Magnetism effect of current

→ Oersted discovery

→ current carrying conductor is electrically neutral.
  ↳ produces only magnetic field not electric field.

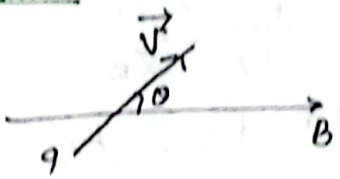
→ charge at rest → produces electric field only.

→ charge in motion →
  (a) uniform motion → produces both electric field & magnetic field
  (b) Accelerated motion → produces electric field, Magnetic field and electromagnetic radiation.

* Motion of charge particle in magnetic field

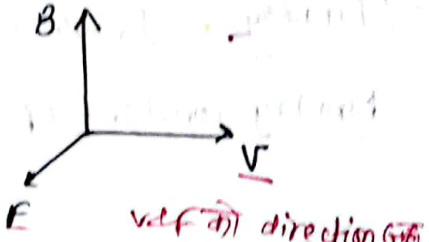
$F = BqV\sin\theta$

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



(1) If, $\theta = 0°$ or $180°$, $F = 0$
path → straight line
speed → straight line
No acc^{n}, velocity, speed, momentum & K.E } → constant

(2) IF $\theta = 90°$, $F = BqV$ (maximum)
path → circular in (x-z) plane



V की direction और E वाले plane

$\because \frac{mv^2}{r} = BqV$

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

$P = mV$

$r = \frac{P}{qB} = \frac{\sqrt{2mE_k}}{qB}$

$r = \frac{\sqrt{2mqV}}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}}$

Q. A proton and α-particles are projected in the region of uniform magnetic field with equal K.E perpendicular to the direction of field. Find the ratio of radius of circular path followed by them.

$$r = \frac{\sqrt{2mE_k}}{qB}$$

$$r \propto \frac{\sqrt{m}}{q}$$

α-particle	proton
$m_\alpha = 4m$	$m_p = m$
$q_\alpha = 2e$	$q_p = e$

$$\frac{r_p}{r_\alpha} = \sqrt{\frac{m_p}{m_\alpha}} \times \frac{q_\alpha}{q_p}$$

$$= \sqrt{\frac{1}{4}} \times \frac{2}{1}$$

$$= 1:1.$$

$$\frac{T_p}{T_\alpha} = \frac{m}{4m} \times \frac{2q}{q}$$

$$= 1:2$$

Time period

$$T = \frac{2\pi r}{v} = \frac{2\pi \frac{mv}{qB}}{v} = \frac{2\pi m}{qB}$$

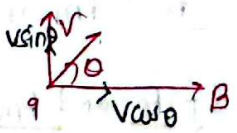
$$\boxed{T = \frac{2\pi m}{qB}}$$

Frequency

$$\boxed{F = \frac{1}{T} = \frac{qB}{2\pi m}}$$

→ Speed and Kinetic energy remains constant but velocity and momentum changes. due to direction.

③ If θ is any angle except 0°, 180° & 90°, then path will be spiral or helical nature.



Time period $\boxed{(T) = \frac{2\pi m}{qB}}$

Pitch → distance between 2 helix,

Distance/pitch = $v\cos\theta \times \frac{2\pi m}{qB}$ (v x t)

Motion of charge particle in electric field

$F = qE$

If $\theta = 0°$, or $180°$

path → straight line

+ve charge particles moves along the direction of field.

-ve charge particles opposite to the direction of field.

If θ = any angle except $0°$ or $180°$,

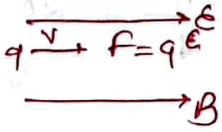
path → parabolic

Motion of charge particle in both field

① If E & B are parallel, & v is also parallel to E & B.

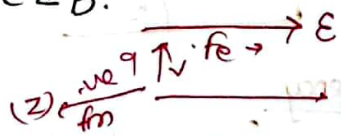
$F_e = qE$, $F_m = 0$

path → straight line



② If E & B are parallel & v is ⊥r to both E & B.

$F_e = qE$, $F_m = Bqv$

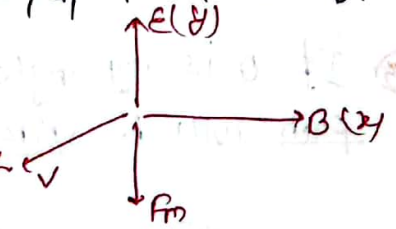


→ F_e & F_m are perpendicular to each other. but they can't cancel to each other.

path → curved path

③ E & B are perpendicular to each other and v is perp to both E & B.

