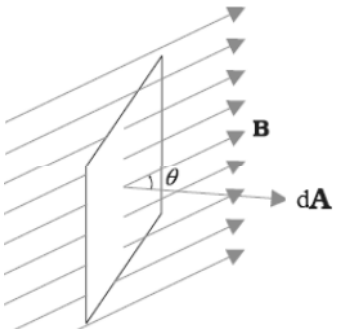
CBSE Class-12 Physics Quick Revision Notes
Chapter-06: Electromagnetic Induction

- **Magnetic Flux:**
  Magnetic flux through a plane of area dA placed in a uniform magnetic field B



  $$\phi = \int \vec{B}.d\vec{A}$$
  If the surface is closed, then
  $$\phi = \int \vec{B}.d\vec{A}$$
  This is because magnetic lines of force are closed lines and free magnetic poles do not exist.
- **Faraday's Law:**
  a) First Law: whenever there is a change in the magnetic flux linked with a circuit with time, an induced emf is produced in the circuit which lasts as long as the change in magnetic flux continues.
  b) Second Law: According to this law,
  Induced emf, $E \propto \left(\frac{d\phi}{dt}\right)$
- **Lenz's Law:**
  The direction of the induced emf or current in the circuit is such that it opposes the cause due to which it is produced, so that,
  $$E = -N\left(\frac{d\phi}{dt}\right)$$
  Where N is the number of turns in coil
  Lenz's law is based on energy conservation.
- **Induced EMF and Induced Current:**
  a) Induced EMF,
  $$E = -N\frac{d\phi}{dt}$$
  $$= -\frac{N(\phi_2 - \phi_1)}{t}$$
  b) Induced current,
  $$I = \frac{E}{R} = -\frac{N}{R}\left(\frac{d\phi}{dt}\right)$$
  $$= -\frac{N}{R}\frac{(\phi_2 - \phi_1)}{t}$$
  Charge depends only on net change in flux does not depends on time.
- **Induced Emf due to Linear Motion of a Conducting Rod in a Uniform Magnetic Field**
  The induced emf,

$$E = -\vec{l}.(\vec{v} x \vec{B})$$

If $\vec{e}, \vec{v}$ *and* $\vec{B}$ are perpendicular to each other, then

$$E = Bvl$$

- **Induced EMF due to Rotation of a Conducting Rod in a Uniform Magnetic Field:**

The induced emf,

$$E = \frac{1}{2} B\omega l^2 = B\pi n l^2 = BAn$$

Where n is the frequency of rotation of the conducting rod.

- **Induced EMF due to Rotation of a Metallic Disc in a Uniform Magnetic Field:**

$$E_{OA} = \frac{1}{2} B\omega R^2 = B\pi R^2 n = BAn$$

- **Induced EMF, Current and Energy Conservation in a Rectangular Loop Moving in a Non – Uniform Magnetic Field with a Constant Velocity:**

a) The net increase in flux crossing through the coil in time Δt is,

$$\Delta\phi = (B_2 - B_1) lv\Delta t$$

b) Induced emf in the coil is,

$$E = (B_1 - B_2) lv$$

c) If the resistance of the coil is R, then the induced current in the coil is,

$$I = \frac{E}{R} = \frac{(B_1 - B_2)}{R} lv$$

d) Resultant force acting on the coil is

$$F = Il(B_1 - B_2)(\text{ towards left})$$

e) The work done against the resultant force

$$W = (B_1 - B_2)^2 \frac{l^2 v^2}{R} \Delta t \text{ joule}$$

Energy supplied in this process appears in the form of heat energy in the circuit.

f) Energy supplied due to flow of current I in time Δt is,

$$H = I^2 R\Delta t$$

$$Or\ H = (B_1 - B_2)^2 \frac{l^2 v^2}{R} \Delta t \text{ joule}$$

Or H = W

- **Rotation of Rectangular Coil in a Uniform Magnetic Field:**

a) Magnetic flux linked with coil

$$\phi = BAN \cos\theta$$

=BAN cosωt

b) Induced emf in the coil

$$E = \frac{d\phi}{dt} = BAN\omega \sin \omega t = E_0 \sin \omega t$$

c) Induced current in the coil.

