PRAYAS

JEE 2025

Lecture - 07 | Physics

Magnetism

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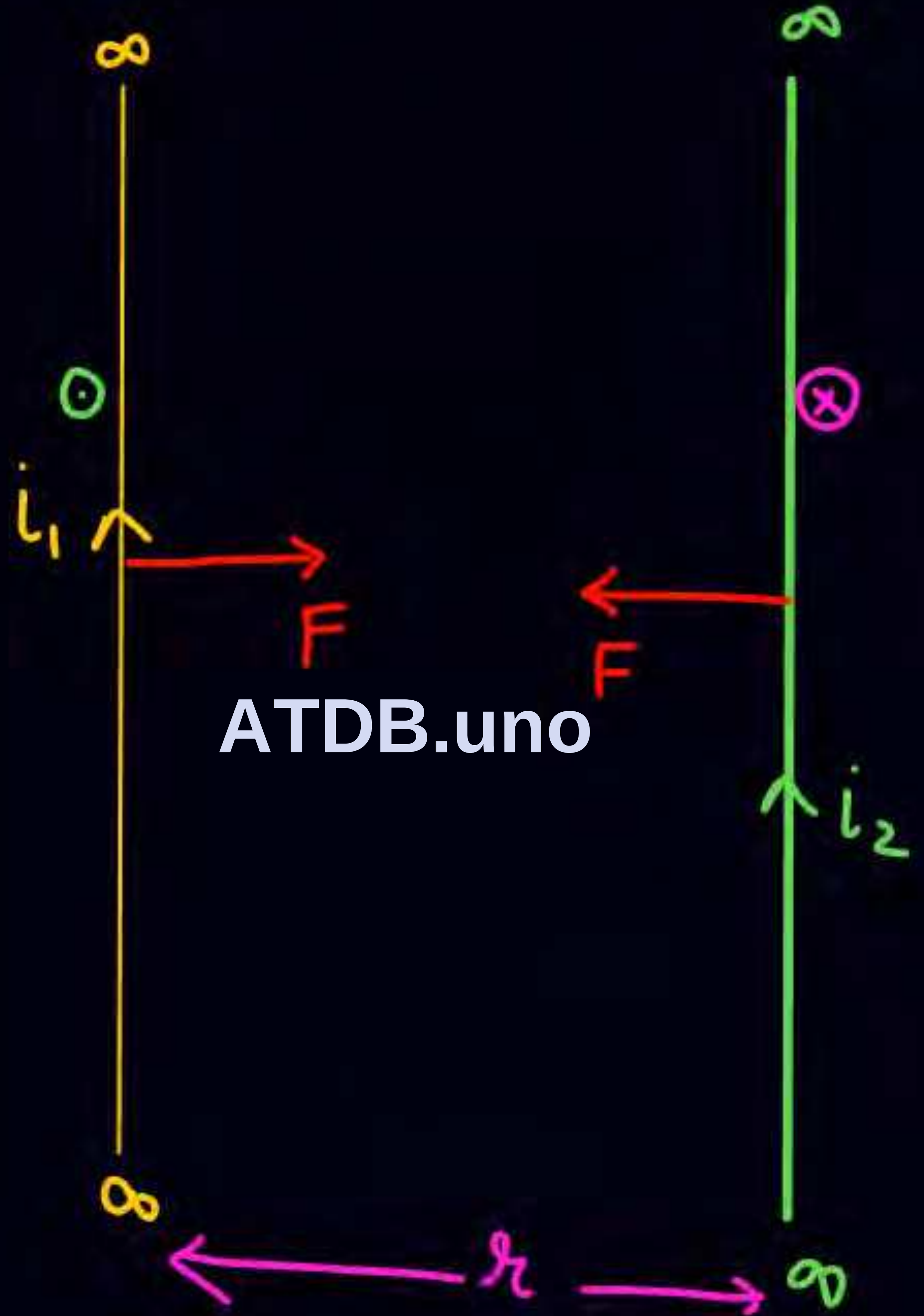
Topics *to be covered*

1. Force on current carrying wire inside $\vec{B}$
2. magnetic moment
3. Torque on current carrying loop in magnetic field.
4.

Force between Two parallel wire

Force per Unit length

$$= \frac{2k i_1 i_2}{r}$$

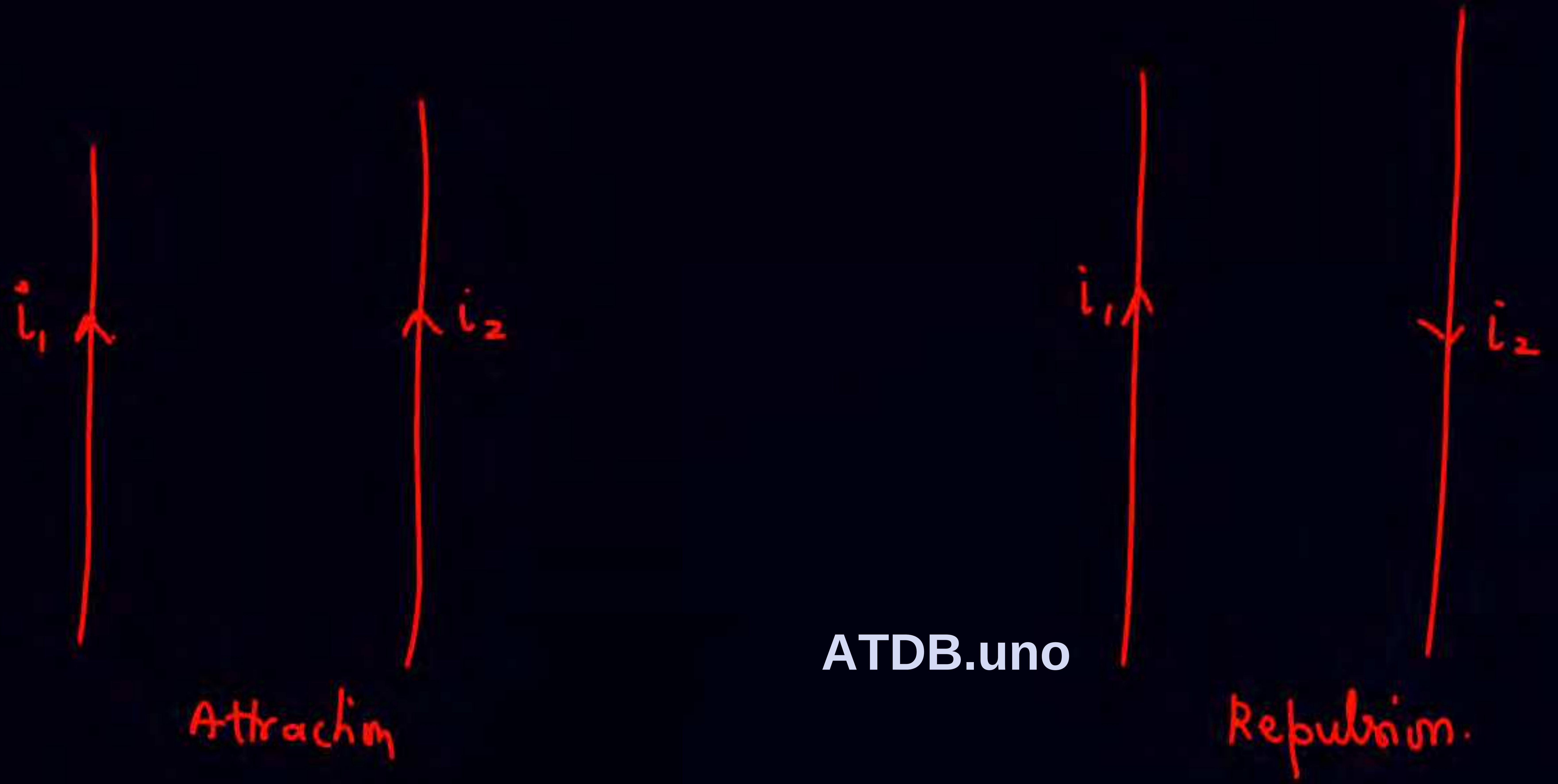


i के wire को Consider

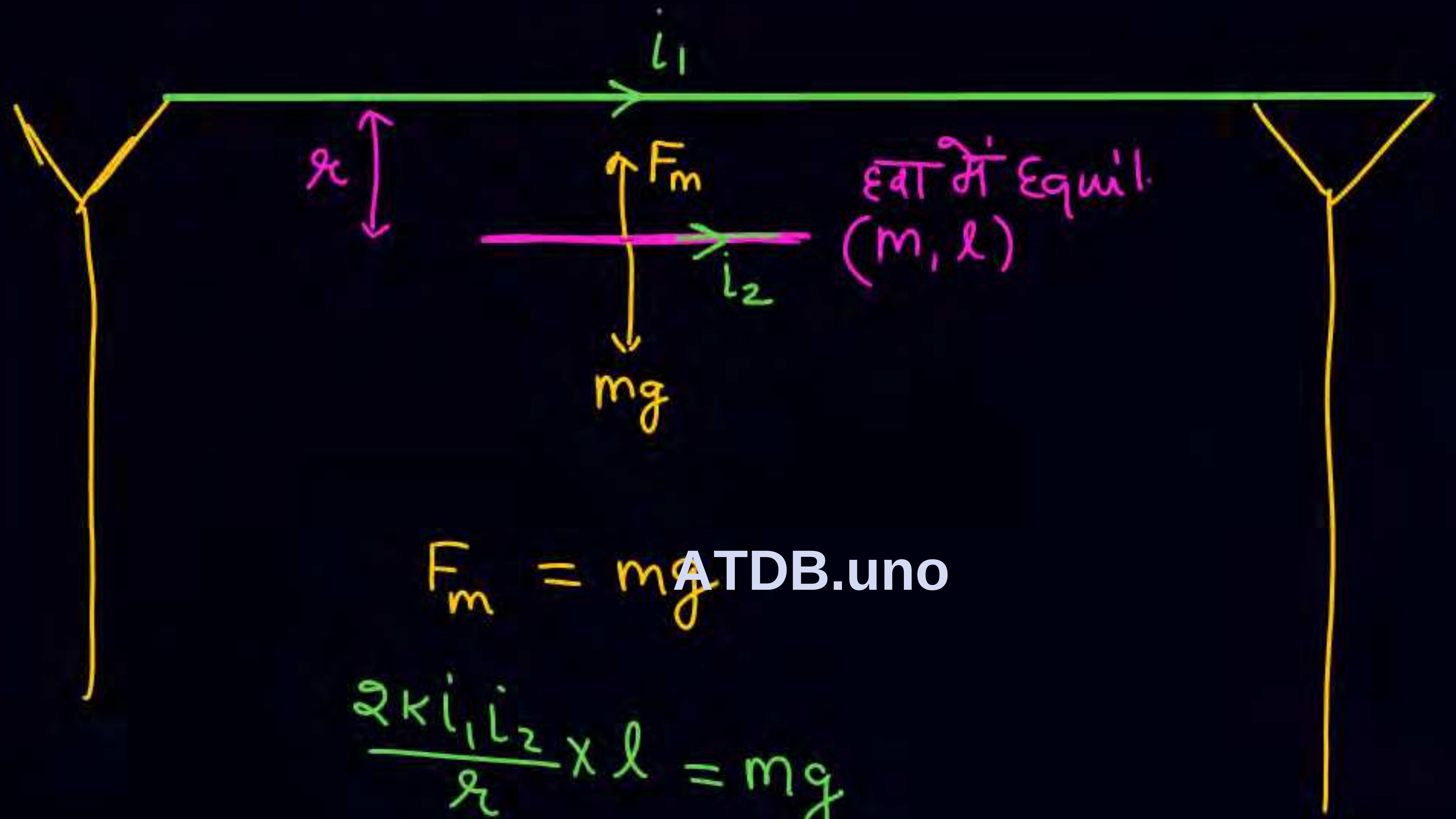
$$F = i_2 l B$$

$$F = i_2 \cdot l \cdot \frac{2k i_1}{r}$$

$$\frac{F}{l} = \frac{2k i_1 i_2}{r}$$


i1
i2
Attraction
i1
i2
Repulsion.

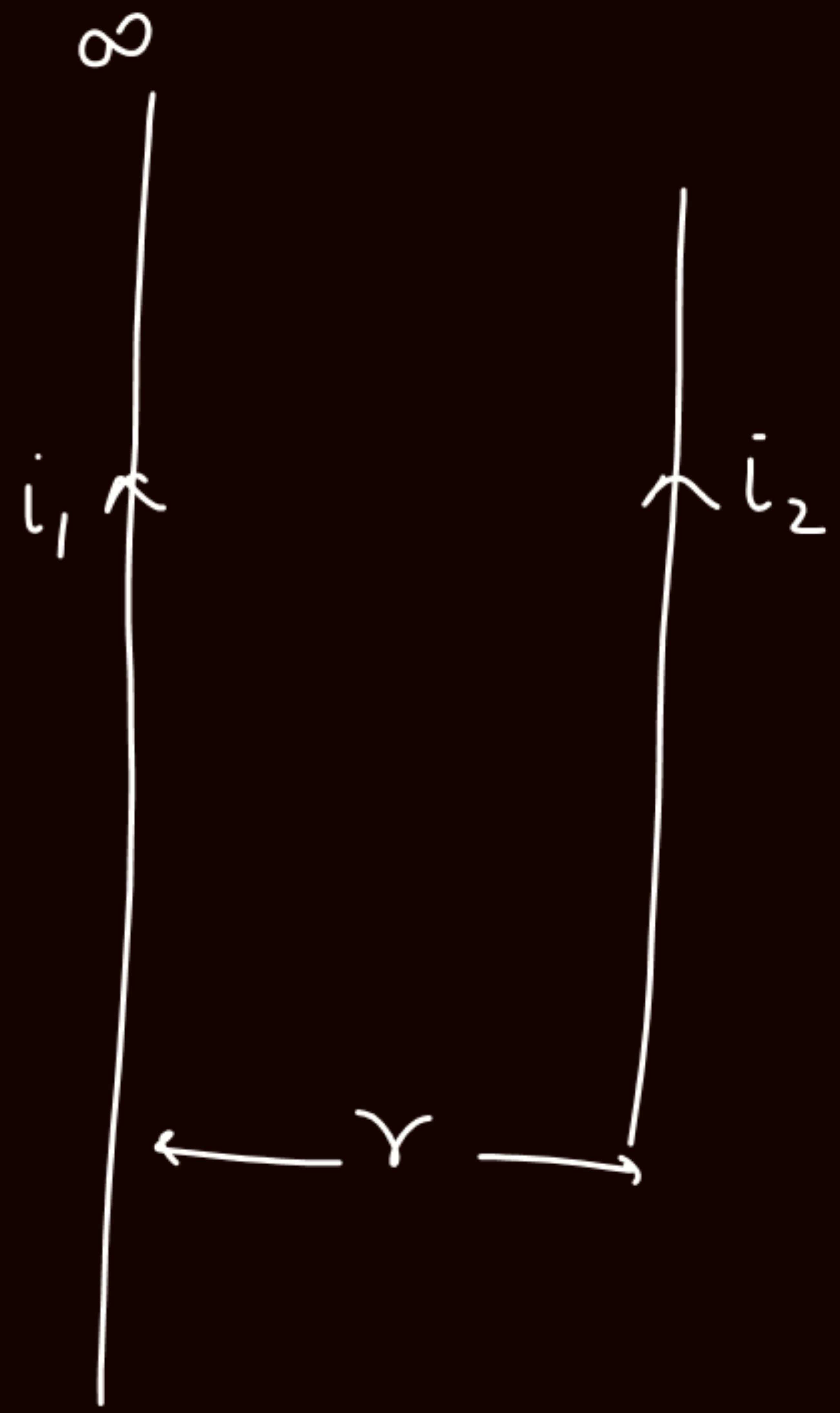
Q



$$F_m = mg$$

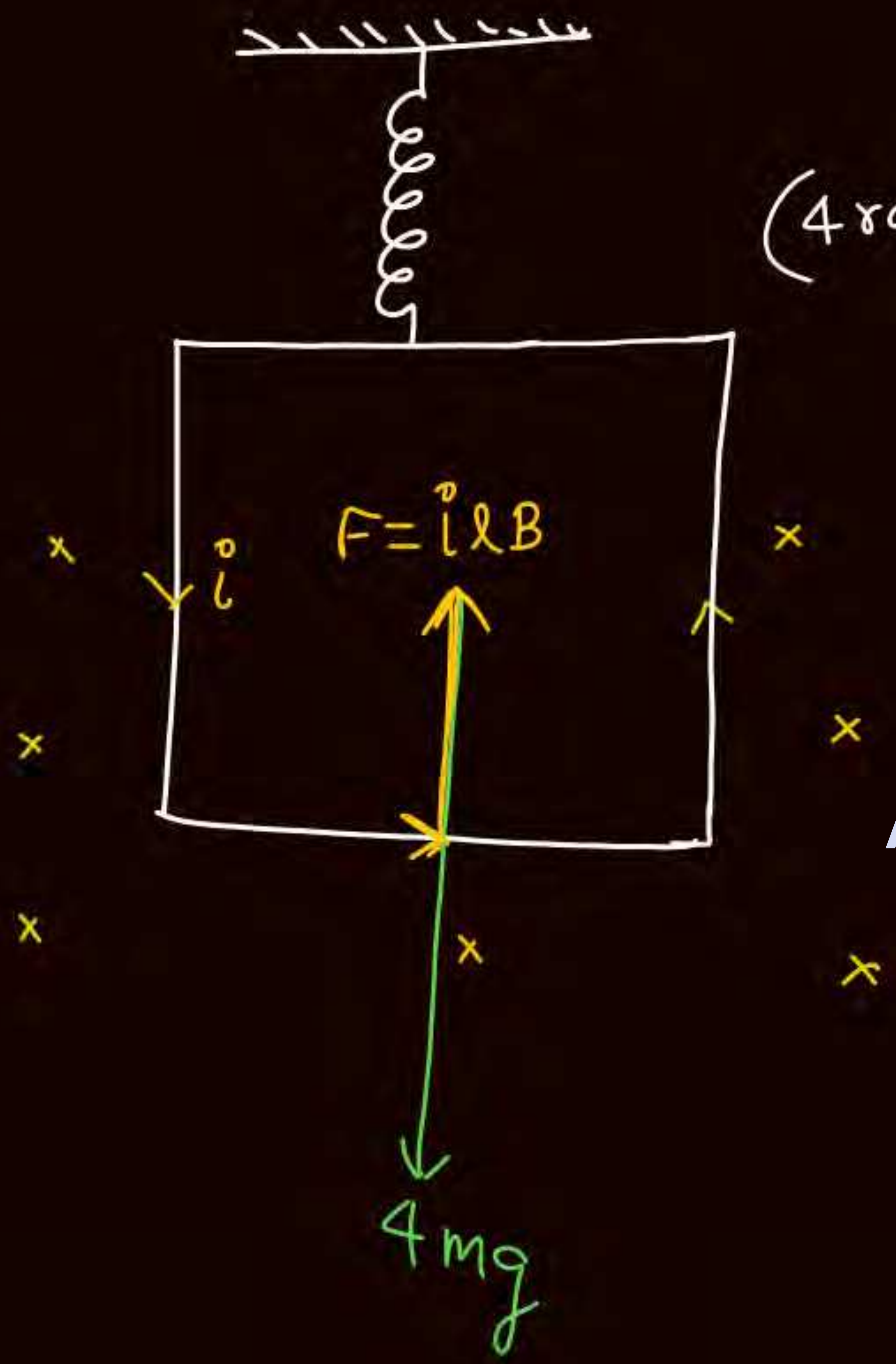
$$\frac{2 k i_1 i_2}{r} \times l = mg$$

Q



10m ì 4π $F = \frac{2k i_1 i_2}{r} \times 10$

Q



(4 rod each m, l)

