

Magnetic Flux

Magnetic flux through an area A is given by ϕ

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

SI unit of ϕ is weber (Wb) or Tesla meter² (T m²).

If $\vec{B}$ is uniform

$$\phi = \vec{B} \cdot \vec{A}$$

$$\phi = |\vec{B}| \cdot |\vec{A}| \cos\theta$$

Faraday's Law of Induction

Magnitude of induced EMF in a circuit is equal to the rate of change of magnetic flux w.r.t. time through the circuit.

$$\mathcal{E} = \left| \frac{d\phi}{dt} \right|$$

↓

EMF Induced

$$<\mathcal{E}> = \left| \frac{\Delta\phi}{\Delta t} \right|$$

If N turns,

$$\mathcal{E} = N \left| \frac{d\phi}{dt} \right|$$

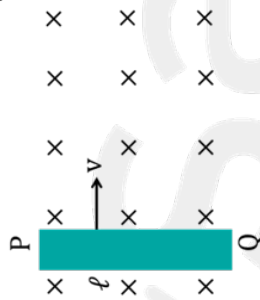
MIND MAP

Electromagnetic Induction

Lenz's Law

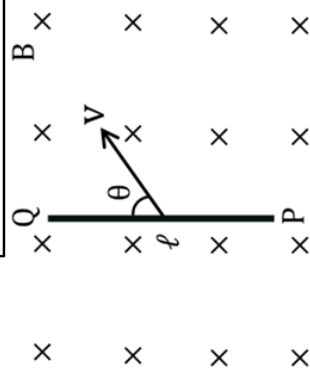
Induced emf opposes its cause of generation.

Lenz's law is based on law of conservation of energy.



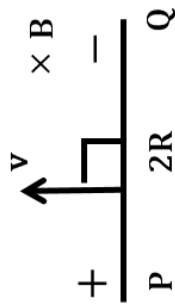
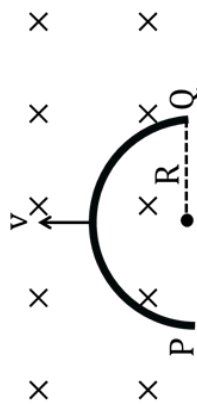
$$V_P - V_Q = \frac{B\omega(r_2^2 - r_1^2)}{2}$$

$$V_P - V_Q = B\ell v$$



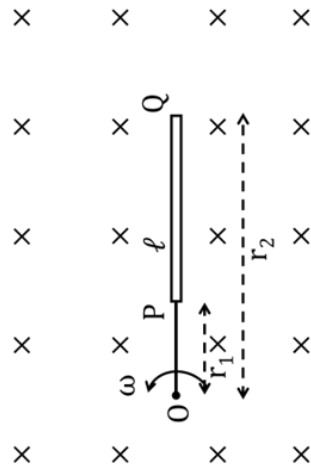
$$\mathcal{E} = V_Q - V_P = B\ell v_{\perp} = B\ell v \sin\theta$$

Arbitrary Shaped Wire



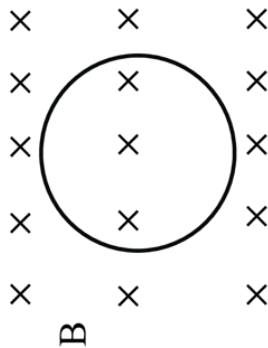
$$\mathcal{E} = B\ell v = B(2R)V = V_P - V_Q$$

EMF due to Rotation of Wire

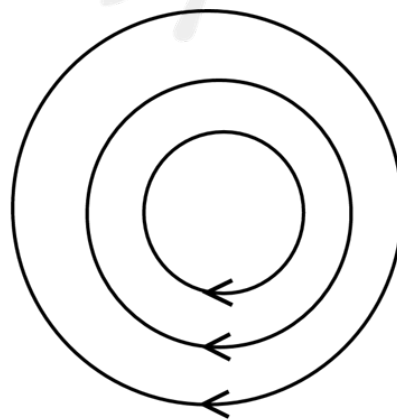


$$V_P - V_Q = \frac{B\omega(r_2^2 - r_1^2)}{2}$$

Induced Electric Field



$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt}$$

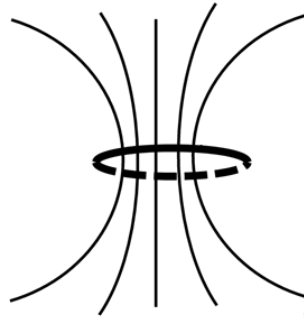


- Produced by the changing magnetic field
- Non-electrostatic and non-conservative in nature
- Cannot define a potential for it
- Form closed loops. No source and sink

MIND MAP

Electromagnetic Induction

Self Inductance



Flux through a coil having current 'i' due to its own current is ϕ then

$$\phi \propto i$$

$$\phi = L i$$

Self Inductance of Coil
or
Coefficient of Self Induction



$$\phi = L i$$

SI unit of L is henry (H)

$$1 \text{ henry} = \frac{1 \text{ Weber}}{1 \text{ Ampere}}$$

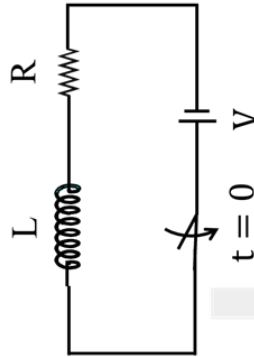
L depends on :-

- ❖ Geometrical construction of coil
- ❖ Intrinsic material properties

Symbolic Representation of Inductor

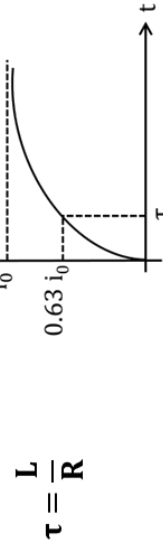
$\text{Inductor Symbol: } L$
 $\phi = L i$
 $\mathcal{E} = -\frac{d\phi}{dt} = -\frac{L di}{dt}$

