VISUAL PHYSICS

SHORT NOTES

CHAPTER

Electromagnetic Induction

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H-C=C-H

ELECTROMAGNETIC INDUCTION

As we know Electric current $\rightarrow$ Magnetic field $\xrightarrow{\text{then}}$ Magnetic Field $\rightarrow$ Electric Current

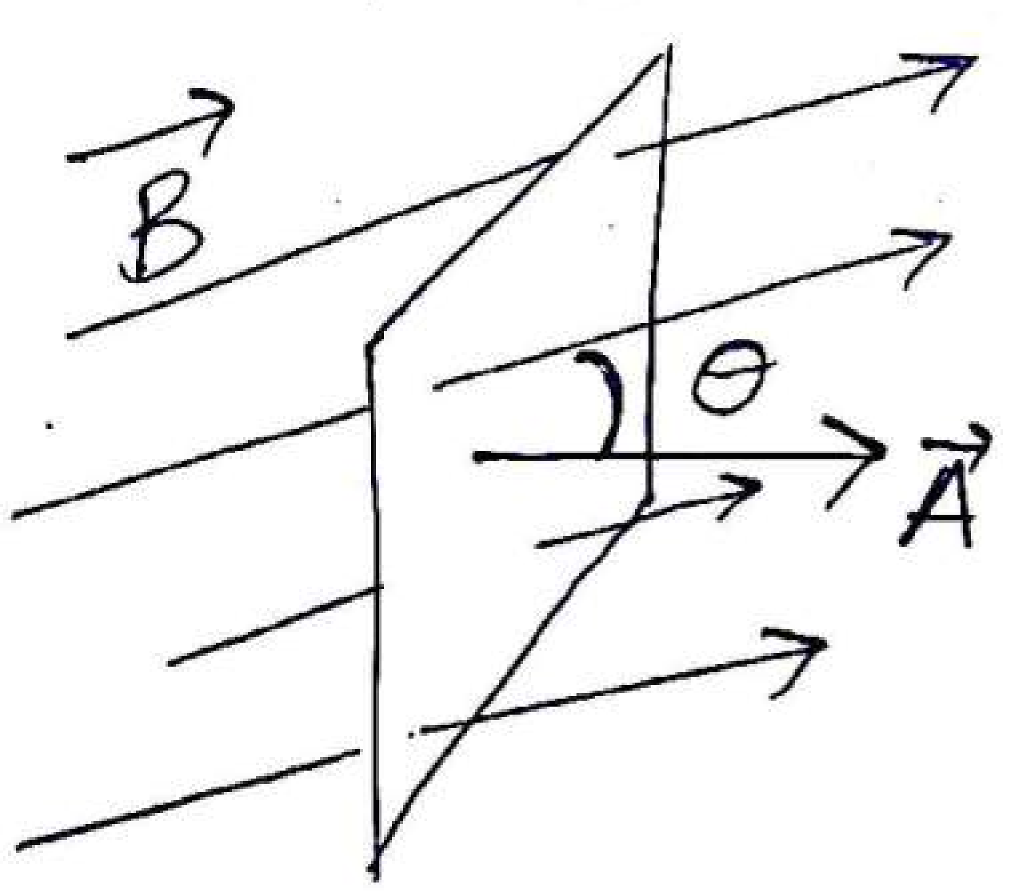
Magnetic flux:

SAME as we discussed for Electric flux.

$\rightarrow$ The number of magnetic field lines passing per unit perpendicular Area is known as magnetic Field Intensity $= B$

