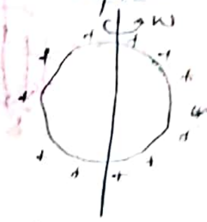
Disc

$\frac{\vec{M}}{L} = \frac{Q}{2m}$

$\vec{M} = \frac{Q\omega}{2m}\left(\frac{mR^2}{2}\right)$

$\vec{M} = \frac{QR^2\omega}{4}$

Hollow Sphere



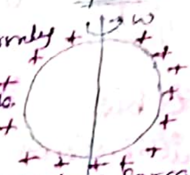
$\frac{\vec{M}}{L} = \frac{Q}{2m}$

$\vec{M} = \frac{Q}{2m}\left(\frac{2}{3} mR^2\omega\right)$

$\vec{M} = \frac{QR^2\omega}{3}$

Conducting Solid Sphere

charge is uniformly distributed only outside. It is just like a hollow sphere for calculating $\vec{M}$.



$\frac{\vec{M}}{L} = \frac{Q}{2m}$

~~$\vec{M} = \frac{Q}{2m}\left(\frac{2}{5} mR^2\omega\right)$~~

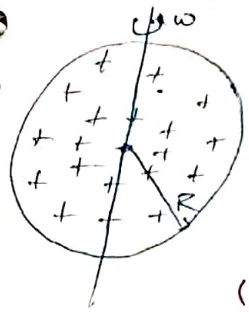
~~$\vec{M} = \frac{QR^2\omega}{5}$~~

$\frac{\vec{M}}{L} = \frac{Q}{2m}$

$\vec{M} = \frac{Q}{2m}\left(\frac{2}{3} mR^2\omega\right)$

$\vec{M} = \frac{QR^2\omega}{3}$

Non Conducting solid sphere

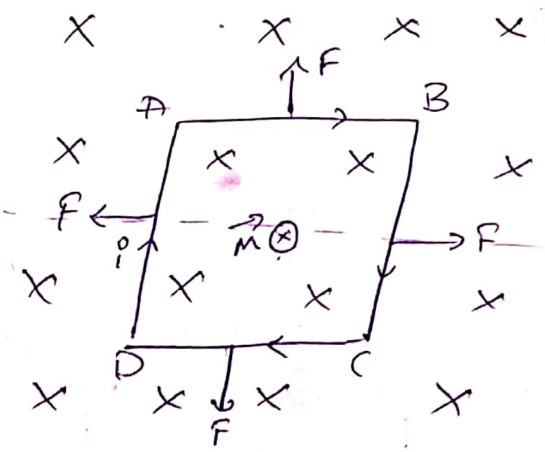


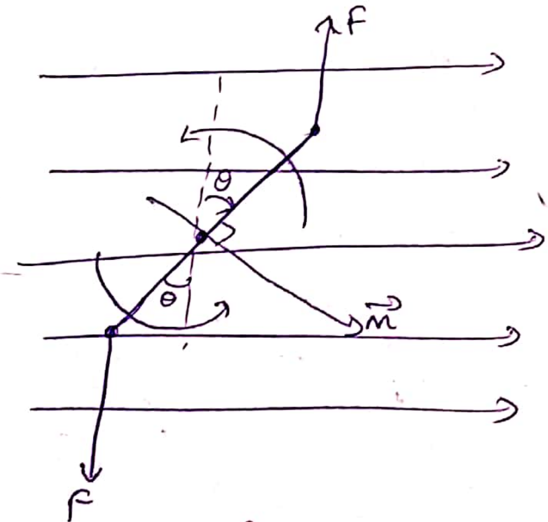
$\frac{|\vec{M}|}{L} = \frac{Q}{2m}$

$M = \frac{Q}{\cancel{2m}} \frac{\cancel{2} mR^2\omega}{5}$

$(\vec{M}) = \frac{QR^2\omega}{5}$

Force ~~actin~~ & Torque acting dipole in uniform $\vec{B}$:-





$F = i(LB\sin 90)$

$F = iLB$

$\tau_{net} = F\left(\frac{L}{2}\sin\theta\right) + F\left(\frac{L}{2}\sin\theta\right)$

$= FL\sin\theta$

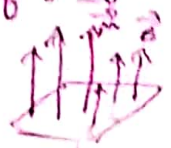
$\tau_{net} = (iLB)(L\sin\theta)$

$\boxed{\text{Energy stored in magnetic dipole} = -\vec{M}\cdot\vec{B}}$

$\boxed{\tau_{net} = MB\sin\theta}$

$\boxed{\tau = \vec{M}\times\vec{B}}$

If $\theta = 0$



$\tau = MB\sin 0° = 0$

$U = -\vec{M}\cdot\vec{B}$

$= -MB\cos 0$

$\boxed{U_{min} = -MB}$

stable equilibrium

If $\theta = 180°$

$\tau = MB\sin 180°$
$= 0$

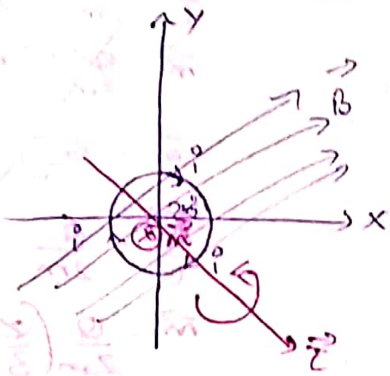
$U = -\vec{M}\cdot\vec{B}$

$U = -MB\cos 180°$

$\boxed{U_{max} = MB}$

unstable equilibrium

Q)



$\vec{M} = -\pi r^2 i\,\hat{k}$

$\vec{B} = B_0(\hat{i} + \hat{j})$

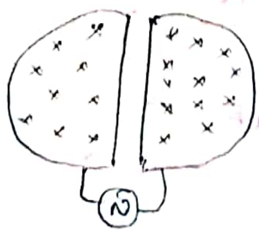
$\vec{\tau} = \vec{M} \times \vec{B} = \cancel{\pi r^2 i B_0 (-\hat{j})}$

$|\vec{\tau}| = MB\sin 90°$

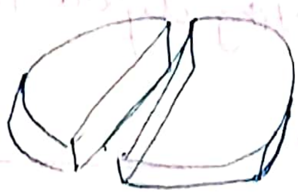
$|\vec{\tau}| = \pi r^2 B$

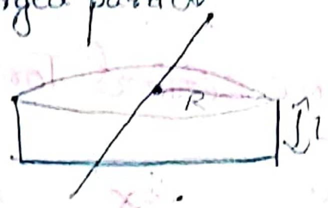
Cyclotron

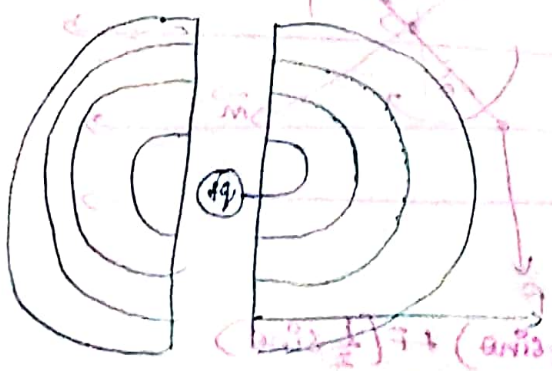
→ used to speed up the charged particle

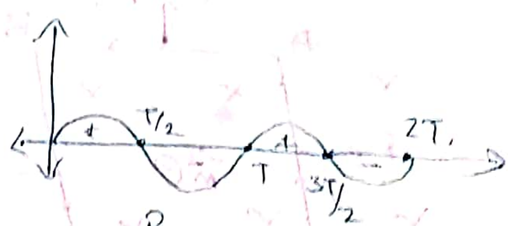


$E = E_0 \sin\omega t$









$0 - T/2$ $\quad$ $T/2 - T$

Time taken to change the polarity

= time spend by charged particle

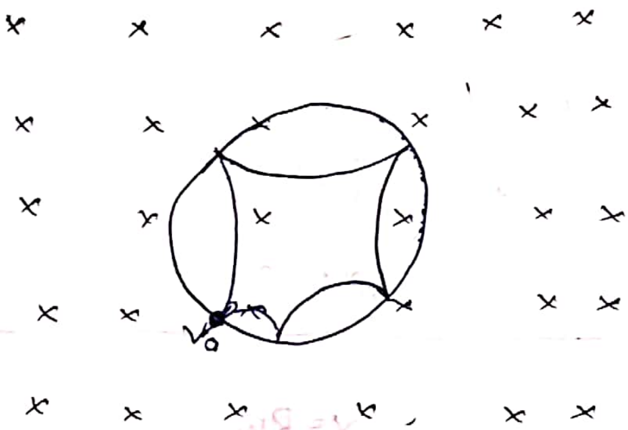
$\frac{T}{2} = \frac{2\pi m}{qB/2}$ $\quad$ $T = \frac{2\pi m}{qB}$

