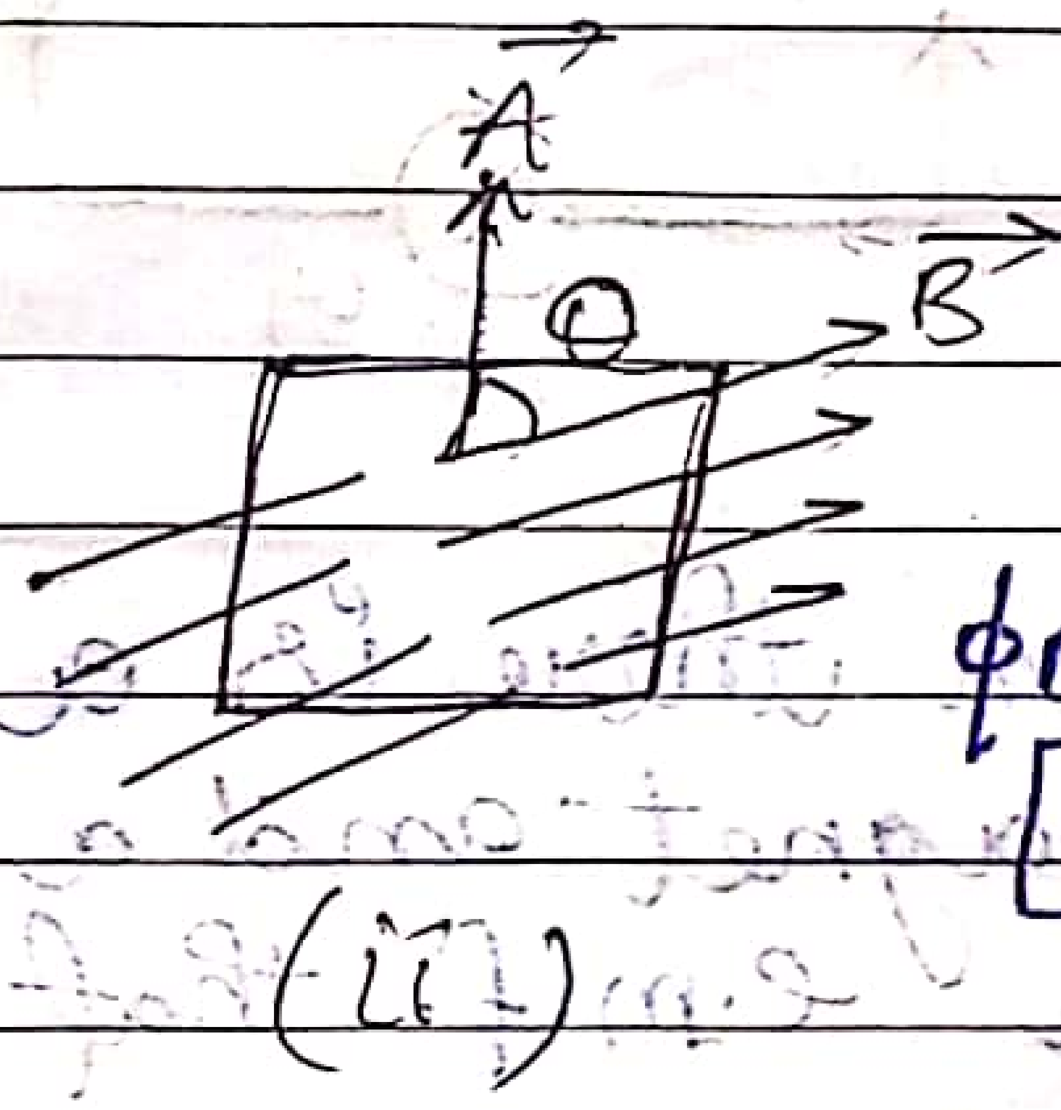
Electro Magnetic Induction

Magnetic flux – The total number of magnetic field lines crossing through any surface normally when it is placed in a magnetic field is known as the magnetic flux of that surface.

