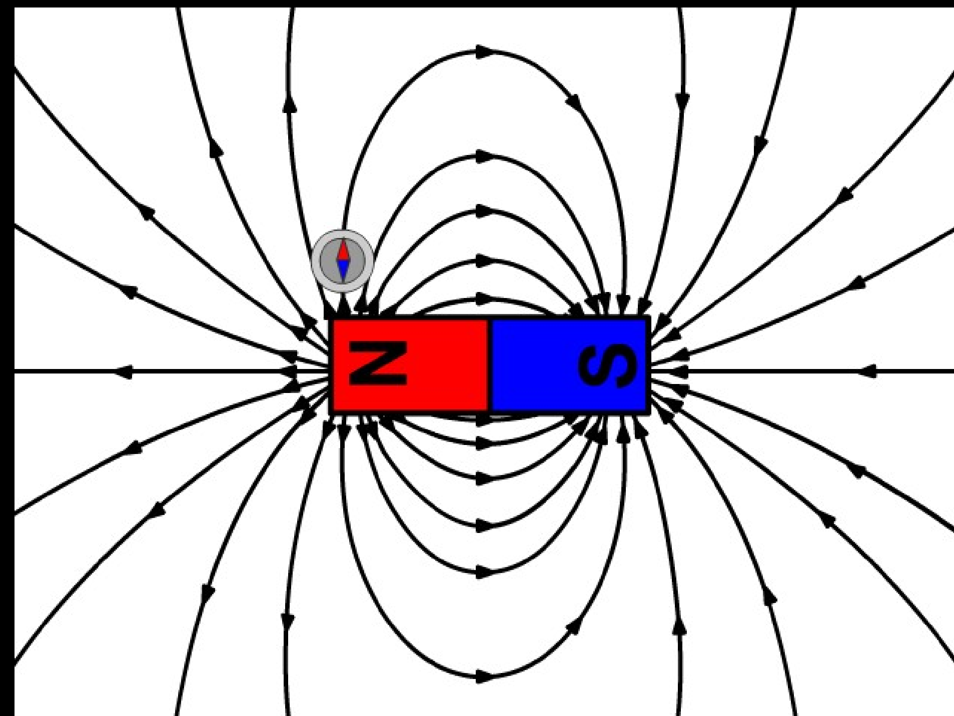
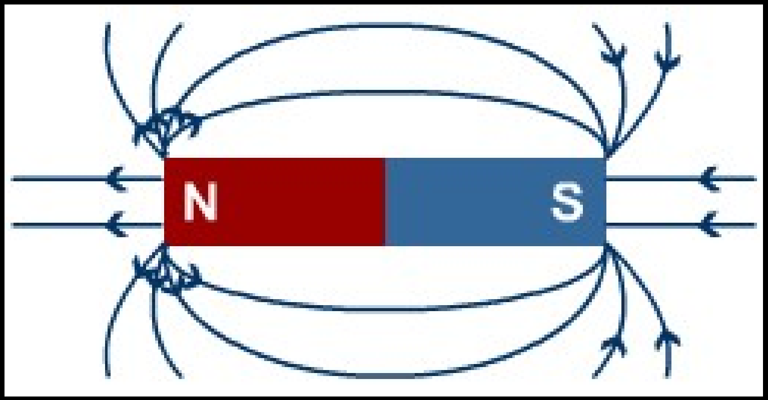
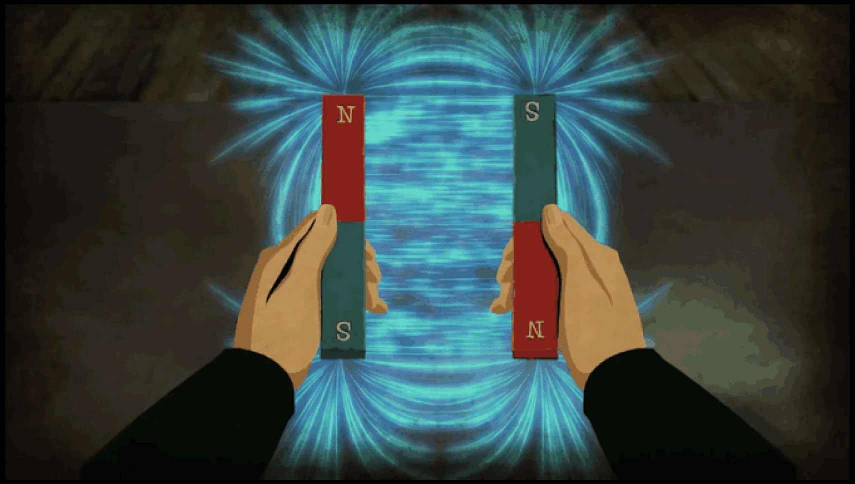
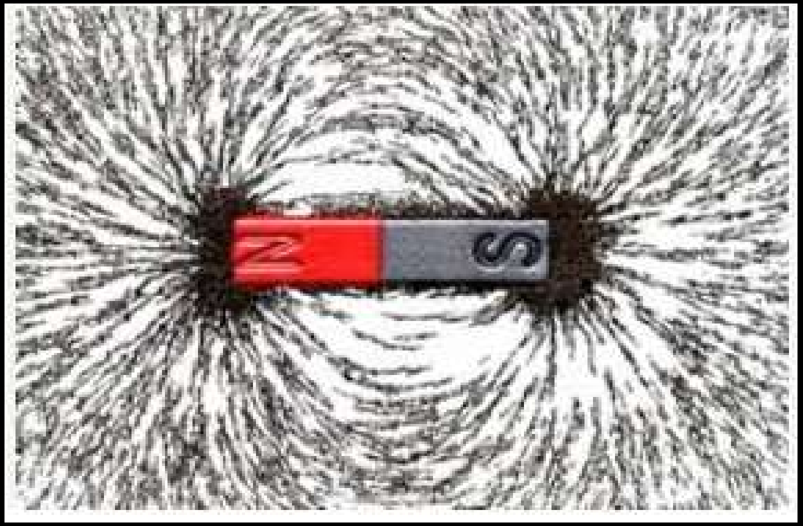
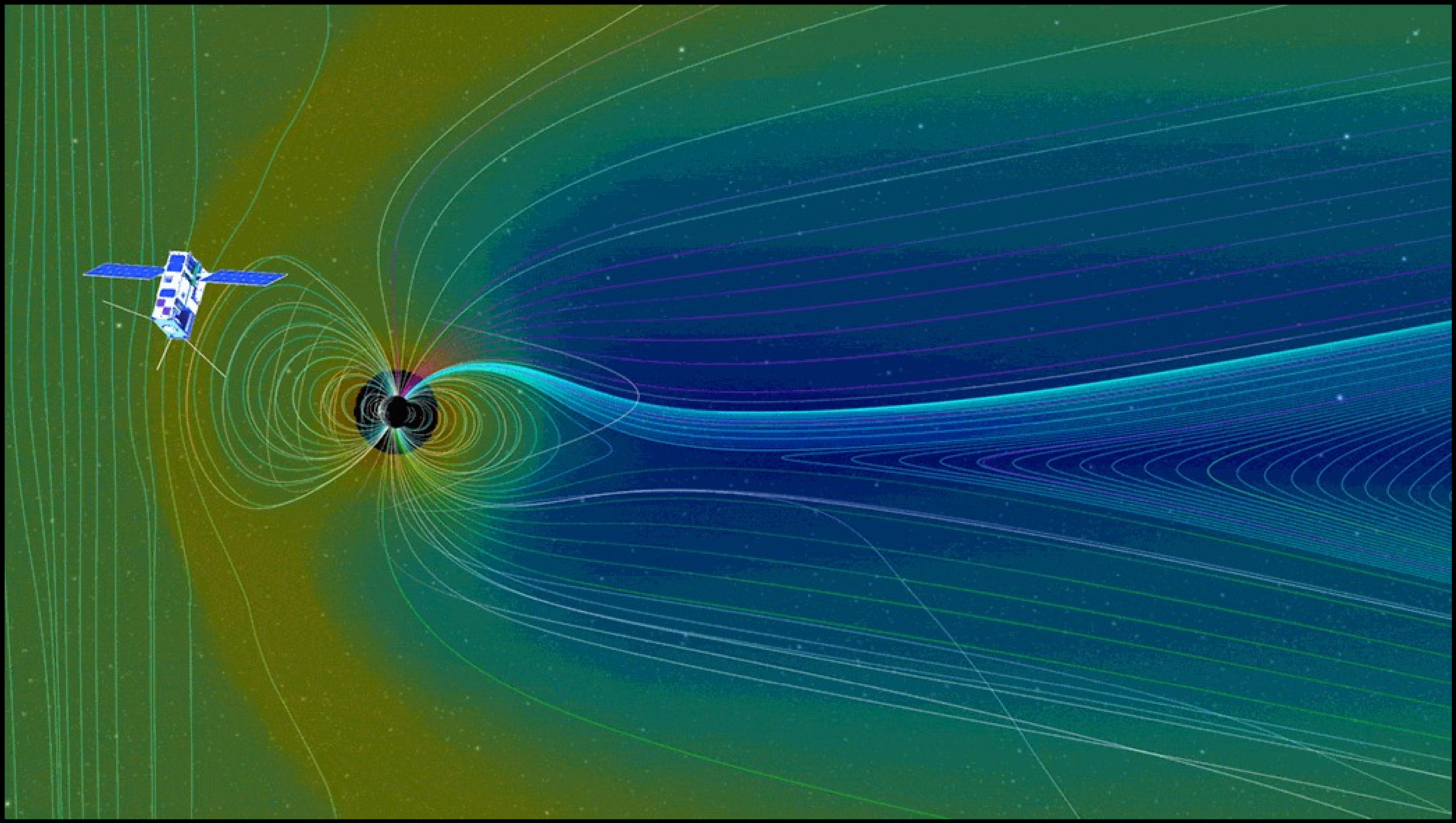
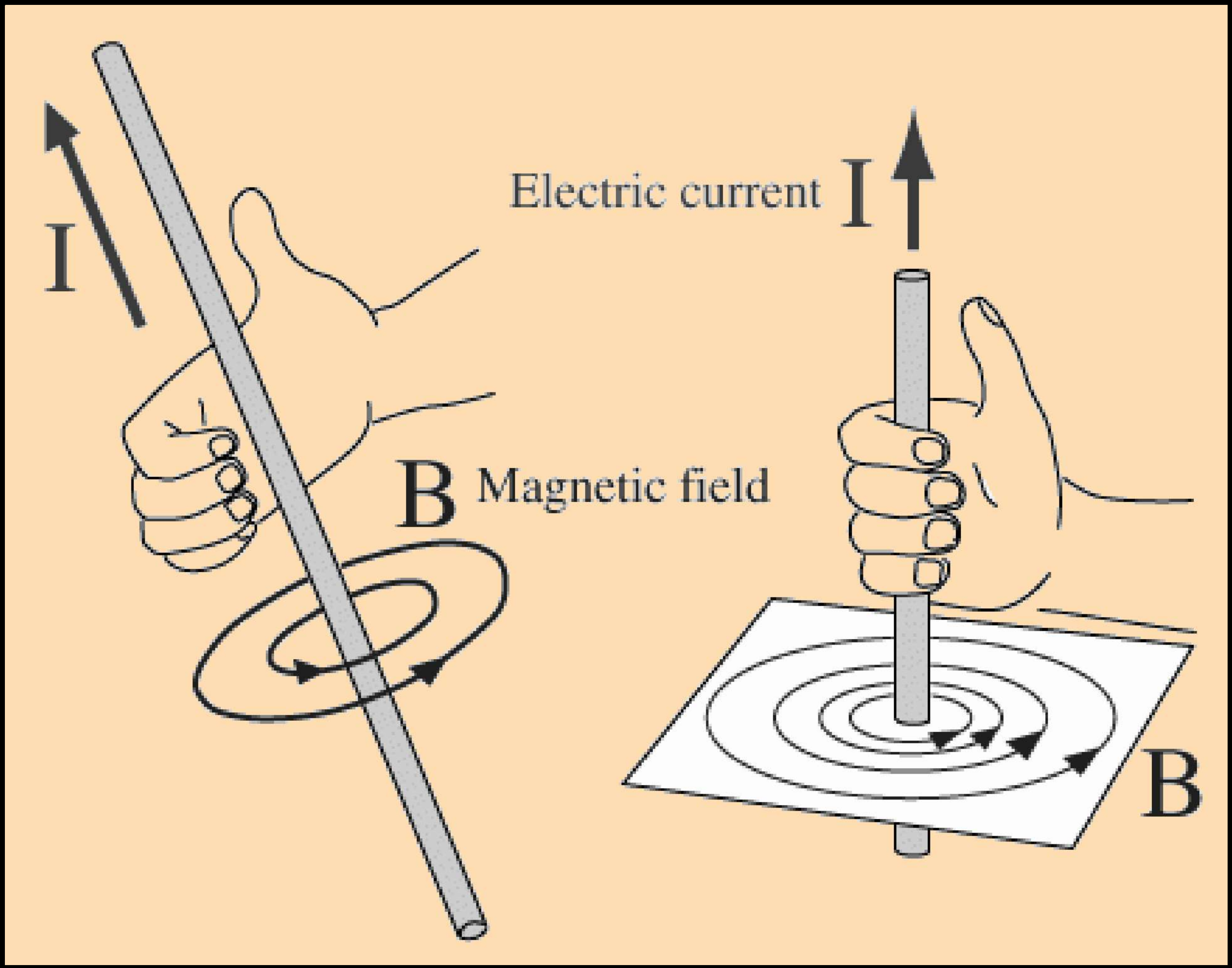

N
S


N
S


N
S
S
N


N
S



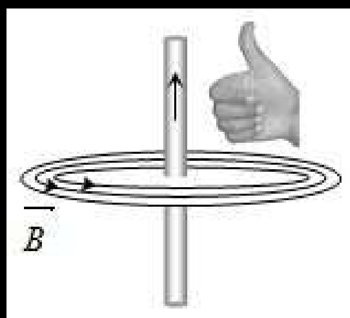

I
Electric current I
B Magnetic field
B

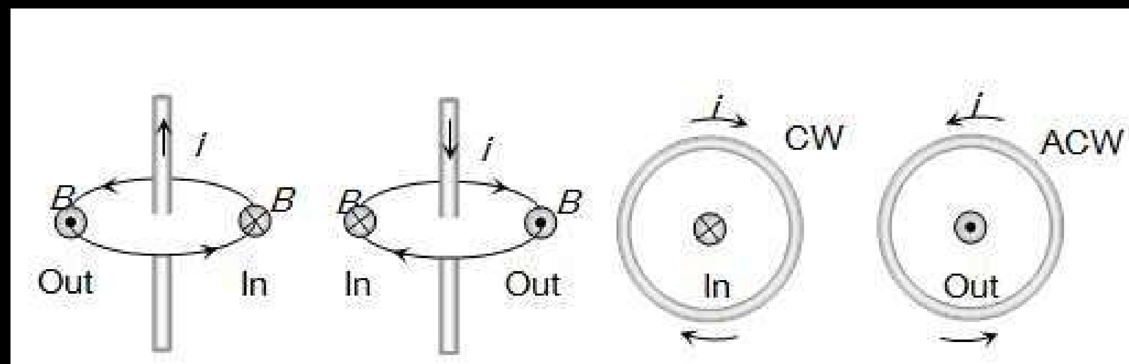
Aurora Borealis

Magnetism

→ Production of B (magnetic field)

→ Effect of B on charges & current carrying wire.

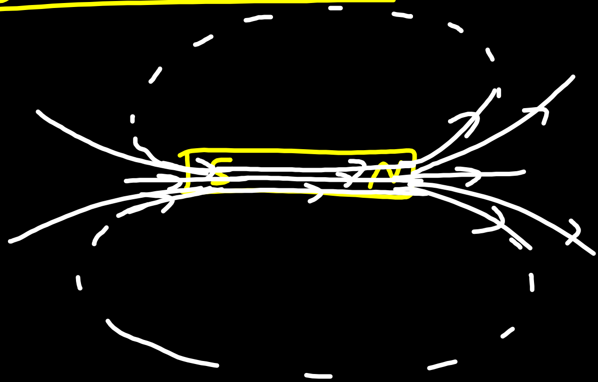

B


i
B
B
Out
In
i
B
B
In
Out
i
CW
In
i
ACW
Out

Magnetic Field

B lines N to S outside

S to N inside magnet.



naturally occuring magnets.

moving charges

Current Carrying Wire

Units & Dimensions

Ⓑ magnetic field

current

$$\boxed{F = B I l}$$

force — length

$$\frac{Kg\,\cancel{m}}{s^2} = B(A)(\cancel{m})$$

$$\frac{Kg}{A s^2} = B$$

Tesla

$$[M A^{-1} T^{-2}] = [B]$$

t.me/ajitlulla

$$1\,T = 1\,\frac{Weber}{m^2} = 1\,\frac{Wb}{m^2}$$

C.G.S unit ⇒ gauss

$1\,T = 10^4$ gauss

$= 10^4\ \frac{Maxwell}{cm}$

$\mu_0 \rightarrow$ permeability of free space

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

current

distance.

$$M A^{-1} T^{-2} = \frac{[\mu_0][A]}{[L]}$$

$$[M L A^{-2} T^{-2}] = [\mu_0]$$

$$\frac{\text{Tesla m}}{A}$$

$\frac{Tm}{A}$ Unit of μ_0

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

$$\boxed{\mu_0 = 4\pi \times 10^{-7} \quad \frac{Tm}{A}}$$

Unit & Dimensions

Q $\frac{E}{B} = ?$ $\longrightarrow$ m/s $[LT^{-1}]$

Q $\frac{1}{\sqrt{\mu_0 \varepsilon_0}} = ?$ $\longrightarrow$ m/s $[LT^{-1}]$

$E \to$ electric field

$B \to$ magnetic field

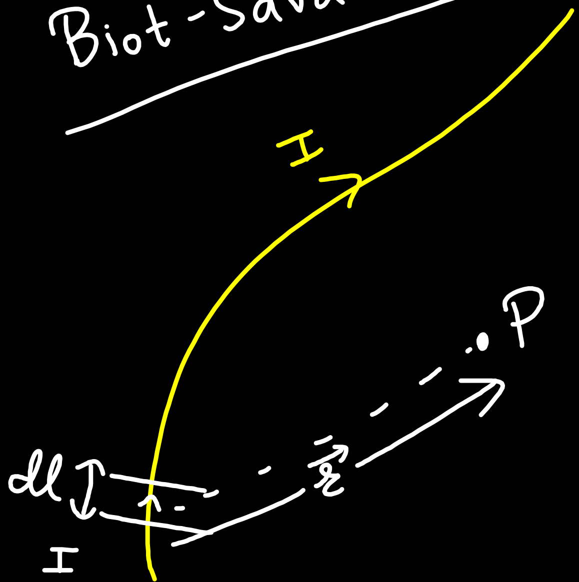
$\mu_0 \to$ permeability

$\varepsilon_0 \to$ permittivity

$\frac{E}{B} = c$ speed of light

$\frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c$ " " "

Biot-Savart Law



B at P due to element $\propto \dfrac{I\vec{dl}\times\vec{r}}{|r|^3}$

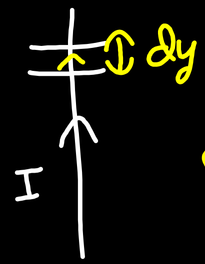
$\dfrac{\mu_0}{4\pi} = 10^{-7}\,\dfrac{Tm}{A}$

$$\boxed{dB = \frac{\mu_0}{4\pi}\,\frac{I\vec{dl}\times\vec{r}}{|r|^3}}$$

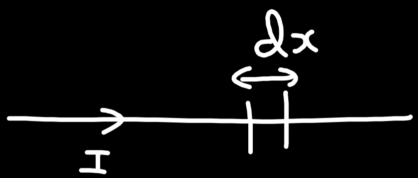
$\vec{dl}$
- magnitude dl
- direction ⇒ along direction of current.

$\vec{r}$ ⇒ position vector of P w.r.t. element

element to Point



$$\vec{dl} = dy\,\hat{j}$$



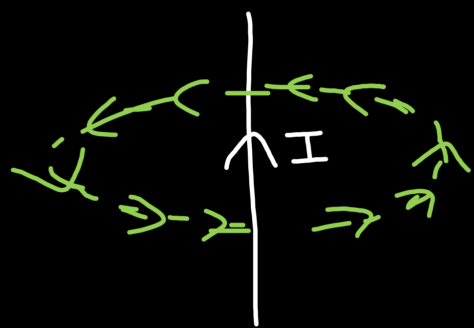
$$\vec{dl} = dx\,\hat{i}$$

Magnetic Field Directions

Right hand Thumb Rule

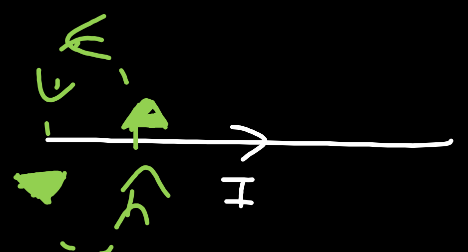
Right hand Screw Rule

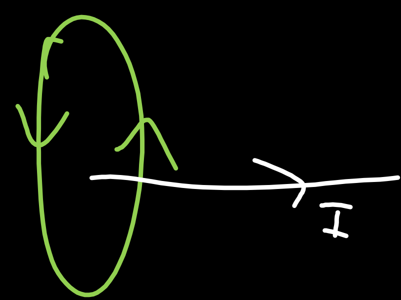
Sudarshan Chakra

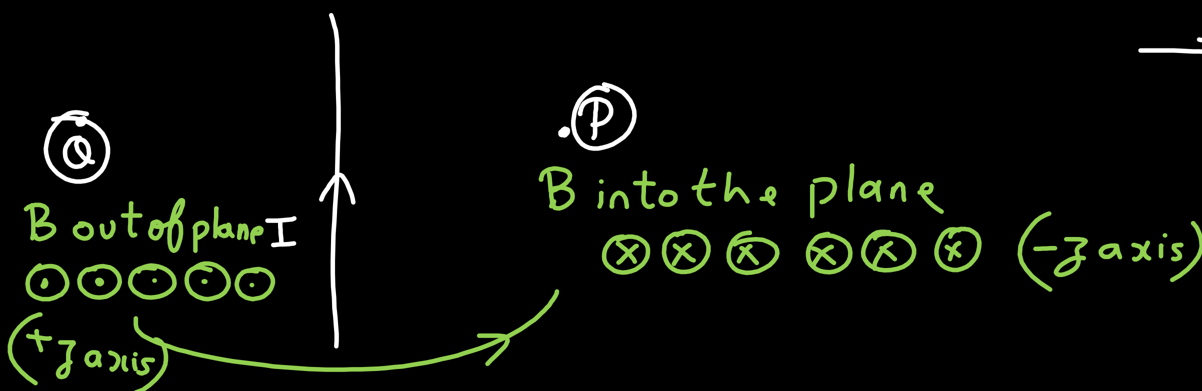


→ Point streched Thumb along I

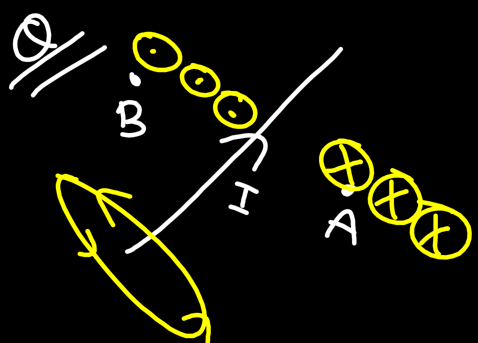
→ curl your fingers ⇒ it will give direction of magnetic field (loop)

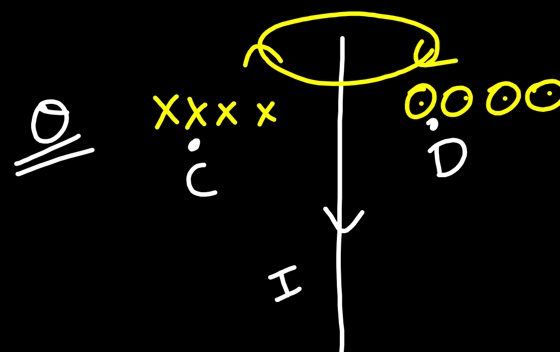


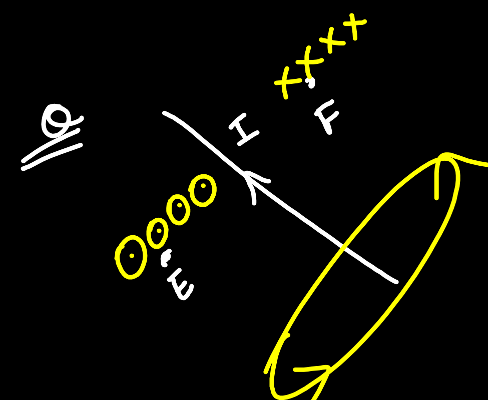


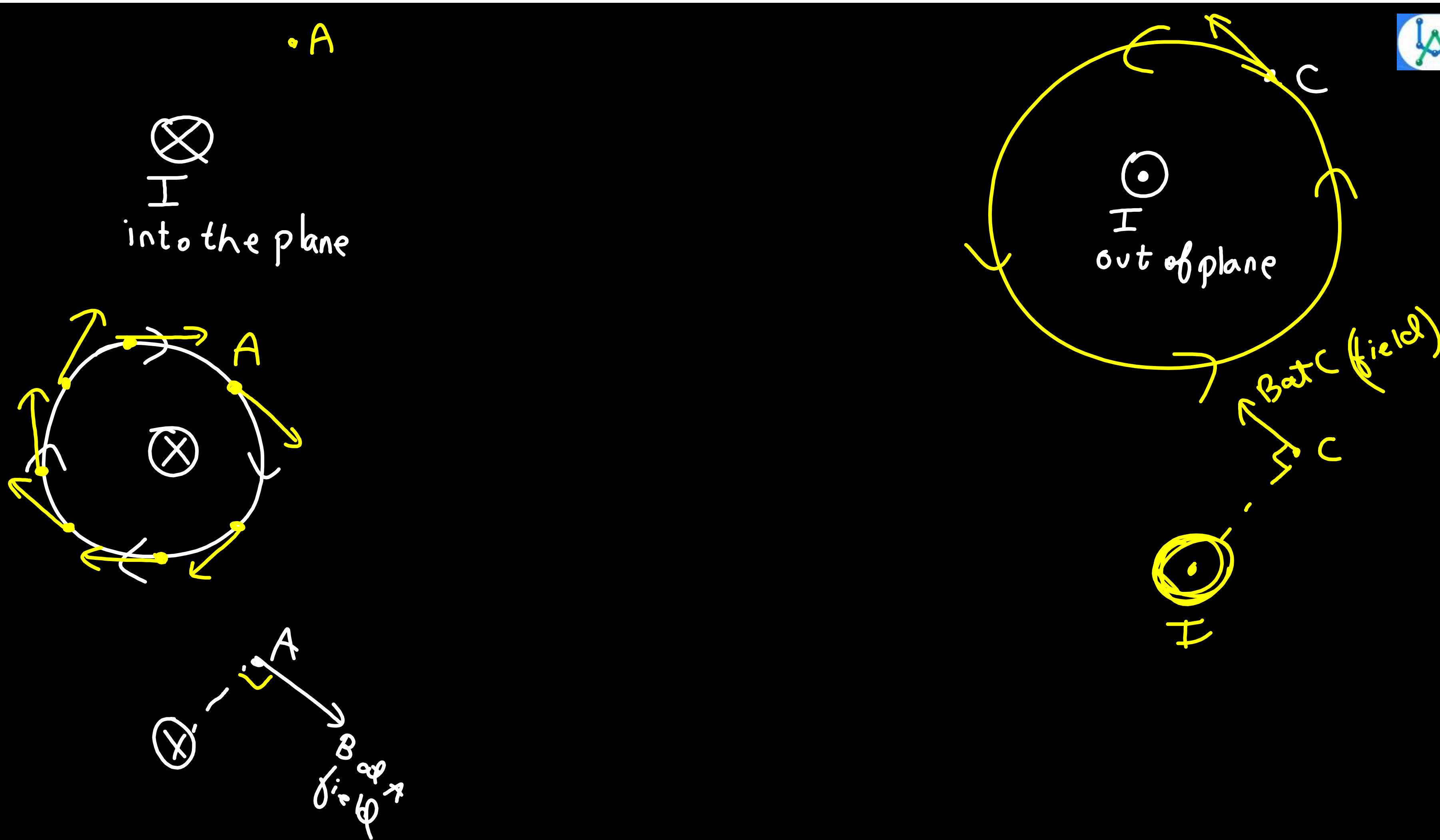


→ direction of B can be given tangent at point on B lines (loop)