as flux, $\phi = \vec{B} \cdot \vec{A}$

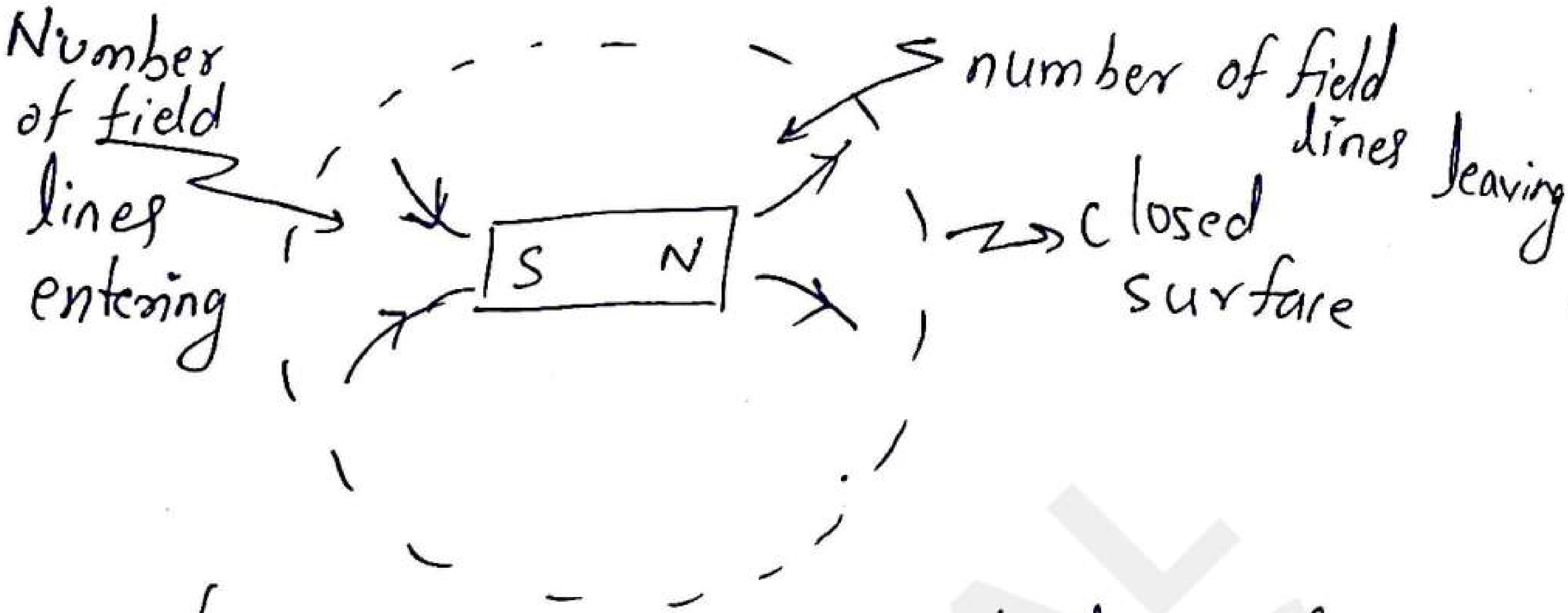
$= BA \cos\theta$



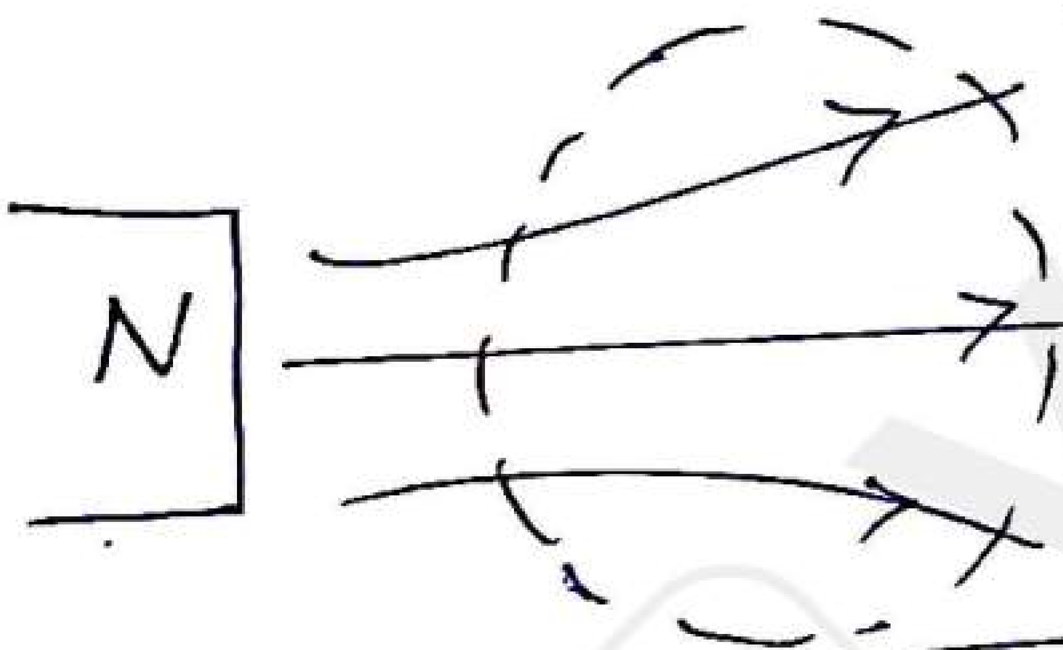
angle between $\vec{B}$ & $\vec{A}$

Area vector

Now flux for a closed surface.



ϕ_{net} = Zero, As magnet always comes in pair (North + south)



→ still $\phi_{net} = 0$

Gauss law

$$\boxed{\text{so for magnet, no matter what the flux for closed surface = Zero}}$$

$$\oint \vec{B} \cdot d\vec{A} = \mu_0 M_{ecn}$$

→ zero as of magnetic dipole

→ Net magnetic charge enclosed

closed surface

as, $\phi_{in} = \phi_{out}$

$\Rightarrow \boxed{\phi_{net} = 0}$

for $\phi_{net} \neq 0$, magnetic monopoles should exists

☆ Hence gauss law says that Magnetic monopoles do not exists

Farady's law:

observe ↳ Current in the coil is produced when flux linked with the coil changes

Magnet move relative to coil

Coil move relative to magnet.