$[\phi_B = BA]$

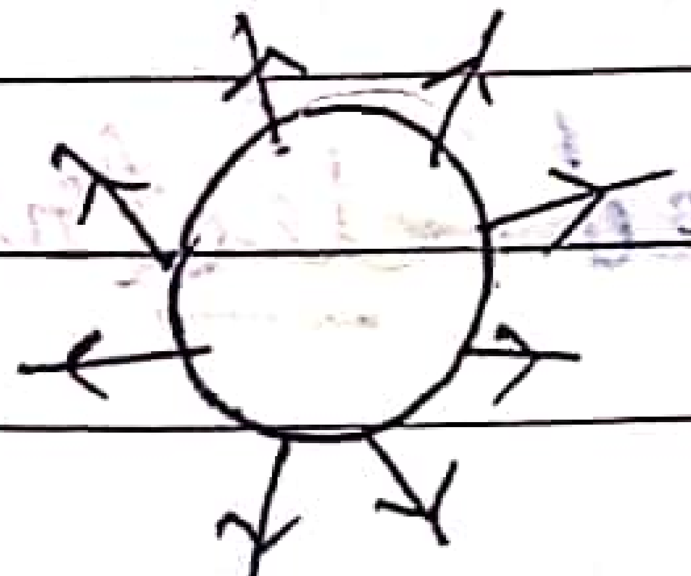
(i)



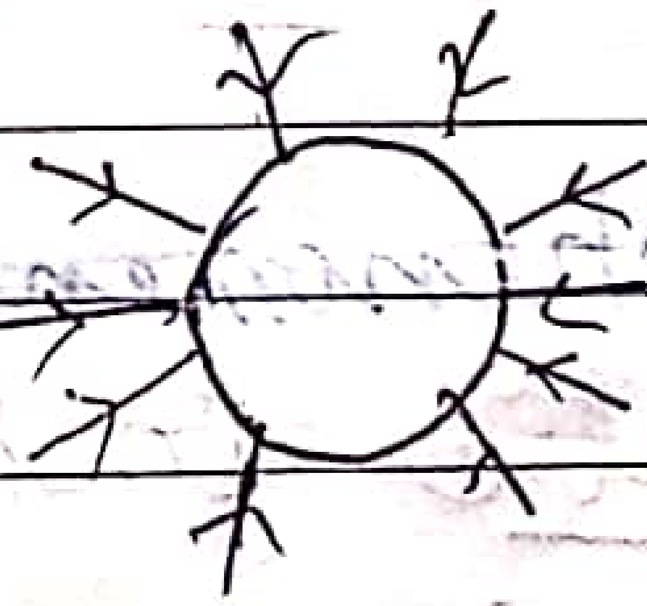
$\phi_B = \vec{B} \cdot \vec{A}$
$[= BA\sin\theta]$

(ii)

It is a scalar quantity. Its S.I unit is $T\text{-}m^2$ or "weber".

