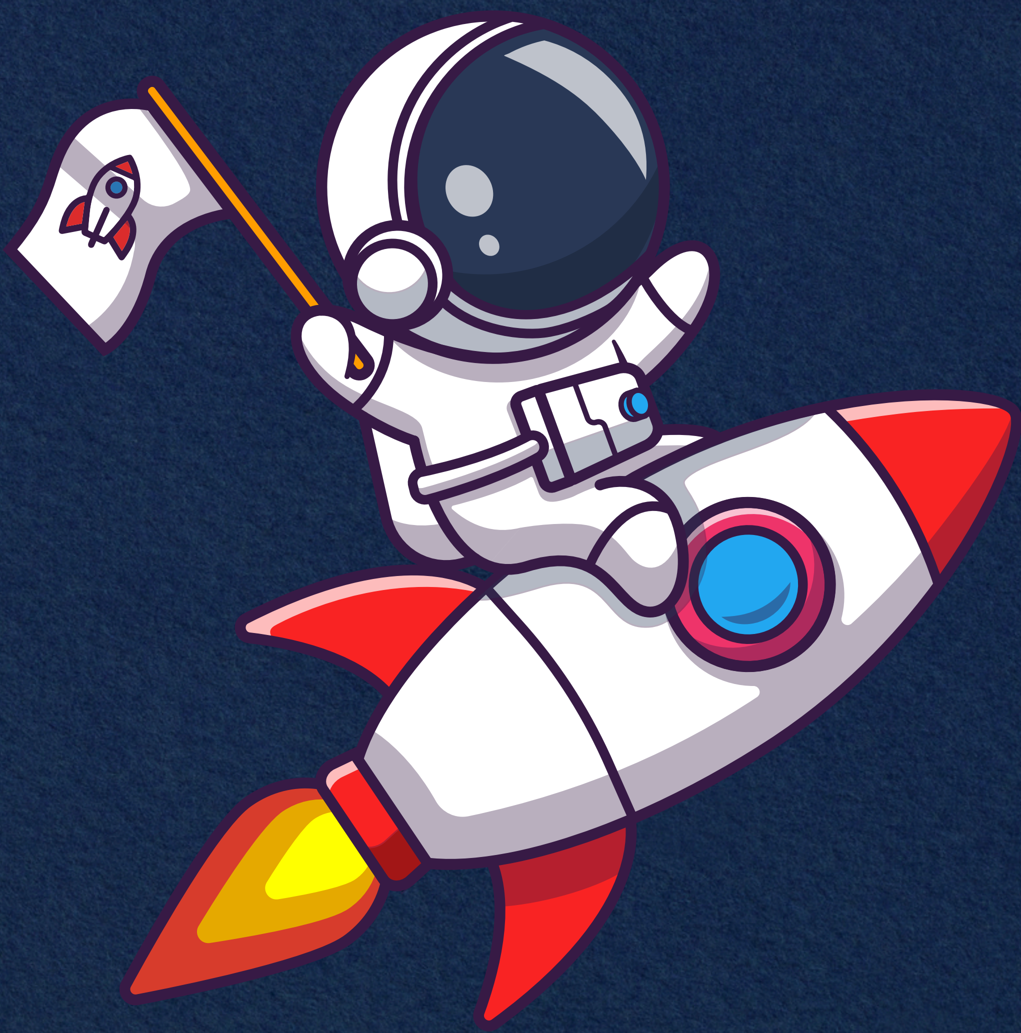
Class 12

# PHYSICS

## SHORT NOTES



# Chapter-6

# Electromagnetic Induction

★. Electromagnetic Induction :- (EMI)

The phenomena of generating current and E.M.F by changing magnetic fields is called E.M.I.

→ The current produced by electromagnetic induction is called Induced current.

→ Many devices like generators, dynamos, and transformer works on this principle.

★. Magnetic flux ($\phi$) :-

The number of magnetic field lines passing perpendicular through a surface is called magnetic flux.