① Reading of spring

$$4mg - ilB = Kx_i$$

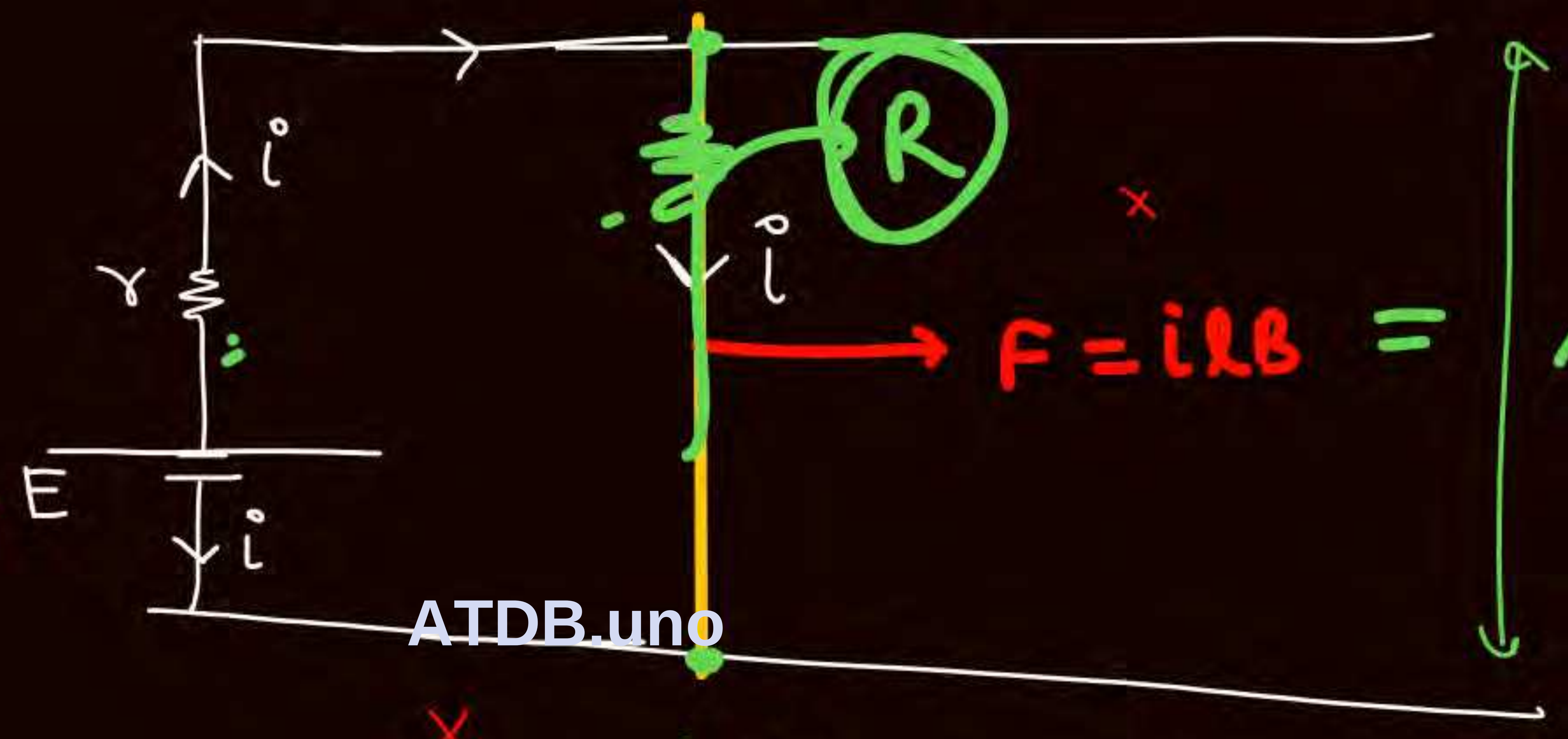
② If dirⁿ of current is reversed

$$4mg + ilB = Kx_f$$

Q रेलवाला Qun

$F = i l B$

$i = \dfrac{E}{r+R}$



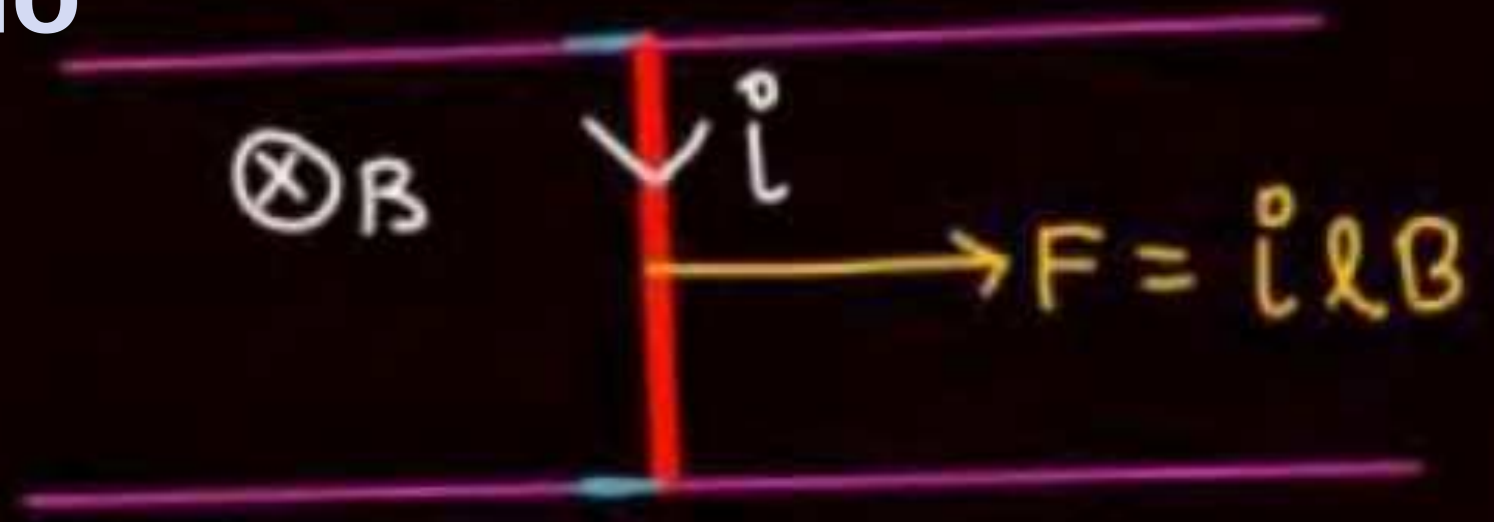
$F = i l B = \mu m g$

$\dfrac{i l B}{m}$

Q Two metal rails placed horizontally and parallel to each other at a separation l. A rod of mass m can slide on rail. Current in the circuit is i.

① find μ_{min} so that it can prevent wire from sliding.

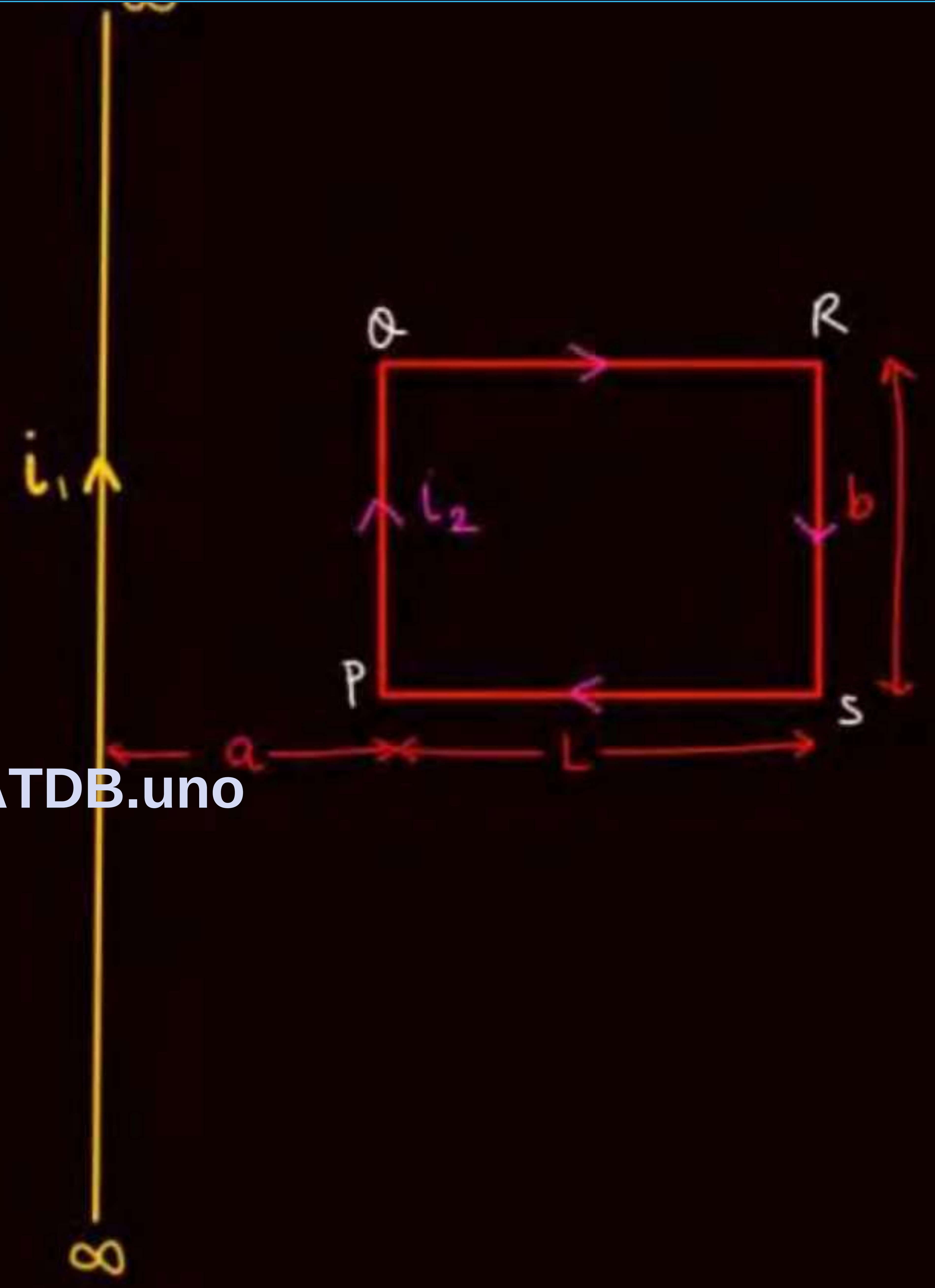
$$ilB = \mu mg \Rightarrow \mu = \frac{ilB}{mg} = \mu_{min}$$



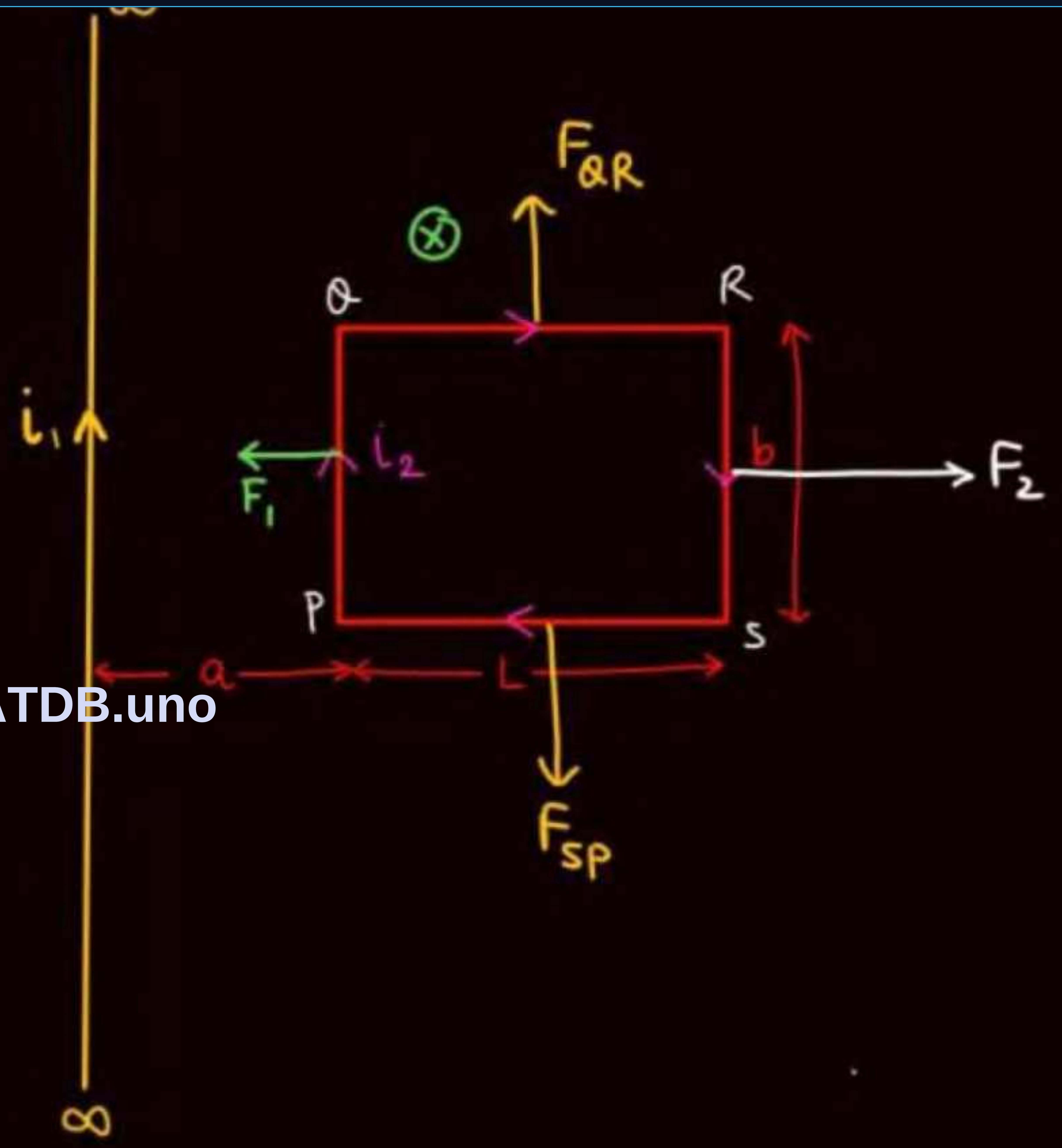
② If $\mu = \frac{\mu_{min}}{2}$, find a_{cc} of wire.

$$a = \frac{ilB - f}{m} = \frac{ilB - \mu N}{m} = \frac{ilB - \frac{ilB}{2mg} mg}{m} = \frac{ilB}{2m}$$

Q Find force applied by ∞ wire on loop PQRS.



Q Find force applied by ∞ wire on loop PQRS.



Force on PQ due to ∞ wire

$$= \frac{2ki_1i_2}{a} b = F_1 \text{ (left)}$$

Force on RS due to ∞ wire

$$= \left(\frac{2ki_1i_2}{a+L}\right) b \text{ (Right)}$$

$$\vec{F}_{net} = \vec{F}_{PQ} + \vec{F}_{RS} + (\vec{F}_{QR} + \vec{F}_{SP})$$

$$\vec{F}_{net} = \frac{2ki_1i_2}{a} b - \frac{2ki_1i_2}{(a+b)} b$$

(Attraction)

Q

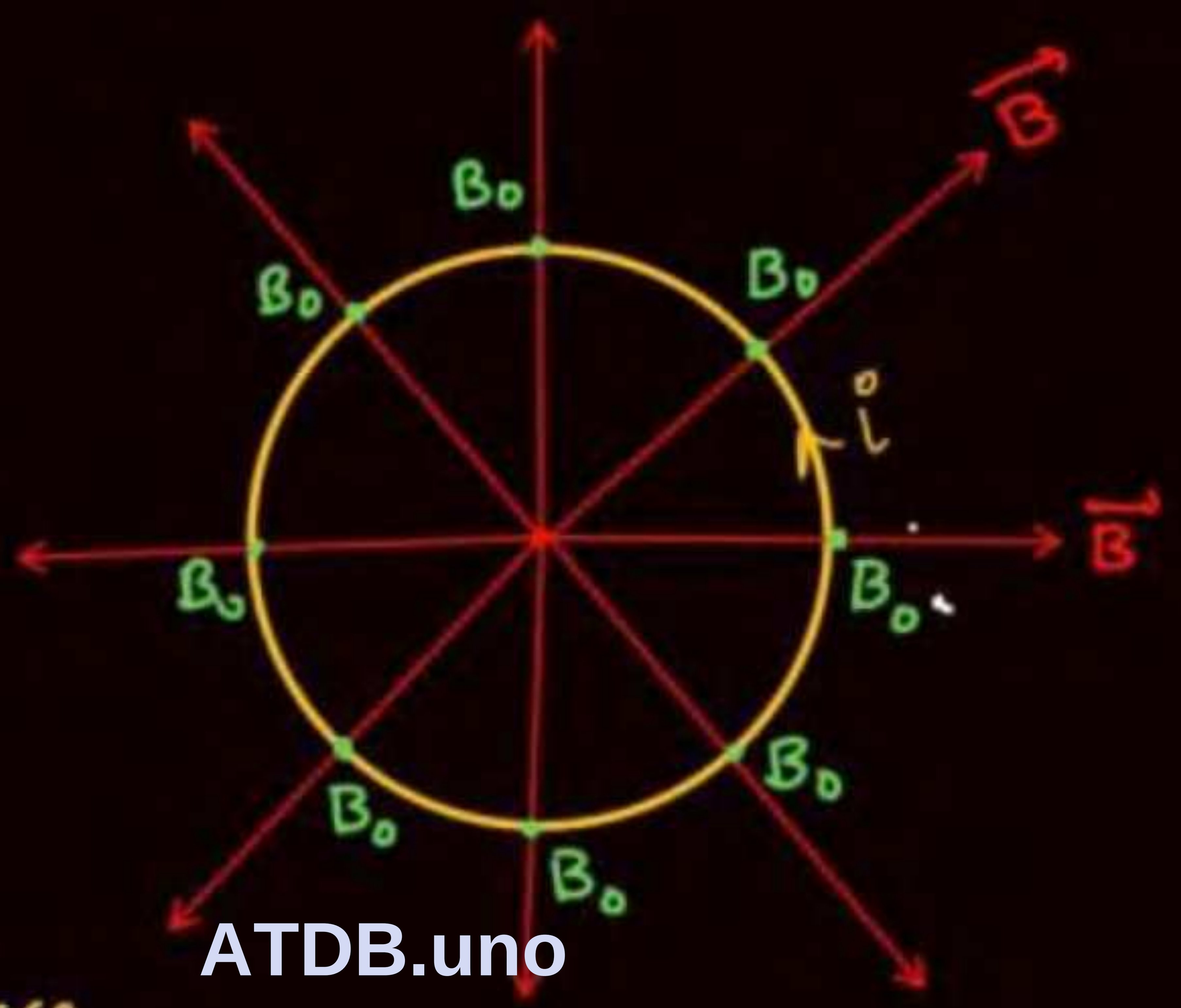
$$(F_2)_{\text{due to } 1} = i \ell B_{\text{due to '1'}}$$

$$F = i_2 \cdot b \cdot \frac{2ki_1}{a}$$

$$F = \frac{2k i_1 i_2}{a} b$$

Q

A current carrying circular loop is placed on x-y plane in a two dimentional magnetic field as shown in figure. strength of M.F. on pheripheri of loop is B_0. Find magnetic force on wire.



