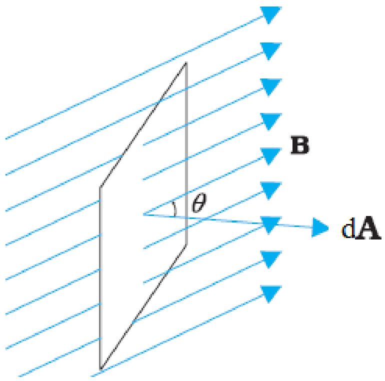
Ch: Electromagnetic Induction

Class XII Physics

Chapter Notes

Magnetic Flux

Magnetic flux through a plane of area **d*A*** placed in a uniform magnetic field **B**



$\phi = \int \vec{B}.d\vec{A}$

If the surface is closed, then

$\phi = \oint \vec{B}.\, \vec{d}.A = 0$

This is because magnetic lines of force are closed lines and free magnetic poles do not exist.

Electromagnetic Induction: 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:

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,

$E = -N\left(\frac{d\phi}{dt}\right)$

$N \rightarrow$ No. of turns in coil

Lenz's law based on energy conservation.

EMF Current and Charge Induced in the Circuit

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.

Emf Induced Due to Linear Motion of a Conducting Rod in a Uniform Magnetic Field

$$E = -\vec{\ell}.(\vec{v} \times \vec{B})$$

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

$$E = Bv\ell$$

Induced EMF Due to Rotation of a Conducting Rod in a Uniform Magnetic Field

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

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

i) Net increase in flux crossing through the coil in time Δt

$$\Delta\phi = (B_2 - B_1)\ell v \ \Delta t$$

ii) Emf induced in the coil

$$E = (B_1 - B_2)\ell v$$

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

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

iv) Resultant force acting on the coil

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

v) The work done against the resultant force

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

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

vi) Energy supplied due to flow of current I in time Δt

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

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

Or H = W

Rotation of Rectangular Coil in a Uniform Magnetic Field

a) Magnetic flux linked with coil

$$\phi = BAN\cos\theta$$
$$= BAN\cos\omega t$$

b) Emf induced in the coil

$$E = \frac{d\phi}{dt} = BA\,N\omega\sin\omega t = E_0\sin\omega t$$

c) Current induced 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 (L)

On changing the current in a coil, an induced e.m.f. is produced in the coil then the phenomenon is called self in induction

i) $\phi \propto I$ or $\phi = LI$

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

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

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

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

iii) Self inductance of a circular coil

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

iv) Self inductance of a solenoid

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

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

a For series combination:

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

b 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 e.m.f. is produced in that coil, then this phenomenon is called mutual induction.

b) $\phi_2 \propto I_1$ or $\phi_2 = MI_1$

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

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

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

d) $M_{12} = M_{21} = M$

e) Mutual inductance two coaxial solenoids

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

f) If two coils of self inductance L_1 and L_2 are wound over each other, the mutual inductance is given by

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

Where K is called coupling constant.

g) For two coils wound in same direction and connected in series

$L = L_1 + L_2 + 2M$

For two coils wound in opposite direction and connected in series

$L = L_1 + L_2 - 2M$

For two coils in parallel

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

Energy Stored in an Inductor

Energy stores in the form of M.F.

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

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.

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

c) $\frac{I_p}{I_s} = \frac{n_s}{n_p}$ (For ideal transformer)

d) In an ideal transformer:

$E_pI_p = E_sI_s$ or $P_{in} = P_{out}$

e) In step – down transformer:

$n_s > n_p$ or $K > 1$

$E_s > E_p$ and $I_s < I_p$

f) In step – down transformer:

$n_s < n_p$ or $K < 1$

$E_s < E_p$ and $I_s > I_p$

g) Efficiency $\eta = \frac{P_{out}}{P_{in}} \times 100\%$

Generator or Dynamo

It is a device by which mechanical energy is converted into electrical energy. It is based on the principle of E.M.I.

AC Generator

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

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

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

Or $E = e_b + i_a R$

Where R is the resistance of the coil.

Out put Power = $i_a e_b$

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