$2\pi/\omega_a = \frac{\pi m}{qB}$

wave frequency $= \omega_0 = \frac{qB_0}{m}$ = angular velocity of charged particle

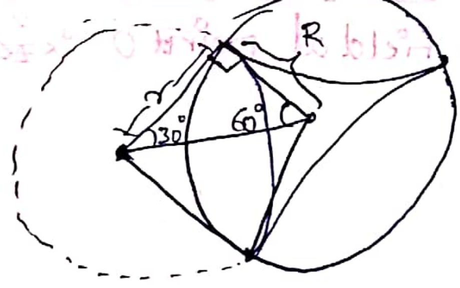
---

Q) A non-conducting cylindricall shell of radius R is placed in uniform magnetic field. The axis of the cylinder is parallel to the direction of magnetic field. A hole is drilled in cylinder and a particle having charge q and mass m is projected with velocity v_0 perpendicular to magnetic field and directed towards the axis of cylinder as shown in figure. The particle colloids elastically with the wall of cylinder and rebounds.



As it is elastic the total path will be symmetric.

① Minimum no of collission to come out will be ②



② $\frac{1}{\sqrt{3}} = \frac{R}{r}$

$r = R\sqrt{3}$

$\frac{mv_0}{qB} = R\sqrt{3}$

$v_0 = \frac{(R\sqrt{3})qB}{m}$ [∵ Maximum speed]

③ Minimum time

Angle rotated $= 60^0$

$t_{i\,collission} = \frac{\pi/3}{\omega}$

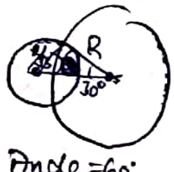
$= \frac{\pi m}{3qB}$

$t_{total} = 3t_{collis.} = \frac{\pi m}{qB}$

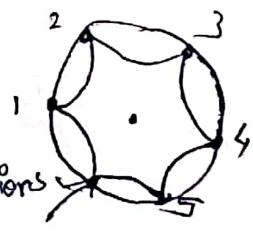
④ If particle is projected with velocity $v_0/3$

$r = \frac{mv_0}{3qB} = \frac{(R\sqrt{3})qB\, \cancel{m}}{\cancel{m}\, 3qB}$

$r = \frac{R}{\sqrt{3}}$



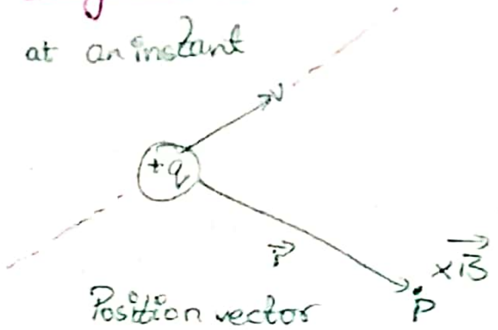
Angle = 60°



5 collisions

Magnetic field due to moving charges

at an instant



Position vector should be drawn from a charge to point P

$$\boxed{d\vec{B} = \frac{\mu_0 q}{4\pi}\left(\frac{\vec{v}\times\hat{r}}{r^2}\right)}$$

$$\boxed{d\vec{B} = \frac{\mu_0 q}{4\pi}\left(\frac{\vec{v}\times\vec{r}}{r^3}\right)}$$

If $\vec{v}$ and $\vec{r}$ are parallel to each other

$|d\vec{B}| = 0$

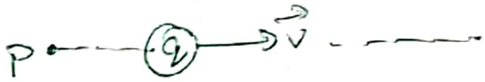
If $\vec{v}$ and $\vec{r}$ are antiparallel to each other

$|d\vec{B}| = 0$

μ_0 = permittivity of free space

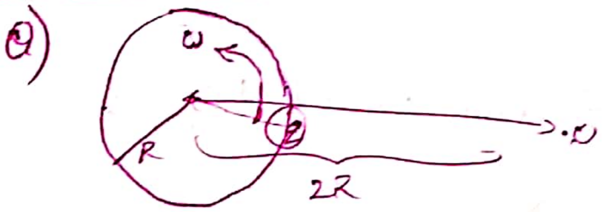
$\frac{\mu_0}{4\pi} = 10^{-7}$ | B → Tesla (or) Wb/m^2

$|d\vec{B}| = 0$



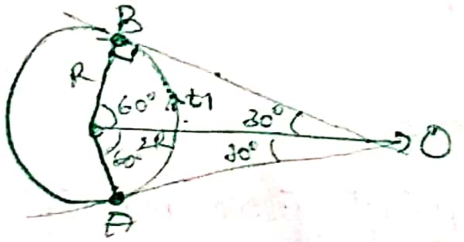
$|d\vec{B}| = 0$

Q)



$v = R\omega$

Find min time interval b/w two instants at which magnetic ~~find~~ field at point O is zero



$\frac{240}{360} \times \frac{2\pi}{\omega} = \frac{2\pi}{3\omega}$

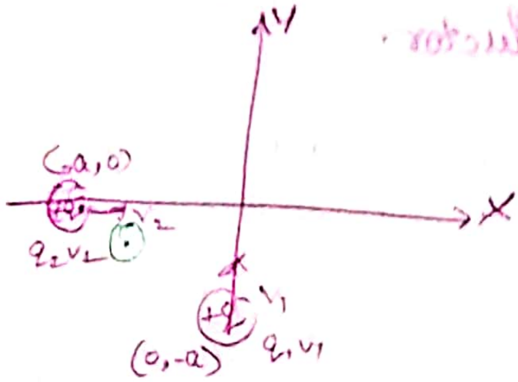
A→B ACW

$t = \frac{2\pi}{3\omega}$ → min.

B→A ACW

$t = \frac{4\pi}{3\omega}$

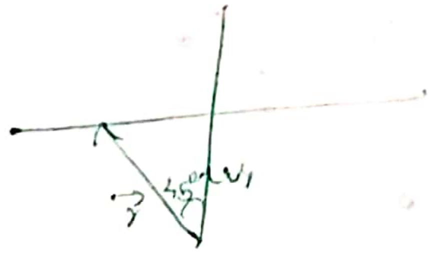
Q)



At given instant find the force acting on q_2 by q_1? (Neglect Electrostatic force)

$v_1\hat{i} \times a\hat{i} - a\hat{j}$

$\frac{\mu_0 q_1}{4\pi} \; \frac{-v_1 a\hat{k}}{a^2}$



$$B = \frac{\mu_0 q}{4\pi}\left(\frac{\vec{v}\times\hat{r}}{r^2}\right)$$

$$= \frac{\mu_0 q_1}{4\pi}\left(\frac{v_1 \times 1 \times \sin 45}{2a^2}\right)$$

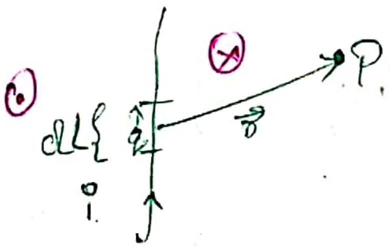
$$\vec{B} = \frac{\mu_0 q_1 v_1}{8\sqrt{2}\pi a^2}\,\hat{k} \; \odot$$

$$F_{on\,q_2} = q_2 v_2 B$$

$$= q_2 v_2 \frac{\mu_0 q_1 v_1}{8\sqrt{2}\pi a^2}(-\hat{j})$$

$$F_{on\,q_2} = \frac{\mu_0 q_1 q_2 v_1 v_2}{8\sqrt{2}\pi a^2}(-\hat{j})$$

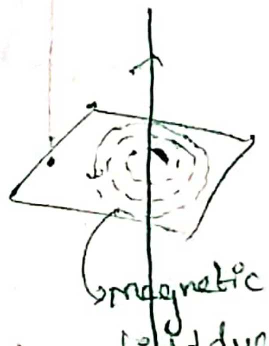
Magnetic field due to current carrying conductors.



