Magnetic Circuits :

Current in electric ckt = flux in magnetic ckt

Magnetomotive force : (MMF)

* In magnetic circuits, flux is present due to mmf

mmf $\propto$ current and no. of turns.

mmf is expressed in ampere turns.

Magnetic strength : (H)

mmf per unit length of magnetic circuit is called magnetic field strength / intensity

* $$H = \frac{mmf}{length} = \frac{i \times N}{l}$$

(Independent of medium)

* Magnetic permeability

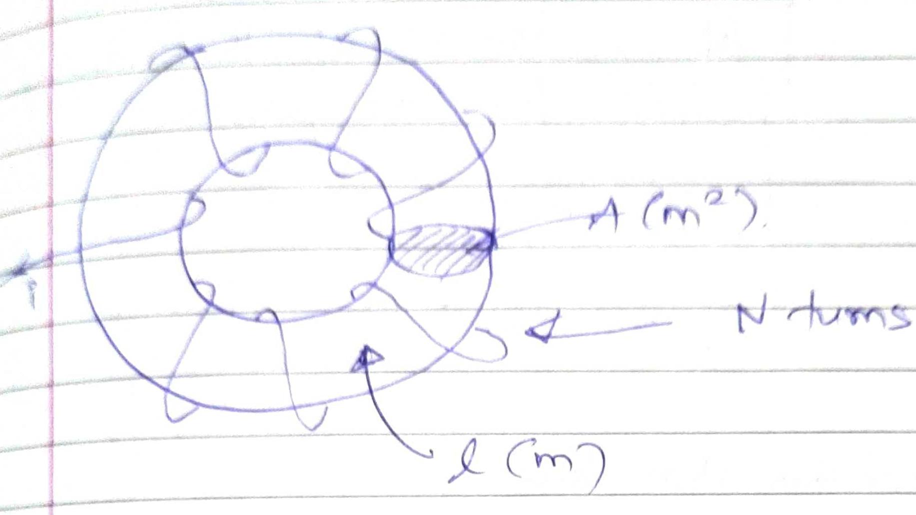
$$\mu_0 = \frac{B_0}{H_0} = 4\pi \times 10^{-7}$$

* If core is replaced by magnetic material, then flux $\uparrow$ hence mmf $\uparrow$, hence flux density $\uparrow$

$$\boxed{\mu_r = \frac{\mu}{\mu_0}}$$

Reluctance : Measure of opposition by magnetic circuit to setting up of flux

$$R = \frac{1}{\mu} \times \frac{l}{A} = \frac{1}{\mu_r \mu_0} \cdot \frac{l}{A} = \frac{F}{\phi}$$



$$\boxed{mmf = F = N i}$$

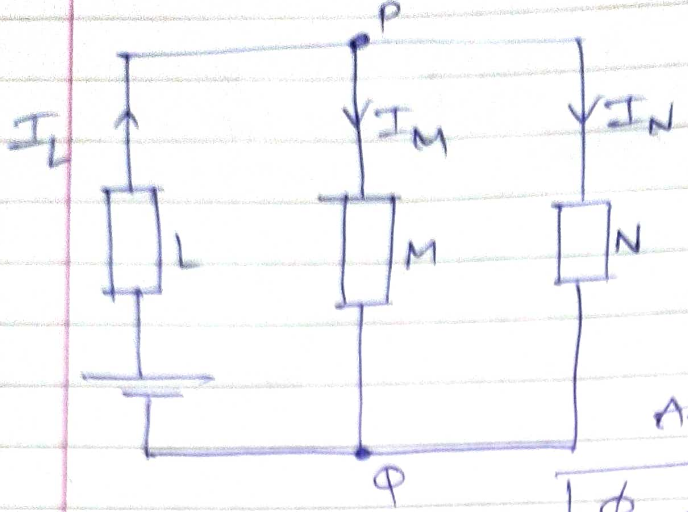
$$H = \frac{F}{l} \qquad \phi = BA$$

$$\frac{\phi}{F} = \frac{BA}{Hl} = \frac{B}{H} \times \frac{A}{l} = \mu \times \frac{A}{l} = \frac{\mu_r \mu_0 A}{l}$$

$$R = \frac{l}{\mu_r \mu_0 A} \Rightarrow \frac{1}{R} = \mu_0 \mu_R \frac{A}{l}$$

$$\boxed{\text{Permeance} = \frac{1}{R} = \frac{\phi}{F}}$$

Kirchoff's flux law.