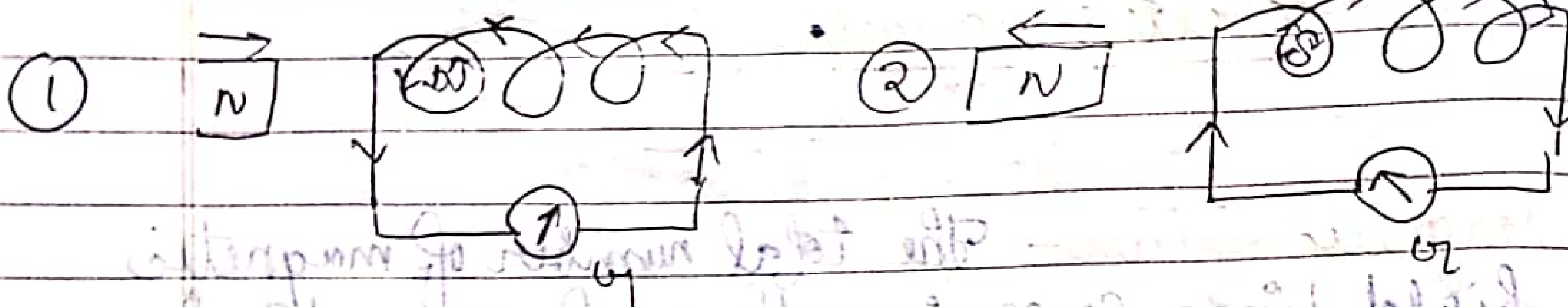


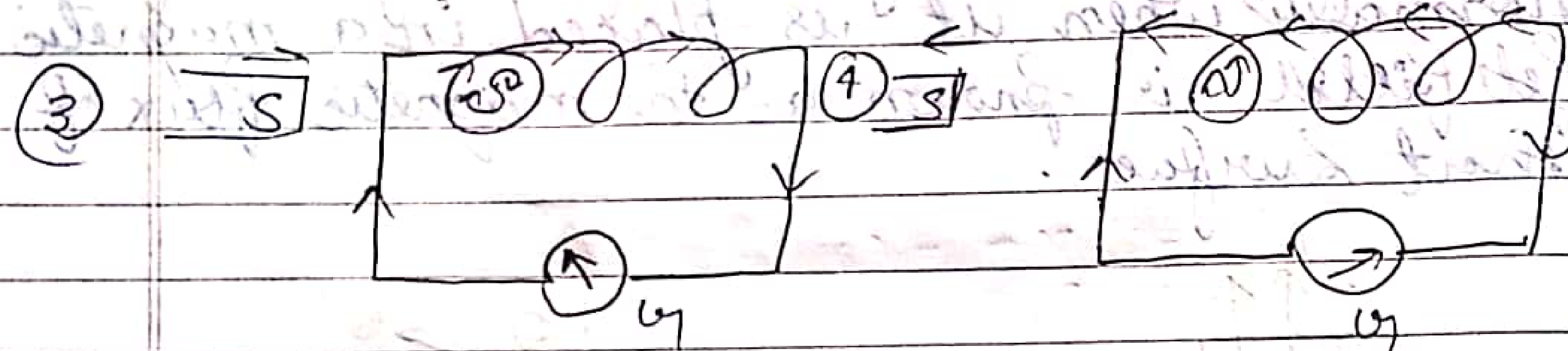
$[\phi_B = +ve]$



$[\phi_B = -ve]$

Electromagnetic Induction





A when there is a relative motion b/w a magnet and a coil there induced an e.m.f. that is called induced Emf

If the coil is closed hey there is flowing an electric current that is called induced current

This phenomenon is called electro-magnetic induction

★ Faraday's Laws of electro magnetic Induction

For electromagnetic induction Faraday's given two laws—

1. 1st Law — Whenever the amount of magnetic flux linked with circuit changes an

emf is induced in it.

→ Lentz Law
2. 2nd Law - The magnitude of induced emf in a circuit is equal to the ~~weight~~ /rate of change of magnetic flux through the circuit i.e -

$$e = -\frac{d\phi_B}{dt}$$

If there are N number of turns then

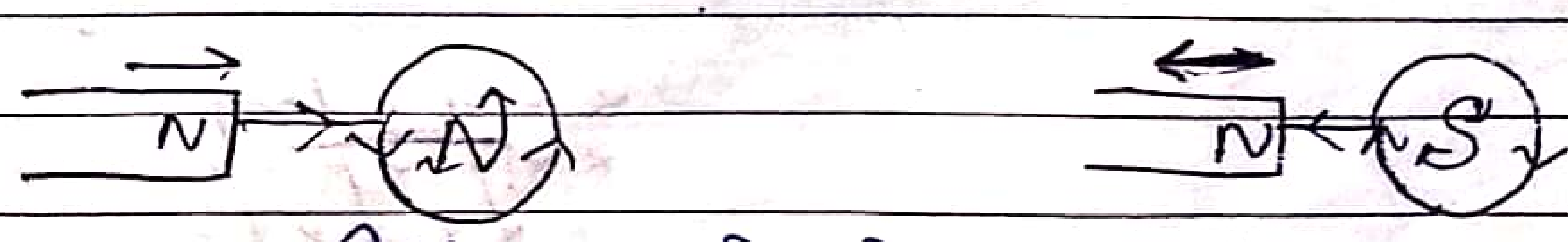
$$e = -N\frac{d\phi_B}{dt}$$

$$e = -\frac{d(N\phi_B)}{dt}$$

NOTE → The minus sign indicates that the direction of induced emf is such that it always apposes the change in magnetic flux.

Lenz's Law

According to this law the polarity of induced emf is such that it tends to produce a current which apposes the change in magnetic flux that produced in.



Lenz Law follows the Conservation Law of energy.