→ Scalar quantity.

$$\phi_B = \vec{B} \cdot \vec{A}$$

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

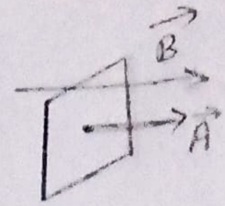
where $\vec{A}$ is Area vector

→ Unit :- Tesla Meter$^2$ ($Tm^2$) or Weber (Wb)

→ Dimensional formula :- $[M^1L^2T^{-2}A^{-1}]$

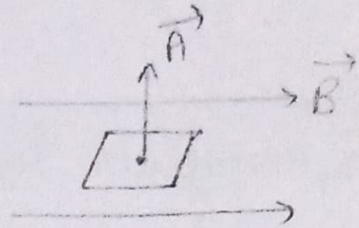
Case-I :- If $\theta = 0°$ ($\vec{B} \parallel \vec{A}$)

$$\boxed{\phi_B = BA}$$ (Maximum).




Case-II :- If $\theta = 90°$ ($\vec{B} \perp \vec{A}$)

$$\boxed{\phi_B = 0}$$ (Min.)




**Note :-**

$\phi$ is taken positive if field lines come outward.
$\phi$ is taken negative if field lines are inward.

* for Non-uniform surface area :-

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

**Note :-**

→ Magnetic field due to a closed loop is always zero.

$$\boxed{\phi_{closed} = \oint \vec{B}.d\vec{A} = 0}$$



A. Faraday & Henry Experiment :-

- Experiment - 1 :- (Current induced by a magnet)
Relative motion b/w coil and magnet is responsible for induction of current.

- Experiment - 2 :- (Current induced by coil)
Relative motion b/w coil and coil is responsible for induction of current.

- Experiment - 3 :- (Current induced by changing current)
Due to change in current in coil B, magnetic field also change is which causes deflection in galvanometer.

• Conclusion :- (cause of induced EMF)

→ All experiment shows that induced emf and current appears in a coil due to change in amount of magnetic flux linked with the coil.

## ★. Faraday's Law of EMI :-

① Faraday's first law :- whenever the amount of magnetic flux linked with circuit changes then an e.m.f is induced in the circuit.

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② Faraday's 2nd Law :- According to this, "the magnitude of induced e.m.f in a circuit is directly proportional to the rate of change in magnetic flux linked with the circuit.

Induced e.m.f :- $e = -N\frac{d\phi}{dt}$

Induced current :- $I = -\frac{N}{R}\frac{d\phi}{dt}$

Induced charge :- $dQ = -\frac{N}{R}d\phi$

→ E.M.F depends on flux rate of change.

→ Induced charge does not depend on time.

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## ★. LENZ's Law :-

According to this, "the direction of induced e.m.f or induced current in coil is always produced in such a way that it opposes the cause by which it is produced.

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

Here, -ve sign shows that induced e.m.f opposes the rate of change in flux.

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## ✯ Lenz law in accordance with law of conservation of energy :-

→ Lenz law follows conservation of Energy.

→ When magnet is allow to move or away towards coil, then work done to move magnet remains equal to the total electrical energy produced in coil.

$$E_{initial} = E_{final}$$

## ✯ Note :-




- Fleming's Right Hand rule :-

  Hand → Motion of conductor
  fore finger → Magnetic field
  Middle finger → Induced current.

2018

## ✯ Motional E.M.F :-

$$e = Blv$$

- Special Case :-

  If Rod moves at any angle $\theta$.

$$e = Blv \sin\theta$$

$$e = (\vec{V} \times \vec{B}) . l$$

★ Motional emf can also be understand by using Lorentz force :-

Induced e.m.f :- $e = BVl$

$e = (\vec{V} \times \vec{B}) \cdot \vec{l}$

Induced current : $I = \frac{BVl}{R}$

**Note :-**

If any two terms among $\vec{B}$, $\vec{V}$ & $\vec{l}$ are parallel then e.m.f = 0.

★ Rotational E.m.f (Rotation of a rod in a magnetic field) :-

$e = \frac{1}{2} B \omega l^2$ — ω is angular velocity

→ E.m.f depends on B, ω and length 'l'.

★ Note :-

① Let a metallic wheel with spokes. Each spoke is of 'l' length.

$e = \frac{1}{2} B \omega l^2$

② Induced e.m.f for mettalic disc :-

$e = \frac{1}{2} B \omega l^2$

## ☆. Self Induction :-

Self induction is the phenomenon in which change in the magnetic flux associated with a coil induces an emf in same coil.

→ **Principle :-**

According to lenz's law, the induced emf opposes the change in magnetic flux causing it.