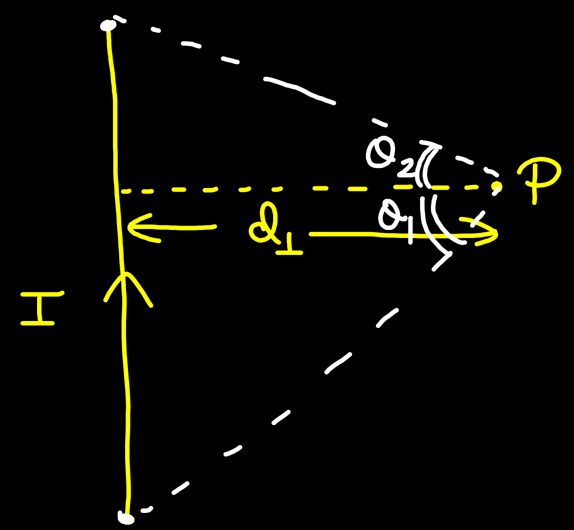






A
I
into the plane
A
A
C
I
out of plane
B at C (field)
C
I

B due to St. line I carrying wire

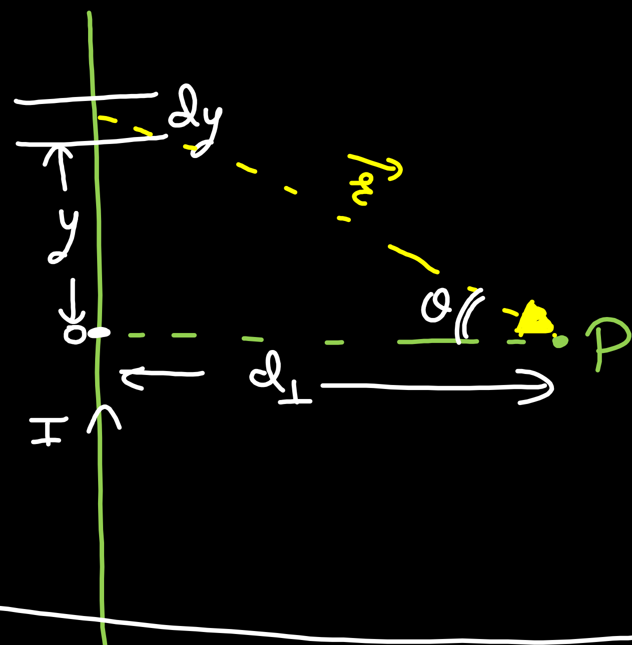


$$B \text{ at } P = \frac{\mu_0 I}{4\pi d_\perp}\left(\sin\theta_1 + \sin\theta_2\right)$$

θ_1 & θ_2 $\Rightarrow$ angle made at point By joining ends with $\perp$'ar line of wire

ek angle upar $\Leftarrow$
ek angle niche
from $\perp$'ar line of wire

$d_\perp \Rightarrow$ $\perp$'ar distance from wire



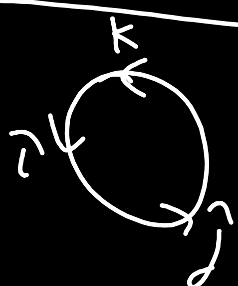
$$I\vec{dl} = I(dy\,\hat{j})$$

$$\vec{r} = d_\perp \hat{i} + (-y)\hat{j}$$

$$|r| = \sqrt{d_\perp^2 + y^2}$$

$$B = \frac{\mu_0}{4\pi}\,\frac{I(dy\,\hat{j}) \times (d_\perp \hat{i} - y\hat{j})}{\left(\sqrt{d_\perp^2 + y^2}\right)^3}$$

#



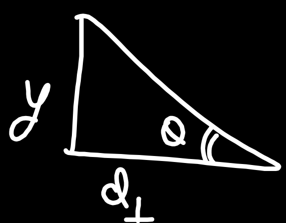
$\hat{i} \times \hat{j} = \hat{k}$ $\qquad$ $\hat{j} \times \hat{i} = -\hat{k}$

$\hat{j} \times \hat{k} = +\hat{i}$ $\qquad$ $\hat{i} \times \hat{k} = -\hat{j}$

$\hat{k} \times \hat{i} = +\hat{j}$ $\qquad$ $\hat{k} \times \hat{j} = -\hat{i}$

$$= \frac{\mu_0 I}{4\pi}\left[d_\perp \frac{dy}{(d_\perp^2 + y^2)^{3/2}}\right](-\hat{k})$$

$$= \frac{\mu_0 I d_\perp}{4\pi} \int \frac{dy}{(d_\perp^2 + y^2)^{3/2}}$$



$$\frac{y}{d_\perp} = \tan\theta$$

$$y = d_\perp \tan\theta$$

$$dy = d_\perp \sec^2\theta \, d\theta$$

$$\Rightarrow \frac{\mu_0 I d_\perp}{4\pi} \; \frac{d_\perp \sec^2\theta \, d\theta}{d_\perp^3 \sec^3\theta}$$

$$= \frac{\mu_0 I}{4\pi d_\perp} \int \cos\theta \, d\theta$$

$$\frac{\mu_0 I}{4\pi d_\perp} \left[\sin\theta\right]_{-\theta_1}^{\theta_2}$$

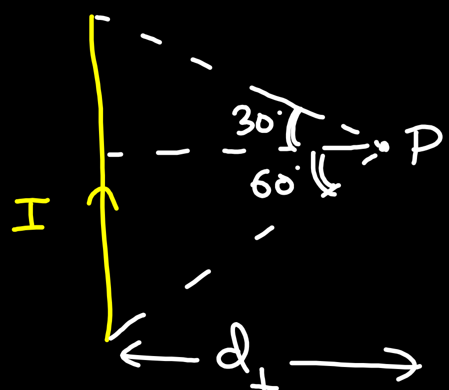
HL − LL

$$\sin\theta_2 - (\sin(-\theta_1))$$

$$B = \frac{\mu_0 I}{4\pi d_\perp}(\sin\theta_2 + \sin\theta_1)$$

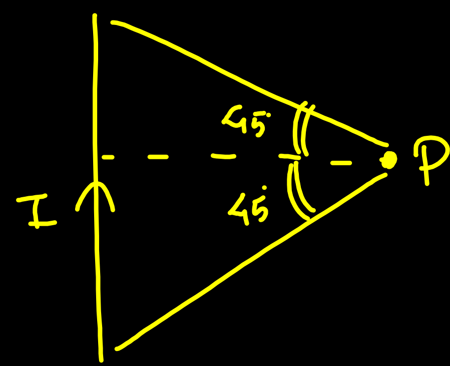
Different Cases

Point not symmetric



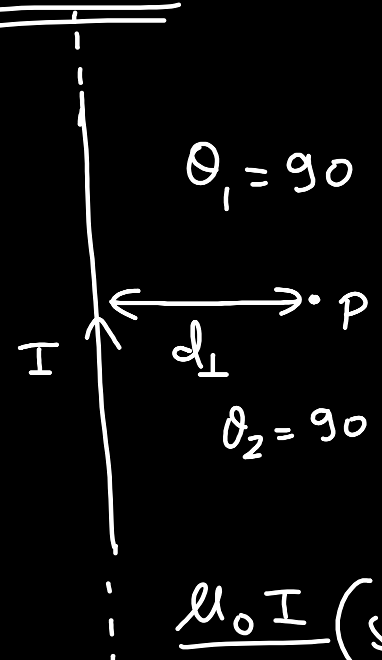
$$\frac{\mu_0 I}{4\pi d_\perp}\left(\sin 30 + \sin 60\right)$$

Point Symmetric



$$\frac{\mu_0 I}{4\pi d_\perp}\left(\sin 45 + \sin 45\right)$$

∞ wire ☆



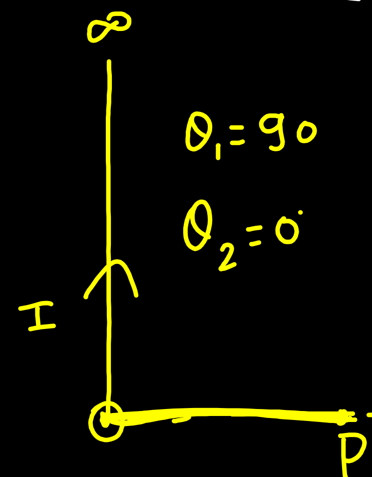
$\theta_1 = 90$

$\theta_2 = 90$

$$\frac{\mu_0 I}{4\pi d_\perp}(\sin 90 + \sin 90)$$

$$\boxed{B = \frac{\mu_0 I}{2\pi d_\perp}}$$ ☆

Semi ∞ wire



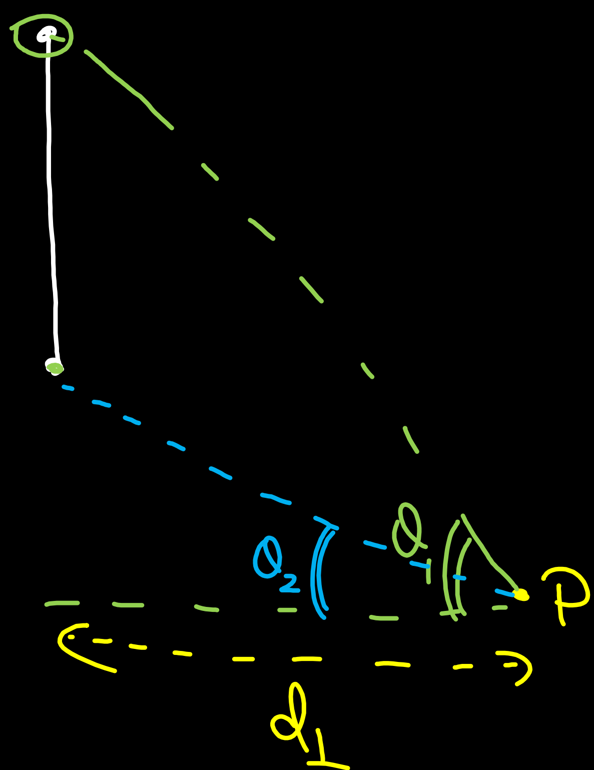
$\theta_1 = 90$

$\theta_2 = 0°$

$$B = \frac{\mu_0 I}{4\pi d_\perp}(\sin 90 + \sin 0)$$

$$\boxed{B = \frac{\mu_0 I}{4\pi d_\perp}}$$

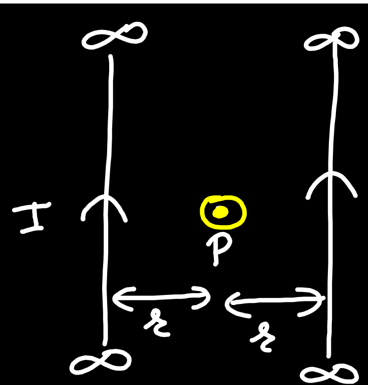
Point outside the wire



$$\frac{\mu_0 I}{4\pi d_\perp}\left(\sin\theta_1 + \sin(-\theta_2)\right)$$

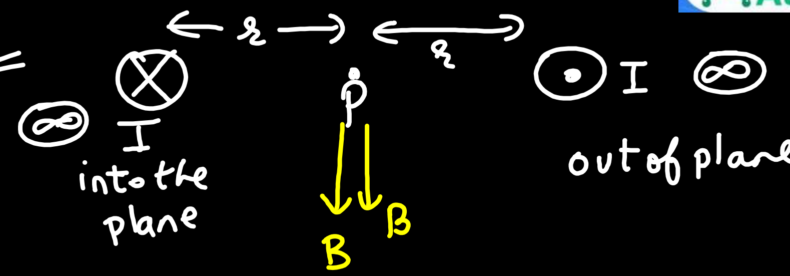
$$\boxed{\frac{\mu_0 I}{4\pi d_\perp}\left(\sin\theta_1 - \sin\theta_2\right)}$$

Q



B_{net} at $P = 0$

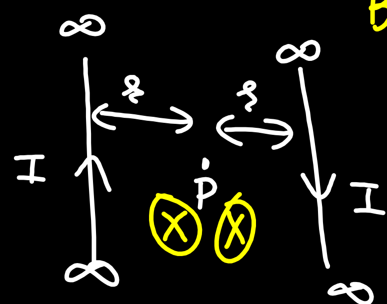
Q



$$B_{net} = \frac{\mu_0 I}{2\pi r} + \frac{\mu_0 I}{2\pi r}$$

$$= \frac{\mu_0 I}{\pi r}\left(-\hat{j}\right)$$

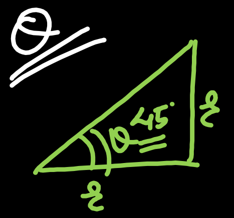
Q



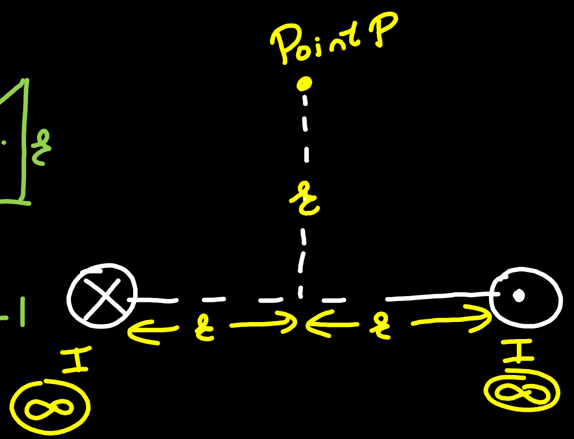
$$B_{net} = \frac{\mu_0 I}{2\pi r} + \frac{\mu_0 I}{2\pi r}$$

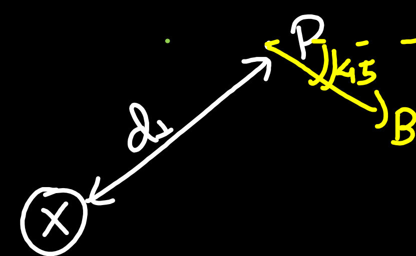
$$= \frac{\mu_0 I}{\pi R}\left(-\hat{k}\right)$$

θ



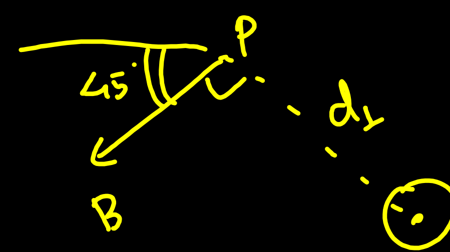
$\tan\theta = \frac{r}{r} = 1$

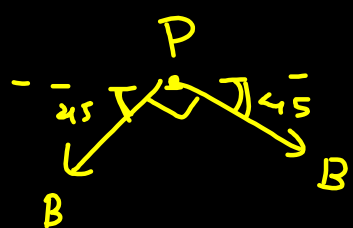




$d_1 = r\sqrt{2}$

$$B = \frac{\mu_0 I}{2\pi\left(r\sqrt{2}\right)}$$



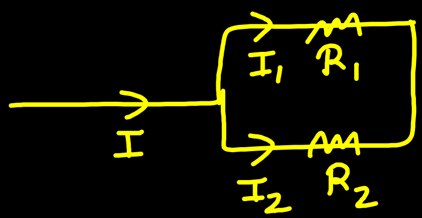


$$R = \sqrt{a^2 + b^2 + 2ab\cos\theta}$$

$B\sqrt{2}$

$$B_{net} = \left[\frac{\mu_0 I}{2\pi\left(r\sqrt{2}\right)}\right]\sqrt{2} = \frac{\mu_0 I}{2\pi r}\left(-\hat{j}\right)$$

Current distribution in loop



$I \propto \frac{1}{\text{Resistance}}$

|| flow

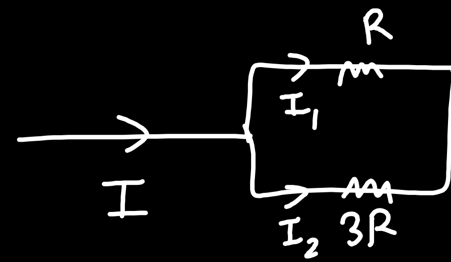
$I = I_1 + I_2$

$I_1 R_1 = I_2 R_2$

$\frac{I_1}{I_2} = \frac{R_2}{R_1}$

$I_1 = \left(\frac{R_2}{R_1+R_2}\right) I$

$I_2 = \left(\frac{R_1}{R_1+R_2}\right) I$

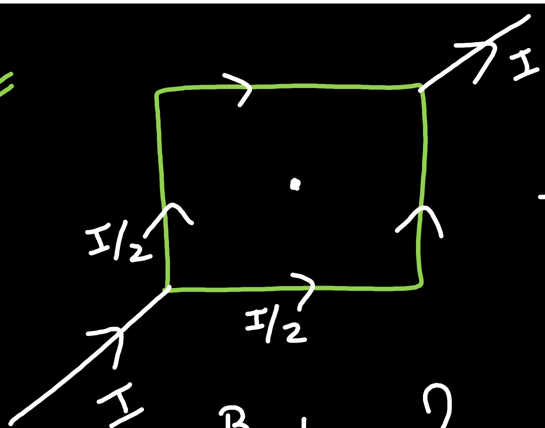


$\frac{I_1}{I_2} = \frac{3R}{R} = \frac{3}{1}$

$I_1 = \frac{3}{(3+1)} \times I = \frac{3I}{4}$

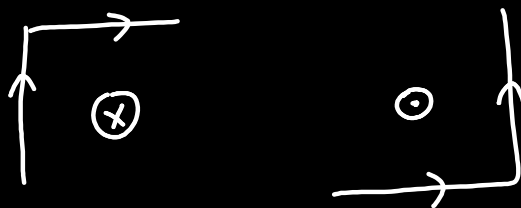
$I_2 = \frac{1}{3+1} \times I = I/4$

Q



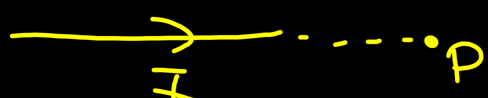
l = length

$B_{net\,c} = ?$

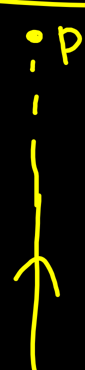


$B_{net} = 0$

Q Point along wire

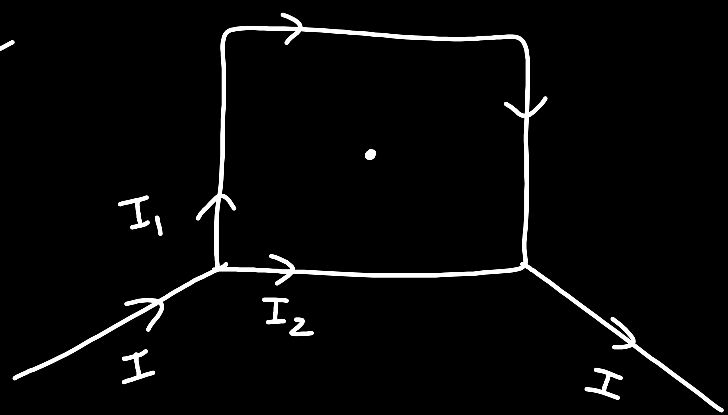


$B_{at\,P} = 0$



$B_{at\,P} = 0$

Q

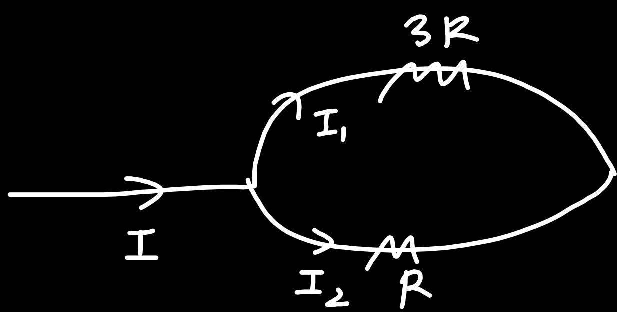


resistance of each wire = R

length " " " = l

B_{net} at c = ?

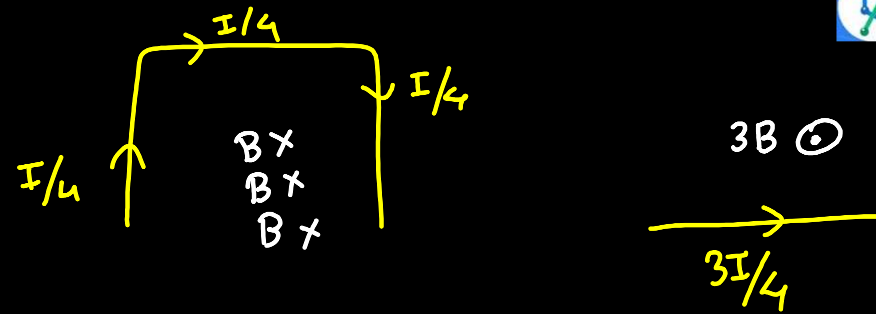
Ans = 0



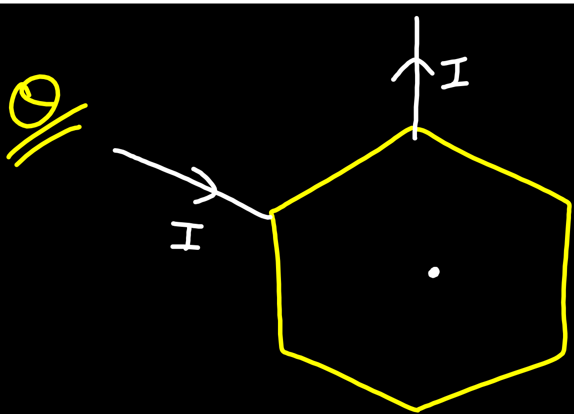
$$\frac{I_1}{I_2} = \frac{R}{3R} = \frac{1}{3}$$

$$I_1 = \left(\frac{1}{1+3}\right) I = I/4$$

$$I_2 = \left(\frac{3}{1+3}\right) I = 3I/4$$

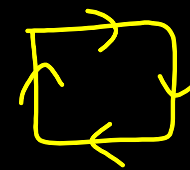


$$\boxed{B_{net} = 0}$$

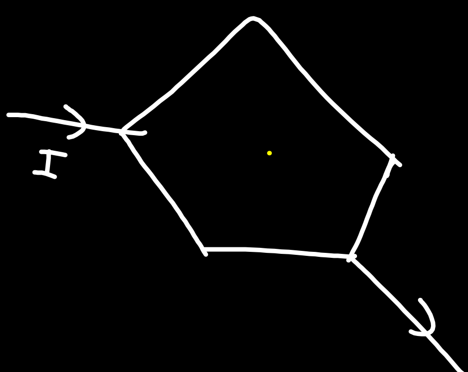


$B_{net} = 0$

loop complete

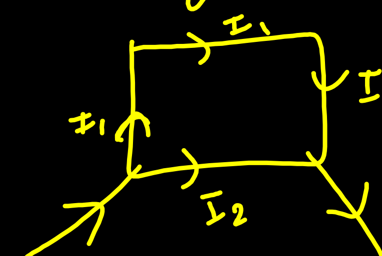


$B_{at\ c} \neq 0$



$B_{net} = 0$

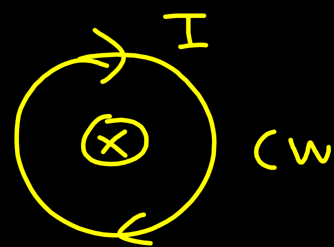
I distribution symmetric



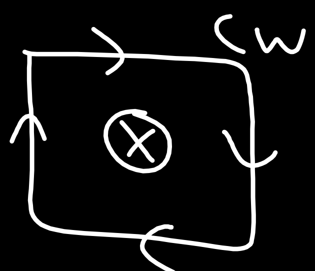
$B_{net\ c} = 0$

B due to Ring

B = out of plane



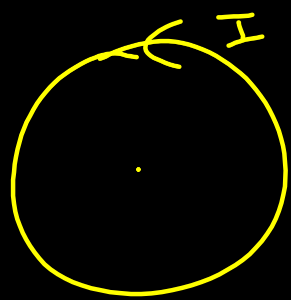
B = into the plane



Direction by simple right hand rule

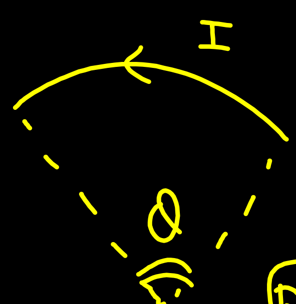
$\Rightarrow$ fingers ghuma do loop mein

Thumb aapko B de dega.



