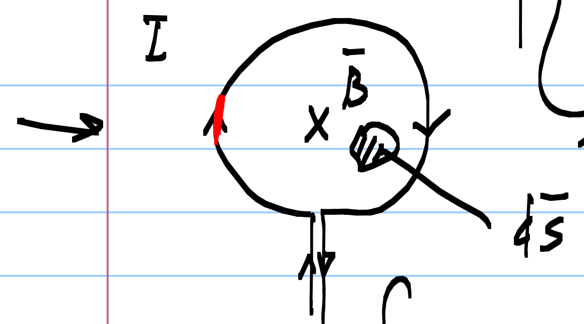
EC1010: Lecture 42

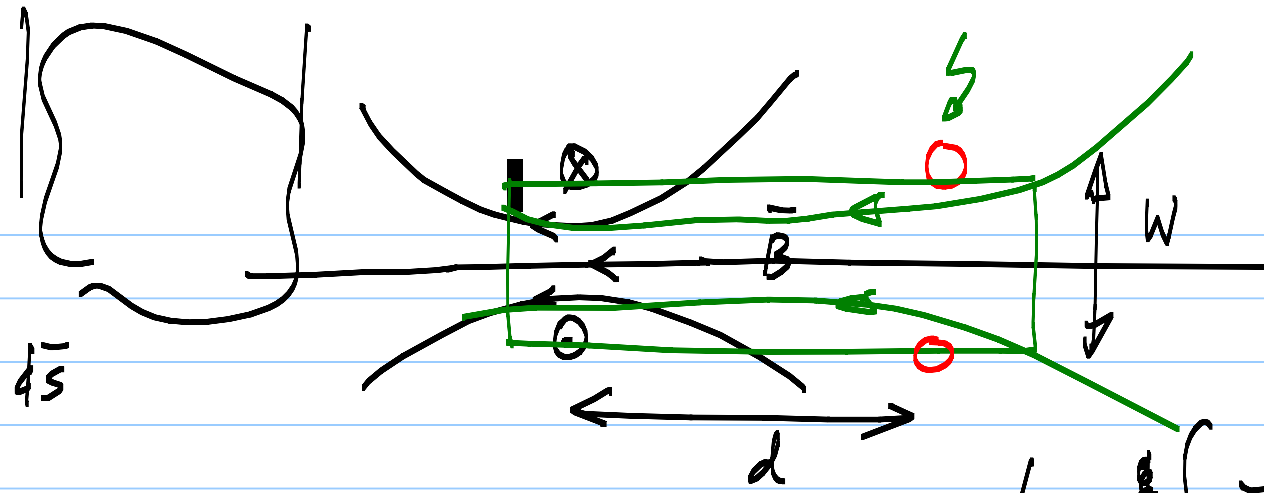
$\mathcal{P} = \mu_r \mu_0 \cdot \frac{A}{l}$

ϕ : Wb $\quad \bar{B}$: Wb/m^2 (T) (Flux density)

$\mathcal{F}$: A·turns $\quad \bar{H}$: $\frac{\text{A·turns}}{m}$ $\quad \oint \bar{H} \cdot d\bar{l} = N \cdot I$