Ans $F_{net} = i \cdot B \cdot 2\pi R$

Sol^n

force on small element dl

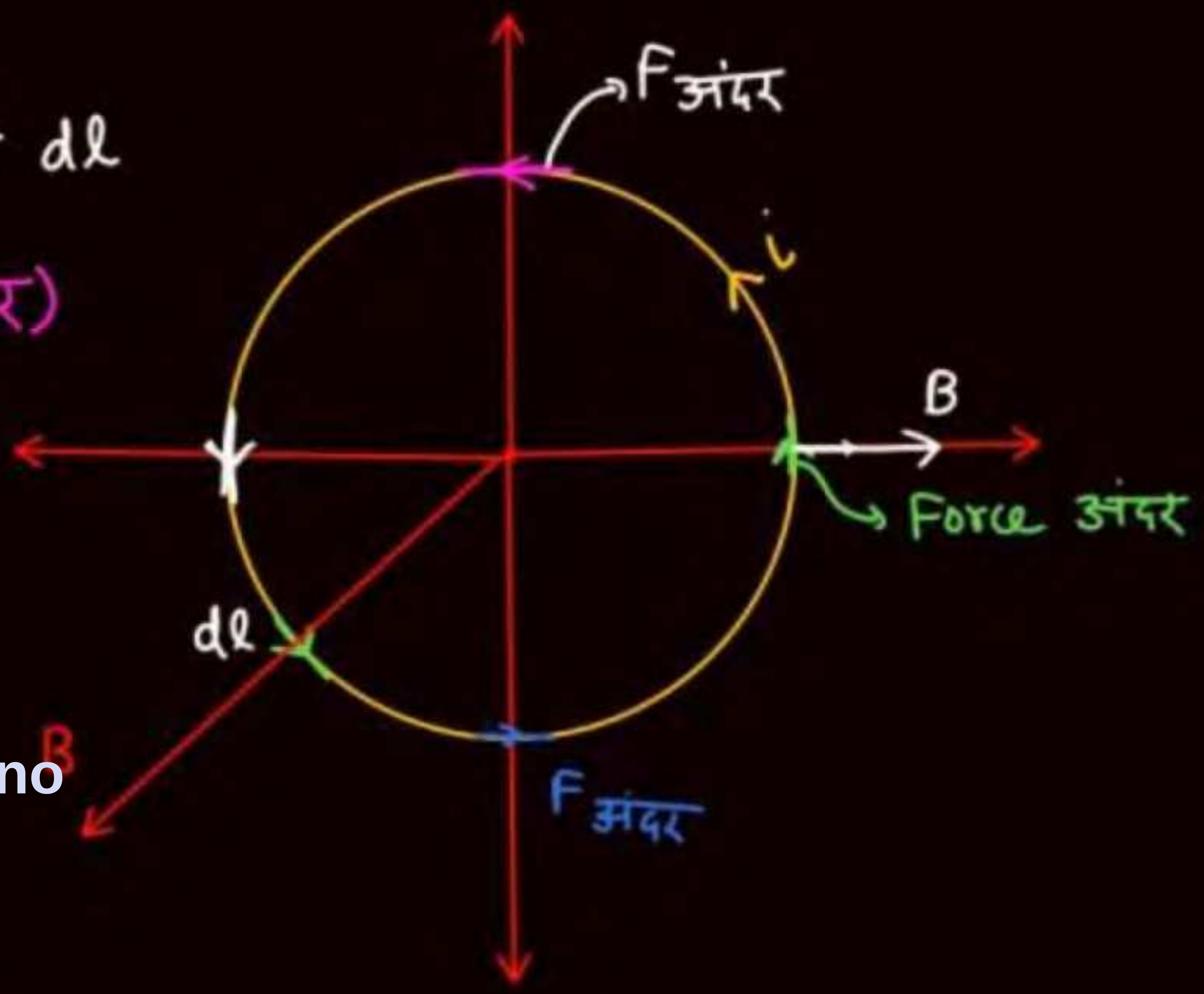
$$dF = i \cdot dl \cdot B \ (\text{अंदर})$$

$$F_{net} = \int dF$$

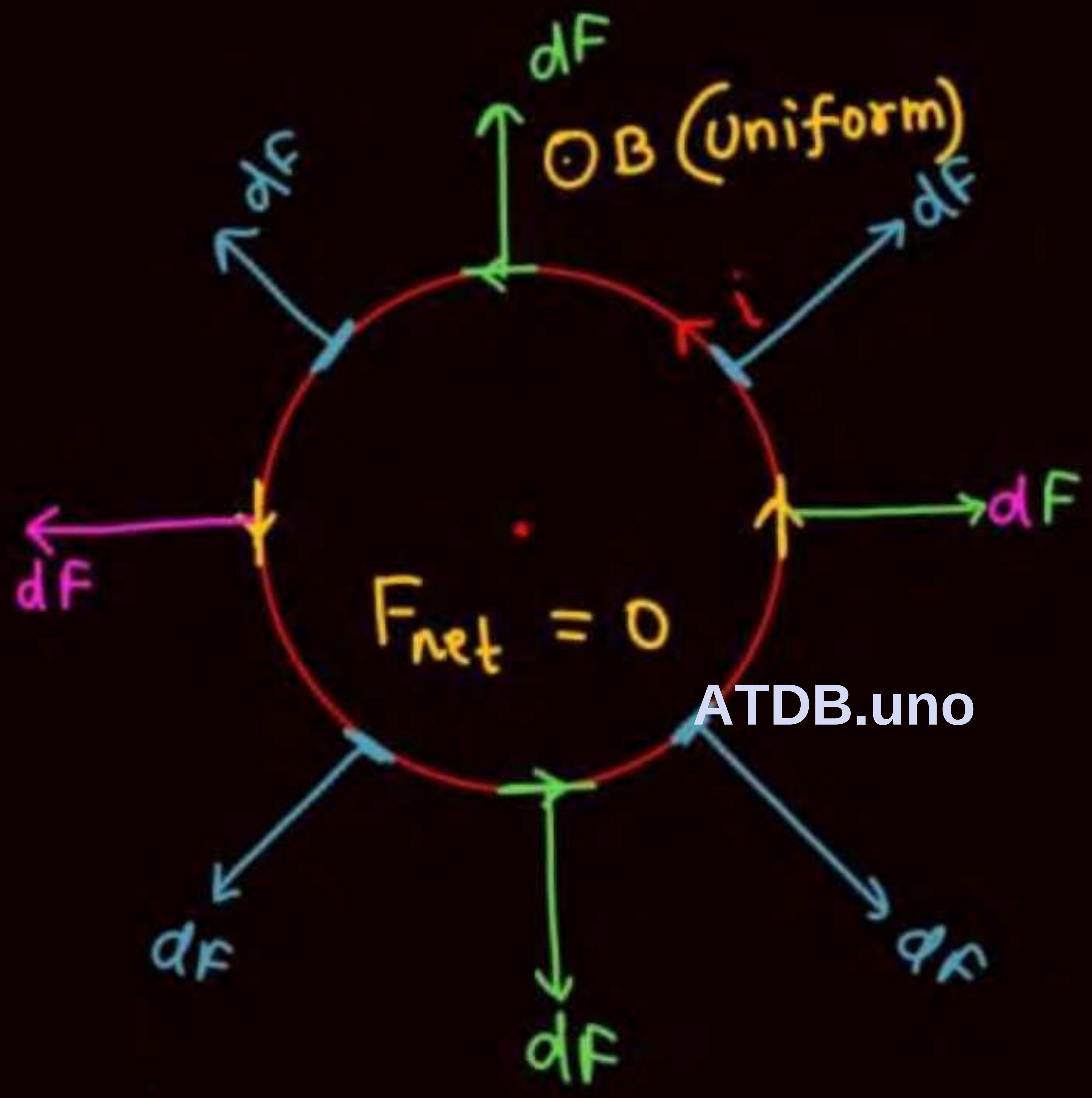
$$= \int i \cdot dl \cdot B$$

$$= i \cdot B \int dl$$

$$\boxed{F_{net} = i \cdot B \cdot 2\pi R}$$



Q

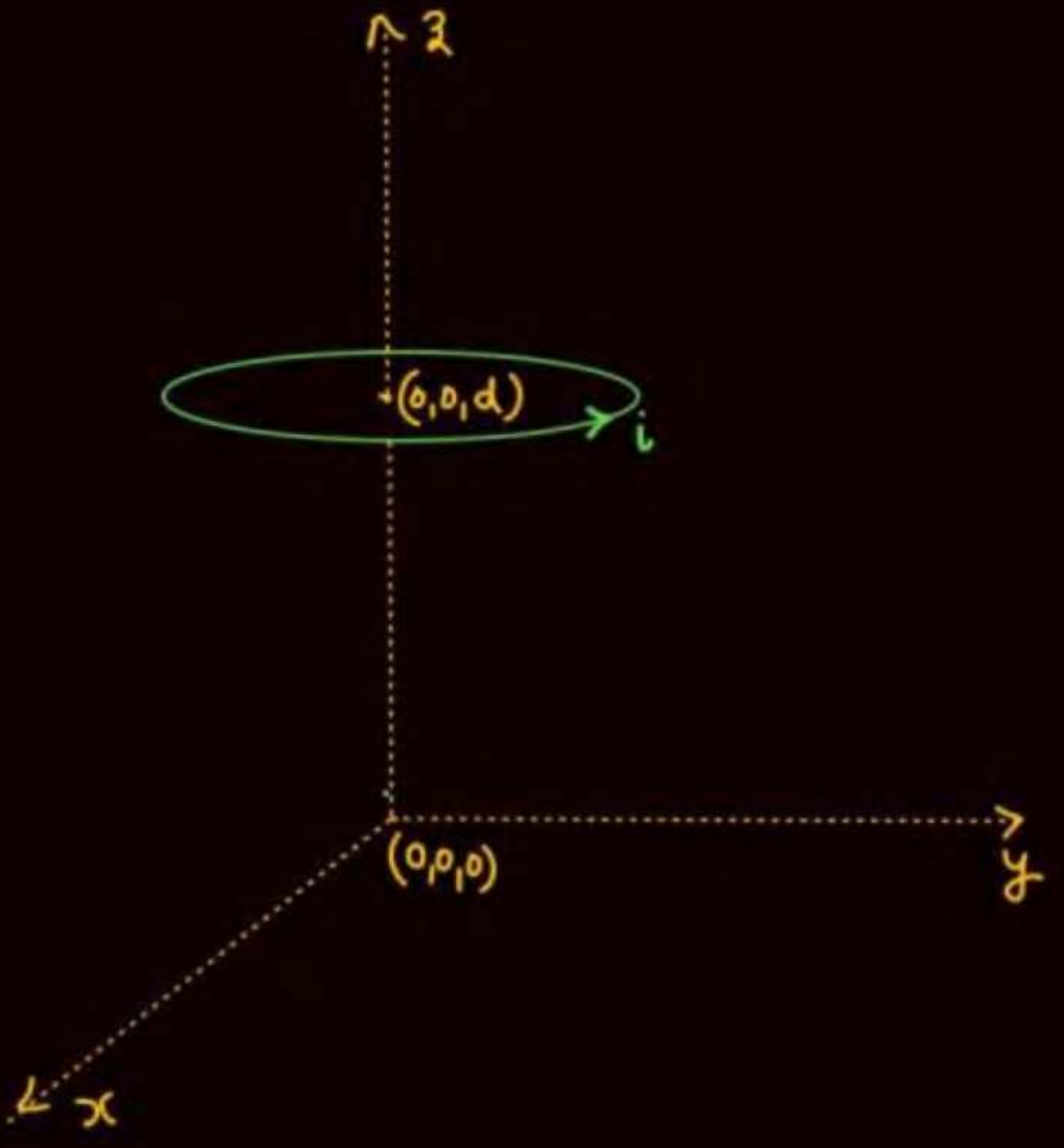


$F_{net} = 0$

Q $\vec{B} = B_0 \vec{e_r}$ where $\vec{e_r}$ is unit vector along the radial direction.

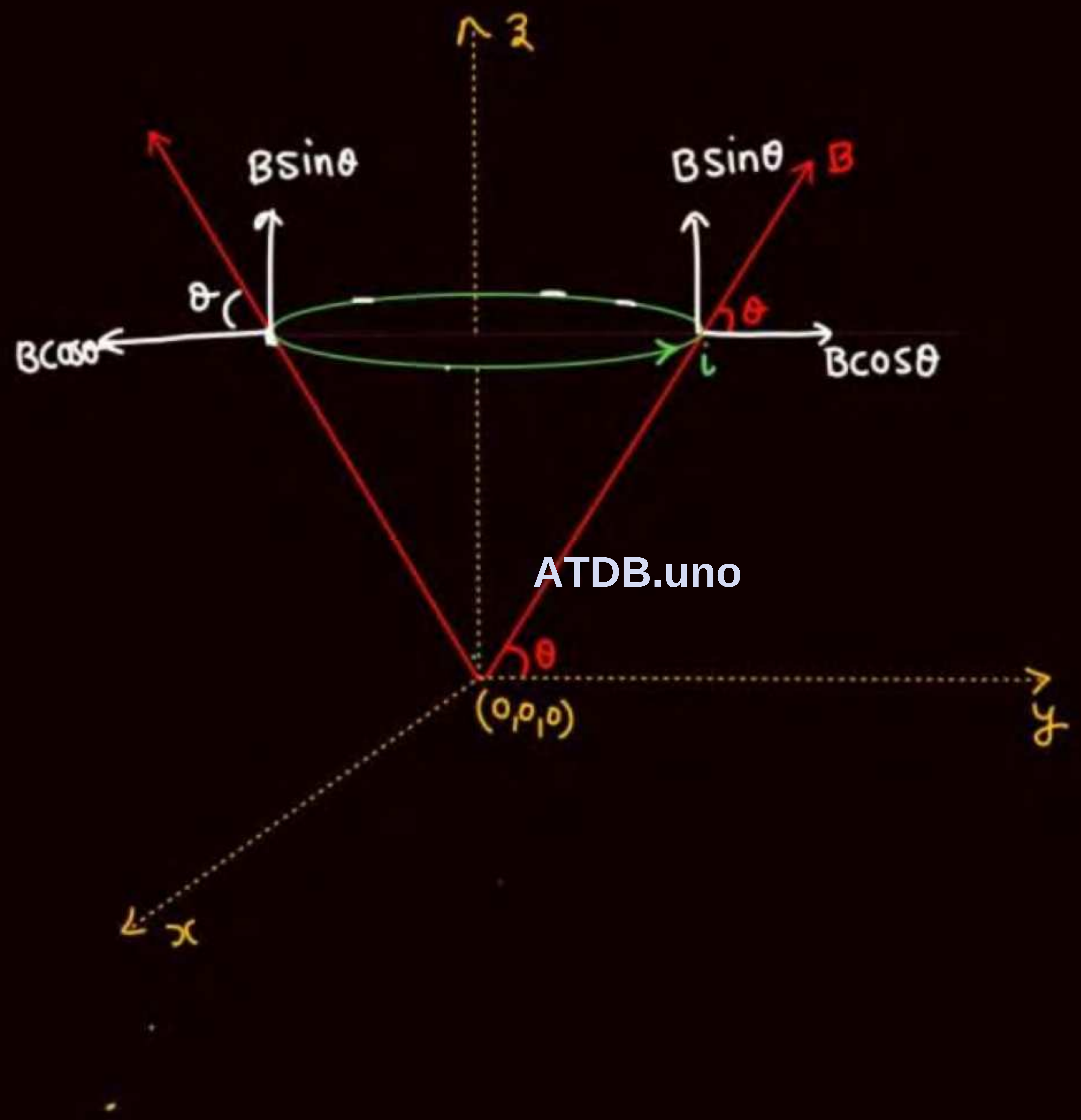
$\vec{B} = B_0 \hat{r}$

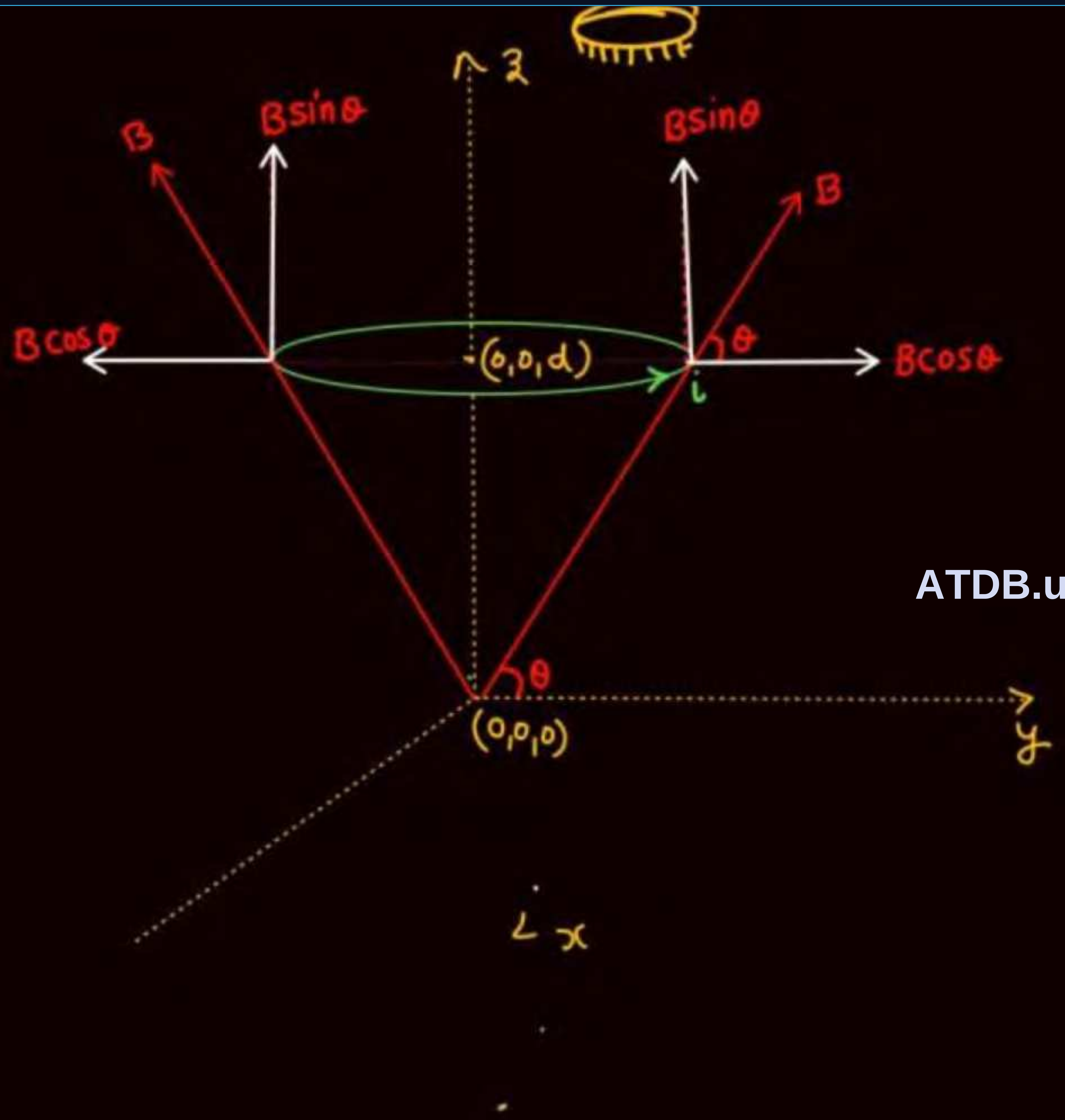
A circular loop of radius R is carrying current i is placed parallel to x-y plane and center at (0,0,d). Find magnitude of magnetic force on loop.

