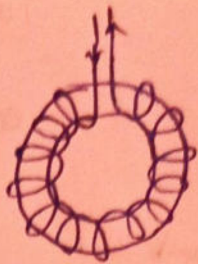
Magnetic Circuit :-



$N =$ Total no. of turns
$I =$ current flowing through coil
$l =$ length of magnetic material
$A =$ Cross-sectional Area
$H =$ magnetic field Intensity

from Ampere's Circuital law,

$$\oint H \cdot dl = NI$$

$$H \cdot l = NI$$

$$\boxed{H = \frac{NI}{l}} \quad [AT/m]$$

Let $B =$ flux density (wb/m^2)
$\Phi =$ Total flux (wb)
then $\Phi = B \cdot A$

$$\boxed{B = \mu_0 \mu_m H}$$

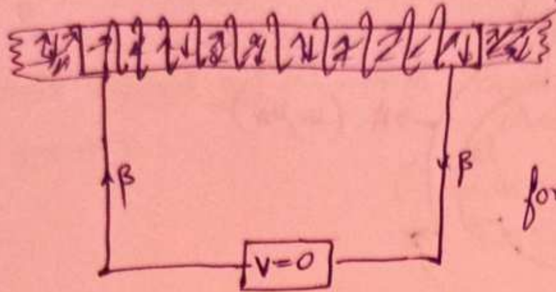
$$\boxed{\Phi = \frac{\mu_0 \mu_m NIA}{l}}$$

but $\Phi = \frac{NI}{R} = \frac{F}{R}$ where $R =$ Reluctance

so $\boxed{R = \frac{l}{\mu_0 \mu_m A}}$

Magnetic circuit	Electric Circuit
① flux (Φ)	① current (I)
② MMF (F)	② emf (V)
③ Reluctance (R)	③ resistance (R)
④ $\Phi = \frac{F}{R}$ (hysteresis loop)	④ $I = \frac{V}{R}$ (Ampere's law)
⑤ μ	⑤ e

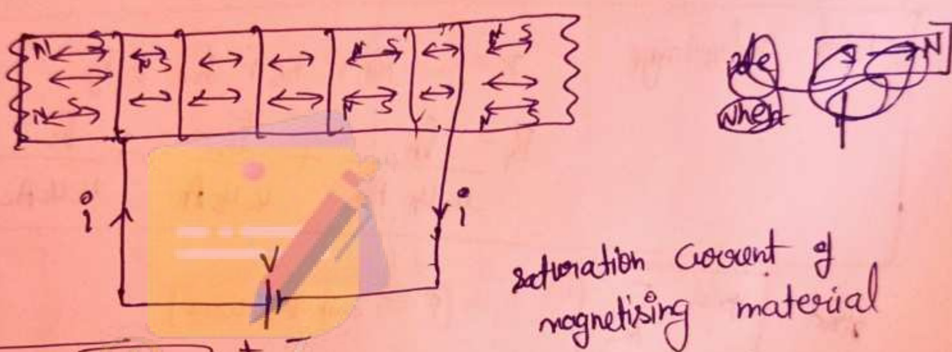
Magnetisation characteristics -



flux ≃ 0 (small value)