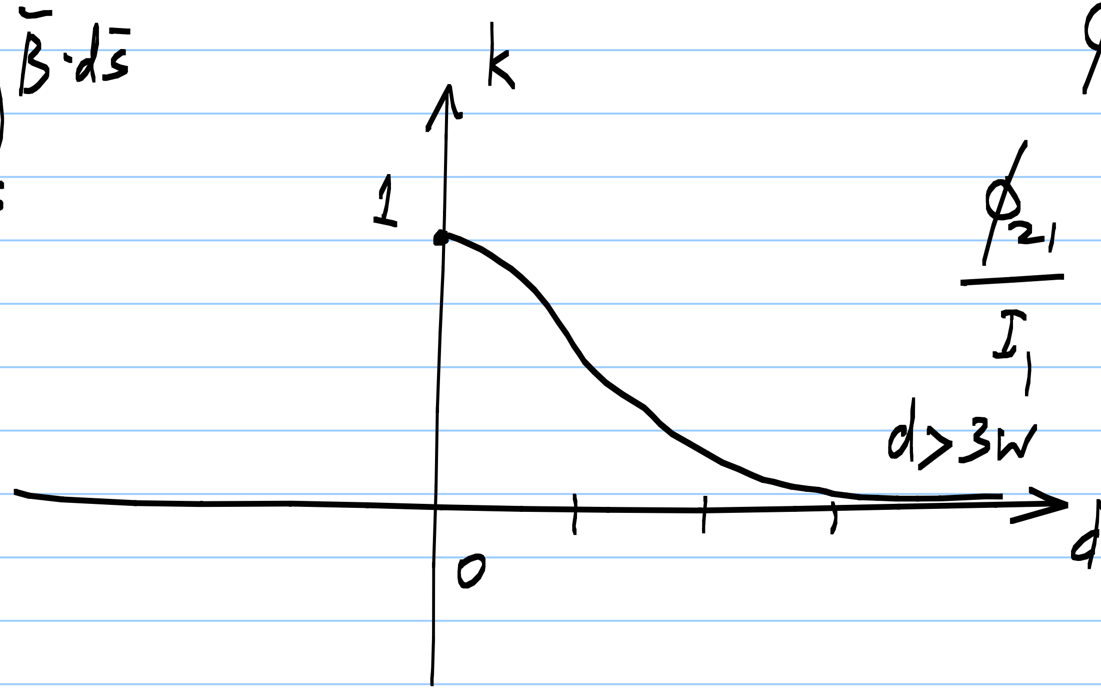
$\mathcal{R} = \frac{\mathcal{F}}{\phi} = \frac{\text{A·turns}}{\text{Wb}}$





$(\;)\,I = \phi = \int_S \bar{B} \cdot d\bar{s}$

Inductance L



$\phi_{21} = \oint \bar{B} \cdot d\bar{s}$

surface of loop 2

$\frac{\phi_{21}}{I_1} = M$

$d > 3W$ negligible coupling

Solenoid (air core)

