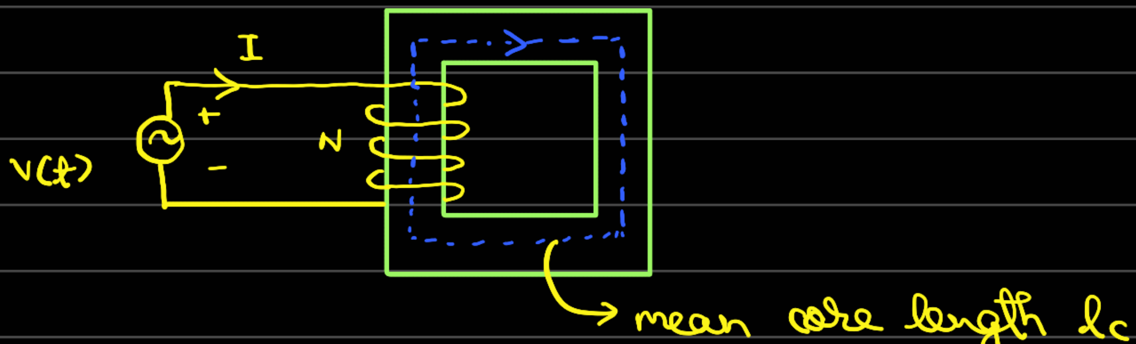
Day – 15

→ **magnetic Circuits :**



Assumptions

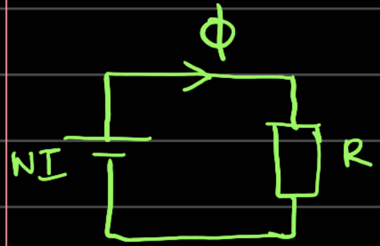
(i) All the flux lines are confined to core.
(ii) Flux density is uniform throughout the core
(iii) Hysteris and saturation effects of the core are neglected.

$$\oint_c \vec{H} \cdot d\vec{l} = \int_s \vec{J} \cdot d\vec{s}$$

$$\Rightarrow H_c l_c = NI \quad \text{———} \quad (1)$$

$$B = \mu_0 \mu_r H_c \quad \text{———} \quad (2)$$

$$\Phi = BA_c \Rightarrow NI = \Phi \underbrace{\frac{l_c}{\mu_0 \mu_r A_c}}_{\text{Reluctance of core}} \quad \text{———} \quad (3)$$



→ Inductance —

$$v(t) = i(t)R + \frac{d\psi(t)}{dt} \qquad (\psi = N\phi = LI)$$

$$N\phi = LI$$

$$\Rightarrow N\left(NI/\mathcal{R}\right) = LI$$

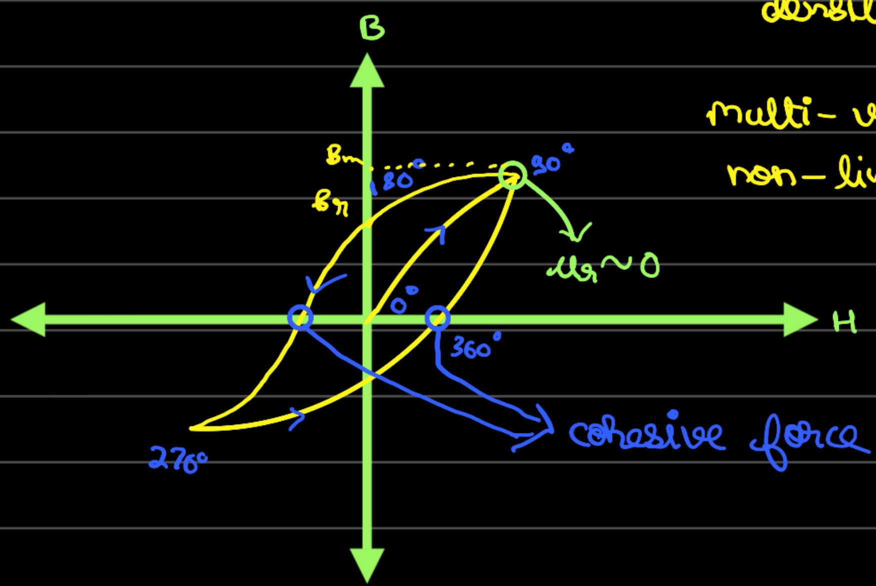
$$\Rightarrow L = \frac{N^2}{\mathcal{R}}$$