$$\boxed{i \propto \frac{d\phi}{dt}}$$

→ rate of change of flux

Current produce

means EMF is produced

Creation of Induced EMF and current Because of changing magnetic flux

↳ Electromagnetic Induction

$$\boxed{|\varepsilon| = \left|\frac{d\phi}{dt}\right|}$$

rate of change of magnetic flux

emf produced

Faraday's law of Induction

⇒ If 'N' turns then,

$$\boxed{|\varepsilon| = N\left|\frac{d\phi}{dt}\right|}$$

Now $\boxed{\phi = BA\cos\theta}$

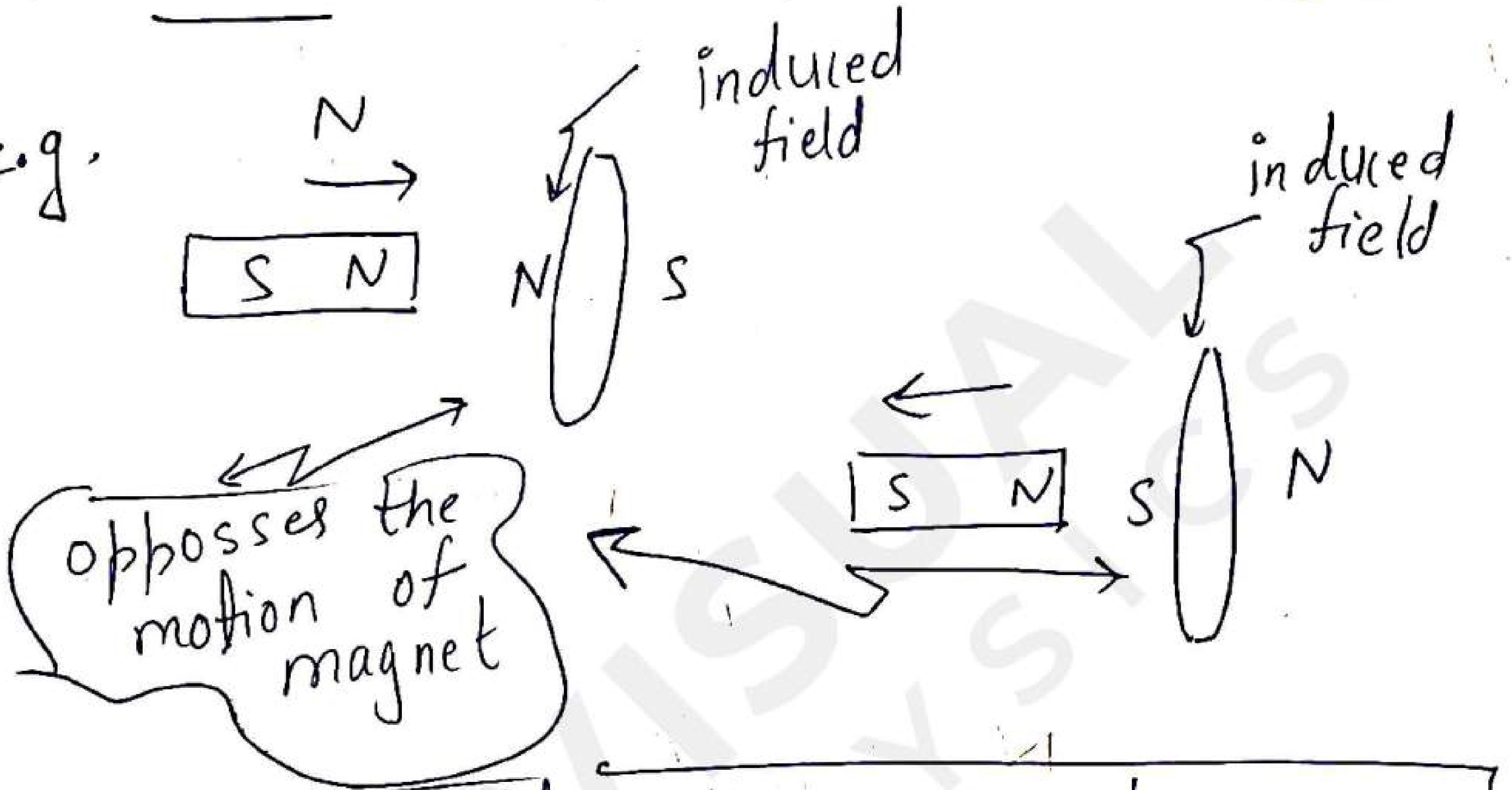
so, ϕ change

- changing Area
- magnetic field
- orientation of coil

Lenz's law

→ effect always opposes the cause

e.g.



Induced field opposses the change in flux direction not the external field

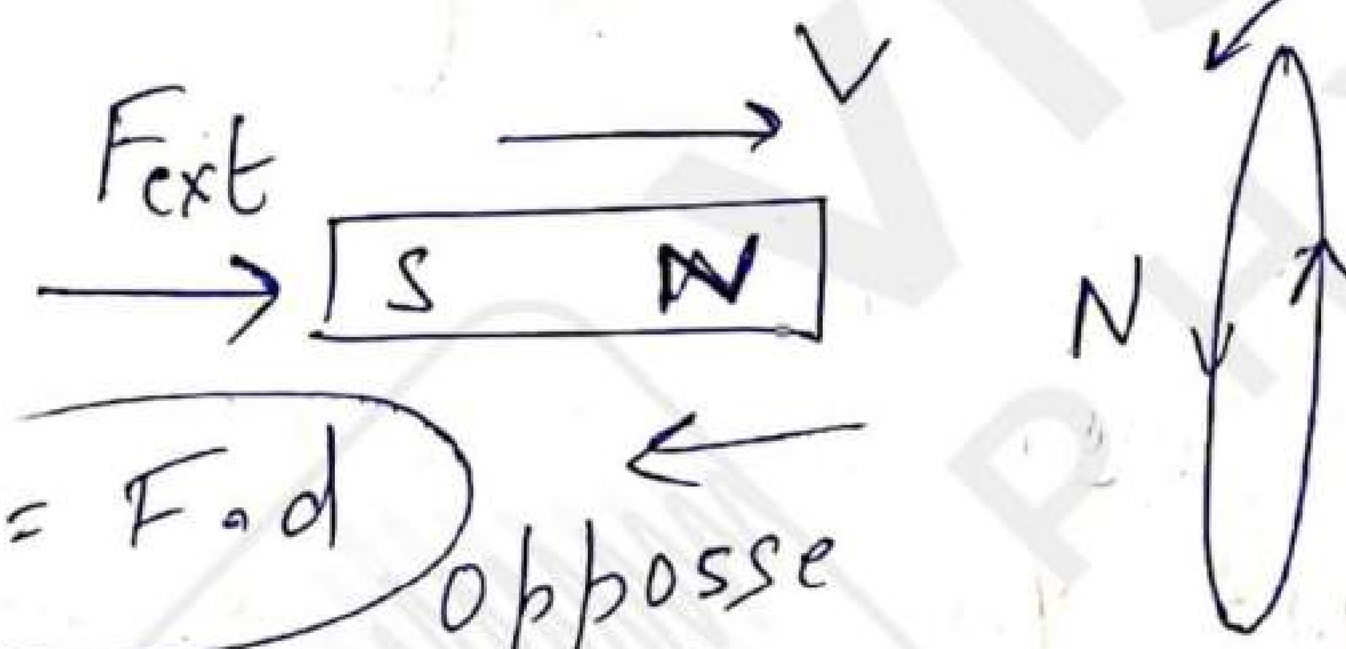
⇒ $$\boxed{\mathcal{E} = -\frac{d\phi}{dt}}$$

represents that direction of $|\mathcal{E}|$ is opposite to the change in flux direction

Conservation of Energy $\Rightarrow$ Lenz's law

* As from lenz's law induced emf is opposite to change in flux direction, so the restriction in motion goes in the form of field or current in coil