$$\boxed{B \text{ at } C = \frac{\mu_0 I}{2r}}$$

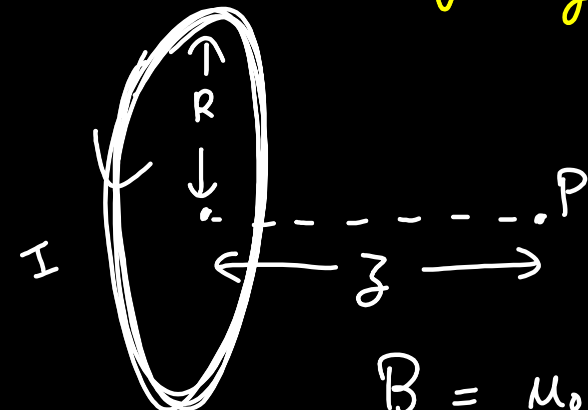
$\frac{\theta}{2\pi}$ (multiply)



$$\boxed{B_c = \frac{\mu_0 I}{4\pi r}\theta}$$

θ in radian

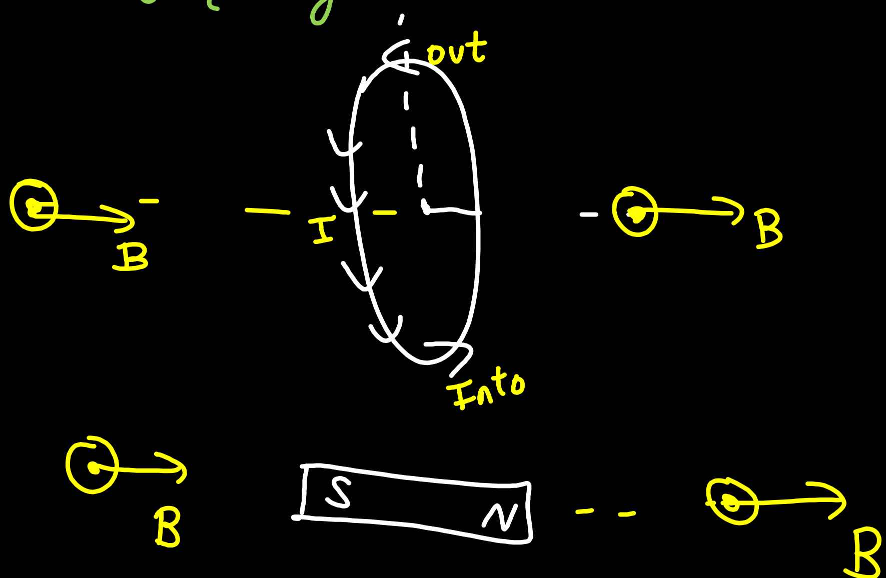
B at axis of ring



$$B = \frac{\mu_0 I R^2}{2\left(R^2+z^2\right)^{3/2}}$$

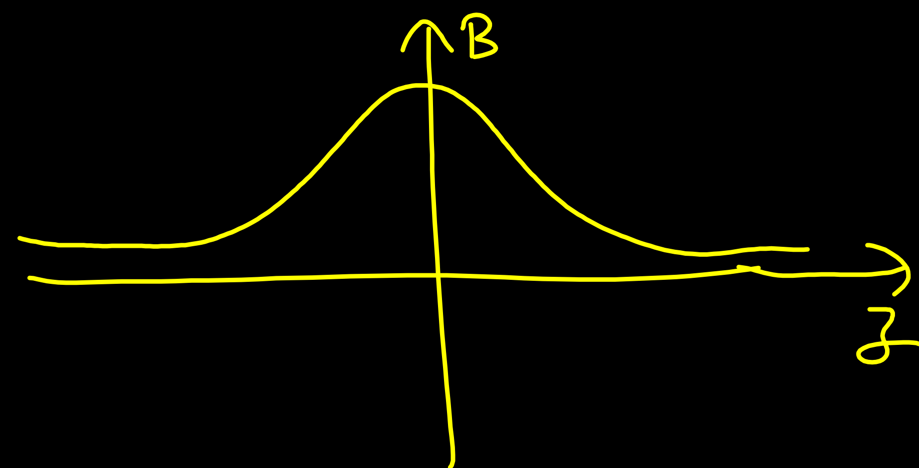
B due to ring on axis

\# every current carrying loop can be considered as bar magnet



\# fingers in current loop thumb gives north pole

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



$11^{th} \rightarrow$ G.O.A.T

$12^{th} \rightarrow$ Bounceback

t.me/ajitlulla

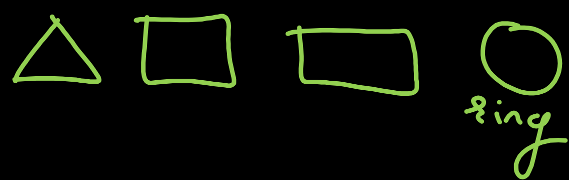
Ampere's Law

$$\boxed{\oint \vec{B}\cdot\vec{dl} = \mu_0 I_{enclosed}}$$

line interal

for a closed 2D loop

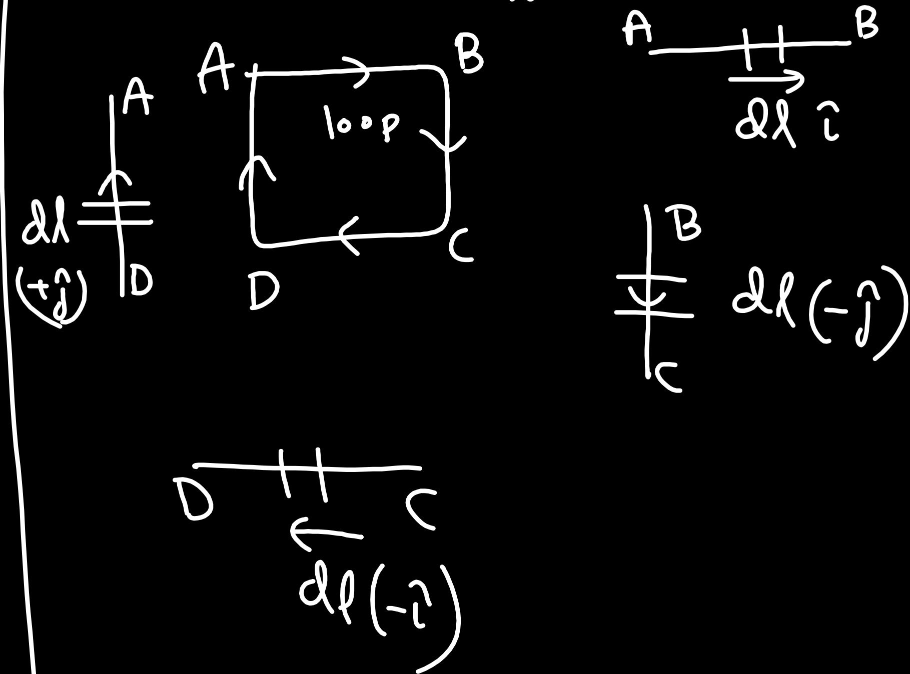
Ex

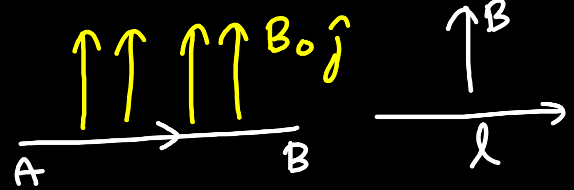


\# line integral around any closed loop is equal to $\mu_0 (I_{enclosed})$

Line integral

$\vec{dl} \Rightarrow$ differential element of loop.

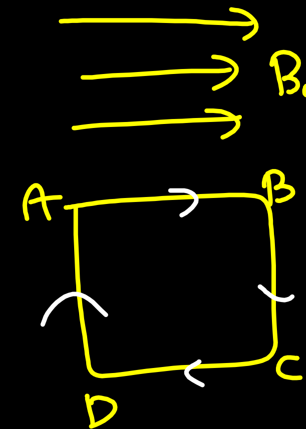




$$\int \vec{B}\cdot\vec{dl} = 0$$
along AB

$$\int \vec{B}\cdot\vec{dl} = B_0 l$$
along AB

Q//

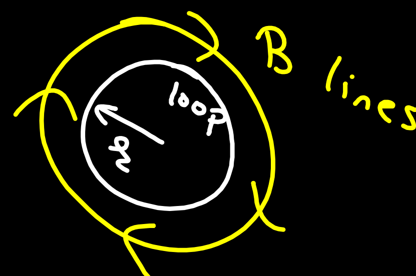


$B_0\hat{i}$ (constant

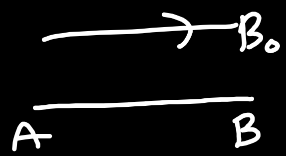
$B_0 l + 0 + 0 + (-B_0 l)$

$$\oint \vec{B}\cdot\vec{dl} = 0$$
of complete loop

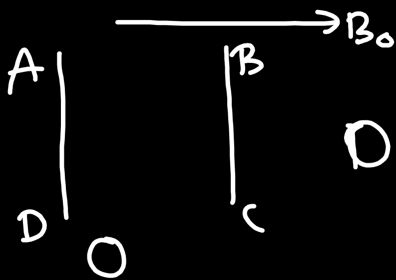
Q=

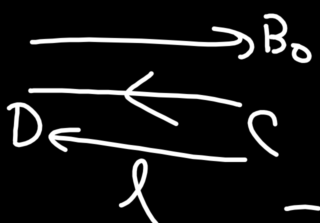


$$\oint \vec{B}\cdot\vec{dl} = \underline{B_0 2\pi r}$$
of complete loop



$B_0 l$

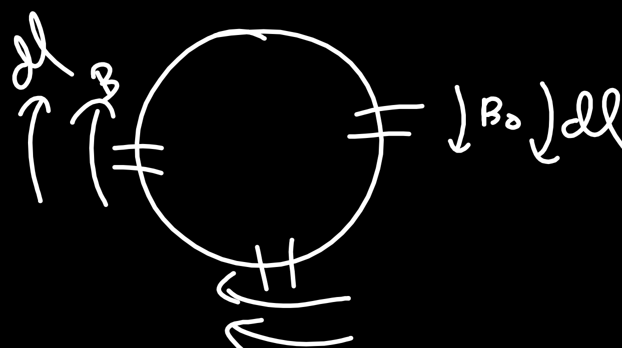




$-B_0 l$

$\vec{a} \cdot \vec{b} = |a|\,|b| \cos\theta$

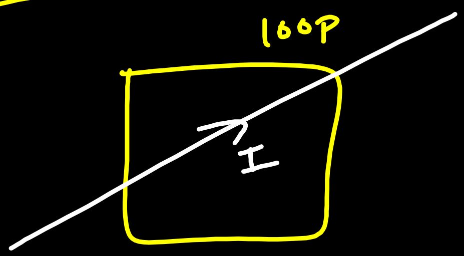
$\vec{B} \cdot \vec{dl} = \int |B|\,|dl| \cos\theta = \int B\,|dl| \cos 0$



$= B \int |dl|$

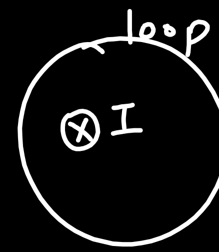
$= \underline{B\, 2\pi r}$

$I_{enclosed}$



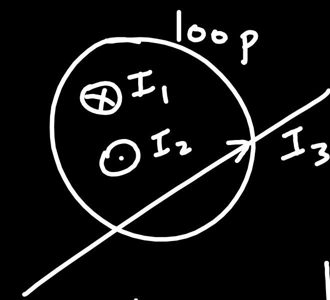
$I_{enclosed} = 0$

#



$I_{enclosed} = I$

#

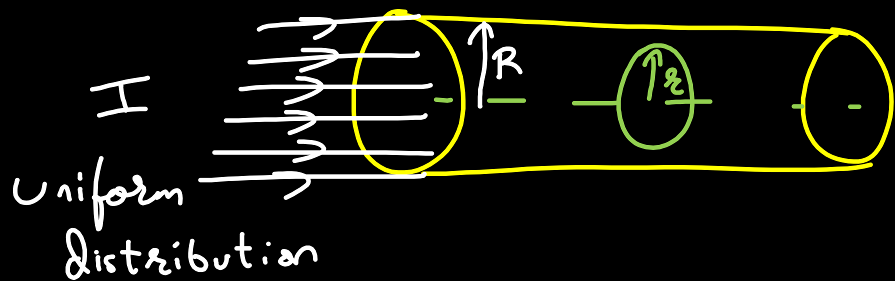


$I_{encl} = |I_1 - I_2|$

\# loop in plane ⊥'ur to current
for $I_{enclosed}$

Q

Solid cylinder



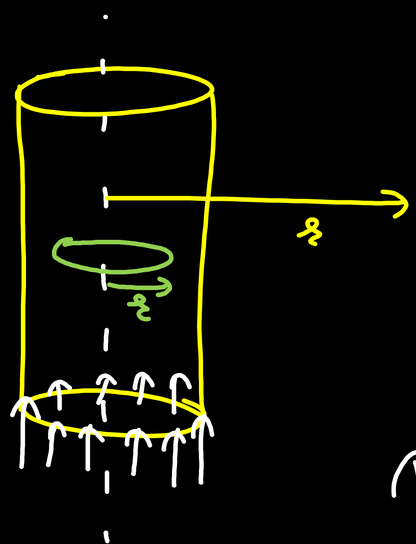
$$\pi R^2 \longrightarrow I$$

$$\pi r^2 \longrightarrow \frac{I}{\cancel{\pi} R^2} \cancel{\pi} r^2$$

$I_{enclosed}$ through loop = ?

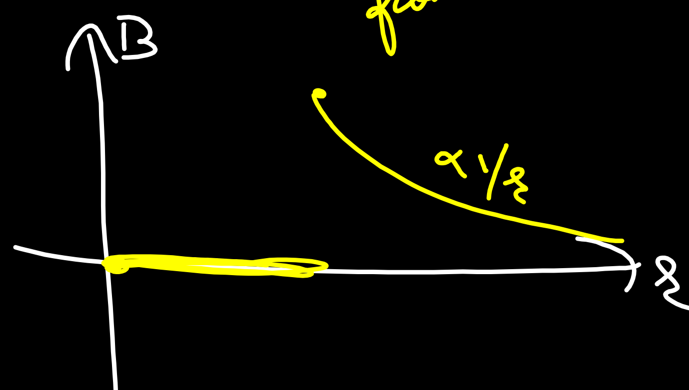
$$= \frac{I r^2}{R^2}$$

B inside hollow cylinder I carrying



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

distance from axis



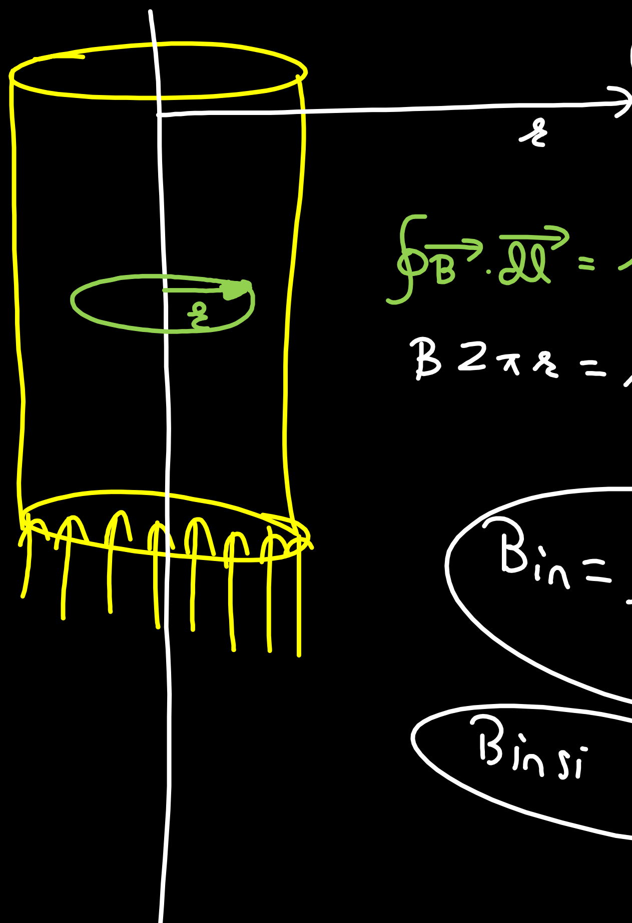
$B_{inside} = 0$

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_{enclose} 0$$

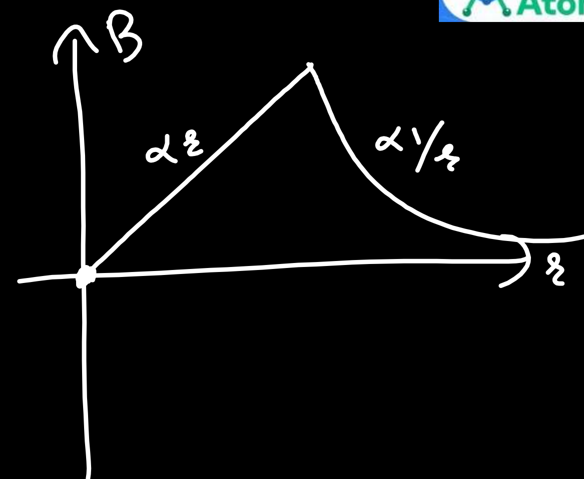
$$B\, 2\pi r = 0$$

$$B_{ins} = 0$$

B inside solid Cylinder I carrying



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



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

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

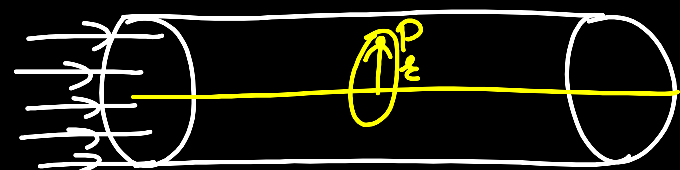
$$B_{in} = \frac{\mu_0 I r}{2\pi R^2}$$

$$B_{insi} \propto r$$

$$J = \frac{I}{\pi R^2}$$

$$\boxed{\vec{B}_{in} = \frac{\mu_0}{2}\, \vec{J} \times \vec{r}}$$

$J \Rightarrow$ variable



Suppose

$J = J_0 r$

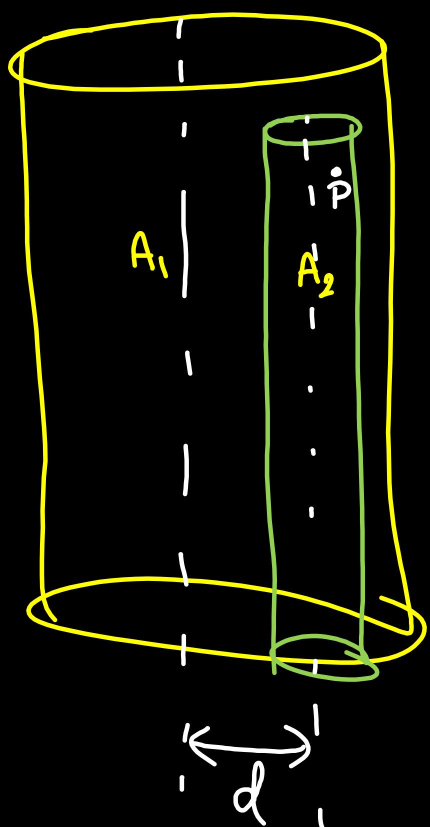
$$I_{enclosed} = \int_0^r J \, dA$$

Step done already in Bounceback of Current electricity

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

$$B \, 2\pi r = \mu_0 I_{enclosed}$$

Cavity inside Cylinder



B at P = ?

current density = J
(constant uniform)

$$B_{full} = \frac{\mu_0}{2}\left(\vec{J} \times \vec{r}_{PA_1}\right)$$

$$B_{cavity} = \frac{\mu_0}{2}\left(\vec{J} \times \vec{r}_{PA_2}\right)$$

$$B_{remaining} = B_{full} - B_{cavity}$$
$$= \frac{\mu_0}{2}\left[\vec{J}\right] \times \left(\vec{r}_{PA_1} - \vec{r}_{PA_2}\right)$$

$\vec{r}_{PA_1} = -\vec{r}_{A_1P}$

$\vec{r}_{PA_2} = -\vec{r}_{A_2P}$

\# Ans is independent of position of P.

\# B_{inside} cavity constant

$$B_{net} = \frac{\mu_0}{2}\vec{J} \times \left(\vec{r}_{A_2P} - \vec{r}_{A_1P}\right)$$

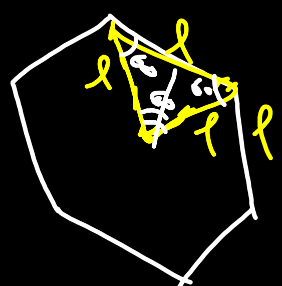
$$= \frac{\mu_0}{2}\left(\vec{J} \times \vec{r}_{A_2A_1}\right)$$

$$B_{net} = \frac{\mu_0}{2} J d$$

Magnitude of magnetic field (in SI units) at the centre of a hexagonal shape coil of side 10 cm, 50 turns and carrying current I (Ampere) in units of $\frac{\mu_0 I}{\pi}$ is :

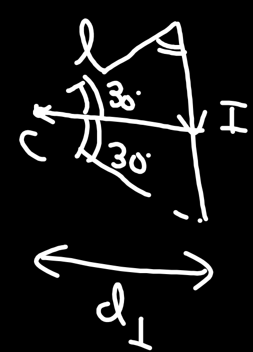
[Sep. 03, 2020 (I)]

(a) $250\sqrt{3}$ (b) $50\sqrt{3}$ (c) $500\sqrt{3}$ (d) $5\sqrt{3}$



$l = 10\,cm$

50 turns



$\theta_1 = \theta_2 = 30°$

$d_\perp = l\cos 30$

$$\frac{\mu_0 I}{4\pi(d_\perp)}(\sin 30 + \sin 30) \times 6 \times 50$$

$$\frac{\mu_0 I}{4\pi\left(l\frac{\sqrt{3}}{2}\right)}\left(\frac{1}{2}+\frac{1}{2}\right) \times 300$$

$$\frac{\mu_0 I}{4\pi(0.1)\sqrt{3}} \times 2 \times 1 \times 300$$

$$= \frac{\mu_0 I}{\pi} \times \frac{2 \times 3000}{2 \times 4 \times \sqrt{3}} = \frac{1500}{\sqrt{3}} = 500\sqrt{3}\,\frac{\mu_0 I}{\pi}$$

A current of 1.5 A is flowing through a triangle, of side 9 cm each. The magnetic field at the centroid of the triangle is

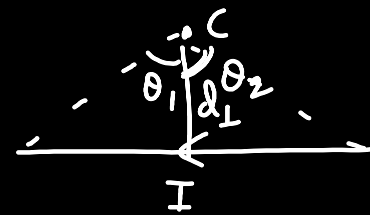
(Assume that, the current is flowing in the clockwise direction.)

a. 3×10^{-7} T, outside the plane of triangle

b. $2\sqrt{3} \times 10^{-7}$ T, outside the plane of triangle

c. $2\sqrt{3} \times 10^{-5}$ T, inside the plane of triangle

d. 3×10^{-5} T, inside the plane of triangle



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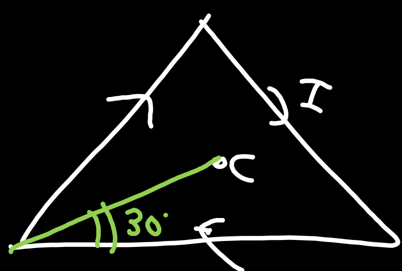
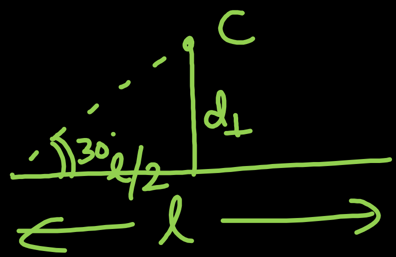
$l = 9\,cm$

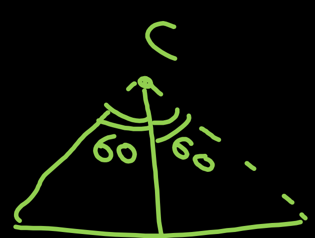
$I = 1.5\,A$





$\tan 30 = \frac{d_\perp}{l/2}$

$\frac{l}{2\sqrt{3}} = d_\perp$



$$\frac{\mu_0 I}{4\pi d_\perp}(\sin 60 + \sin 60) \times 3$$

$$= \frac{\mu_0 I}{4\pi\left(\frac{l}{2\sqrt{3}}\right)}\left(\frac{\sqrt{3}}{2}+\frac{\sqrt{3}}{2}\right) \times 3$$

$$= \frac{\mu_0 I}{4\pi l}\, 2\sqrt{3} \times \sqrt{3} \times 3 = \frac{9}{2}\,\frac{\mu_0 I}{\pi l}$$

$$= \frac{\cancel{9} \times \cancel{4}^{\,2}\cancel{\pi} \times 10^{-7}}{\cancel{2}\;\cancel{\pi} \times \cancel{9}}\, 100 \times 1.5$$

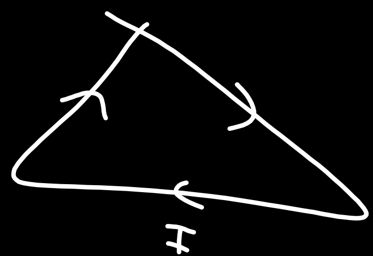
$$= 3 \times 10^{-5}$$

The magnitude of the magnetic field at the center of an equilateral triangular loop of side 1 m which is carrying a current of 10 A is : **[10 April 2019, II]**

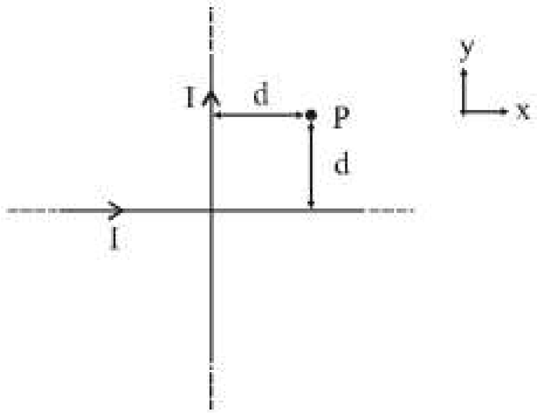
[Take $\mu_o = 4\pi \times 10^{-7}\ NA^{-2}$]

(a) $18\ \mu T$ (b) $9\ \mu T$ (c) $3\ \mu T$ (d) $1\ \mu T$

H.W.



Two very long, straight, and insulated wires are kept at 90° angle from each other in *xy*-plane as shown in the figure.



These wires carry currents of equal magnitude I, whose directions are shown in the figure. The net magnetic field at point P will be : **[12 April 2019, I]**

(a) Zero

(b) $-\frac{\mu_0 I}{2\pi d}(\hat{x}+\hat{y})$

(c) $\frac{+\mu_0 I}{\pi d}(\hat{z})$

(d) $\frac{\mu_0 I}{2\pi d}(\hat{x}+\hat{y})$

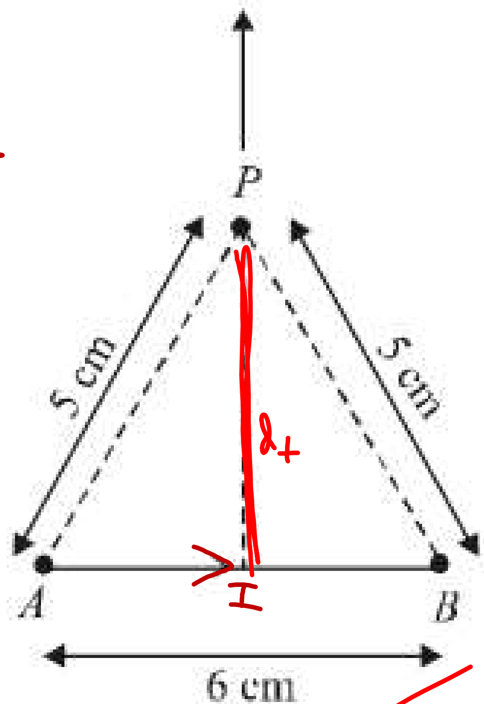
$\otimes$ B $\odot$ B

$B_{net} = B - B$

$= 0$

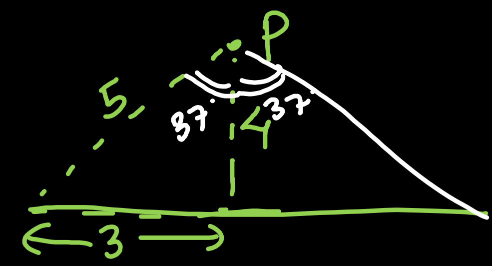
Find the magnetic field at point P due to a straight line segment AB of length 6 cm carrying a current of 5 A. (See figure) ($\mu_o = 4\pi \times 10^{-7}$ N-A^{-2}) **[12 April 2019, II]**

$I = 5A$



$d_\perp = 4$

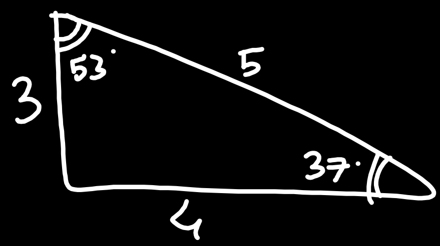
(a) 2.0×10^{-5}T
(b) 1.5×10^{-5}T
(c) 3.0×10^{-5}T
(d) 2.5×10^{-5}T



$$\frac{\mu_0}{4\pi}\frac{I}{d_\perp}\left(\sin 37 + \sin 37\right)$$

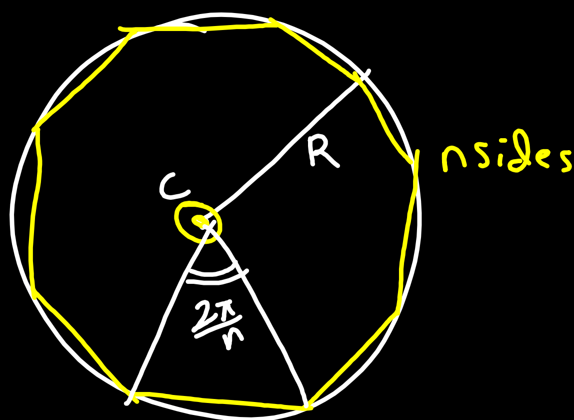
$$\frac{10^{-7}\times 5}{(0.04)} \times \frac{2\times 3}{5}$$

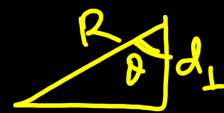
$$1.5\times 10^{-5}\ T$$



$$\sin 37 = 3/5$$

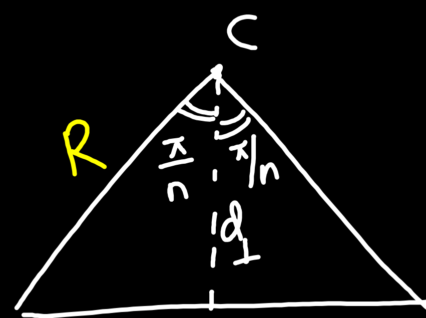
A current I flows along a thin wire shaped as a regular polygon of **n** sides which can be inscribed into a circle of radius R. Find magnetic induction at the center of the polygon.





$$\cos\theta = \frac{d_\perp}{R}$$

$$R\cos\theta = d_\perp$$



$$\theta_1 = \theta_2 = \pi/n$$

$$d_\perp = R\cos(\pi/n)$$

$$\frac{\mu_0 I}{4\pi\left(R\cos\frac{\pi}{n}\right)}\left[\sin(\pi/n) + \sin(\pi/n)\right] \times n$$

$$= \frac{\mu_0 I n}{4\pi R}\,\frac{2\sin(\pi/n)}{\cos(\pi/n)} \Rightarrow \boxed{\frac{\mu_0 n I}{2\pi R}\tan(\pi/n)}$$

Magnetic fields at two points on the axis of a circular coil at a distance of 0.05 m and 0.2 m from the centre are in the ratio 8 : 1. The radius of coil is

a. 0.2 m
b. 0.1 m
c. 0.15 m
d. 1.0 m

$$\frac{B_1}{B_2} = \frac{8}{1}$$

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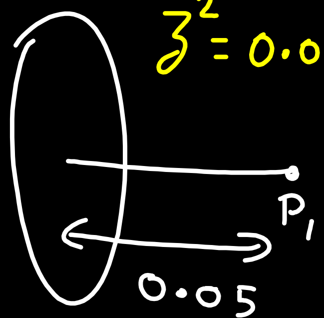
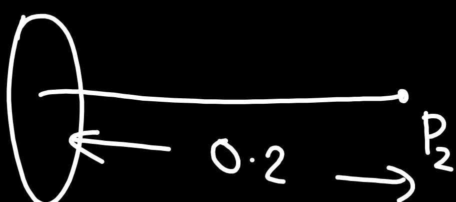
radius = ?