Induced Charge And Induced Current

If N is the number of turns & R is the resistance of a coil then-

$$\text{induced emf } (e) = -N\frac{d\phi_B}{dt}$$

Induced current

$$i = \frac{e}{R} = \frac{N\,d\phi_B}{R\,dt}$$

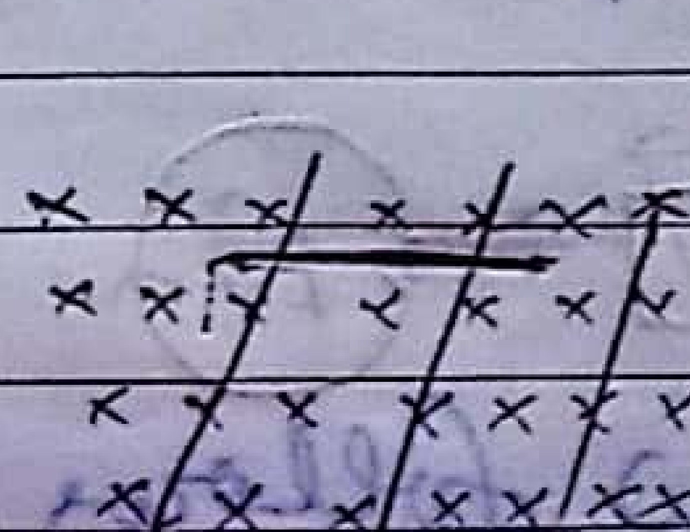
$$\left[\, i = \frac{N}{R}\frac{d\phi_B}{dt} \,\right]$$

Induced ~~Current~~ Charge

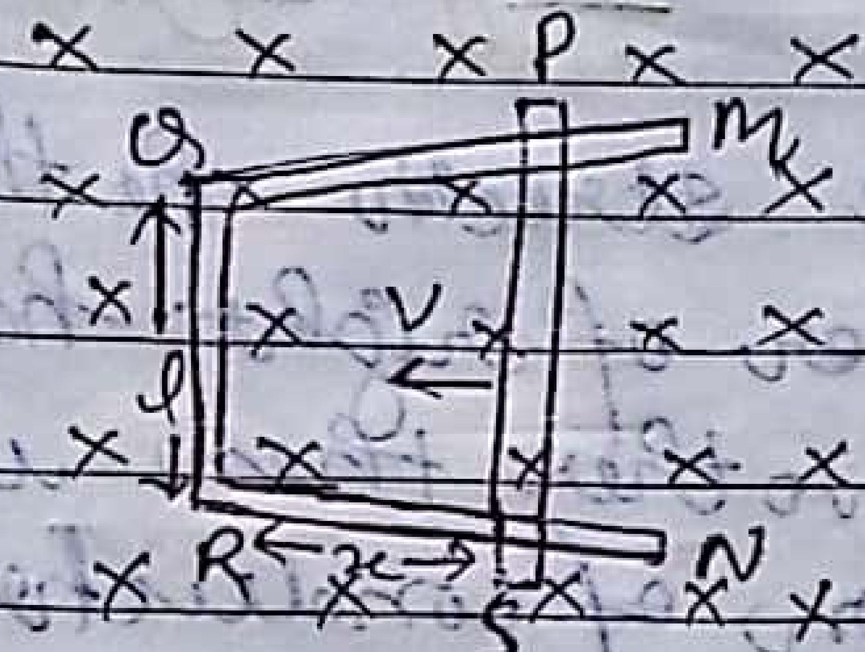
$$q = i\,dt = \frac{N}{R}\frac{d\phi_B}{dt} \times dt$$

$$\left[\, q = \frac{N}{R}\,d\phi_B \,\right]$$

✓ Motional electromotive Force



Let us consider a rectangular conductor PQRS in which the conductor PQ is free to move, it is putting in uniform magnetic field B



The rod PQ is moved ~~over~~ the towards the left with a velocity v.

the induced emf :—

$$e = \frac{d\phi_B}{dt} \quad \text{—①}$$

Let RS = S and QR = l Then magnetic flux in closed in PQRS

$$\phi_B = B.A$$

$$\phi_B = B \times (l \times x)$$

differen. w.r to. 't'

