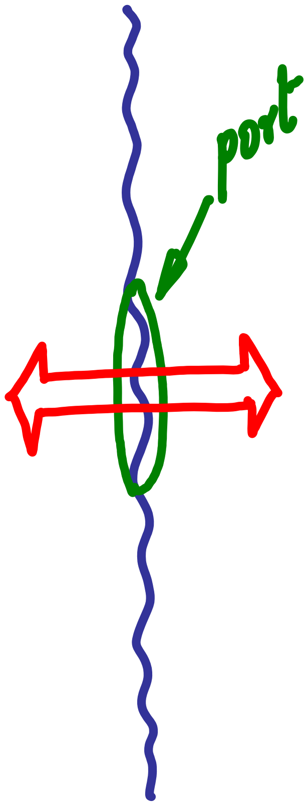
Magnetics for DC-DC converters

Electrical

potential across v

current thro' i



Magnetic

potential $\Rightarrow$ mmf

magnetomotive force

flow $\Rightarrow$ $\dfrac{d\phi}{dt}$

FARADAY EQN.

AMPERE'S RULE

Electric

$v = N\dfrac{d\phi}{dt}$

i

Magnetic.

$Ni = mmf$

mmf

$\dfrac{d\phi}{dt}$

$Ni = \int H \cdot dl$

$Ni = H \cdot l_m$

$$\boxed{H = \frac{Ni}{l_m}}$$

N

Number of turns of the winding.

$$\boxed{\begin{aligned} v &= N\frac{d\phi}{dt} \\ mmf &= \underline{\underline{Ni}} \end{aligned}}$$

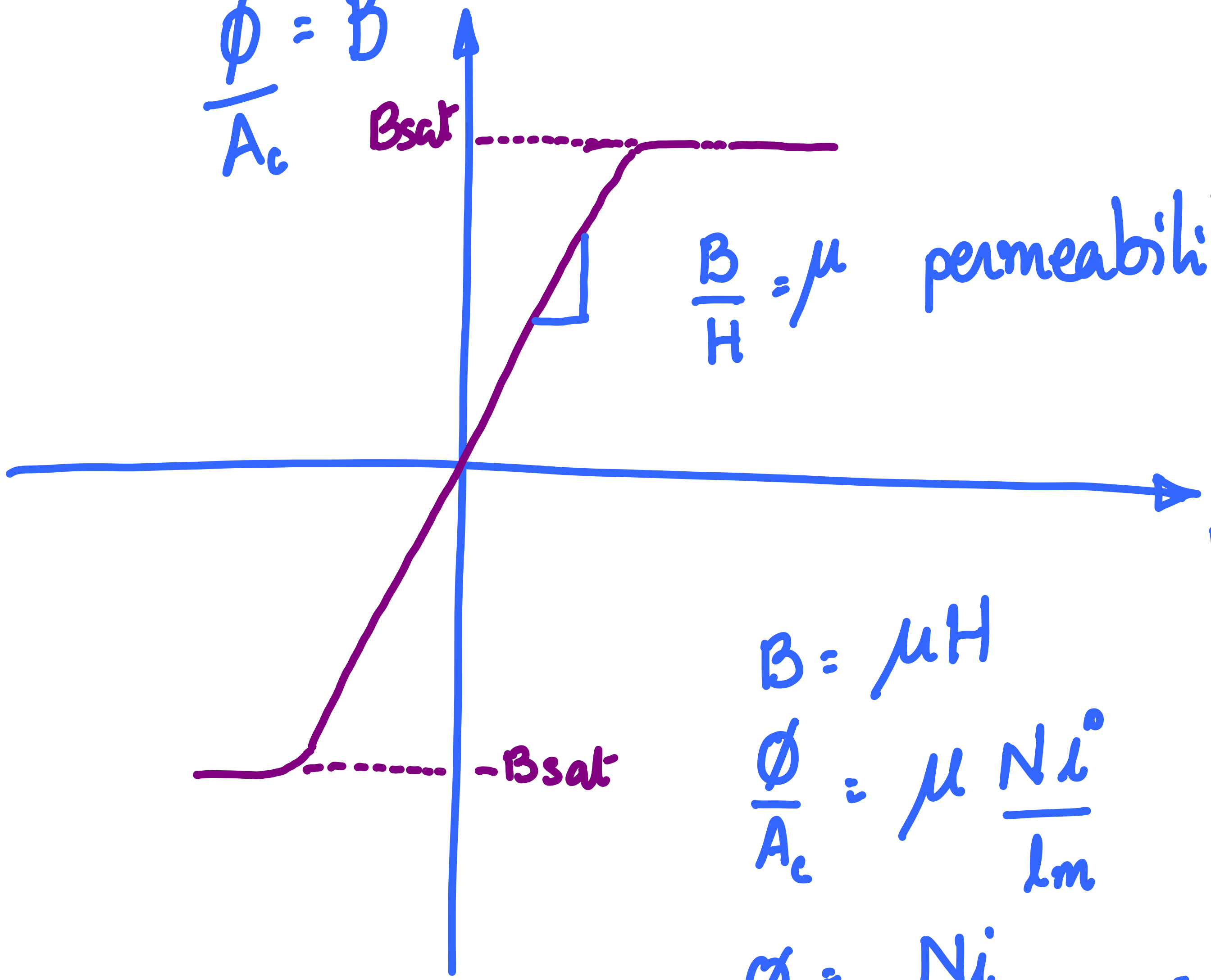
power :

