Already Done in Previous Part of Moving Charges - - -

→ B calculation

→ effect of B on moving charge

→ " " " " Current carrying wire

→ force b/w two current " ".

Charge in both $\vec{E}$ & $\vec{B}$

$\vec{F} = Q\vec{E}$

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

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

Lorentz

force

Case 1

$\longrightarrow B$

$\longrightarrow E$

+Q

rest

released.

initially $\vec{F} = Q\vec{E}$

$Q \rightarrow$ vel

$\longrightarrow B$

$\vec{V} \parallel$ to $\vec{B}$

$\vec{F} = Q(\vec{v} \times \vec{B}) = 0$

St. line constant acc. motion

$acc = \dfrac{QE}{m}$

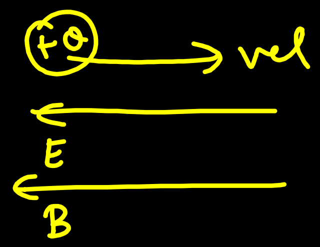
$u = 0$

$t = t$

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

$v = u + at$

Case 2



$\vec{V}$ anti $\parallel$ to $\vec{B}$

$\vec{F}_{electric} = Q\vec{E}$

$F_{mag} = Q(\vec{v} \times \vec{B})$
$= 0$

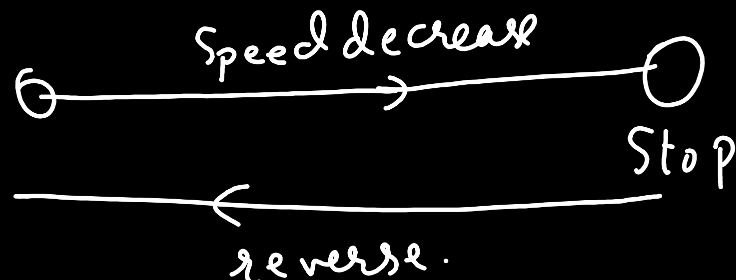
$\leftarrow \bigcirc$
QE

\# St. line retardation

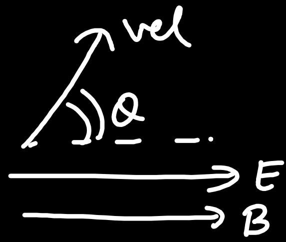
$u = u$

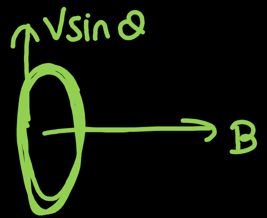
$a = -\dfrac{QE}{m}$

$\leftarrow$
electric force



Case 3





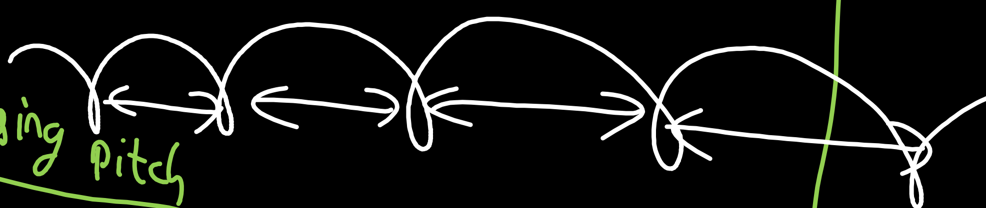
Circle in Plane ⊥'ur to B

→ $v\cos\theta$
→ E
→ B

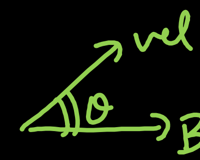
○ → force QE

→ accelerated $\left(\frac{QE}{m}\right)$

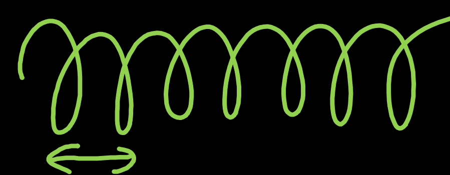
⇓ vector addition



helical with increasing pitch

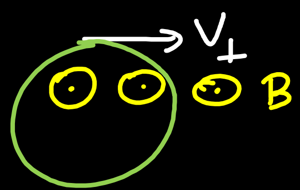


helix



pitch constant.

Let's try to find coordinates

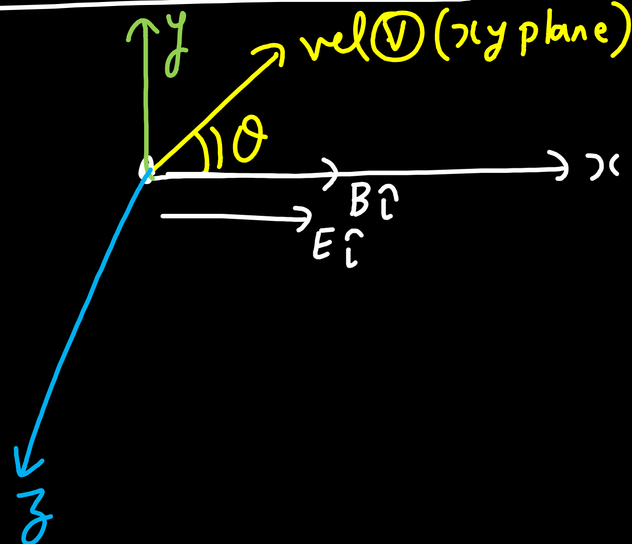


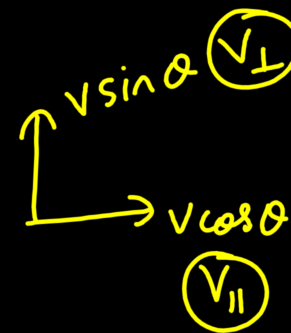
$$r = \frac{m v_\perp}{QB}$$

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

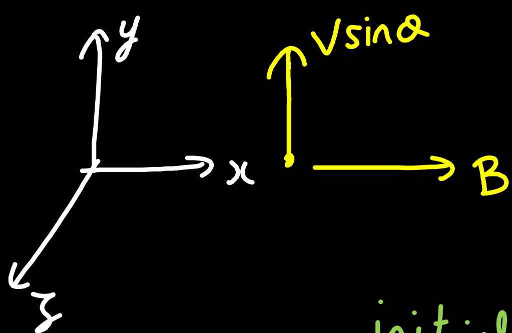
$$\theta_{rot} = \omega t$$

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



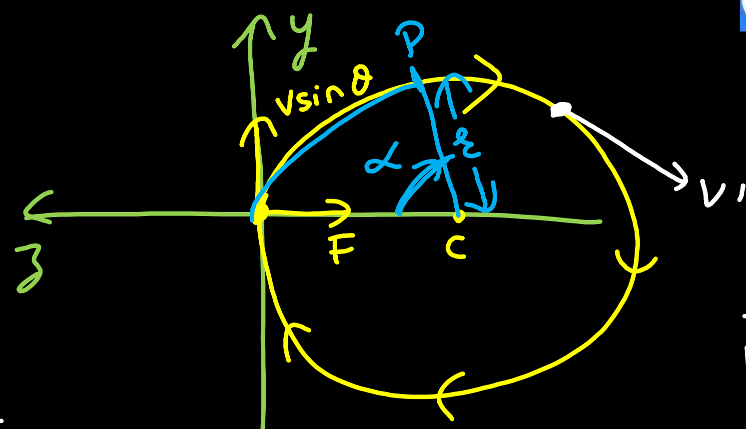


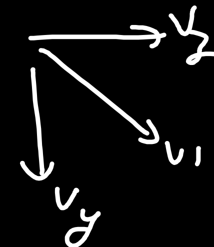
Circular Motion



initial F in $-z$ axis

circle plane yz plane





speed in yz plane always constant

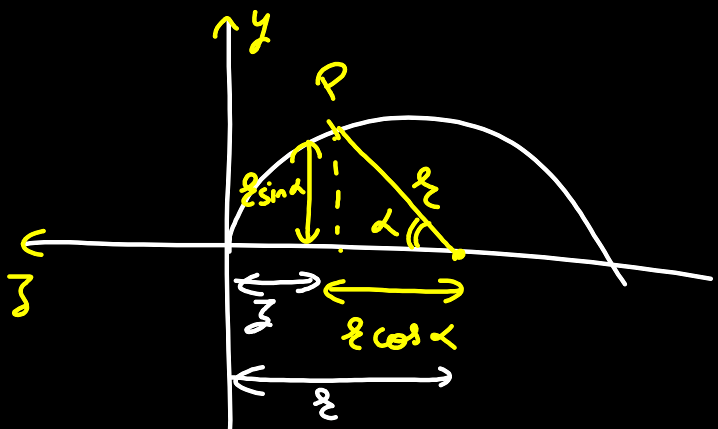
$$r = \frac{mv_\perp}{QB}$$

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

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

$$V' = v\sin\theta$$

$$\sqrt{v_y^2 + v_z^2} = v\sin\theta$$



$$y \text{ coordinate} = r \sin\alpha$$

$$= \frac{mV_\perp}{QB} \sin(\omega t)$$

$$z \text{ coordinate} = -(r - r\cos\alpha)$$

X axis

$\longrightarrow V\cos\theta$

$\longrightarrow QE$

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

$$x = (V_\parallel t) + \frac{1}{2}\left(\frac{QE}{m}\right)t^2$$

Q/ $\vec{E} = E_0 \hat{i}$

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

initial vel $= V_0 \hat{j}$

Find time when speed of particle becomes $2V_0$.

$+Q$, m is projected from origin

a) $\dfrac{mV_0}{QE}$

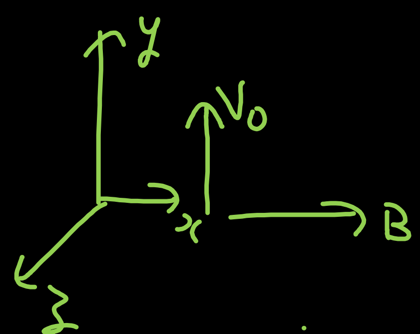
b) $\dfrac{2mV_0}{QE}$

c) $\dfrac{mV_0}{2QE}$

d) $\dfrac{\sqrt{3}\,mV_0}{QE}$

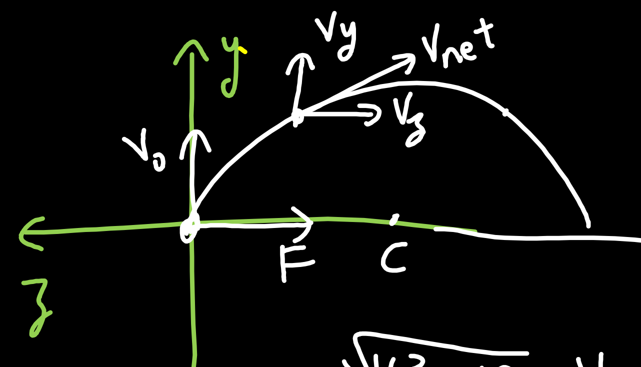
$\longrightarrow$ x axis

$+Q \longrightarrow$ force $= QE$



circle plane

yz plane.



$\sqrt{V_y^2 + V_z^2} = V_{net} = V_0$

$$V_x\hat{i} + V_y\hat{j} + V_z\hat{k}$$

$$\text{Speed} = \sqrt{V_x^2 + V_y^2 + V_z^2}$$

$$(2v_0)^2 = V_x^2 + \underline{\underline{(V_y^2 + V_z^2)}}$$

$$4v_0^2 = V_x^2 + V_0^2$$

$$3V_0^2 = V_x^2$$

$$\sqrt{3}\,V_0 = V_x$$

X axis

$$u = 0$$

$$a = \frac{QE}{m}$$

$$V = \sqrt{3}\,V_0$$

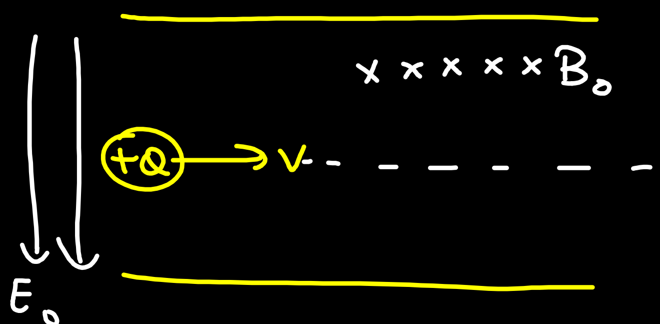
$$v = u + at$$

$$\sqrt{3}\,V_0 = 0 + \frac{QE}{m}t$$

$$\frac{\sqrt{3}\,mV_0}{QE} = t$$

Case : Next

Velocity Selector

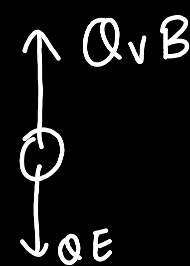


Particle — No deflection

No change in vel.

$\vec{F} = Q\vec{E}$

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



net F = 0

$\cancel{Q}E = \cancel{Q}vB$

$E = vB$

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

J. J. thomspon to find specific charge $\Rightarrow \frac{Q}{m}$

acc by potial ΔV_{acc}

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

$$WD = Q(\Delta V_{acc}) \rightarrow KE$$

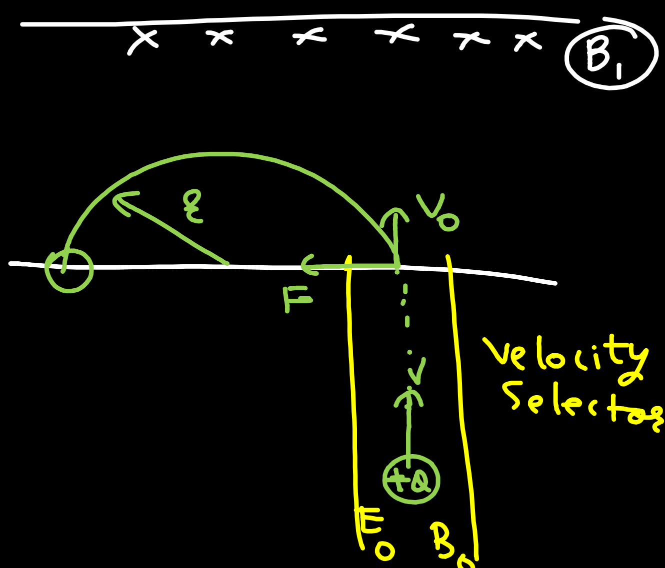
$$\frac{1}{2}mv^2 = Q\Delta V_{acc}$$

$$v = \sqrt{\frac{2Q\Delta V_{acc}}{m}}$$

$$\sqrt{\frac{2Q\,V_{acc}}{m}} = \frac{E}{B}$$

$$\frac{Q}{m} = \frac{E^2}{2B^2 V_{acc}}$$

Mass Spectrometer



$$\frac{E_0}{B_0} = v$$

r is measured

$$r = \frac{mv}{QB_1}$$

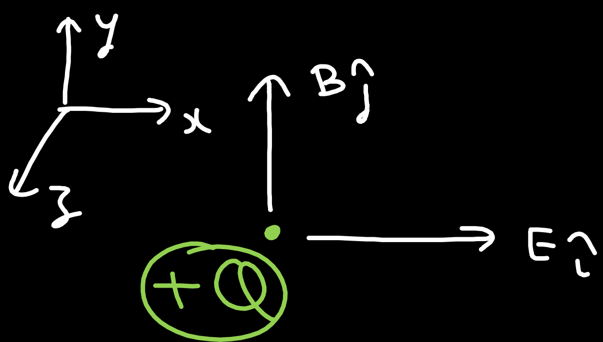
$$m = \frac{QB_1 r}{v}$$

$$m = \frac{QB_1 r B_0}{E_0}$$

Case: Next

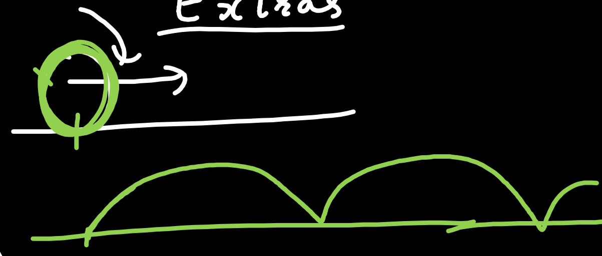
E & B are ⊥'ar & charge is released from rest