$z^2 = 0.0025$

$$B = \frac{\mu_0 I R^2}{2(R^2 + 0.0025)^{3/2}}$$

$$\frac{B_1}{B_2} = \left(\frac{R^2 + 0.04}{R^2 + 0.0025}\right)^{3/2} = \frac{2^3}{1}$$



$$B_2 = \frac{\mu_0 I R^2}{2(R^2 + 0.04)^{3/2}}$$

take power 2/3 both sides

$$\frac{R^2 + \cancel{0.0025}\ 0.04}{R^2 + \cancel{0.04}\ 0.0025} = \frac{4}{1}$$

$$R^2 + 0.04 = 4R^2 + 0.01$$

$$0.03 = 3R^2$$

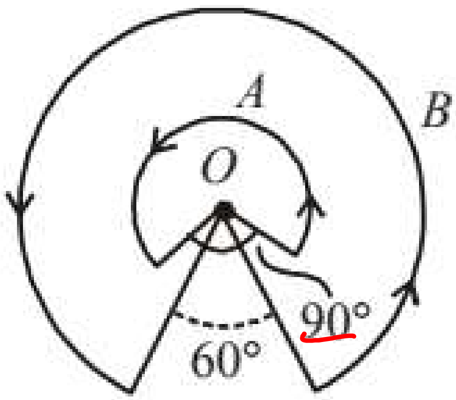
$$0.01 = R^2$$

$$\underline{0.1 = R}$$

A wire A, bent in the shape of an arc of a circle, carrying a current of 2 A and having radius 2 cm and another wire B, also bent in the shape of arc of a circle, carrying a current of 3 A and having radius of 4 cm, are placed as shown in the figure. The ratio of the magnetic fields due to the wires A and B at the common centre O is :

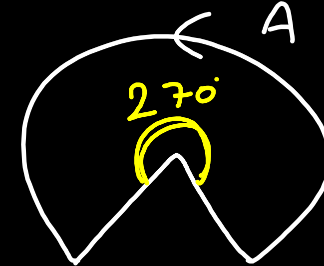
[Sep. 04, 2020 (I)]

$\frac{\mu_0 I}{4\pi r}\theta$



(a) 4 : 6 (b) 6 : 4

(c) 2 : 5 (d) 6 : 5

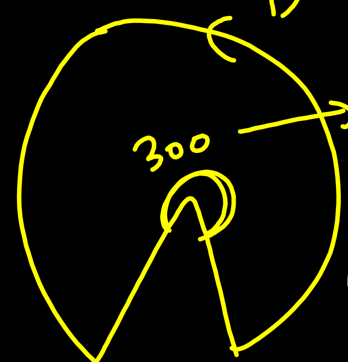


$\frac{3\pi}{2}$

$I = 2$

$r = 2$

$B_1 = \frac{\mu_0(2)}{4\pi(2)}\frac{3\pi}{2}$



$\frac{5\pi}{3}$

$I = 3$

$r = 4$

$B = \frac{\mu_0(3)}{4\pi(4)}\frac{5\pi}{3}$

$\frac{B_1}{B_2} = \frac{3\pi}{2}\,\frac{4\ \cancel{3}}{\cancel{3}\ 5\pi} = \frac{12}{10} = \frac{6}{5}$

Break
20min

Resume class 4:30pm

A very long wire *ABDMNDC* is shown in figure carrying current *I*. *AB* and *BC* parts are straight, long and at right angle. At *D* wire forms a circular turn *DMND* of radius *R*.

AB, *BC* parts are tangential to circular turn at *N* and *D*. Magnetic field at the centre of circle is:

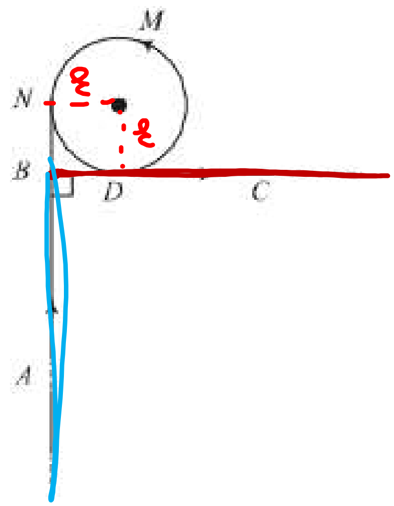
[8 Jan 2020, II]

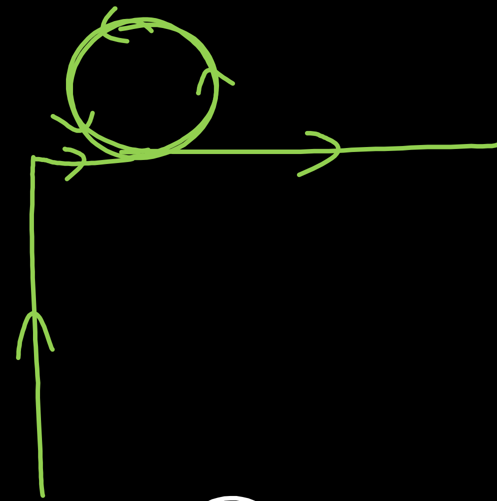
(a) $\frac{\mu_0 I}{2\pi R}\left(\pi+\frac{1}{\sqrt{2}}\right)$

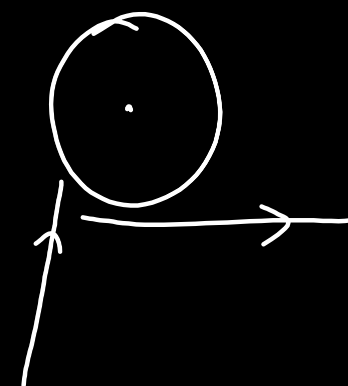
(b) $\frac{\mu_0 I}{2\pi R}\left(\pi-\frac{1}{\sqrt{2}}\right)$

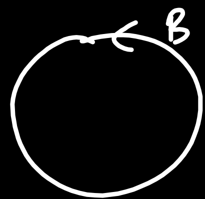
(c) $\frac{\mu_0 I}{2\pi R}(\pi+1)$

(d) $\frac{\mu_0 I}{2R}$

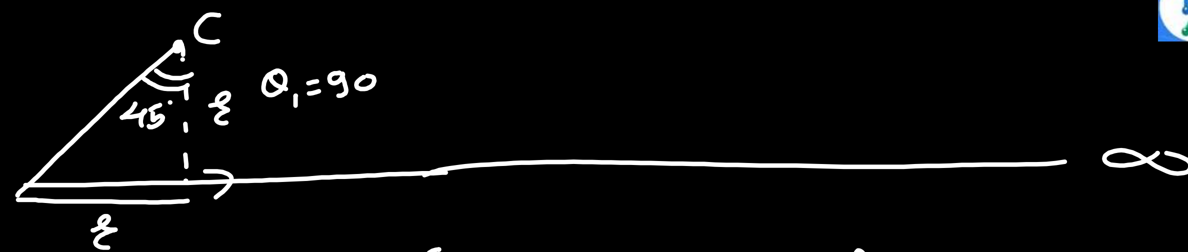




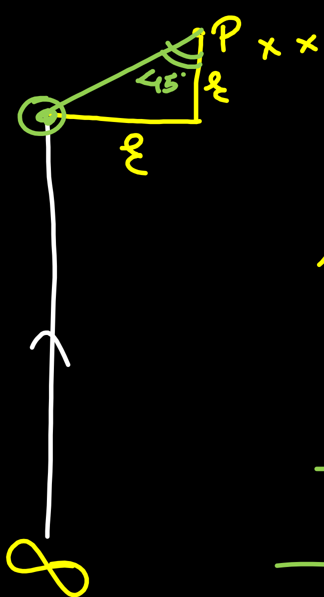




$$B = \frac{\mu_0 I}{2r}(+\hat{k})$$



$$\frac{\mu_0 I}{4\pi r}(\sin 90 + \sin 45) + \hat{k}$$



$$\frac{\mu_0 I}{4\pi r}\left(\sin 90 + \sin(-45)\right)(-\hat{k})$$

$$\frac{\mu_0 I}{4\pi r}(\sin 90 - \sin 45)(-\hat{k})$$

$$B_{net} = \vec{B_1} + \vec{B_2} + \vec{B_3}$$

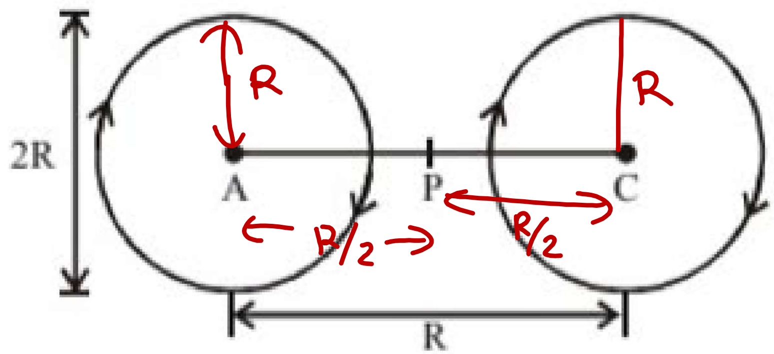
$$\frac{\mu_0 I}{2r} + \frac{\mu_0 I}{4\pi r}\left(1 + \frac{1}{\sqrt{2}}\right) - \frac{\mu_0 I}{4\pi r}\left(1 - \frac{1}{\sqrt{2}}\right)$$

$$= \frac{\mu_0 I}{2r} + \frac{\mu_0 I}{4\pi r}\left(\sqrt{2}\right)\hat{k}$$

$$= \frac{\mu_0 I}{2\pi r}\left[\pi + \frac{1}{\sqrt{2}}\right]\hat{k}$$

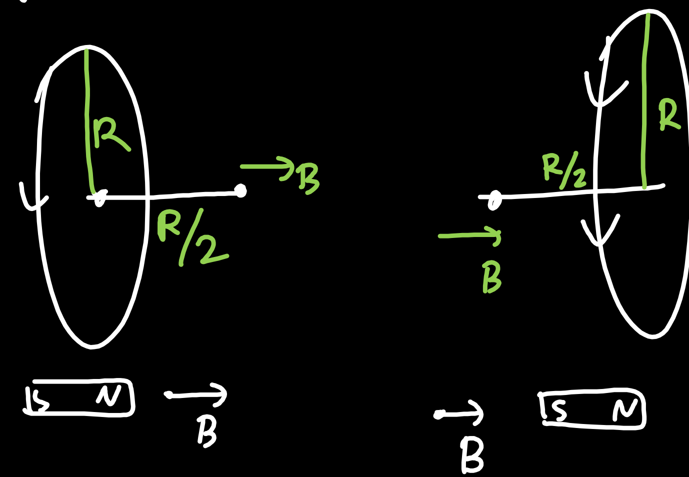
A Helmholtz coil has pair of loops, each with N turns and radius R. They are placed coaxially at distance R and the same current I flows through the loops in the same direction. The magnitude of magnetic field at P, midway between the centres A and C, is given by (Refer to figure):

[Online April 15, 2018]



(a) $\dfrac{4N\mu_0 I}{5^{3/2}R}$ (b) $\dfrac{8N\mu_0 I}{5^{3/2}R}$ (c) $\dfrac{4N\mu_0 I}{5^{1/2}R}$ (d) $\dfrac{8N\mu_0 I}{5^{1/2}R}$

H.W.



Two identical wires A and B, each of length 'l', carry the same current I. Wire A is bent into a circle of radius R and wire B is bent to form a square of side 'a'. If B_A and B_B are the values of magnetic field at the centres of the circle and square respectively, then the ratio $\frac{B_A}{B_B}$ is:

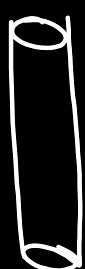
[2016]

(a) $\frac{\pi^2}{16}$ (b) $\frac{\pi^2}{8\sqrt{2}}$ (c) $\frac{\pi^2}{8}$ (d) $\frac{\pi^2}{16\sqrt{2}}$

A long, straight wire of radius a carries a current distributed uniformly over its cross-section. The ratio of the magnetic fields due to the wire at distance $\frac{a}{3}$ and $2a$, respectively from the axis of the wire is: **[9 Jan 2020, I]**

(a) $\frac{2}{3}$ (b) 2 (c) $\frac{1}{2}$ (d) $\frac{3}{2}$

Radius = a



B_{inside}
$r = a/3$

$$\boxed{\frac{\mu_0 I}{2\pi R^2}\frac{a}{3}}$$

$B_{out} =$
$r = 2a$

$$\boxed{\frac{\mu_0 I}{2\pi (2a)}}$$

The figure shows a long coaxial cable in which a current I flows down through the inner cylinder of radius a and the same current flows back up through the outer cylinder of radius 2a. The cylinders are insulated from each other and the current is uniformly distributed over the area of the cross-section in each cylinder. The strength of the magnetic field at a distance $3a/2$ from the axis of the cable is

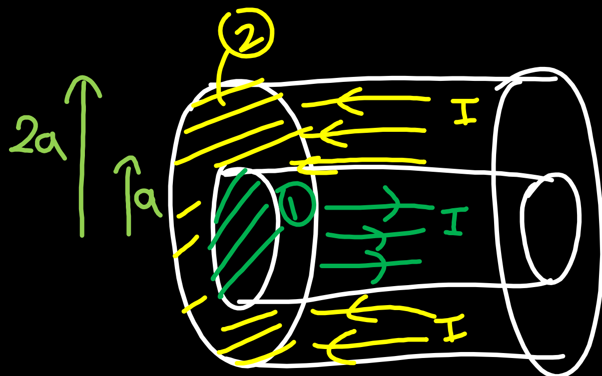
H.W.

(A) $B = \frac{5\mu_0 I}{36\pi a}$

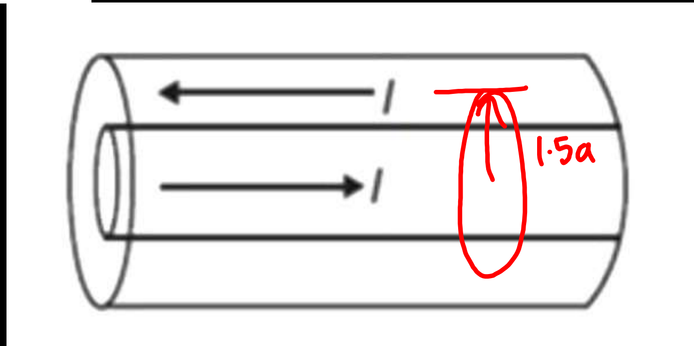
(B) $B = \frac{5\mu_0 I}{12\pi a}$

(C) $B = \frac{7\mu_0 I}{12\pi a}$

(D) $B = \frac{7\mu_0 I}{36\pi a}$



B at distance 1.5a



Solenoid

A cylindrical coil of many tightly wound turns of insulated wire with generally diameter of the coil smaller than its length is called a solenoid.

A magnetic field is produced around and within the solenoid.

The magnetic field within the solenoid is uniform and parallel to the axis of solenoid

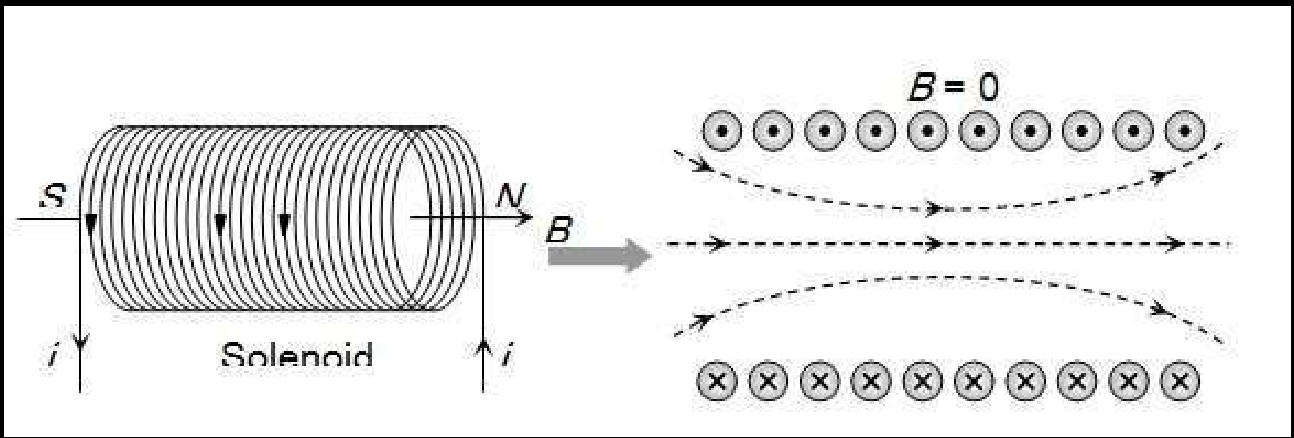
ideal

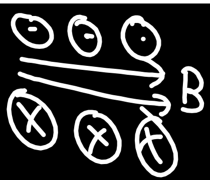
length >>> radius

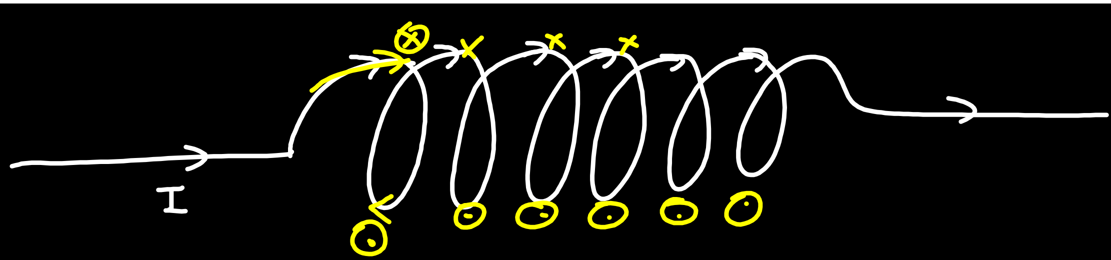
tightly closely packed turns

$B_{outside} = 0$

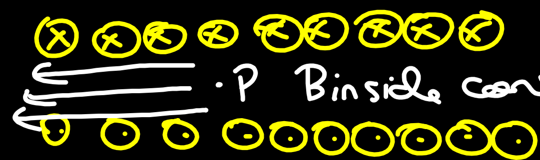
B_{inside} constant.





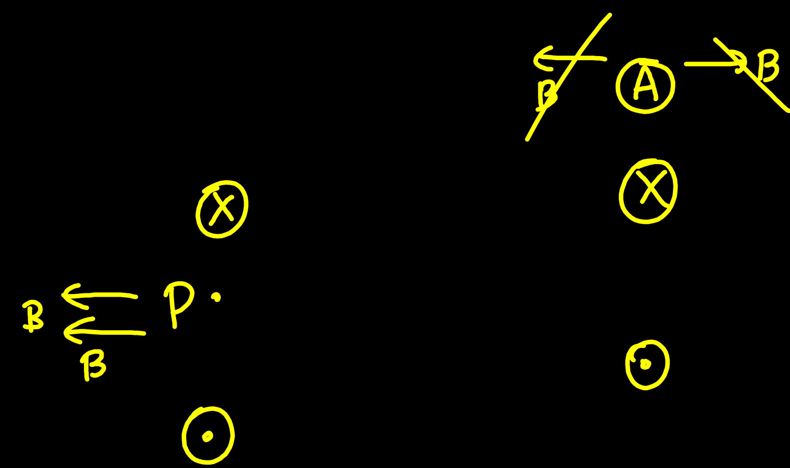


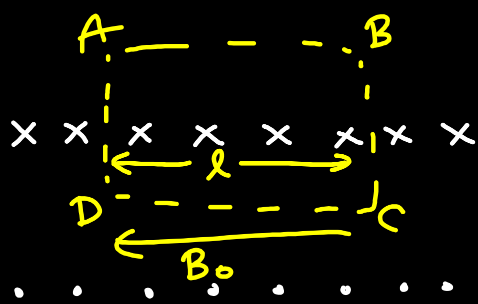
$\cdot A \quad B_{outside} = 0$



$\cdot P \quad B_{inside}$ constant

$B_{outside} = 0$





$\int \vec{B} \cdot \vec{dl}$

AB
0

BC
0

CD
$B_0 l$

DA
0

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

$N \rightarrow$ no. of turns

$$B_0 l = \mu_0 (N I)$$

$$B_0 = \mu_0 \left(\frac{N}{l}\right) I$$

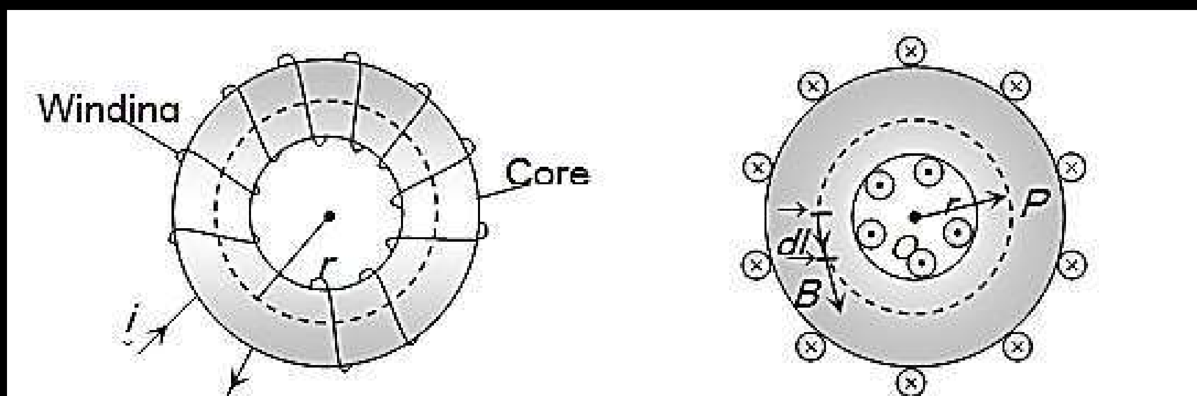
$$\boxed{B_0 = \mu_0 n I}$$

n = no. of turns per unit length.

Toroid

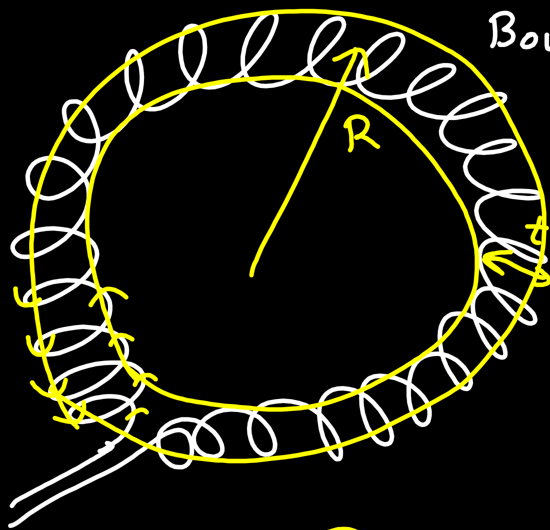
A toroid can be considered as a ring shaped closed solenoid.

