MASTERJEE CLASSES

ELECTROMAGNETIC INDUCTION

BRAIN MAP

CLASS XII

Combination of Inductors

- Inductors in series, $L_S = L_1 + L_2 \pm 2M$
- Inductors in parallel, $L_P = \dfrac{L_1L_2 - M^2}{L_1 + L_2 + 2M}$
- If coils are far away, then $M = 0$.

  So, $L_S = L_1 + L_2$ and $L_P = \dfrac{L_1L_2}{L_1 + L_2}$

Magnetic Energy

- Energy stored in an inductor, $U_B = \dfrac{1}{2}LI^2$
- Energy stored in the solenoid, $U_B = \dfrac{1}{2\mu_0}B^2Al$
- Magnetic energy density, $u_B = \dfrac{U_B}{V} = \dfrac{B^2}{2\mu_0}$

L–R Circuit

- Current growth in L–R circuit $I = I_0(1 - e^{\,t/\tau_L})$
- Current decay in L–R circuit, $I = I_0(e^{\,t/\tau_L})$

  Here, τ_L = Time constant = $\dfrac{L}{R}$

  $I_0 = \dfrac{\varepsilon}{R}$

Inductance

- Emf induced in the coil/conductor, $\varepsilon = -L\dfrac{dI}{dt}$
- Coefficient of self induction, $L = \dfrac{N}{I}\phi_B = \dfrac{-\varepsilon}{dI/dt}$
- Self inductance of a long solenoid, $L = \mu_0\mu_r n^2 Al = \dfrac{\mu_0\mu_r N^2 A}{l}$
- Mutual inductance, $M = \dfrac{N_2\phi_2}{I_1} = \dfrac{-\varepsilon_2}{(dI_1/dt)} = \dfrac{-\varepsilon_1}{(dI_2/dt)}$
- Mutual inductance of two long coaxial solenoids,

  $$M = \mu_0\mu_r \pi r_1^2 n_1 n_2 l = \frac{\mu_0\mu_r N_1N_2A_1}{l}$$
- Coefficient of coupling, $k = \dfrac{M}{\sqrt{L_1L_2}}$

  For perfect coupling, $k = 1$ so, $M = \sqrt{L_1L_2}$

Lenz's Law

- The direction of the induced current is such that it opposes the change that has produced it.
- If a current is induced by an increasing(decreasing) flux, it will weaken (strengthen) the original flux.
- It is a consequence of the law of conservation of energy.

Induced Electric Field

- It is produced by change in magnetic field in a region. This is non-conservative in nature.

  $$\oint \vec{E}\cdot d\vec{l} = -\frac{d\phi_B}{dt} = -A\frac{dB}{dt} \neq 0$$
- This is also known as integral form of Faraday's law.

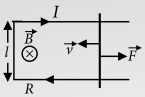
Magnetic Flux and Faraday's Law

- Magnetic flux $\phi_B = \vec{B}\cdot\vec{A} = BA\cos\theta$
- Faraday's law : Whenever magnetic flux linked with a coil changes, an emf is induced in the coil.
  - Induced emf, $\varepsilon = -N\dfrac{d\phi_B}{dt}$
  - Induced current, $I = \dfrac{\varepsilon}{R} = N\dfrac{(-d\phi_B/dt)}{R}$
  - Induced charge flow, $\Delta Q = I\Delta t = -N\dfrac{\Delta\phi_B}{R}$

Energy Consideration in Motional emf

- Emf in the wire, $\varepsilon = Bvl$
- Induced current, $I = \dfrac{\varepsilon}{R} = \dfrac{Bvl}{R}$
- Force exerted on the wire,

  $F = \dfrac{B^2l^2v}{R}$



- Power required to move the wire, $P = \dfrac{B^2l^2v^2}{R}$

  It is dissipated as Joule's heat.

Motional emf

- On a straight conducting wire, $\varepsilon = Bvl$
- On a rotating conducting wire about one end, $\varepsilon = \dfrac{B\omega l^2}{2}$

  Here, $\vec{B}, \vec{v}(=\omega r\hat{v})$ and $\vec{l}$ are perpendicular to each other.

Electric Generator

- Mechanical energy is converted into electrical energy by virtue of electro-magnetic induction.
- Induced emf,

  $\varepsilon = NAB\omega\sin\omega t = \varepsilon_0\sin\omega t$
- Induced current,

  $I = \dfrac{NBA\omega}{R}\sin\omega t = I_0\sin\omega t$

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