→ final path is cycloid

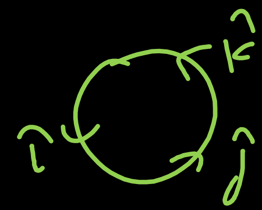


m rest

Extras



$$\vec{vel} = V_x\hat{i} + V_z\hat{k}$$



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

$$= QE_0\hat{i} + Q(V_x\hat{i} + V_z\hat{k}) \times (B_0\hat{j})$$

$$= QE_0\hat{i} + QV_xB_0\hat{k} + QV_zB_0(-\hat{i})$$

$$\vec{acc} = \frac{(QE_0 - QB_0V_z)}{m}\hat{i} + \frac{QB_0V_x}{m}\hat{k}$$

$$a_x = \left(\frac{QE - QB v_z}{m}\right)$$

diff.

$$a_z = \frac{QB_0 v_x}{m}$$

$$\frac{da_x}{dt} = 0 - \frac{QB}{m}\frac{dv_z}{dt}$$

$$= -\frac{QB}{m^2} a_z$$

$$\frac{d^2 v_x}{dt^2} = -\frac{Q^2 B^2}{m^2} V_x$$

SHM Example

$$\frac{d^2x}{dt^2} = -\omega^2 x$$

V_x is performing SHM

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

$$V_x = A\sin(\omega t)$$

V_x

diff

a_x

$t=0 \quad a_x = A\omega\cos(\omega t)$

$$a_x = A\omega \longrightarrow \frac{QE_0}{m}$$

$$A = \frac{E_0}{B_0}$$

$$V_x = \frac{E}{B} \sin(\omega t)$$

$$x = \frac{E}{B\omega}(1 - \cos \omega t)$$

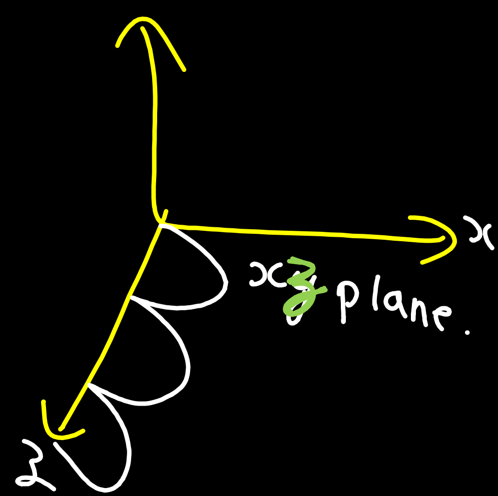
z axis

$$V_z = \frac{E}{B}(1 - \cos \omega t)$$

$$z = \frac{E}{B\omega}\left(\omega t - \sin(\omega t)\right)$$

$$x = \frac{E}{B\omega}(1 - \cos \omega t)$$

$$z = \frac{E}{B\omega}\left(\omega t - \sin(\omega t)\right)$$



Q. More than Correct

charge particle enters in gravity free space & it comes out without change in vel. $\vec{E}$ or $\vec{B}$ may be present which case it can be possible

a) $E = 0$ $\quad B = 0$

b) $E = 0$ $\quad B \neq 0$

c) $E \neq 0$ $\quad B \neq 0$

~~d)~~ $E \neq 0$ $\quad B = 0$

+Q a ✓

+Q → v

→ B

(b) ✓

$F_{mag} = 0$

$F_{electric} = 0$

(c)

$\uparrow QvB$

+Q → v

$\downarrow QE$

$QE = QvB$

Q. charge at rest experences Electromagnetc force

$\longrightarrow E$

$+Q$

a) E must be there

b) B must " "

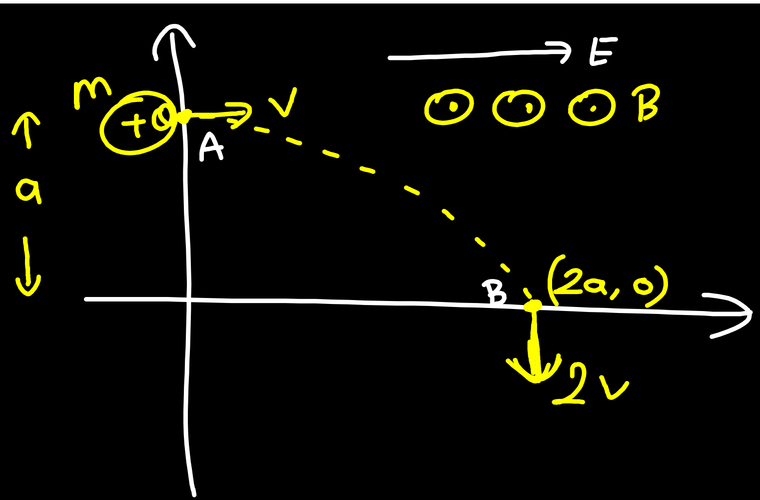
c) B may or may not be there.

d) E " " " " " "

Q

Jee.

(gravity free)



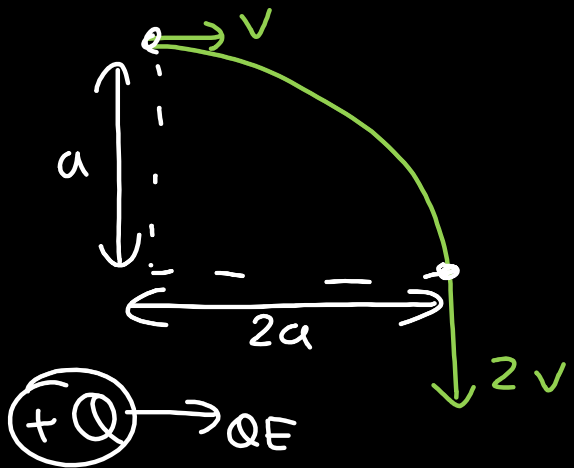
$$\text{Power} = \vec{F}\cdot\vec{v}$$

Find

① E in terms of m, v, a & Q

② Power of E at A & at B

③ Power of B at A & at B
(rate of WD)



$$WD_{mag} = 0$$

$$WD_{Elec} = \Delta KE$$

$$= \frac{1}{2}m(2v)^2 - \frac{1}{2}m(v)^2$$

$$(F)(disp) = \frac{3}{2}mv^2$$

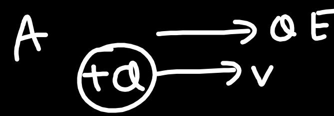
$$(QE)(2a) = \frac{3}{2}mv^2$$

$$\boxed{E = \frac{3mv^2}{4Qa}}$$

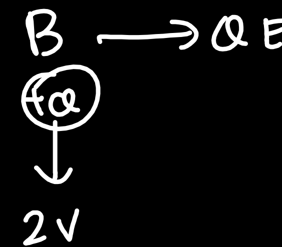
$$WD_{mag} = 0$$

$$\text{Power} = \frac{d(WD)}{dt}$$

$$\text{Power}_{mag} = 0$$



$$\text{Power}_{\text{at } A} = QEv$$



$$\text{Power}_{\text{at } B} = 0$$

Force on Current Carrying Wire in $\vec{B}$

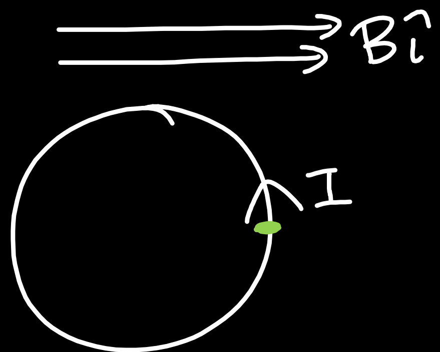
$$\vec{F} = \int I \, \vec{dl} \times \vec{B}$$

already done in previous lecture.

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

displacement Jaisa

Closed loop in uniform $\vec{B}$

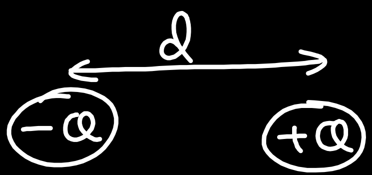


$$F_{mag,\,net} = 0$$

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

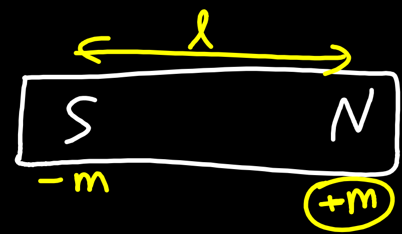
Torque on loop

$\vec{M}$ (magnetic diapole moment)



$\vec{P} = Q(d)$

(−ve to +ve)



$$\boxed{\vec{M} = (+m)\, l}$$

m = pole strength

$\vec{M}$ of a Current Carrying loop

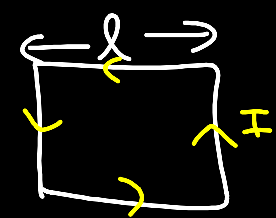
$$\vec{M} = I\,(\vec{area})$$

N turns

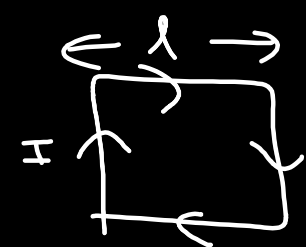
$$\boxed{\vec{M} = N I\,(\vec{area})}$$

$\vec{area}$ → magnitude area

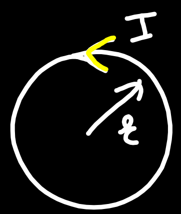
$\vec{area}$ → direction $\perp$'ur to plane of loop



$$\vec{M} = I l^2 (+\hat{k})$$



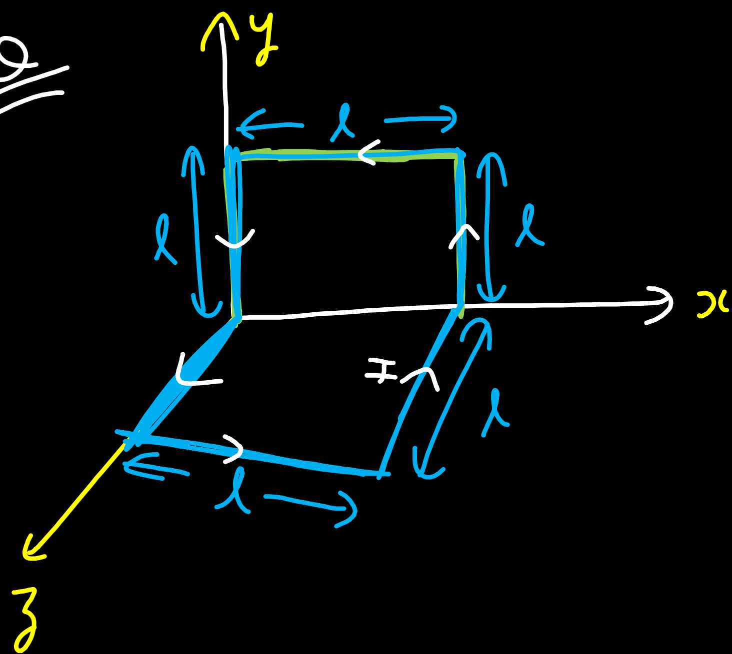
$$\vec{M} = I l^2 (-\hat{k})$$



100 turns

$$\vec{M} = (I \pi r^2)(100)(+\hat{k})$$

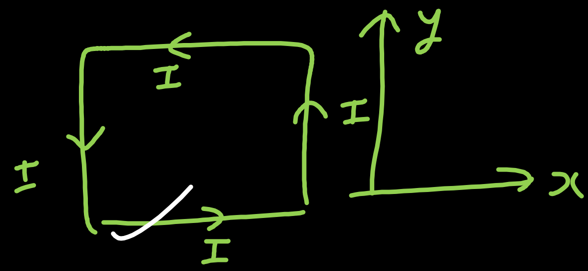
Q



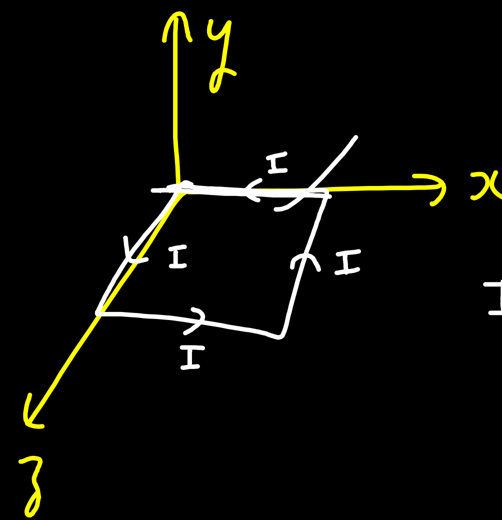
$\vec{M} =$

$\xrightarrow{I}$ assume

$\xleftarrow{I}$



$$I\ell^2(+\hat{k})$$



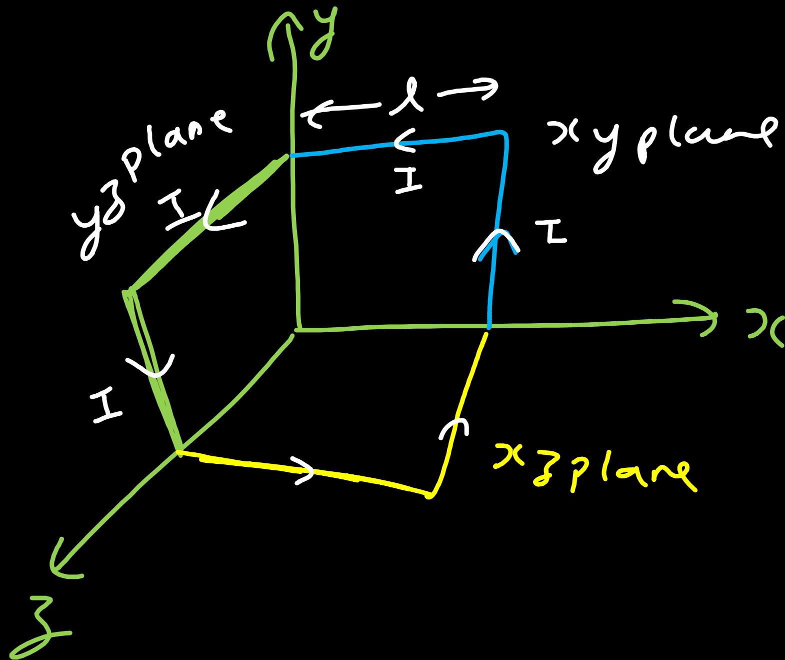
$$I\ell^2(+\hat{j})$$

$$\vec{M} = I\ell^2(+\hat{k} + \hat{j})$$

$$|M| = I\ell^2\sqrt{1^2+1^2}$$

$$= \sqrt{2}\, I\ell^2$$

Q

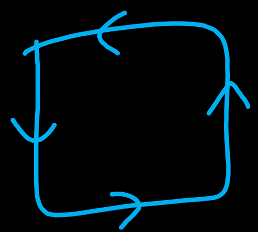


all length l

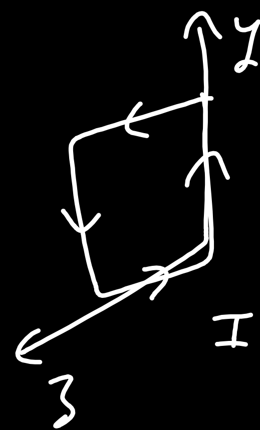
xy plane $\vec{M}$ $+\hat{k}$ or $-\hat{k}$

yz " $\vec{M}$ $+\hat{i}$ or $-\hat{i}$

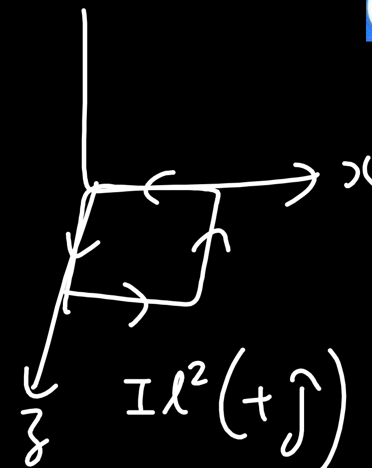
xz " $\vec{M}$ $+\hat{j}$ or $-\hat{j}$.