$$\vec{dB} = \frac{\mu_0 q}{4\pi}\left(\frac{\vec{v}\times\hat{r}}{r^2}\right)$$

$$\vec{dB} = \frac{\mu_0 q}{4\pi}\left(\frac{\frac{d\vec{l}}{dt}\times\hat{r}}{r^2}\right)$$

$$\vec{dB} = \frac{\mu_0 \frac{q}{dt}}{4\pi}\,\frac{(d\vec{L}\times\hat{r})}{(r^2)}$$



magnetic field due to closed loop

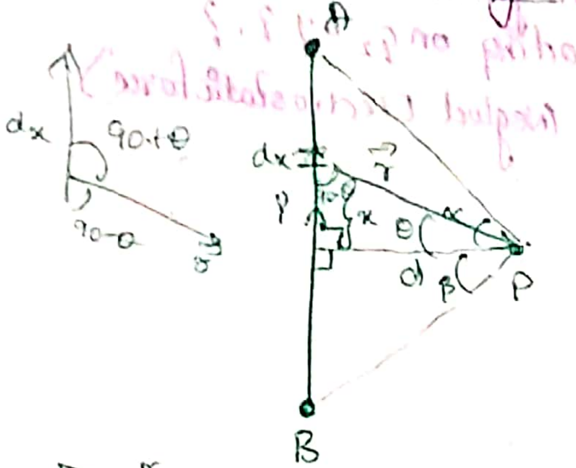
$\vec{dL} \rightarrow$ should be taken along the direction of current

Biosavarts Law

$$\boxed{\vec{dB} = \frac{\mu_0 i}{4\pi}\left(\frac{d\vec{L}\times\hat{r}}{r^2}\right)}$$

Scanned with CamScanner

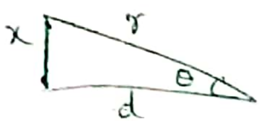
$\vec{B}$ due to finite straight conductor



Magnetic field due to small part at point P is

$$|d\vec{B}| = dB = \frac{\mu_0 i}{4\pi}\left(\frac{\vec{dx} \times \hat{r}}{r^2}\right)$$

$$\frac{\mu_0 i}{4\pi}\left(\frac{dx \cdot \sin(90+\theta)}{r^2}\right)$$



$$|d\vec{B}| = \frac{\mu_0 i}{4\pi}\left(\frac{dx \cdot \cos\theta}{r^2}\right)$$

~~$x = r\sin\theta$~~

$x = d\tan\theta$ $\quad r = \frac{d}{\cos\theta} = d\sec\theta$ $\quad (d\vec{B}) = \frac{\mu_0 i}{4\pi}\left(\frac{d\sec^2\theta\, d\theta \cos\theta}{d^2\sec^2\theta}\right)$

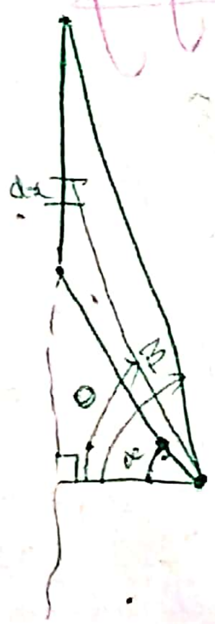
$dx = d\sec^2\theta\, d\theta$

$$\int d\vec{B} = \frac{\mu_0 i}{4\pi}\int_{-\beta}^{\alpha}\left(\frac{\cos\theta\, d\theta}{d}\right)$$

$$\vec{B} = \frac{\mu_0 i}{4\pi d}\left(\sin\theta\right]_{-\beta}^{\alpha}$$

$$\boxed{\vec{B} = \frac{\mu_0 i}{4\pi d}(\sin\alpha + \sin\beta)}$$

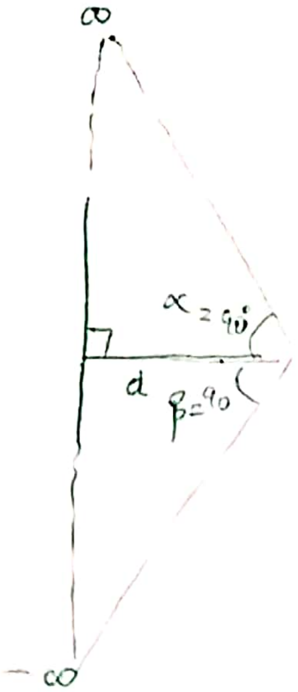
→ If point P is not infront of wire



$$B = \frac{\mu_0 i}{4\pi d}\int_{\alpha}^{\beta}\cos\theta\, d\theta$$

$$= \frac{\mu_0 i}{4\pi d}[\sin\beta - \sin\alpha]$$

$\vec{B}$ due to infinite wire



$$\vec{B} = \frac{\mu_0 i}{4\pi d}[1+1]$$

$$\vec{B} = \frac{\mu_0 i}{2\pi d}$$

$\vec{B}$ due to semi infinite rod

$$\vec{B} = \frac{\mu_0 i}{4\pi d}[1+0]$$

$$\vec{B} = \frac{\mu_0 i}{4\pi d}$$

$\vec{B}$ due to semifinite rod:

$$B = \frac{\mu_0 i}{4\pi d}(\sin\alpha + \sin 90^\circ)$$

$$\vec{B} = \frac{\mu_0 i}{4\pi d}(1+\sin\alpha)$$

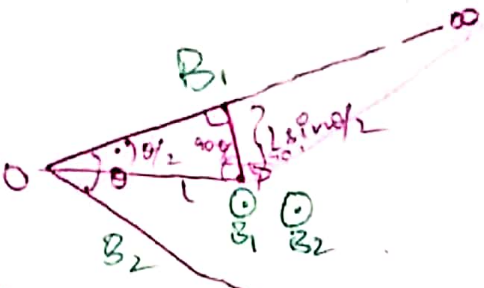
Q) 

Find magnetic field induction at the centre of square.

$$B_{AB} = \frac{\mu_0 i}{4\pi a/2}(\sin 45 + \sin 45)$$

$$B_{AB} = \frac{\mu_0 i}{2\pi a}\frac{2}{\sqrt{2}} = \frac{\mu_0 i}{\sqrt{2}\pi a}$$

$$B_{total} = \frac{4\mu_0 i}{\sqrt{2}\pi a} = \frac{2\sqrt{2}\mu_0 i}{\pi a}$$

Q) 

Find the magnetic field induction at point

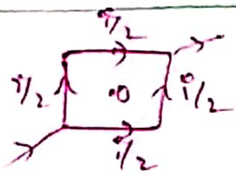
$$d = L\sin\theta/2$$

$$B_1 = \frac{\mu_0 i}{4\pi d}\left(\sin(90-\theta/2) + \sin 90\right)$$

$$= \frac{\mu_0 i}{4\pi L\sin\theta/2}\left(\cos\theta/2 + 1\right)$$

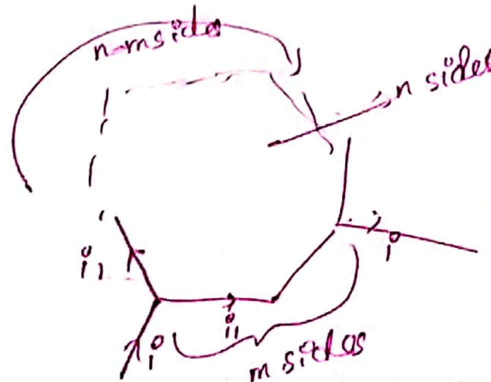
$$B_1 = \frac{\mu_0 i}{4\pi L}\left(\cot\theta/2 + \operatorname{cosec}\theta/2\right)$$

$$B_{total} = \frac{\mu_0 i}{2\pi L}\left(\cot\theta/2 + \operatorname{cosec}\theta/2\right)$$