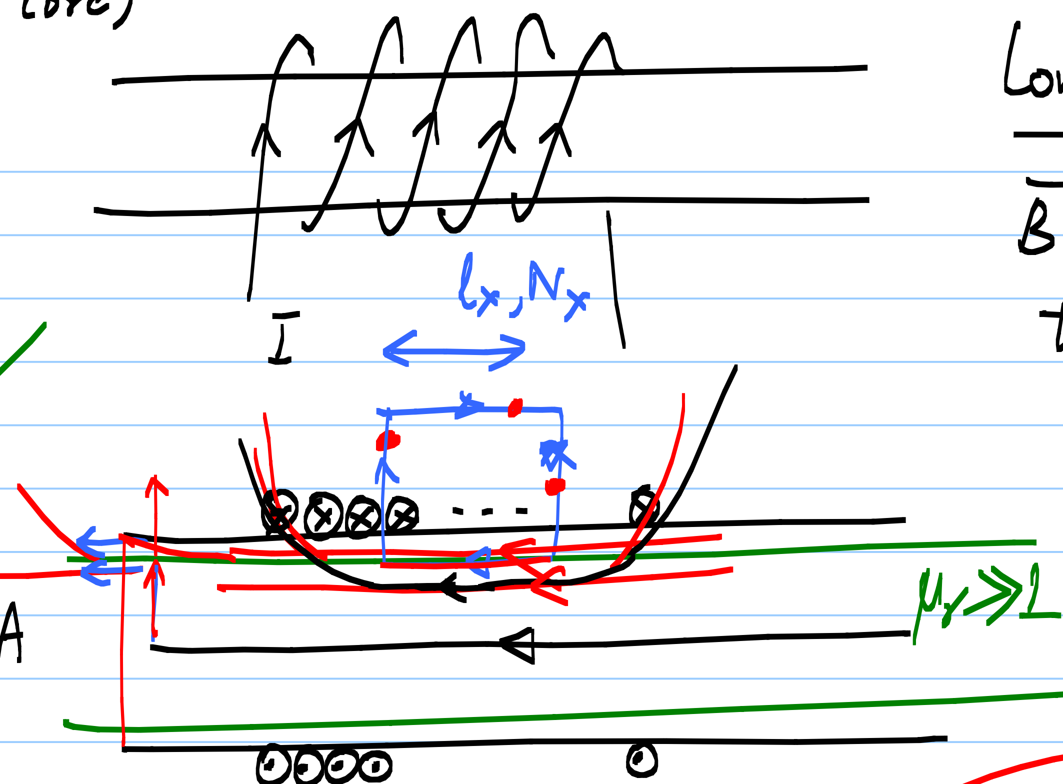
$H \cdot l_x = N_x \cdot I$

$H = \left(\frac{N_x}{l_x}\right) \cdot I$ ✓

$B = \mu_r \mu_0 \left(\frac{N_x}{l_x}\right) I$

$\phi = B \cdot A$

$= \mu_r \mu_0 A \cdot \frac{N_x}{l_x} \cdot I$



$\psi = N \cdot \phi = \mu_r \mu_0 A N \cdot \frac{N_x}{l_x} I$

flux linkage

Inductance of a solenoid

Long solenoid:

$\bar{B}$: parallel to the axis & uniform inside the coil

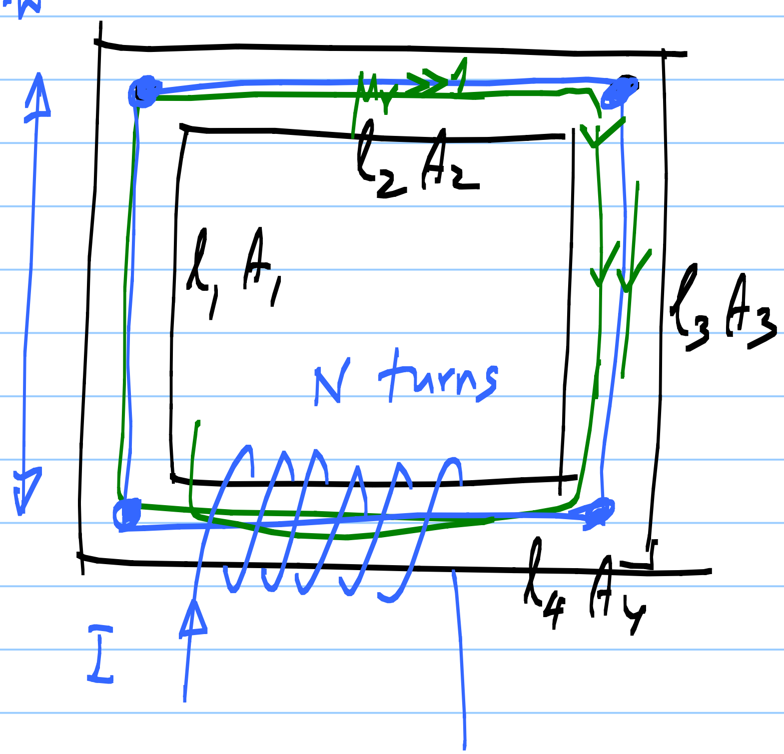
$\mathcal{F} = N \cdot I$ ✓

$\phi = \mu_r \mu_0 \cdot A \cdot \frac{N_x}{l_x} \cdot I$

$\mathcal{P} = \frac{\phi}{\mathcal{F}} = \mu_r \mu_0 A \cdot \frac{N_x / l_x}{N}$

$= \frac{1}{\frac{1}{\mu_r \mu_0}\left(\frac{l_1}{A_1} + \cdots \frac{l_4}{A_4}\right)}$

