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 ω about its one end, in a uniform perpendicular magnetic field B is 1/2 B ω ℓ^2.

    4.1.   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.
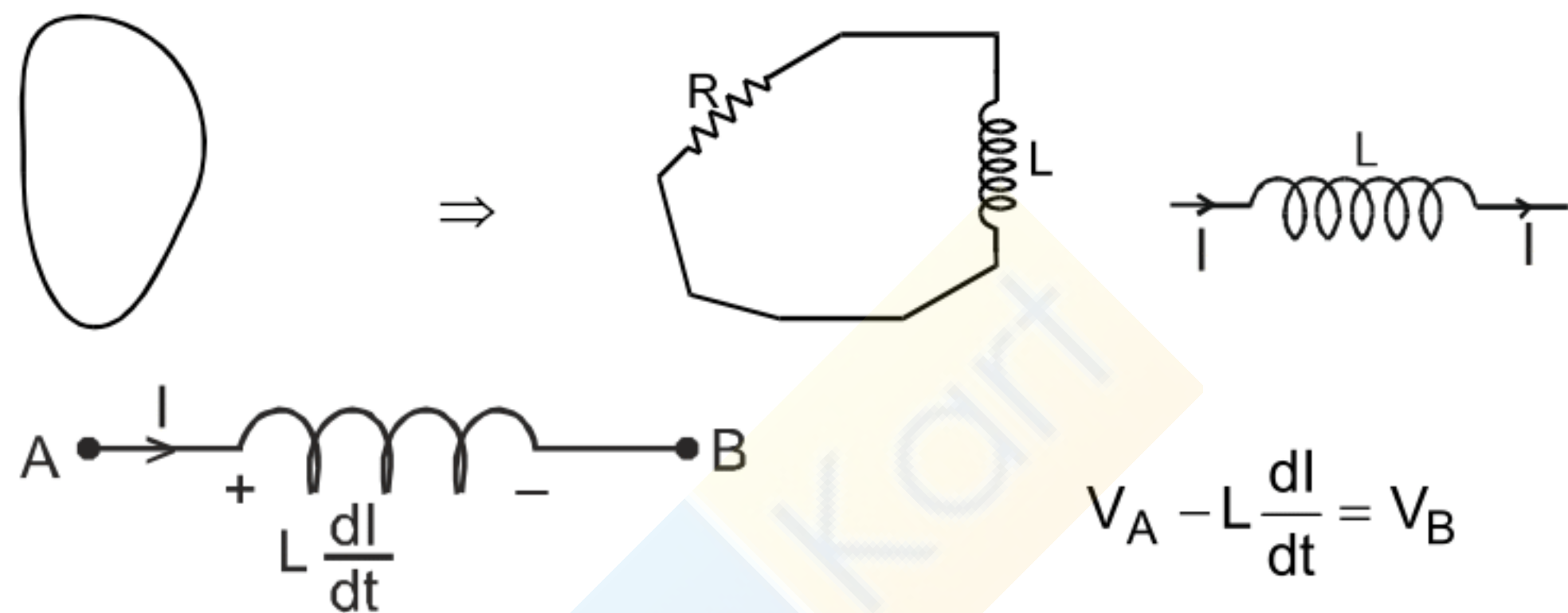
6. Self induction

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

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

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 $I = \dfrac{\mathcal{E}}{R}(1 - e^{\frac{-Rt}{L}})$

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 $= \dfrac{\mathcal{E}}{R}$, which is independent of L.
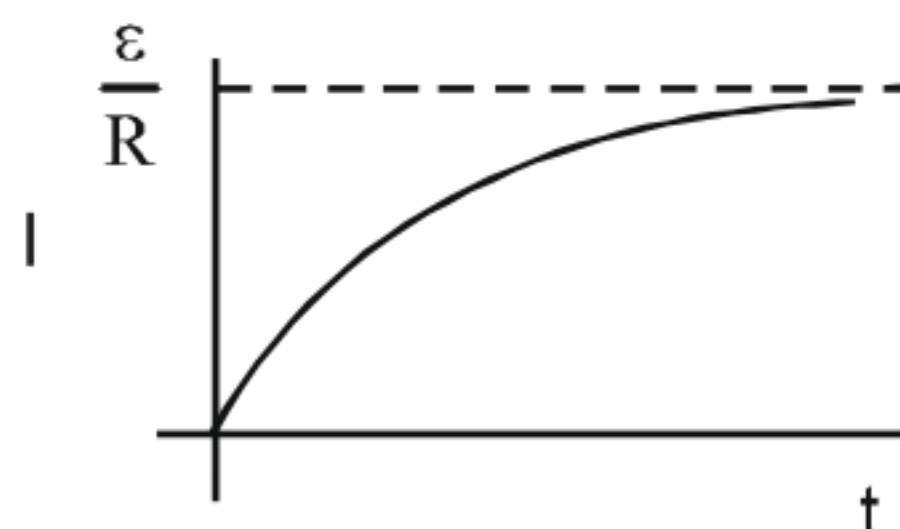
2. After one time constant , current in the circuit =63% of the final current.
3. More time constant in the circuit implies slower rate of change of current.