Q) 

All sides are having equal resistance. Find the magnetic field induced at centre O is

Zero

Q) 

Each side is having same resistance.

$$i_1 = \frac{n-m}{n} i$$

$$i_2 = \frac{m}{n} i$$

Net magnetic field due to m sides is

$$B_1 \propto i_1(m)$$

$$B_1 \propto \frac{(n-m)m}{n} i$$

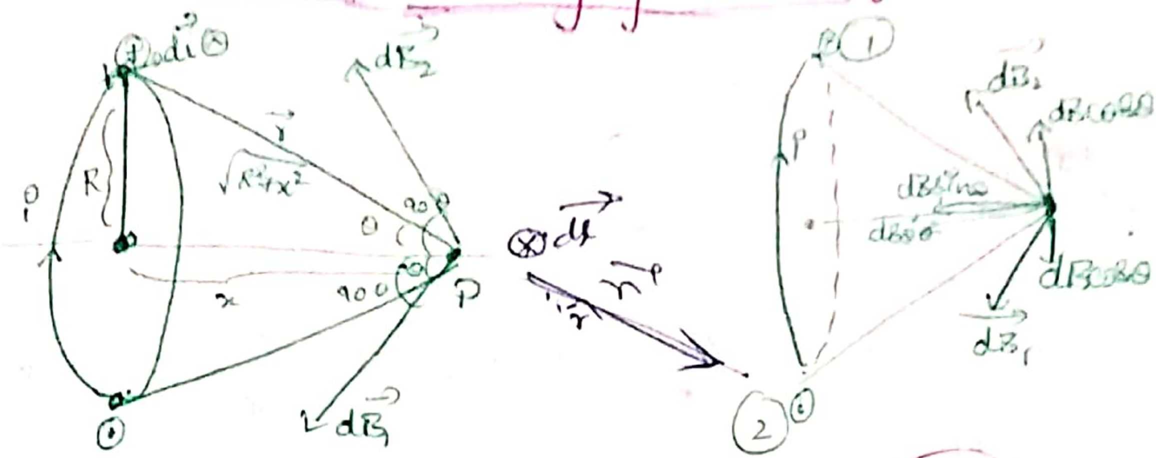
Net magnetic field due to n-m sides

$$B_2 \propto i_2(n-m)$$

$$B_2 \propto \frac{m(n-m)}{n} i$$

Net Magnetic field at centre is zero

$\vec{B}$ due to circular current carrying conductor :-



$$|d\vec{B}| = \frac{\mu_0 i}{4\pi}\left(\frac{dl \cdot 1 \cdot \sin 90}{r^2}\right)$$

$$= \frac{\mu_0 i}{4\pi}\left(\frac{dL}{R^2+x^2}\right)$$

Net Magnetic field due to circular wire

$$B_{net} = \int dB \sin\theta$$

$$B_{net} = \frac{\mu_0 i}{4\pi(R^2+x^2)}\int dl \frac{R}{\sqrt{R^2+x^2}}$$

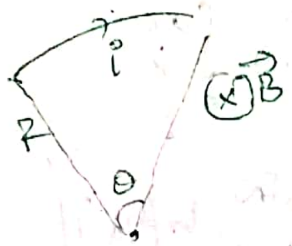
$$B_{net} = \frac{\mu_0 i R}{4\pi(R^2+x^2)^{3/2}}(2\pi R)$$

$$\boxed{B_{net} = \frac{\mu_0 i R^2}{2(R^2+x^2)^{3/2}}}$$

If wire has n loops then the total magnetic fied will be nB_{net}

$$= \frac{\mu_0 n i R^2}{2(R^2+x^2)^{3/2}}$$

$\vec{B}$ due to sector :- (or) arc



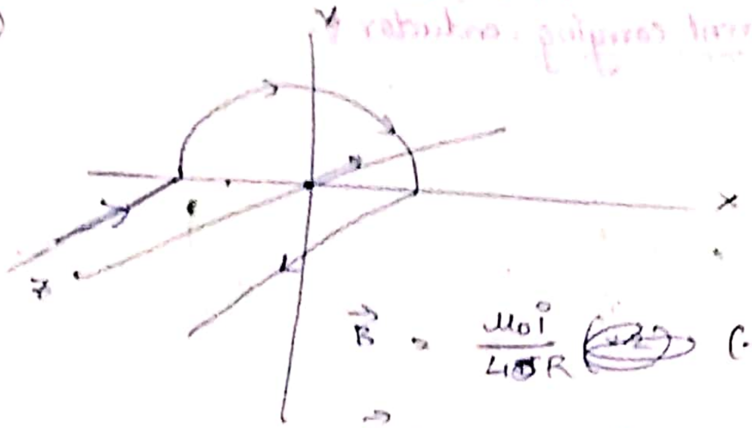
$$\frac{\mu_0 i}{2R} \to 2\pi$$

$$? \to \theta$$

$$B = \frac{\theta}{2\pi}\left(\frac{\mu_0 i}{2R}\right)$$

$$\boxed{B = \frac{\mu_0 i \theta}{4\pi R}}$$

Q) Find magnetic field ...

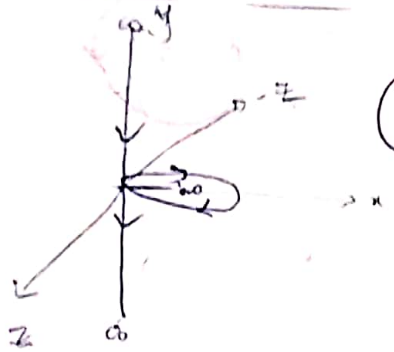


$$\vec{B} = \frac{\mu_0 i}{4\pi R}(-\hat{k}) + \left(\frac{\mu_0 i}{4\pi R}\right)2\,(-\hat{j})$$

$$\vec{B} = -\frac{\mu_0 i}{4\pi R}\left(\hat{k} + 2\hat{j}\right)$$

$$|\vec{B}| = -\frac{\sqrt{5}\,\mu_0 i}{4\pi R}$$

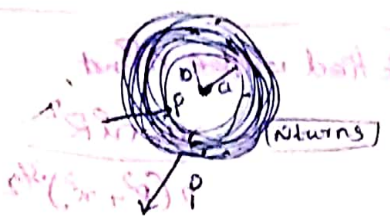
a)



$$\left(\frac{\mu_0 i}{4\pi R}\right)2 = \frac{\mu_0 i}{2R}$$

$$\vec{B} = \left(\frac{\mu_0 i}{4\pi R}\right)2\,(-\hat{k}) + \frac{\mu_0 i}{2R}(-\hat{j})$$

Q)



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

$$dB = \frac{\mu_0 i}{2x}dx$$

$$\vec{dB} = \frac{\mu_0 i\,(b-a)}{2x\,N}dx$$

$$\vec{dB} = \frac{\mu_0 i}{2x}\frac{N\,dx}{b-a}$$

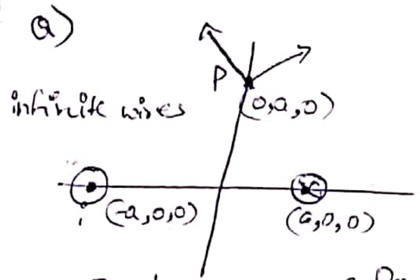
$b-a \rightarrow N$ turns

$dx \rightarrow ?$

$$\int \vec{dB} = \frac{\mu_0 i N}{2(b-a)}\int_a^b \frac{dx}{x}$$

$$\boxed{\vec{B} = \frac{\mu_0 i N}{2(b-a)}\ln(b/a)}$$

Q)



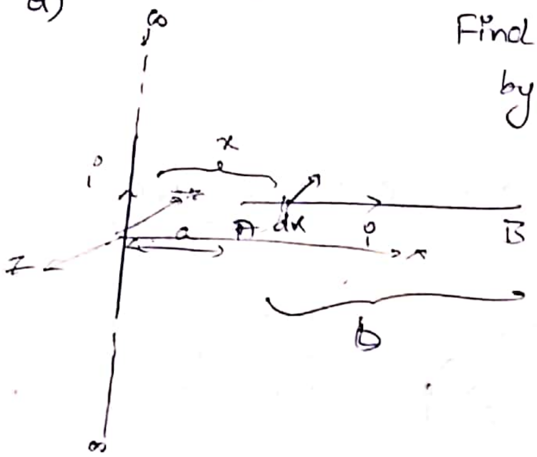
Find the magnetic field at P

$\frac{\mu_0 i}{4\pi a}$

$\sqrt{2}\,\frac{\mu_0 i}{2\,4\pi(\sqrt{2}a)} = \frac{\mu_0 i}{2\,4\pi a}(+\hat{j})$

Q)

Find the force acting on AB wire by infinite.