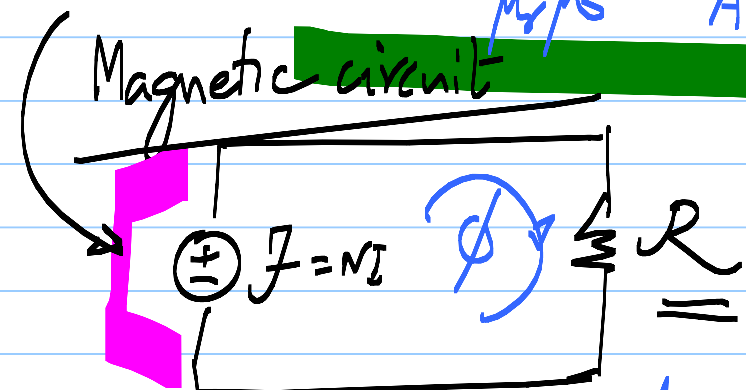
$l_{loop} = 4 \cdot W$



$\mathcal{F} = N \cdot I$

$\mathcal{R} = \frac{1}{\mu_r \mu_0} \cdot \frac{l_{loop}}{A}$

Magnetic circuit



$\phi = NI / \mathcal{R} = \mu_r \mu_0 \cdot \frac{A}{l_{loop}} \cdot NI$

Flux $\phi = \mu_r \mu_0 \cdot \frac{A}{l_{loop}} \cdot N_1 I$

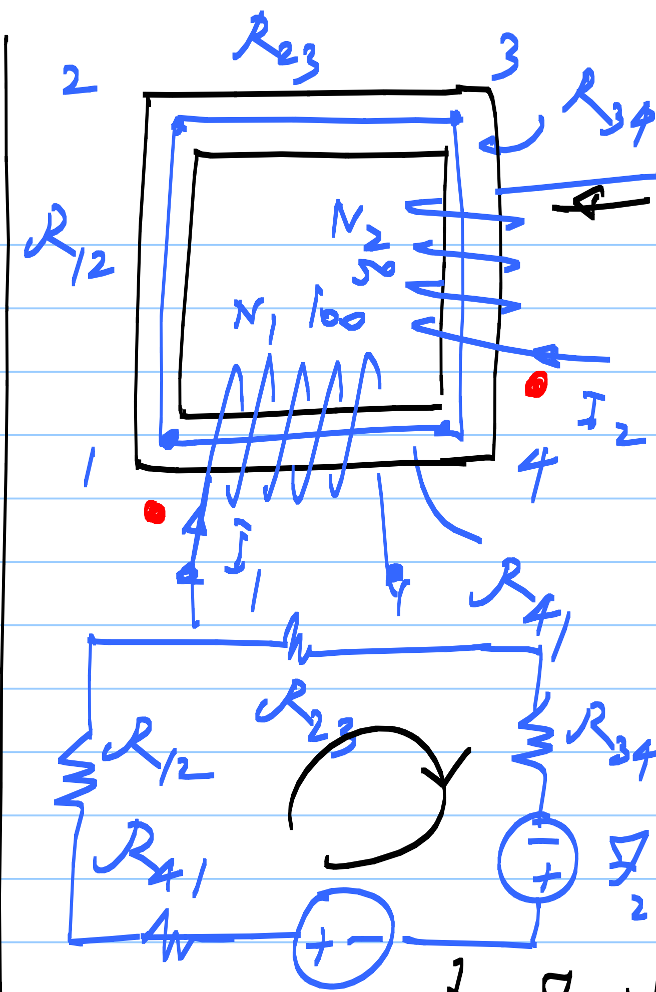
Flux linkage (N turns) $\psi = \mu_r \mu_0 \cdot \frac{A}{l_{loop}} \cdot$ ~~$N^2 I$~~ $N_1 I_1 \cdot N_2$