F_e & F_m may be parallel or antiparallel.



- If F_e and F_m are antiparallel but equal in magnitude
  - ↳ they cancel each other
    - ↳ charge particle moves undeviated
      - ↳ cross field

If $F_e = F_m$

$qE = Bqv$

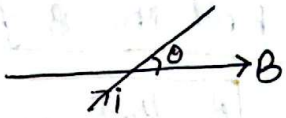
$$v = \frac{E}{B}$$

Condition of no force in magnetic field

(i) If $\theta = 0$ $\theta = 0$ or 180°
(ii) If no external magnetic field.
(iii) For neutral charge i.e. $q = 0$
(iv) For stationery charge i.e. $v = 0$
(v) ~~For~~ charged particle in cross field

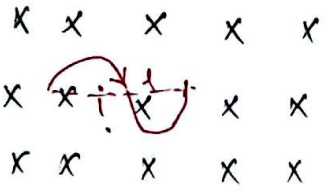
Current carrying conductor in magnetic field

$$F = BIL\sin\theta$$



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

For zig-zag wire

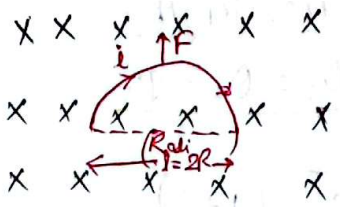


$x \rightarrow$ ⊗ magnetic field

~~B = B~~

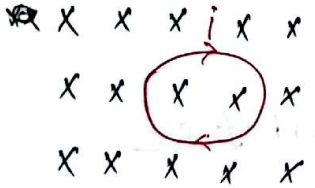
$F = BIl_{displa}$

$F = BIl$



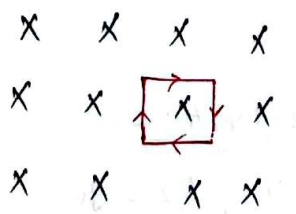
$F = BIl_{disp}$ $(l_{disp} = 2R)$

$F = BI \times 2R$



$F = BIl_{disp}$ $(l_{disp} = 0)$

$F = 0$



$F = BIl_{disp}$ $(l_{disp} = 0)$

$F = 0$

Closed loop → F = 0

Biot - savart law



$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

In vector form,

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

$$dB = \frac{\mu_0}{4\pi}\frac{\frac{q}{dt}\times dl\sin\theta}{r^2} \qquad \left[I = \frac{q}{dt}\right]$$

$$= \frac{\mu_0}{4\pi}\frac{qv\sin\theta}{r^2} \qquad \left[\frac{dl}{dt} = v\right]$$

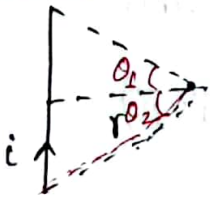
$$\boxed{\vec{dB} = \frac{\mu_0}{4\pi}\frac{q(\vec{v}\times\vec{r})}{r^3}}$$

* Application

① To Find the B for a straight current carrying conductor

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

It is for finite length.



- For infinite length:—

$$\theta_1 = \theta_2 = 90^\circ$$



$$B = \frac{\mu_0 I}{4\pi r}(1+1)$$

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

- For semi infinite length:—

$$\theta_1 = 0^\circ, \quad \theta_2 = 90^\circ$$

$$B = \frac{\mu_0 I}{4\pi r}(\sin 0^\circ + \sin 90^\circ)$$

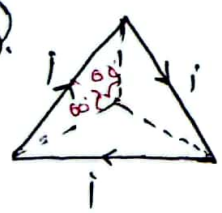
$$\boxed{B = \frac{\mu_0 I}{4\pi r}}$$

- In any point of axis

$$B = 0.$$

$\theta_1 = 0^\circ$ & $\theta_2 = 0^\circ$

Q.