→ **Formulas :-**

Magnetic flux $\boxed{\phi = LI}$

Self Inductance coefficient :- $\boxed{L = \frac{\phi}{I}}$  Unit → $\frac{\text{Weber}}{\text{Ampere}}$ = Henry (H) $[M^1 L^2 T^{-2} A^{-2}]$

Induced emf :- $\boxed{e = -L\frac{dI}{dt}}$

• **Cofficient of Self Inductance :-**

If rate of change in current is 1 A/s then total induced e.m.f is called self inductance.

$\boxed{e = L}$  $\left(\text{If } \frac{dI}{dt} = 1\right)$

→ Scalar quantity.

2013 RBSE

☆. **Note :-**

→ Self Inductance depends on :-

① Number of turns

② cross sectional area

③ Nature of material of coil.

## ★ Self Inductance of a Solenoid :-

Supp. 2016 RBSE

$$L = \frac{\mu_0 N^2 \pi R^2}{l}$$ (Forvaccum)

$$L = \frac{\mu_0 \mu_r N^2 A}{l}$$ (For any other material)

## ★ Magnetic energy in an inductor :-

$$U = W = \frac{1}{2} L I^2$$

## ★ Note :-

(RBSE 2024)

→ Self Inductance plays role of inertia because it resists any change in the current like inertia resists change in motion. This is due to induced emf opposing variation in current, similar to how inertia opposes acceleration.

## ★ Mutual Inductance :-

The phenomenon of producing induced EMF in a secondary coil due to a change in magnetic flux caused by a current change in the primary coil is called Mutual Inductance.

• Formula :-

Cofficient of Mutual Inductance :- $$M = \frac{\phi_2}{I_1}$$ unit = $\frac{\text{weber}}{\text{Ampere}}$ = Henry (H)

Induced emf :- $$e_2 = -\frac{d\phi_2}{dt} = -M\frac{dI_1}{dt}$$

where $\phi_2$ = magnetic flux in secondary coil

$I_1$ = Current in Primary coil

## Cofficient of Mutual Inductance:-

flux produced in secondary coil is directly perportional to change in current in primary coil.

**Note:-**

M depends on →

1. Number of turns in coils
2. Size and shape of coil (Area)
3. Distance b/w the coil
4. Medium b/w coils

RBSE 2014

## ☆ Mutual Inductance b/w two co-axial solenoids:-

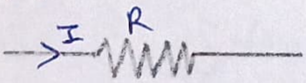
$$M = \frac{\mu_0 N_1 N_2 A}{l}$$ For air or vaccum

$$M = \frac{\mu_0 \mu_r N_1 N_2 A}{l}$$ for other medium.

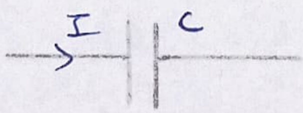
## ☆ Cofficient of Coupling:-

$$K = \frac{\phi_s}{\phi_p} = \frac{M}{\sqrt{L_1 L_2}}$$

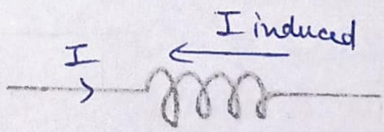
**☆ Note:-**




$\Delta V = IR$




$\Delta V = \frac{q}{C}$




$\Delta V = -L\frac{dI}{dt}$

# A.C Generator :-

2020, 2016, 2013 RBSE

→ The instrument which converts mechanical energy in the form of alternating current.

• Principle :-

It works on Electromagnetic Induction

• Parts :-

① field Magnet (S & N Pole)
② Armature (ABCD) (coil)
③ Slip rings ($C_1$ & $C_2$)
④ Brushes ($B_1$ & $B_2$)

→ If coil is at any angle θ with magnetic field.

So,

Magnetic flux :- $\phi = NBA \cos \omega t$

Induced emf :- $e = e_0 \sin \omega t$

$e = e_0 \sin(2\pi f t)$ where $e_0 = NBA\omega$ (constant)

• Variation of emf with resp of time (t) :-

| t → | t = 0 | t = T/4 | t = T/2 | t = 3T/4 | t = T |
|---|---|---|---|---|---|
| θ → | 0 | π/2 | π | 3π/2 | 2π |
| e → | 0 | $e_0$ | 0 | $-e_0$ | 0 |