induced



$\Rightarrow$ current (i)
so energy lost in 't' time $= (i^2) R t$

$W = F.d$

opposse

Work done in bringing the magnet

Energy Conservation

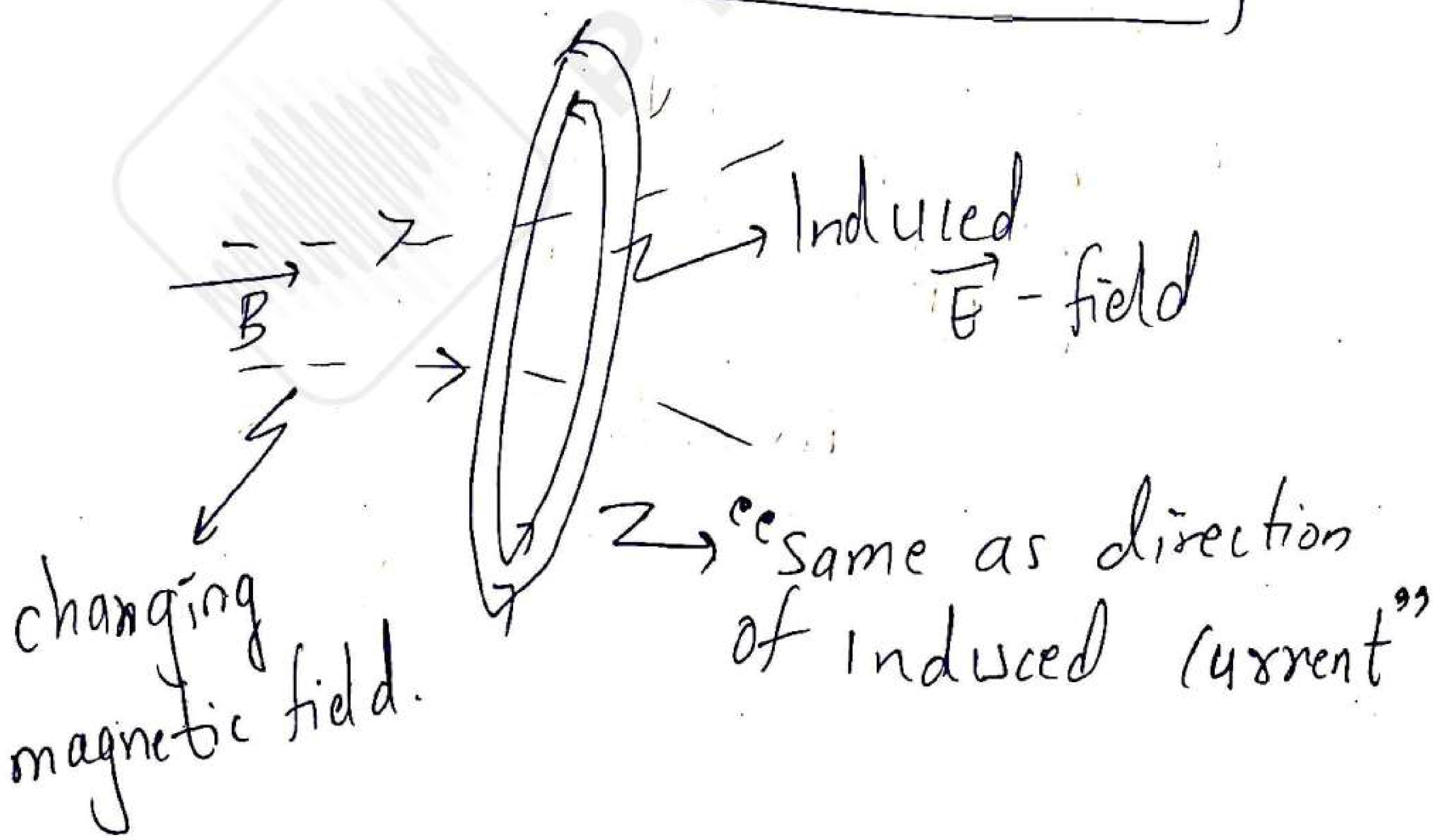
When magnetic flux changes

Electric field is produce

which causes the Induced current.

if coil is not there, even then Electric field in space is produced.

★ Induced electric field → Closed loop



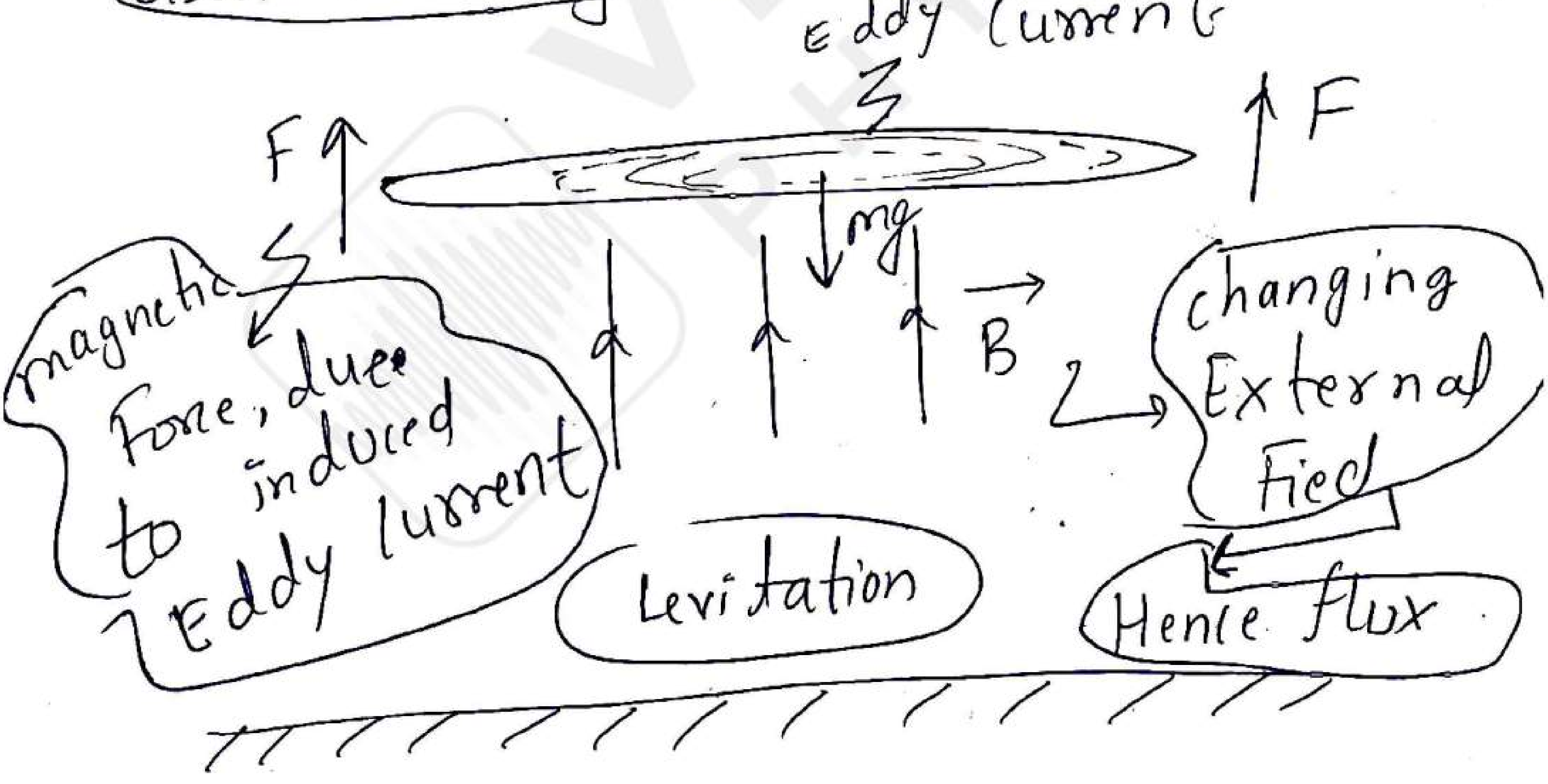
If disc is placed, in changing magnetic flux

→ due to concentric Electric-field is produced

→ concentric electron motion occurs

Hence we say Eddy current is produced.