$I\ell^2(+\hat{k})$



$I\ell^2(+\hat{i})$

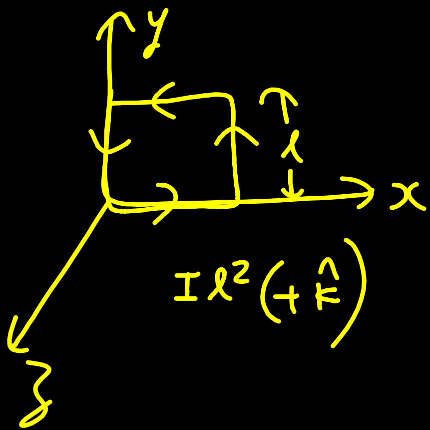


$I\ell^2(+\hat{j})$

$$\vec{M} = I\ell^2(\hat{i} + \hat{j} + \hat{k})$$

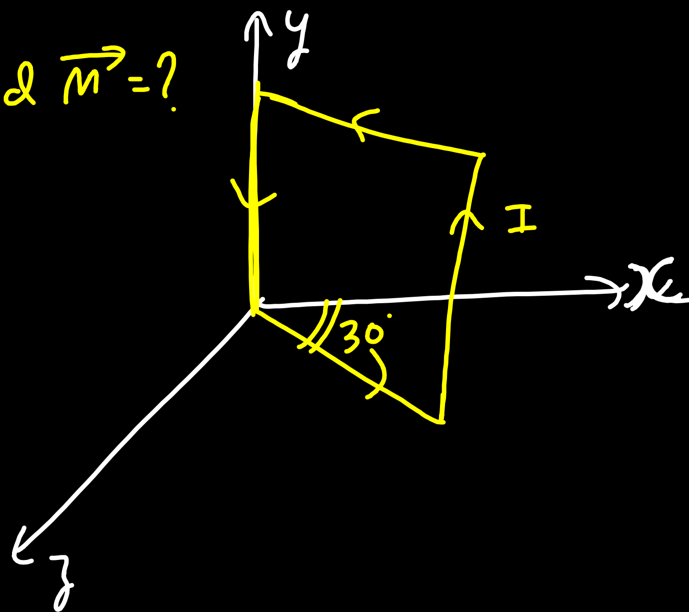
$$|M| = \sqrt{3}\, I\ell^2$$

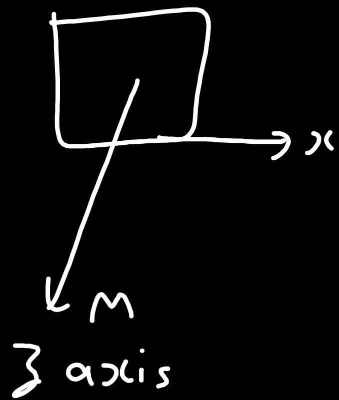
Rotating the plane



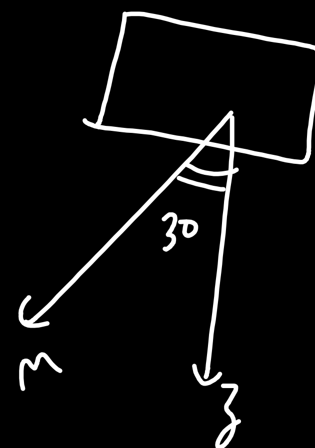
$I\ell^2(+\hat{k})$

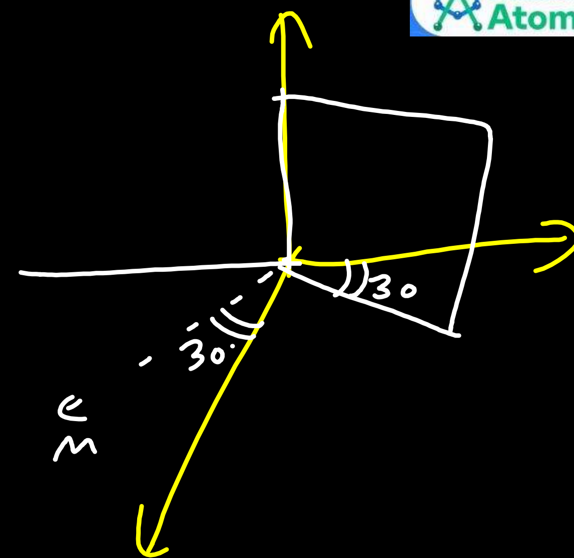
Find $\vec{M} = ?$

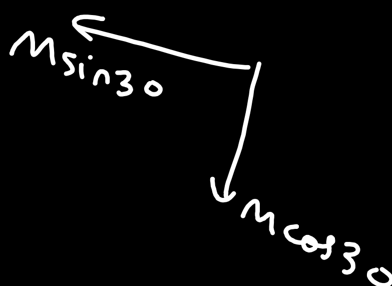




turn by 30°







$$I\ell^2 \cos 30 + \hat{k} \quad I\ell^2 \sin 30 \left(-\hat{i}\right)$$

$$\vec{M} = I\ell^2 \left(-\frac{1}{2}\hat{i} + \frac{\sqrt{3}}{2}\hat{k} \right)$$

Torque on Current Carrying due to $\vec{B}$ (external)

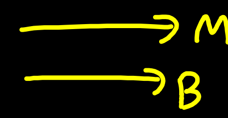
$$\boxed{\vec{\tau} = \vec{M} \times \vec{B}}$$

Sense of rotation

\# $\vec{M}$ wants aling along $\vec{B}$

\# when $\tau = 0$ rotational equilibrium

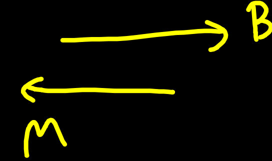
θ



$\tau = 0$

Stable Equilibrium.

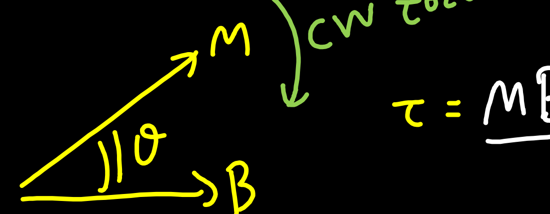
θ



$\tau = 0$

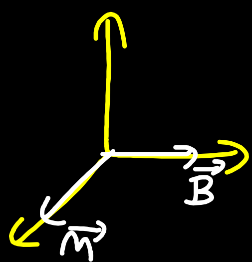
Unstable Equilibrium.

θ



$\tau = \underline{MB\sin\theta}$

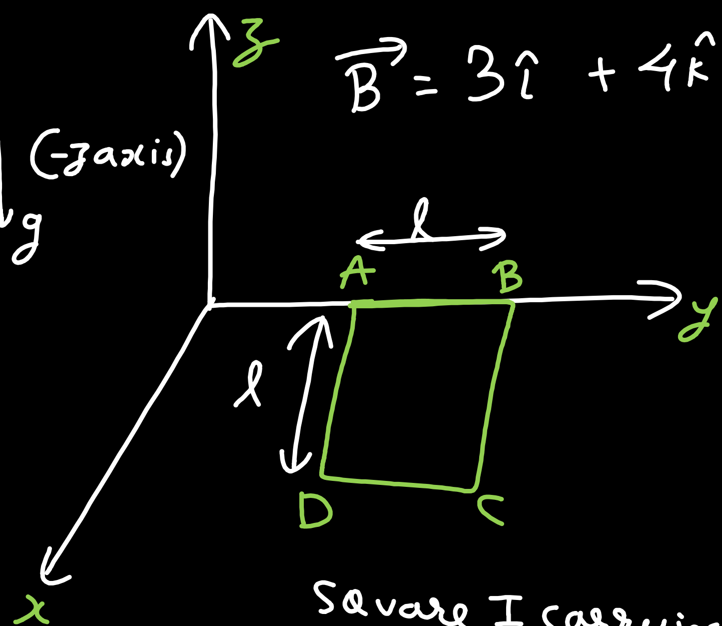

I
B
rotate
M
$\vec{B}$


$\vec{B}$
$\vec{M}$

Q

$\vec{B} = 3\hat{i} + 4\hat{k}$

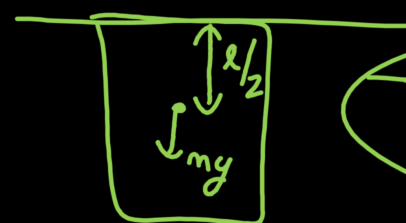
$\downarrow g$ (−z axis)



Square I carrying loop

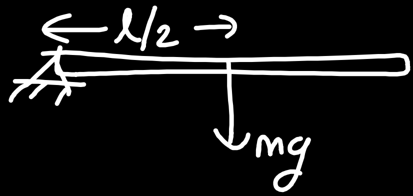
AB is hinged

Find I in loop such that is stays in equilibrium??



$\tau_{mg} = mg\dfrac{l}{2}$

Torque = (force) ($\perp$'ur distance)



$$\tau = mg\frac{l}{2}$$

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

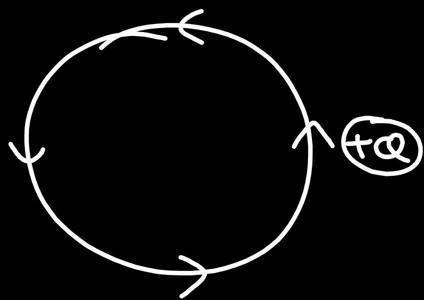
$$= Il^2(+\hat{k}) \times (3\hat{i} + 4\hat{k})$$

$$= \underline{\underline{Il^2(3)(\hat{j})}}$$

$$mg\frac{l}{2} = Il^2(3)$$

$$\frac{mg}{6l} = I$$

$\vec{M}$ of charge rotating



U.C.M.

speed constant

$$\vec{M} = I\,\vec{\text{area}}$$

$$T = \frac{2\pi r}{v} = \frac{2\pi}{\omega}$$

$$f = \frac{1}{T}$$

$$I = \frac{Q}{T} = Qf$$

$$I = \frac{Qv}{2\pi r}$$

$$M = I\pi r^2$$

$$= \frac{Qv}{2\pi r}\pi r^2$$

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

angular momentum $L = mvr$

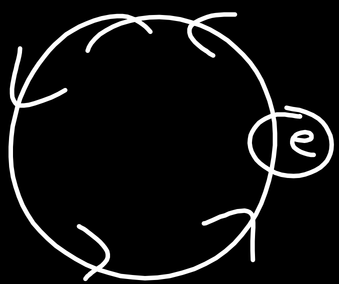
$L = I\omega$ for body

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

$$\frac{M}{L} = \frac{Qvr/2}{mvr}$$

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

also Bohr Model can be included



$$\frac{mv^2}{r} = \frac{KQ_1Q_2}{r^2}$$

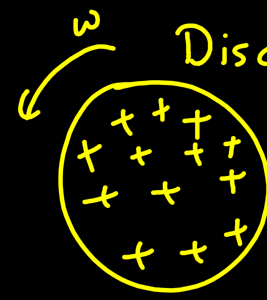
$$mvr = \frac{nh}{2\pi}$$

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

Ring

$$M = \frac{Q(\cancel{m}r^2)\omega}{2\cancel{m}}$$

Disc

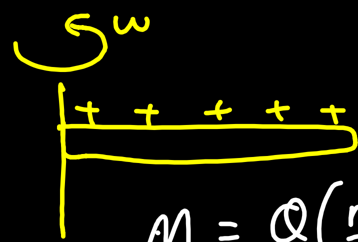


$$M = \frac{Q\left(\frac{mr^2}{2}\right)\omega}{2m}$$

$$M = \frac{Q\omega r^2}{4}$$

Body

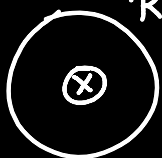
$I\omega$



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

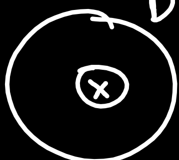
$$= \frac{Q\omega l^2}{6}$$

Ring

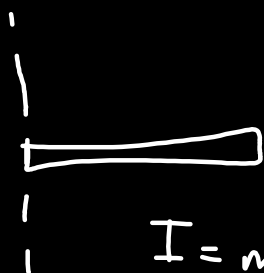


$I = mr^2$

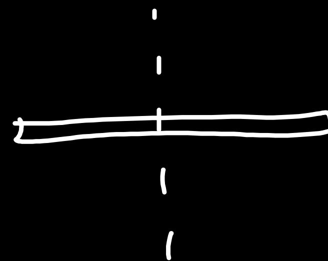
Disc



$I = \frac{mr^2}{2}$

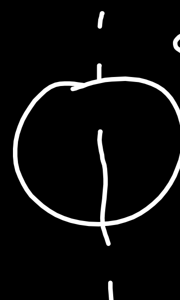


$I = \frac{ml^2}{3}$



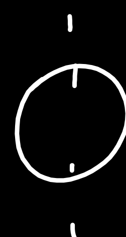
$I = \frac{ml^2}{12}$

Solid Sp



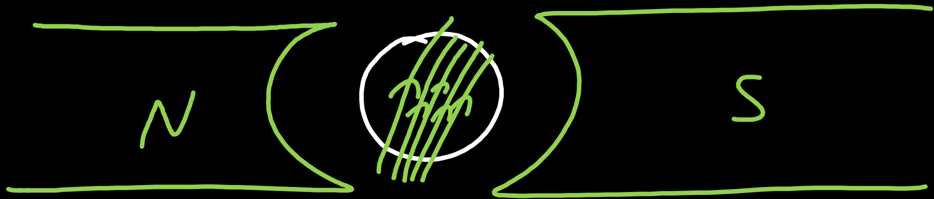
$\frac{2}{5} mr^2$

Hollow Sp



$\frac{2}{3} mr^2$

Moving Coil Galvanometer

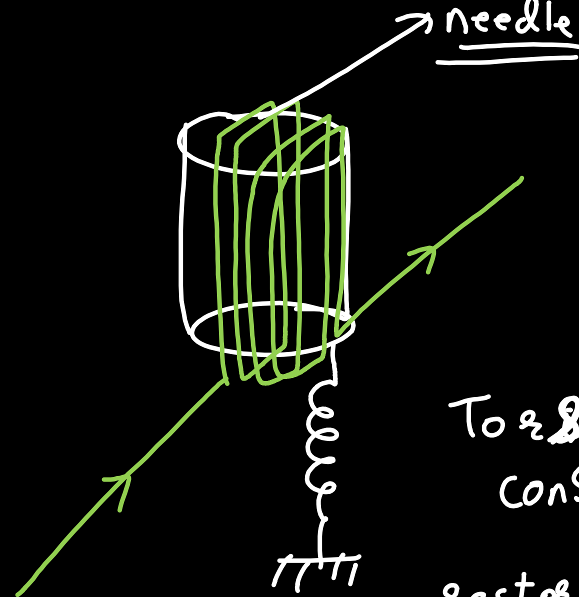


Top view

$$\boxed{|M| = NIA}$$

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

M & B are always cross to each other $\theta = 90^\circ$



Torsional constant $= K$

restoring Torque $= K\theta$

Concept → magnetic Torque

$\theta = 90°$

$\tau = MB$

$\tau = NIAB$

needle equilibrium

$\tau_{mag} = \tau_{sp}$

$NIAB = K\theta$

$\left(\frac{radian}{Ampere}\right)$ or $\left(\frac{degree}{Ampere}\right)$

$$\boxed{\frac{\theta}{I} = \frac{NAB}{K}}$$ → current sensitivity

$\Delta V = IR$

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

$\frac{\theta}{I}$ → $\frac{\theta R}{V} = \frac{NAB}{k}$

$$\boxed{\frac{\theta}{\Delta Voltage} = \frac{NAB}{KR}}$$ → Voltage "

$\dfrac{\theta}{I} = \dfrac{NAB}{K}$

$\dfrac{\theta}{\Delta \text{Voltage}} = \dfrac{NAB}{KR}$

$R \rightarrow$ resistance.

$R = \dfrac{\rho l}{A}$

N double

R double

$\dfrac{\cancel{2}}{\cancel{2}} = 1$

N is doubled

current sensitivity double

Voltage sensitivity remains same.