$$I = \frac{E}{R} = \frac{BAN\omega}{R}\sin\omega t$$

$$= \frac{E_0}{R}\sin\omega t$$

d) Both Emf and current induced in the coil are alternating

- **Self-Induction and Self Inductance:**

a) The phenomenon in which an induced emf is produced by changing the current in a coil is called self in induction.

$$\phi \propto I \text{ or } \phi = LI$$

$$or \text{ L}=\frac{\phi}{I}$$

$$E = -L\frac{dI}{dt}$$

$$L = \frac{E}{-(dI/dt)}$$

where L is a constant, called self inductance or coefficient of self – induction.

b) Self inductance of a circular coil

$$L = \frac{\mu_0 N^2 \pi R}{2} = \frac{\mu_0 N^2 A}{2R}$$

c) Self inductance of a solenoid

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

d) Two coils of self – inductances L_1 and L_2, placed far away (i.e., without coupling) from each other.

i) For series combination:

$$L = L_1 + L_2 . \ldots . L_n$$

ii) For parallel combination:

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots . + \frac{1}{L_n}$$

- **Mutual Induction and Mutual Inductance:**

a) On changing the current in one coil, if the magnetic flux linked with a second coil changes and induced emf is produced in that coil, then this phenomenon is called mutual induction.

$$\phi_2 \propto I_1 \text{ or } \phi_2 = MI_1$$

$$\text{Or } M = \frac{\phi_2}{I_1}$$

$$E_2 = -\frac{d\phi_2}{dt} = -M\frac{dI_1}{dt}$$

$$M = \frac{E_2}{-(dI_1 / dt)}$$

Therefore, $M_{12} = M_{21} = M$

b) Mutual inductance two coaxial solenoids

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

c) If two coils of self- inductance L_1 and L_2 are wound over each other, the mutual inductance is,

$$M = K\sqrt{L_1 L_2}$$

Where K is called coupling constant.

d) Mutual inductance for two coils wound in same direction and connected in series

$$L = L_1 + L_2 + 2M$$

e) Mutual inductance for two coils wound in opposite direction and connected in series

$$L = L_1 + L_2 - 2M$$

f) Mutual inductance for two coils in parallel

$$L = \frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$$

- **Energy Stored in an Inductor:**

$$U_B = \frac{1}{2} L I^2{}_{\max}$$

- **Magnetic Energy Density:**

$$U_B = \frac{B^2}{2\mu_0}$$

- **Eddy Current:**

When a conductor is moved in a magnetic field, induced currents are generated in the whole volume of the conductor. These currents are called eddy currents.

- **Transformer:**

a) It is a device which changes the magnitude of alternating voltage or current.

$$\frac{E_s}{E_p} = \frac{n_s}{n_p} = K$$

b) For ideal transformer:

$$\frac{I_p}{I_s} = \frac{n_s}{n_p}$$

c) In an ideal transformer:

$$E_p I_p = E_s I_s$$

d) In step – up transformer:

$n_s > n_p$ or K > 1

$E_s > E_p$ and $I_s < I_p$

e) In step – down transformer:

$n_s < n_p$ or K < 1

$E_s < E_p$ and $I_s > I_p$

f) Efficiency

$$\eta = \frac{E_s I_s}{E_p I_p} x100\%$$

- **Generator or Dynamo:**

It is a device by which mechanical energy is converted into electrical energy. It is based on the principle of electromagnetic induction.

- **Different Types of Generator:**

a) AC Generator

It consists of field magnet, armature, slip rings and brushes.

b) DC Generator

It consists of field magnet, armature, commutator and brushes.

- **Motor:**

It is a device which converts electrical energy into mechanical energy.

Back emf $e \propto \omega$

Current flowing in the coil,

$$i_a = \frac{E - e_b}{R}$$

$$E = e_b + i_a R$$

Where R is the resistance of the coil.

Out put Power = $i_a e_b$

Efficiency,

$$\eta = \frac{e_b}{E} \times 100\%$$