$\underline{\underline{v}} \cdot \underline{\underline{i}} =$ watts

$N\frac{d\phi}{dt} \cdot i =$ watts

$\underline{\underline{mmf}} \cdot \underline{\underline{\frac{d\phi}{dt}}} =$ watts.

$$\frac{\phi}{A_c} = B$$



$$\frac{B}{H} = \mu \quad \text{permeability}$$

$$H = \frac{Ni}{l_m}$$

$$B = \mu H$$

$$\frac{\phi}{A_c} = \mu \frac{Ni}{l_m}$$

$$\phi = \frac{Ni}{(l_m/\mu A_c)} = \frac{Ni}{\mathcal{R}} = \frac{mmf}{\mathcal{R}}$$

$$\phi = \frac{mmf}{\mathcal{R}} = \left(\frac{1}{\mathcal{R}}\right) \cdot mmf$$

$[Q = C\,V]$ electrical equivalent

$$\Lambda = \frac{1}{\mathcal{R}}$$ permeance

(capacitance concept)

$$\boxed{\phi = \Lambda \cdot mmf}$$

$$\phi = \Lambda \cdot Ni$$

$$N\frac{d\phi}{dt} = \Lambda \cdot N^2 \frac{di}{dt}$$

$$v = \underbrace{\Lambda N^2}_{\text{inductance value}} \frac{di}{dt} = L\frac{di}{dt}$$

$$L = \Lambda N^2$$

L: obtained from electrical design.

Λ: A_L factor nH/turns^2

$$N = \sqrt{\frac{L}{\Lambda}}$$

$$L = \Lambda N^2$$

$$= \frac{1}{\mathcal{R}} \cdot N^2 = \left(\frac{\mu A_c}{l_m}\right) \cdot N^2$$

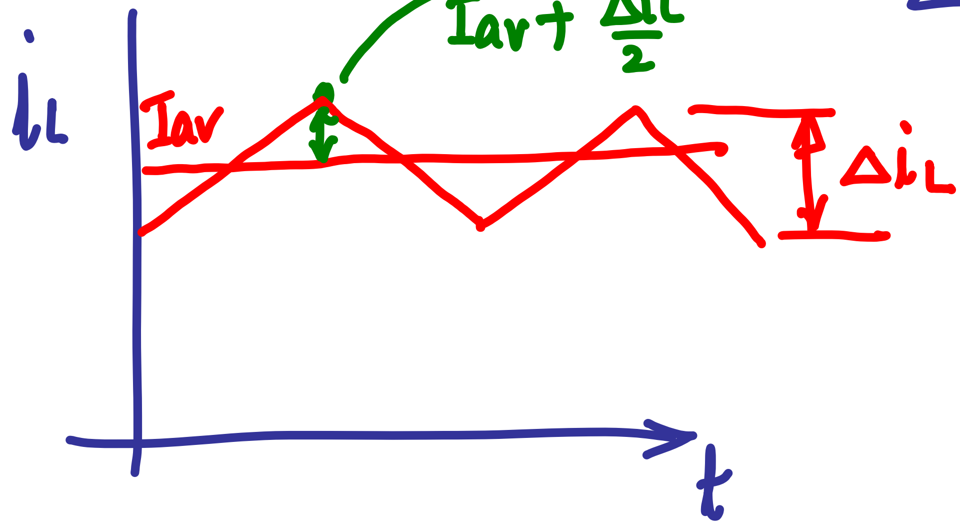
$$\boxed{L = \frac{\mu_0 \mu_r A_c N^2}{l_m}}$$