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

$dF = i\,dx\,\frac{\mu_0 i}{2\pi \cdot x}$

$\vec{F} = \frac{\mu_0 i^2}{2\pi}\left[\ln x\right]_a^{a+b}$

$F = \frac{\mu_0 i^2}{2\pi} \ln \frac{b+a}{a} \; (+\hat{k})$

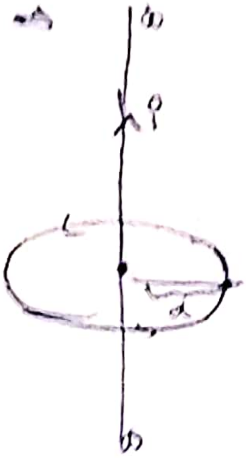
Ampere's Law

To find out magnetic field

It states that line integral of magnetic field along closed loop is always equal to μ_0 times of current enclosed.

$$\oint \vec{B}\cdot\vec{dl} = \mu_0\left[i_{enclosed}\right]$$

$\oint \vec{B}\cdot\vec{dl} = \mu_0(i - 2i) = -\mu_0 i$



By ampere circuital law

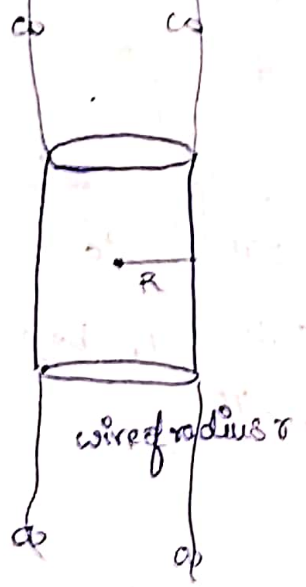
$$\oint \vec{B}\cdot\vec{dl} = \mu_0(i_{enclosed})$$

$$\vec{B}\oint \vec{dl} = \mu_0 i$$

$$\vec{B}(2\pi d) = \mu_0 i$$

$$\vec{B} = \frac{\mu_0 i}{2\pi d}.$$

★ $\vec{B}$ at a point on the surface of the wire



Take a loop which coincides with the radius of circle of wire.

$$\int \vec{B}\cdot\vec{dl} = \mu_0 i$$

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

$\vec{B}$ at a point inside the wire

$$\int \vec{B}\,\vec{dl} = \mu_0 \frac{i}{\pi R^2}\pi r^2$$

$l = 2\pi x$

$\cancel{dl = 2\pi dx}$

$$2\pi\vec{B}\int dl = \mu_0 \frac{i}{\cancel{\pi}R^2}x^2$$

$$2\pi\vec{B}\int\frac{dx}{x^2} = \frac{\mu_0 i x^2}{R^2} \Rightarrow 2\pi\vec{B}\,\cancel{2\pi x = \frac{\mu_0 i x^2}{R^2}}$$

$$\cancel{\vec{B}\left[\frac{-1}{x}\right]_0 = \frac{\mu_0 i}{2\pi R^2}}$$

$B(2\pi R) = \mu_0 i$

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

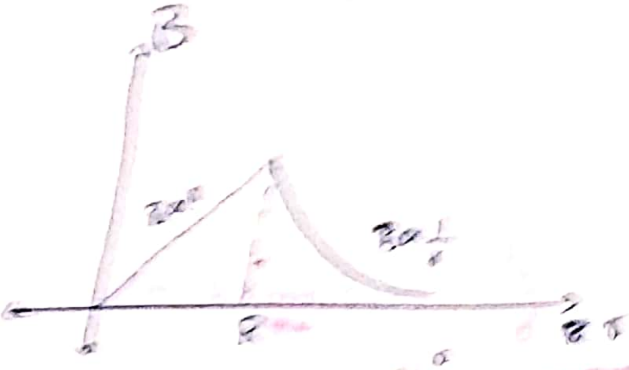
$B \oint dl = \frac{\mu_0 i r^2}{R^2}$

$B(2\pi r) = \frac{\mu_0 i r^2}{R^2}$

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

$\boxed{B \propto r}$

$B_{center} = 0$



$B_{max} = \frac{\mu_0 i}{2\pi R}$

Variable current density

$J = J_0 \left(1 - \frac{r}{R}\right)$

$r \to$ distance from the axis of wire to the point

$i = J \times Area$

$= J_0\left(1 - \frac{x}{R}\right) 2\pi x \, dx$

$di = J_0 \left(x - \frac{x^2}{R}\right) 2\pi \, dx$

$\int di = J_0 2\pi \int_0^r x - \frac{x^2}{R} \, dx$

$i = J_0 2\pi \left(\frac{r^2}{2} - \frac{r^3}{3R}\right)$

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

$= \frac{\mu_0 J_0 2\pi \left(\frac{r^2}{2} - \frac{r^3}{3R}\right)}{2\pi r}$

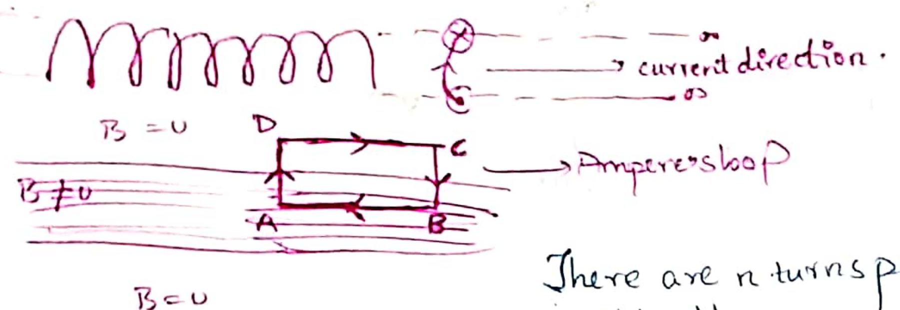
$\boxed{B = \mu_0 J_0 \left(\frac{r}{2} - \frac{r^2}{3R}\right)}$ $r < R$

if $r = R/2$, $B = \mu_0 J_0 \left(\frac{R}{4} - \frac{R^2}{12R} \right)$

$= \mu_0 J_0 \left(\frac{R}{6} \right)$

$$\boxed{B = \frac{\mu_0 J_0 R}{6}}$$

Magnetic field in a long solenoid. (infinitelong) :-



There are n turns per unit length

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 i_{enclosed}.$$

$$\underbrace{\int_A^D \vec{B} \cdot \vec{dl}}_{0} + \underbrace{\int_D^C \vec{B} \cdot \vec{dl}}_{0} + \underbrace{\int_C^B \vec{B} \cdot \vec{dl}}_{0} + \int_B^A \vec{B} \cdot \vec{dl} = \mu_0 (n i l)$$