Used in magnetic Levitation



As, work done In closed loop of induced field $= \oint \vec{F} \cdot \vec{ds} = W$

$$= \oint q\vec{E} \cdot \vec{ds}$$

So, $\text{Emf} = \mathcal{E} = \frac{W}{q}$

$$\Rightarrow \boxed{\mathcal{E} = \oint \vec{E} \cdot \vec{ds}}$$

★ **Induced $\vec{E}$ is symmetry about $\vec{B}$**

$$\Rightarrow \boxed{\mathcal{E} = \oint \vec{E} \cdot \vec{ds}} \boxed{= \frac{d\phi}{dt}}$$

Can be any closed loop

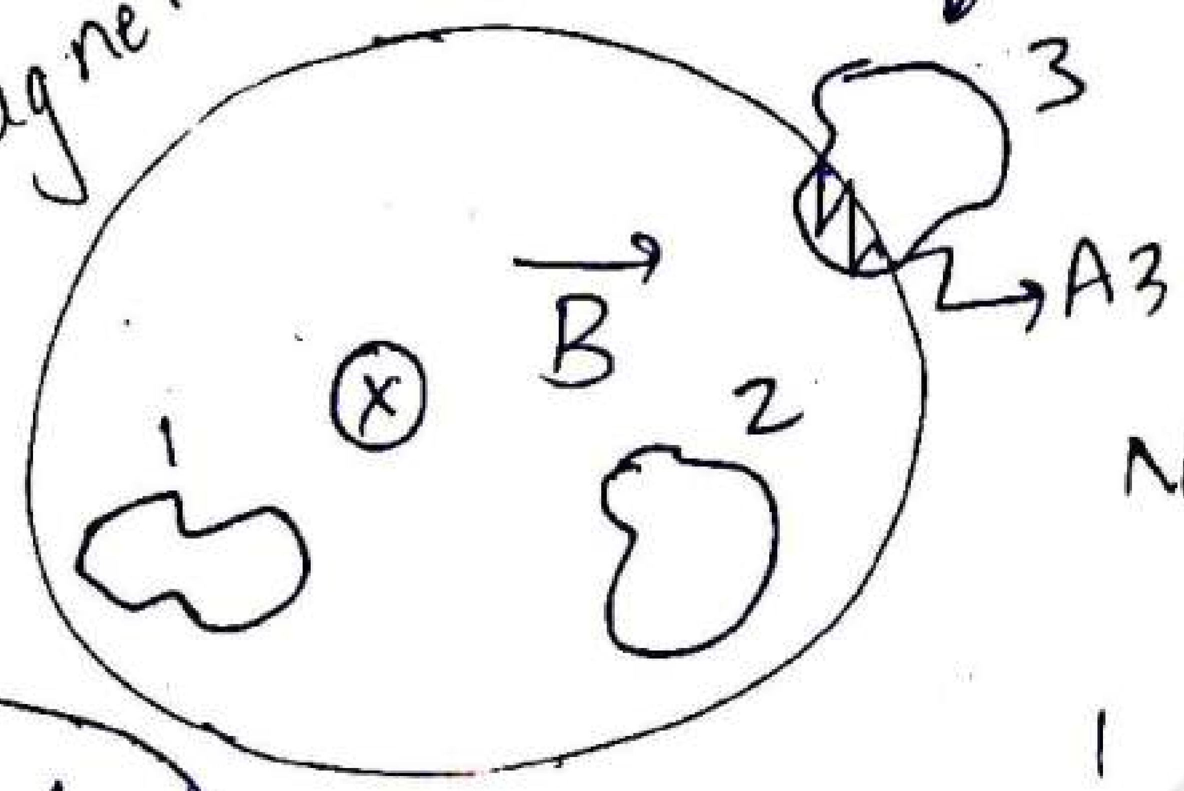
Now, $\phi = BA$

so if Area are equal for any path

emf induced will be equal

Area linked with magnetic field $\vec{B}$ are not same

Flux linked



Net area of loop 1, 2 & 3 are equal but $A_1 = A_2 \neq A_3$

$$A_1 = A_2 \neq A_3$$

$$|\mathcal{E}_1| = |\mathcal{E}_2| \neq |\mathcal{E}_3|$$

Now for Electrostatic field

$$\oint \vec{E} \cdot \vec{dl} = 0$$

Hence Conservative field

But Induced $\vec{E}$-field is not Conservative

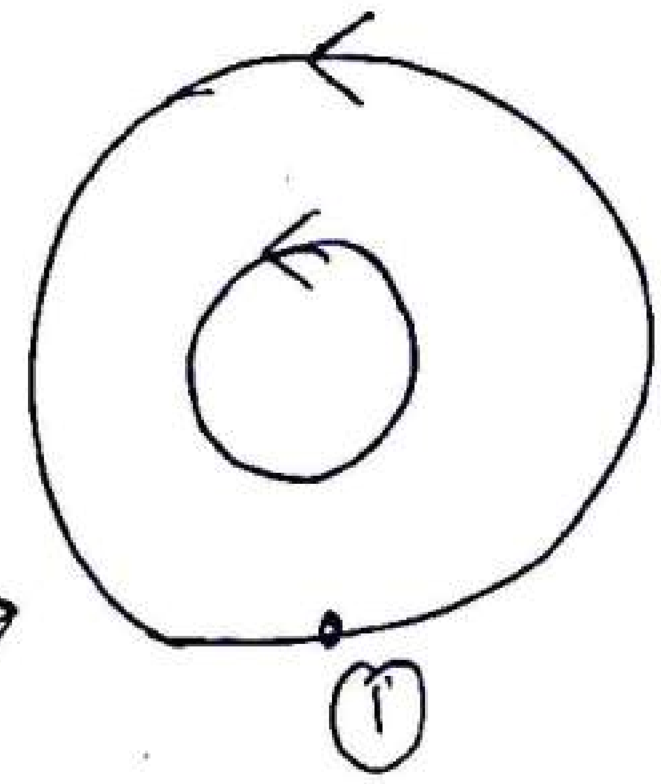
Non-Conservative ⇒ $\oint \vec{E} \cdot \vec{dl} \neq 0$

potential

'V' cannot be defined for Induced field

(as same point then have different 'V')