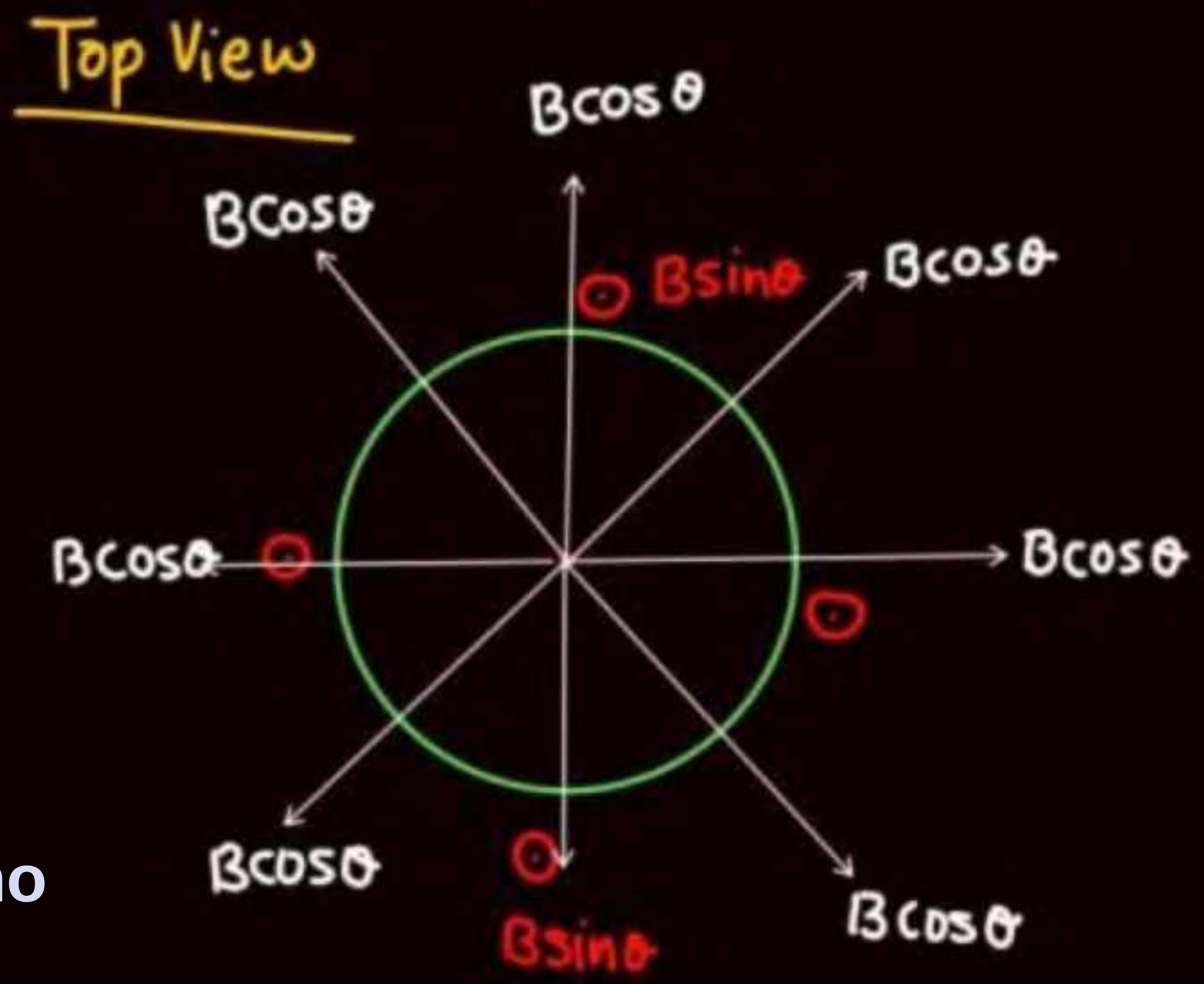


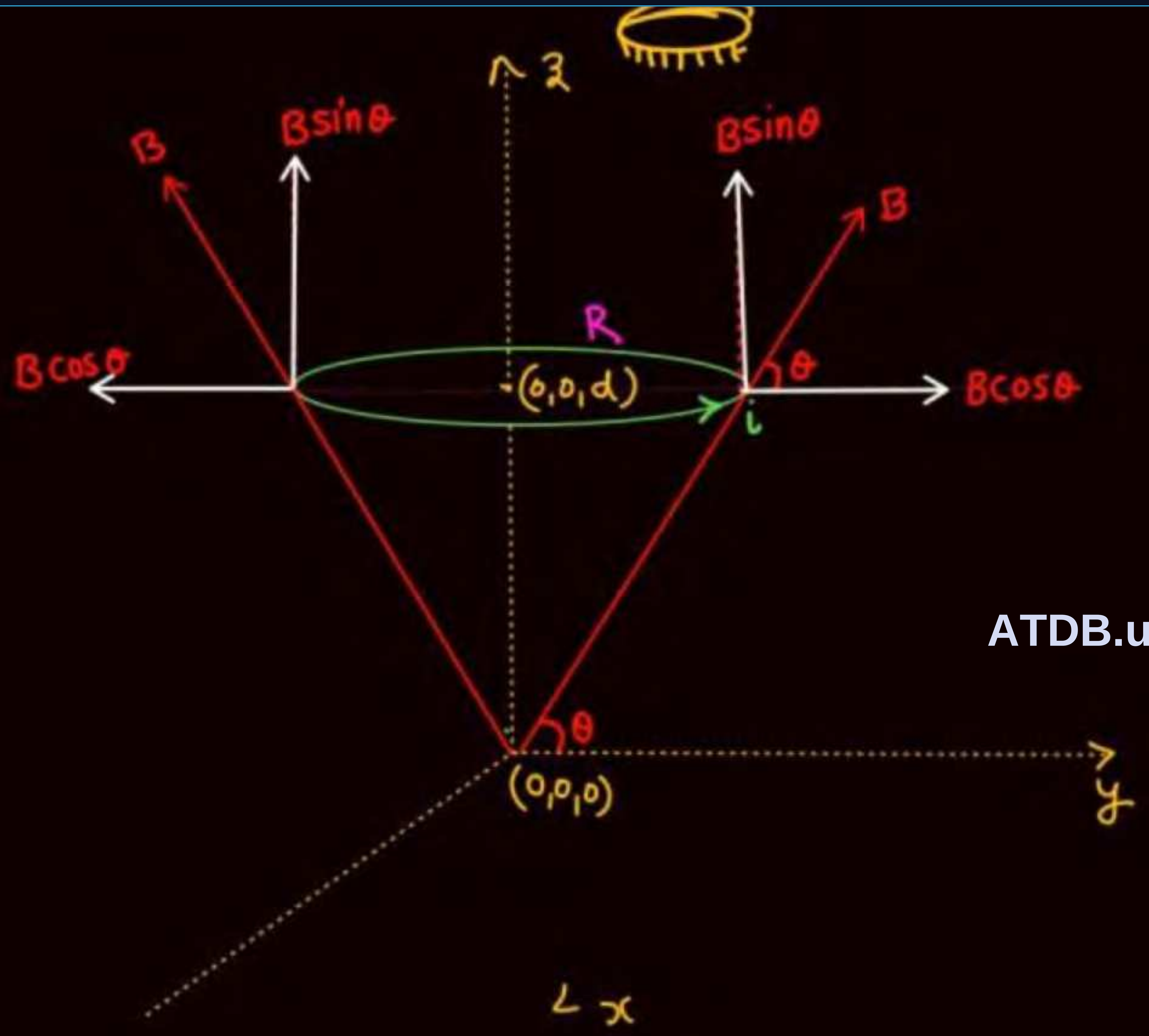
②

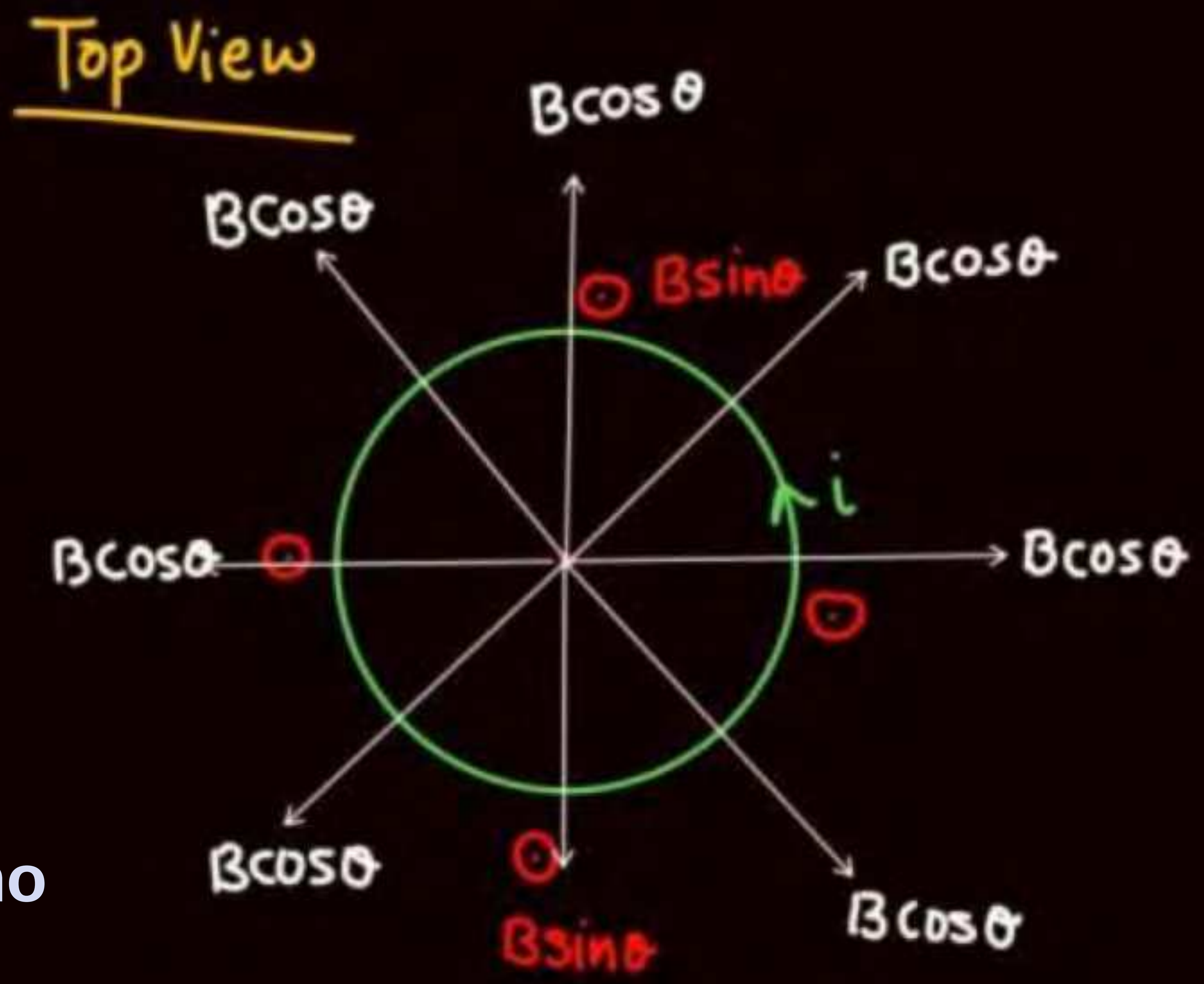

z
(0,0,d)
i
(0,0,0)
y
x


z
Bsinθ
Bsinθ
B
θ
θ
BCosθ
i
Bcosθ
θ
(0,0,0)
y
x


z
B
Bsinθ
Bsinθ
B
Bcosθ
(0,0,d)
θ
Bcosθ
i
θ
(0,0,0)
y
x


Top View
Bcosθ
Bcosθ
Bsinθ
Bcosθ
Bcosθ
Bcosθ
Bcosθ
Bcosθ
Bsinθ
Bcosθ





Force due to $B\sin\theta = 0$ (उटपटांग wire)

Force due to $B\cos\theta = i \cdot 2\pi R \cdot B\cos\theta$

$$F_{net} = i \cdot 2\pi R B\cos\theta = i \cdot 2\pi R \frac{B R}{\sqrt{R^2 + d^2}}$$