Total mf towards a junction is eqcial to the total flux away from the junction.

At P,

$$\boxed{\phi_L = \phi_M + \phi_N}$$

Kirchoff's magnetomotive law :

In a closed magnetic ckt, the algebraic sum of the product of the field strength and length of each part of the ckt is equal to resultant mmf

Total mmf of coil $= H_L \cancel{l_L} + H_M l_M$

$= H_L l_L + H_N l_N$

$0 = H_M l_M - H_N l_N$

Self Inductance :

$$e \propto \frac{di}{dt} \quad \text{or} \quad e = L\frac{di}{dt}$$

$L \equiv$ Self Inductance

Energy stored in inductor

$$\boxed{E = \frac{1}{2} L i^2}$$

$$e = N\frac{d\phi}{dt} = L\frac{di}{dt}$$

$$\therefore \boxed{L = N\frac{d\phi}{di}}$$

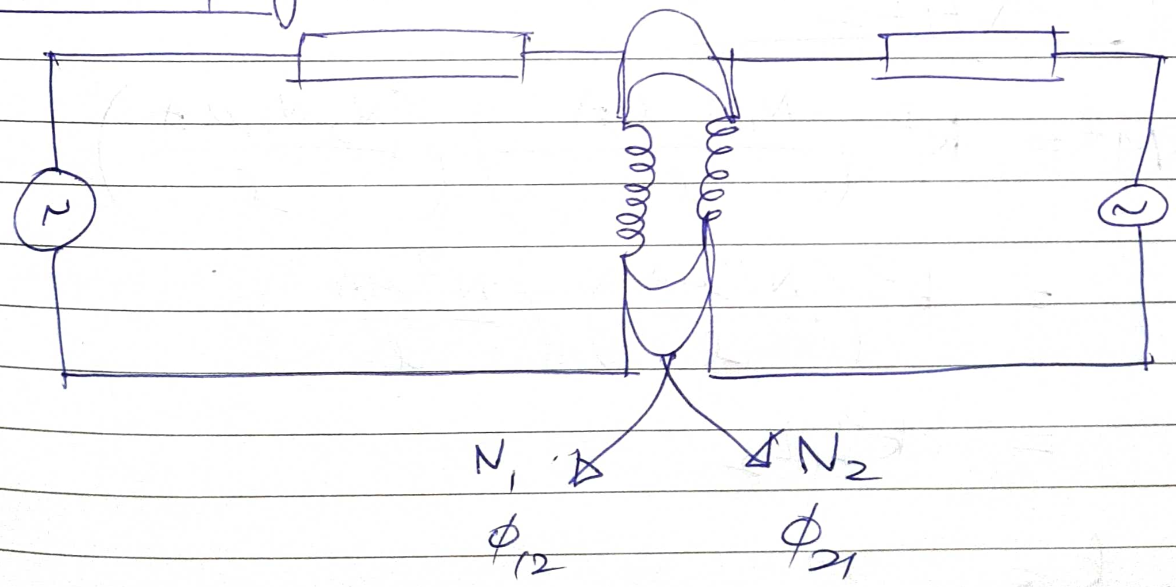
$$\phi = \frac{Ni}{R} \quad \text{and} \quad R = \frac{1}{\mu}\frac{l}{A}$$

$\therefore$ For linear change,

$$\boxed{L = \frac{N^2 \mu A}{l}}$$

Mutual inductance :