$$\frac{d\phi_B}{dt} = \frac{d}{dt}\left[B \times (l \cdot x x)\right]$$

$$\frac{d\phi_B}{dt} = Bl\left(\frac{d}{dt}x\right)$$

$$= Bl(-v)$$

$$= -Blv$$

From eqn – ①

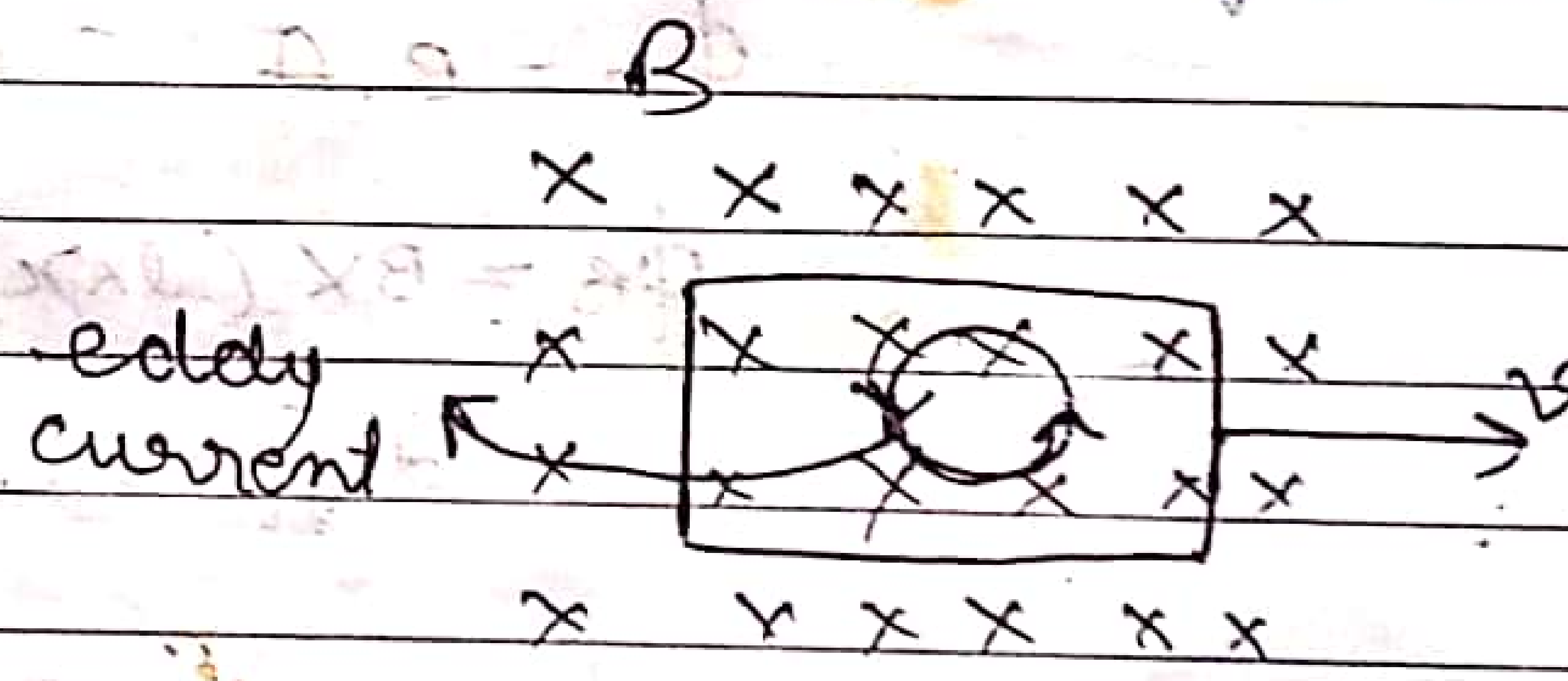
$$[e = Blv]$$

Flaming Right hand Rule

If we strecth the thumb, the forefinger & Central finger of right hand perpendicularly to each other then it thumb represent the motion of conducter & forefinger represent the direction of mgnetic field the centre finger represent the direction of induced current.

Eddy Current

The Current induced in bulk piece of Conductors when the magnetic fluse link with it changes are known as eddy current.



Effects of eddy current

Eddy currents causes unnecessary heating and wastage of power. The heat produced by eddy current may even damage the insulation of coil.

This effect can be minimise by using laminations of metals to make a metal core. This arrangement reduces the strength of eddy current.

Applications of eddy current

Eddy currents are useful in many ways for e.g. (1) Induction Furnace

In this high temperature can be produced by using eddy current when an AC current passed through the coil of furnace the eddy current generated in the metal which produces high temperature

(2) Electromagnetic damping

In order to immedietly bringing the moving coil of a Galvanometer to rest we make the use of electromagnetic daping which uses eddy current to brings the coil in rest.