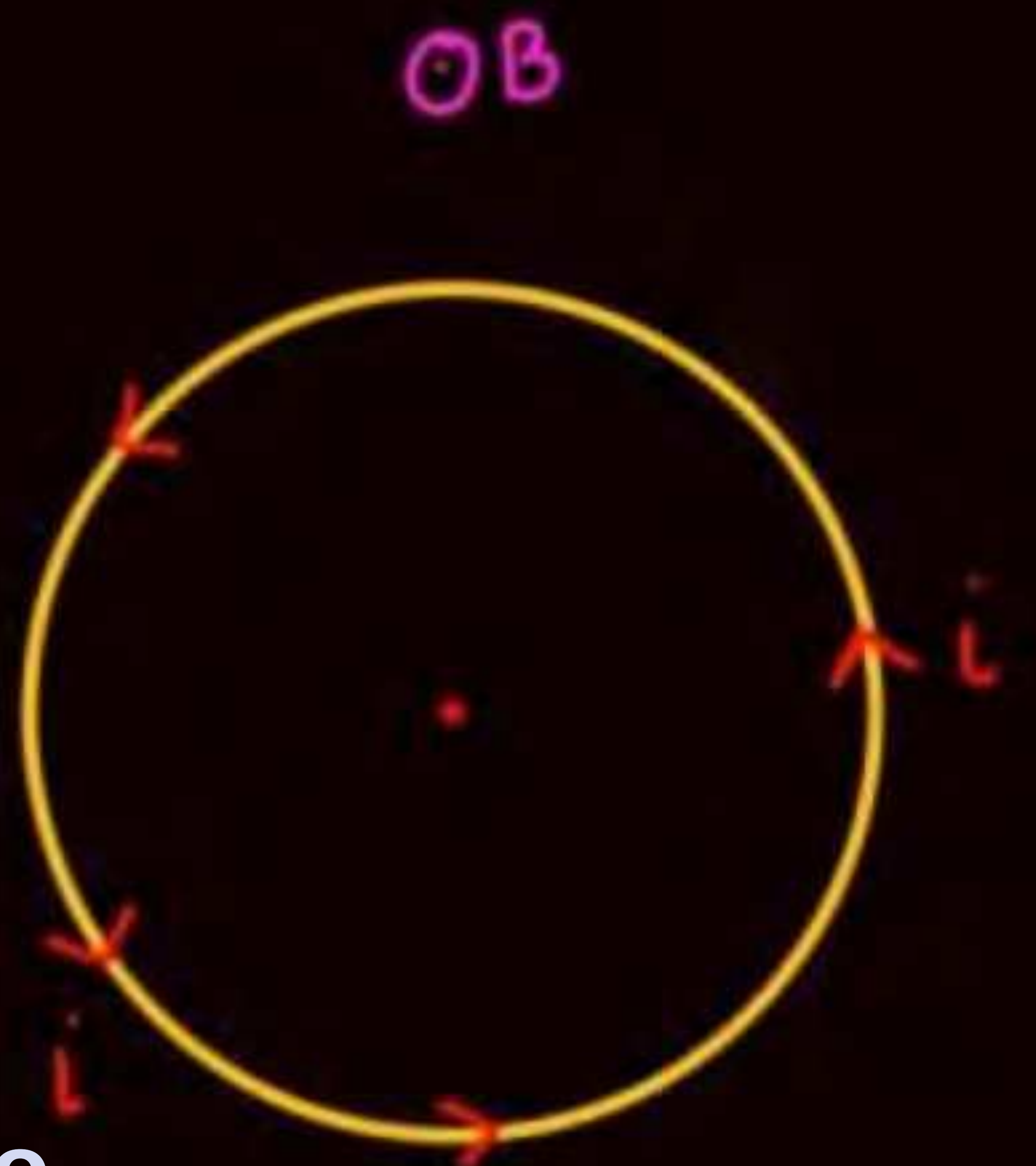
Q

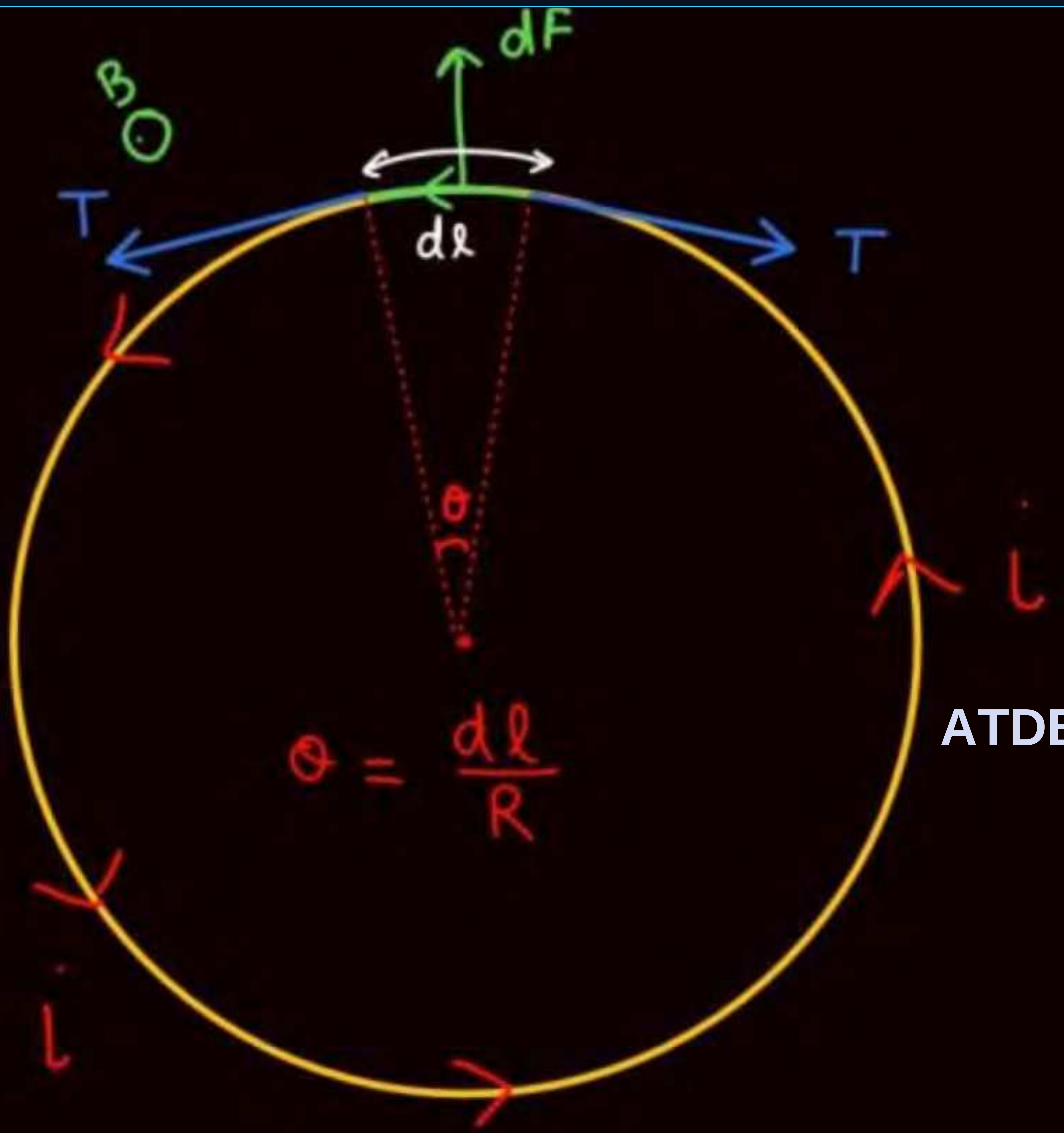
① Find net force on circular loop = 0

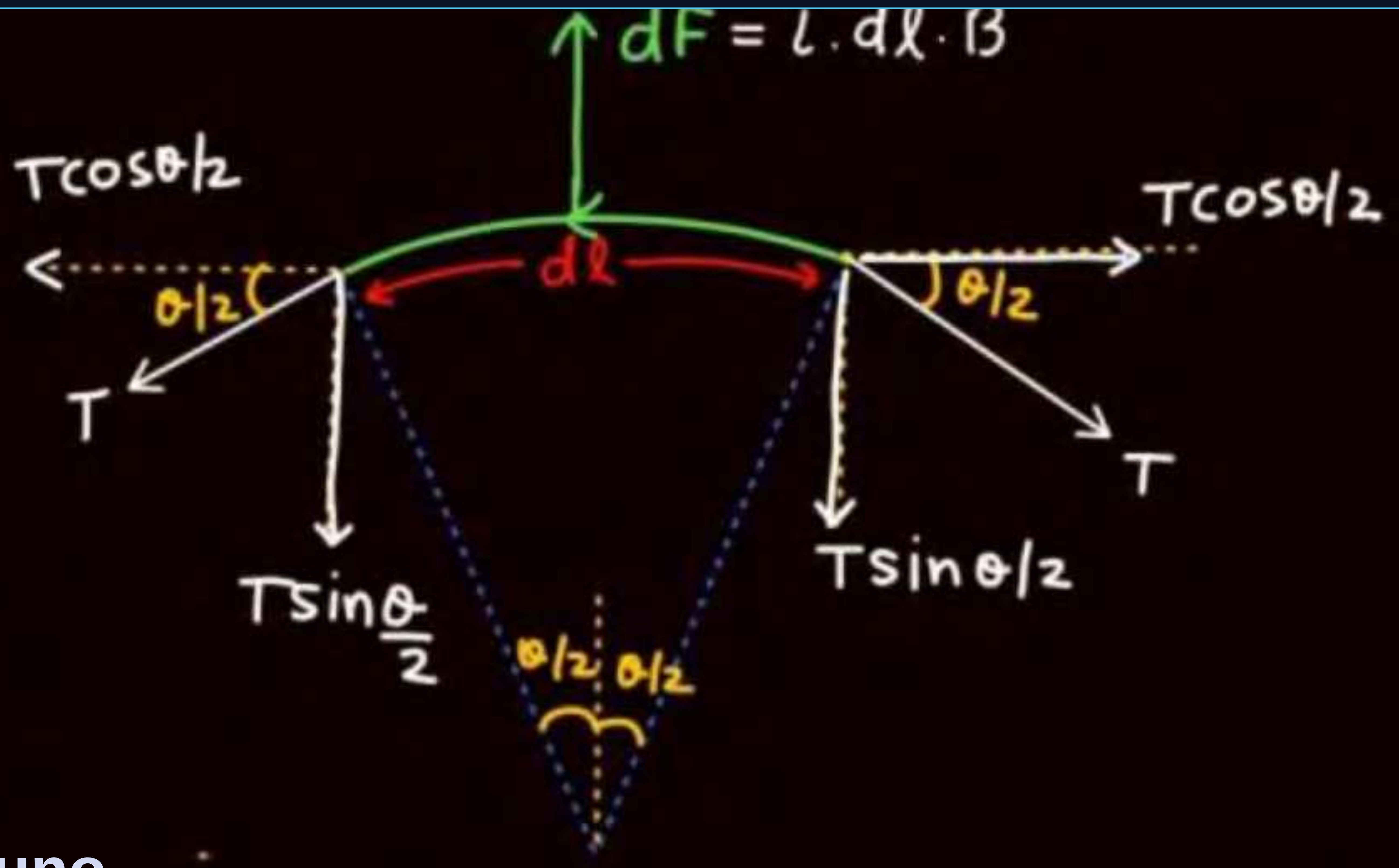
② Find tension develope in wire.

$T = iRB$ (Ans)

③ $\frac{T}{A} = Y \frac{\Delta R}{R}$







$$dF = 2T\sin\frac{\theta}{2}$$

$$\sin\frac{\theta}{2} \approx \frac{\theta}{2}$$

$$dF = 2T\frac{\theta}{2}$$

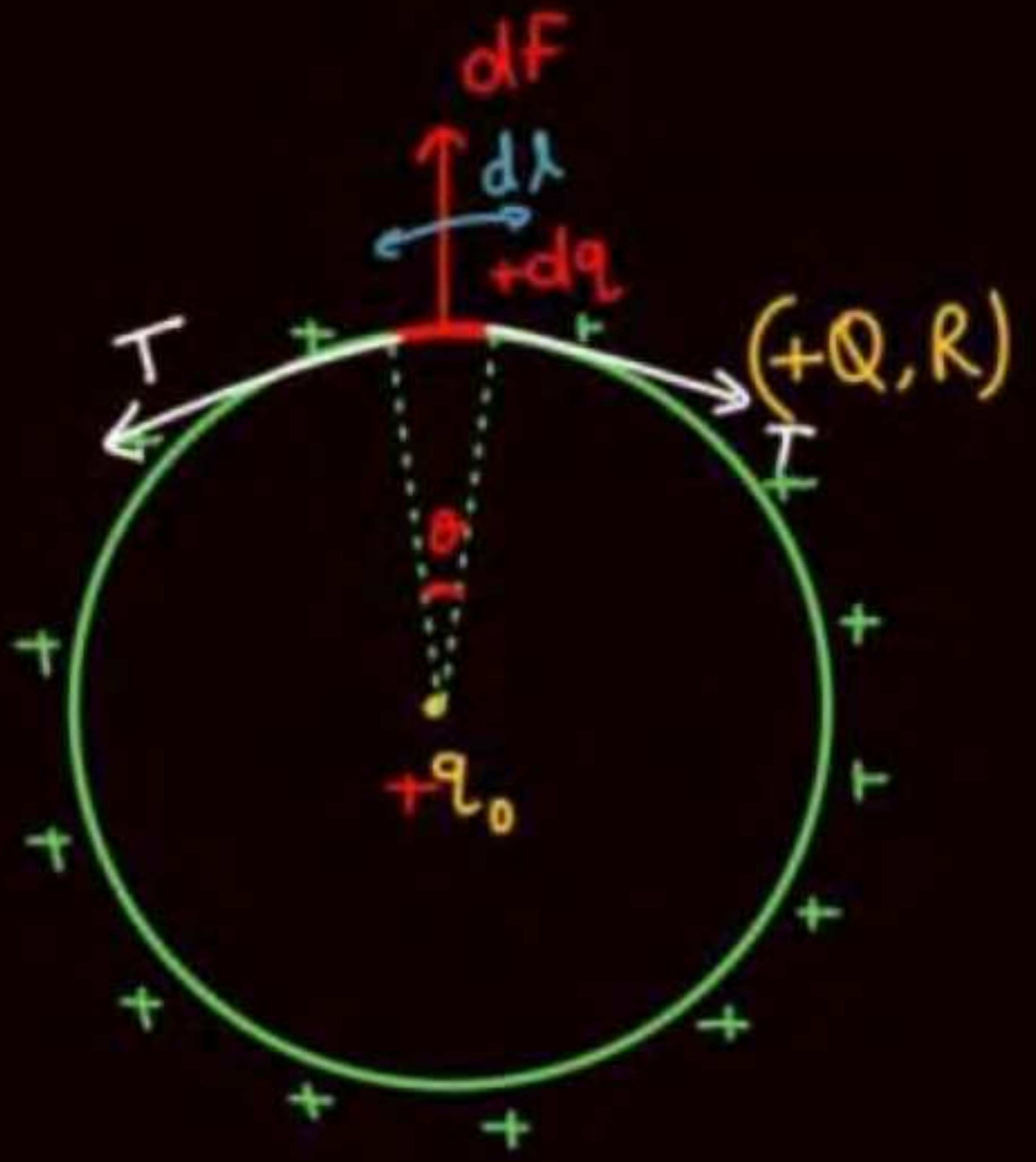
$$i \cdot dl \cdot B = T\theta = T\frac{dl}{R}$$

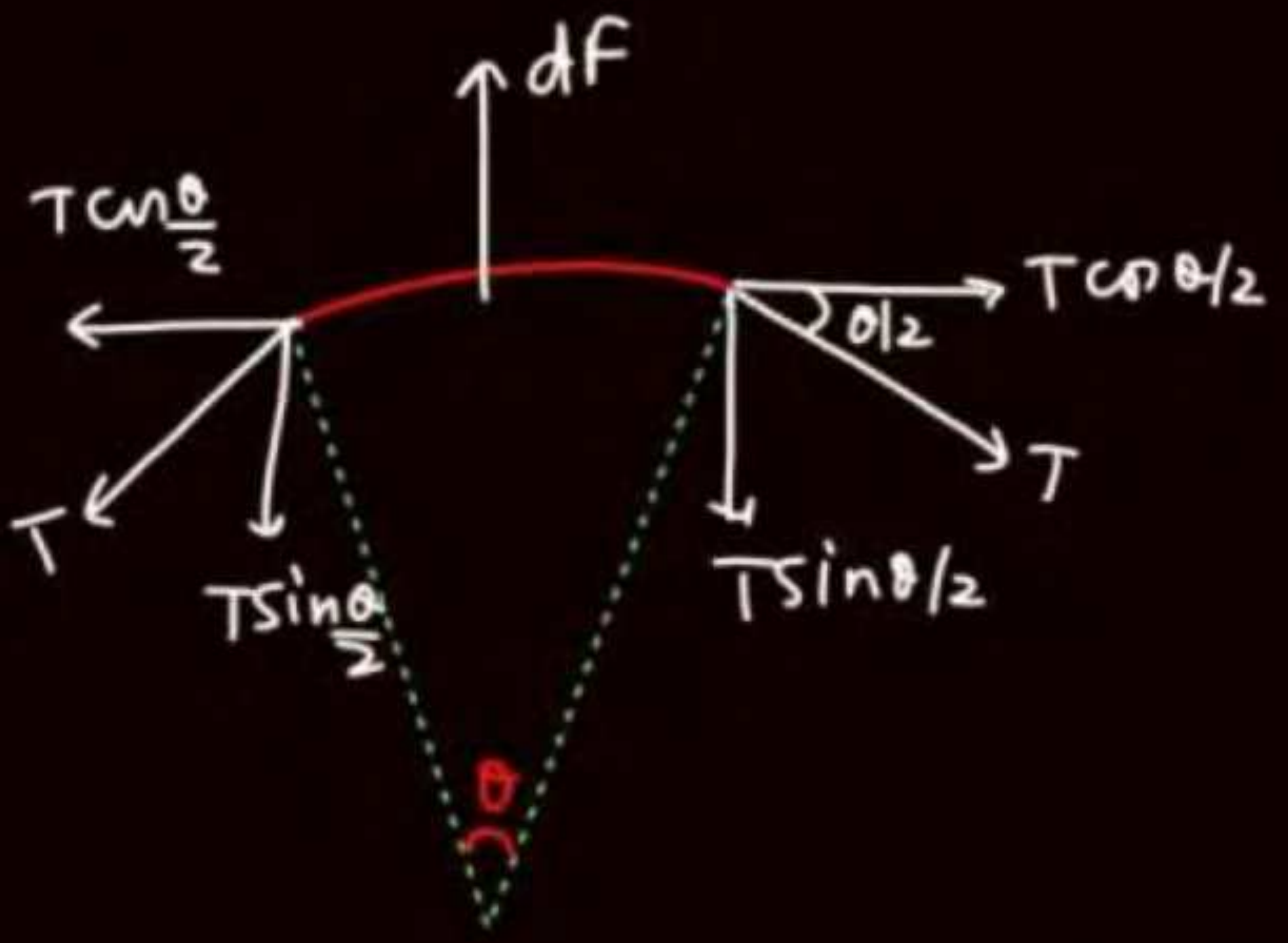
$$i\,\cancel{dl}\,B = T\frac{\cancel{dl}}{R}$$