A galvanometer is used in laboratory for detecting the null point in electrical experiments. If, on passing a current of 6 mA it produces a deflection of 2°, its figure of merit is close to : **[Sep. 05, 2020 (II)]**

(a) 333° A/div. (b) 6×10^{-3} A/div.

(c) 666° A/div. (d) 3×10^{-3} A/div.

$I = 6\,mA \quad \theta = 2^\circ$

figure of merit

$\frac{I}{\theta}$ = current per division ⇒ figure of merit

$$\frac{6\,mA}{2^\circ} = 3 \times 10^{-3} \frac{A}{div}$$

A galvanometer coil has 500 turns and each turn has an average area of $3 \times 10^{-4}\ m^2$. If a torque of 1.5 Nm is required to keep this coil parallel to a magnetic field when a current of 0.5 A is flowing through it, the strength of the field (in T) is ____________. **[NA Sep. 03, 2020 (II)]**

$N = 500$

$A = 3 \times 10^{-4}$

$I = 0.5$

$\tau = 1.5$

$B = ?$

$\tau = MB$

$\tau = NIAB$

$B = 20\ T$

A galvanometer having a resistance of 20 Ω and 30 division on both sides has figure of merit 0.005 ampere/ division. The resistance that should be connected in series such that it can be used as a voltmeter upto 15 volt, is:

[11 Jan 2019, II]

(a) 100 Ω (b) 120 Ω (c) 80 Ω (d) 125 Ω

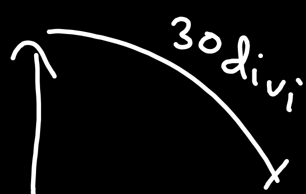
$\cancel{30} \times \frac{5}{100\cancel{0}}$

$0.005\ I$ in 1 divi

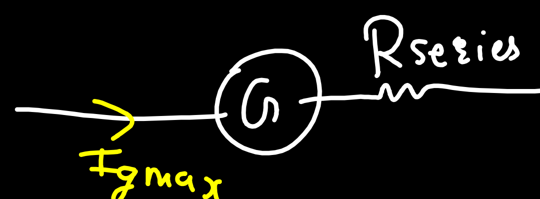
$30(0.005)\ I$ in 30 divi

$0.15\ A$ in 30 divi

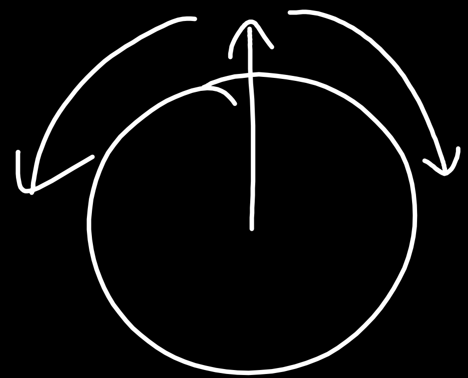
$R_{gal} = 20\Omega$



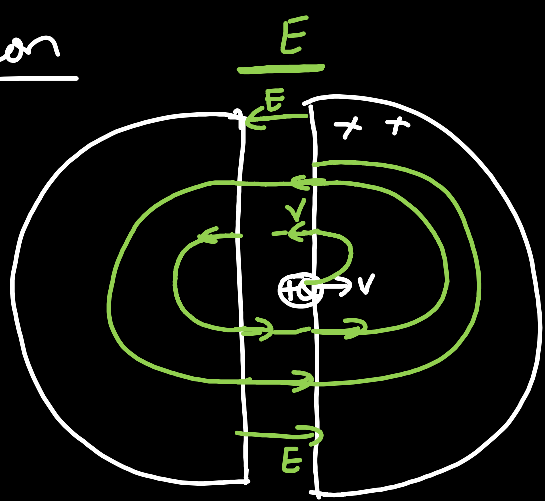
$I_{g\,max} = 0.15$



$\underline{\underline{I_g(G + R_{series})}} = 15$



Cyclotron



Particle accelerator

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

$$\text{freq} = \frac{QB}{2\pi m} \quad \frac{1}{T}$$

$\rightarrow E$ $t=0$

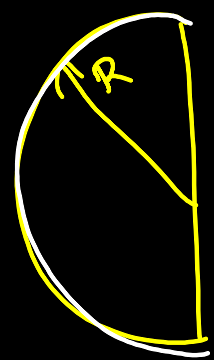
$\leftarrow E$ $t = T/2$

$\rightarrow E$ $t = T$

freq of cyclotron = freq of oscillation of E = freq of charged particle (circle)

Max Speed / max KE

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



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

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

$$\frac{QBR_{max}}{m} = V_{max}$$

$$KE_{max} = \frac{1}{2} m v^2 = \frac{1}{2} m \frac{Q^2 B^2 R^2}{m^2}$$

$$KE_{max} = \frac{Q^2 B^2 R^2}{2m}$$

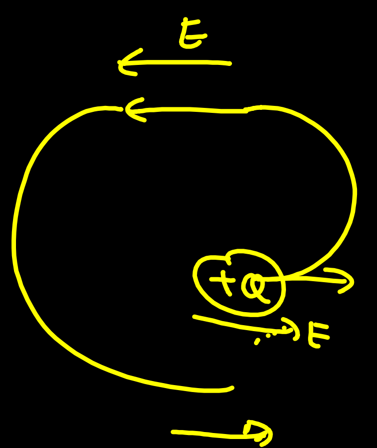
Cannot be used for neutron & electron

→ small size

speed up very fast

$$m' = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

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

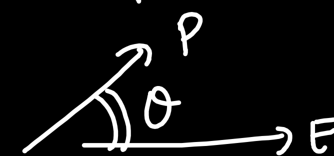


Revision Electrostatics Diapole

$\vec{P} = Q(d)$

$-ve$ to $+ve$

τ on diapole in E_{ext}



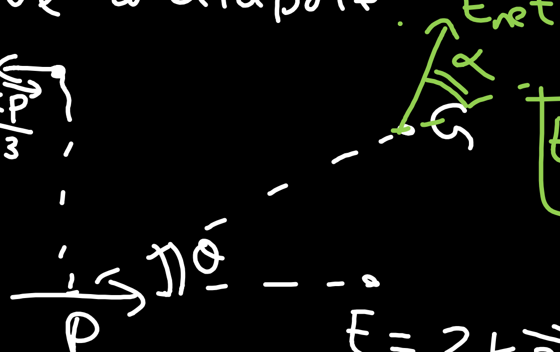
$\vec{\tau} = \vec{P} \times \vec{E}$

$\tau = PE\sin\theta$

Small oscillation

$$\text{Time} = 2\pi\sqrt{\frac{I}{PE}}$$

E due to diapole



$\vec{E} = -\frac{K\vec{P}}{r^3}$

$$\boxed{E = \frac{KP}{r^3}\sqrt{1+3\cos^2\theta}}$$

$$\boxed{\tan\alpha = \frac{\tan\theta}{2}}$$

$$E = \frac{2K\vec{P}}{r^3}$$

Force on diapole in uniform E = 0

Pot. Energy of diapole = $-\vec{P} \cdot \vec{E}$

WD on " = ΔU (change in Pot. energy.)

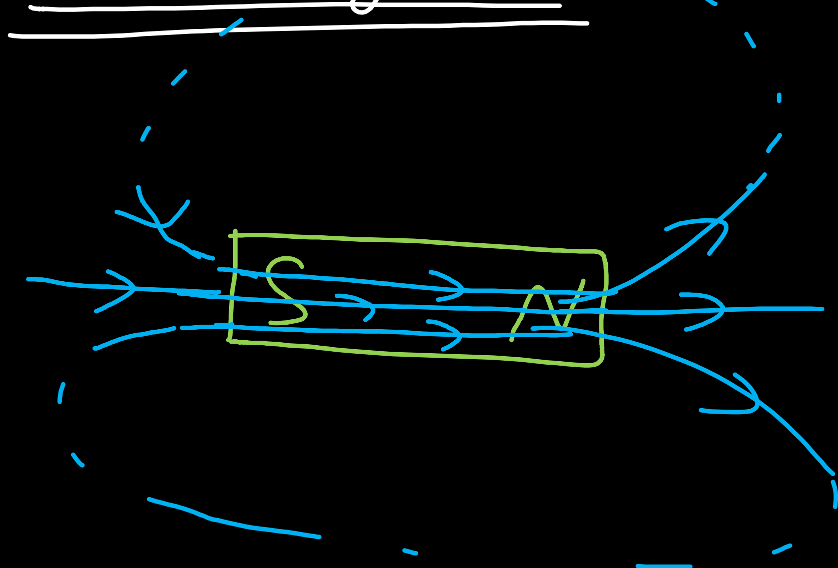
F on diapole in non uniform E = $\vec{P} \cdot \frac{d\vec{E}}{dx}$

analogy

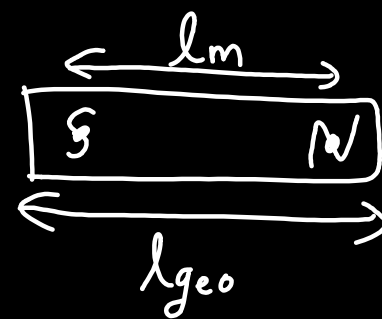
$\varepsilon_0 \rightarrow \frac{1}{\mu_0}$

Electric	Magnetic
$K = \frac{1}{4\pi\varepsilon_0}$	$\frac{\mu_0}{4\pi}$
Q charge	m (pole strength)
$\vec{P}$	$\vec{M}$
E	B

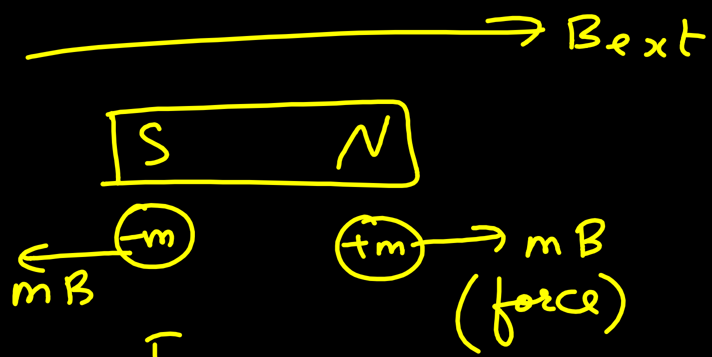
Bar Magnet



$$\vec{M} = (m)(l_m)$$



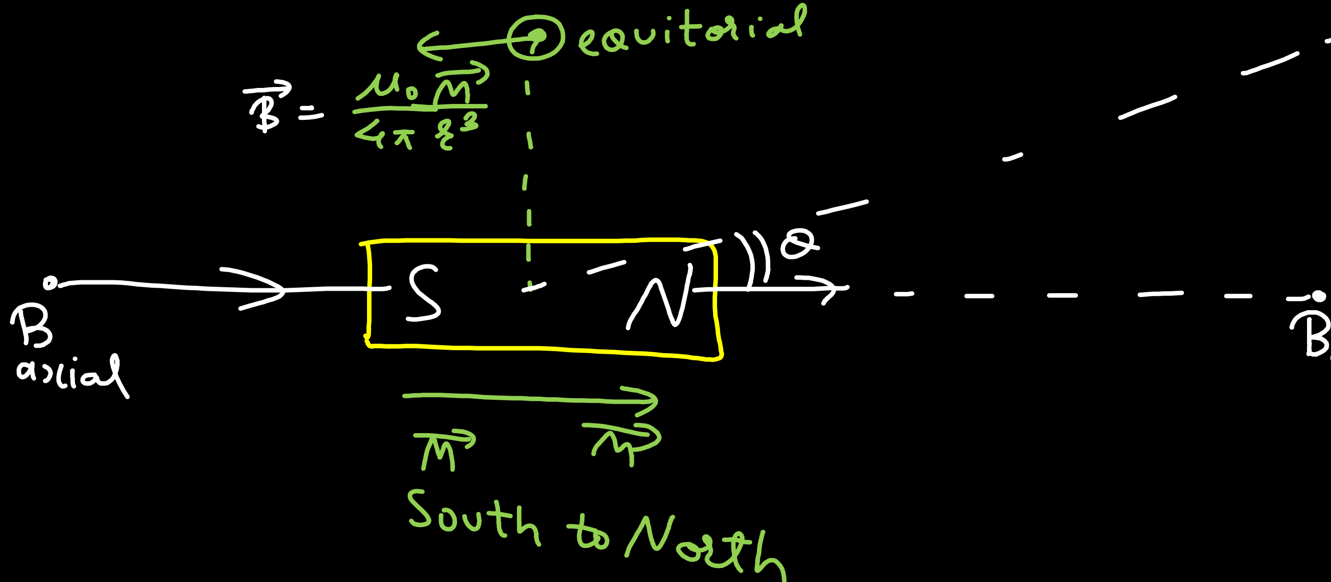
$$\frac{l_m}{l_{geo}} \approx 0.84$$



$F_{net} = 0$

in uniform $\vec{B}$.

$\vec{B}$ due to Bar Magnet



$$\vec{B} = \frac{\mu_0 \vec{M}}{4\pi r^3}$$

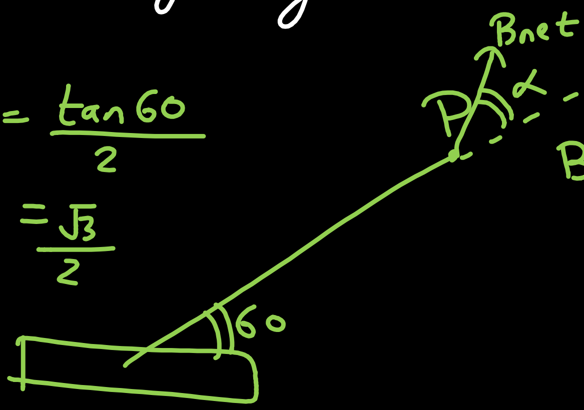
$$\vec{B}_{axial} = 2\left(\frac{\mu_0}{4\pi}\right)\frac{\vec{M}}{r^3}$$

$$\frac{\mu_0 M}{4\pi r^3}\sqrt{1+3\cos^2\theta}$$

$$\tan\alpha = \frac{\tan\theta}{2}$$

Q Find B due to diapole magnetic moment = $1.2\ Am^2$ at a point 1m away from it in a direction making angle 60° with diapole axis.

$$\tan\alpha = \frac{\tan 60}{2} = \frac{\sqrt{3}}{2}$$

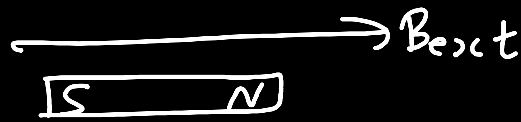


$$\alpha = \tan^{-1}\left(\sqrt{3}/2\right)$$

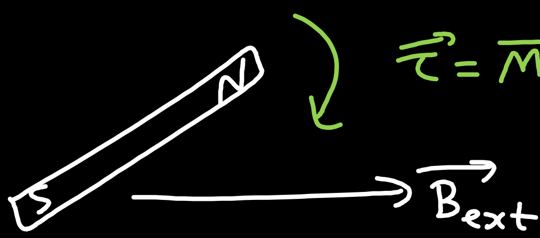
$$B = \frac{\mu_0 M}{4\pi r^3}\sqrt{1+3\cos^2\theta}$$

$$= \frac{10^{-7}\times 1.2}{(1)^3}\sqrt{1+3\left(\frac{1}{4}\right)}$$

$$= \frac{1.2}{2}\times 10^{-7}\sqrt{7} = \sqrt{7}\times 0.6\times 10^{-7}\ T$$



$\vec{M}$ wants to align along $\vec{B}$



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

relesed from rest

Small angle oscillation

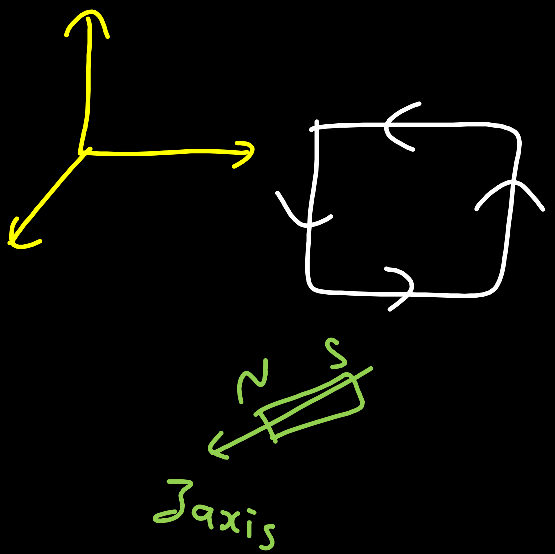
$$T = 2\pi\sqrt{\frac{I}{MB}}$$

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

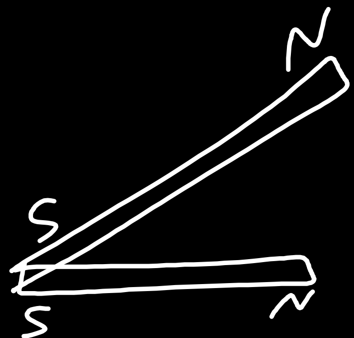
$$WD_{ext} = \Delta U$$

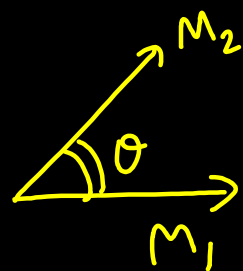
Force on bar magnet in non uniform B $= \vec{M} \cdot \dfrac{d\vec{B}}{dx}$.