Centroid = ?

$$B = \frac{\mu_0 i}{4\times\frac{1}{2\sqrt{3}}}(\sin 90^\circ + \sin 90^\circ)$$

$$= \frac{2\sqrt{3}\mu_0 I}{4\pi l}\times\frac{2\sqrt{3}}{2} = \frac{6\mu_0 I}{4\pi l}$$

$$\cos 30^\circ = \frac{b}{l}$$



$$\frac{b}{l} = \frac{\sqrt{3}}{2}$$

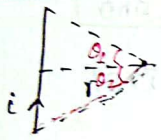
$$\frac{l\sqrt{3}}{2}\times\frac{1}{3} = \frac{l}{2\sqrt{3}} \qquad \left(b = \frac{l}{2\sqrt{3}}\right)$$

$$3B = \frac{18\mu_0 I}{4\pi l}$$

$[I = q/dt]$

$\frac{}{dt} = V]$

arrying conductor



n any point of axis

$B = 0.$

$\theta_1 = 0^\circ$

$\theta_2 = 0^\circ$

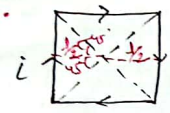
$\sin 30^\circ = \frac{b}{l}$

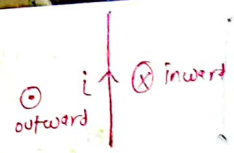


$\frac{b}{l} = \frac{l\sqrt{3}}{2}$

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

$\frac{I}{\pi l}$ $\left(b = \frac{l}{2\sqrt{3}}\right)$





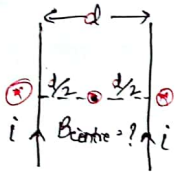
$B = \frac{\mu_0 I}{4\pi \frac{l}{2}} (\sin 45^\circ + \sin 45^\circ)$

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

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

$\therefore B_{net} = 4B$

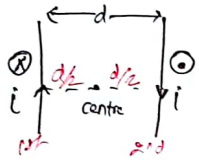
$= \frac{4\mu_0 I}{\sqrt{2}\pi l}$



$B_1 = \frac{\mu_0 I}{2\pi \frac{d}{2}}$ $B_2 = \frac{\mu_0 I}{2\pi \frac{d}{2}}$

$B_{net} = B_1 - B_2$

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

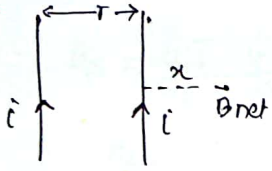


$B_1 = \frac{\mu_0 I}{2\pi \frac{d}{2}}$ $B_2 = \frac{\mu_0 I}{2\pi \frac{d}{2}}$

$B_{net} = B_1 + B_2$

$= \frac{\mu_0 I}{2\pi \frac{d}{2}} + \frac{\mu_0 I}{2\pi \frac{d}{2}}$

$\boxed{B_{net} = \frac{\mu_0 I}{2\pi d}}$

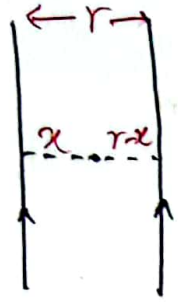


$B_1 = \frac{\mu_0 I}{2\pi(r+x)}$, $B_2 = \frac{\mu_0 I}{2\pi x}$

$B_{net} = \cancel{\mu_0 I +}\ B_1 + B_2$

$= \frac{\mu_0 I}{2\pi(r+x)} + \frac{\mu_0 I}{2\pi x}$

$= \cancel{\mu_0 I}$



$B_1 = \frac{\mu_0 I}{2\pi x}$ (inward)

$B_2 = \frac{\mu_0 I}{2\pi(r-x)}$ (out)

$B_{net} = B_1 - B_2$ (inward)

(2) To find the magnetic field intensity for circular current carrying coil :-



$$B_{centre} = \frac{\mu_0 I}{2R}$$

For N-turns,

$$B_{centre} = \frac{\mu_0 NI}{2R}$$

For angle subtain;

$2\pi \longrightarrow \frac{\mu_0 I}{2R}$

$\theta \longrightarrow \frac{\mu_0 I}{2R}\frac{\theta}{2\pi}$

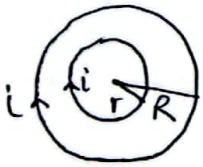


For 60°,

$$B = \frac{\mu_0 I}{2R} \times \frac{\pi/3}{2\pi}$$

$$B = \frac{\mu_0 I}{12R}$$

① Clockwise current ↳ inward

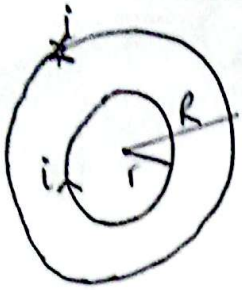


$B_{\text{सानो}} = \frac{\mu_0 i}{2r}$ (x)

$B_{\text{ठुलो}} = \frac{\mu_0 I}{2R}$ (x)