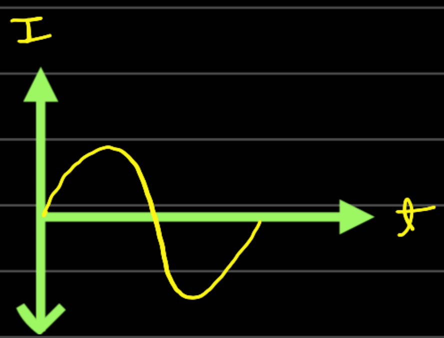
$$\Rightarrow \boxed{L = \frac{N^2 \mu_0 \mu_r A_c}{l_c}}$$

→ B-H curve of a magnetic material :

$B_r \rightarrow$ residual flux density

multi-valued and non-linear function





→ Power loss :

$$P_h = \frac{1}{T}\int VI\,dt \qquad (T \rightarrow \text{time period})$$

$$= \frac{1}{T}\int N\frac{d\phi}{dt} \times \frac{H l_c}{N}\, dt$$

$$= \frac{1}{T}\int A_c\, dB\, H l_c$$

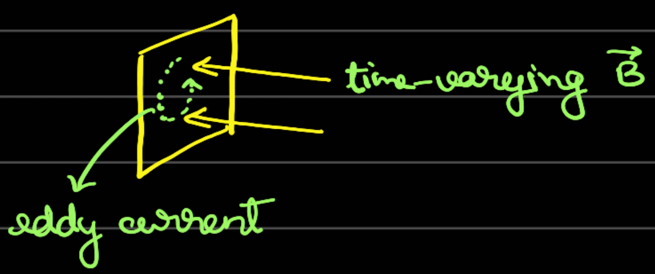
$$= f A_c l_c \int H\, dB$$

$$\Rightarrow P_h = f \underbrace{V_c}_{\text{Volume of core}} \cdot \text{Area of B-H loop}$$

→ **Steinmetz formula:**

$$P_h = \underbrace{K}_{\text{Depends on material}} \underbrace{B_m^{x}}_{\text{maximum flux density}} f \qquad (x \sim 1.5 \text{ to } 2.5)$$

→ **Eddy current losses** –



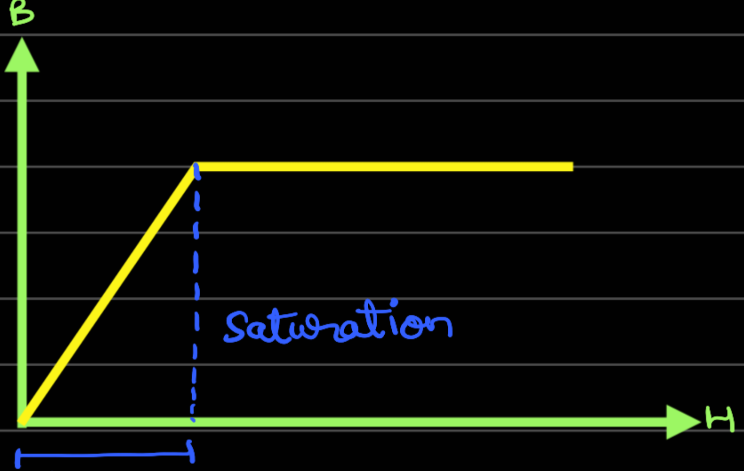
Eddy currents arise because magnetic material is also an electrical conductor