$$\boxed{T = iRB}$$

Irodov 5

Q

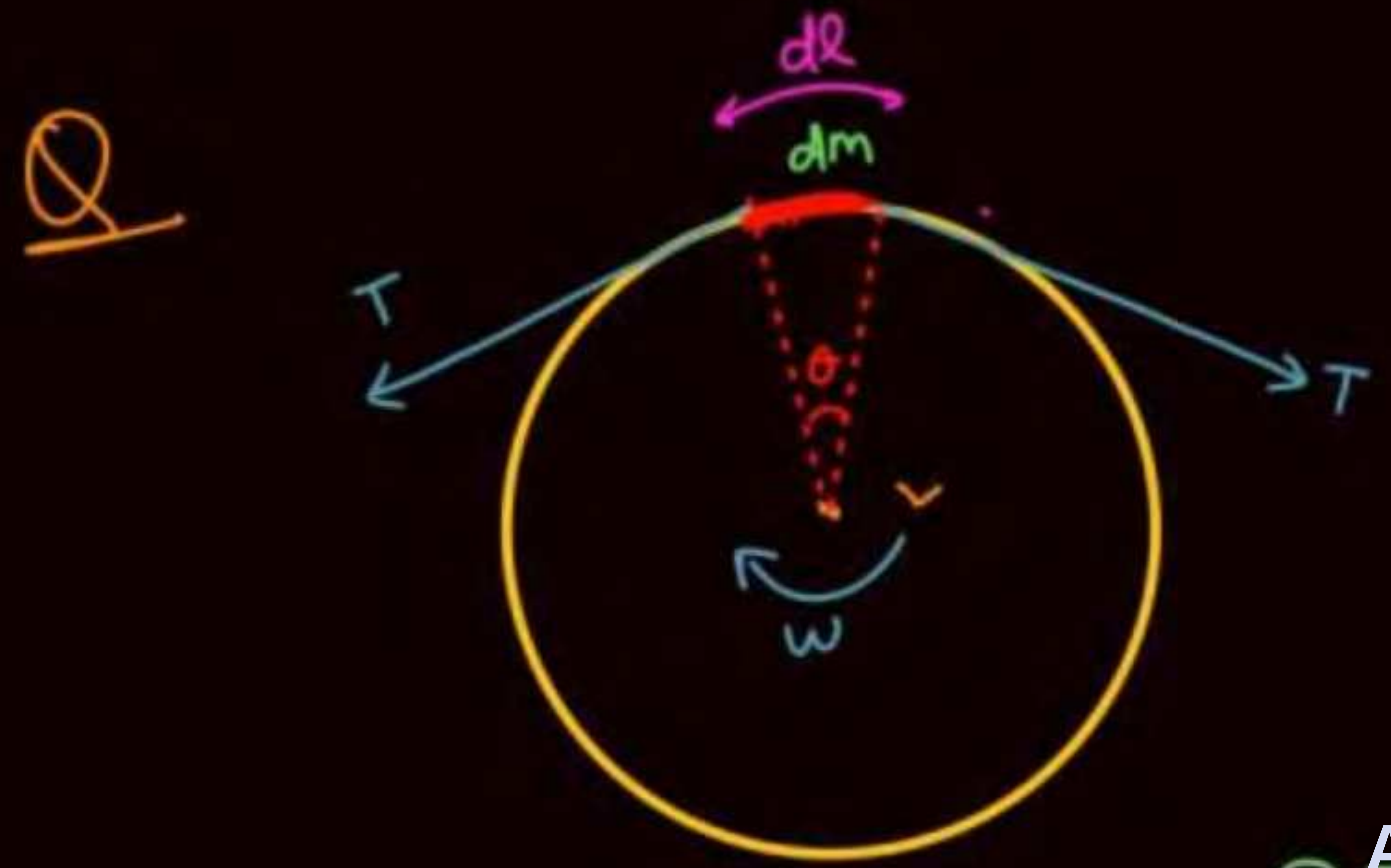


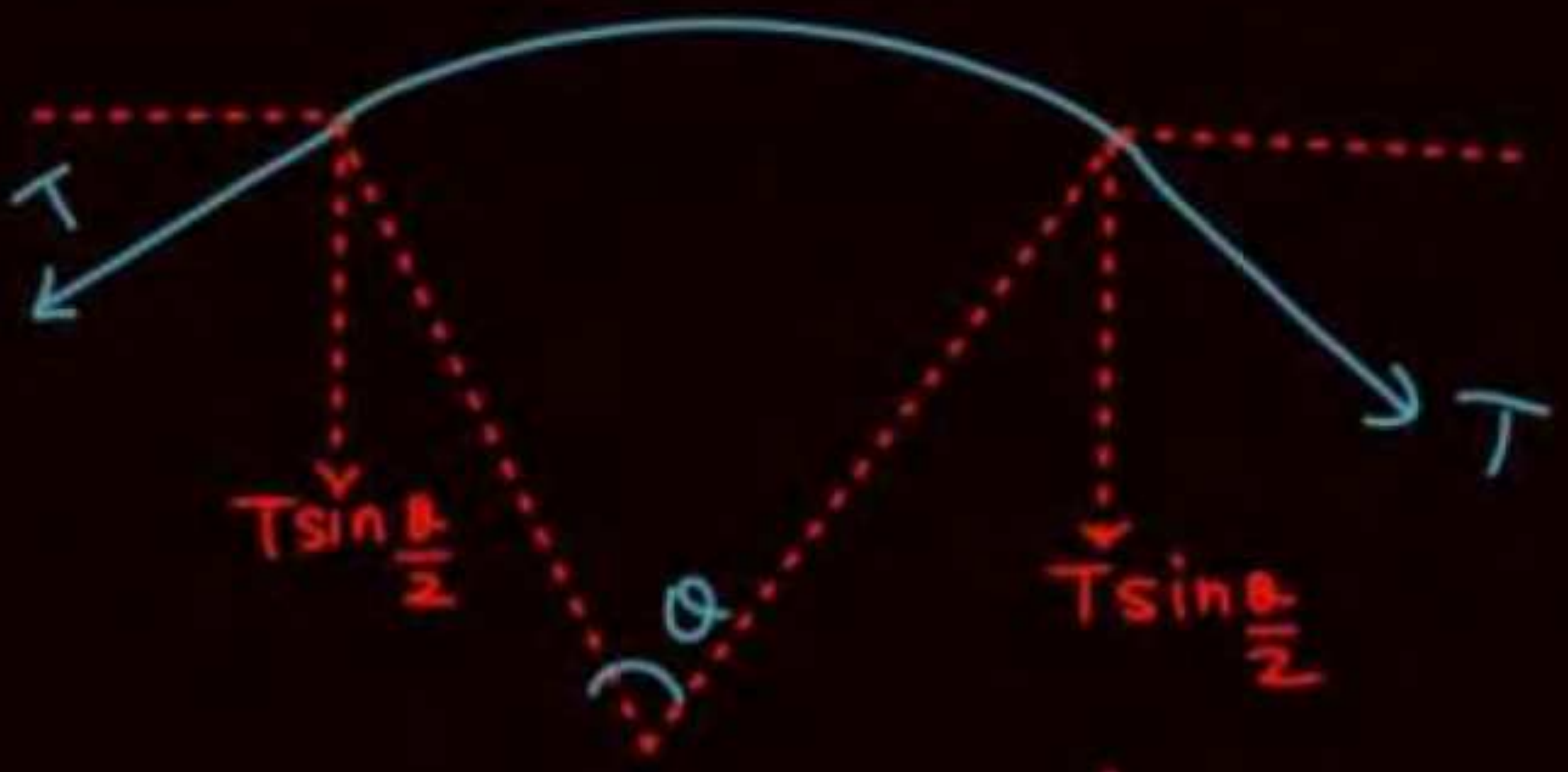


$$dF = 2T\sin\theta/2 = T\theta$$

$$\frac{Kq_0\,dq}{R^2} = T\frac{dl}{R}$$

$$\frac{Kq_0}{R}\left(\frac{dq}{dl}\right) = T = \frac{Kq_0\lambda}{R}$$





$$2T\sin\frac{\theta}{2} = (dm)R\omega^2$$

$$2T\frac{\theta}{2} = dm.R\omega^2$$

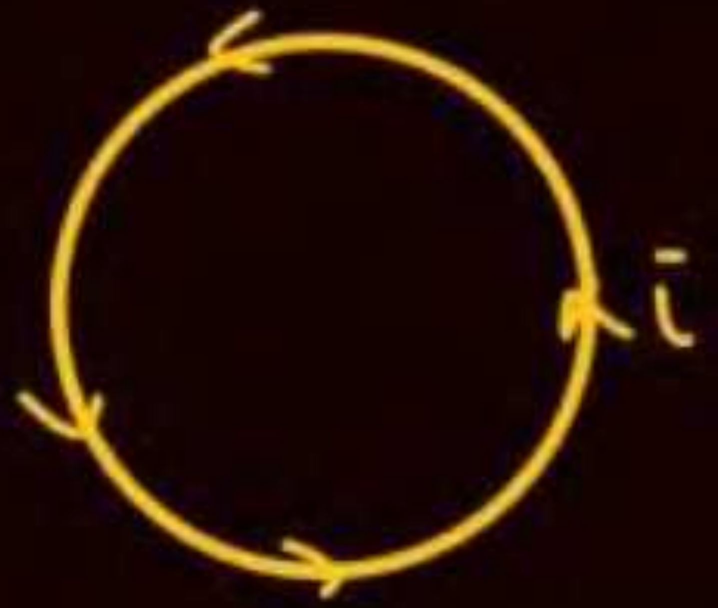
$$T.\frac{dl}{R} = dm R\omega^2$$

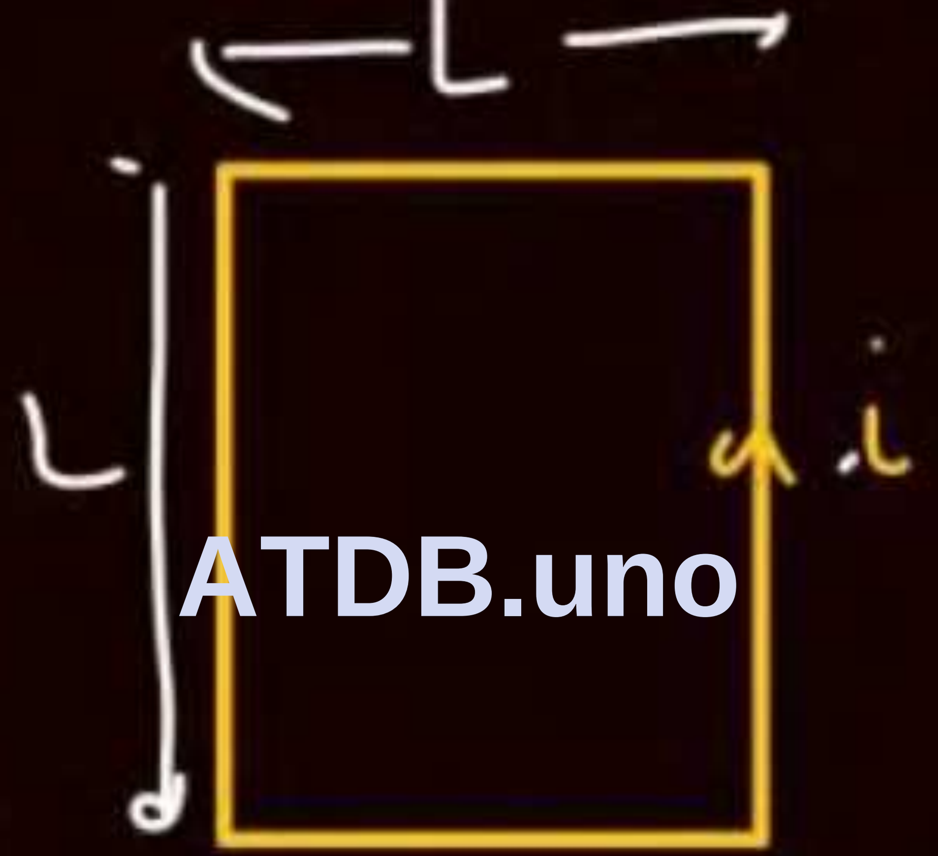
$$T = \left(\frac{dm}{dl}\right)R^2\omega^2$$

$$\boxed{T = \lambda R^2\omega^2}$$

magnetic moment

$\vec{m} = i\vec{A}$





$i \times L^2 (\hat{k})$

$m = i\pi R^2$

$\vec{m} = i\pi R^2 \times (\hat{k})$

Magnetic dipole moment / magnetic moment

x-y plane मे
current (cw ⇒) $\hat{k}$
Acw ⇒ $-\hat{k}$

- magnetic dipole moment of a current carrying loop is given by

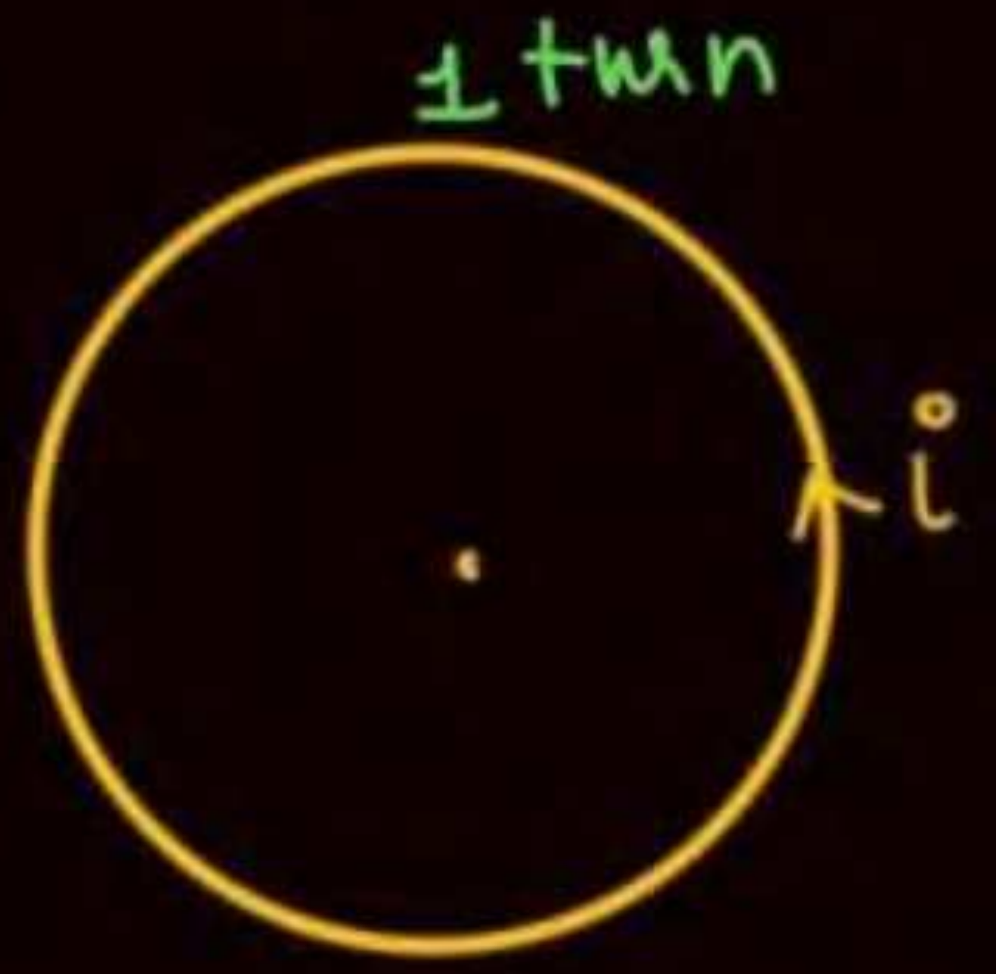
$$\vec{M} = i\vec{A}$$

For n loop

$$\vec{M} = i n \vec{A}$$

if n → no. of turn

$$\vec{m} = i\vec{A} . n$$

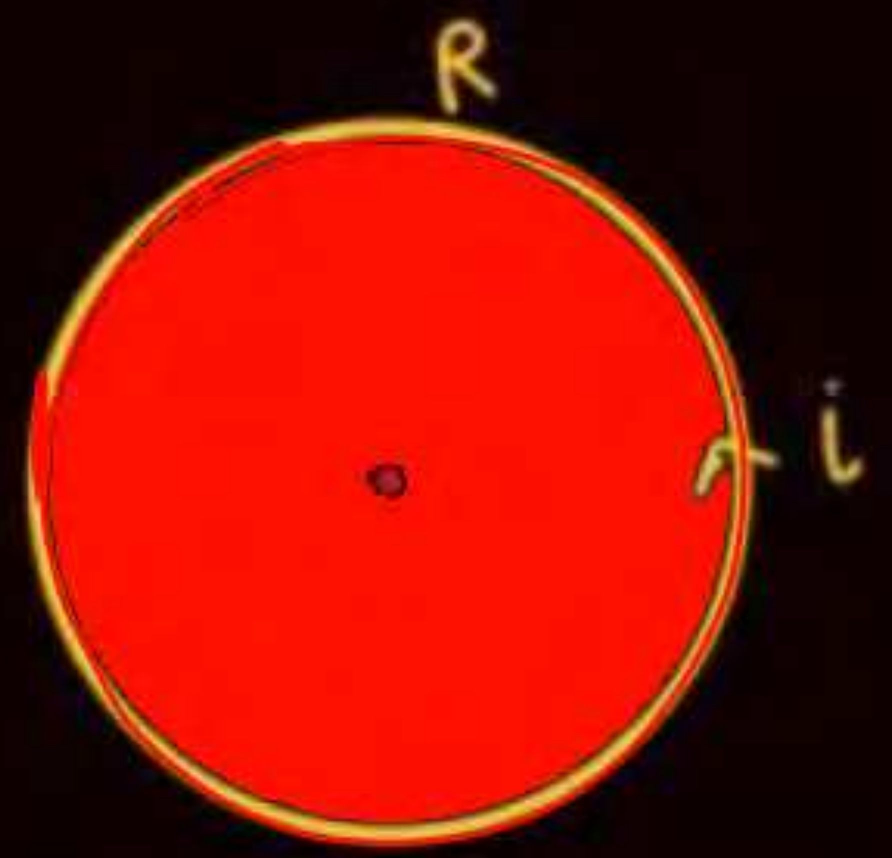


magnetic dipole moment $= \vec{m} = i\pi R^2 (\hat{k})$

$m = i\pi R^2$ (magnitude)

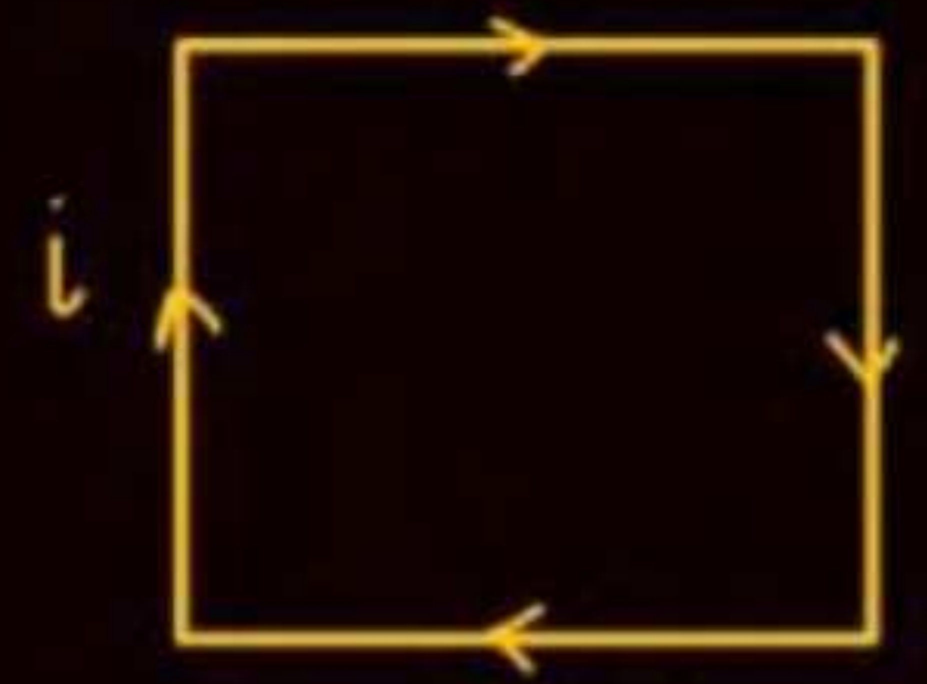
* Dir^n of $\vec{m}$ is given by right hand thumb rule.

Q



$\vec{m} = i \cdot \pi R^2 \hat{k}$

Q (square 'L')

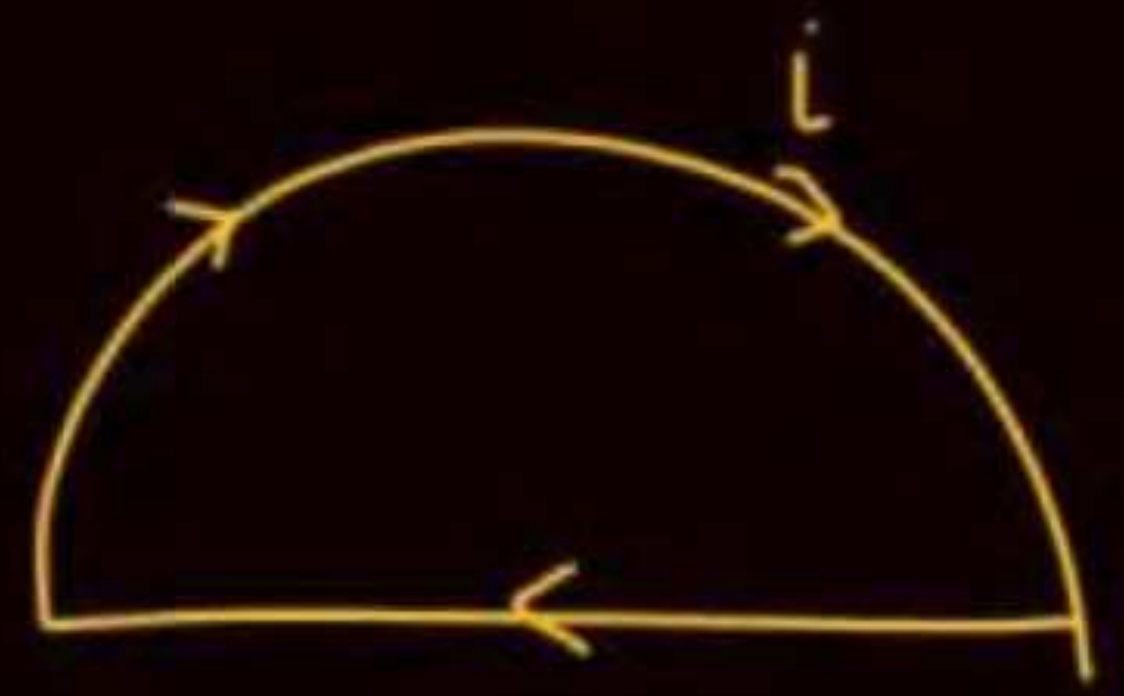


$\vec{m} = i L^2 (-\hat{k})$

Q (Ractangle L, b)