$B_{net} = B_{\text{सानो}} + B_{\text{ठुलो}}$ (x)

$$B_{net} = \frac{\mu_0 I}{2}\left(\frac{1}{R} + \frac{1}{r}\right)$$

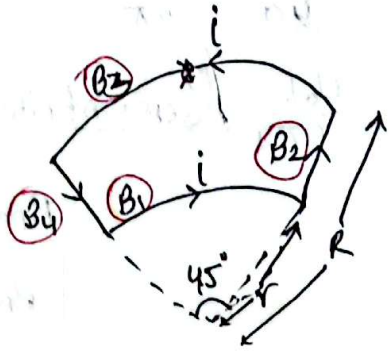


$B_{सानो} = \frac{\mu_0 i}{2r}$ (x)

$B_{ठुलो} = \frac{\mu_0 i}{2R}$ ⊙

$B_{net} = B_{सानो} - B_{ठुलो}$ (x)

$$B_{net} = \frac{\mu_0 I}{2}\left(\frac{1}{r} - \frac{1}{R}\right)$$



~~$B_{सानो}$ =~~

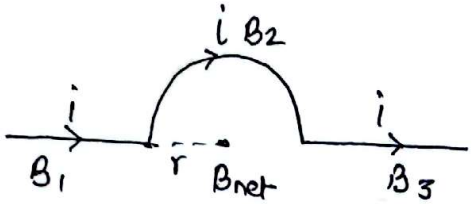
$B_1 = \frac{\mu_0 i}{2r} \times \frac{\pi/4}{2\pi}$

$B_1 = \frac{\mu_0 I}{16r}$ (x) $B_2 = 0$ (axis मा पर्ई, $\theta = 0^\circ$)

$B_3 = \frac{\mu_0 i}{16R}$ (⊙) $B_4 = 0$ (axis, $\theta = 0$)

$B_{net} = B_1 - B_3$

$$B_{net} = \frac{\mu_0 I}{16}\left(\frac{1}{r} - \frac{1}{R}\right)$$



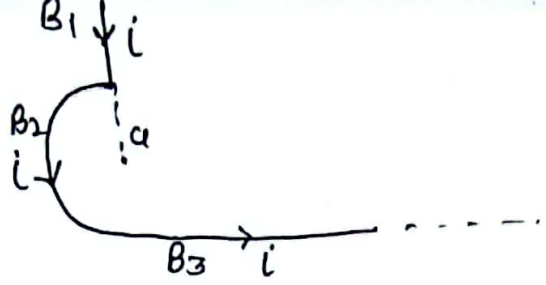
$B_1 = 0$ (axis मा पर्ई।)

$B_2 = \frac{\mu_0 I}{2R}\frac{\pi}{2\pi}$ ($\theta = 180^\circ$)

$B_2 = \frac{\mu_0 I}{4R}$

$B_3 = 0.$

$\therefore B_{net} = \frac{\mu_0 I}{4R}$



$B_1 = 0$ (axis par)

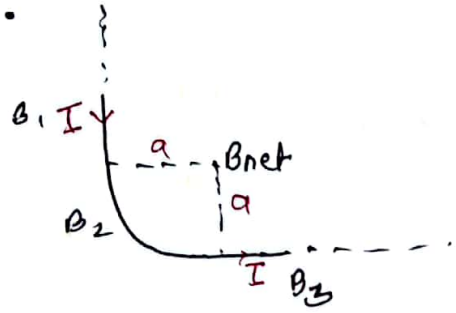
$B_2 = \frac{\mu_0 I}{4a}$ (semicircle) $\theta = 180°$

$B_3 = \frac{\mu_0 I}{2a} \times \frac{\theta}{2\pi}$

$B_3 = \frac{\mu_0 I}{4\pi a}$ (Semi infinite rod)

$B_{net} = B_2 + B_2$

$$B_{net} = \frac{\mu_0 I}{4a}\left(1 + \frac{1}{\pi}\right)$$



$B_1 = \frac{\mu_0 I}{4\pi a}$ (Semi infinite) (out)

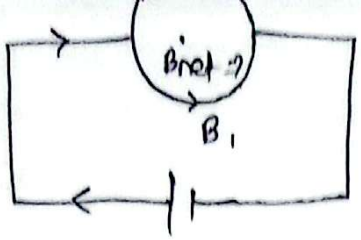
$B_2 = \frac{\mu_0 I}{2a} \times \frac{\pi/2}{2\pi}$ (90° angle)

$B_2 = \frac{\mu_0 I}{8a}$ (out)