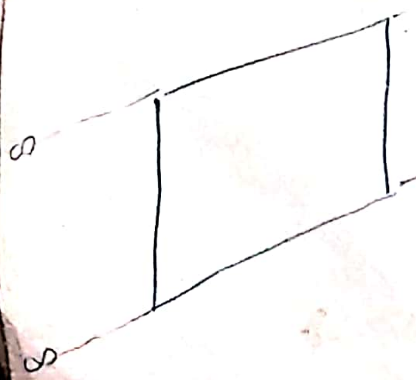
outside the wir

Both are in $\perp^{lar}$ ~~opposite direction~~

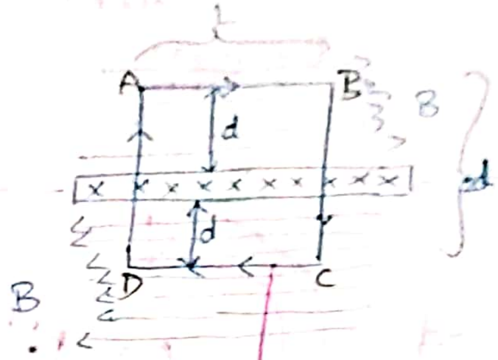
$B(l) = \mu_0 n i l$

$$\boxed{B = \mu_0 n i}$$

Magnetic field due to infinitely long current carrying sheet



Take 'K' as current flown per unit length



Ampere's loop

$\oint \vec{B}\cdot d\vec{l} = \mu_0 (I_{enclosed})$

$\int_{AB} \vec{B}\cdot d\vec{l} + \int_{BC} \vec{B}\cdot dl + \int_{CD} \vec{B}\cdot d\vec{l} + \int_{DA} \vec{B}\cdot dl = \mu_0 K l$

0

Both are $\perp^{lar}$ to magnetic field.

$Bl + Bl = \mu_0 K l$

$$\boxed{B = \frac{\mu_0 K}{2}}$$

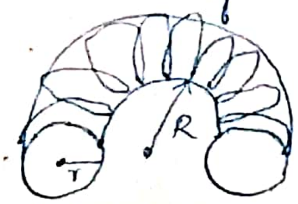
independent of distance.

Toroid :-

Field lines inside a toroid.

concentric circles are field lines.

If half of it is cut, we get.



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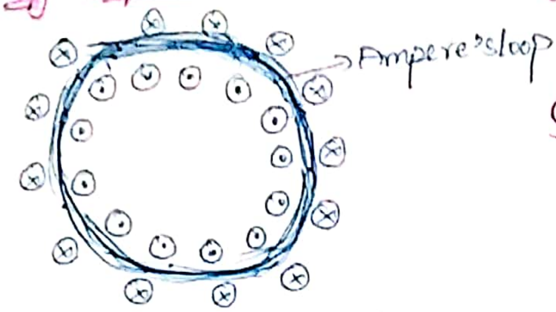
B inside Toroid if $r <<<< R$

By Ampere's law

N - No. of turns of spring like structure

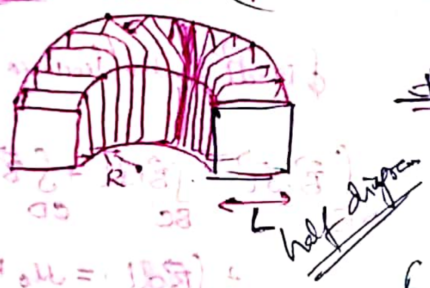


$$\oint \vec{B}\cdot d\vec{l} = \mu_0 (i_{enclosed})$$

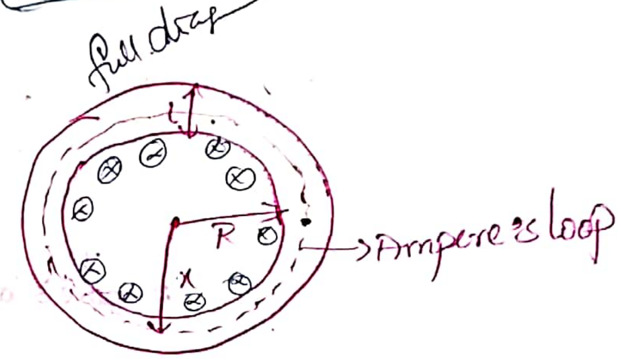
$$B(2\pi R) = \mu_0 N i$$

$$\boxed{B = \frac{\mu_0 N i}{2\pi R}}$$

Toroid with (square c.s)



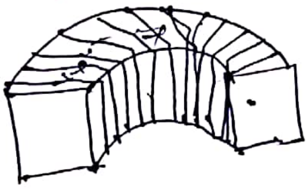
$\neq$



$$\oint \vec{B}\cdot d\vec{l} = \mu_0 \, i_{enclosed}$$

$$\cancel{B(4L)} \; B(2\pi x) = \mu_0 (Ni)$$

$$B = \frac{\mu_0 N i}{2\pi x}$$



B at inner edge $= \dfrac{\mu_0 N i}{2\pi R}$

B at outer edge $= \dfrac{\mu_0 N i}{2\pi (R+L)}$

If $L <<<< R$, $B \approx \dfrac{\mu_0 N i}{2\pi R}$

$\vec{B}$ inside the cavity

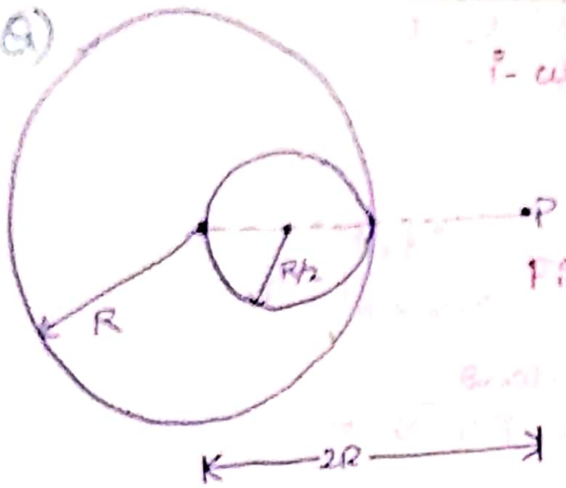
at P - B_P due to C_1 - B_P due to C_2

$= \frac{\mu_0}{2}(\vec{J}\times\vec{r_1}) - \frac{\mu_0}{2}(\vec{J}\times\vec{r_2})$

$= \frac{\mu_0}{2}(\vec{J}\times(\vec{r_1}-\vec{r_2}))$

$$\boxed{\vec{B} = \frac{\mu_0}{2}(\vec{J}\times\vec{C_1C_2})}$$

Q)



i - current carrying in the wire after cavity has been made.

Find B at 'P' due to remaining part.

$$J = \frac{i}{\pi R^2 - \pi\left(\frac{R}{2}\right)^2} = \left(\frac{i}{\frac{3\pi R^2}{4}}\right) = J$$

$B_{at\,P} = B_{\text{without removing out}} - B_{\text{removed part}}$

$B_{\text{without removing}} \Rightarrow \mu_0 (J)(\pi R^2) = B(2\pi(2R))$

$\rightarrow B = \frac{\mu_0 J R}{4}$

$B_{\text{removed part}} \longrightarrow \mu_0 J\left(\frac{\pi R^2}{4}\right) = B\left(2\pi\left(\frac{3R}{2}\right)\right)$

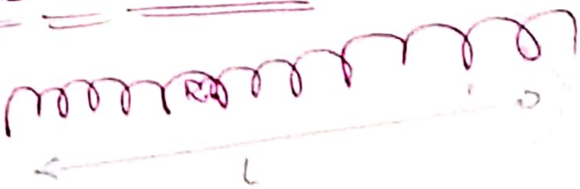
$\rightarrow B = \frac{\mu_0 J R}{12}$

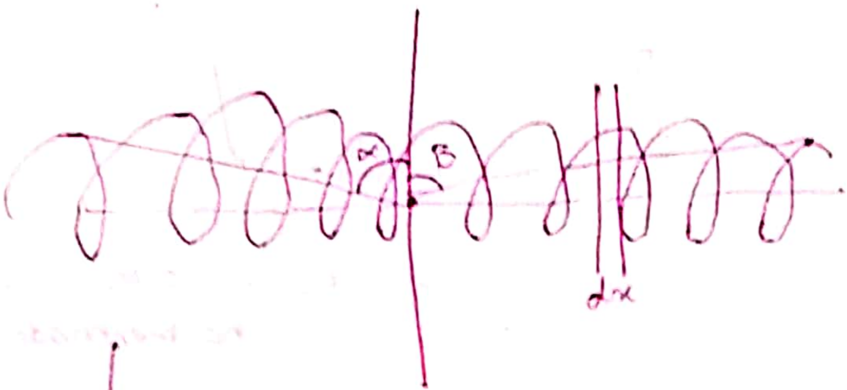
$$B_{at\,P} = \frac{\mu_0 J R}{4} - \frac{\mu_0 J R}{12} = \frac{\mu_0 J R}{6} = \frac{\mu_0 R}{6} \cdot \frac{i \times 4}{3\pi R^2} = \frac{2\mu_0 i}{9\pi R}$$