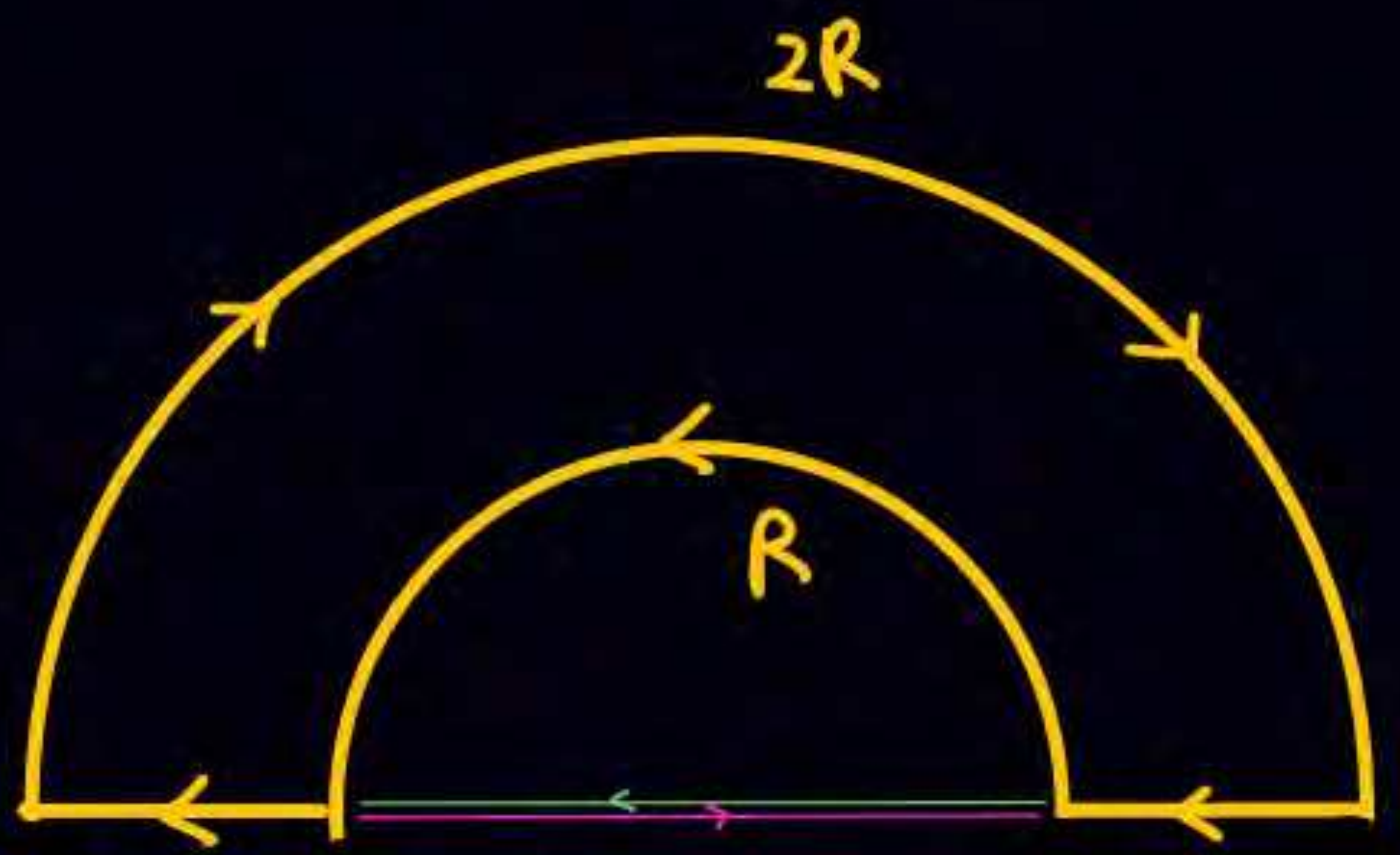
$\vec{m} = i L b (\hat{k})$

Q

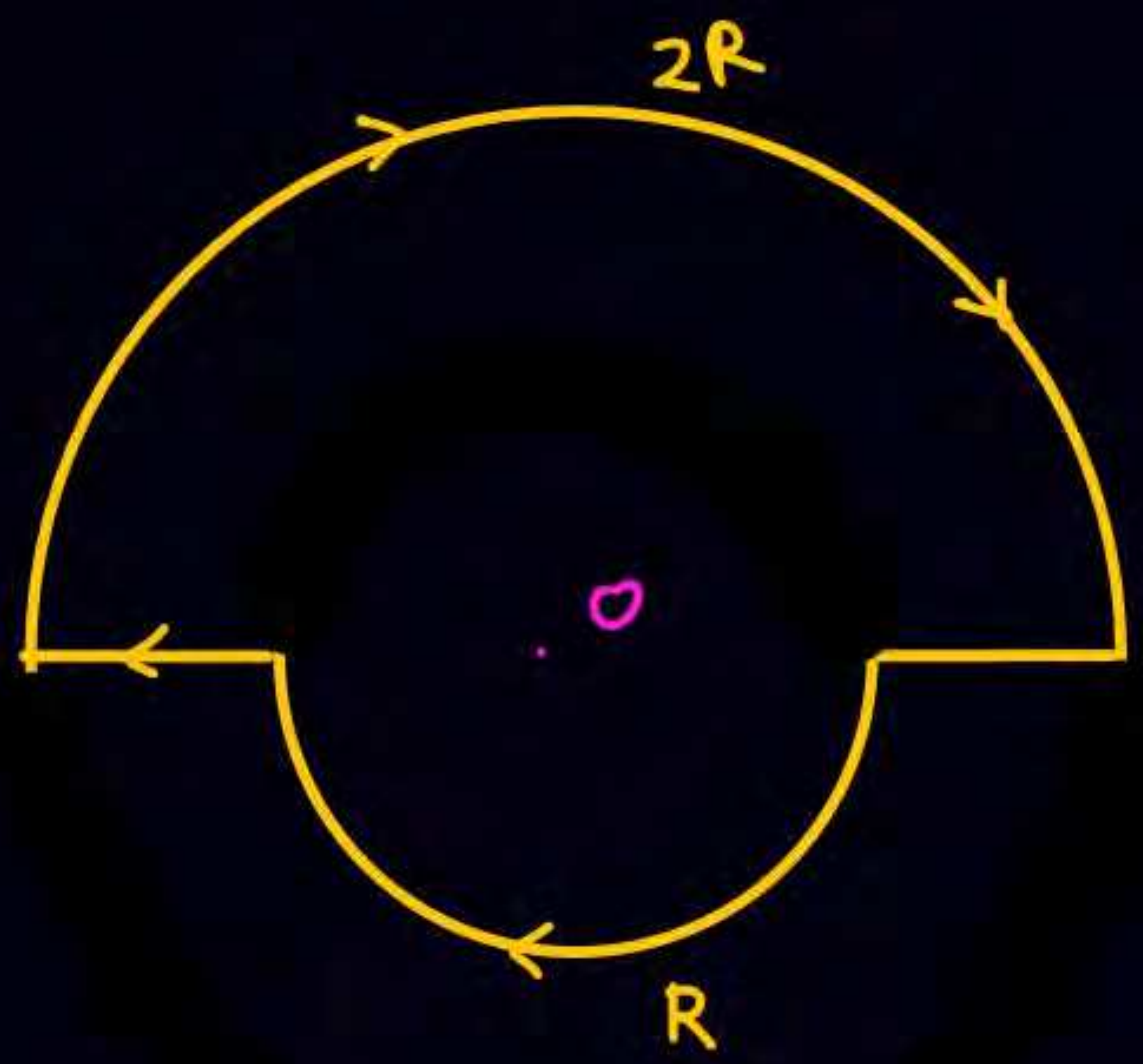


$\vec{m} = i \frac{\pi R^2}{2} (-\hat{k})$

Q



$$\vec{m} = \frac{i\cdot\pi(2R)^2}{2}(-\hat{k}) + \frac{i\pi R^2}{2}(+\hat{k})$$

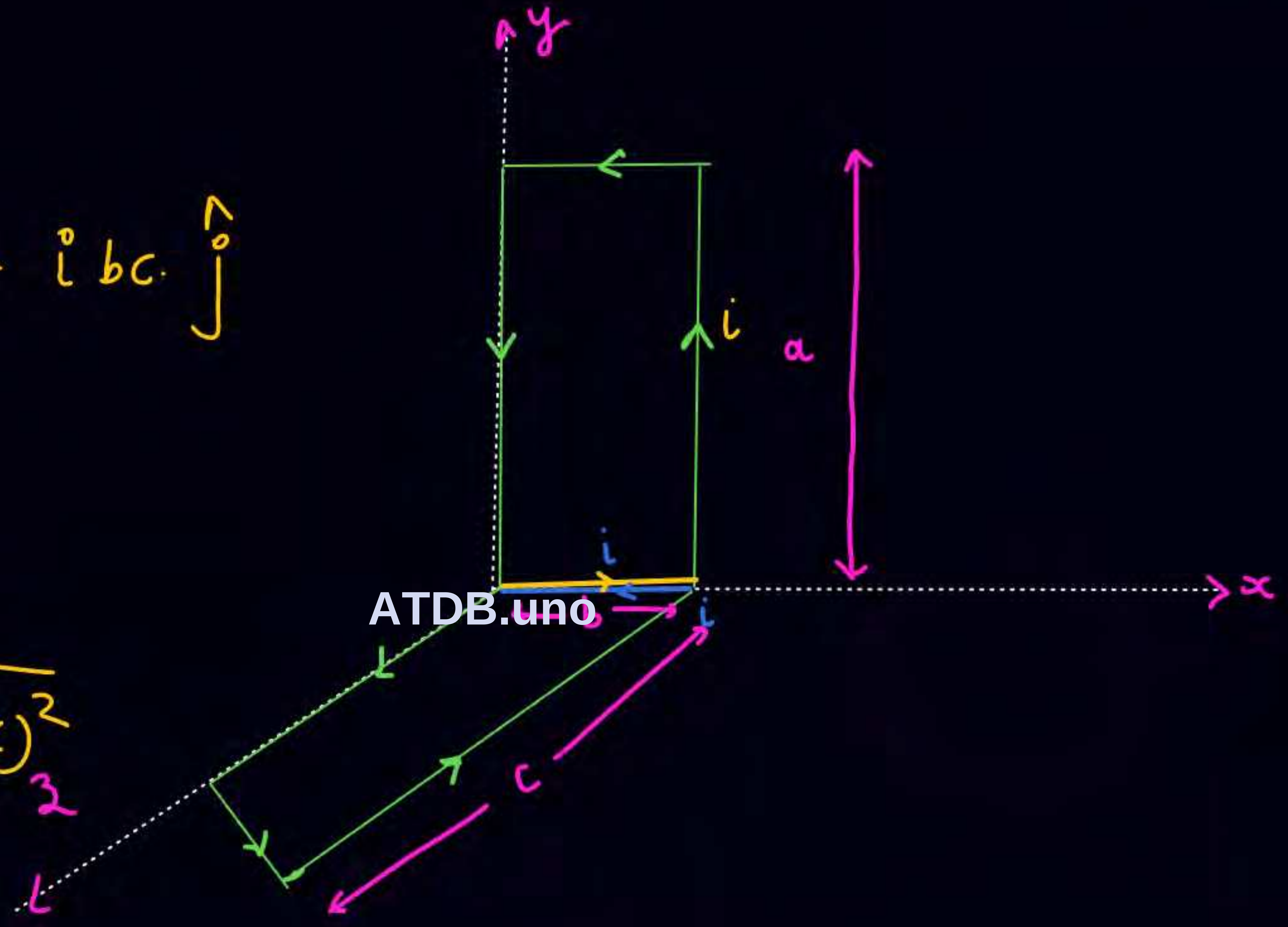


$$\vec{m} = \left[\frac{i\pi(2R)^2}{2} + \frac{i\pi R^2}{2}\right](-\hat{k})$$

$$\vec{m}_{net} = i\,ab\,\hat{k} + i\,bc\,\hat{j}$$

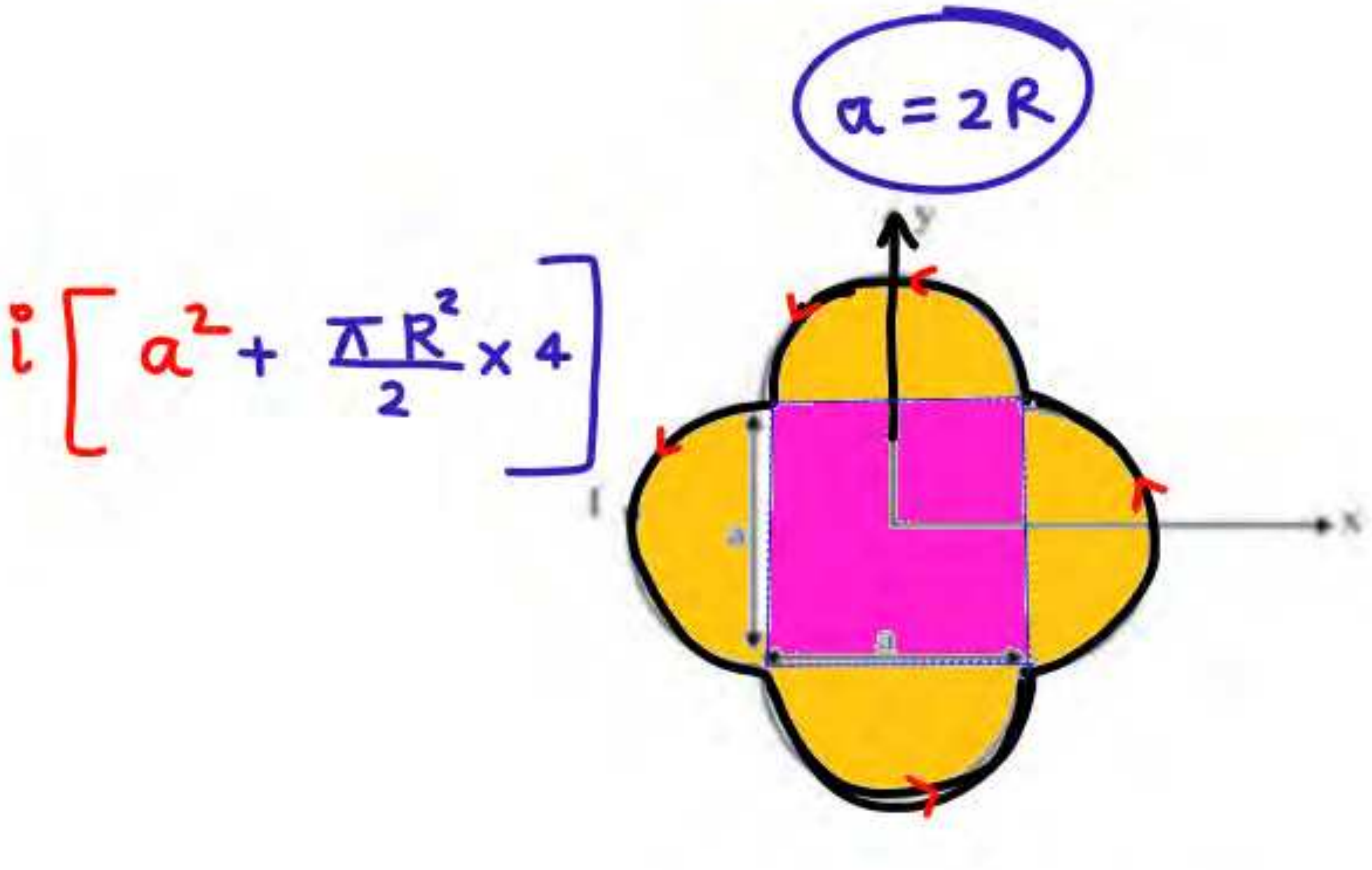
~~$i\,ab + i\,bc$~~

$$m = i\sqrt{(ab)^2 + (bc)^2}$$



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

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



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

Current carrying loop in magnetic field (Uniform)

$\tau = F\frac{L}{2} + F\frac{L}{2} = FL = iL^2B$

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

(square L)

Force on PQ = 0

Force on RS = 0

Force on QR = iLB अंदर

" " SP = iLB बाहर

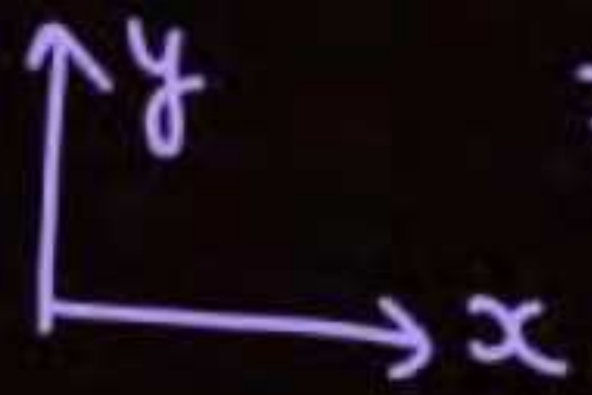
$F_{net} = 0$

$(\vec{\tau})_{abt\ SP} = FL = iLBL$

$= iL^2B(+\hat{j})$

$= mB(\hat{j})$

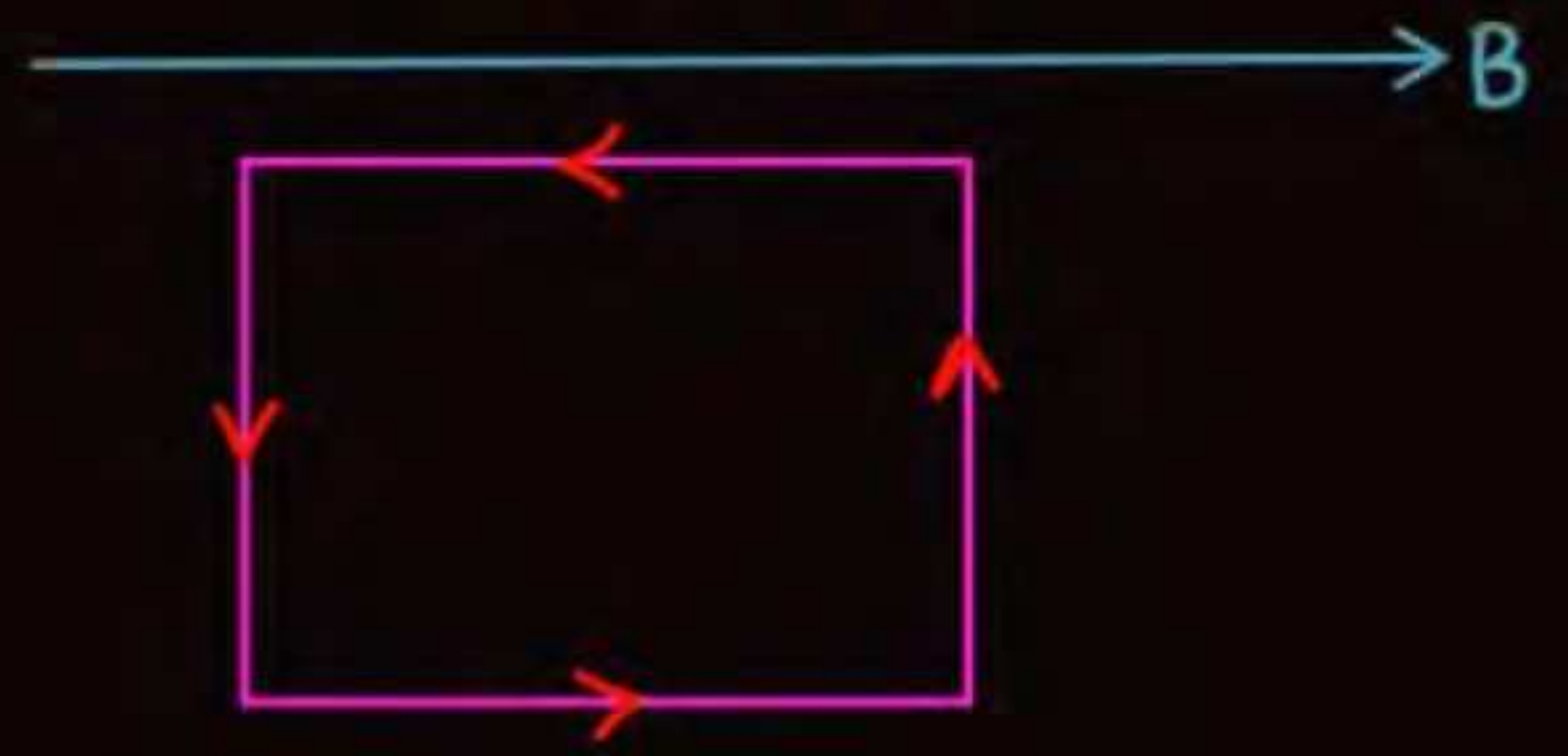
$$\vec{\tau} = \vec{m} \times \vec{B}$$



$\vec{\tau} = r \times \vec{F}$

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

(Square L)



$$\vec{m} = iL^2\hat{k}$$

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

$$\vec{\tau} = \vec{m}\times\vec{B} = (iL^2\hat{k})\times(B\hat{i})$$

$$= iL^2B(\hat{j})$$

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

Electric dipole moment

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

* $T = 2\pi\sqrt{\frac{I}{PE}}$

* $\theta = 0$, $F = 0$, $\tau = 0$, U_{min} → Stable Equil.
* $\theta = 180$, $F = 0$, $\tau = 0$, U_{max} → Unstable Equil.