Induced field

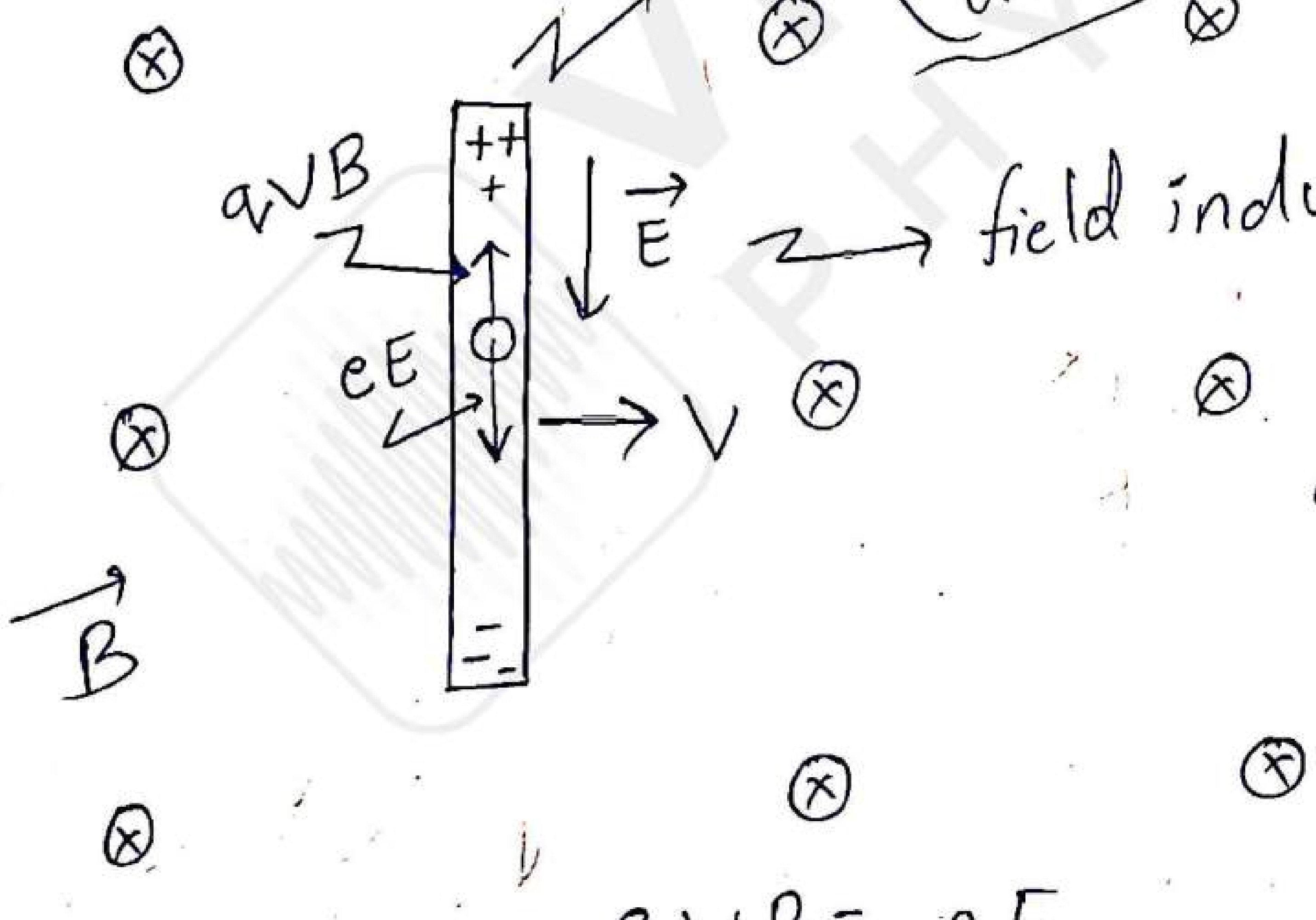


Now work done in completing one circular path $\neq 0$

$$\boxed{\mathcal{E} = \oint \vec{E} \cdot \vec{dl}}$$

emf induced

magnetic force drift the electrons



field induced due to seperation of electrons

$$qvB = eE \qquad (q = e)$$

Now $\Rightarrow E = vB$

or $\boxed{\vec{E} = \vec{v} \times \vec{B}}$

so, motional emf $= \mathcal{E} = \vec{E} \cdot \vec{dl} = \int (\vec{v} \times \vec{B}) \cdot \vec{dl}$

☆ direction of Emf can be found using right hand cross-product.