Hence it is like an endless cylindrical solenoid Consider a toroid having n turns per unit length.



$$B = \frac{\mu_0 N i}{2\pi r} = \mu_o n i \text{ Where } n = \frac{N}{2\pi r}$$

$B_{outside} = 0$

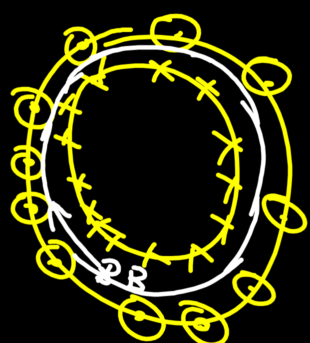


thickness <<< R

closely packed

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

$$n = \frac{N}{\text{length}}$$



$$\boxed{n = \frac{N}{2\pi R}}$$

A solenoid of 1000 turns per metre has a core with relative permeability 500. Insulated windings of the solenoid carry an electric current of 5 A. The magnetic flux density produced by the solenoid is

(Permeability of free space = $4\pi \times 10^{-7}$ H/m)

a. πT **b.** $2 \times 10^{-3}\ \pi$T **c.** $\frac{\pi}{5}$T **d.** $10^{-4}\ \pi$T

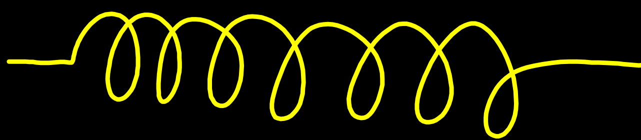
JEE 2021

$B = \mu_0 \mu_r n I$

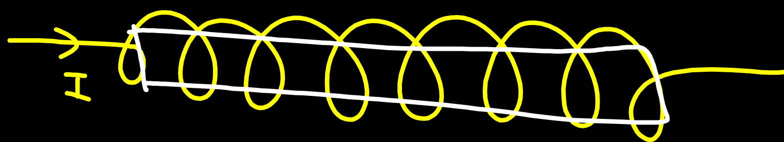
$= (4\pi \times 10^{-7})(500)(1000)(5A)$

$= \pi$

Medium change



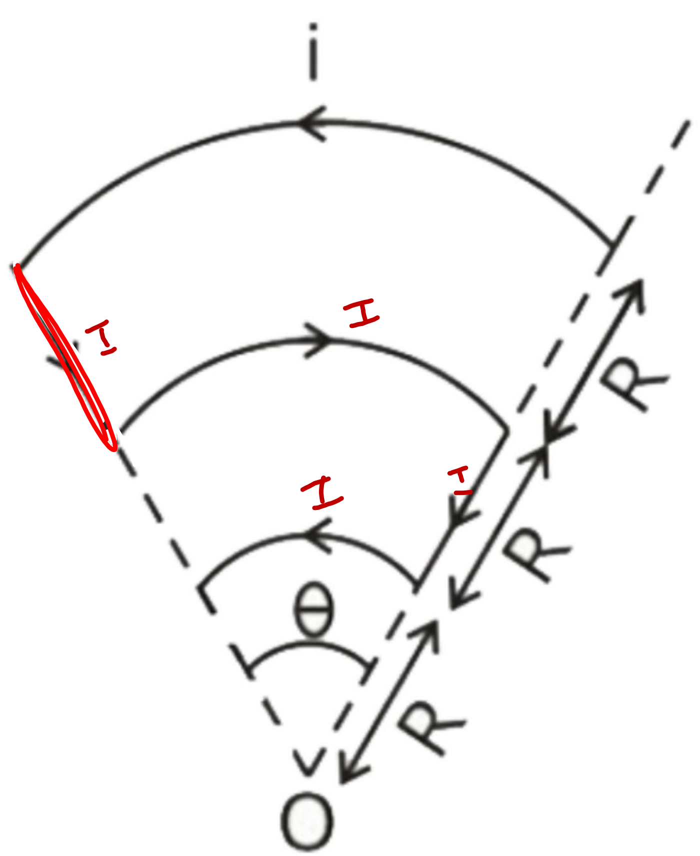
$B = (\mu_0 n I)$ vaccum



$$\mu_0 \longrightarrow \mu_r \mu_0$$

$$\underline{B_{insi} = \mu_0 \mu_r n I}$$

A conductor is carrying a current i. the magnetic field intensity at a the point O which is the common centre of three arcs is



A) $\frac{5\mu_0 I\theta}{24\pi r}$

B) $\frac{\mu_0 I\theta}{24\pi r}$

C) $\frac{11\mu_0 I\theta}{24\pi r}$

D) zero

$r = 3R$ $\quad$ $r = 2R$ $\quad$ $r = R$

$\frac{\mu_0 I \theta}{4\pi(3R)}$ $+k$ $\quad$ $\frac{\mu_0 I \theta}{4\pi(2R)}$ $-k$ $\quad$ $\frac{\mu_0 I \theta}{4\pi(R)}$ $+k$

$$\Rightarrow \left[\frac{\mu_0 I \theta}{4\pi R}\right]\left[\frac{1}{3}+\frac{1}{1}-\frac{1}{2}\right]$$

$$\frac{4}{3}-\frac{1}{2}$$

$$\frac{5\mu_0 I\theta}{24\pi R}$$

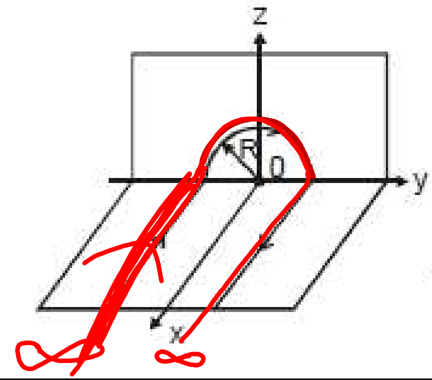
Find the magnetic induction at the point O if the wire carrying a current I has the shape shown in figure a, b, c. The radius of the curved part of the wire is R, the linear parts of the wire are very long.

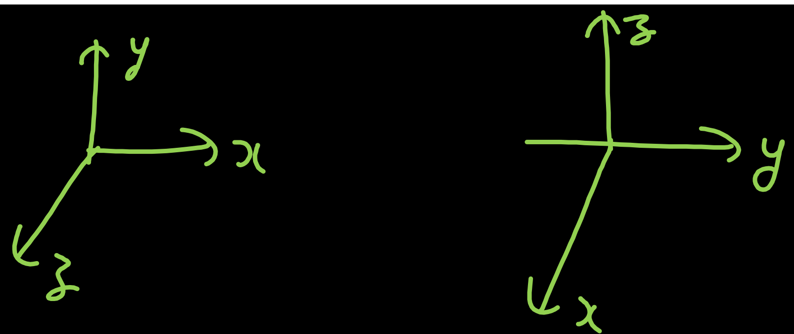
(A) $B = \frac{\mu_0}{4\pi}\frac{\left(\sqrt{4-\pi^2}\right)I}{R}$

(B) $B = \frac{\mu_0}{4\pi}\frac{\left(\sqrt{4+\pi^2}\right)I}{4R}$

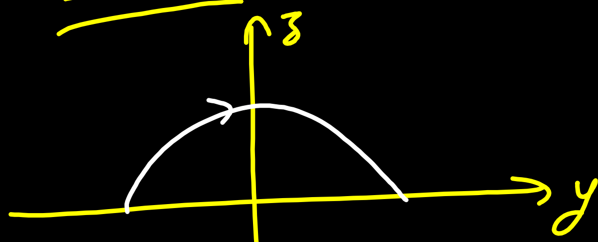
(C) $B = \frac{\mu_0}{4\pi}\frac{\left(\sqrt{4+\pi^2}\right)I}{2R}$

(D) $B = \frac{\mu_0}{4\pi}\frac{\left(\sqrt{4+\pi^2}\right)I}{R}$



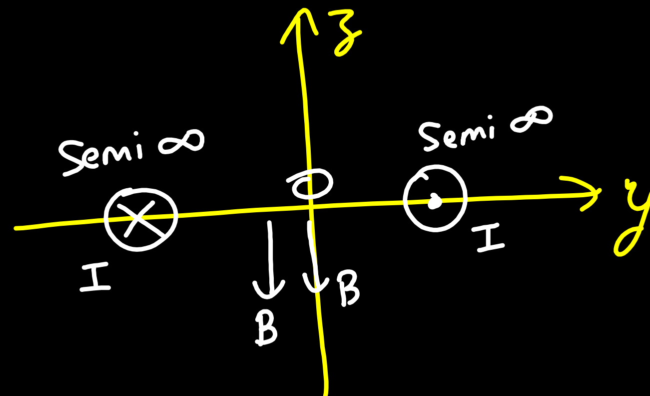


plane



$$\frac{\mu_0 I}{4\pi R}(\pi)$$

$$\frac{\mu_0 I}{4R}(-\hat{i})$$



$$B_{net} = B_1 + B_2 \left(-\hat{k}\right)$$

$$= \frac{\mu_0 I}{4\pi r} + \frac{\mu_0 I}{4\pi r}\left(-\hat{k}\right)$$

$$= \frac{\mu_0 I}{2\pi r}\left(-\hat{k}\right)$$

$$\vec{B}_{net} = \frac{\mu_0 I}{4R}(-\hat{i}) + \frac{\mu_0 I}{2\pi R}(-\hat{k})$$

$$= \frac{\mu_0 I}{2\pi R}\left(\frac{\pi}{2}(-\hat{i}) + 1\,(-\hat{k})\right)$$

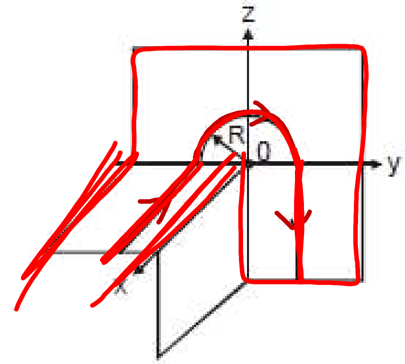
$$= \frac{\mu_0 I}{4\pi R}\left[\pi(-\hat{i}) + 2\,(-\hat{k})\right]$$

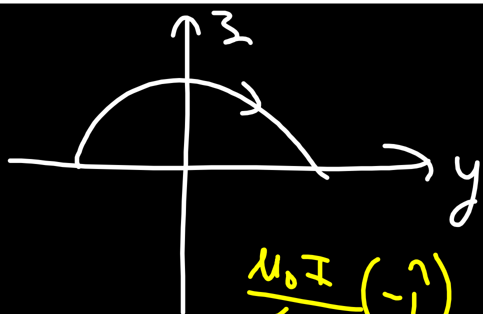
$$\frac{\mu_0 I}{4\pi R}\sqrt{\pi^2 + 4}$$

Find the magnetic induction at the point O if the wire carrying a current I has the shape shown in figure a, b, c. The radius of the curved part of the wire is R, the linear parts of the wire are very long.

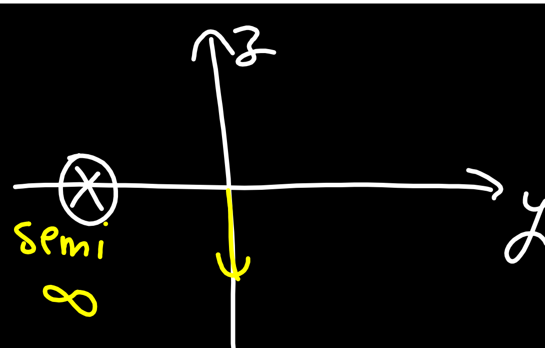
(A) $B = \dfrac{\mu_0}{2\pi}\dfrac{\left(\sqrt{2+2\pi+\pi^2}\right)I}{R}$ (B) $B = \dfrac{\mu_0}{4\pi}\dfrac{\left(\sqrt{2+2\pi+4\pi^2}\right)I}{R}$

(C) $B = \dfrac{\mu_0}{4\pi}\dfrac{\left(\sqrt{2+\pi+\pi^2}\right)I}{R}$ (D) $B = \dfrac{\mu_0}{4\pi}\dfrac{\left(\sqrt{2+2\pi+\pi^2}\right)I}{R}$

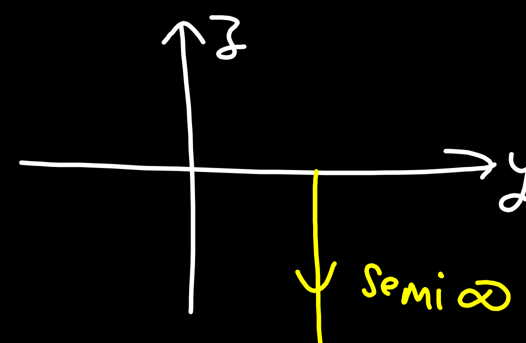




$\dfrac{\mu_0 I}{4R}(-\hat{i})$



$B = \dfrac{\mu_0 I}{4\pi R}(-\hat{k})$



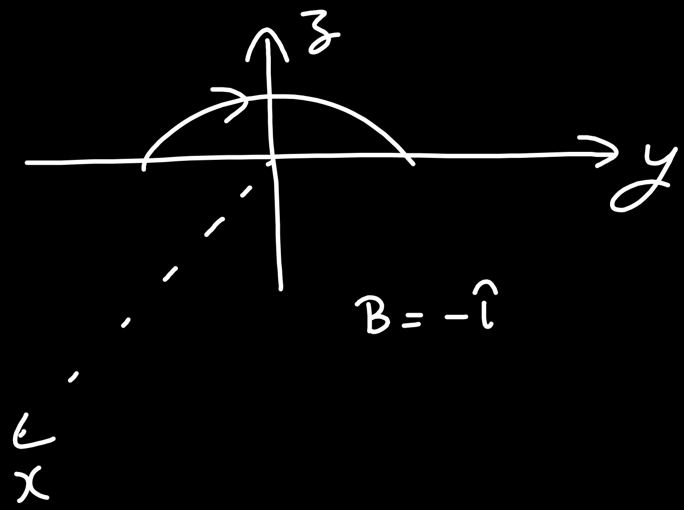
$\dfrac{\mu_0 I}{4\pi R}(-\hat{i})$

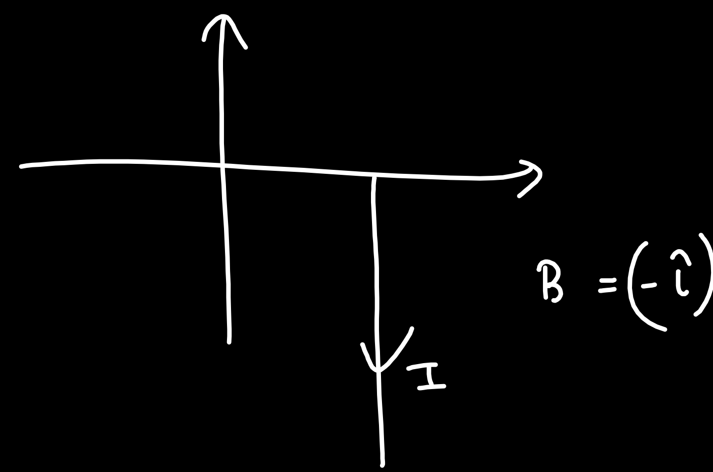
$$B_{net} = \left(\frac{\mu_0 I}{4R} + \frac{\mu_0 I}{4\pi R}\right)(-\hat{i}) + \frac{\mu_0 I}{4\pi R}(-\hat{k})$$

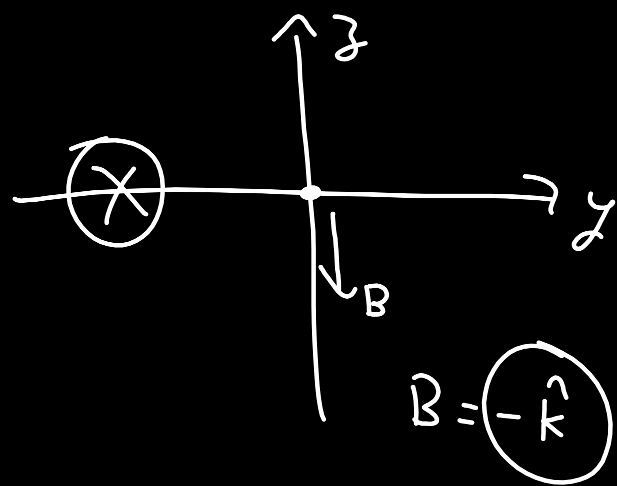
$$= \frac{\mu_0 I}{4\pi R}\left[(\pi + 1)(-\hat{i}) + 1(-\hat{k})\right]$$

$$= \frac{\mu_0 I}{4\pi R}\sqrt{(1+\pi)^2 + 1^2}$$

$$= \frac{\mu_0 I}{4\pi R}\sqrt{2 + \pi^2 + 2\pi}$$


z
y
x
B = −î

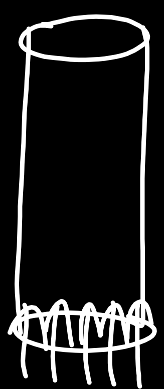

B = (−î)
I


z
y
B
B = −k̂

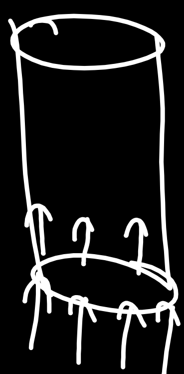
A current I flows in an infinitely long wire with cross section in the form of a semi-circular ring of radius R. The magnitude of the magnetic induction along its axis is: [2011]

(a) $\frac{\mu_0 I}{2\pi^2 R}$ (b) $\frac{\mu_0 I}{2\pi R}$ (c) $\frac{\mu_0 I}{4\pi R}$ (d) $\frac{\mu_0 I}{\pi^2 R}$

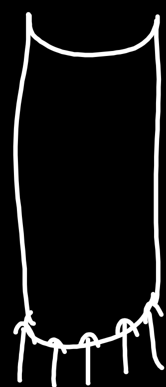
Solid Cylinder



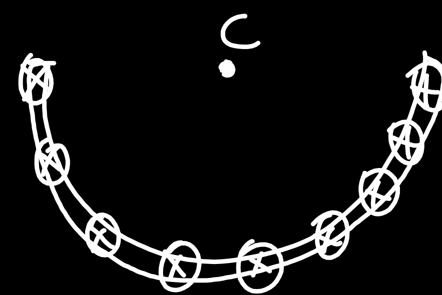
hollow Cylinder



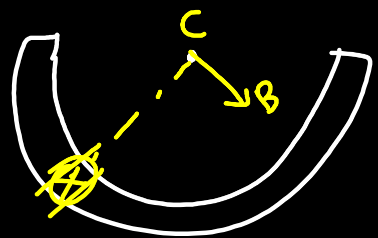
Half ring

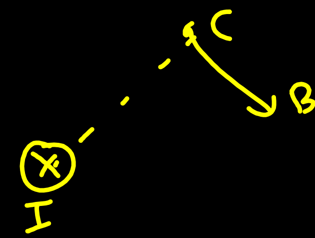


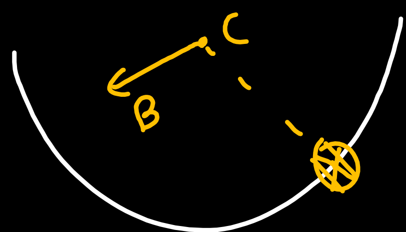
Top View

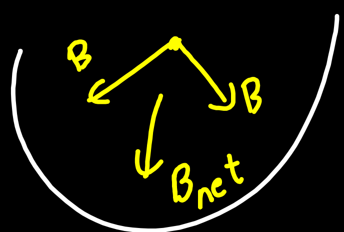


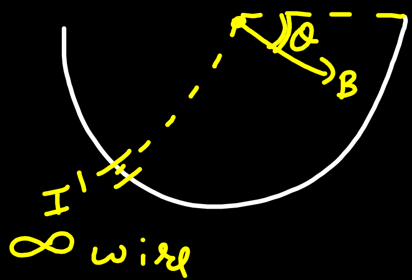
total current = I


C
B


C
B
I


C
B


B
B
B_{net}



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

$$B_y = B\sin\theta$$

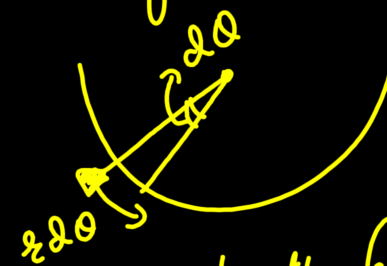
$$= \int \frac{\mu_0 I'}{2\pi R}\sin\theta$$

$$= \frac{\mu_0}{2\pi R}\int \frac{I\,d\theta}{\pi}\sin\theta$$

$$= \frac{\mu_0 I}{2\pi^2 R}\int_0^{\pi}\sin\theta\,d\theta$$

$$= \frac{\mu_0 I}{2\pi^2 R}\times 2 = \boxed{\frac{\mu_0 I}{\pi^2 R}}$$

I' find

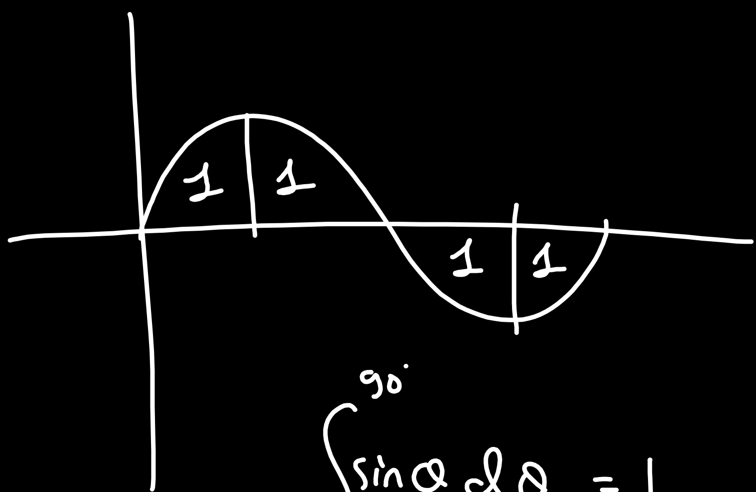


$$\text{arclength} = (\text{radius})(\text{angle}) = (r\,d\theta)$$

$$\pi R \rightarrow I$$

$$R\,d\theta \rightarrow \frac{I}{\pi R}R\,d\theta$$

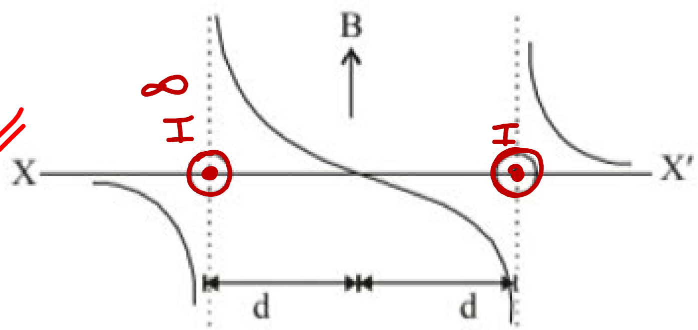
$$\frac{I\,d\theta}{\pi}\quad I'$$

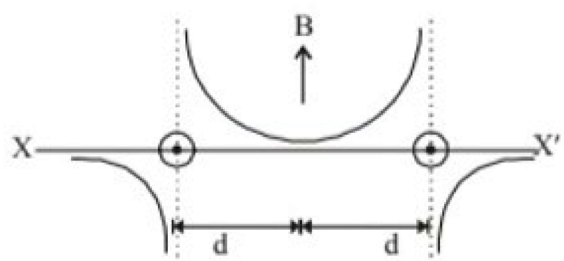


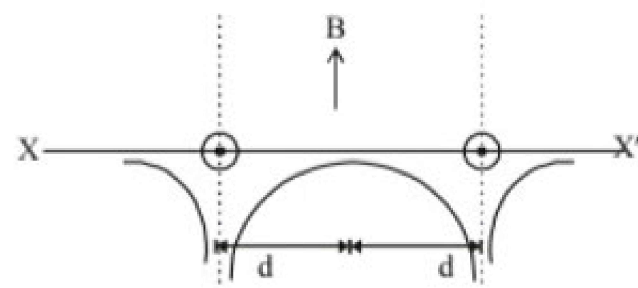
$$\int_0^{90^\circ} \sin\theta \, d\theta = 1$$

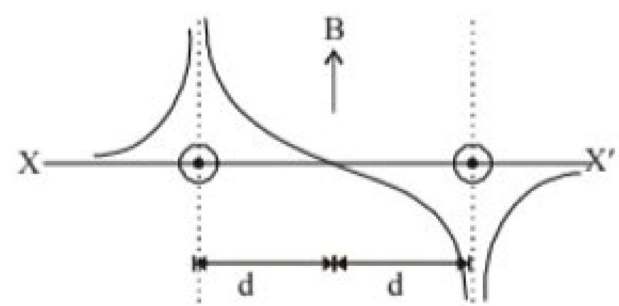
$$\int_0^{180^\circ} \sin\theta \, d\theta = 2$$

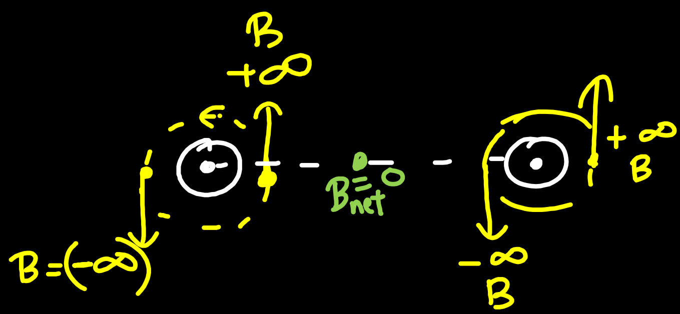
Two long parallel wires are at a distance 2d apart. They carry steady equal currents flowing out of the plane of the paper as shown. The variation of the magnetic field B along the line XX' is given by **[2010]**

(a)


(b)


(c)


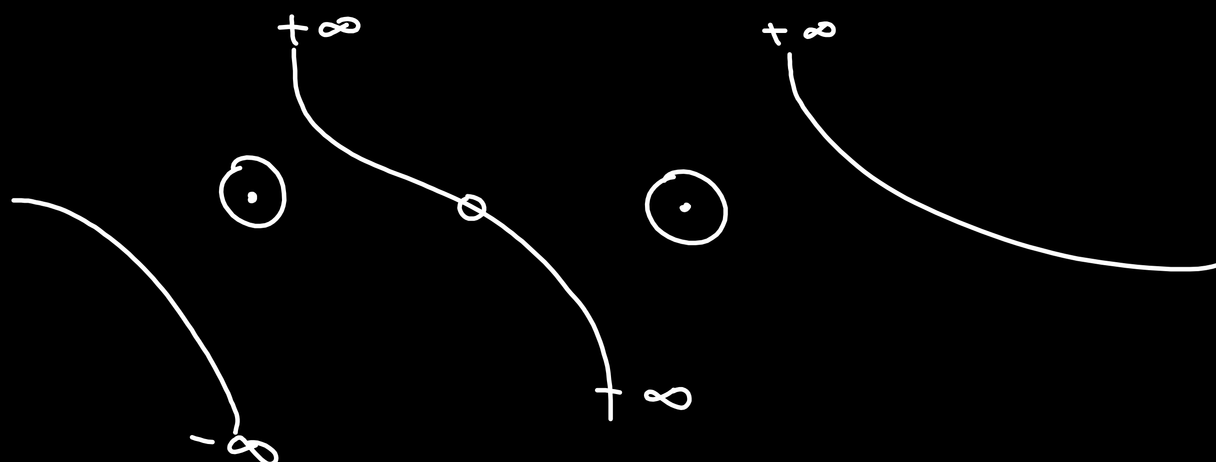
(d)




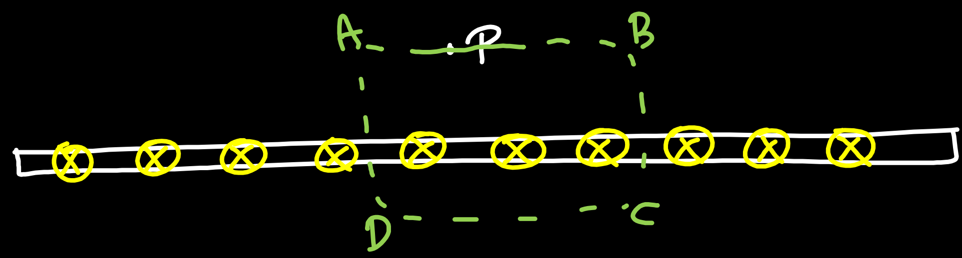
identify B at very close to wires

identiy $B_{net} = 0$ points

$$B = \frac{\mu_0 I}{2\pi r}$$
(∞ wire)



Q



Current per unit length is λ

B at P = ?

a) $\mu_0 \lambda$

b) $\mu_0 \lambda/2$

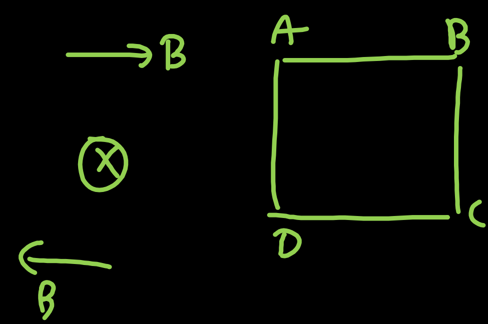
c) $2\mu_0 \lambda$

d) None.