EM coupling :



$$e_2 = M_{12}\frac{di_1}{dt} \quad - (1)$$

$$\phi_1 = \phi_{11} + \phi_{12}$$

$$\phi_2 = \phi_{22} + \phi_{21}$$

$$M_{12}\frac{di_1}{dt} = N_2\frac{d\phi_{12}}{dt}$$

$$\therefore \boxed{M_{12} = N_2\frac{d\phi_{12}}{di_1}} \quad \boxed{M_{21} = N_1\frac{d\phi_{21}}{di_2}}$$

i.e. $\boxed{M_{12} = M_{21}}$

coeff. of coupling :

$$\boxed{k = \frac{M}{\sqrt{L_1 L_2}}}$$

$$M^2 = k^2\left(\frac{N_1 N_2 \mu A}{l}\right)\left(\frac{N_2 N_1 \mu A}{l}\right)$$

$$= k^2\left(\frac{N_1^2 \mu A}{l}\right)\left(\frac{N_2^2 \mu A}{l}\right)$$

$$= k^2 L_1 L_2$$

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

Dot Conventions :

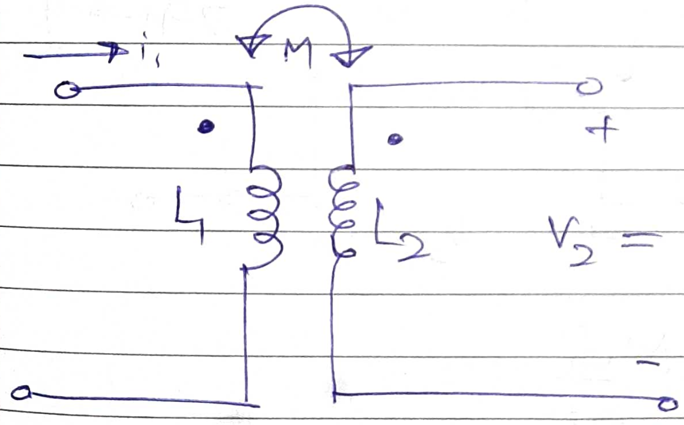
Voltage across coil 1 is

$$\boxed{V_1 = L_1\frac{di_1}{dt} + M\frac{di_2}{dt}}$$

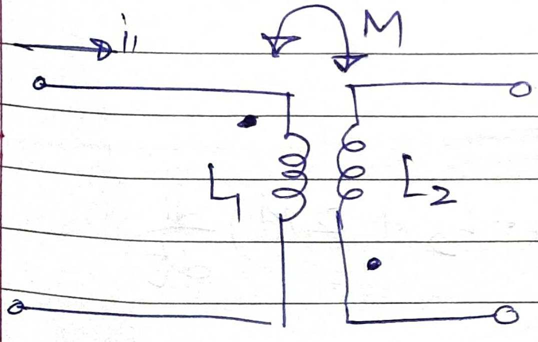
$$\boxed{V_2 = L_2\frac{di_2}{dt} + M\frac{di_1}{dt}}$$

Dot convention : Determines sign of mutual voltage without going into physical construction of the coils.

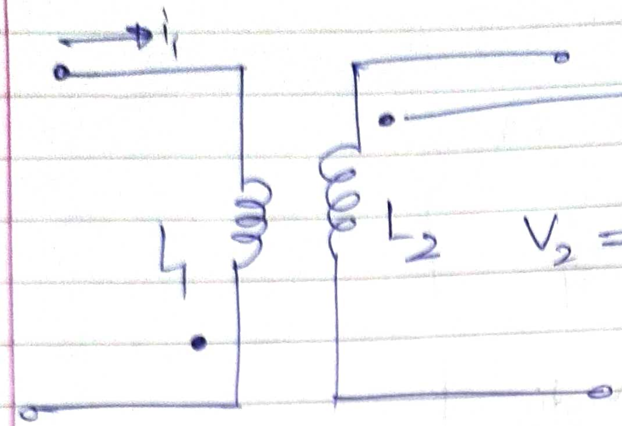
A current entering the dotted terminal of one coil produces an open-circuit voltage which is positively sensed at the dotted terminal of 2nd coil.