$B_3 = \frac{\mu_0 I}{4\pi a}$ (semiinfinite) (out)

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

$$B_{net} = \frac{\mu_0 I}{4a}\left(\frac{1}{\pi} + \frac{1}{2} + \frac{1}{\pi}\right)$$



$$B_2 = \frac{\mu_0 I/2}{4R} \quad (\times)$$

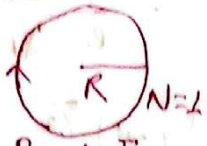
$$B_1 = \frac{\mu_0 I/2}{4R} \quad (\cdot)$$

$$B_{net} = B_2 - B_1$$

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

Q. A uniform steady current carrying ~~coil~~ wire is bent in the form of a circular loop. the magnetic field intensity at centre is 10 Tesla. If the same wire is now converted into 2 smaller identical loop then magnetic field intensity at centre will be:

(a) 10T (b) 20T (c) 40T (d) 5T



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

(2) N = 2

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

$$= 4\frac{\mu_0 I}{2R}$$

$$\therefore 4B = 4 \times 10$$

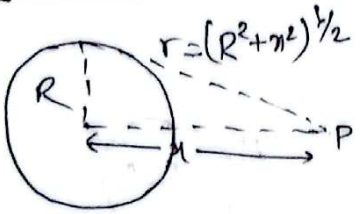
$$= 40T$$

For three loops, $B' = 3^2 B$

For 4 loops $B' = 4^2 B$

for n loops, $\boxed{B' = n^2 B}$

③ Magnetic field intensity at any point on the axis of circular ~~of~~ current carrying coil:-



$$B_{axis} = \frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}$$

For N turns,

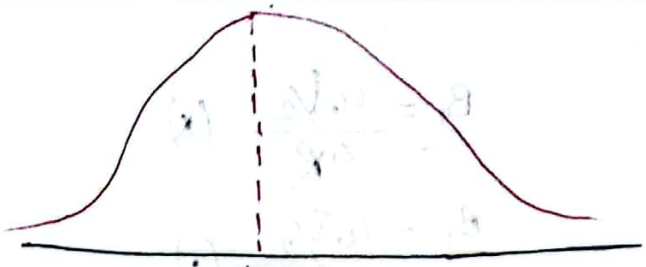
$$\boxed{B_{axis} = \frac{\mu_0 N I R^2}{2(R^2+x^2)^{3/2}}}$$

at centre, $x = 0$.

$$B_{centre} = \frac{\mu_0 I}{2R}$$

at $x = R$,

$$B_{axis} = \frac{\mu_0 I R^2}{2(R^2+R^2)^{3/2}} = \frac{\mu_0 I}{\sqrt{32}R}$$



8. The magnetic field intensity due to circular current carrying coil at any point in the axis is equal to $\frac{1}{8}$th of the magnetic field intensity at its centre. Find the distance of that point of axis from centre of the coil of radius R.

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

$B_{axis} = \frac{1}{8} B_{centre}$

$$\frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}} = \frac{1}{8} \frac{\mu_0 I}{2R}$$

$$8R^3 = (R^2+x^2)^{3/2}$$

cube root :-

$$2R = (R^2+x^2)^{\frac{1}{2}}$$

squaring,

$$4R^2 = R^2+x^2$$

$$3R^2 = x^2$$

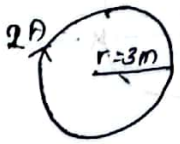
$$\therefore x = \sqrt{3}R$$

Magnetic Moment (M) :-



$M = IA$, A = area of loop
I = current

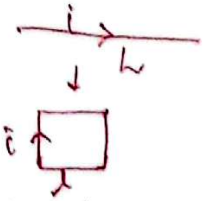
unit → Ampere × metre^2
= Am^2



$M = 2 \times \pi r^2$
$= 2 \times \pi 9$
$= 18\pi$

3. Two identical wires of equal length L carrying equal current, one is shaped into a square and another is shaped into a circle. Find the ratio of their magnetic moment?