Inductance

There are two type of inductance.

(1) Self Inductance
When the emf is induced in a single isolated coil due to change of flux

through the coil by means of varying the current through the same coil. This phenomenon is called Self Inductance

★ Cofficient of self inductance

Let us consider a coil of N turns carrying a current I

Let ϕ_B is the magnetic flux bounded by every turn then then —

$N\phi_B$ is called flux linkages

[Flux linkages ∝ current] Inductance Rule

$$N\phi_B \propto I$$

$$N\phi_B = LI$$

where L is a constant it is called Cofficient of self ~~inductance~~ induction or self inductance

$$\left[L = \frac{N\phi_B}{I} \right]$$

The unit of self inductance is weber/Am it is called Henary (H)

$$1 mH = 10^{-3} H$$

$$1 \mu H = 10^{-6} H$$

If $I = 1$ ampere
then $\left[L = N\phi_B \right]$

★ "The self inductance of a coil is numerically equal to the number of magnetic flux linkages with the coil when unit current is flowing through the coil."

According to Faraday's law

$$e = -N \frac{\Delta \phi_B}{\Delta t}$$

$$e = -\frac{\Delta (N\phi_B)}{\Delta t}$$

$$\because N\phi_B = LI$$

$$e = -\frac{\Delta (LI)}{\Delta t}$$

$$e = -L\left(\frac{\Delta I}{\Delta t}\right)$$

$$\left[L = -\frac{e}{\left(\frac{\Delta I}{\Delta t}\right)} \right]$$

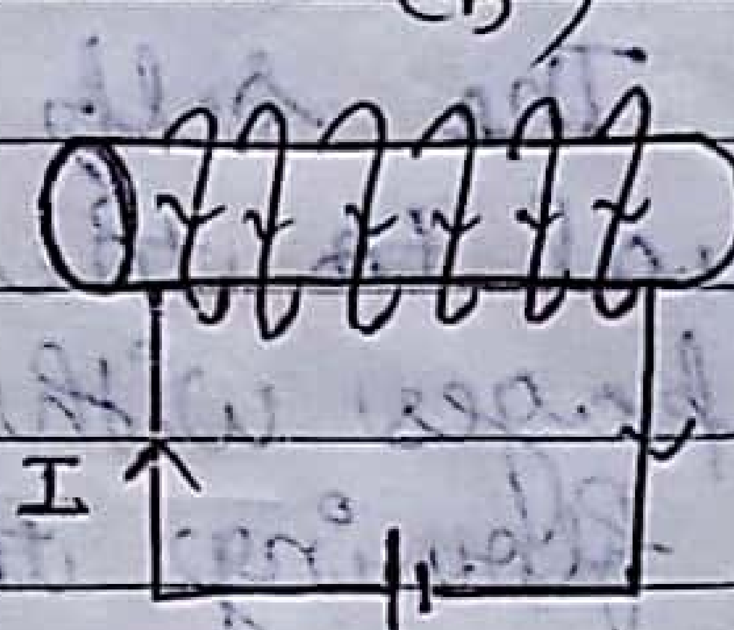
If $\frac{\Delta I}{\Delta t} = 1$

$$\boxed{e = L}$$

★ "The self inductance of a coil is numerically equal to the induced emf in the coil when the rate of flow of current in coil is unit."

Self inductance of a Solenoid

Length = l
No. of turns = N
Area of cross section = A
The current in Solenoid = I



The magnetic field inside the Solenoid.

$$B = \mu_0 n I \quad \text{where } n = \frac{N}{l}$$

$$B = \mu_0 \frac{N}{l} I$$

$$\phi_B = BA$$
$$\phi_B = \mu_0 \frac{N}{l} I A$$

Flux linkage to the Solenoid

$$N\phi_B$$
$$= N \times \mu_0 \frac{N}{l} I A$$
$$N\phi_B = \mu_0 \frac{N^2}{l} I A \quad -(1)$$

$$\because N\phi_B = LI \quad -(2)$$

from eqn (1) & (2)

$$L I = \mu_0 \frac{n^2}{l} I A$$

$$L = \frac{\mu_0 n^2 A}{l}$$

Energy Store in an inductor

The self induced emf is called back emf also because it apposes any change in the current in the circuit.