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 :**

$$L = \frac{V_A - V_B}{dI/dt} \quad ..(1)$$
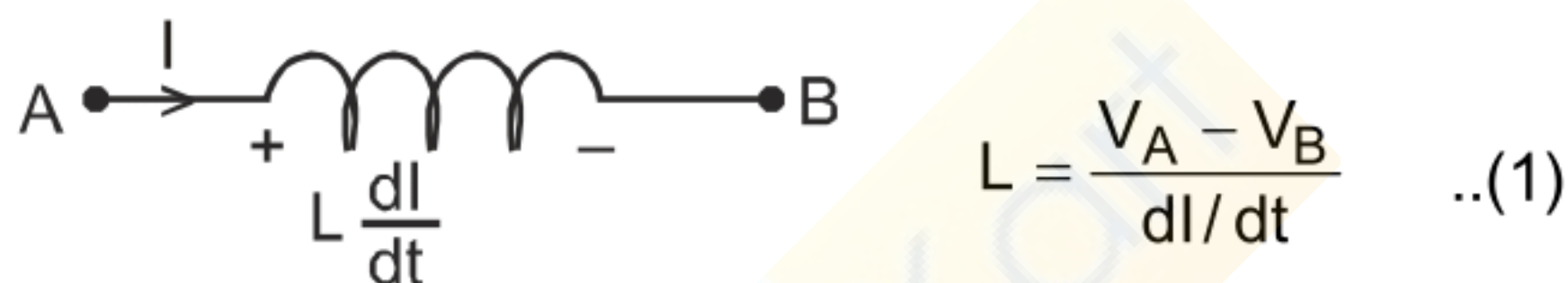
1.   **Series combination :**
$L = L_1 + L_2$ (neglecting mutual inductance)
$L = L_1 + L_2 + 2M$ (if coils are mutually coupled and they have winding in same direction)
$L = L_1 + L_2 - 2M$ (if coils are mutually coupled and they have winding in opposite direction)
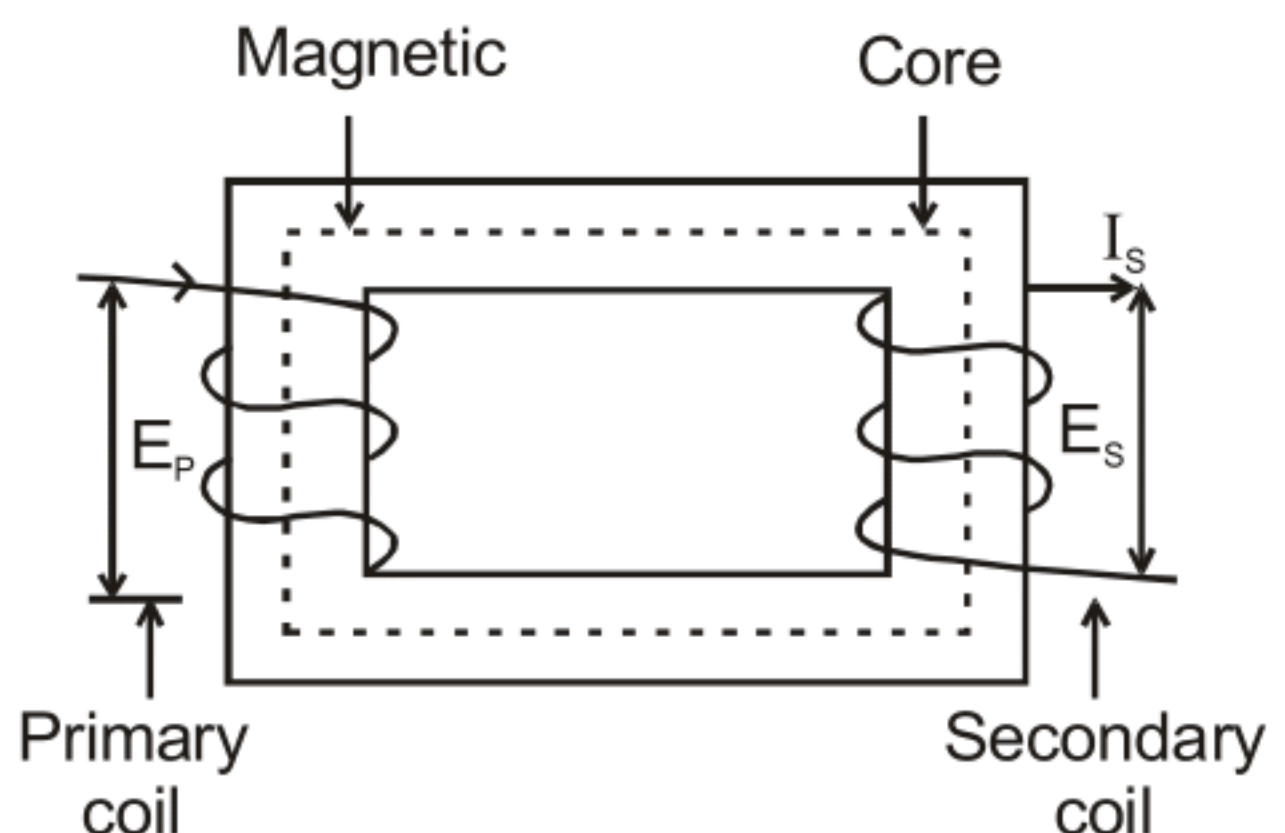
2.   **Parallel Combination :**

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

For two coils which are mutually coupled it has been found that $M \le \sqrt{L_1 L_2}$

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.

11.   **LC Oscillations**

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