(a) 1:1 (b) $\pi:4$ (c) $4:\pi$ (d) $1:2$

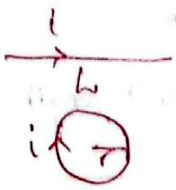


$L = 4l$

$l = \frac{L}{4}$

$M_1 = iA$

$= i\frac{l^2}{16}$



$L = 2\pi r$

$r = \frac{L}{2\pi}$

$M_2 = iA$

$= i\pi\frac{L^2}{4\pi^2}$

$\frac{M_1}{M_2} = \frac{\frac{l^2}{16}}{\frac{l^2}{4\pi}}$

$\therefore M_1 : M_2 = \pi : 4$

* Magnetic moment due to the electron revolving around the circular path of radius (r) :-



$M = iA$ $\quad A = \pi r^2$

$M = \frac{ev}{2\pi r} \times \pi r^2$ $\quad i = e/t$

$= \frac{e}{\frac{2\pi r}{v}}$ $\quad \therefore i = \frac{ev}{2\pi r}$

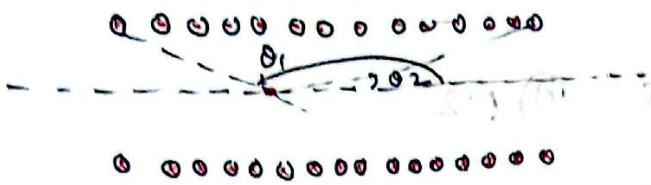
$M = \frac{evr}{2}$

for moving charge particle, 'q'

$M = \frac{qvr}{2}$ $\quad \therefore v = \omega r$

$M = \frac{q\omega r.r}{2} = \frac{qr^2\omega}{2}$

4) Magnetic field intensity due to current carrying solenoid:-

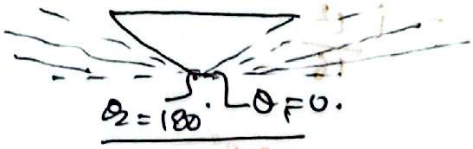


$n = \frac{N}{L}$, no. of turns per unit length.

$$B = \frac{\mu_0 n I}{2}(\cos\theta_1 - \cos\theta_2)$$

- For infinite length,

$\theta_1 = 0°$, $\theta_2 = 180°$

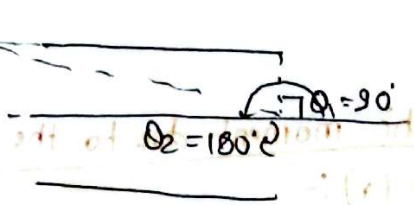


$$B_{inside} = \frac{\mu_0 n I}{2} \times 2$$

$$B_{inside} = \mu_0 n I$$

- at anyone end

$\theta_1 = 90°$, $\theta_2 = 180°$



$$B_{end} = \frac{\mu_0 n I}{2} \quad *$$

$$B_{end} = \frac{B_{inside}}{2}$$

→ Inside the solenoid, field is uniform

→ Current carring solenoid act as bar magnet.

N = total no. of turns

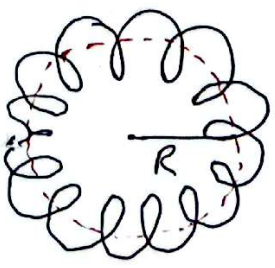
l = length of solenoid

n = no. of turns per unit length.

* Toroid → Solenoid coil in the form of circle.

$$B = \mu_0 n I$$

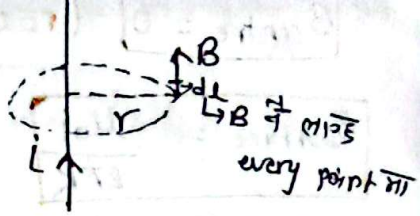
$$n = \frac{N}{2\pi R}$$



Ampere's circuital law:-

→ only for symmetry.

→ $\oint B \cdot dl = \mu_0 I$



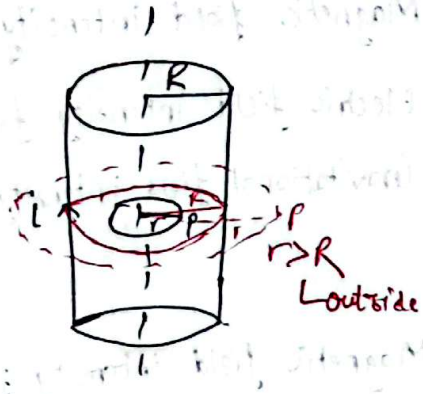
I = enclosed current

$\oint$ → closed intregral

$B \cdot 2\pi r = \mu_0 I$

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

* hollow cylinder

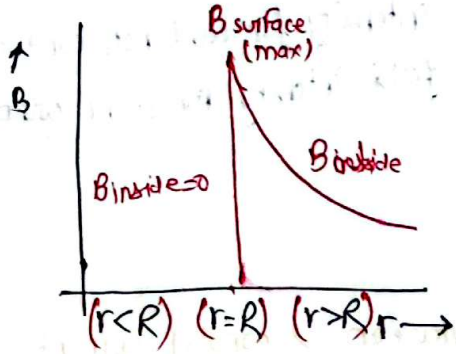


$B_{inside} \cdot 2\pi r = \mu_0 \times 0$ (no enclosed current)