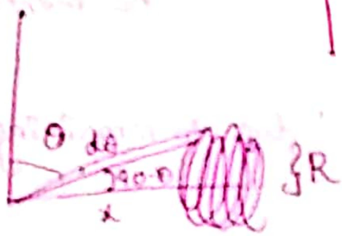
$$\boxed{B_{at\,P} = \frac{2\mu_0 i}{9\pi R}}$$

Magnetic field due to solenoid

No. of turn per unit length = n







$$dB = \frac{\mu_0 n i\, dx\, R^2}{2(x^2+R^2)^{3/2}}$$

$x = R\tan\theta$

$dx = R\sec^2\theta\, d\theta$

$$dB = \frac{\mu_0 n i R^2 R \sec^2\theta\, d\theta}{2R^3 \sec^3\theta}$$

$$\int dB = \frac{\mu_0 n i}{2}\int_{-\alpha}^{\beta} \cos\theta\, d\theta$$

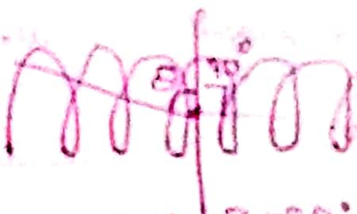
$$B_{net} = \frac{\mu_0 n i}{2}(\sin\alpha + \sin\beta)$$

→ If solenoid is infinitely long then, $\alpha = \beta = 90°$.

$$\boxed{B_{net\ inside} = \mu_0 n i}$$ $\vec{B}$ is uniform

→ If solenoid is semi-infinite then

$$\boxed{B_{net} = \frac{\mu_0 n i}{2}(1+\sin\theta)}$$



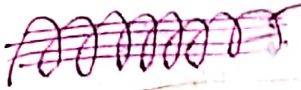
$\alpha = 0$ $\beta = 90°$

→ magnetic field at one end $= \frac{\mu_0 n i}{2}(\sin 0 + \sin 90)$

$= \frac{\mu_0 n i}{2}$

$\alpha = 0$, $\beta = 90°$

→ If medium of solenoid is changed other than vaccum then.

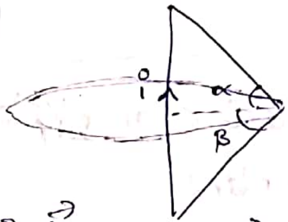


→ μ_r = relative permeability

$\mu_r = \frac{\mu_{medium}}{\mu_0}$.

$$\boxed{B = \frac{\mu_r \mu_0 n i}{2}(\sin\alpha + \sin\beta)}$$

Q) Find $\oint \vec{B}\cdot\vec{dl}$ around the wire?

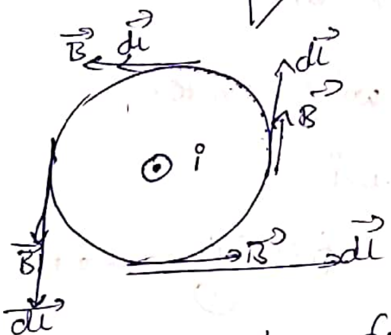


$B = \frac{\mu_0 i}{4\pi d}(\sin\alpha + \sin\beta)$

$\oint \vec{B}\,\vec{dl} = B\int dl\cos 0°$

$= \frac{\mu_0 i}{4\pi d}(\sin\alpha + \sin\beta)\,2\pi d$

$$\boxed{\oint \vec{B}\cdot\vec{dl} = \frac{\mu_0 i}{2}(\sin\alpha + \sin\beta)}$$



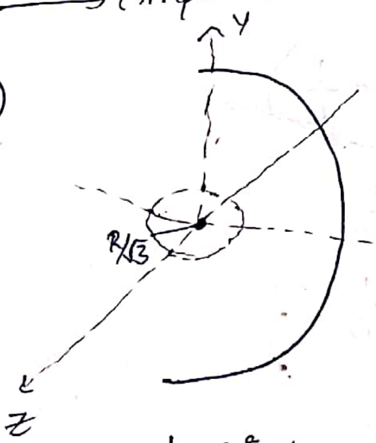
By ampere's law, $\oint \vec{B}\cdot\vec{dl} = \mu_0 i$ ✗

Note:-

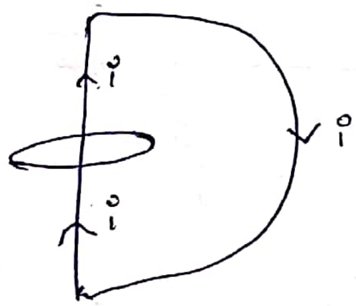
→ Ampere's law is applicable for infinitely current carrying conductors.

→ Ampere's law is valid for closed current carrying conductors.

Q) Find the $\oint \vec{B}\cdot\vec{dl}$ around given circle?



Apere's law can be applicable for closed loop. So, to solve first close the circuit.

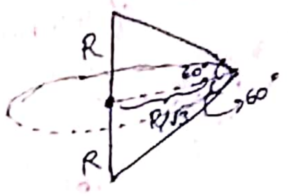


By amperes's law:-

$\oint \vec{B}\cdot\vec{dl} = \mu_0 i$

$\oint_{straight} \vec{B}\cdot\vec{dl} + \oint_{circular} \vec{B}\cdot\vec{dl} = \mu_0 i$

$$\oint_{(straight)} \vec{B}\cdot\vec{dL} = \frac{\mu_0 i}{2}(\sin\alpha + \sin\beta)$$

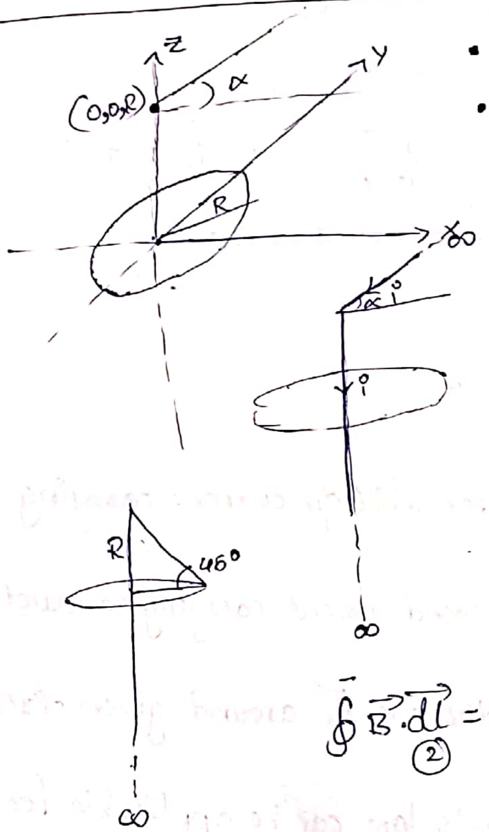


$$= \frac{\mu_0 i}{2}\left(\frac{\sqrt{3}}{2} + \frac{\sqrt{3}}{2}\right)$$

$$\boxed{\oint_{straight} \vec{B}\cdot\vec{dL} = \frac{\sqrt{3}\,\mu_0 i}{2}}$$

$$\boxed{\oint_{circular} \vec{B}\cdot\vec{dL} = \mu_0 i\left(1 - \frac{\sqrt{3}}{2}\right)}$$

Q)



- $\oint \vec{B}\cdot\vec{dl}$ along the circle on xyplane
- wire is in xz plane.

⟹ make the wire infinite.