The work need to be done against the back emf in establishing the current this work done is stored as potential energy in inductor.

$W = qe$

$I = \frac{q}{t}$

$\frac{dq}{dt} \times e$

$$\frac{dW}{dt} = eI$$

$$\therefore e = L\frac{dI}{dt}$$

$$\frac{dW}{dt} = LI\frac{dI}{dt}$$

$dw = LI\,dI$

The total workdone in establishing current from $0 \rightarrow I$

$$W = \int_0^I dw = \int_0^I LI \cdot dI$$

$$= L\left[\frac{I^2}{2}\right]_0^I$$

$$\boxed{u = \frac{1}{2} L I^2}$$

Mutual Inductance

The Phenomenon according to which an emf. is produced in secondary coil when we change the current in Primary coil is called mutual inductance.

Cofficient of mutual induction
OR
Mutual inductance

Let a current I_1 flows in primary coil due to which the magnetic flux linked with each turns of secondary coil is ϕ_2. Let the total No. of turns in secondary coil is N_2

$$N_2 \phi_2 \propto I_1$$

$$N_2 \phi_2 = M I_1$$

where M is a Constant
it is called mutual inductance b/w two coils

$$\left[M = \frac{N_2 \phi_2}{I_1} \right]$$

If $I_1 = 1$
Then $\left[M = N_2 \phi_2 \right]$

" The mutual inductance b/w two coils will be equal to the flux linkages in Secondary coil when unit current is flow in Primary coil."

* According to Farady's Law inducedemf -

$$e = - M \frac{\Delta \phi_2}{\Delta t}$$

$$e = - \frac{\Delta (N_2 \phi_2)}{\Delta t} \qquad N_2 \phi_2 = M I_1$$

$$e = - \frac{\Delta (M I_1)}{\Delta t}$$

$$e = - M \left(\frac{\Delta I_1}{\Delta t} \right)$$

$$\left[M = - \frac{e}{\left(\frac{\Delta I_1}{\Delta t} \right)} \right]$$

If $\frac{\Delta I_1}{\Delta t} = 1$ amp/sec

$$[M = e]$$

"The mutual inductance b/w two coils will be equal to the induced emf in secondary coil when the rate of change of current in primary coil is unit."

The SI unit of Mutual inductance is Henary.

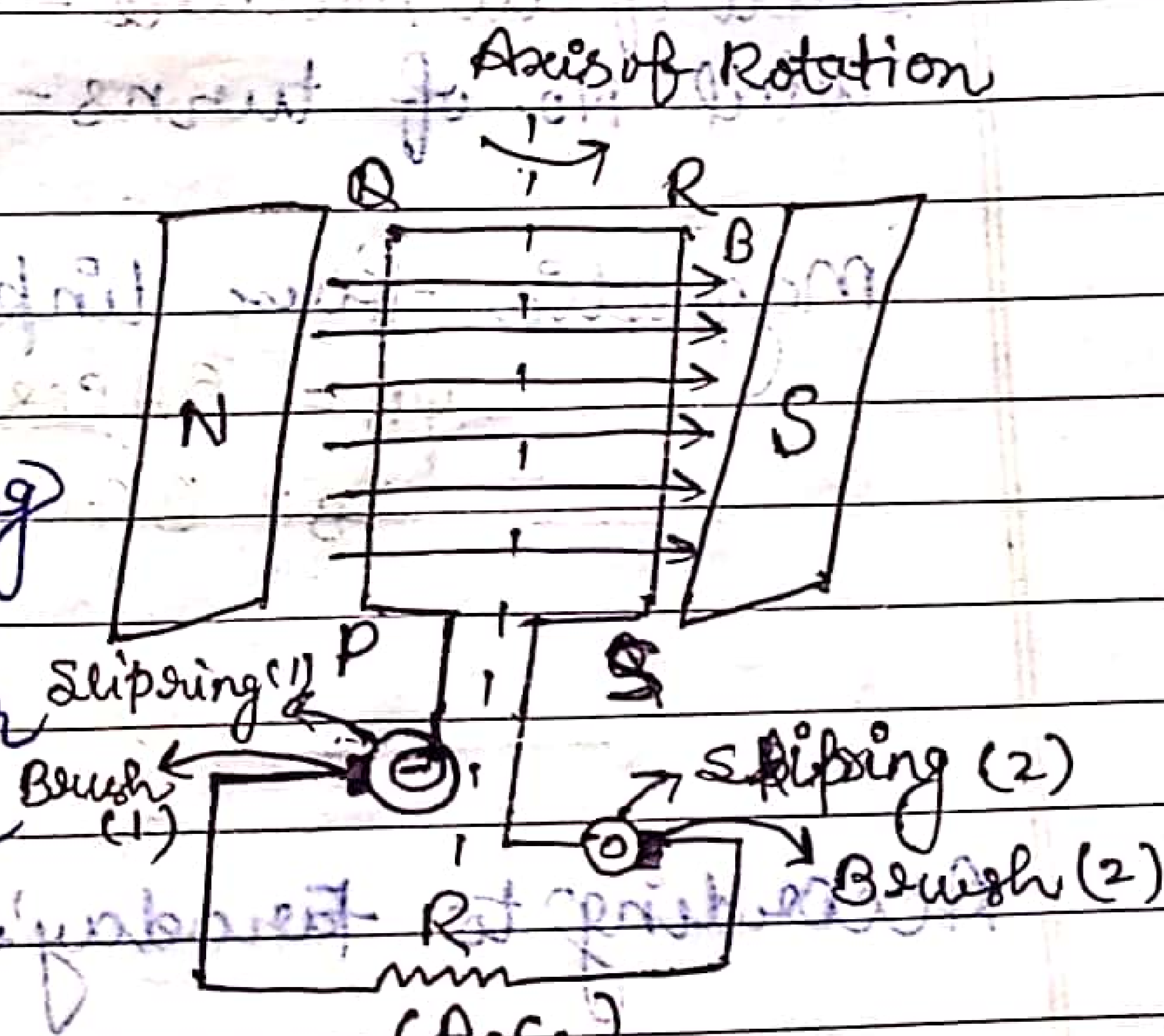
Alternating Current (AC)