for ideal net flux ≃ 0

here when we apply some external voltage source then -

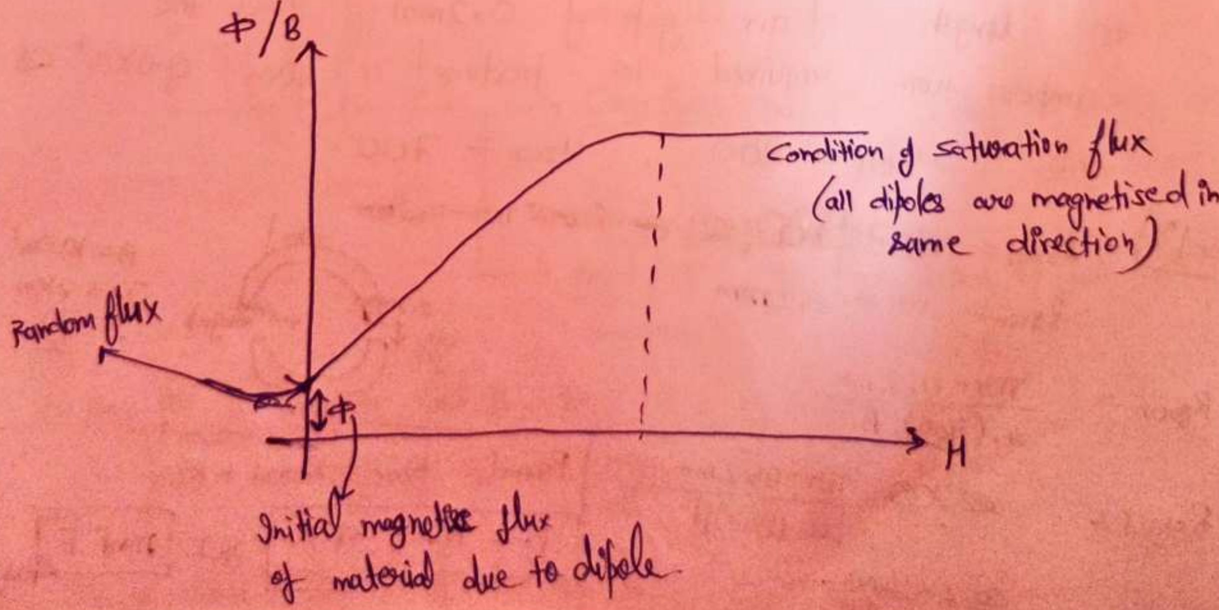


saturation current of magnetising material

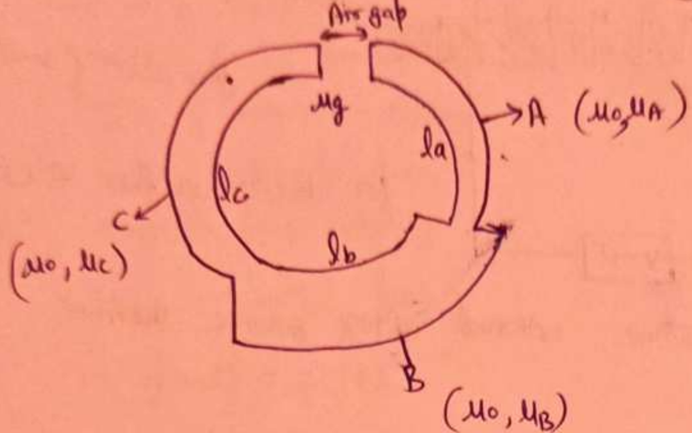
if —|⊢— ⇒ N ⟷ S
+ -

if —|⊢— ⇒ S ⟷ N
- +

hence depend on pole voltage



Types of magnetic circuits - 2 types → (1) series magnetic ckt
(2) parallel magnetic ckt



$(\mu_g = 1)$

Total Reluctance
$$R = R_A + R_B + R_C + R_g$$
$$R = \frac{l_A}{\mu_0 \mu_A A_A} + \frac{l_B}{\mu_0 \mu_B A_B} + \frac{l_c}{\mu_0 \mu_c A_c} + \frac{l_g}{\mu_0 A_g}$$

And $\boxed{\Phi = \frac{F}{R}}$ (F = ampere turns)

Q) A ring has a diameter of 21 cm and cross sec^n area of 10 cm^2. the ring is made of semi circular cross section from cast Iron & steel. with each joint having a reluctance (R) equal to length of air gap of 0.2mm. find the ampere turn required to produce a flux 0.8×10^{4} wb the $\mu_{steel} = 800$, $\mu_{Iron} = 700$.

Sol^n) $l_{steel} = \pi r - 0.2\,mm$

$l_{Iron} = \pi r - 0.2\,mm$

$A = 10\,cm^2$
$D = 21\,cm$
$r = \frac{21}{2}$

$$R_{Iron} = \frac{\pi r - 0.2\,mm}{\mu_0 (700) A}$$

$$R_{steel} = \frac{\pi r - 0.2\,mm}{\mu_0 (800) A}$$

$$R_{air} = \frac{0.2 \times 2\,mm}{\mu_0 \times 1 \times A}$$

$R_{Total} = R_{Iron} + R_{steel} + R_{air}$

$\boxed{F = NI = \Phi R}$ get $\boxed{mmf\ F}$ Ans//

Types of Induced emf :-

① Dynamically induced emf ~~(static conductor rotating mag. field)~~
② Statically induced emf

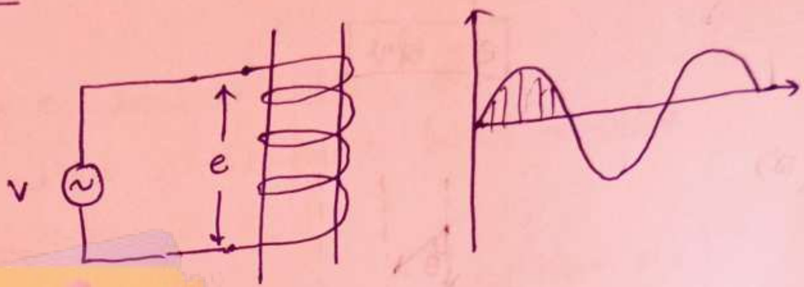
① **Dynamically induced emf** :- → ⓐ conductor is static but mag. field is rotating Eg) Sychronous motor.