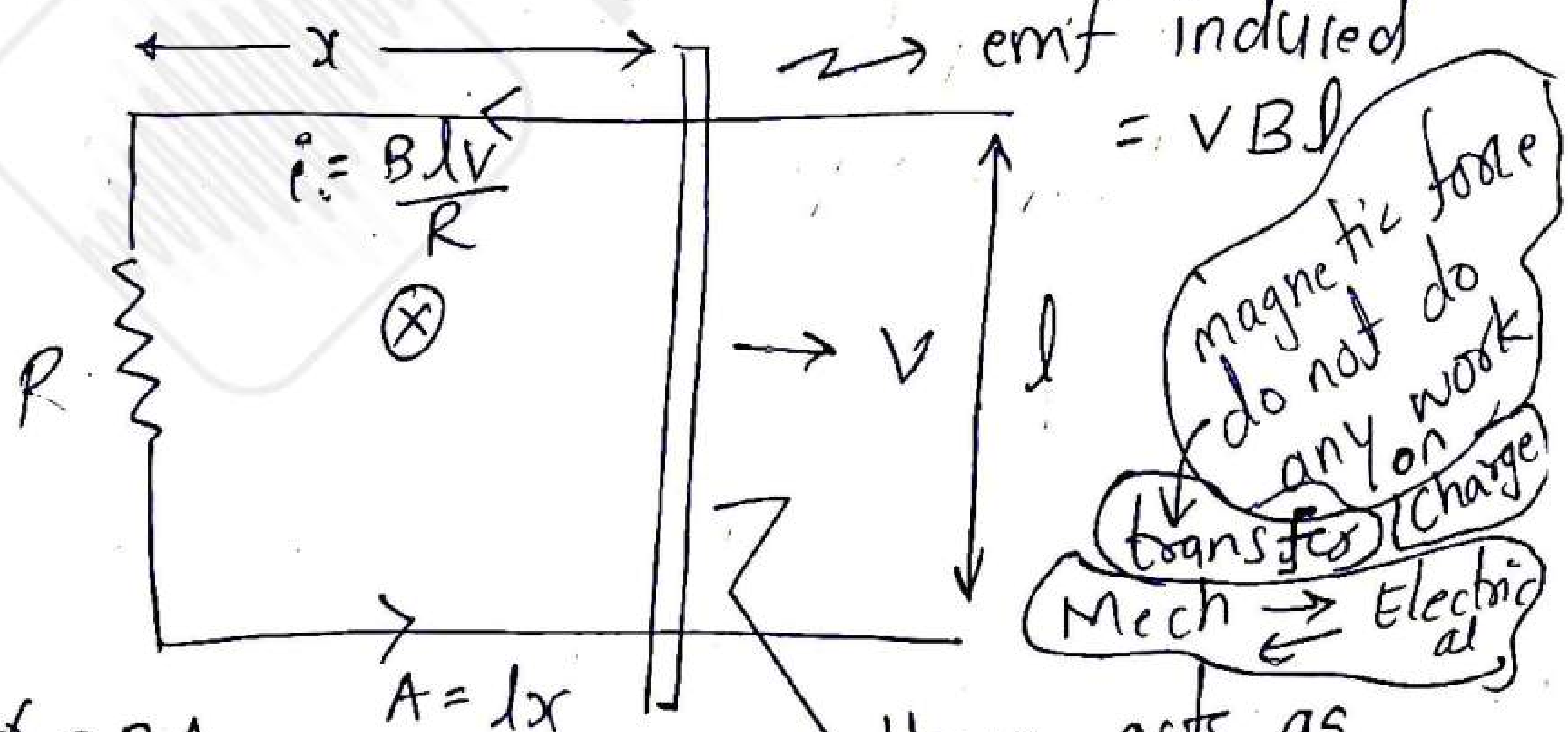
Now

$(\vec{V} \times \vec{B}) \cdot \vec{l} \rightarrow$ Scalar Triple product of $\vec{B}$, $\vec{V}$, and $\vec{l}$

In scalar Triple product

$$\boxed{(\vec{V} \times \vec{B}) \cdot \vec{l} = V_{\perp} B_{\perp} l_{\perp}}$$

mutual perpendicular components



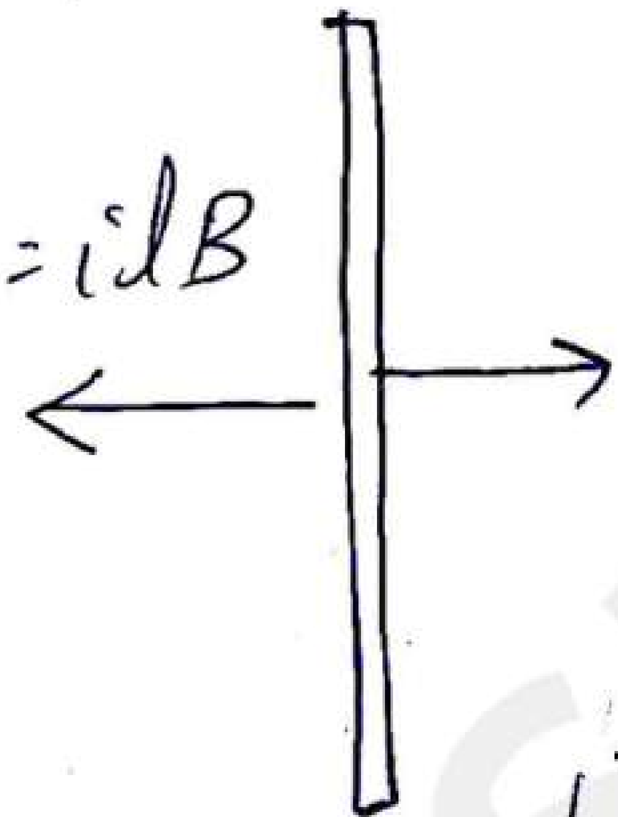
Hence acts as battery

or $\phi = BA$

$$\Rightarrow \mathcal{E} = \frac{d\phi}{dt} = \frac{d(Blx)}{dt} = \underline{\underline{Blv}}$$