$\mu_0 = 4\pi \times 10^{-7}$ H/m

Electrical	Mechanical
L, i	A_c
v_L	A_w
$\mathcal{E} \leftrightarrow$ joules	$B_{sat} \leftrightarrow$ material
	N
	gauge of copper

Energy

$$\mathcal{E}_{max} = \frac{1}{2} L I_m^2$$



$$I_m = \left(I_{av} + \frac{\Delta i_L}{2}\right)$$

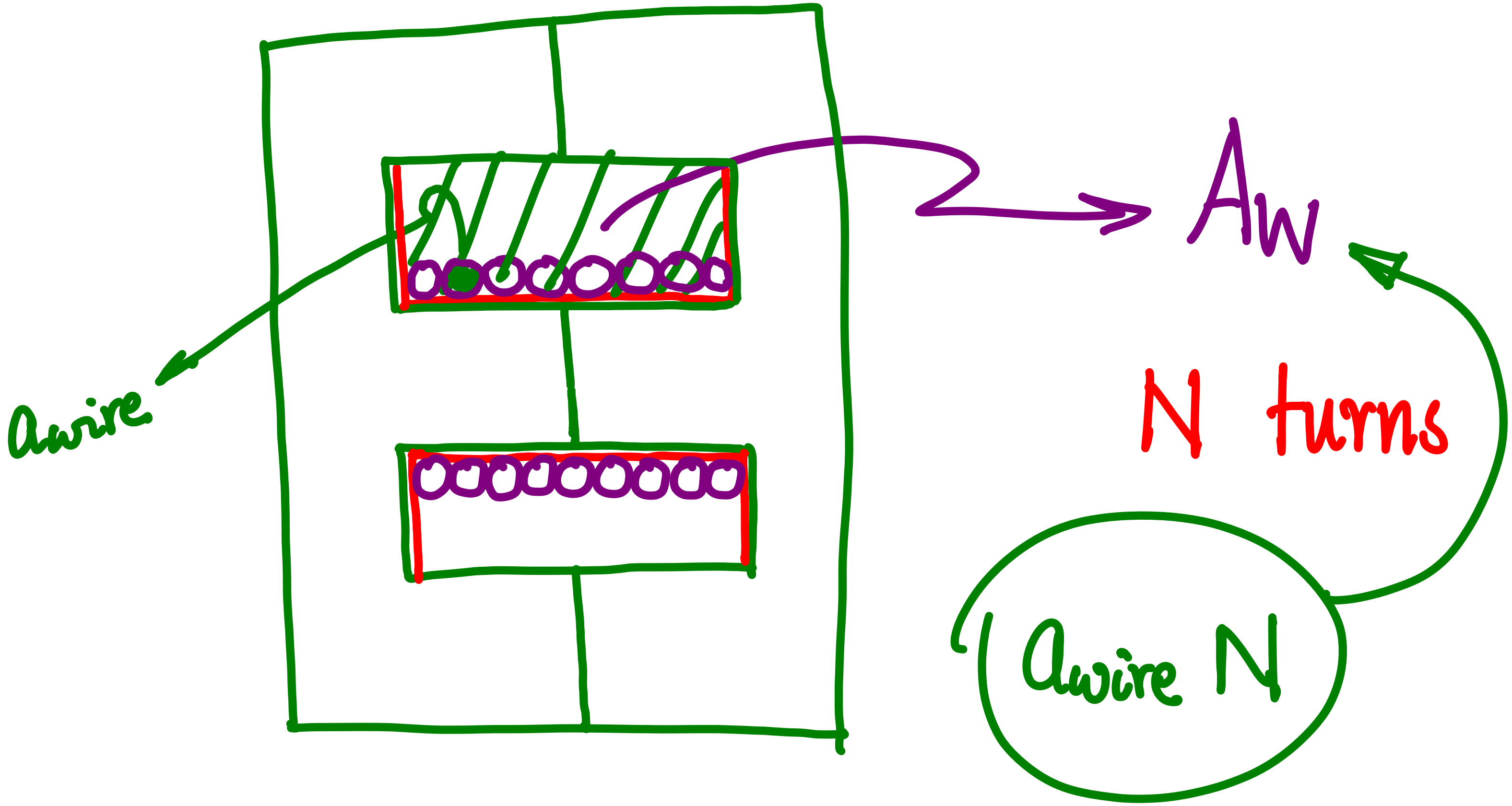
$$\mathcal{E} = \frac{1}{2} L I_m^2 = \frac{1}{2} \cdot \underbrace{L I_m} \cdot \underbrace{I_m}$$