$$P_e = K' B_m^2 f^2 \underbrace{t^2}_{\text{thickness}}$$

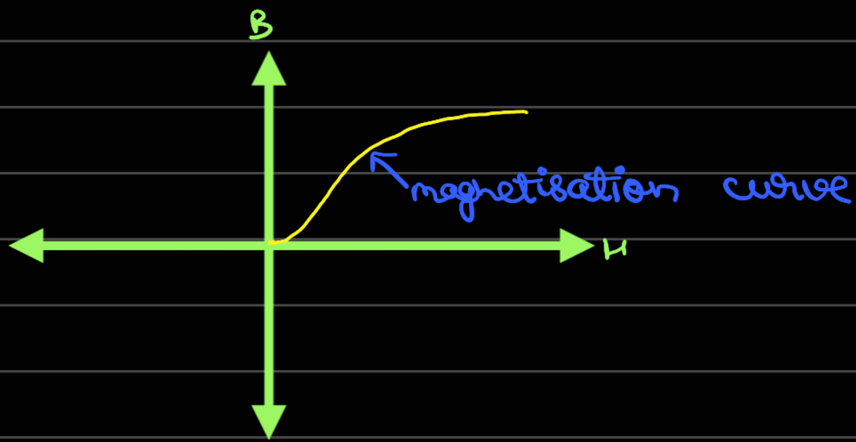
→ **Core loss / magnetic loss** –

$$\text{Iron loss} = P_h + P_e$$

→ Injustice to the B-H curve -

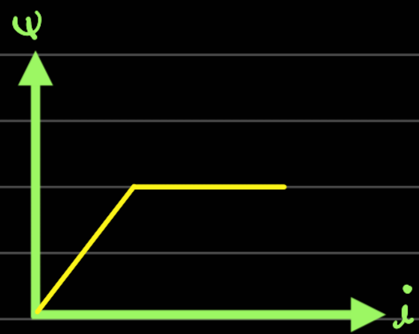


$B = \mu_0 \mu_r H$

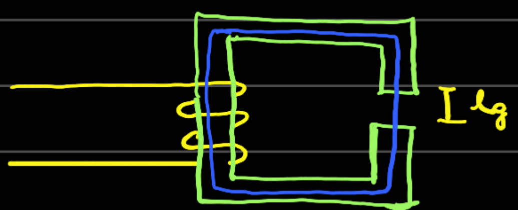


$$V = iR + \frac{d\psi}{dt} = iR + N\frac{d\phi}{dt}$$

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



→ Stabilizing Inductance -



$$L = \frac{N^2}{\mathcal{R}} = \frac{N^2}{\left(\frac{l_c}{\mu_0 \mu_r A_c}\right)}$$

$$L = \frac{N^2}{\mathbb{R}_c + \mathbb{R}_g} \approx \frac{N^2}{\mathbb{R}_g} = \frac{N^2}{\left(\frac{l_g}{\mu_0 A_c}\right)}$$

→ The derivation –

Ampere's circuital law : $\oint_C \vec{H}\cdot d\vec{l} = \int_S \vec{J}\cdot d\vec{S}$

$$B_g = B_c \quad \because \quad \phi_g = \phi_c$$

$$\Uparrow$$

$$A_g = A_c$$

But $H_g >> H_c$

$$H_c l_c + H_g l_g = NI$$

$$\Rightarrow \frac{B_c l_c}{\mu_0 \mu_r} + \frac{B_c l_g}{\mu_0} = NI$$

$$\Rightarrow \frac{\phi l_c}{\mu_0 \mu_r A_c} + \frac{\phi l_g}{\mu_0 A_c} = NI$$

Now $N\phi = LI$

So $LI\left(\frac{l_c}{\mu_0 \mu_r A_c} + \frac{l_g}{\mu_0 A_c}\right) = N^2 I$

$$\Rightarrow L = \frac{N^2}{\mathbb{R}_c + \mathbb{R}_g}$$