$\therefore \boxed{B_{inside} = 0}$

$B_{surface} \times 2\pi R = \mu_0 i$

$$\boxed{B_{surface} = \frac{\mu_0 I}{2\pi R}}$$

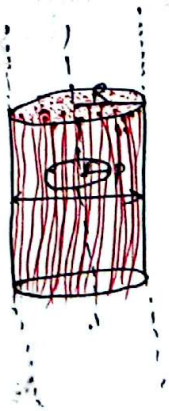


$B_{outside} \times 2\pi r = \mu_0 i$

$$\boxed{B_{outside} = \frac{\mu_0 i}{2\pi r}} \quad (r>R)$$

* Solid cylinder

Magnetic field intensity for current carrying solid cylindrical rod



i' → amperes loop भित्रको current

$B_{inside} \cdot 2\pi r = \mu_0 i'$

$B_{inside} \cdot 2\pi r = \frac{\mu_0 \times i \times r^2}{R^2}$

$\because \pi R^2 = i$

$1 \longrightarrow \frac{i}{\pi R^2}$

$\pi r^2 = \frac{i}{\pi R^2} \times \pi r^2$

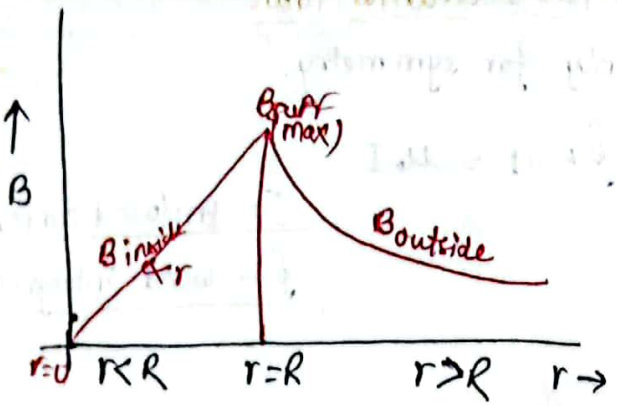
$$\boxed{i' = \frac{i \times r^2}{R^2}}$$

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

$B_{centre} = 0$ $(r=0)$

$B_{surface} = \frac{\mu_0 i}{2\pi R}$ $(r=R)$

$B_{outside} = \frac{\mu_0 i}{2\pi r}$ $(r>R)$



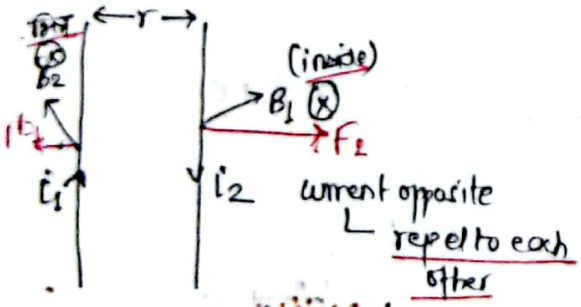
- Magnetic field intensity for hollow cylinder
- Electric field intensity for spherical conductor
- Gravitational field intensity for hollow sphere

→ inside from surface = zero
surface = maximum
outside → goes on decreasing

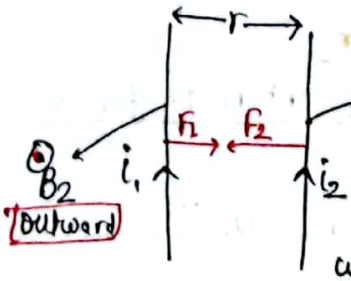
- Magnetic field intensity for solid cylinder
- Electric field intensity for solid non conducting sphere
- Gravitational field intensity for solid sphere

→ centre = zero
centre to surface (inside) → Neg
surface → maximum
outside → Goes on decreasing

Force between 2 parallel current carrying conductor:-



current opposite → repel to each other



parallel current carrying conductor current in same direction → attract to each other

$f_1 = B_2 I_1 l_1$

$f_1 = \frac{\mu_0 i_2}{2\pi r} i_1 . l_1$

$F = \frac{F_1}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}$

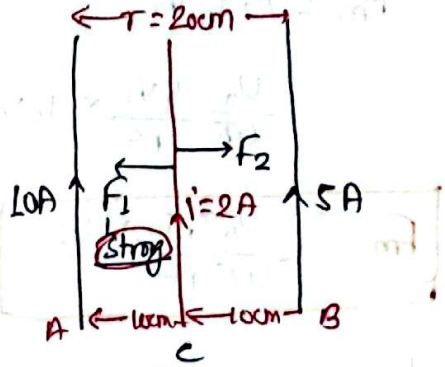
Force per unit length.