Current Carrying loop can be treated as a bar Magnet



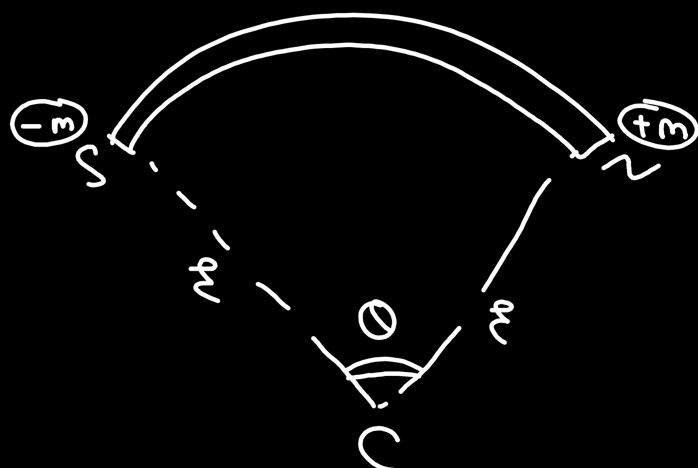
$$\vec{M} = (I\vec{A})N$$

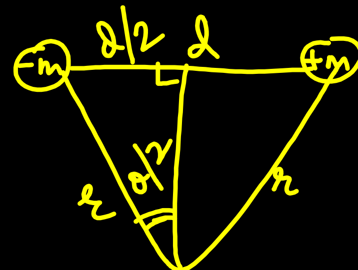




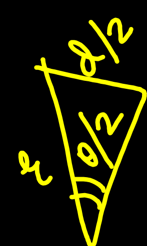
$$M_{net} = \sqrt{M_1^2 + M_2^2 + 2M_1M_2\cos\theta}$$

$$M = md$$





$$M = m\left(2r\sin\left(\frac{\theta}{2}\right)\right)$$



$$\sin\theta/2 = \frac{d/2}{r}$$

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

Magnetisation

B

created field

Vaccum

$$\vec{H} = \frac{\vec{B}}{\mu_0}$$

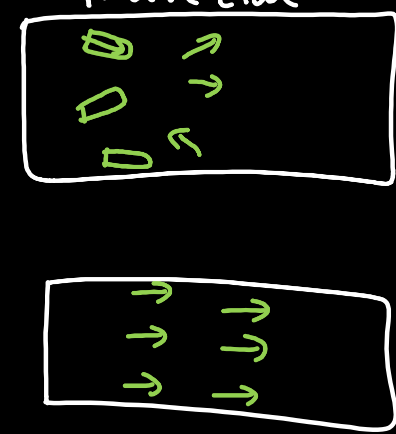
magnetizing field

unit of H $\Rightarrow$ A/m

$$\vec{B} = \mu_0 \vec{H}$$

B_{ext}

material



$$B_{net\ inside} = B_{ext} + B_{induced}$$

Unit A/m

H $\quad$ I

B unit T

I (intensity of magnetisation)

$$I = \frac{M}{\text{Volume}}$$ (magnetic moment induced)

unit of $I \rightarrow A/m$

$$B_{induced} = \mu_0 I$$

$$B_{ext} = \mu_0 H$$

$$B_{induced} = \mu_0 I$$

$$B_{net} = \mu_0 H + \mu_0 I$$

$$B_{net} = \mu_0 (H + I)$$

$\mu_0 \longrightarrow \mu_0 \mu_r$

Vaccum medium

$B = \mu_0 H$

vaccum

medium

$B_{net} = \mu_0 \mu_r H$

$B_{net} = B_{net}$

$\mu_0 \mu_r H = \mu_0 (H + I)$

$\mu_r = \left(\frac{H + I}{H} \right)$

$\frac{I}{H} = \chi$

susceplitibity

$\mu_r = 1 + \frac{I}{H}$

$\mu_r = 1 + \chi$

$B_{ext} = \mu_0 H$

$B_{induced} = \mu_0 I$

$B_{\substack{net \\ inside}} = \mu_0 (H + I)$

$B_{\substack{net \\ inside}} = \mu_0 \mu_r H$

$\boxed{\mu_r = 1 + \chi}$

$\chi = \dfrac{I}{H} \longrightarrow$ Magnetic susceptibility

magnetisation $\propto \dfrac{B}{Temp}$

$B_{ext} = 1$

$\boxed{B_{ins} = 1.2}$

χ less

Paramagnet

$\boxed{B_{insi} = \text{very high}}$

χ more

Ferromagnet

$B_{ext} = 1$

$\boxed{B_{insi} = 0.9}$

$\underline{\underline{\chi \; -ve}}$ small

$\underline{\text{Dimagnetic}}$

$\longrightarrow B_{ext}$

$\boxed{\xleftarrow{B_{induc}}}$

$B_{net} = B_{ext} - B_{induced}$

$B_{ext} = \mu_0 H$

magnetic field

(T)

magnetising field

A/m

$B_{induced} = \mu_0 I$

$B_{net} = \mu_0 (H + I)$

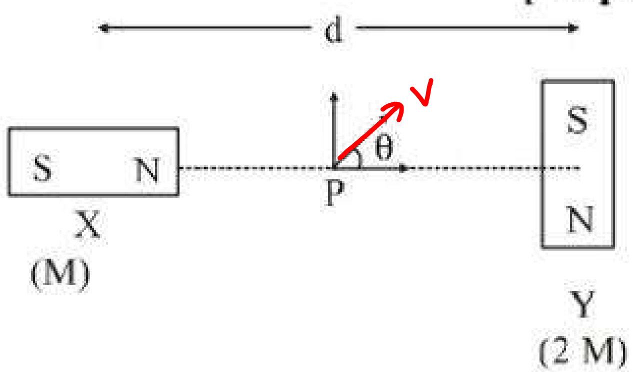
$B_{net} = \mu_0 \mu_r H$

$\mu_r = 1 + \chi$

$\chi = \frac{I}{H}$

Two magnetic dipoles X and Y are placed at a separation d, with their axes perpendicular to each other. The dipole moment of Y is twice that of X. A particle of charge q is passing through their midpoint P, at angle $\theta = 45°$ with the horizontal line, as shown in figure. What would be the magnitude of force on the particle at that instant? (d is much larger than the dimensions of the dipole)

[8 April 2019 II]



(a) $\left(\frac{\mu_0}{4\pi}\right)\frac{M}{\left(\frac{d}{2}\right)^3} \times qv$ (b) 0

(c) $\sqrt{2}\left(\frac{\mu_0}{4\pi}\right)\frac{M}{\left(\frac{d}{2}\right)^3} \times qv$ (d) $\left(\frac{\mu_0}{4\pi}\right)\frac{2M}{\left(\frac{d}{2}\right)^3} \times qv$

M

$\frac{\mu_0 (2m)}{4\pi\, r^3}$

$\frac{\mu_0 2M}{4\pi\, r^3}$

2M

B_{net}

v

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

$= 0$

A magnet of total magnetic moment $10^{-2}\hat{i}$ A-m^2 is placed in a time varying magnetic field, $B\hat{i}(\cos\omega t)$ where B = 1 Tesla and $\omega = 0.125$ rad/s. The work done for reversing the direction of the magnetic moment at t = 1 second, is: **[10 Jan. 2019 I]**

(a) 0.01 J (b) 0.007 J

(c) 0.028 J (d) 0.014 J

at $t = 1$

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

$\vec{M} = 10^{-2}\hat{i}$

$B = B\cos(\omega t)\hat{i}$

H.W.

WD

$$U_{ini} = -MB\cos\theta$$

$$U_{ini} = -MB\cos 0$$
$$= -MB$$

$$\Delta U = WD_{ext}$$

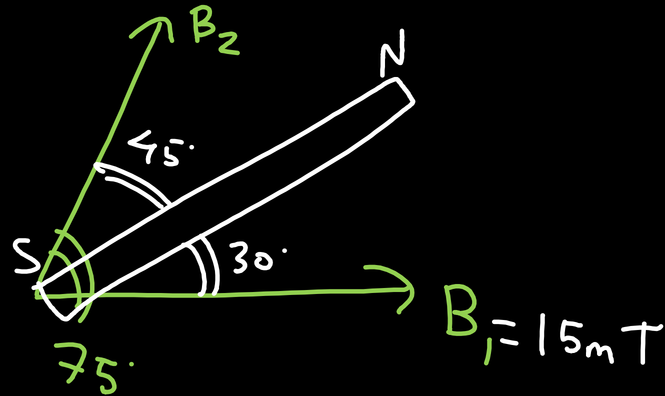
$$U_{final} = -MB\cos 180^\circ$$

$$= +MB$$

A magnetic dipole is acted upon by two magnetic fields which are inclined to each other at an angle of 75°. One of the fields has a magnitude of 15 mT. The dipole attains stable equilibrium at an angle of 30° with this field. The magntidue of the other field (in mT) is close to :

[Online April 9, 2016]

(a) 1 (b) 11 (c) 36 (d) 1060



$$\cancel{m}B_1 \sin 30 = \cancel{m}B_2 \sin 45$$

$$15\,\frac{1}{2} = B_2\,\frac{1}{\sqrt{2}}$$

$$\frac{15}{\sqrt{2}} = B_2$$

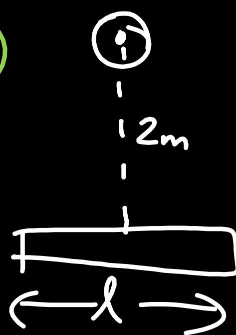
$$11\,mT \simeq B_2$$

A bar magnet of length 6 cm has a magnetic moment of 4 J T^{-1}. Find the strength of magnetic field at a distance of 200 cm from the centre of the magnet along its equatorial line. **[Online May 7, 2012]**

(a) 4×10^{-8} tesla (b) 3.5×10^{-8} tesla

(c) 5×10^{-8} tesla (d) 3×10^{-8} tesla

H.W.



$$B = \left(\frac{\mu_0}{4\pi}\right)\frac{M}{r^3}$$

$l = 6cm$

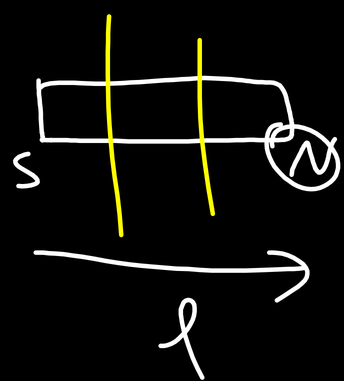
$M = 4$

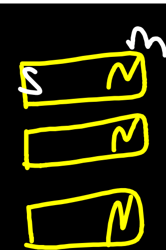
The length of a magnet is large compared to its width and breadth. The time period of its oscillation in a vibration magnetometer is 2s. The magnet is cut along its length into three equal parts and these parts are then placed on each other with their like poles together. The time period of this combination will be **[2004]**

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

$$T = 2s = 2\pi\sqrt{\frac{I}{MB}}$$

$M = ml$





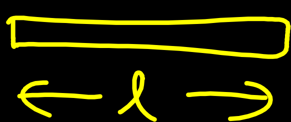
$ml/3$

$ml/3$

$ml/3$

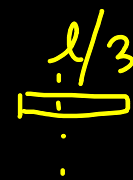
$M_{tot} = ml$

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



m

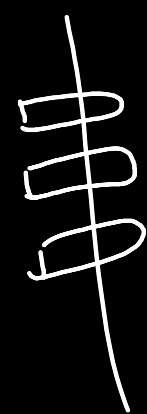
$$I = \frac{ml^2}{12}$$



m/3

$$I = \frac{(m/3)(l/3)^2}{12}$$

$$= \frac{ml^2}{27\ 12}$$



$$I_{tot} = \left(\frac{ml^2}{12}\right)\frac{1}{27} \times 3$$

$$= I\,\frac{1}{9}$$

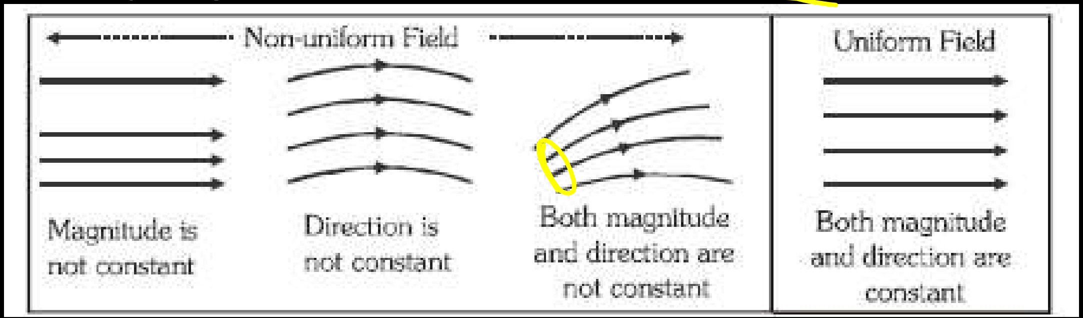
$I \to 1/9$ times

Time $\to \sqrt{1/9}$ time

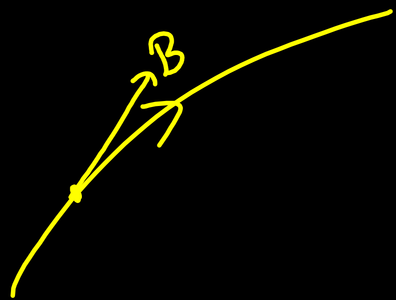
$= \frac{1}{3}$ times.

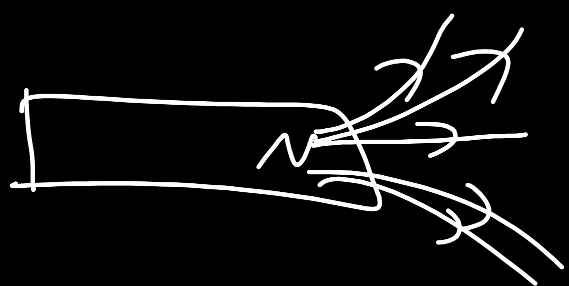
Magnetic Field lines Properties

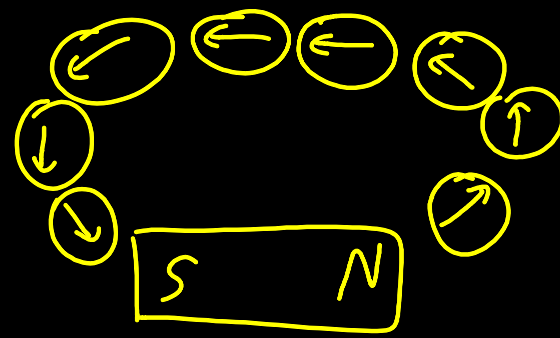
- Magnetic field lines are closed curves.
- Tangent drawn at any point on the field line represents direction of the field at that point.
- Field lines never intersects to each other.
- At any place crowed line represent stronger field while distant lines represents weaker field .
- In any region , if field lines are equidistant and straight the field uniform otherwise not.