$$V_2 = M\frac{di_1}{dt}$$

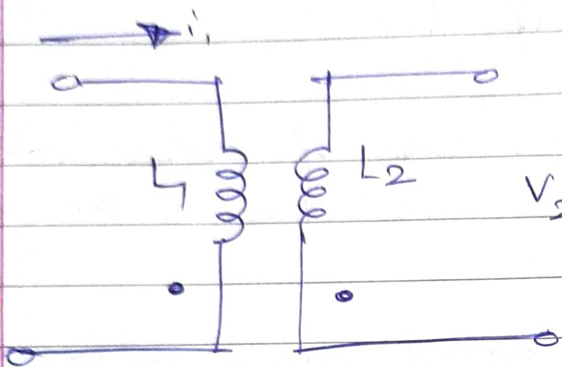


$$V_2 = -M\frac{di_1}{dt}$$



Represents positive terminal

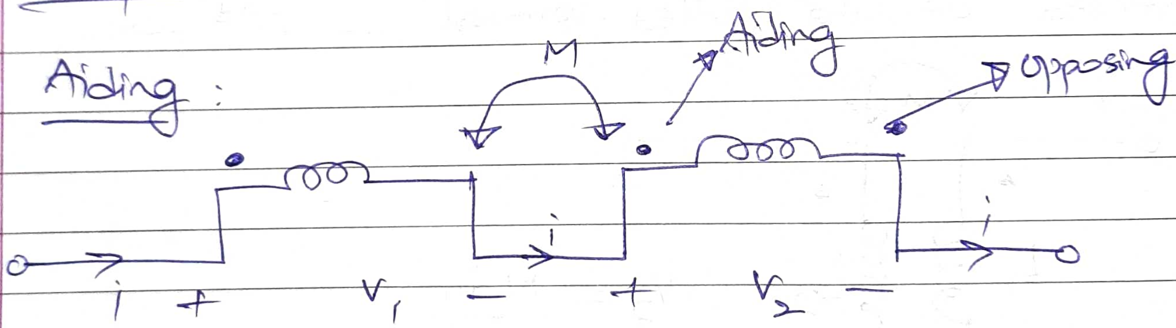
$$V_2 = -M\frac{di_1}{dt}$$



$$V_2 = M\frac{di_1}{dt}$$

Coupled coils in Series

Aiding :



$$V_1 = L_1\frac{di}{dt} + M\frac{di}{dt}$$

$$V_2 = L_2\frac{di}{dt} + M\frac{di}{dt}$$

$$V = V_1 + V_2 = (L_1 + L_2 + 2M)\frac{di}{dt}$$

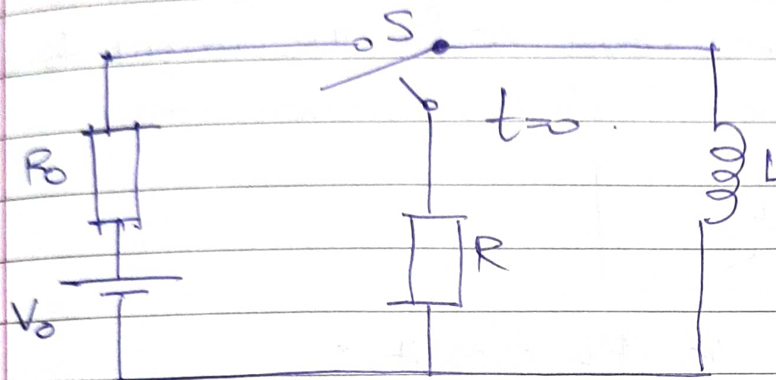
Opposing : $V_1 + V_2 = (L_1 + L_2 - 2M)\frac{di}{dt}$

DC Transients :

Time taken by a circuit from one steady state to another is known as transient time.

RL circuit :

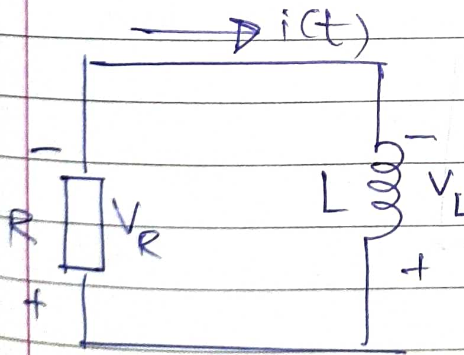
$i(t) = I_0$ at $t=0$ (Assumption)



Assume that circuit is in this condition for a long time so as to achieve steady state.