$$\boxed{A_w}$$

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

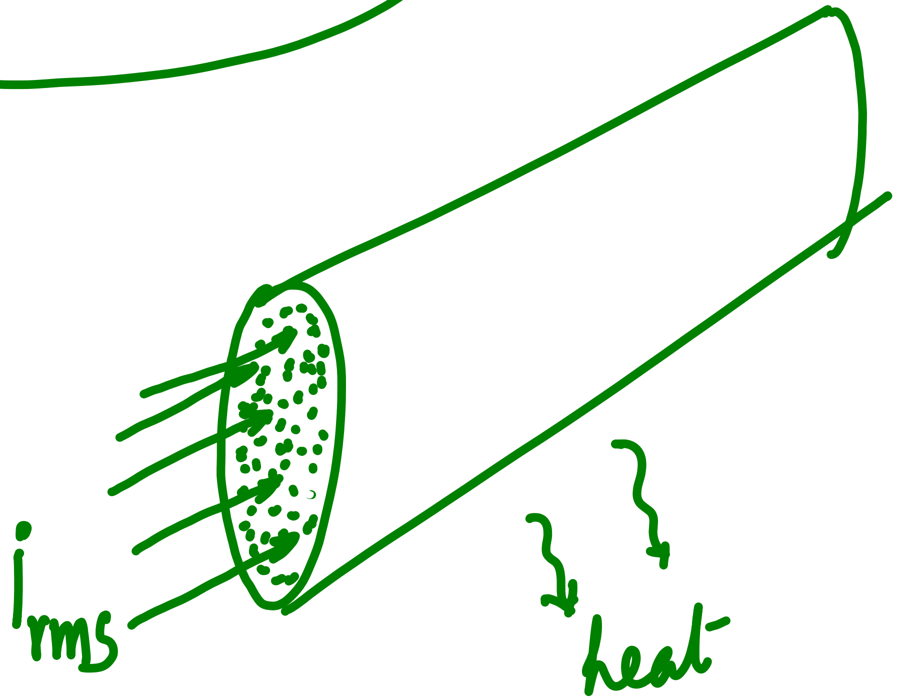
$$= N \phi_m = L I_m$$

$$= N \boxed{A_c} B_m = L I_m$$



$A_w > N\, a_{wire}$

$$A_w > N a_{wire}$$



$J = 3 \, A/mm^2$

$3 \times 10^6 \, A/m^2$

$2 \, A/mm^2$ to $5 \, A/mm^2$

J current density Amps/m^2

A/mm^2

$$J = \frac{I_{rms}}{a_{wire}} = \frac{I_m/K_c}{a_{wire}}$$

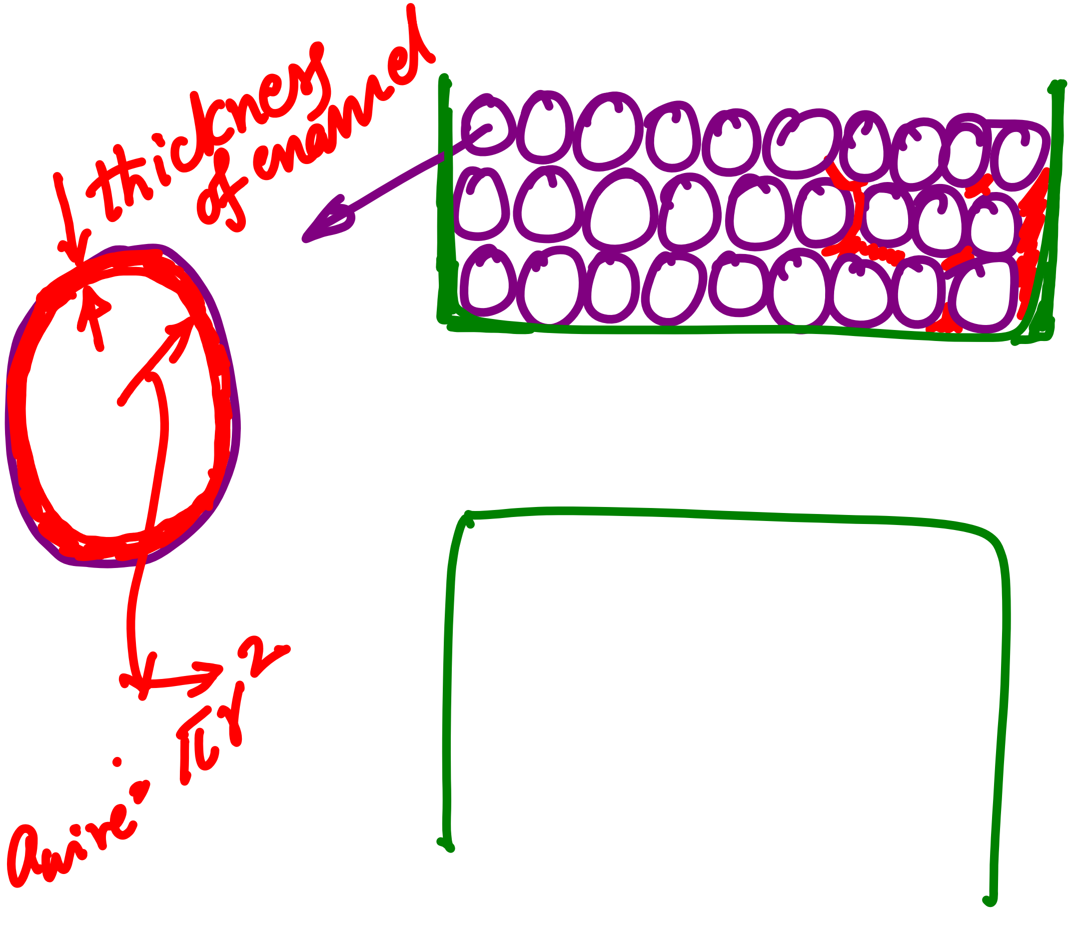
$$\boxed{a_{wire} = \frac{I_{rms}}{J}}$$

$$I_m = K_c J a_{wire}$$

$$A_w > N a_{wire}$$

$$N \frac{I_{rms}}{J} = \frac{N I_m}{K_c J}$$

$$\boxed{I_m = \frac{A_w K_c J}{N}}$$



airgaps

A_w

$K_w A_w$ $\quad K_w < 1$

inductors = 0.6

transformers = 0.2 to 0.4

$$K_w A_w > N a_{wire}$$

$$K_w A_w = \frac{N I_m}{K_c J}$$

$$I_m = \frac{K_w K_c J A_w}{N}$$

$$\mathcal{E} = \frac{1}{2} \cdot L I_m \cdot I_m$$

$$= \frac{1}{2} \cdot \cancel{N} A_c B_m \cdot \frac{K_c K_w A_w J}{\cancel{N}}$$

$$\boxed{A_w A_c = A_p = \frac{2\mathcal{E}}{K_c K_w J B_m}}$$