$$\frac{I}{\text{length}} = \lambda$$

$$I = \lambda l$$

Very large metal shell



$$\oint \vec{B}\cdot\vec{dl}$$

$AB = B_0 l$

$BC = 0$

$CD = B_0 l$

$DA = 0$

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

$$B_0 l + B_0 l = \mu_0 \lambda l$$

$$2 B_0 \cancel{l} = \mu_0 \lambda \cancel{l}$$

$$B_0 = \frac{\mu_0 \lambda}{2}$$

Energy Stored in Magnetic Field

energy density = energy per Volume = $\frac{1}{2}\frac{1}{\mu_0}B^2$

$$\boxed{\frac{\text{energy}}{\text{Volume}} = \frac{1}{2\mu_0}B^2}$$

extra

energy density = $\frac{1}{2}\varepsilon_0 E^2$

Electro Magn

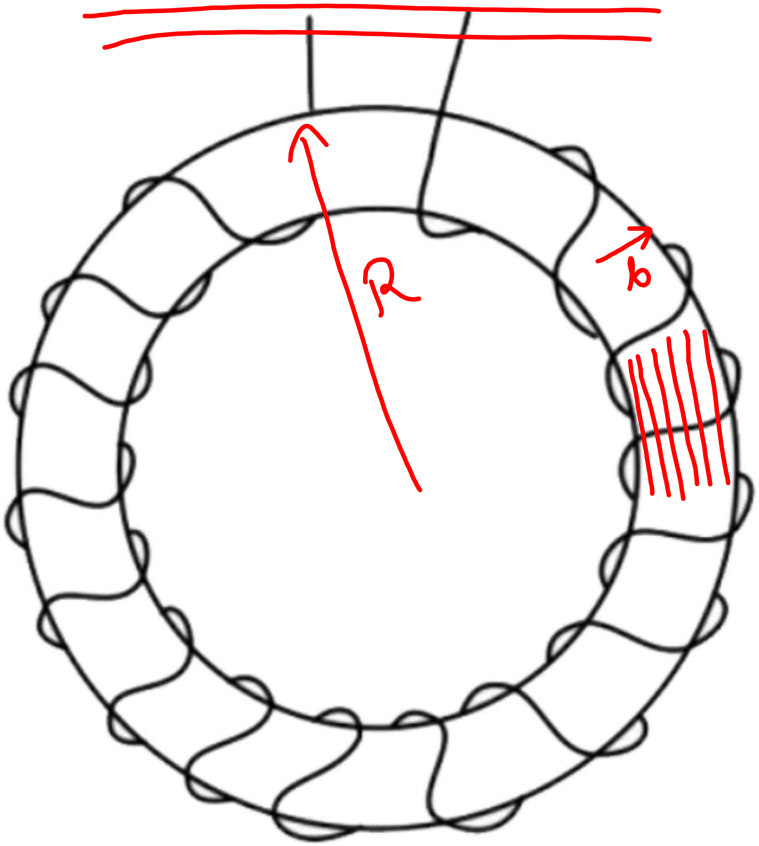
$E \longrightarrow B$

$\varepsilon_0 \longrightarrow \frac{1}{\mu_0}$

k

$\frac{1}{4\pi\varepsilon_0}$ $\frac{\mu_0}{4\pi}$

Consider a toroid of circular cross - section of radius b, major radius R much greater than minor radius b, (see diagram) find the total energy stored in magnetic field of toroid -



B → given = B

(A) $\frac{B^2\pi^2 b^2 R}{2\mu_0}$

(B) $\frac{B^2\pi^2 b^2 R}{4\mu_0}$

(C) $\frac{B^2\pi^2 b^2 R}{8\mu_0}$

(D) $\frac{B^2\pi^2 b^2 R}{\mu_0}$

$$\frac{\text{energy}}{\text{Vol}} = \frac{1}{2\mu_0} B^2$$

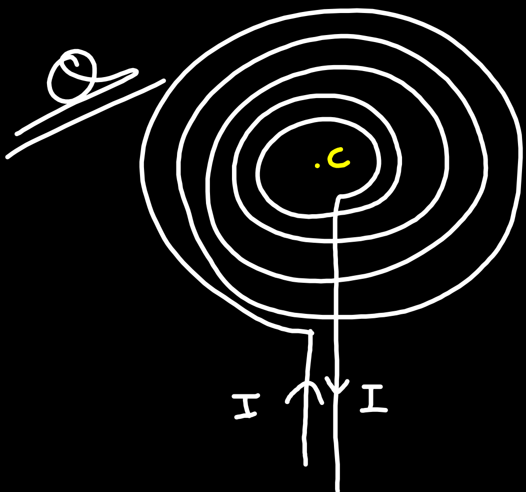
$$\text{energy} = \frac{1}{2\mu_0} B^2 (\text{Vol})$$

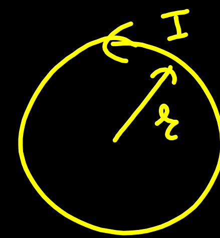
$$= \frac{1}{2\mu_0} B^2 (\text{area})(\text{length})$$

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

G.O.A.T

11th Physics

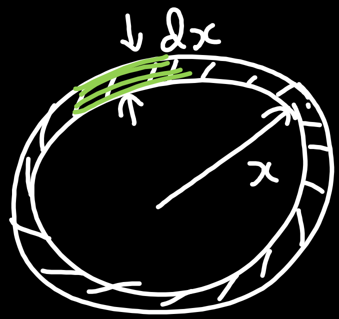




$$B = \frac{\mu_0 I}{2r}$$

Spiral of N turns carrying current I. outer radius = b inner radius = a

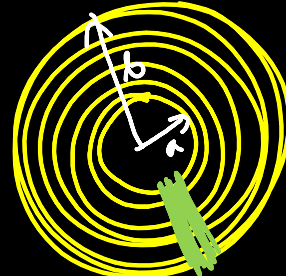
Find B at Center?



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

due to 1 loop

multiply by no. of turns



$(b-a) \longrightarrow N$

$dx \longrightarrow \left(\frac{N}{b-a}\right) dx$

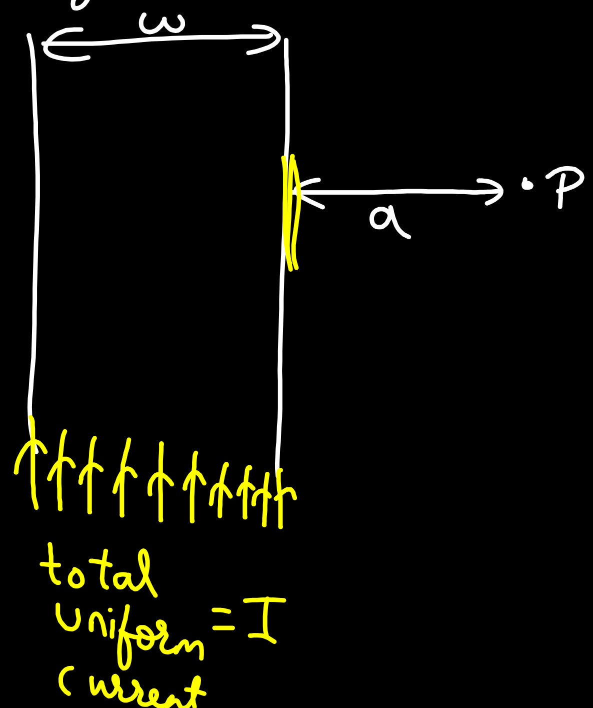
$$B = \int_a^b \frac{\mu_0 I}{2x} \frac{N}{b-a}\, dx$$

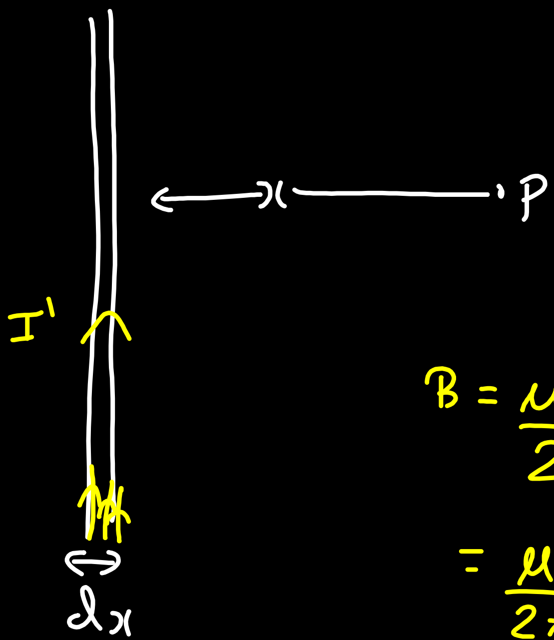
$$= \frac{\mu_0 I N}{2(b-a)} \int \frac{dx}{x}$$

$$= \frac{\mu_0 I N}{2(b-a)} \left[\ln x\right]_a^b = \boxed{\frac{\mu_0 I N}{2(b-a)} \ln\left(b/a\right)}$$

Q. Large Metal Sheet width $= w$

Find B at P??





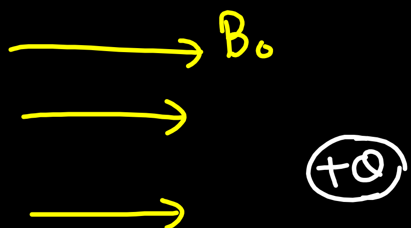
$$\boxed{\begin{aligned} &\omega \longrightarrow I \\ &dx \rightarrow \frac{I}{w}\,dx = I' \end{aligned}}$$

$$B = \frac{\mu_0 I'}{2\pi x}$$

$$= \frac{\mu_0}{2\pi x}\,\frac{I}{w}\,dx$$

$$= \frac{\mu_0 I}{2\pi w}\int_a^{a+w}\frac{dx}{x} = \frac{\mu_0 I}{2\pi w}\ln\left(\frac{a+w}{a}\right)$$

Effect of Magnetic Field on Charges



externally created

force applied by $\vec{B}$ on charge $= Q(\vec{v} \times \vec{B})$

Cross Product

$\vec{a} \times \vec{b} = ab\sin\theta\, \hat{n}$

$\hat{n}$: Unit vector decided by right hand rule.

$\hat{i} \times \hat{j} = \hat{k}$

$\hat{j} \times \hat{i} = -\hat{k}$

$\vec{c} = \vec{a} \times \vec{b}$

$\hat{k} = \hat{i} \times \hat{j}$

\# $\vec{c}$ is ⊥'ar to $\vec{a}$

$\vec{c}$ " " " $\vec{b}$

$\vec{c}$ " " " plane of $\vec{a}$ & $\vec{b}$.

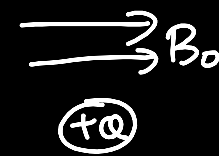
$\vec{a} = a_1\hat{i} + a_2\hat{j} + a_3\hat{k}$

$\vec{b} = b_1\hat{i} + b_2\hat{j} + b_3\hat{k}$

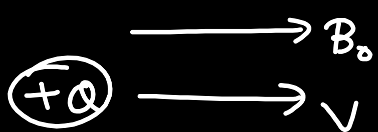
$$\vec{a} \times \vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix}$$

① charge at rest

$v = 0$ $\quad F = 0$ $\quad$ no effect of B on charge



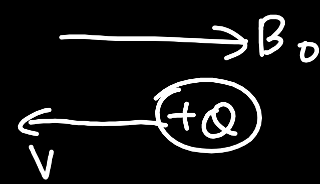
② velocity $\parallel$ or anti $\parallel$ to $\vec{B}$



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

$= QvB\sin\theta$ $\quad \boxed{\theta = 0^\circ}$

$F = 0$



$\sin 180 = 0$

$F = QvB\sin(180)$

$F = 0$

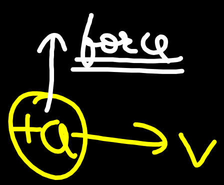
③ initial velocity $\perp$'ur to $\vec{B}$.

$$\vec{F} = Q(\vec{v} \times \vec{B}) \qquad \theta = 90^\circ$$

$$|F| = QvB\sin\theta$$

$$\boxed{|F| = QvB}$$

$\times \quad \times \quad \times \quad \times \quad \times \quad \times \quad B_0(-\hat{k})$



$F = QvB$

Right hand thumb Rule

→ Join vectors tail to tail

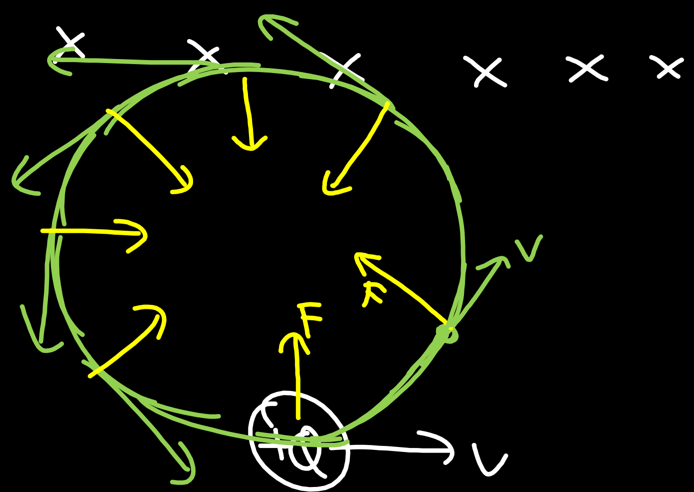
→ Curl fingers from 1st vector to 2nd vector via shortest angle

→ thumb gives directⁿ of cross product

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

$\vec{F}$ will always be ⊥'ur to $\vec{vel}$.

" " " " " to $\vec{B}$



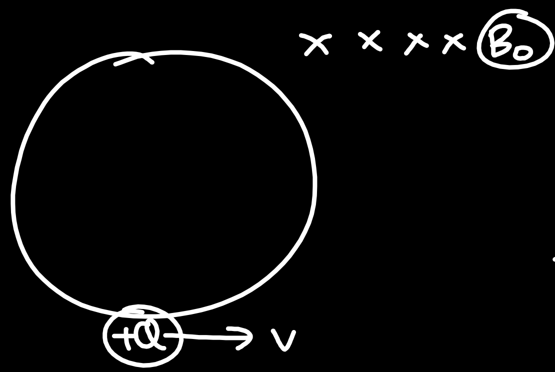
Hence path will be U.C.M. (uniform circular motion)

Strongly recommended

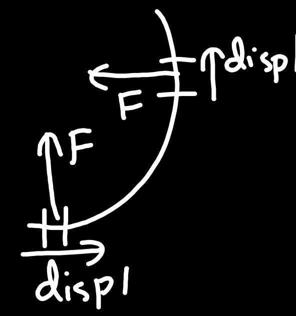
G.O.A.T

circular motion

#



$WD = \vec{Force} \cdot \vec{displ}$



WD by magnetic force = 0

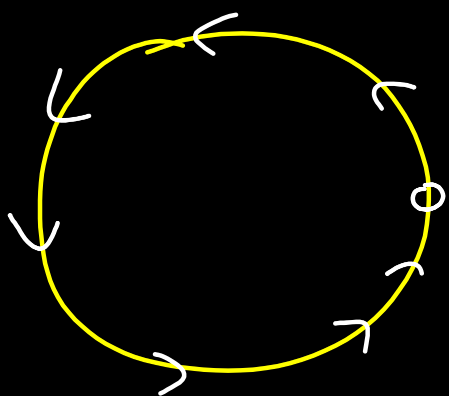
(force always ⊥'ur to motion)

$WD_{net} = \Delta KE$

$$0 = 0$$

<u>KE & speed constant</u>

U.C.M



$$F_{net\ center} = m a_c$$

$$\boxed{F_{net\ center} = m\left(\frac{v^2}{r}\right)}$$

$$\boxed{V = r\omega}$$

equal angle covered in equal time

Speed constant.

$$\boxed{\text{Distance} = r\theta}$$ (θ in radians)

$$\boxed{\text{Displacement} = 2r\sin(\theta/2)}$$

$$\boxed{|\text{change in vel}| = 2v\sin(\theta/2)}$$

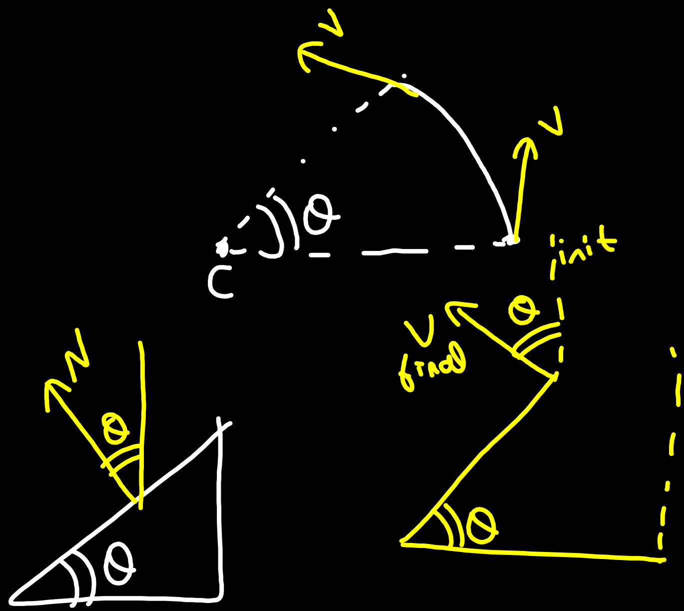
$\omega \to$ constant

$\alpha \to 0$

$$\theta = \omega t + \frac{1}{2}\alpha t^2$$

$$\boxed{\theta_{rotated} = \omega t}$$

$$\boxed{\text{Time Period} = \frac{2\pi}{\omega}}$$



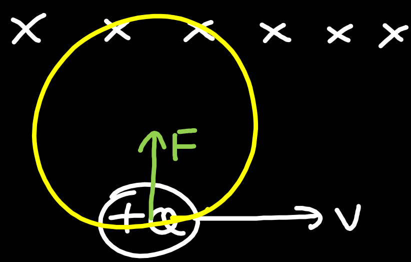
velocity is tangential.

angle b/w initial & final vel = arc angle

= angle b/w radius

angle of deviation → arc angle

#



$$|F|_{mag} = QvB$$

$$F_{net_c} = \frac{mv^2}{r}$$

$$Q\cancel{v}B = \frac{mv^{\cancel{2}}}{r}$$

$$\boxed{r = \frac{mv}{QB}}$$

$\Rightarrow$ $v = r\omega$

$$\cancel{v} = \left(\frac{m\cancel{v}}{QB}\right)\omega$$

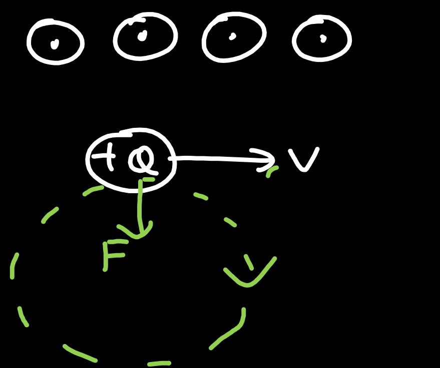
$$\frac{QB}{m} = \omega$$

$\Rightarrow$ Time Period $= \frac{2\pi r}{v} = \frac{2\pi}{\omega}$

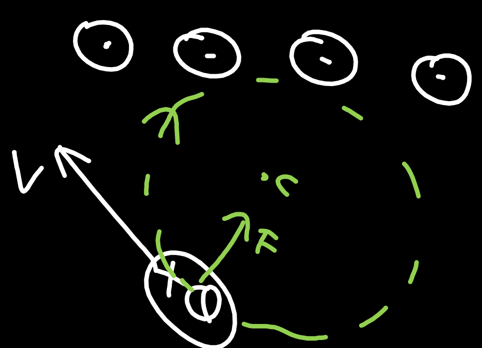
$$\boxed{\text{Time} = \frac{2\pi m}{QB}}$$

Direction of Force

1



2



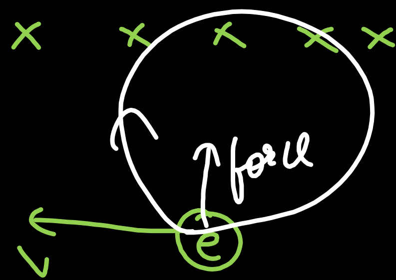
3

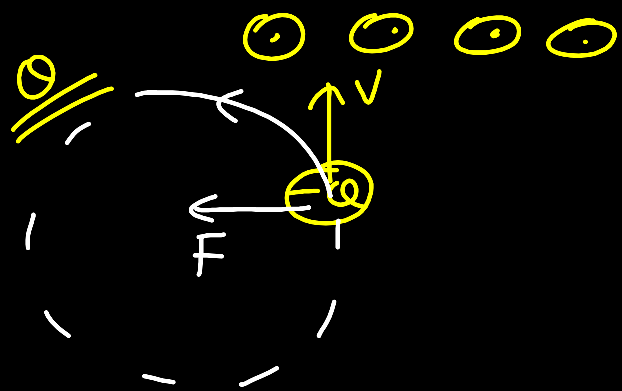
4

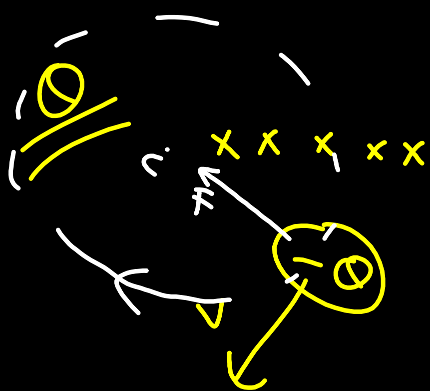
$$\vec{F} = Q(\vec{v} \times \vec{B})$$

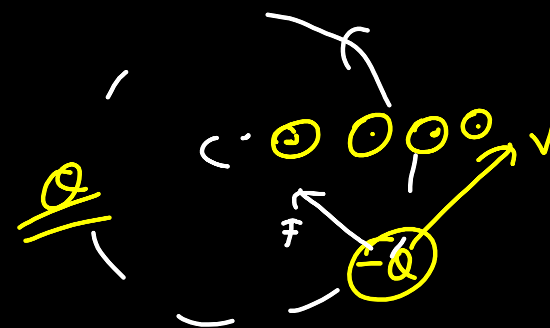
-ve charge = alert

(-ve charge)
electron is fired as shown where F is acting




V
F


F
V


V
F

$$\boxed{\mathcal{R} = \frac{mv}{QB} = \frac{P}{QB} = \frac{\sqrt{2m(KE)}}{QB} = \frac{\sqrt{2m(Q\,V_{acc})}}{QB}}$$

$$KE = \frac{P^2}{2m}$$

$$\sqrt{2m(KE)} = P$$

electro.

$$WD = (Q\,\Delta V_{acc\ voltage})$$

$$WD = \Delta KE$$

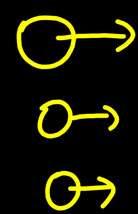
Q

Proton $^{1}_{1}H$

Deutron $^{2}_{1}H$

α particle $^{4}_{2}He^{+2}$

$\times \ \times \ \times \ \times \ \times \ \times$ B



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

Find ratio of their radius.

if (1) all fired with same speed.

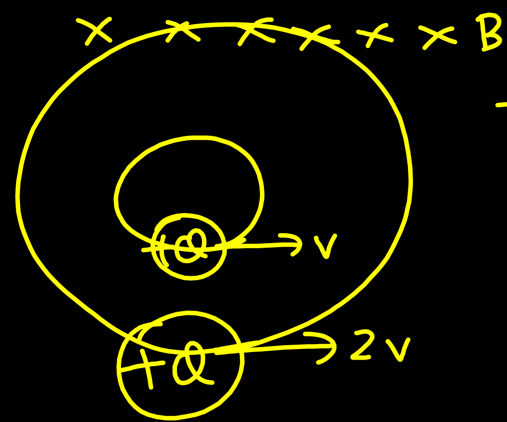
$$r \propto \frac{m}{Q}$$

Proton	Deut	α
$\frac{m}{e}$	$\frac{2m}{e}$	$\frac{4m}{2e}$

$$\boxed{1 : 2 : 2}$$

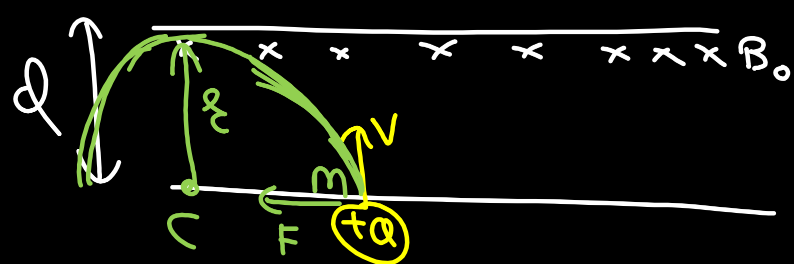
$$\boxed{\text{Time} = \frac{2\pi m}{QB}}$$

→ independent of radius & speed.



Time Same

Q

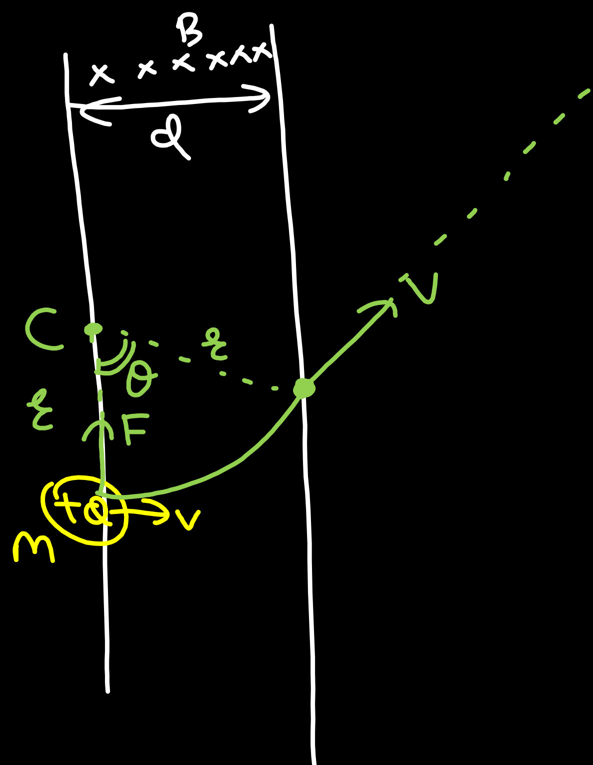


Condition for no collision with upper plate

$$r \leq d$$

$$\boxed{\frac{mv}{QB} \leq d}$$

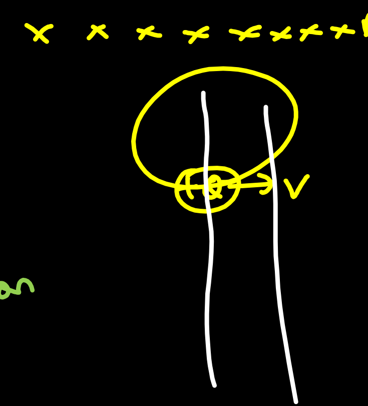
Q. $d < radius$

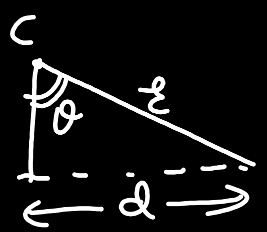


Find ① θ in terms of r & d

② angle of deviation

③ time spent in B





$$\sin\theta = \frac{d}{r}$$

① $$\boxed{\theta = \sin^{-1}\left(\frac{d}{r}\right)}$$

② $$Ans = \theta$$
$$= \sin^{-1}\left(\frac{d}{r}\right)$$

(radian)

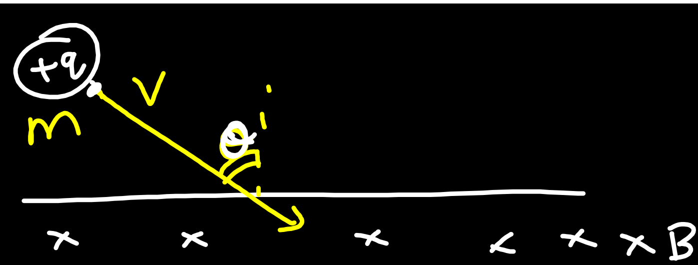
③ $$\theta = \omega t$$
rotated

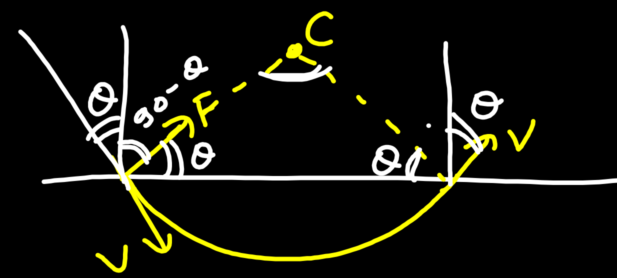
$$\theta = \frac{QB}{m} t$$

$$\theta\left[\frac{m}{QB}\right] = t$$

$$\frac{m}{QB}\sin^{-1}\left(\frac{d}{r}\right) = t$$

Q

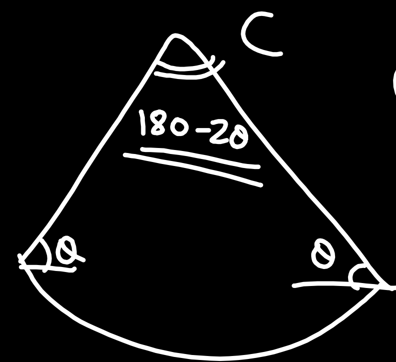




Find (1) deviation of B

(2) time spent in B.