Since I_0 is not changing with time, current through inductor

$$I_0 = \frac{V_0}{R_0}$$



Applying KVL,

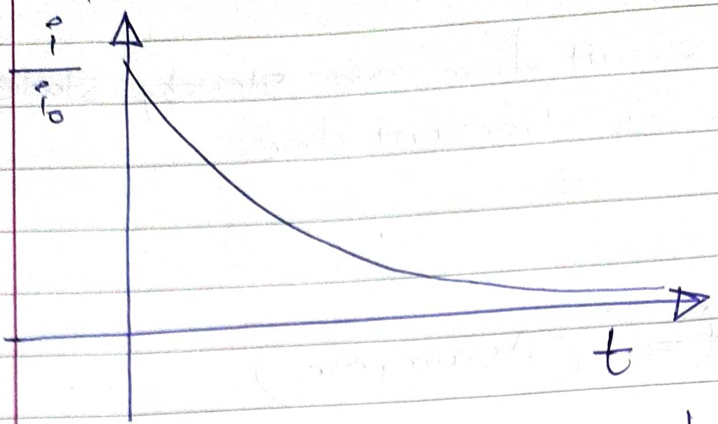
$$Ri + L\frac{di}{dt} = 0$$

$$\frac{di}{dt} + \frac{R}{L}i = 0$$

$$\Rightarrow \int_{I_0}^{i(t)} \frac{di}{i} = \int_0^t -\frac{R}{L}\,dt$$

$$\Rightarrow \boxed{i(t) = I_0 e^{-Rt/L}}$$

Nature of the response :



Time const : Time reqd ~~to~~ for the current to drop to zero if continued to drop at initial rate

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

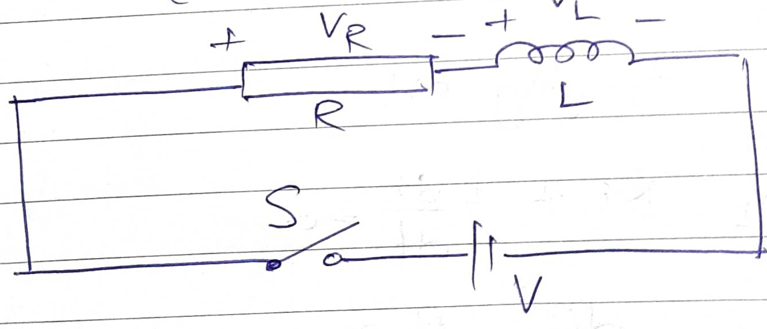
Growth of current in RL circuit :

Before closing the switch, ~~Ef~~

$i(0^-) = 0.$

Since an inductor cannot change current in zero time,

$i(0^+) = 0.$



$$L\frac{di}{dt} + iR = V$$

$$\boxed{i(t) = I_0\left(1 - e^{-t/\tau}\right)}$$

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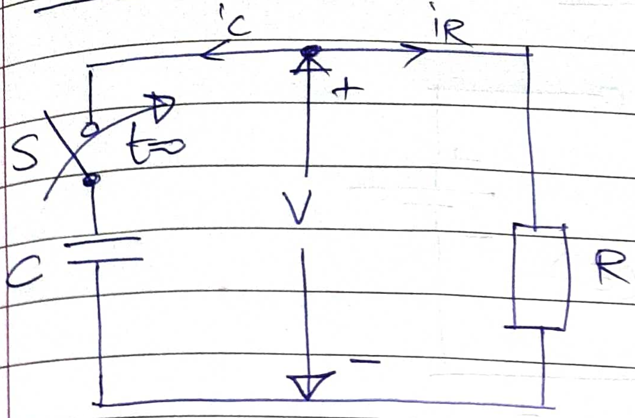
RC circuit :