Q

→ E

→ P

F = 0

small angle rotate & release

$T = 2\pi\sqrt{\frac{I}{PE}}$ → $T = 2\pi\sqrt{\frac{I}{mB}}$

magnetic dipole moment

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

$\vec{P} \rightarrow \vec{m}$

$\vec{E} \rightarrow \vec{B}$

$\vec{\tau} = \vec{P} \times \vec{E} \rightarrow \vec{\tau} = \vec{m} \times \vec{B}$

$U = -\vec{P}\cdot\vec{E} \rightarrow U = -\vec{m}\cdot\vec{B}$

$U = -mB\cos\theta$

→ $\theta = 0$, $F = 0$, $\tau = 0$, U_{min} (Unstable)

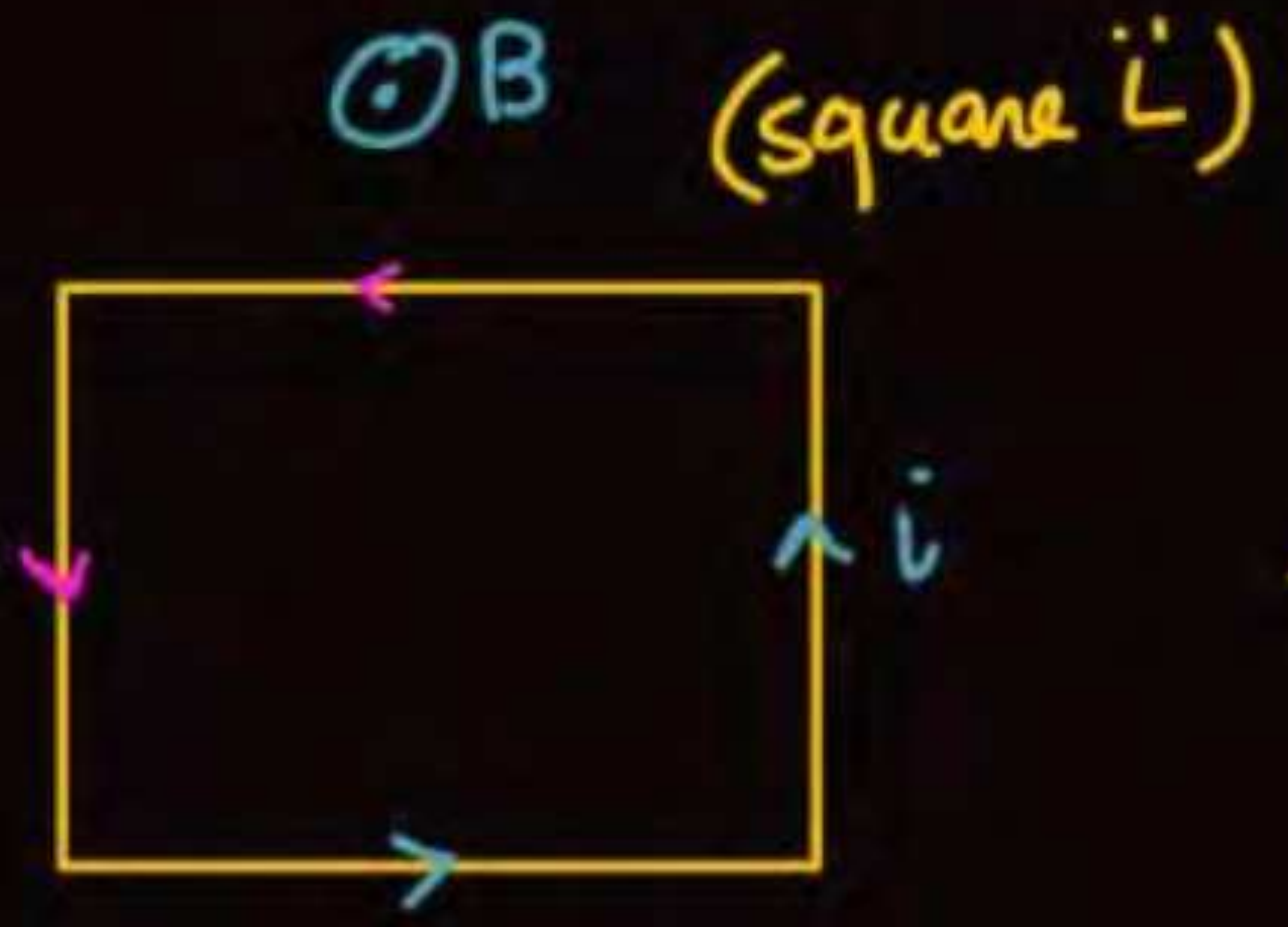
→ $\theta = 180$, $F = 0$, $\tau = 0$, U_{max} (Unstable)

Q

$F = 0$, $\vec{\tau} = \vec{m} \times \vec{B}$

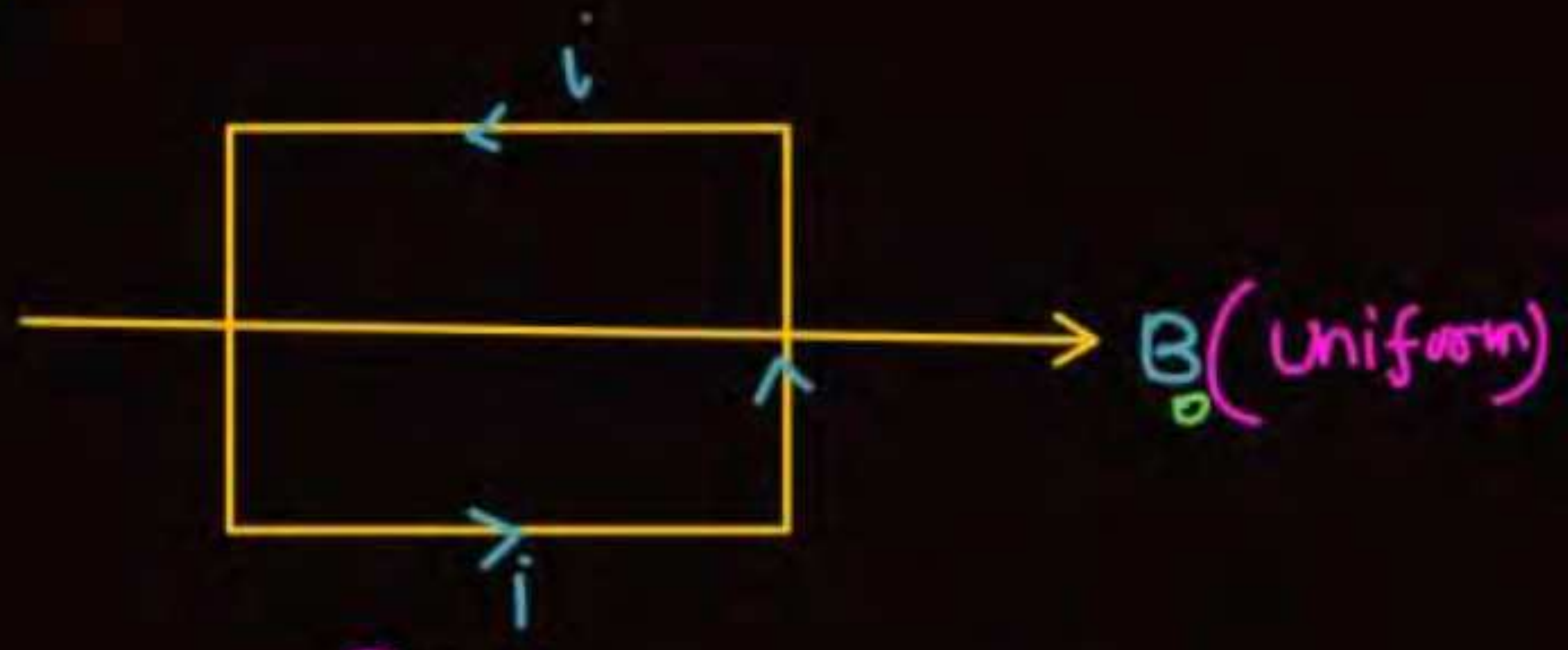
$\theta = 0$, $\tau = 0$

(Stable)



$F = 0$

$\theta = 0$, $\tau = 0$, Stable



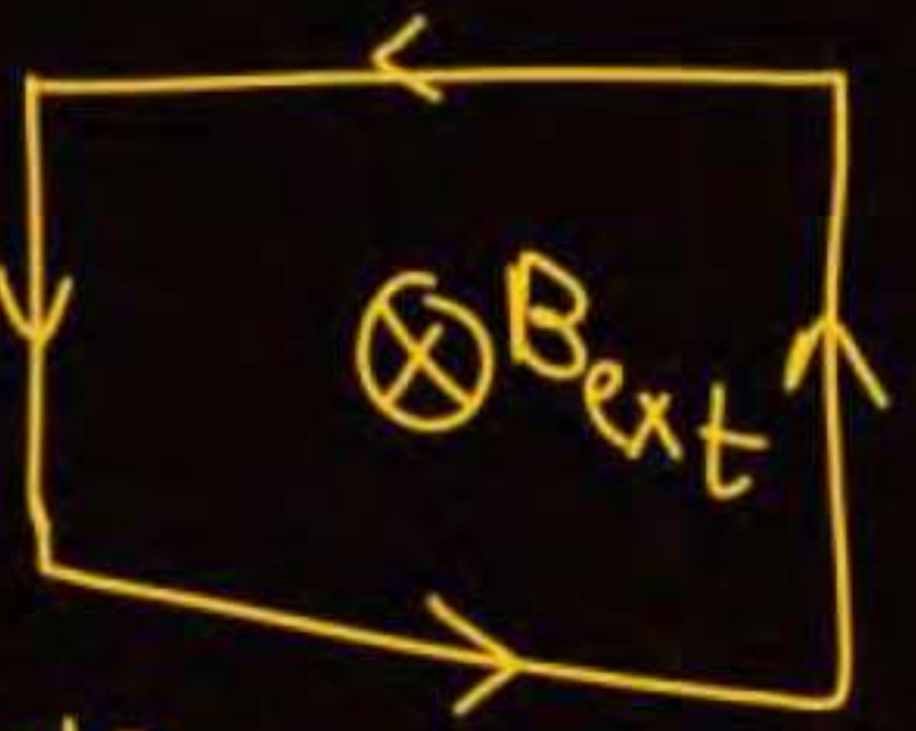
$F = 0$

$\tau \neq 0$ $\qquad \vec{m} = L^2 \hat{k}$

$\theta = 90°$ $\qquad \vec{B} = B_0 \hat{i}$

$\vec{\tau} = \vec{m} \times \vec{B} \neq 0$

Q



$\theta = 180$, Unstable

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

$\theta = 0$

$\tau = 0$

$\Rrightarrow$

$$\tau = PE\sin\theta$$

for small displacement

$$\sin\theta \approx \theta$$

$$\vec{\tau} = -PE\,\theta$$

$$\vec{\tau} = -(K)\,\vec{\theta}$$

Angular SHM ✓

$$\vec{F} = -k\vec{x}$$

$$T = 2\pi\sqrt{\frac{m}{K}}$$

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

$\vec{P} \uparrow\uparrow \vec{E}$ Stable

$\theta = 0$

$\vec{m} \uparrow\uparrow \vec{B}$ (Stable)

$\Rightarrow$ $\theta = 0$, parallel

$\vec{P} \uparrow\downarrow \vec{E}$ Unstable

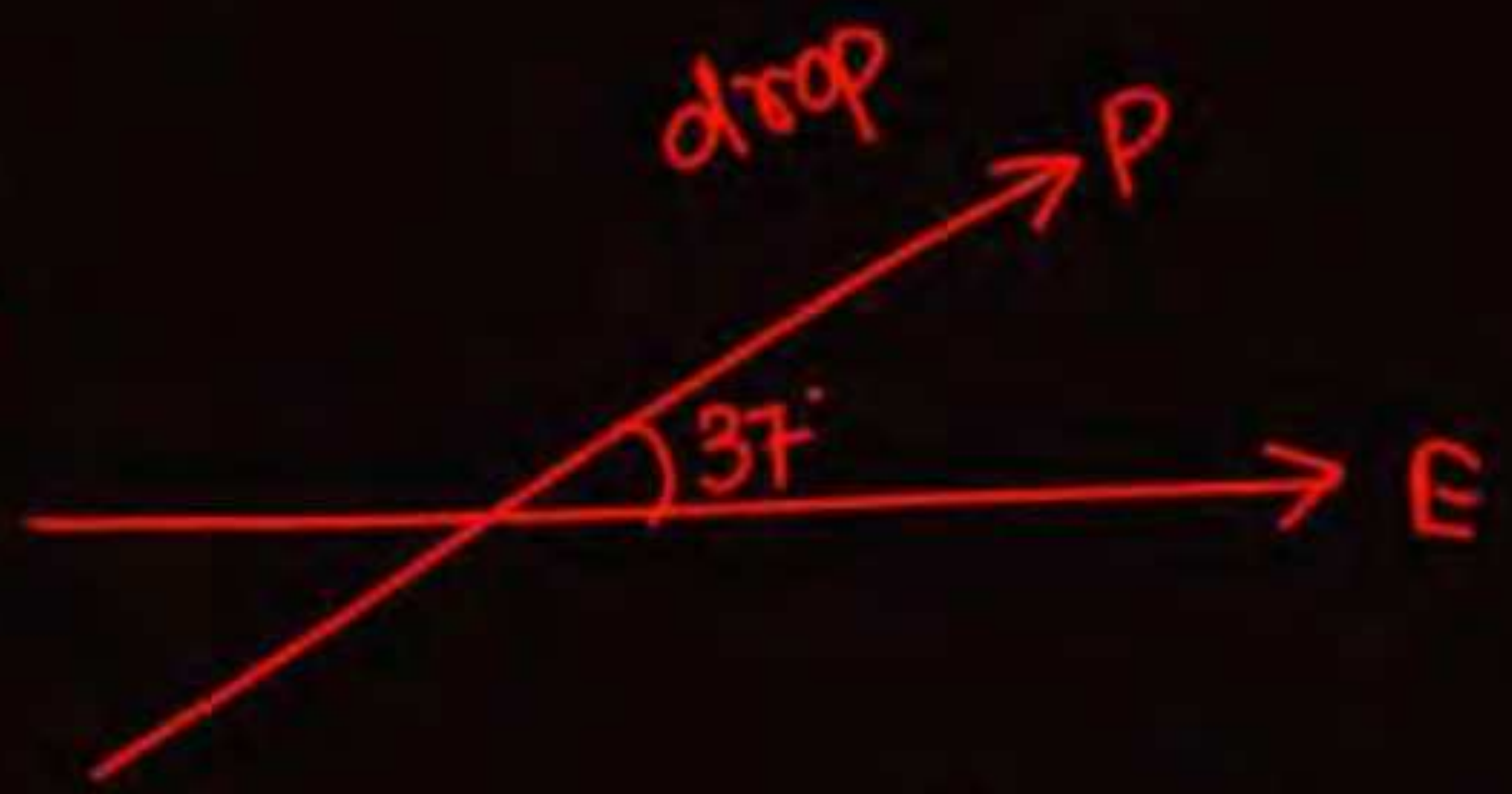
$\theta = 180$

$\vec{m} \uparrow\downarrow \vec{B}$ (Antiparallel)

$\theta = 180$, (Unstable)

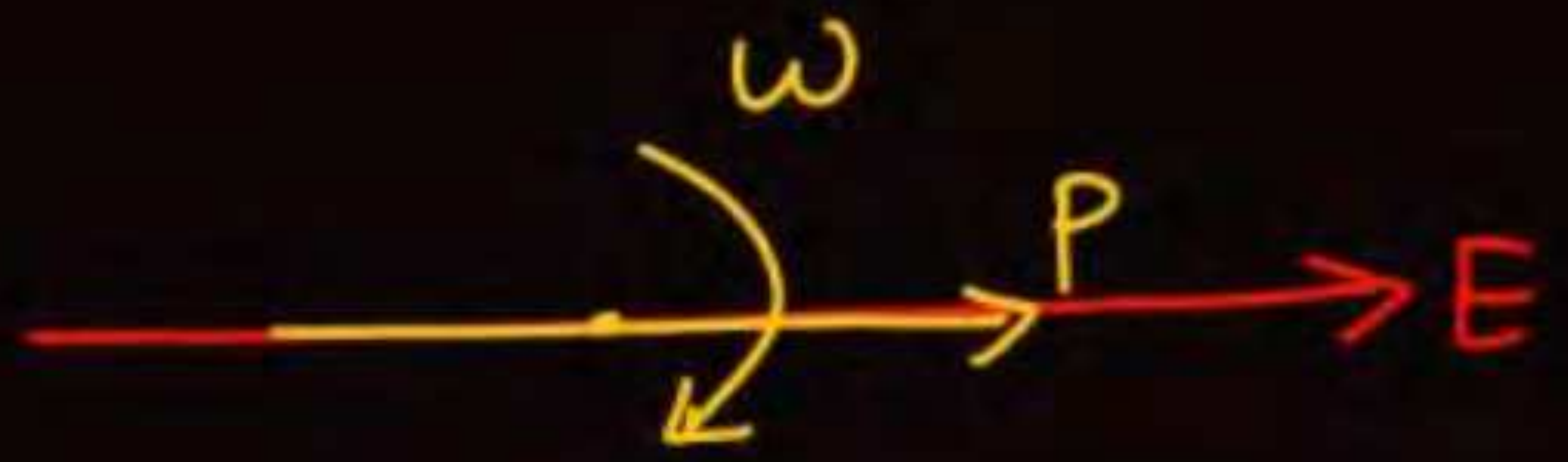
पुरानी बातें

Q



$$PE = U = -\vec{P}\cdot\vec{E} = -PE\cos\theta$$

$\Rightarrow$



$$K_i + U_i = K_f + U_f$$

$$0 + (-PE\cos 37^\circ) = \frac{1}{2}I\omega^2 + (-PE\cos 0)$$

$\omega = \checkmark$

HomeWork

- Revise all the qus of today class
- HCV page 251

  (24–55)

page 231 ⇒ (10–20) must try.

(21, 22, 23, 24, 25, 26, 27) = मन करे तो कर लीजो :)


THANK
YOU