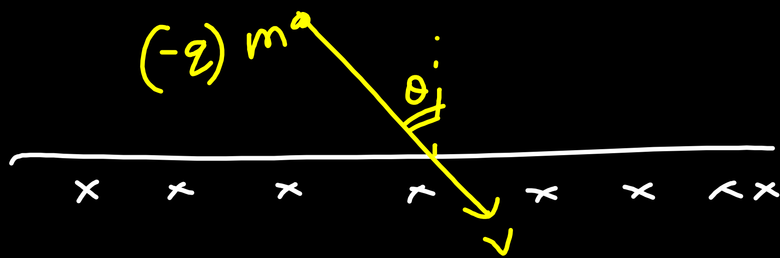
Ans $\Rightarrow \pi - 2\theta$



$\pi - 2\theta$

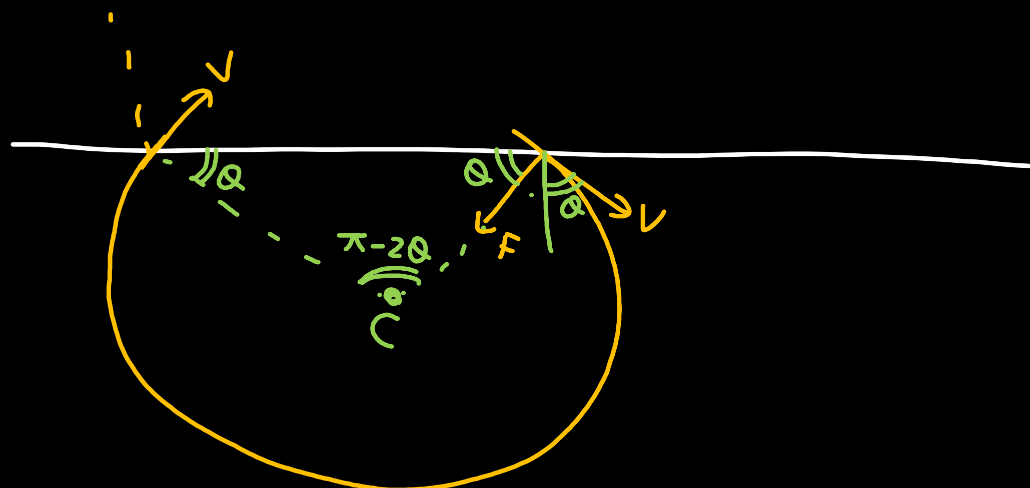
$$\theta_{rotated} = \omega t \Rightarrow t = \frac{\pi - 2\theta}{\omega} = \frac{(\pi - 2\theta)}{qB} m$$

Q



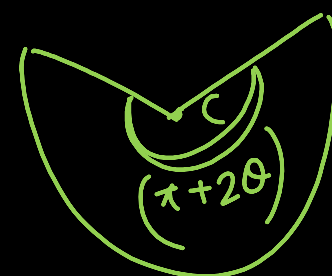
Ans ⇒ ① $\pi + 2\theta$

② $\dfrac{\pi + 2\theta}{\omega} = t$

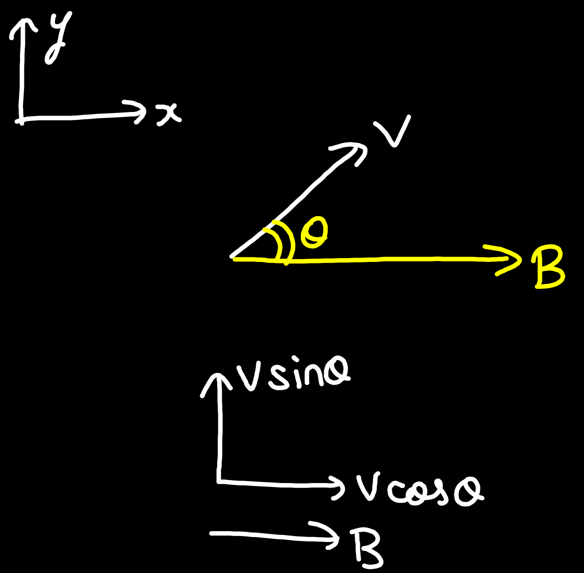


$2\pi - (\pi - 2\theta)$

$= \pi + 2\theta$



4) When vel is at an angle from $\vec{B}$ (hellical path)



Parallel vel

$\longrightarrow V\cos\theta$

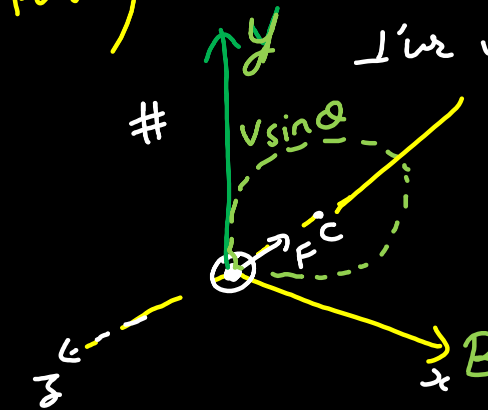
$\longrightarrow B$ x axis

force on particle $= 0$

motion Unchanged

$\longrightarrow$ uniform vel

$\perp$'r vel.

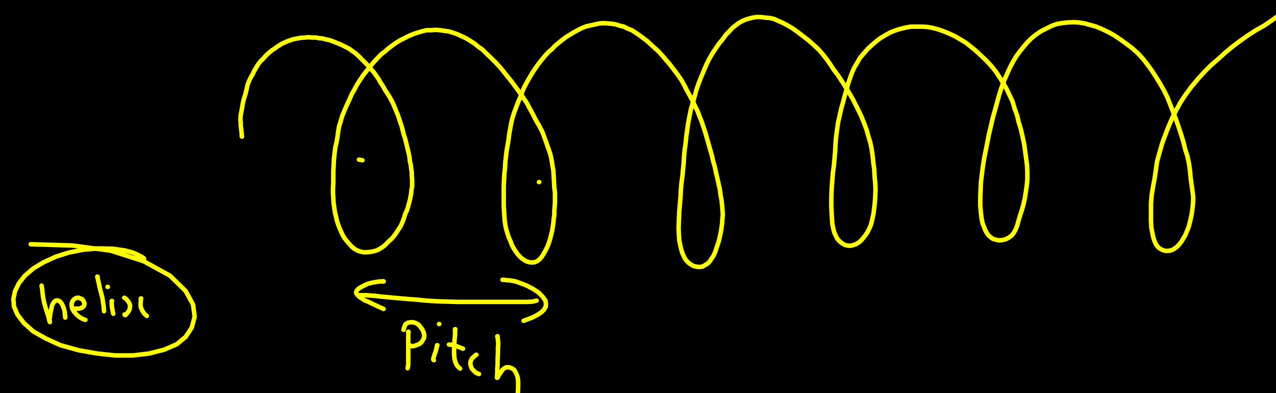


Circle yz plane

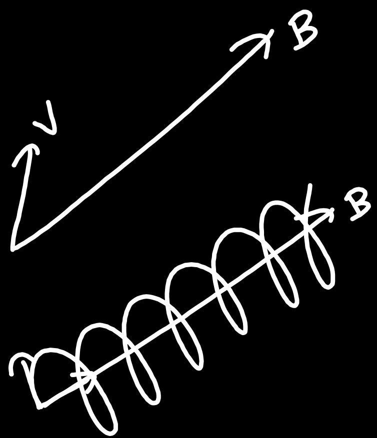
circle plane is $\perp$'ur to $\vec{B}$

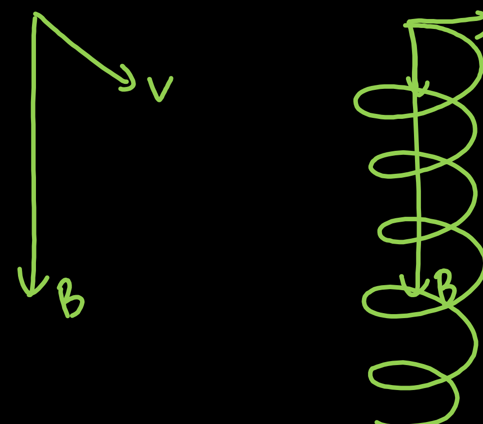
vector addition of both motion

axis along B direction.



$$\text{Pitch} = (V_{\parallel})(\text{Time Period}) = V_{\parallel}\left(\frac{2\pi m}{qB}\right)$$



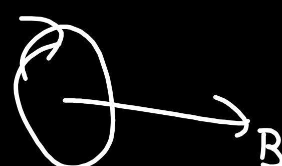


Hellical Path $\Rightarrow$ $\longrightarrow V_{\parallel}$

dist = $V_{\parallel}$ (time)

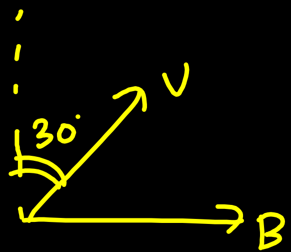
+

Circle plane ($V_{\perp}$)



$r = \dfrac{mV_{\perp}}{QB}$ $\quad T = \dfrac{2\pi m}{QB}$

Q//



$V_\perp$: $V\cos 30 = V\sqrt{3}/2$

$V_\parallel$: $V\sin 30 = V/2$

$r = ?$

$T = ?$

pitch $= ?$

$$r = \frac{mV_\perp}{QB} = \frac{m\,V\sqrt{3}}{QB\,2}$$

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

$$\text{pitch} = V_\parallel T = \frac{V}{2}\left(\frac{2\pi m}{QB}\right)$$

(5) If both $\vec{E}$ & $\vec{B}$ present

$\vec{F} = Q\vec{E}$ $\qquad$ $\vec{F} = Q(\vec{v} \times \vec{B})$

$$\boxed{\vec{F} = Q\vec{E} + Q(\vec{v} \times \vec{B})}$$

Lorentz force

diff special case

① particle moves undeviated without change in vel.

$\underline{\underline{E \,\&\, B}}$

$+Q \rightarrow v$ - - - -

acc $= 0$

$$F_{net} = 0 = Q\vec{E} + Q(\vec{v} \times \vec{B})$$

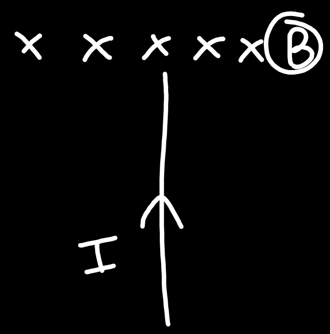
$$0 = \vec{E} + (\vec{v} \times \vec{B})$$

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

more cases of $\vec{E}$ & $\vec{B}$ togather in next lecture.

Magnetic Force on Current Carrying Wire

#AT24



Extra

$I\ell \Rightarrow Qv$

$(neAv)\ell$

$\underline{(nA\ell)}ev$

$(Ne)v$

Qv

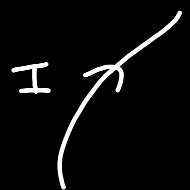
$n = \dfrac{\text{no.}}{\text{Volume}}$

$\text{Vol} = A\ell$

$$\vec{F} = Q\vec{v} \times \vec{B}$$

$$\vec{F} = I\vec{dl} \times \vec{B}$$

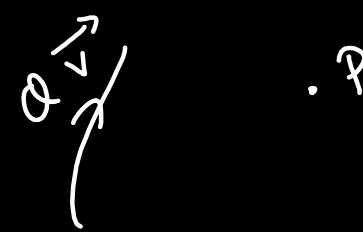
Biot Savart's Law



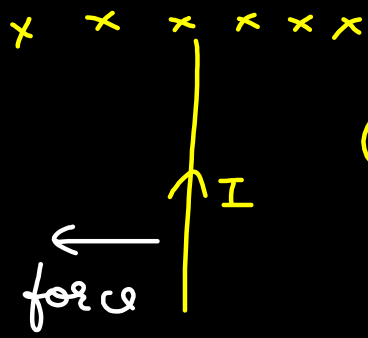
$$\vec{B} = \frac{\mu_0}{4\pi}\,\frac{I\vec{dl} \times \vec{r}}{|r|^3}$$

$\vec{B}$ due to moving charge

$$\vec{B} = \frac{\mu_0}{4\pi}\,\frac{Q\vec{v} \times \vec{r}}{|r|^3}$$



Magnetic Force on Current Carrying Wire



$$\vec{F} = I\vec{l} \times \vec{B}$$

$$|F| = IlB\sin\theta$$

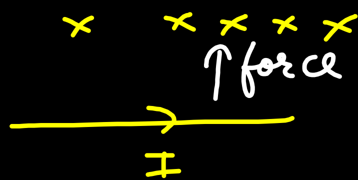
if I & B are ⊥'ue

$$F = BIl$$

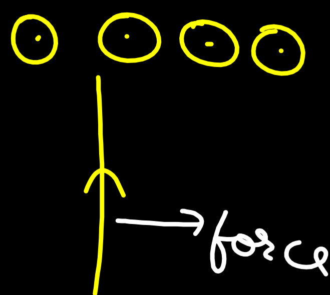
if I & B have angle θ

$$F = BIl\sin\theta$$

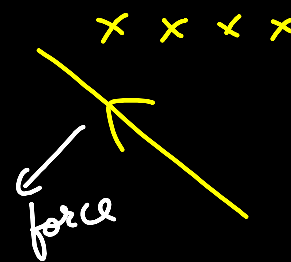
Q 1



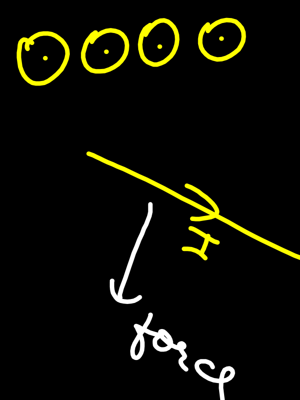
Q 2



Q 3



Q 4



$$\vec{F} = I\vec{l} \times \vec{B}$$

$\vec{F}$ ⊥'ar to $\vec{l}$

$\vec{F}$ ⊥'ar to $\vec{B}$

Vector

⊥ मतलब Dot Product = 0

$$\vec{F} \cdot \vec{l} = 0$$

$$\vec{F} \cdot \vec{B} = 0$$

if only magnetic force applicable

$$\vec{a} \cdot \vec{l} = 0$$

$$\vec{a} \cdot \vec{B} = 0$$

$$\vec{F} = Q(\vec{V} \times \vec{B})$$

$$\vec{F}_{mag} \cdot \vec{V} = 0$$

$$\vec{F}_{mag} \cdot \vec{B} = 0$$

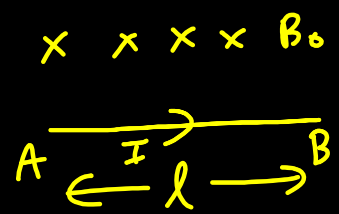
if no other force

$$\vec{a} \cdot \vec{V} = 0$$

$$\vec{a} \cdot \vec{B} = 0$$

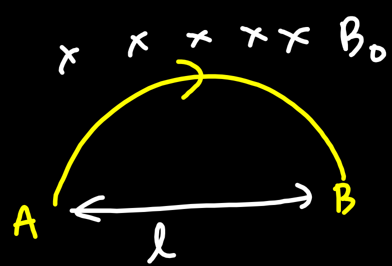
$\vec{l} \Rightarrow$ Displacement Jaisahai (initial to final)

Q//



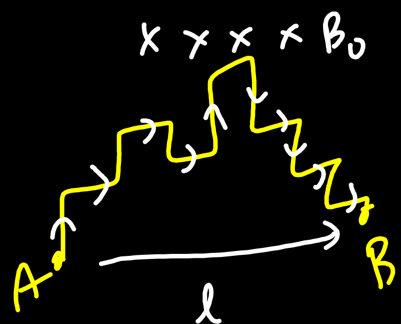
$B_0 I l(+\hat{j})$

Q//



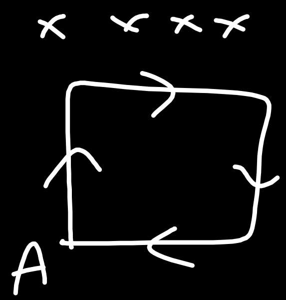
$B_0 I l(+\hat{j})$

Q//

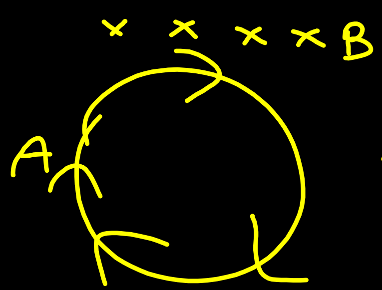


$B_0 I l(+\hat{j})$

Closed loop in Uniform $\vec{B}$

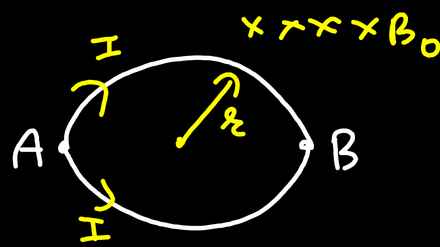


$F_{net} = 0$

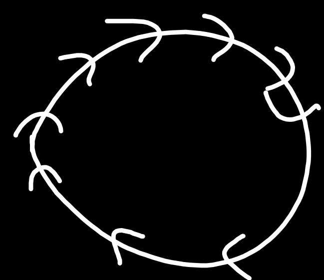


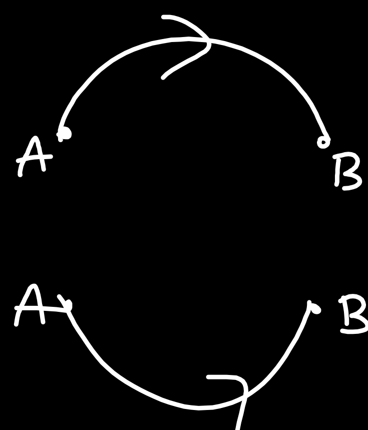
$F_{net} = 0$

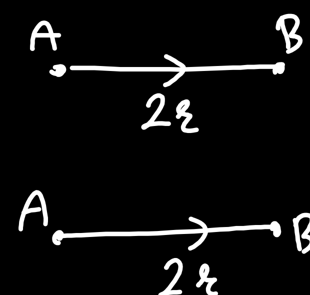
Q



Force on AB =







$B_0 I (2r)$

$B_0 I (2r)$

$$F_{net} = 4 B_0 I r$$

A proton, a deuteron and an α-particle are moving with same momentum in a uniform magnetic field. The ratio of magnetic forces acting on them is .... and their speed is .... in the ratio.

a. 1 : 2 : 4 and 2 : 1 : 1 **b.** 2 : 1 : 1 and 4 : 2 : 1

c. 4 : 2 : 1 and 2 : 1 : 1 **d.** 1 : 2 : 4 and 1 : 1 : 2

JEE 2021

$P = mv$

$F = QvB$ $\quad \frac{P}{m} = V$

$F = Q\frac{P}{m}B$

$F \propto \frac{Q}{m}$

Prot Deu α

$\frac{e}{m}$ $\quad \frac{e}{2m}$ $\quad \frac{2e}{4m}$

$1 : \frac{1}{2} : \frac{1}{2}$

$\boxed{2 : 1 : 1}$

A proton and an α-particle (with their masses in the ratio of 1 : 4 and charges in the ratio 1 : 2) are accelerated from rest through a potential difference V. If a uniform magnetic field (B) is set up perpendicular to their velocities, the ratio of the radii $r_p : r_\alpha$ of the circular paths descrfibed by them will be: **[12 Jan 2019, I]**

(a) $1:\sqrt{2}$ (b) $1:2$ (c) $1:3$ (d) $1:\sqrt{3}$

$$r \propto \frac{\sqrt{mQ}}{Q} = \sqrt{\frac{m}{Q}}$$

pro $\qquad \alpha$

$$\sqrt{\frac{m}{e}} \qquad \sqrt{\frac{4m}{2e}}$$

$$1 : \sqrt{2}$$

$$r = \frac{mv}{QB} = \frac{\sqrt{2m(KE)}}{QB} = \frac{\sqrt{2m(QV_{acc})}}{QB}$$

A charged particle carrying charge 1 μC is moving with velocity $(2\hat{i}+3\hat{j}+4\hat{k})$ ms^{-1}. If an external magnetic field of $(5\hat{i}+3\hat{j}-6\hat{k})\times 10^{-3}$ T exists in the region where the particle is moving then the force on the particle is $\vec{F}\times 10^{-9}$ N. The vector $\vec{F}$ is : **[Sep. 03, 2020 (I)]**

(a) $-0.30\hat{i}+0.32\hat{j}-0.09\hat{k}$

(b) $-30\hat{i}+32\hat{j}-9\hat{k}$

(c) $-300\hat{i}+320\hat{j}-90\hat{k}$

(d) $-3.0\hat{i}+3.2\hat{j}-0.9\hat{k}$

$Q = 1\mu C$

$\vec{V} = 2\hat{i}+3\hat{j}+4\hat{k}$

$B = (5\hat{i}+3\hat{j}-6\hat{k})\times 10^{-3}$

$$\vec{F} = Q\vec{v} \times \vec{B}$$

$$= 1 \times 10^{-6}\left[2\hat{i}+3\hat{j}+4\hat{k}\right] \times \left[5\hat{i}+3\hat{j}-6\hat{k}\right] \times 10^{-3}$$

$$= 10^{-9}\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 3 & 4 \\ 5 & 3 & -6 \end{vmatrix} = \hat{i}\left((-18)-12\right) - \hat{j}\left[(-12)-20\right] + \hat{k}\left[6-15\right]$$

$$= -30\hat{i} + 32\hat{j} - 9\hat{k}$$

The figure shows a region of length 'l' with a uniform magnetic field of 0.3 T in it and a proton entering the region with velocity 4×10^5 ms^{-1} making an angle 60° with the field. If the proton completes 10 revolution by the time it cross the region shown, 'l' is close to (mass of proton $= 1.67 \times 10^{-27}$ kg, charge of the proton $= 1.6 \times 10^{-19}$ C)

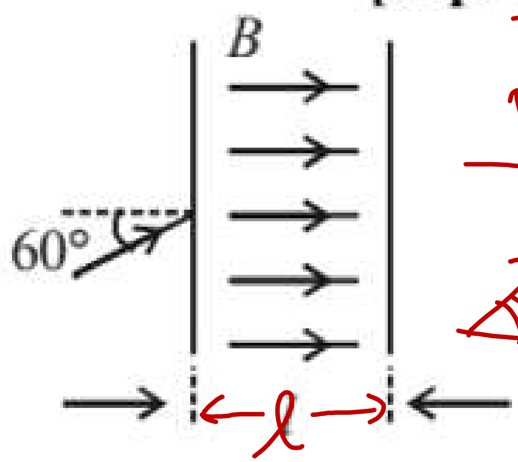
[Sep. 02, 2020 (II)]

(a) 0.11m

(b) 0.88m

(c) 0.44m

(d) 0.22m



$B = 0.3T$

$l = 10 \text{ pitch}$

$= 10 V_{\parallel} T$

$= 10 (v \cos 60) \left(\frac{2\pi m}{QB} \right)$

H.W.

In a certain region static electric and magnetic fields exist. The magnetic field is given by $\vec{B} = B_0(\hat{i} + 2\hat{j} - 4\hat{k})$. If a test charge moving with a velocity $\vec{v} = v_0(3\hat{i} - \hat{j} + 2\hat{k})$ experiences no force in that region, then the electric field in the region, in SI units, is : **[Online April 8, 2017]**

(a) $\vec{E} = -v_0B_0(3\hat{i} - 2\hat{j} - 4\hat{k})$ (b) $\vec{E} = -v_0B_0(\hat{i} + \hat{j} + 7\hat{k})$

(c) $\vec{E} = v_0B_0(14\hat{j} + 7\hat{k})$ (d) $\vec{E} = -v_0B_0(14\hat{j} + 7\hat{k})$

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

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

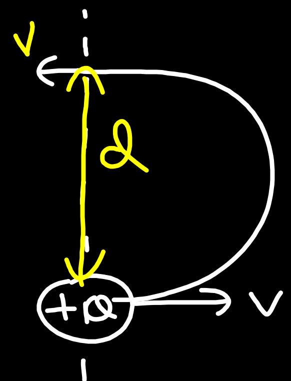
$$B_0(\hat{i} + 2\hat{j} - 4\hat{k}) \times v_0(3\hat{i} - 1\hat{j} + 2\hat{k})$$

$$= V_0 B_0 \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 2 & -4 \\ 3 & -1 & 2 \end{vmatrix}$$

A positive charge 'q' of mass 'm' is moving along the + x axis. We wish to apply a uniform magnetic field B for time Δt so that the charge reverses its direction crossing the y axis at a distance d. Then: **[Online April 12, 2014]**

(a) $B = \frac{mv}{qd}$ and $\Delta t = \frac{\pi d}{v}$ (b) $B = \frac{mv}{2qd}$ and $\Delta t = \frac{\pi d}{2v}$

(c) $B = \frac{2mv}{qd}$ and $\Delta t = \frac{\pi d}{2v}$ (d) $B = \frac{2mv}{qd}$ and $\Delta t = \frac{\pi d}{v}$



$$\text{diameter} = d = 2r$$

$$r = \frac{d}{2} = \frac{mv}{QB}$$

$$B = \frac{2mv}{Qd}$$

$$\text{time} = T/2$$

$$= \frac{2\pi m}{QB} \Big/ 2$$

$$= \frac{\pi m}{QB}.$$

$$\frac{\pi \cancel{m}\, \cancel{Q} d}{\cancel{Q}\, 2 \cancel{m} v}$$

$$\frac{\pi d}{2v}$$

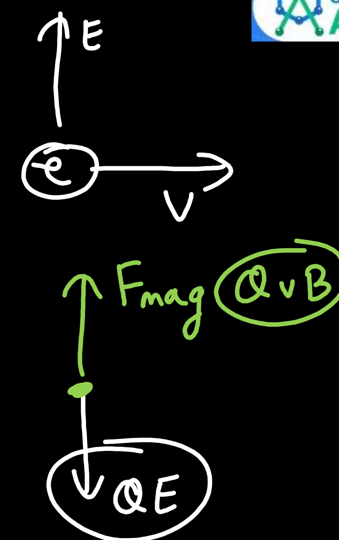
An electron is moving along $+x$ direction with a velocity of 6×10^6 ms^{-1}. It enters a region of uniform electric field of 300 V/cm pointing along $+y$ direction. The magnitude and direction of the magnetic field set up in this region such that the electron keeps moving along the x direction will be : **[Sep. 06, 2020 (I)]**

(a) 3×10^{-4} T, along $+z$ direction

(b) 5×10^{-3} T, along $-z$ direction

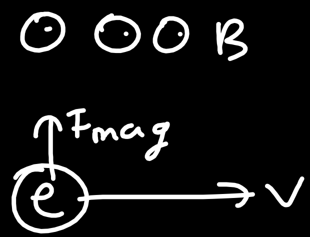
(c) 5×10^{-3} T, along $+z$ direction

(d) 3×10^{-4} T, along $-z$ direction



$|QvB| = QE$

$B = \frac{E}{V}$


B
Fmag
e
v

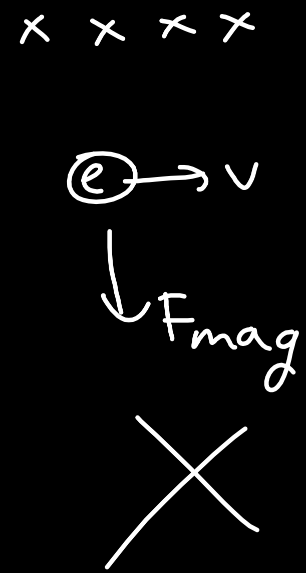
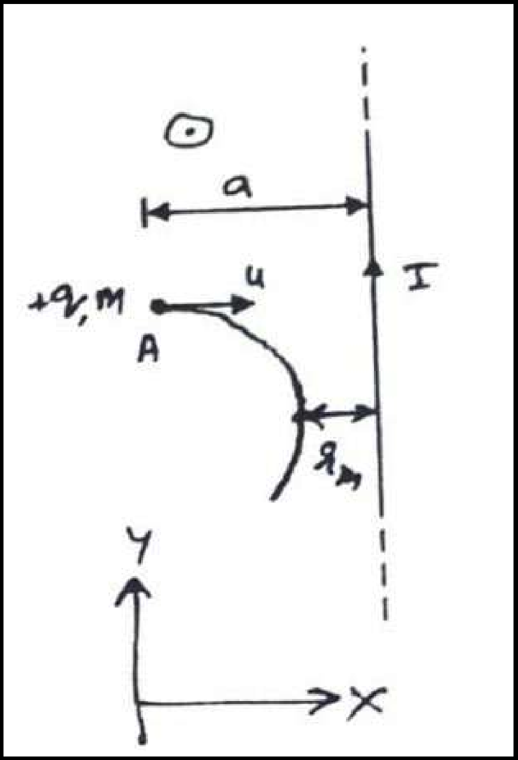
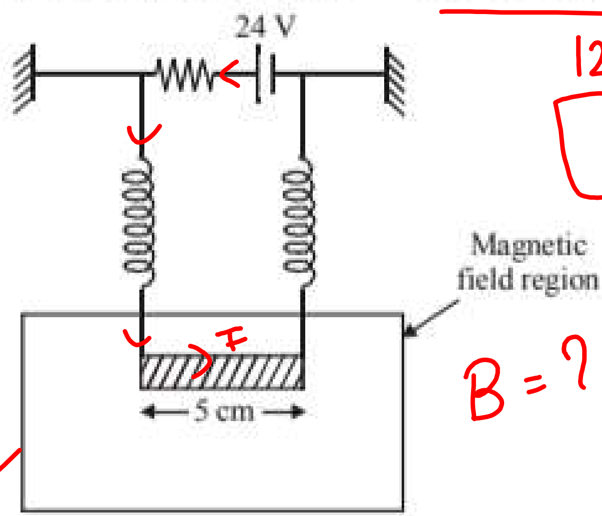
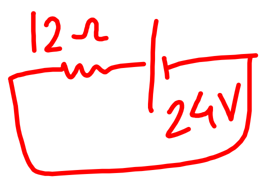

e
v
Fmag

Figure shows a charge particle of charge $+q$ and mass m projected from point A toward a long wire carrying a current I. Find the closest separation of particle from wire during its motion.