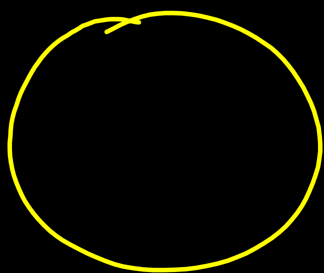
- Magnetic field lines emanate from or enters in the surface of a magnetic material at any angle.
- Magnetic field lines exist inside every magnetised material.
- Magnetic field lines can be mapped by using iron dust or using compass needle


B


N


S
N

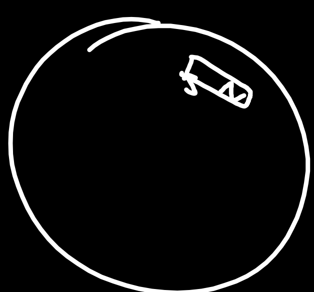
Gauss law in Magnetism



Closed 3D sphere

Total flux = $\dfrac{Q_{enclosed}}{\varepsilon_0}$

$\oint \vec{E} \cdot d\vec{A}$



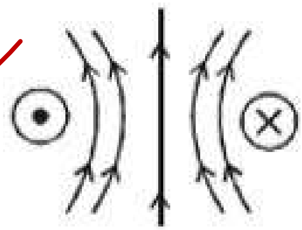
Closed 3D surface

total magnetic flux

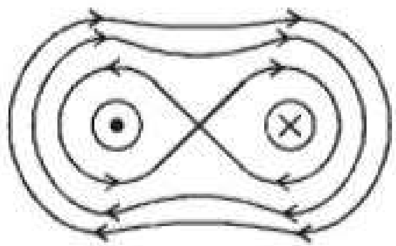
$$\oint \vec{B} \cdot d\vec{A} = \frac{m_{enclosed}}{\varepsilon_0} = 0$$

Choose the correct sketch of the magnetic field lines of a circular current loop shown by the dot ⊙ and the cross ⊗. **[Online April 22, 2013]**

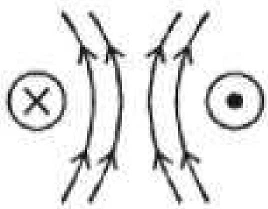
(a)



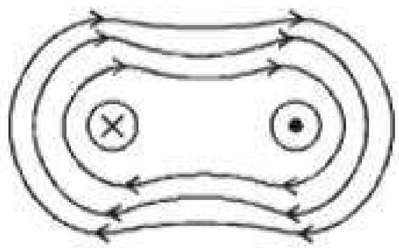
(b)

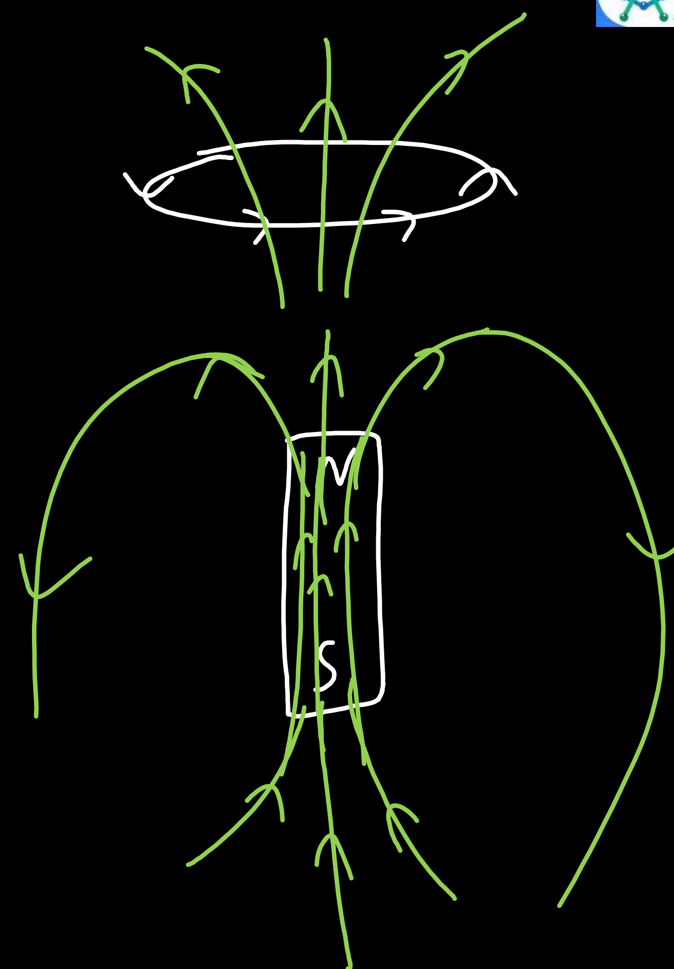


(c)



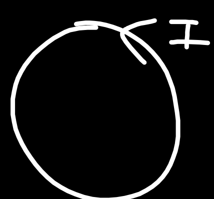
(d)





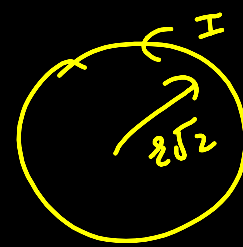
The dipole moment of a circular loop carrying a current I, is m and the magnetic field at the centre of the loop is B_1. When the dipole moment is doubled by keeping the current constant, the magnetic field at the centre of the loop is B_2. The ratio $\frac{B_1}{B_2}$ is: **[2018]**

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



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

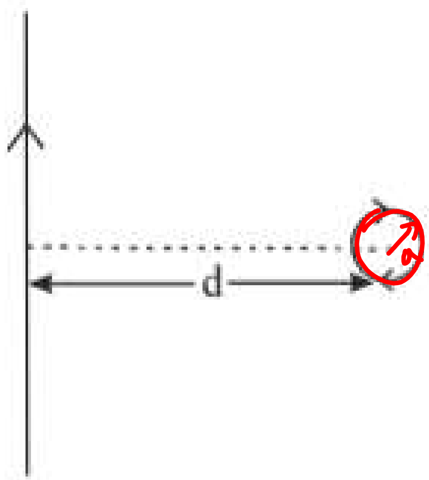
$m = I\pi r^2$



$B_2 = \frac{\mu_0 I}{2(r\sqrt{2})}$

$\frac{B_1}{B_2} = \sqrt{2}$

An infinitely long current carrying wire and a small current carrying loop are in the plane of the paper as shown. The redius of the loop is a and distance of its centre from the wire is d (d>>a). If the loop applies a force F on the wire then: **[9 Jan. 2019 I]**



$M = I\pi a^2$

$F \propto \frac{a^2}{d^2}$

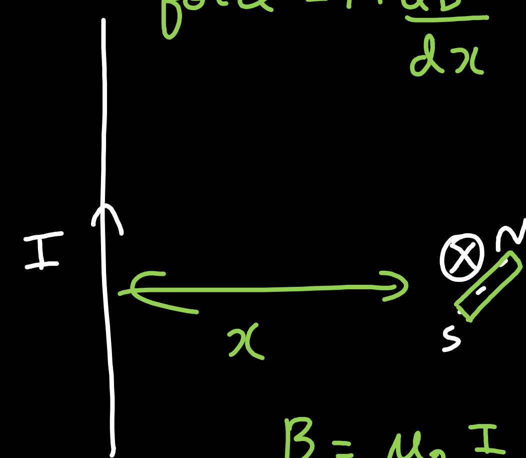
(a) $F = 0$

(b) $F \propto \left(\frac{a}{d}\right)$

(c) $F \propto \left(\frac{a^2}{d^3}\right)$

(d) $F \propto \left(\frac{a}{d}\right)^2$

force $= M \frac{dB}{dx}$



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

$\frac{dB}{dx} = \frac{\mu_0 I}{2\pi}\left(\frac{-1}{x^2}\right)$

$F = I\pi a^2 \left(\frac{\mu_0 I}{2\pi x^2}\right)$

A 25 cm long solenoid has radius 2 cm and 500 total number of turns. It carries a current of 15 A. If it is equivalent to a magnet of the same size and magnetization $\vec{M}$ (magnetic moment/volume), then $|\overline{M}|$ is : **[Online April 10, 2015]**

(a) $30000\pi \, Am^{-1}$ (b) $3\pi \, Am^{-1}$
(c) $30000 \, Am^{-1}$ (d) $300 \, Am^{-1}$

$l = 25 cm$
$r = 2 cm$
$N = 500$
$I = 15 A$

$I = \frac{\text{Moment Magnetic}}{Vol}$

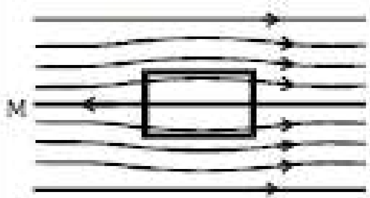
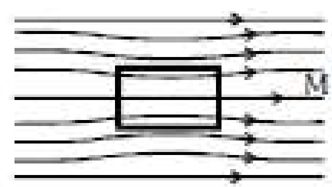
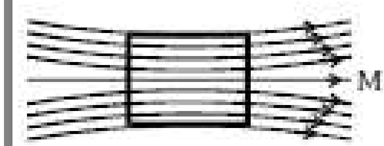
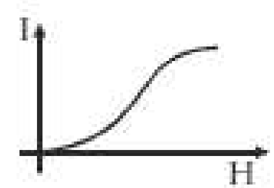
$= \frac{(I)(area)N}{Vol}$

$= \frac{(I)\cancel{(A)}N}{\cancel{(A)}(l)}$

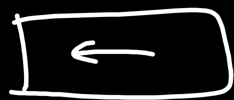
$= \frac{(I)(N)}{l}$

Break Time
20min

Resume 9:10pm

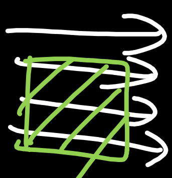
PROPERTIES	DIAMAGNETIC	PARAMAGNETIC	FERROMAGNETIC
Cause of magnetism	Orbital motion of electrons	Spin motion of electrons	Formation of domains
Substance placed in uniform magnetic field.	Poor magnetisation in opposite direction. Here $B_m < B_0$ 	Poor magnetisation in same direction. Here $B_m > B_0$ 	Strong magnetisation in same direction. Here $B_m >>> B_0$ 
I – H curve $\boxed{\rightarrow M}$ $I = \frac{M}{V_{ol}}$	$I \rightarrow$ Small, negative, varies linearly with field 	$I \rightarrow$ Small, positive, varies linearly with field 	$I \rightarrow$ very large, positive & varies non–linearly with field 

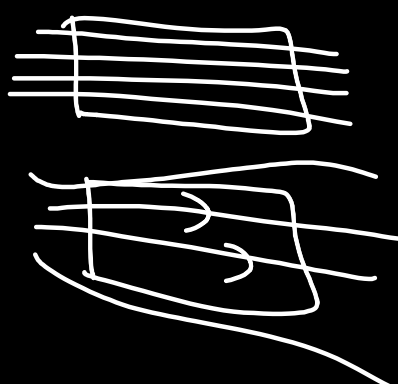
Di



$B_{induced}$ small & opp

χ -ve & small





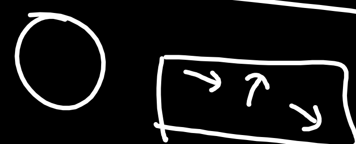
Para

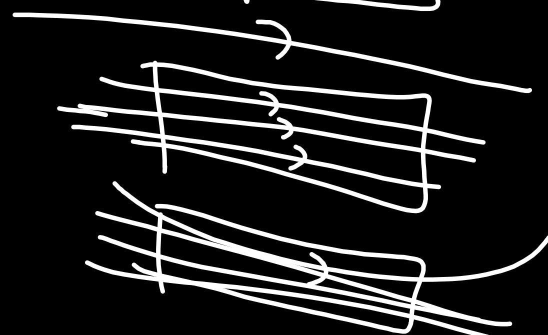
→ induction

$B_{induced}$ small

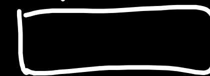
χ +ve small

Unpaired e^-





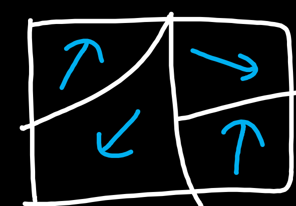
Ferro

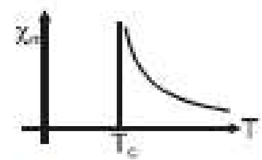


$B_{induced}$ very high

χ +ve high.

Domain

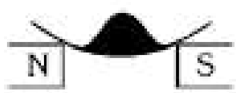
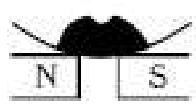
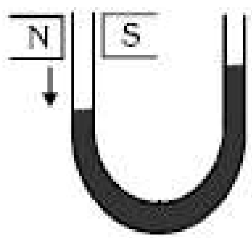
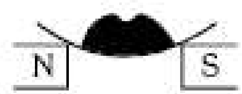
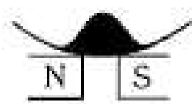
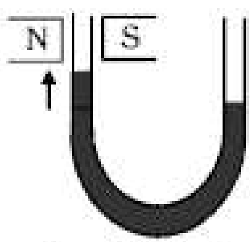
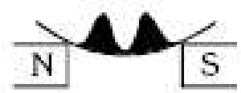
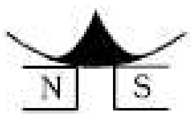


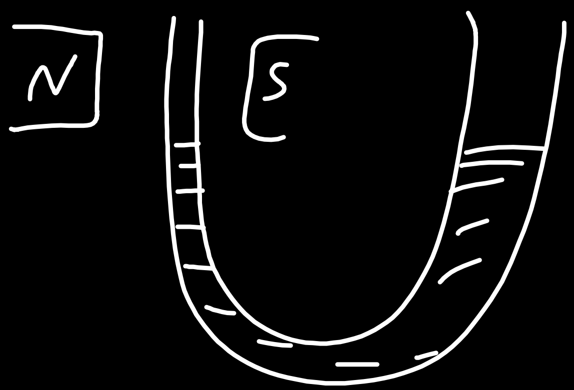
PROPERTIES	DIAMAGNETIC	PARAMAGNETIC	FERROMAGNETIC
$\chi_m - T$ curve	$\chi_m \rightarrow$ small, negative & temperature independent $\chi_m \propto T^0$  $\mu_r = 1 + \chi$	$\chi_m \rightarrow$ small, positive & varies inversely with temp. $\chi_m \propto \frac{1}{T}$ (Curie law) $\chi \propto \frac{1}{Temp}$ 	$\chi_m \rightarrow$ very large, positive & temp. dependent $\chi_m \propto \frac{1}{T-T_c}$ (Curie Weiss law) (for $T > T_C$) (T_C = Curie temperature)  $T_C(I_{iron})$=770°C or 1043K
μ_r	$(\mu < \mu_0)$ $1 > \mu_r > 0$	$2 > \mu_r > 1$ $(\mu > \mu_0)$	$\mu_r >>> 1$ $(\mu >>> \mu_0)$
Magnetic moment of single atom	Atoms donot have any permanent magnetic moment	Atoms have permanent megnetic moment which are randomly oriented. (i.e. in absence of external magnetic field the magnetic moment of whole material is zero)	Atoms have permanent megnetic moment which are organised in domains.