AC Generator.

AC generator is a device which produce electrical energy from mechanical work.

Principle –
It is based on the phenomenon magnetic induction according to which whenever magnetic flux linked with a conductor or coil changes and emf is induced in the coil.

Construction –



1. Armature
A rectangular coil PQRS consisting of a large number of turns of copper wire wound over a soft iron core i.e. called Armature.

2. Field magnet

There are two poles of a strong electromagnet

3. Slip ring

The ends of coil are connected to ~~follow~~ two hollow metallic rings 1 and 2

4. Brushes:

There are two flexible metal plates i.e. called brushes and it kept in contact with slidding ring.

Working

Let the intensity of magnetic field = B
Area of armature = A
Total No. of turns = N

Magnetic flux linked with armature:

$$\phi_B = BA\cos\theta$$

$$\phi_B = BA\cos\omega t$$

$\because \theta = \omega t$

where ω is angular velocity

According to Faraday's law the e.m.f induced:

$$e = -N\frac{d\phi_B}{dt}$$

$$e = -N\frac{d}{dt}(BA\cos\omega t)$$

$$e = -N\times(-BA\sin\omega t)\times\omega$$

$$e = NBA\omega\sin\omega t.$$

∵ Maximum value of $\sin \omega t = \pm 1$

$e_0 = NBA\omega$ (is the maximum value of induced emf)

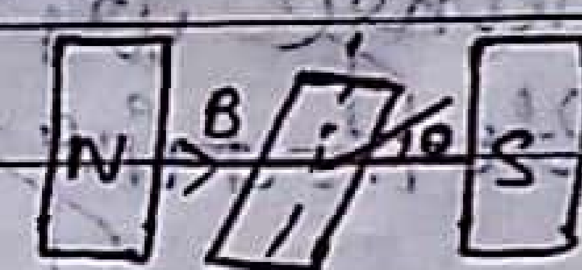
therefore

$$[e = e_0 \sin \omega t]$$

i. When the armature is placed ⊥ to the magnetic field then, $\omega t = 0$

when $\theta = 0$

$[e = 0]$



ii. When $\theta = 90°$

i.e. armature rotate $1/4$th

$[e = + e_0]$

iii. When $\theta = \omega t = 180°$

i.e. armature rotate $1/2$ rotation

$[e = 0]$

iv. When $\theta = \omega t = 270°$

i.e. armature rotate $3/4$th

$[e = - e_0]$

v. When $\theta = \omega t = 360°$

i.e. armature rotate complete rotation

$[e = 0]$