

ELECTROMAGNETIC INDUCTION

1. **Magnetic flux** is mathematically defined as $\phi = \int \vec{B} \cdot d\vec{s}$

2. **Faraday's laws of electromagnetic induction**

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

3. **Lenz's Law** (conservation of energy principle)

According to this law, emf will be induced in such a way that it will oppose the cause which has produced it.

Motional emf

4. **Induced emf due to rotation**

Emf induced in a conducting rod of length l rotating with angular speed ω about its one end, in a uniform perpendicular magnetic field B is $\frac{1}{2} B \omega l^2$.

1. EMF Induced in a rotating disc :

Emf between the centre and the edge of disc of radius r rotating in a

$$\text{magnetic field } B = \frac{B\omega r^2}{2}$$

5. Fixed loop in a varying magnetic field

If magnetic field changes with the rate $\frac{dB}{dt}$, electric field is generated

$$\text{whose average tangential value along a circle is given by } E = \frac{r}{2} \frac{dB}{dt}$$

This electric field is non conservative in nature. The lines of force associated with this electric field are closed curves.

6. Self induction

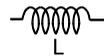
$$\mathcal{E} = -\frac{\Delta(N\phi)}{\Delta t} = -\frac{\Delta(LI)}{\Delta t} = -\frac{L\Delta I}{\Delta t}$$

$$\text{The instantaneous emf is given as } \mathcal{E} = -\frac{d(N\phi)}{dt} = -\frac{d(LI)}{dt} = -\frac{LdI}{dt}$$

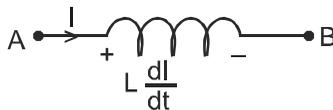
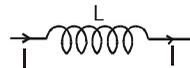
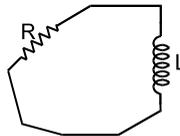
$$\text{Self inductance of solenoid} = \mu_0 n^2 \pi r^2 \ell.$$

6.1 Inductor

It is represent by
electrical equivalence of loop



⇒



$$V_A - L \frac{dI}{dt} = V_B$$

$$\text{Energy stored in an inductor} = \frac{1}{2} LI^2$$

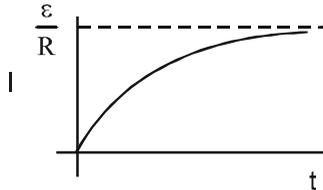
7. Growth Of Current in Series R-L Circuit

If a circuit consists of a cell, an inductor L and a resistor R and a switch S , connected in series and the switch is closed at $t = 0$, the current in the

$$\text{circuit } I \text{ will increase as } I = \frac{\mathcal{E}}{R} (1 - e^{-\frac{Rt}{L}})$$

The quantity L/R is called time constant of the circuit and is denoted by τ . The variation of current with time is as shown.

1. Final current in the circuit = $\frac{\varepsilon}{R}$, which is independent of L .



2. After one time constant, current in the circuit = 63% of the final current.
3. More time constant in the circuit implies slower rate of change of current.

8. Decay of current in the circuit containing resistor and inductor:

Let the initial current in a circuit containing inductor and resistor be I_0 .

Current at a time t is given as $I = I_0 e^{-\frac{Rt}{L}}$

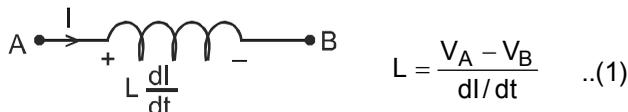
Current after one time constant : $I = I_0 e^{-1} = 0.37\%$ of initial current.

9. **Mutual inductance** is induction of EMF in a coil (secondary) due to change in current in another coil (primary). If current in primary coil is I , total flux in secondary is proportional to I , i.e. $N \phi$ (in secondary) $\propto I$.

$$\text{or } N \phi \text{ (in secondary)} = M I.$$

The emf generated around the secondary due to the current flowing around the primary is directly proportional to the rate at which that current changes.

10. Equivalent self inductance :



1. Series combination :

$$L = L_1 + L_2 \quad (\text{neglecting mutual inductance})$$

$$L = L_1 + L_2 + 2M \quad (\text{if coils are mutually coupled and they have winding in same direction})$$

$$L = L_1 + L_2 - 2M \quad (\text{if coils are mutually coupled and they have winding in opposite direction})$$

2. Parallel Combination :

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} \quad (\text{neglecting mutual inductance})$$

For two coils which are mutually coupled it has been found that $M \leq \sqrt{L_1 L_2}$
 or $M = k\sqrt{L_1 L_2}$ where k is called coupling constant and its value is less than or equal to 1.

$\frac{E_s}{E_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$, where denotations have their usual meanings.

$\Rightarrow \begin{matrix} N_s > N_p \\ E_s > E_p \end{matrix} \rightarrow$
 for step up transformer.

12. LC Oscillations

$$\omega^2 = \frac{1}{LC}$$