If $I_1 = I_2 = 1Amp$, $r = 1m$ $\left(\frac{\mu_0}{4\pi} = 10^{-7}\right)$

$$f = \frac{\mu_0}{2\pi} = 2\times10^{-7}\ N/m$$

1A current → r=1m हुँदा एउटा conductor ले अर्को मा लगाउने force 2×10^{-7} N
then current = 1A in each conductor

Q. What is the resultant force on conductor C?



→ F_{net} on C = $F_1 - F_2$

$$= \frac{\mu_0 i_0 \times 2}{2\pi \times 0.1} - \frac{\mu_0 \times 5 \times 2}{2\pi \times 0.1}$$

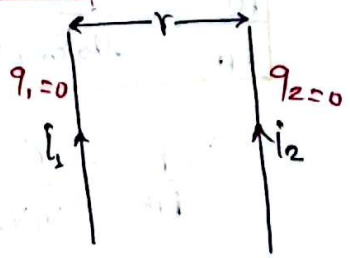
$$= \frac{\mu_0}{2\pi}(200 - 100)$$

$$= 2\times10^{-7}\times100$$

$F_{net} = 2\times10^{-5}$ N towards A.

Relative strength of electric force and magnetic force

① In case of two parallel current carrying conductor:-



$$F_m = \frac{\mu_0 i_1 i_2}{2\pi r}$$

$$F_e = \frac{K q_1 q_2}{r^2}$$

∴ $F_e = 0$ current carrying conductor → Neutral

(Deal only with the magnetic force).

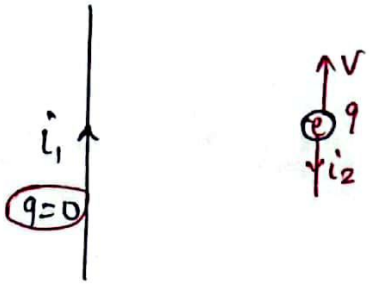
- Current in same direction → attract
- Current in opposite direction → repel

② In case of current carrying conductor and moving charge particles

$F_m = B_1 q V$

$F_e = 0$

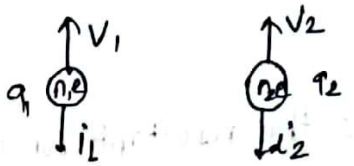
(Deal only with magnetic force)



③ For both moving charged particle:

$F_m = B_1 q_2 V_2$

$= \frac{\mu_0}{4\pi} \frac{q_1 V_1}{r^2} \times q_2 V_2$



(mag. field [illegible])

$$\boxed{F_m = \frac{\mu_0 q_1 q_2 V_1 V_2}{4\pi r^2}} \quad -(i)$$

$$\boxed{F_e = \frac{q_1 q_2}{4\pi \varepsilon_0 r^2}} \quad -(ii)$$

$$\frac{F_e}{F_m} = \frac{\cancel{q_1 q_2}}{\cancel{4\pi}\varepsilon_0 \cancel{r^2}} \times \frac{\cancel{4\pi r^2}}{\mu_0 \cancel{q_1 q_2} V_1 V_2}$$

$$\boxed{\frac{F_e}{F_m} = \frac{1}{\mu_0 \varepsilon_0 V_1 V_2}}$$

$$\boxed{C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \, m/s}$$

So, $\frac{1}{\mu_0 \varepsilon_0} = c^2$

$\therefore \frac{F_e}{F_m} = \frac{c^2}{V_1 V_2}$

$c^2 > V_1 V_2$

So, $\boxed{F_e > F_m}$

Fe dominates the fm.
So, deal only with electric force.

Q. Two electrons are moving in same direction then they ..
(a) attract ↳ magnfield [illegible] (b) repel ↳ electric force [illegible] (c) may attract or repel (d) none

Q. Two protons are moving in same direction → they repel.
(like charges) (Fe > Fm)

Abhishek singh

CamScanner