emf induced

$$i = \frac{Blv}{R}$$



$$F_B = ilB$$

$$F_{ext} = -F_B$$

magnetic force ⊥ charge particle motion

do not provide energy to charge particle

$$\boxed{F_{ext} = \left(\frac{Blv}{R}\right) lB}$$

$$\boxed{P_{ext} = Fv = \left(\frac{B^2 l^2 v^2}{R}\right)}$$

$$P_{diss} = i^2 R = \frac{B^2 l^2 v^2}{R}$$

energy/sec dissipated

power loss

$$\Rightarrow \boxed{P_{ext} = P_{diss}}$$

External Energy/sec provided

Energy Conservation

Induced Emf

If $\vec{B}$ is not changing

Emf is induced by motion of conductor
→ motional emf

No Induced $\vec{E}$-fied

If $\vec{B}$ is changing

because of $\vec{E}$-field induced is emf produced

Induced $\vec{E}$-field

* Motional emf and Induced $\vec{E}$-field Are two different phenomena

But faraday's combine it to

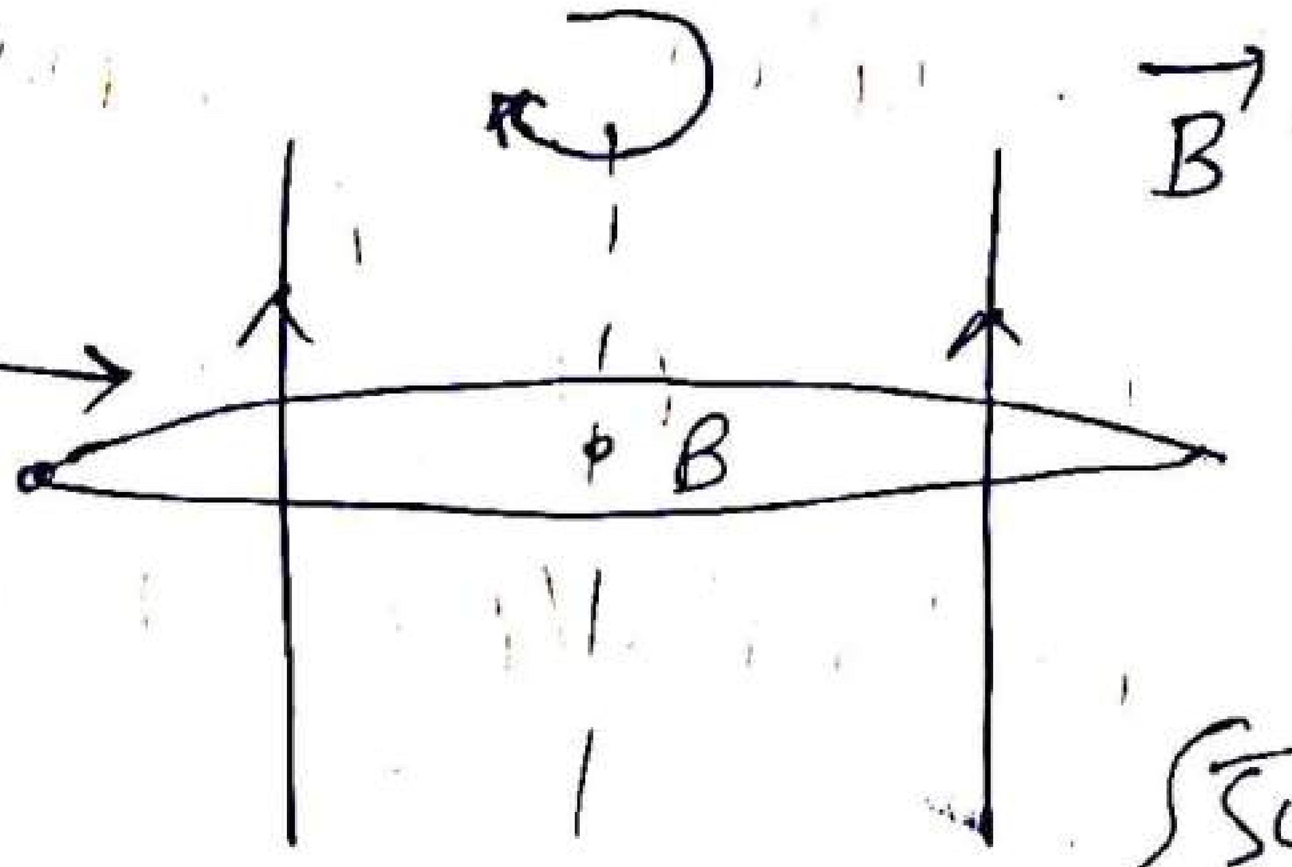
$$\boxed{Emf = \frac{-d\phi}{dt}}$$

valid for most cases

It's an observation not a law

but not true for all

It can be explained by motional emf

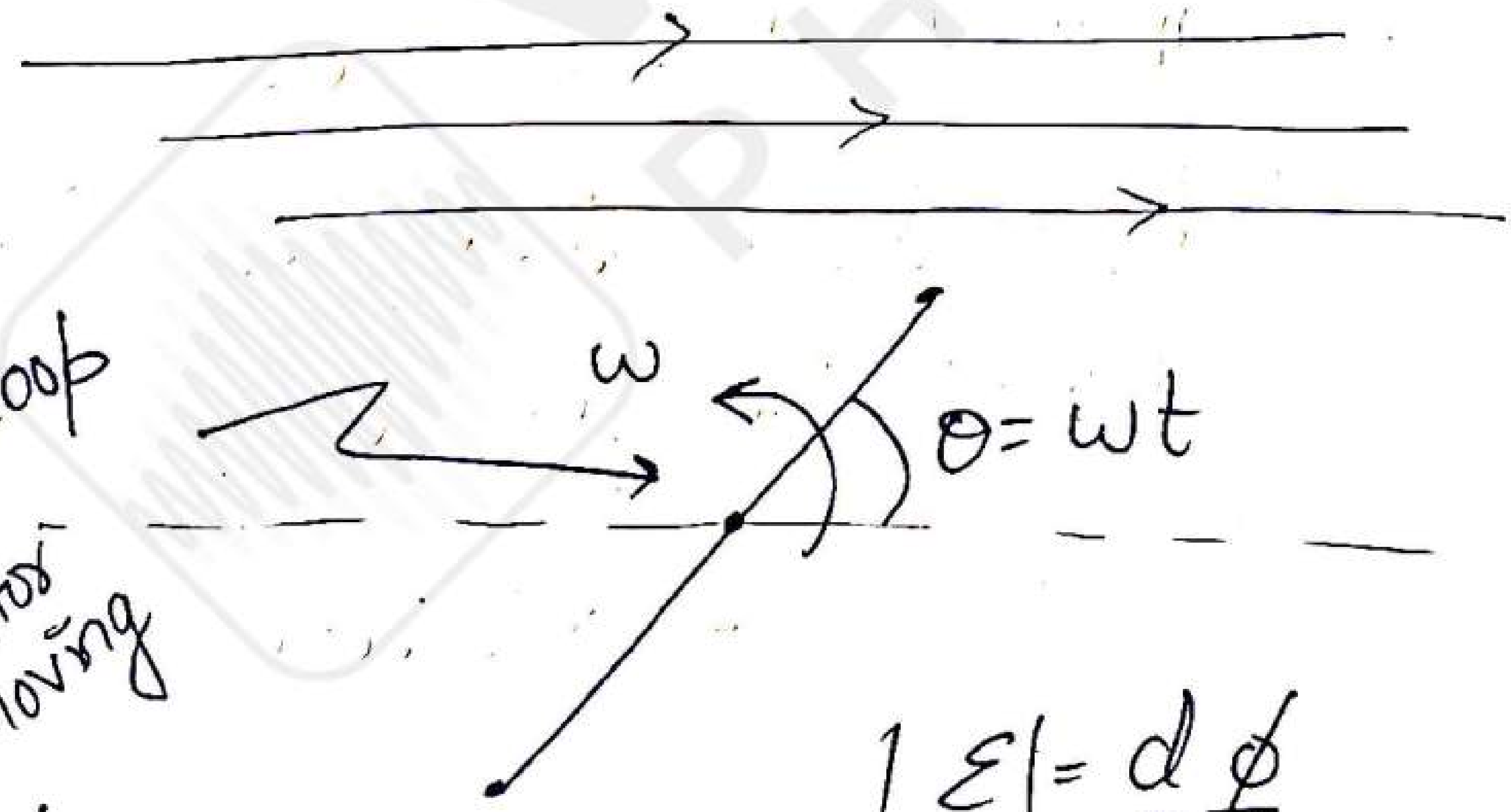


as ϕ is not changing

So Emf between A & B should be zero from faraday law

As $Emf = -\frac{d\phi}{dt}$

but this is not true



As conductor is moving

$$\phi = BA\sin\theta$$

$$\phi = BA\sin\omega t$$

$$|\mathcal{E}| = \frac{d\phi}{dt}$$

$$\Rightarrow \boxed{\mathcal{E} = BA\omega\cos\omega t}$$

Here motional emf is responsible for induced emf for general situation

Initial condition

$$\phi = BA\sin(\theta + \phi)$$

$$\Rightarrow \quad \mathcal{E} = BA\omega\cos(\theta + \phi)$$

maximum value of emf

when, $\boxed{\theta + \phi = 0}$

means $\vec{A}$ is $\perp$ to $\vec{B}$.