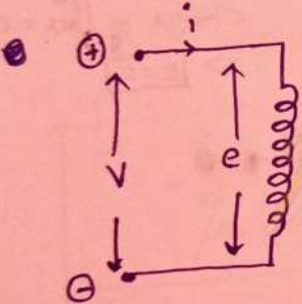
Eg) DC generator

ⓑ conductor is moving but mag. field is static → Eg) DC Generator

② **Statically induced emf** :-

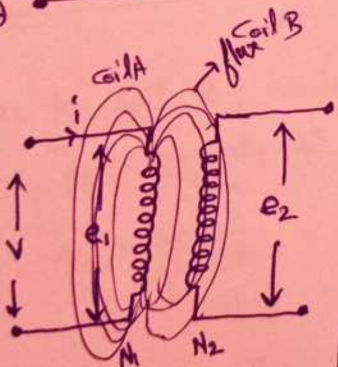
Eg) Transformer





$$e = -N\frac{d\Phi}{dt} = -N\frac{d\Phi}{dt}\cdot\frac{di}{di} = -L\frac{di}{dt}$$

$$\left[\text{where } L = -N\frac{d\Phi}{di}\right]$$



Total flux generated by coil 1 when current i is passed

$\Phi_1 = Li$

Φ_1 → **Likage flux**: The flux linked to only 1 binding is called linkage flux say (Φ_{11})

→ **Useful flux**: The flux linked to both the binding Say (Φ_{12})

As same flux is linked to coil B,

$$\boxed{e_2 = -N_2\frac{d\Phi_{12}}{dt}} = -N_2\frac{d\Phi_{12}}{dt}\cdot\frac{di}{di} = -M\frac{di}{dt}$$

$$\left[\text{where } M = N_2\frac{d\Phi_{12}}{di}\right]$$

the principle of mutual induction.

① Dynamically induced emf :-

(i) Let $(\theta = 90^\circ)$

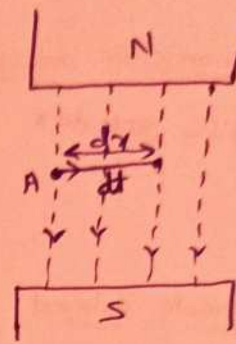
l = length of conductor.

Area of conductor $A = l \cdot dx$

flux, $\phi = BA = Bl\,dx$

emf induced, $e = \dfrac{d\phi}{dt} = Bl\dfrac{dx}{dt}$

$$\boxed{e = Blv}$$



$(\theta = 0^\circ)$

(ii) when conductor will in dir^n of ~~...~~ mag. field, flux linked to coil is max^m but rate of change of flux = 0

$\Rightarrow \boxed{e = 0}$

(iii)

in verticle dir^n $l_v = l\,[\text{redacted}]\cos\theta$

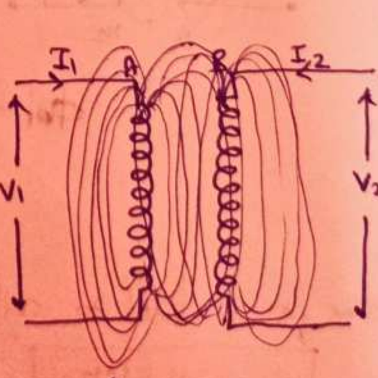
" hori " $l_h = l\sin\theta$

swept area $A = (l\,dx\sin\theta)$

so $\phi = BA = B(l\sin\theta)\,dx$

$$\boxed{e = \frac{d\phi}{dt} = Blv\sin\theta}$$

② Statically induced emf !



Let L_1 & L_2 are ~~...~~ self Inductance of coil A & B resp and M be mutual inductance b/w^n coil A & B

Let V_1 & V_2 applied across A & B resp

Coefficient of Coupling b/w^n A & B =

$$\Phi = \frac{F}{R} = \frac{NI}{l/\mu_0\mu_r A}$$

$$N\Phi = LI$$

$$\frac{N^2 \cancel{I}}{l}(\mu_0\mu_r A) = L\cancel{I}$$

$$\left[L = \frac{N^2 \mu_0\mu_r A}{l}\right]$$

$$L_1 = \frac{N_1^2(\mu_0\mu_r A)}{l}$$

$$L_2 = \frac{N_2^2(\mu_0\mu_r A)}{l}$$

~~Now coupling coefficient -~~

$$\Phi_1 = \frac{N_1 I_1}{l/\mu_0\mu_r A}$$

Now let some part of Φ_1 linked to coil B,
let a factor(k_1) such that $(k_1\Phi_1)$ flux is linked to coil B

then, Mutual inductance, $\leftarrow (N\Phi = MI)$

$$M = N_2\frac{(k_1\Phi_1)}{I_1}$$

$$\boxed{M = \frac{N_2 k_1 N_1 \cancel{I_1}}{l/\mu_0\mu_r A \ \cancel{I_1}} = \frac{k_1 N_1 N_2}{l/\mu_0\mu_r A}} \quad \text{--- (i)}$$