The circuit in figure consists of wires at the top and bottom and identical springs as the left and right sides. The wire at the bottom has a mass of 10 g and is 5 cm long. The wire is hanging as shown in the figure. The springs stretch 0.5 cm under the weight of the wire and the circuit has a total resistance of 12 Ω. When the lower wire is subjected to a static magnetic field, the springs, stretch an additional 0.3 cm. The magnetic field is **[Online May 12, 2012]**





$B = ?$

(a) 0.6 T and directed out of page
(b) 1.2 T and directed into the plane of page
(c) 0.6 T and directed into the plane of page
(d) 1.2 T and directed out of page

$m = \frac{10}{1000}\ kg$

$\uparrow kx + kx$

$\downarrow mg$

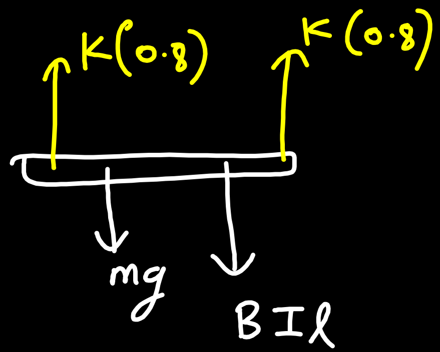
$2kx = mg$

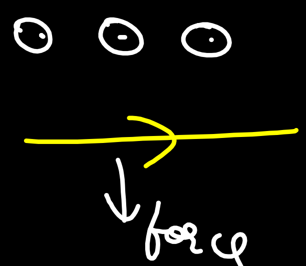
$\cancel{2}k\left(\frac{0.5}{100}\right) = \frac{10}{1000} \times 10$

$K = 10$

$I = \frac{\Delta V}{R}$

$I = \frac{24}{12} = 2$





$$2K\frac{(0.8)}{100} = mg + BIl$$

$$2\frac{10(0.8)}{100}$$

$$\frac{16}{100} = \frac{10}{1000} \times 10$$

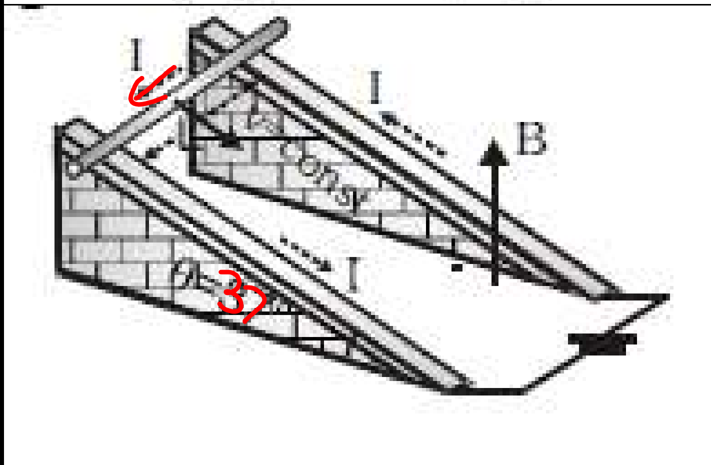
$$.16 = 0.1 + BIl$$

$$0.06 = BIl$$

$$0.06 = B\,2\,\frac{5}{100}$$

$$0.6 = B$$

Two conducting rails are connected to a source of e.m.f. and form an incline as shown in fig. A bar of mass 50 g slides without friction down the incline through a vertical magnetic field B. If the length of the bar is 50 cm and a current of 2.5 A is provided by the battery, for what value of B will the bar slide at a constant velocity ? [$g = 10\ m/s^2$]



(a) 0.4 T

(b) 0.3 T

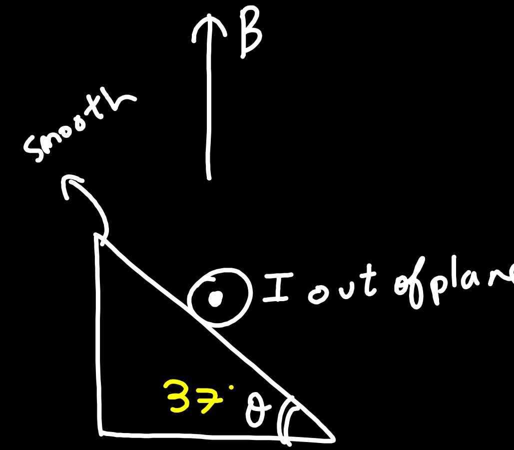
(c) 0.2

(d) 0.5 T

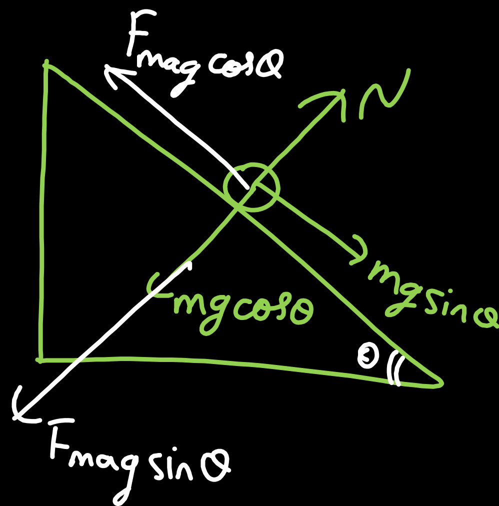
$l = \frac{50}{100}$

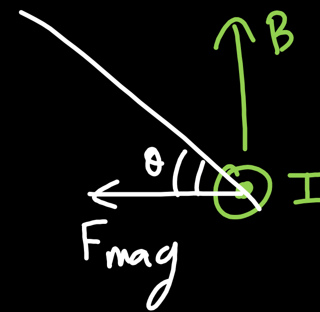
$I = 2.5$

$m = \frac{50}{1000}$



acc = 0





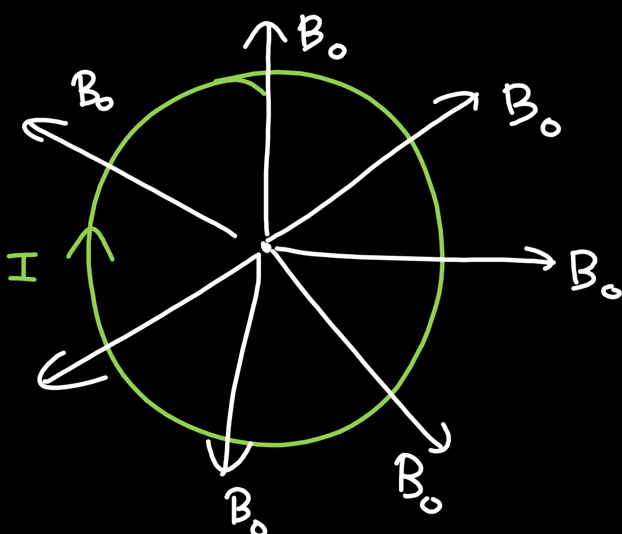
$$F_{mag}\cos\theta = mg\sin\theta$$

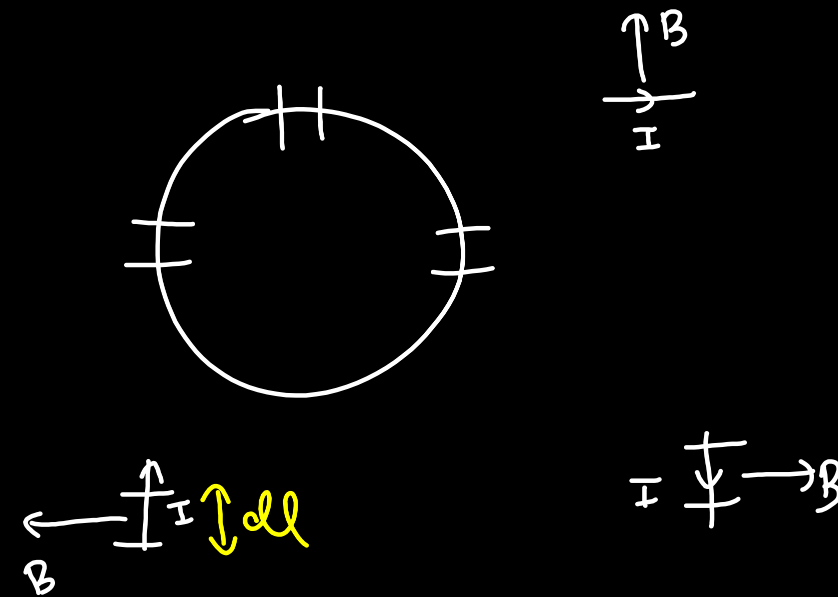
$$BI\ell = mg\tan\theta$$

$$B(2.5)\frac{\cancel{50}}{10\cancel{0}} = \frac{\cancel{50}}{1\cancel{000}}\times 1\cancel{0}\times\frac{3}{4}$$

$$B = \frac{3}{\cancel{4}_2}\times\frac{\cancel{8}}{5} = \frac{3}{10} = 0.3$$

A circular loop of radius *R* carrying current *i* is placed in a magnetic field directed radially outward as shown. The magnitude of field at the periphery is constant, find the force on the loop.





$$F = I\vec{dl} \times \vec{B}$$

$$= |B|\,|I|\,|dl| \sin 90\ \hat{k}$$

$$F = BI\,|dl|$$

$$BI\,|dl|$$

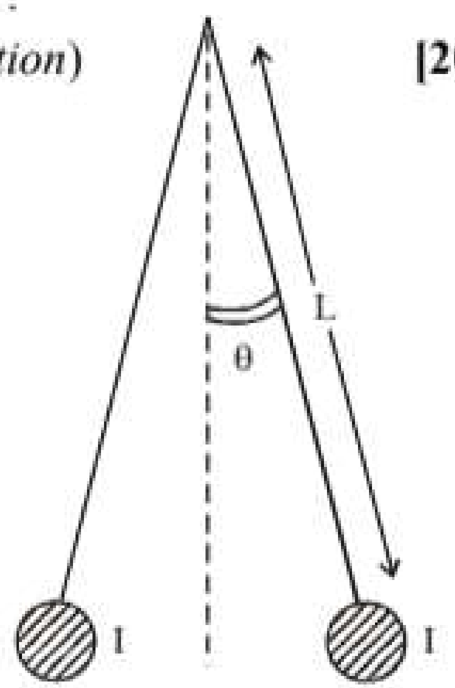
$$\vdots$$

$$BI\,|dl|$$

$$\text{net } F = BI(2\pi r)(+\hat{k})$$

Two long current carrying thin wires, both with current I, are held by insulating threads of length L and are in equilibrium as shown in the figure, with threads making an angle 'θ' with the vertical. If wires have mass λ per unit length then the value of I is :

(g = *gravitational acceleration*) **[2015]**



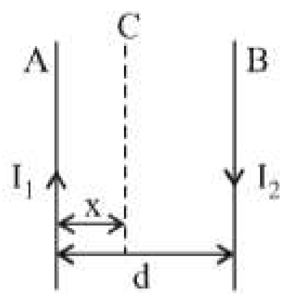
(a) $2\sqrt{\frac{\pi g L}{\mu_0}\tan\theta}$

(b) $\sqrt{\frac{\pi\lambda g L}{\mu_0}\tan\theta}$

(c) $\sin\theta\sqrt{\frac{\pi\lambda g L}{\mu_0\cos\theta}}$

(d) $2\sin\theta\sqrt{\frac{\pi\lambda g L}{\mu_0\cos\theta}}$

Two wires A & B are carrying currents I_1 and I_2 as shown in the figure. The separation between them is d. A third wire C carrying a current I is to be kept parallel to them at a distance x from A such that the net force acting on it is zero. The possible values of x are : **[10 April 2019, I]**



(a) $x = \left(\frac{I_1}{I_1 - I_2}\right)d$ and $x = \frac{I_2}{(I_1 + I_2)}d$

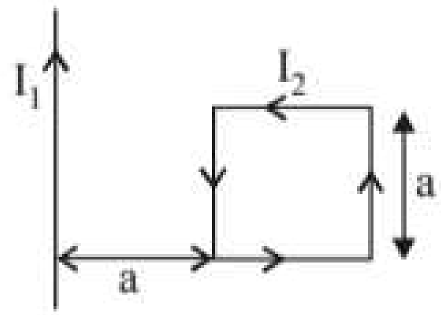
(b) $x = \left(\frac{I_2}{(I_1 + I_2)}\right)d$ and $x = \left(\frac{I_2}{(I_1 - I_2)}\right)d$

(c) $x = \left(\frac{I_1}{(I_1 + I_2)}\right)d$ and $x = \left(\frac{I_2}{(I_1 - I_2)}\right)d$

(d) $x = \pm\frac{I_1 d}{(I_1 - I_2)}$

A rigid square of loop of side 'a' and carrying current I_2 is lying on a horizontal surface near a long current I_1 carrying wire in the same plane as shown in figure. The net force on the loop due to the wire will be:

[9 April 2019 I]



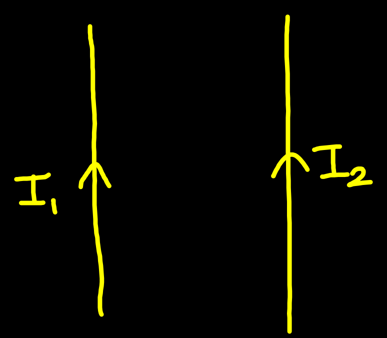
(a) Repulsive and equal to $\frac{\mu_o I_1 I_2}{2\pi}$

(b) Attractive and equal to $\frac{\mu_o I_1 I_2}{3\pi}$

(c) Repulsive and equal to $\frac{\mu_o I_1 I_2}{4\pi}$

(d) Zero

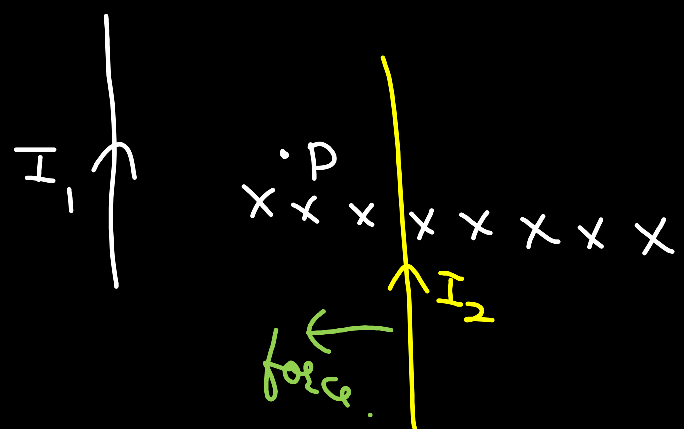
Force b/w Two Current Carrying Wires

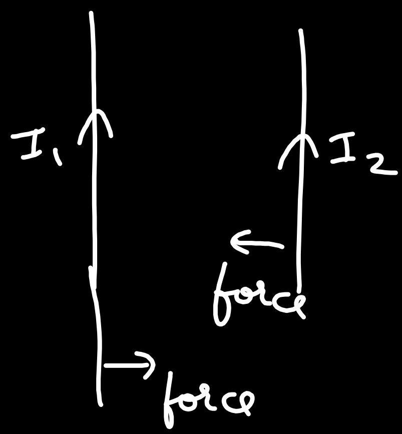


two step force

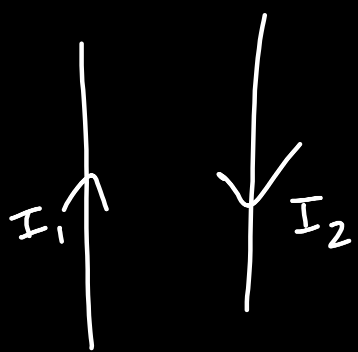
→ 1st wire Ki B over position of 2nd wire

→ Woh B 2nd wire Par force apply karegi



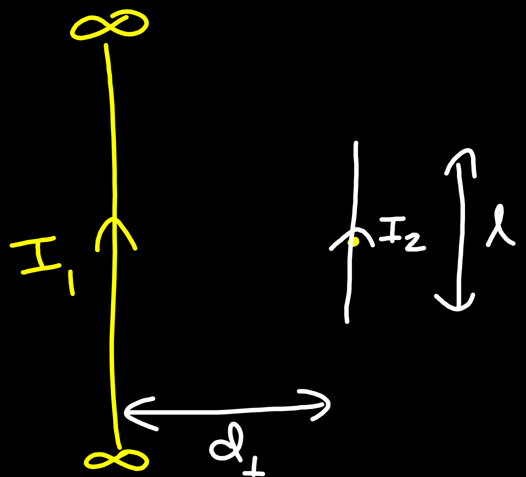


same direction I attract each other



Opp current repeal each other

Q

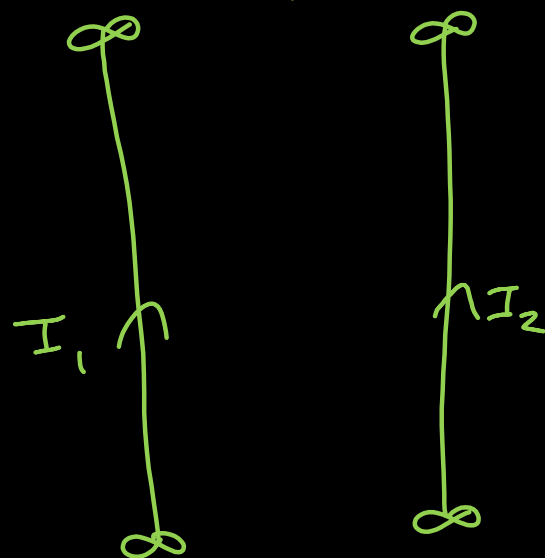


$$B = \frac{\mu_0 I_1}{2\pi d_\perp}$$

force on 2^{nd} wire $= B I_2 l$

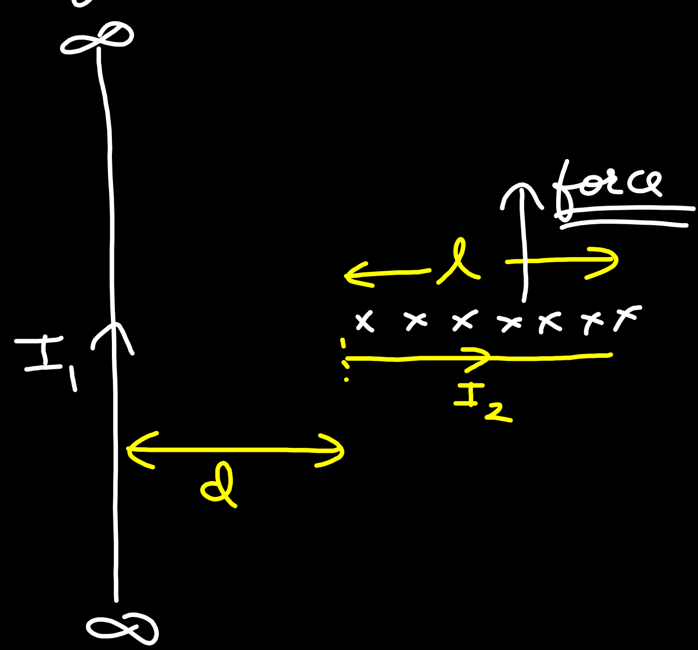
force on 2^{nd} wire $= \left(\frac{\mu_0 I_1}{2\pi d_\perp}\right) I_2 l$

Two ∞ wire

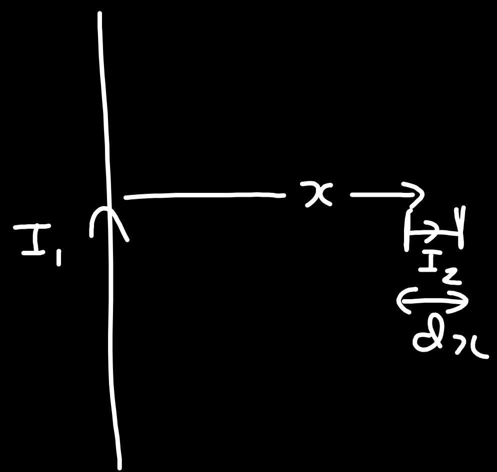


$$\left(\frac{\text{force b/w them}}{\text{length}}\right) = \frac{\mu_0 I_1}{2\pi d_\perp} I_2$$

Q. change in orientation



Force on 2^{nd} wire ??



$$B = \frac{\mu_0 I_1}{2\pi x}$$

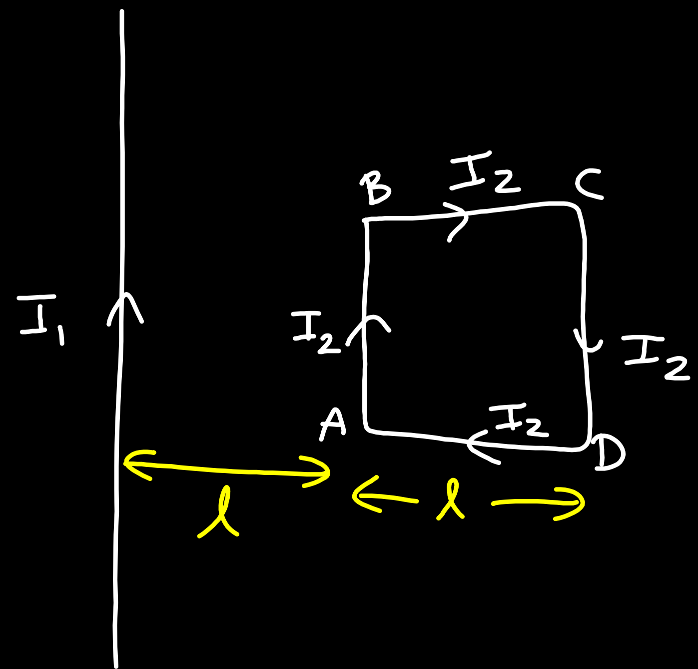
$$F = B I_2 l$$

$$= \frac{\mu_0 I_1}{2\pi x} I_2 \, dx$$

$$= \frac{\mu_0 I_1 I_2}{2\pi} \int_d^{d+l} \frac{dx}{x}$$

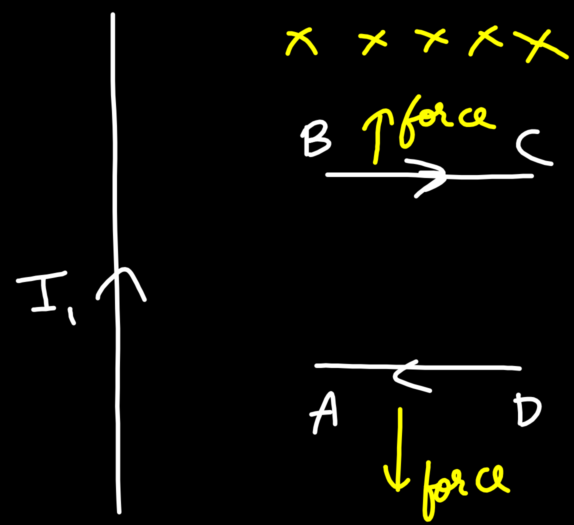
$$= \boxed{\frac{\mu_0 I_1 I_2}{2\pi} \ln\left(\frac{d+l}{d}\right)}$$

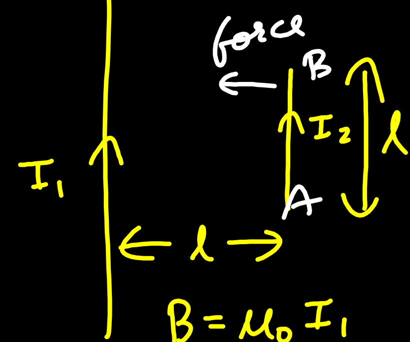
Q



Find magnetic force on loop ABCD due to I_1 ??

net force attraction

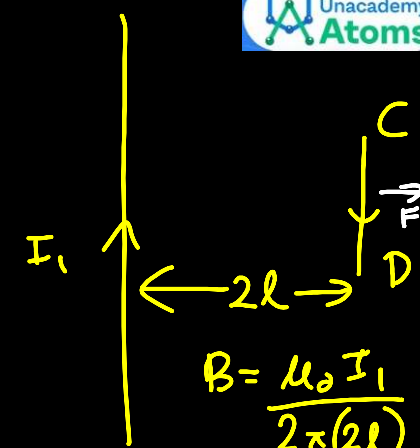




$$B = \frac{\mu_0 I_1}{2\pi l}$$

$$\text{force on } AB = B I_2 l$$

$$= \frac{\mu_0 I_1 I_2}{2\pi}$$



$$B = \frac{\mu_0 I_1}{2\pi(2l)}$$

$$F = B I_2 l$$

$$= \frac{\mu_0 I_1 I_2}{4\pi}$$

$$F_{net} = \frac{\mu_0 I_1 I_2}{2\pi} - \frac{\mu_0 I_1 I_2}{4\pi}$$

$$= \frac{\mu_0 I_1 I_2}{4\pi}$$

→ Next Lecture Targets

→ Some Advanced Problems.

→ Loop as Magnet

→ Torque on loop

→ Cyclotron, vel selectors etc. . . .

→ Magnetism of Matter & Earth Magnetism

→ Special Cases