Initial voltage V_0

$$i_c + i_R = 0$$

$$C\frac{dV}{dt} + \frac{V}{R} = 0.$$

$$\frac{dV}{dt} + \frac{V}{CR} = 0.$$

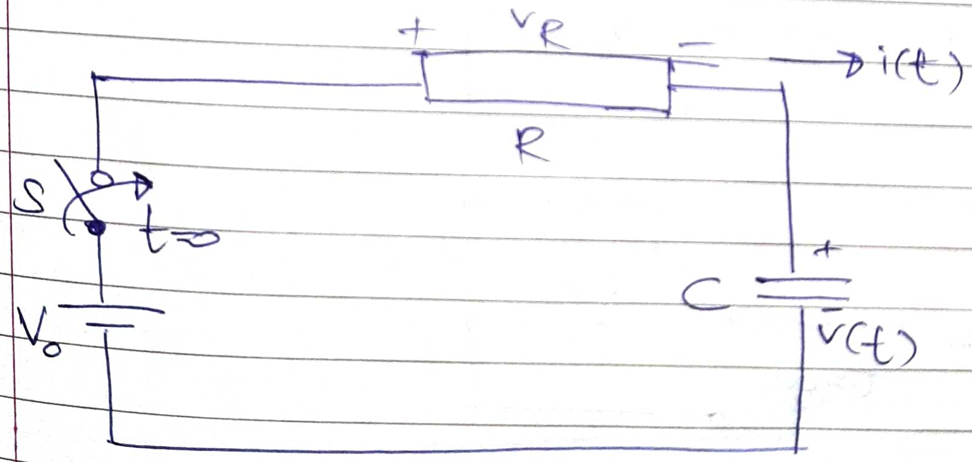
$$\boxed{V = V_0 e^{-t/RC} = V_0 e^{-t/\tau}}$$

Charging :

Instantaneously, $v(0^+) = v(0^-) = 0.$

$$i(0^+) = I_0 = \frac{V_0}{R}$$

$v(t \to \infty) = V_0$ and $i(t \to \infty) = 0.$

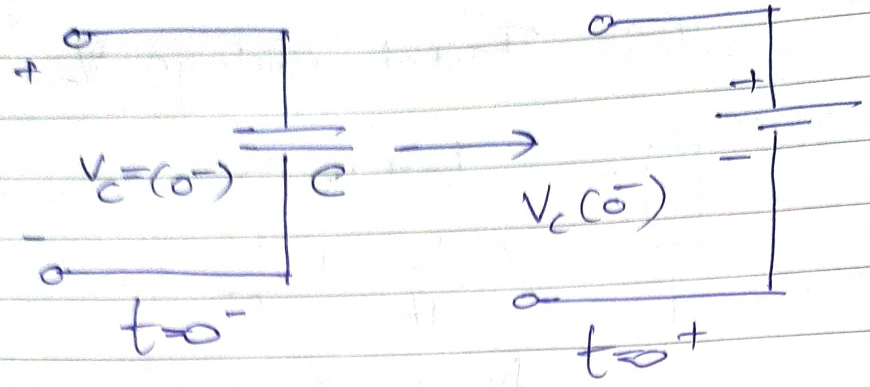


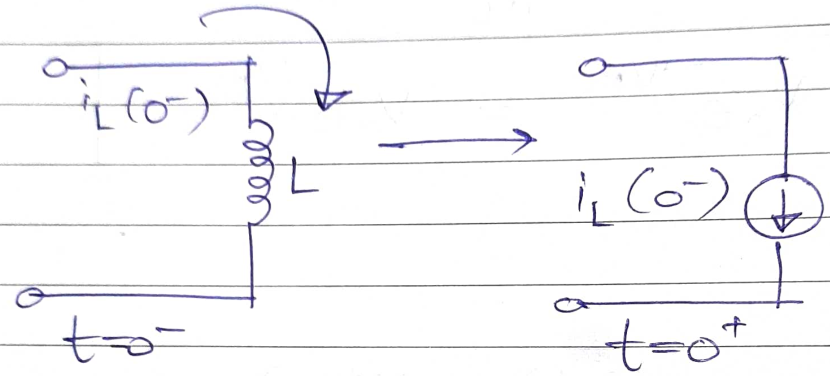
$$iR + v = V_0$$

$$i = C\frac{dV}{dt}$$

$$\boxed{V = V_0\left(1 - e^{-t/\tau}\right)}$$

Determining initial values :





Determining final values :