Now due to coil B, similarly.
let Φ_2 be flux developed across coil B,

$$\Phi_2 = \frac{N_2 I_2}{l/\mu_0\mu_r A}$$

Let k_2 be fraction of flux linked to coil A (i.e $k_2\Phi_2$)

then Mutual inductance -

$$\boxed{M = \frac{N_1(k_2\Phi_2)}{I_2} = \frac{k_2 N_1 N_2}{l/\mu_0\mu_r A}} \quad \text{--- (ii)}$$

multiplying equ^n (i) & (ii)

$$M^2 = \frac{k_1 k_2 \, N_1^2 N_2^2}{\left(l/\mu_0 \mu_r A\right)^2}$$

$$M^2 = K_1 K_2 L_1 L_2$$

$$M = \sqrt{K_1 K_2 L_1 L_2}$$

$$\boxed{M = K\sqrt{L_1 L_2}}$$ [where $K = \sqrt{K_1 K_2}$]

(K = Coeff. of Coupling)

Q.1) Two coils with a coefficient of coupling 0.5 b/w^n them are connected in series so as to magnetise

(a) in the same direction (b) in the opposite direction

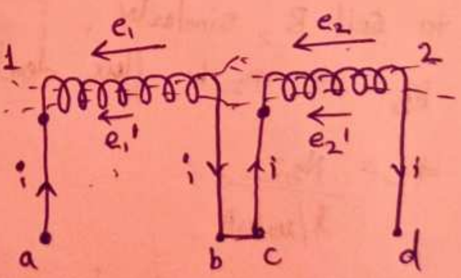
the corresponding value of the total inductances are

for (a) Total Inductance = 1.9 H

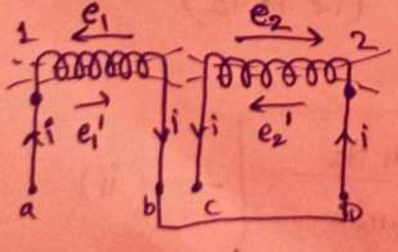
(b) Total Inductance = 0.7 H

find self inductances of the two coils and mutual inductance b/w^n them.

Sol^n)



(a) fluxes are additive to each other i.e when in same direction



(b) in opposite dir^n; subtractive fluxes

If flux is additive $\qquad L_{eq} = L_1 + L_2 + 2M$

If " " subtractive $\qquad L_{eq} = L_1 + L_2 - 2M$

(a) In additive.

$$e = e_1 + e_2 + e_1' + e_2'$$

$$-L_{eq}\frac{di}{dt} = -L_1\frac{di}{dt} + -L_2\frac{di}{dt} + \left(-2M\frac{di}{dt}\right)$$

$$\boxed{L_{eq} = L_1 + L_2 + 2M}$$

(b) In subtractive.

$$e = e_1 + e_2 + 2M\frac{di}{dt}$$

$$-L_{eq}\frac{di}{dt} = -L_1\frac{di}{dt} - L_2\frac{di}{dt} + 2M\frac{di}{dt}$$

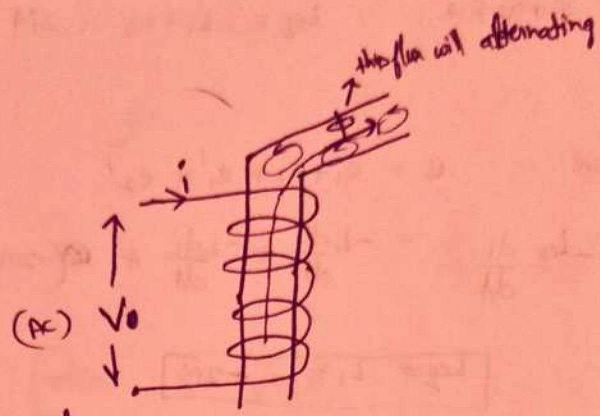
$$\boxed{L_{eq} = L_1 + L_2 - 2M}$$

Losses in magnetic circuit!

① Hysteresis loss ✓

② Eddy loss :-

There will be rate of change of flux in magnetic material also then emf is induced on iron core cause multiple



circular currents (whirls) called as eddy currents.

↳ because surface is short circuited and closed curve should form

and heat loss due to this current is eddy current loss.