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 i$$

$$\oint \vec{B}\cdot\vec{dl}_{1} + \oint \vec{B}\cdot\vec{dl}_{2} = \mu_0 i$$

$$\oint \vec{B}\cdot\vec{dl}_{1} = \frac{\mu_0 i}{2}(\sin 45^\circ + \sin 90^\circ)$$

$$= \frac{\mu_0 i}{2}\left(1 + \frac{1}{\sqrt{2}}\right)$$

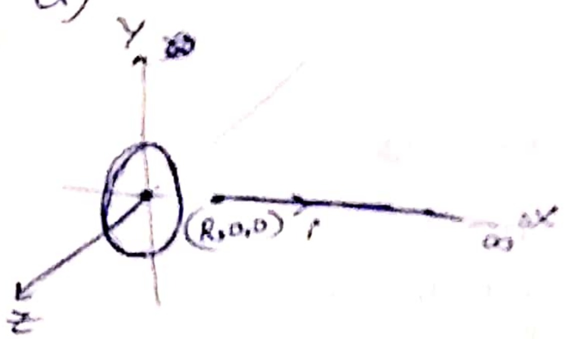
$$\oint \vec{B}\cdot\vec{dl}_{2} = \mu_0 i - \frac{\mu_0 i}{2}\left(1 + \frac{1}{\sqrt{2}}\right)$$

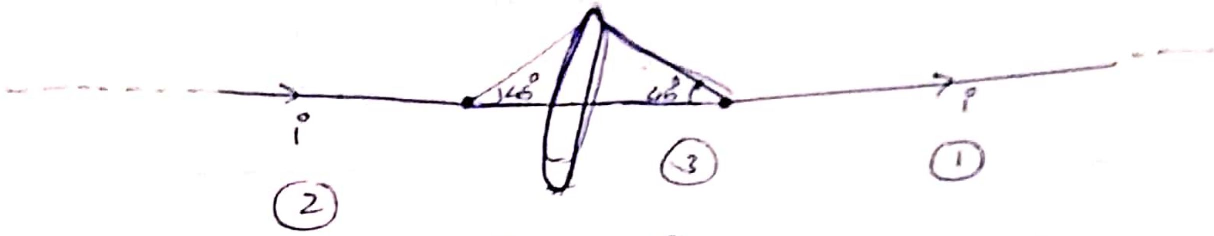
$$= \frac{\mu_0 i}{2} - \frac{\mu_0 i}{2\sqrt{2}}$$

$$\boxed{\oint \vec{B}\cdot\vec{dl}_{2} = \frac{\mu_0 i}{2}\left(1 - \frac{1}{\sqrt{2}}\right)}$$

Q)

Circle is in xz plane. Semi infinite wire is kept along x-axis. Find the $\oint \vec{B}\cdot d\vec{l}$ around the circle.





$$\oint \vec{B}\cdot d\vec{l}_{(1)} = \oint \vec{B}\cdot d\vec{l}_{(2)}$$

$$\oint \vec{B}\cdot d\vec{l}_{(1)} + \oint \vec{B}\cdot d\vec{l}_{(2)} + \oint \vec{B}\cdot d\vec{l}_{(3)} = \mu_0 i.$$

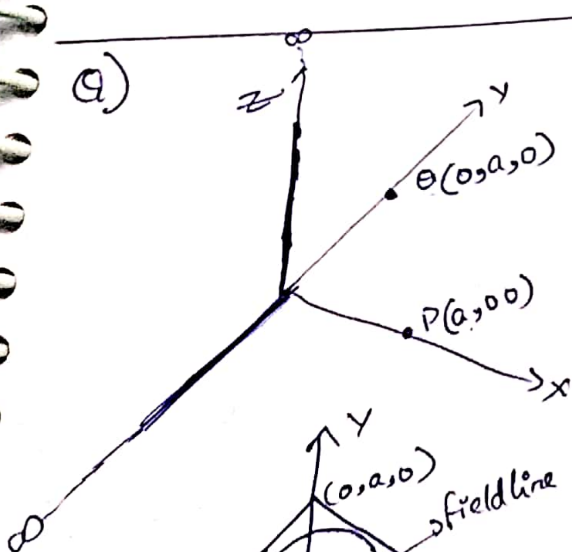
$$2\oint \vec{B}\cdot d\vec{l}_{(1)} + \frac{\mu_0 i}{2}\left(\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{2}}\right) = \mu_0 i$$

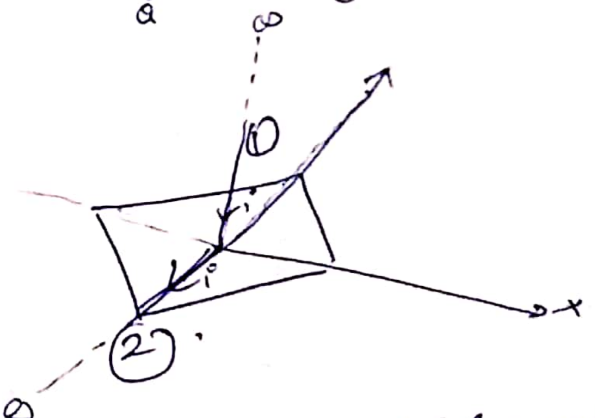
$$2\oint \vec{B}\, d\vec{l}_{(1)} = \mu_0 i - \frac{\mu_0 i}{\sqrt{2}}$$

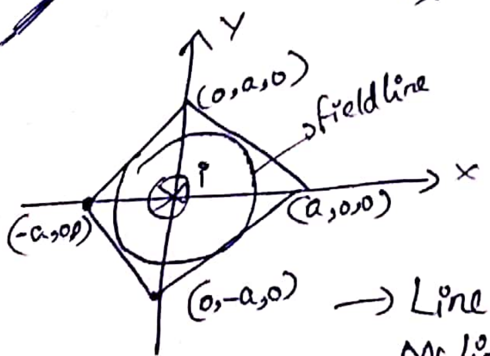
$$\vec{B}\, d\vec{l}_{(1)} = \frac{\mu_0 i}{2}\left(1-\frac{1}{\sqrt{2}}\right)$$

Q)

Find $\int_Q^P \vec{B}\cdot d\vec{l}$ along the line QP?







field magnitude is symmetrical 4 parts will have same line integral due ① part

→ Line integral dute to part ② is zero, as Mf lines ~~due to~~ because it its $\perp^{lar}$ to $d\vec{l}$.

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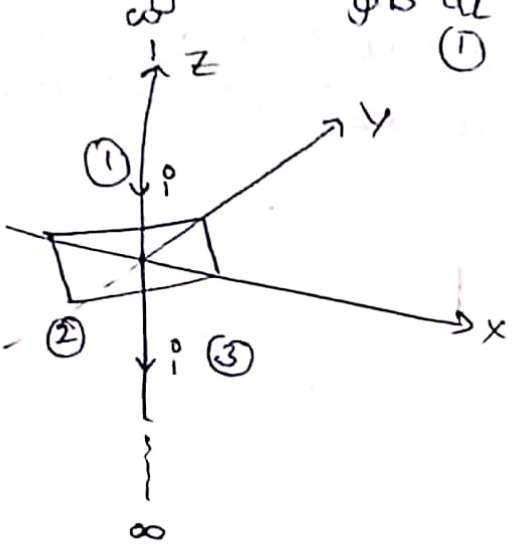
~~Line integral~~ :



$$\oint \vec{B}\cdot\vec{dL}_{(1)} = 4\int_a^P \vec{B}\cdot\vec{dL}$$

$$\oint \vec{B}\cdot\vec{dl}_{(1)} = \oint \vec{B}\cdot\vec{dl}_{(3)}$$

$$\oint \vec{B}\cdot\vec{dl}_{(1)} + \oint \vec{B}\cdot\vec{dl}_{(3)} = \mu_0 i$$

$$2\oint \vec{B}\cdot\vec{dl}_{(1)} = \mu_0 i$$

$$2\cdot 4\cdot \oint_a^P \vec{B}\cdot\vec{dl} = \mu_0 i$$

$$\boxed{\oint_a^P \vec{B}\cdot\vec{dl} = \frac{\mu_0 i}{8}}$$