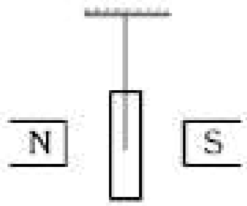
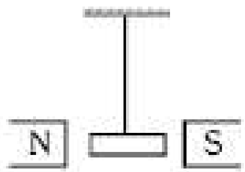
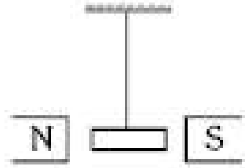
Curie Weiss law

after Curie T ferromagnetic develops paramagnetic nature

$\chi \propto \frac{1}{T-T_c}$

PROPERTIES	DIAMAGNETIC	PARAMAGNETIC	FERROMAGNETIC
Behaviour of substance in Nonuniform magnetic field	It moves from stronger to weaker magnetic field.  Weak Field  Strong field  Level depressed in that limb	It moves with week force from weaker magnetic field to stronger magnetic field.  Weak Field  Strong field  Level slightly rises	Strongly attract from weaker magnetic field to stronger magnetic field.  Weak Field  Strong field


N
S

PROPERTIES	DIAMAGNETIC	PARAMAGNETIC	FERROMAGNETIC
When rod of material is suspended between poles of magnet.	It becomes perpendicular to the direction of external magnetic field. 	If there is strong magnetic field in between the poles then rod becomes parallel to the magnetic field. 	Weak magnetic field between magnetic poles can made rod parallel to field direction. 
Magnetic moment of substance in presence of external magnetic field	Value $\vec{M}$ is very less and opposite to $\vec{H}$.	Value $\vec{M}$ is low but in direction of $\vec{H}$.	$\vec{M}$ is very high and in direction of $\vec{H}$.
Examples	Bi, Cu, Ag, Pb, H_2O, Hg, H_2, He, Ne, Au, Zn, Sb, NaCl, Diamond.(May be found in solid, liquid or gas).	Na, K, Mg, Mn, Sn, Pt, Al, O_2 (May be found in solid, liquid or gas.)	Fe,Co, Ni all their alloys, Fe_3O_4 Gd, Alnico, etc. (Normally found only in solids) (crystalline solids)

A paramagnetic sample shows a net magnetisation of 6 A/m when it is placed in an external magnetic field of 0.4 T at a temperature of 4 K. When the sample is placed in an external magnetic field of 0.3 T at a temperature of 24 K, then the magnetisation will be : **[Sep. 04, 2020 (II)]**

(a) 1 A/m (b) 4 A/m

(c) 2.25 A/m (d) 0.75 A/m

$I = 6\ A/m$

$B = 0.4\ T$

$Temp = 4K$

$B' = 0.3T$

$T' = 24K$

$I = ?$

$6 \propto \frac{0.4}{4}$

$I' \propto \frac{0.3}{24}$

divide

$\frac{6}{I'} = \frac{0.4}{4} \times \frac{24}{0.3}$ 8

$\frac{3}{4} = \frac{6}{8} = I'$

0.75

$\longrightarrow B_{ext}$

material

magnet Ban Gaya

when ext B removed

$\Rightarrow$ retentivity induced B Bachi reh Jati

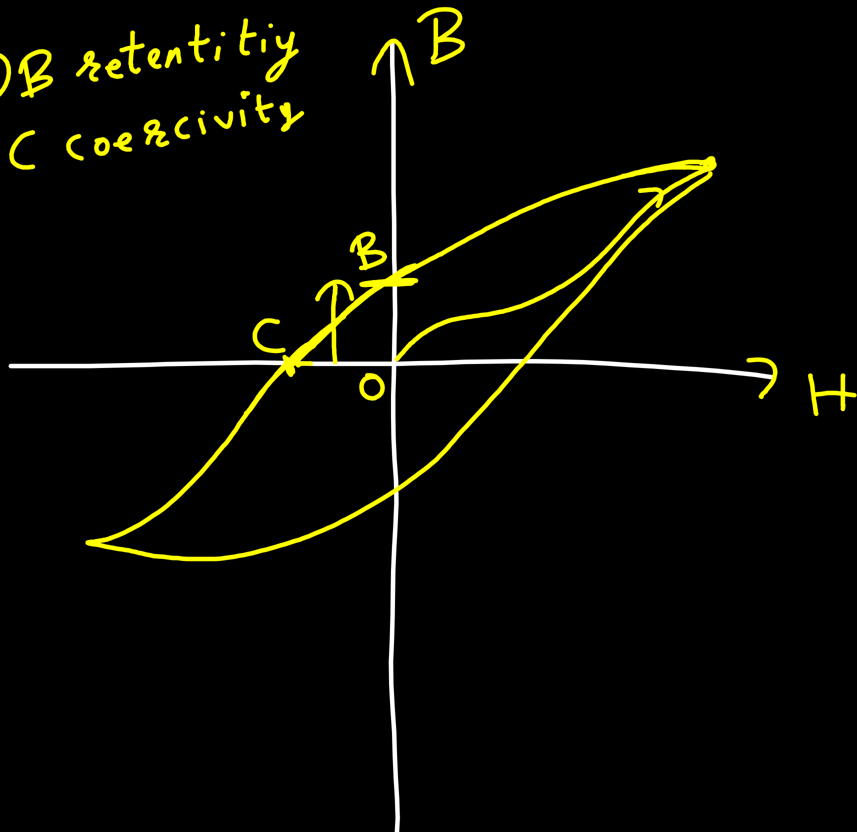
~~Now we need to remove it~~ for that

B_{ext} opp. $\longleftarrow$

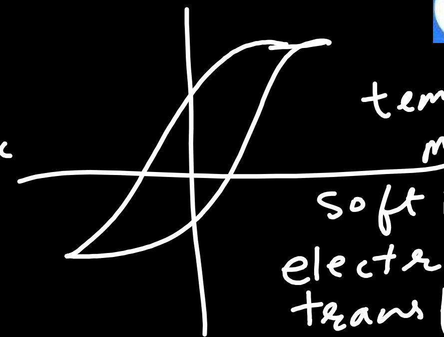
Coercivity

OB retentivity

OC coercivity



Soft magnetic



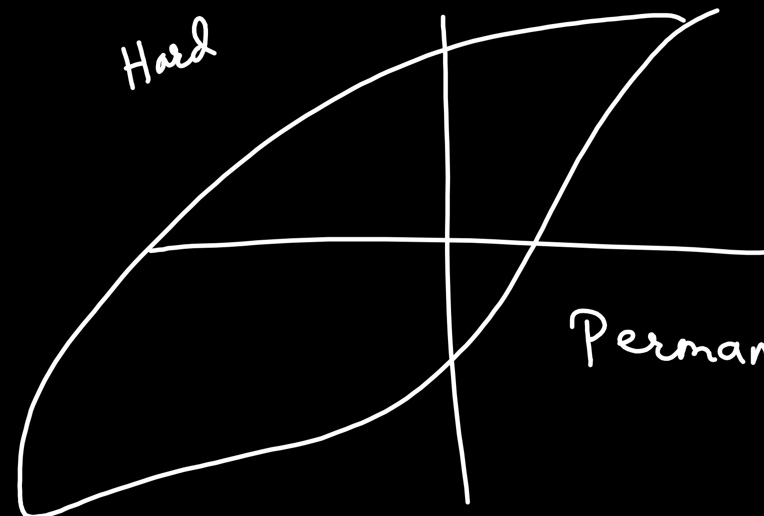
temporary magnet

soft iron

electromagnets

transformers.

Hard



Permanent

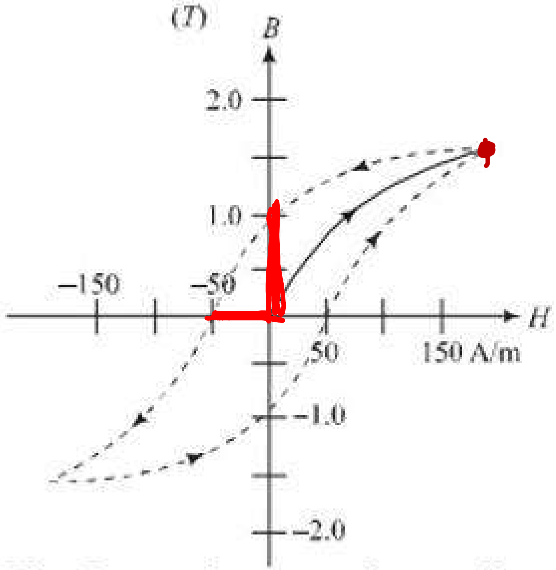
Magnetic materials used for making permanent magnets (P) and magnets in a transformer (T) have different properties of the following, which property best matches for the type of magnet required? **[Sep. 02, 2020 (I)]**

(a) T : Large retentivity, small coercivity

(b) P : Small retentivity, large coercivity

(c) T : Large retentivity, large coercivity

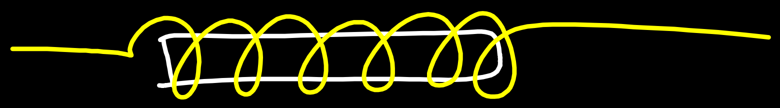
(d) P : Large retentivity, large coercivity



The figure gives experimentally measured B vs. H variation in a ferromagnetic material. The retentivity, co-ercivity and saturation, respectively, of the material are:

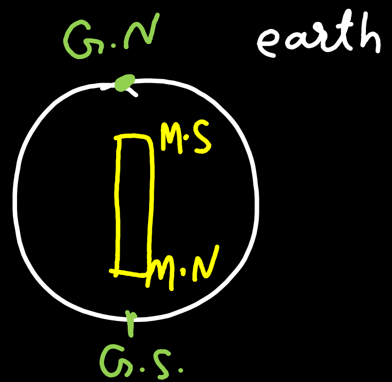
[7 Jan. 2020 II]

(a) 1.5 T, 50 A/m and 1.0 T
(b) 1.5 T, 50 A/m and 1.0 T
(c) 150 A/m, 1.0 T and 1.5 T
(d) 1.0 T, 50 A/m and 1.5 T



Earth Magnetism

Basics Clear

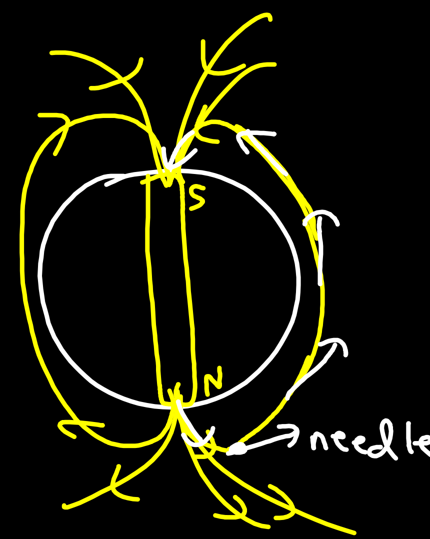


G.N ⇒ geometry north

G.S ⇒ " South

M.S ⇒ magnetic South

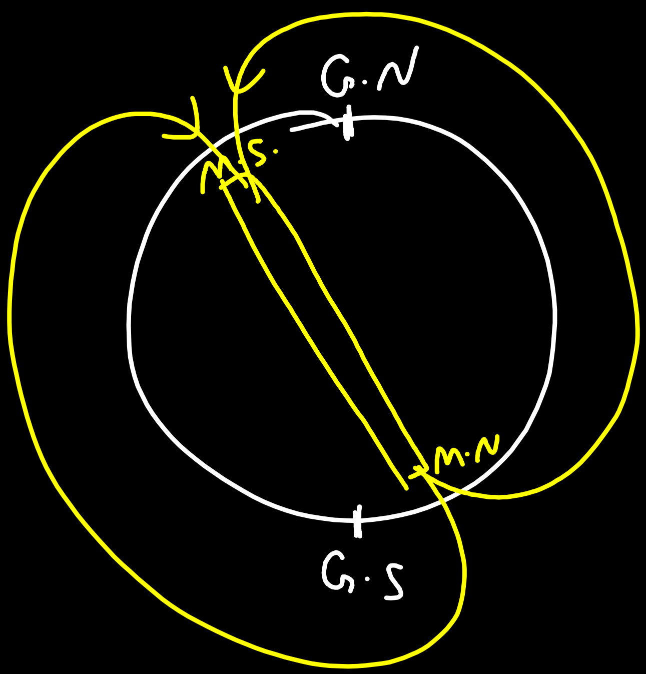
M.N ⇒ " north



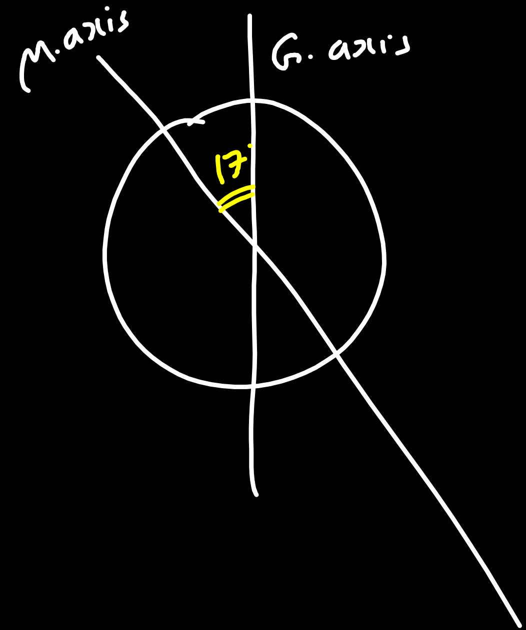
Compass north needle point towards

⇓

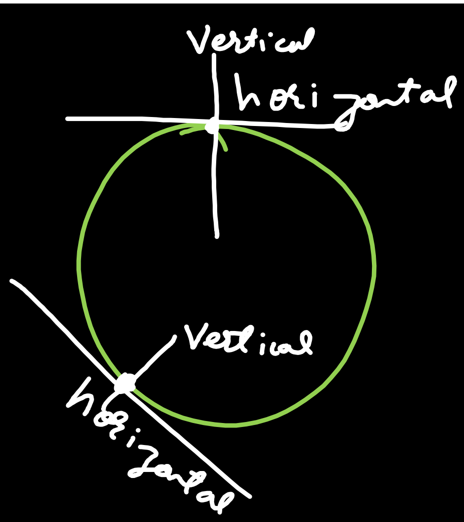
Geo north



G.N
M.S.
M.N
G.S



M.axis
G. axis
17°



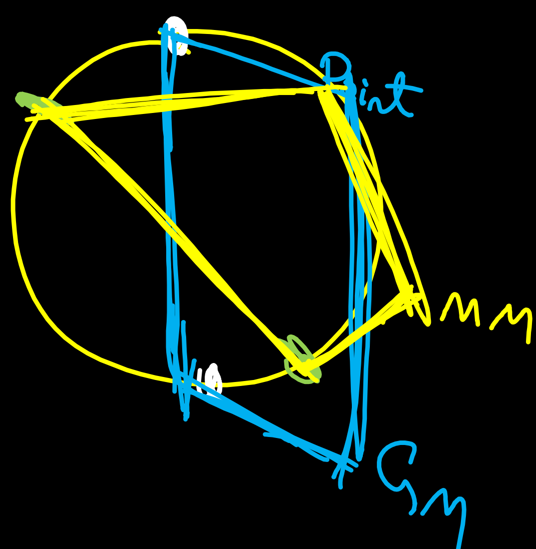
Horizontal $\Rightarrow$ tangent

Vertical $\Rightarrow$ radius

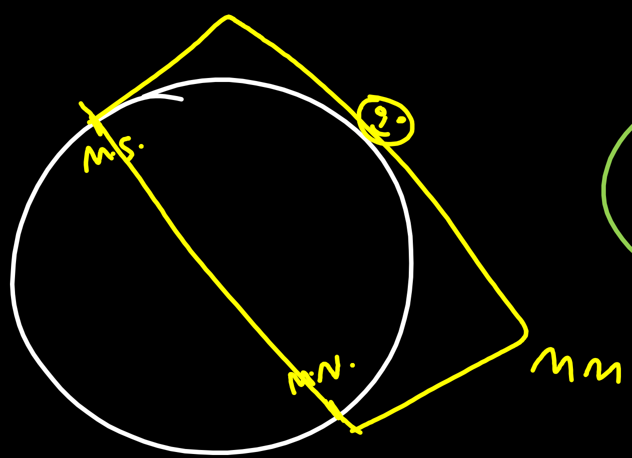
Planes

Geometric Meridian ⇒ passing through G. North & G. South

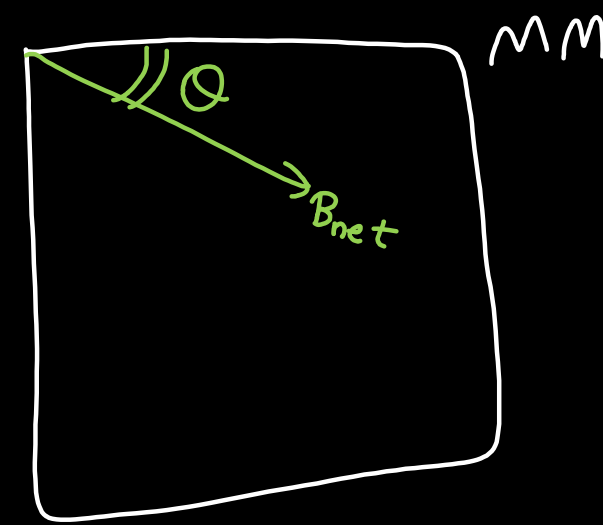
Magnetic Meridian ⇒ " " M. North & M. South