This phenomenon is called Self Induction.
Growth of Current in LR Circuit



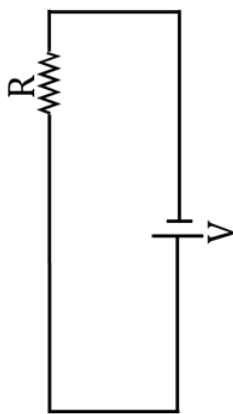
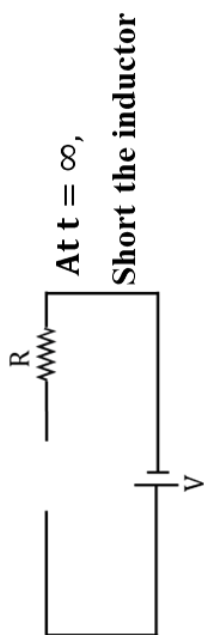
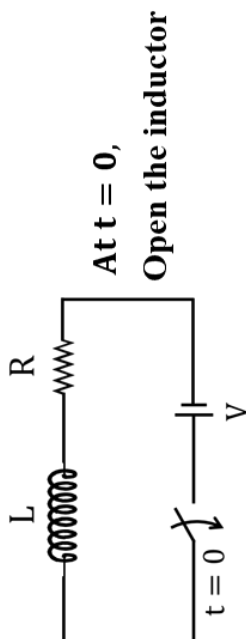
$$i = \frac{V}{R} \left(1 - e^{-\frac{t}{\tau}} \right) = i_0 \left(1 - e^{-\frac{t}{\tau}} \right)$$

Time constant

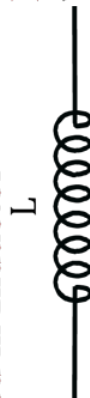


$$\tau = \frac{L}{R}$$

Circuit Analysis



Energy Stored in Inductor



$$\text{Energy} = \frac{1}{2} Li^2$$

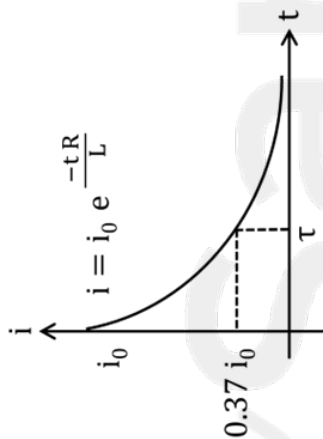
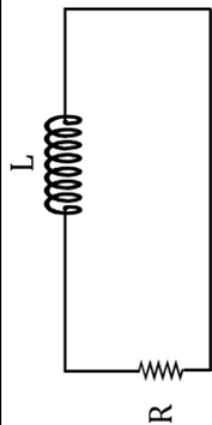
Magnetic Energy Density

$$\text{Magnetic Energy Density} = \frac{B^2}{2\mu_0}$$

Energy Per Unit Volume

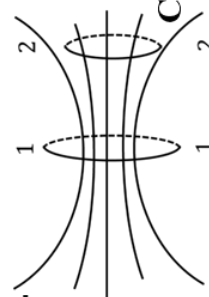
MIND MAP

Electromagnetic Induction



After 1τ , current decays by 63%.

Mutual Inductance



Flux from (2) due to

Theorem of Reciprocity

Current in (1) $m_{21} = m_{12}$

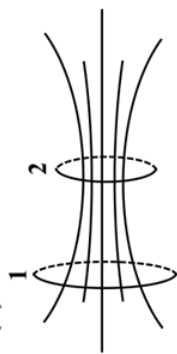
$$\Phi_{21} \propto i_1$$

Mutual Inductance of (2) wrt (1)

$$\Phi_{12} \propto i_2$$

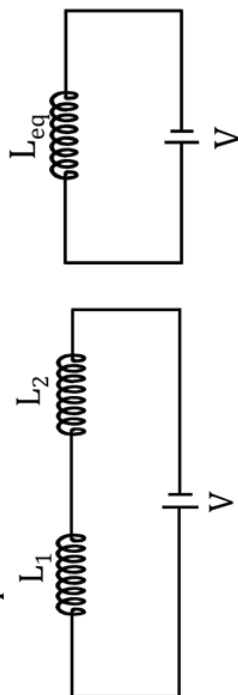
Mut. Ind. of (1) wrt (2)

$$\Phi_{12} = m_{12}i_2$$



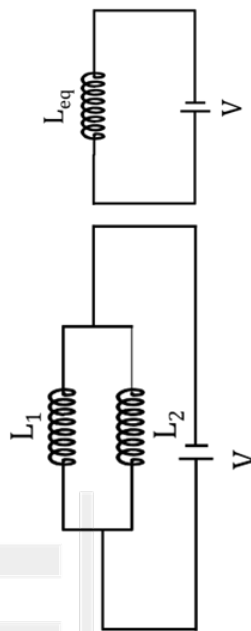
Inductors in Series

$$L_{eq} = L_1 + L_2$$



Inductors in Parallel

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}$$



AC Generator

Nicola Tesla is credited for development of this machine

An AC generator converts mechanical energy to electrical energy.