# ELECTROMAGNETIC INDUCTION

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

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 $\omega$ about its one end, in a uniform perpendicular magnetic field B is 1/2 B $\omega$ $\ell^2$.

1. **EMF Induced in a rotating disc :**

Emf between the centre and the edge of disc of radius r rotating in a magnetic field B = $\dfrac{B\omega r^2}{2}$

5. **Fixed loop in a varying magnetic field**

If magnetic field changes with the rate $\dfrac{dB}{dt}$, electric field is generated whose average tangential value along a circle is given by $E = \dfrac{r}{2}\dfrac{dB}{dt}$

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

6. **Self induction**

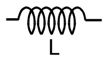
$$\varepsilon = -\frac{\Delta(N\phi)}{\Delta t} = -\frac{\Delta(LI)}{\Delta t} = -\frac{L\Delta I}{\Delta t}.$$

The instantaneous emf is given as $\varepsilon = -\dfrac{d(N\phi)}{dt} = -\dfrac{d(LI)}{dt} = -\dfrac{LdI}{dt}$

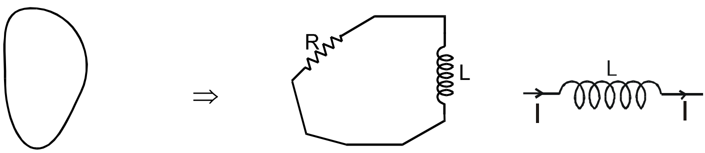
Self inductance of solenoid = $\mu_0 n^2 \pi r^2 \ell$.

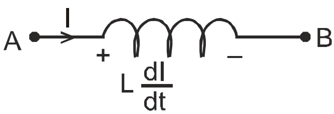
6.1 **Inductor**

It is represent by




electrical equivalence of loop




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

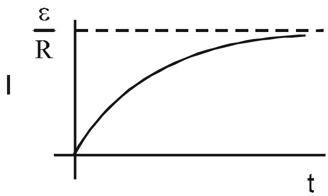
Energy stored in an inductor $= \dfrac{1}{2}LI^2$

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 circuit I will increase as $I = \dfrac{\varepsilon}{R}\left(1 - e^{\frac{-Rt}{L}}\right)$

The quantity L/R is called time constant of the circuit and is denoted by $\tau$. 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 $I = I_0 e^{\frac{-Rt}{L}}$

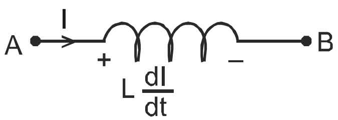
Current after one time constant : $I = I_0 e^{-1}$ =0.37% of initial current.

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.

or N $\phi$ (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 :**




$$L = \frac{V_A - V_B}{dI/dt} \quad ..(1)$$

1. **Series combination** :

$L = L_1 + L_2$ ( neglecting mutual inductance)

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

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

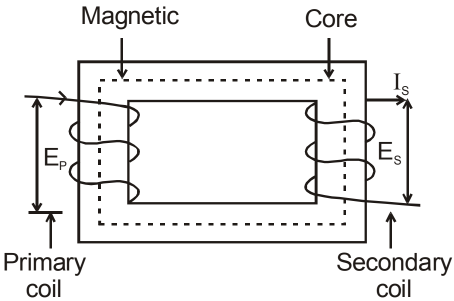
2. **Parallel Combination :**

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

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.




$N_S > N_P$

$\Rightarrow$ $E_S > E_P$ $\rightarrow$

for step up transformer.

**12. LC Oscillations**

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