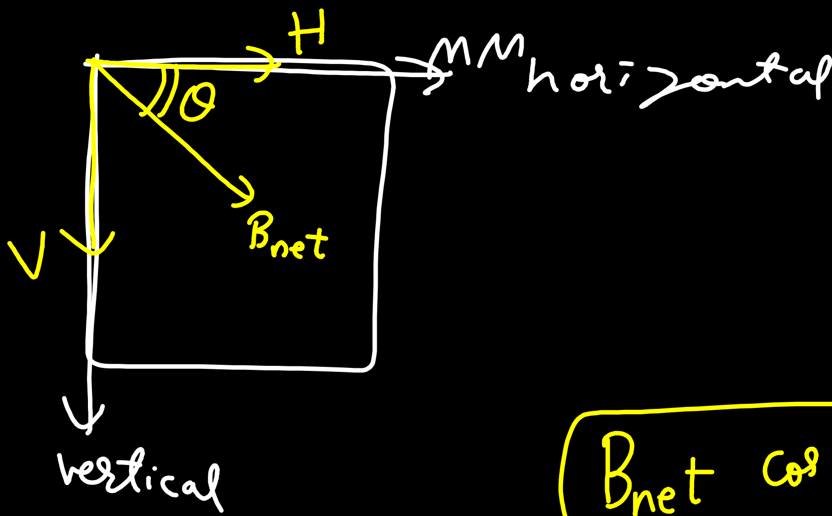


Bnet of earth always lies in Magnetic Meridian



$\theta \rightarrow$ angel of Dip





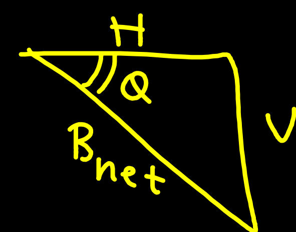
$H \rightarrow$ horizontal componet of earth's magnetic field

$V \rightarrow$ vertical " "
" " "

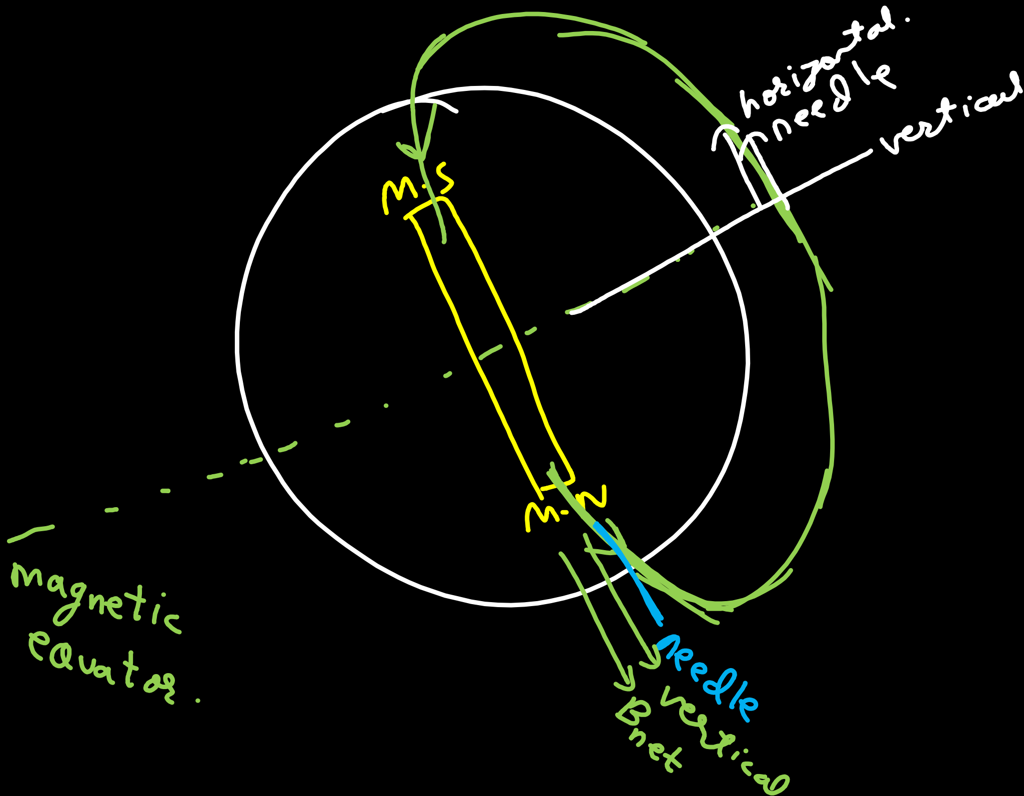
$$\boxed{B_{net}\cos\theta = H}$$

$$\boxed{B_{net}\sin\theta = V}$$

$$B_{net} = \sqrt{H^2 + V^2}$$



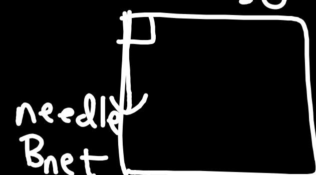
$$\tan\theta_{dip} = \frac{V}{H}$$



needle orientation

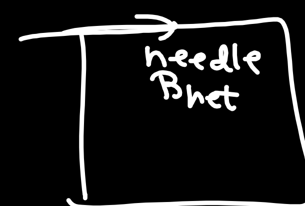
① at poles

② θ dip 90°

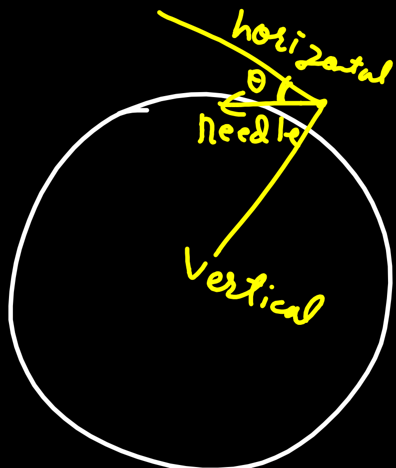


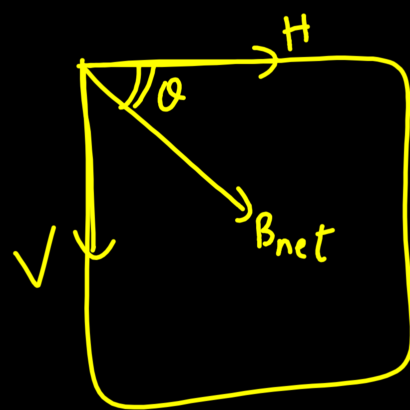
② at magnetic equator

② θ dip 0°.



at any general point





$$B_{net}\sin\theta = V$$
$$B_{net}\cos\theta = H$$

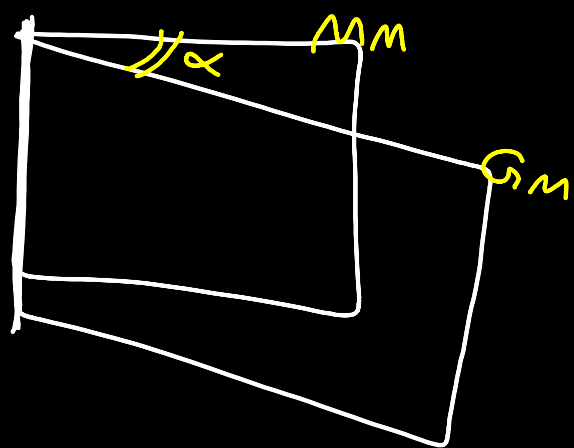
$$\tan\theta = \frac{V}{H}$$

$$\sqrt{V^2 + H^2} = B_{net}$$

Angel of Declination (α_{dec})

angel b/w G. meridian & magnetic meridian.

α_{dec}

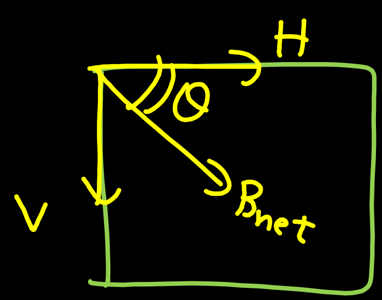


Vertical direction is Same of Both

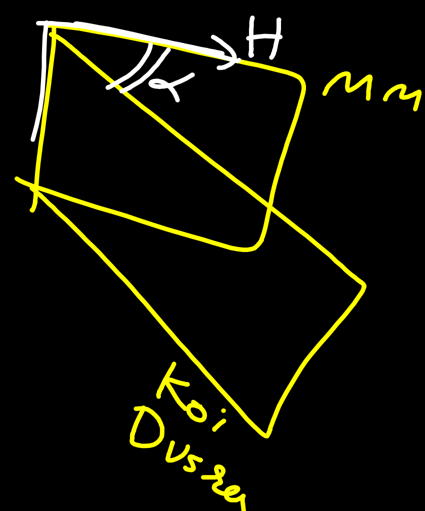
True Angel of Dip & App Angel of Dip

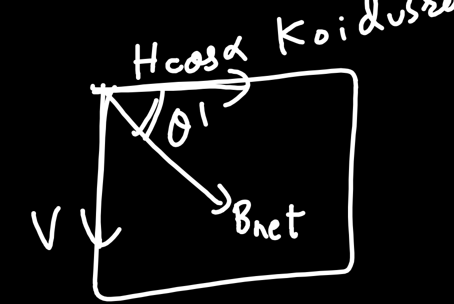
in M. meridian

Koi dusre plane



$$\tan\theta = \frac{V}{H}$$





$$\tan\theta' = \frac{V}{H\cos\alpha}$$

$$\tan\theta' = \frac{\tan\theta}{\cos\alpha}$$

$$\boxed{\tan\theta' = \frac{\tan\theta}{\cos\alpha}}$$

$\theta' \Rightarrow$ app dip

$\theta \Rightarrow$ true dip

$\alpha \Rightarrow$ angel b/w MM & koi Dusra plane.

Q// If a magnetic needle is fixed to move in a plane which makes 30° with M. meridian. Dip angle showed by dip circle in above case is 45. What is true dip angle??

$$\boxed{\theta = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)}$$ Ans.

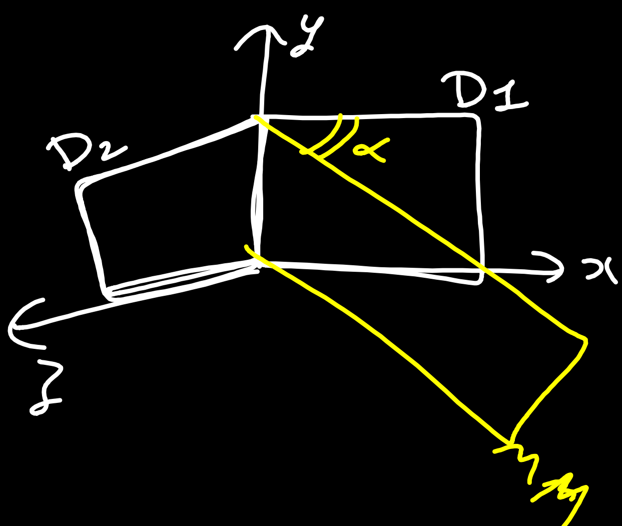
$$\tan\theta' = \frac{\tan\theta}{\cos\alpha}$$

$$\tan 45 = \frac{\tan\theta}{\cos 30}$$

$$1 \cdot \frac{\sqrt{3}}{2} = \tan\theta$$

Special Case

2 double plane ⊥'ar to each other



$$\tan\theta'_{D_1} = \frac{\tan\theta}{\cos\alpha}$$

$$\tan\theta'_{D_2} = \frac{\tan\theta}{\cos(90-\alpha)} = \frac{\tan\theta}{\sin\alpha}$$

$$\cos^2\alpha + \sin^2\alpha = 1$$

$$\frac{\tan^2\theta}{\tan^2\theta'_{D_1}} + \frac{\tan^2\theta}{\tan^2\theta'_{D_2}} = 1$$

$$\frac{1}{\tan^2\theta'_{D_1}} + \frac{1}{\tan^2\theta'_{D_2}} = \frac{1}{\tan^2\theta}$$

$$\boxed{\underbrace{\cot^2\theta'_{D_1}}_{\text{app in } D_1} + \underbrace{\cot^2\theta'_{D_2}}_{\text{app in } D_2} = \underbrace{\cot^2\theta}_{\text{true}}}$$

Vibration Magnetometer

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

horizontal component of earth's magnetic field.

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

needle fixed to rotate in

horizontal plane in presence of earth's magnetic field.

Comparison of earth Horizontal Component at two diff places

$$T_1 = 2\pi\sqrt{\frac{I}{MH_1}}$$

$$T_2 = 2\pi\sqrt{\frac{I}{MH_2}}$$

$$\frac{T_1}{T_2} = \sqrt{\frac{H_2}{H_1}}$$

Two different needles Compare their M

$$T_1 = 2\pi\sqrt{\frac{I_1}{M_1 H}}$$

$$T_2 = 2\pi\sqrt{\frac{I_2}{M_2 H}}$$

$$\frac{T_1}{T_2} = \sqrt{\frac{I_1 M_2}{M_1 I_2}}$$

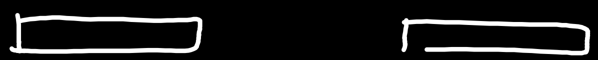
if I same of both (same size & same mass)

$$\frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}}$$

Calculate M if H is Known

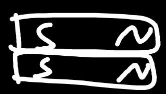
$$T = 2\pi\sqrt{\frac{I}{MH}}$$

Comparison of two M by sum & diff method



$$I_{net} = I_1 + I_2$$

#



M_1

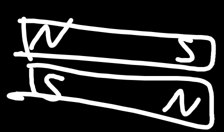
M_2

$$M_{net} = M_1 + M_2$$

$$T_1 = 2\pi\sqrt{\frac{I_{net}}{(M_1+M_2)H}}$$

$$\frac{T_1}{T_2} = \sqrt{\frac{M_1 - M_2}{M_1 + M_2}}$$

#



$$M_{net} = M_1 - M_2$$

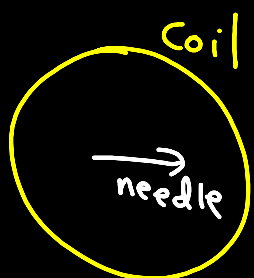
$$T_2 = 2\pi\sqrt{\frac{I_{net}}{(M_1-M_2)H}}$$

Tangent Galvanometer

[I → detect]

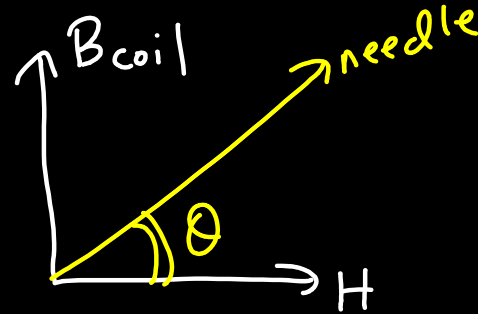
needle free to move in horizontal plane

initially → needle
→ H



If I passes in coil, B generates on needle

Now



$$\tan\theta = \frac{B_{coil}}{H}$$

at a place

$H, 2, r, N, \mu_0$ fixed

$$B_{coil} = H \tan\theta$$

$$N\left(\frac{\mu_0 I}{2r}\right) = H \tan\theta.$$

$$I = K \tan\theta$$

$$K = \frac{2rH}{\mu_0 N}$$

$\theta \rightarrow$ we can measure I

more θ more I

Q when 2A I passes deflection is 30°.
Find I which passes when deflection is 45°?

$I = k \tan 30°$

$2 = k \tan 30$

$I' = k \tan 45$

$$\frac{2}{I'} = \frac{\tan 30}{\tan 45} = \frac{1/\sqrt{3}}{1} = \frac{1}{\sqrt{3}}$$

$2\sqrt{3}\,A = I'$

Unacademy Atoms