$\frac{L_1}{L_2} = n^2 = \left(\frac{N_1}{N_2}\right)^2$

$L = \mu_r \mu_0 \cdot \frac{A}{l_{loop}} \cdot N^2$

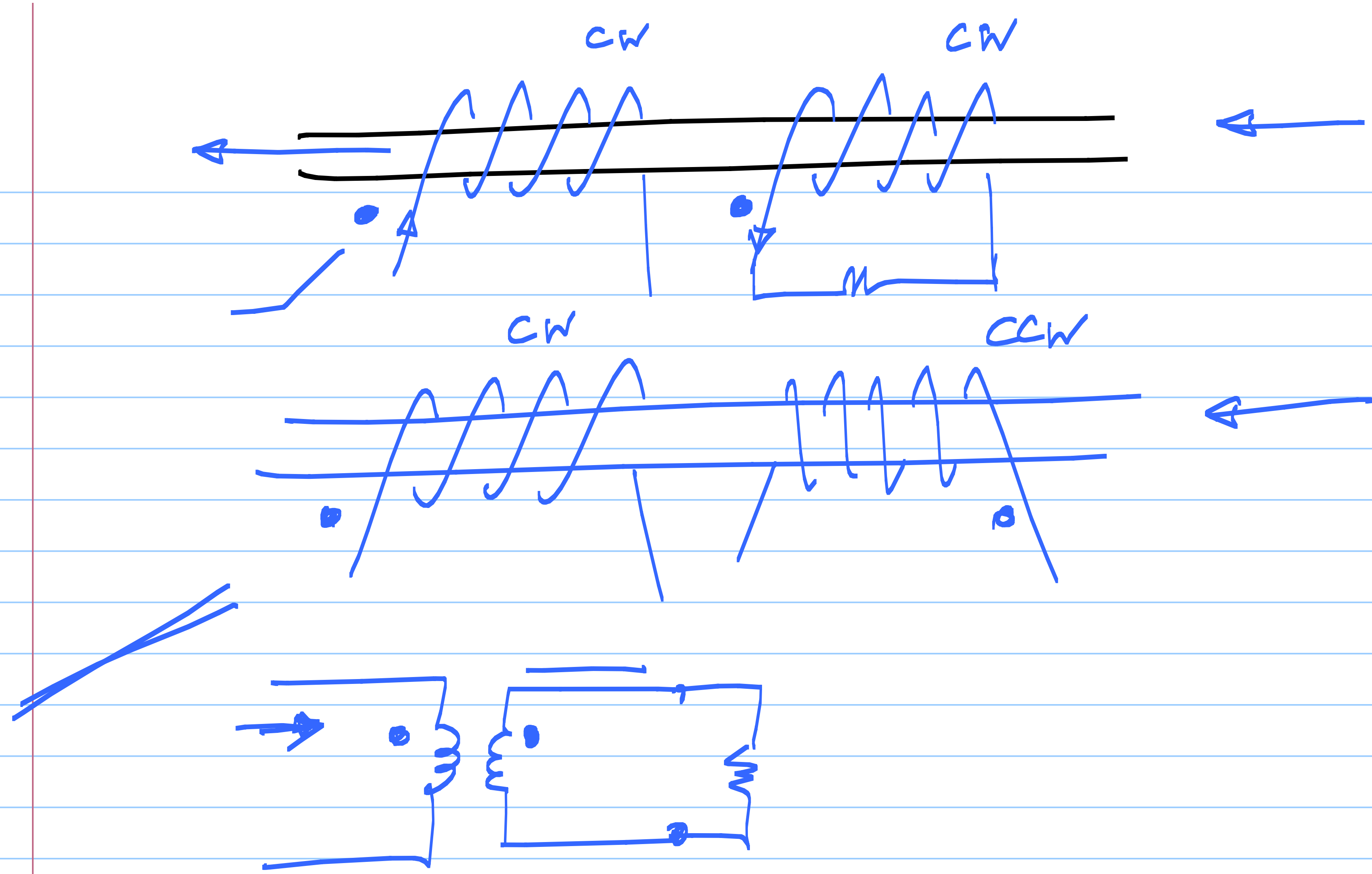
$L_1 = \mu_r \mu_0 \frac{A}{l_{loop}} \cdot N_1^2$; $L_2 = \mu_r \mu_0 \frac{A}{l_{loop}} \cdot N_2^2$

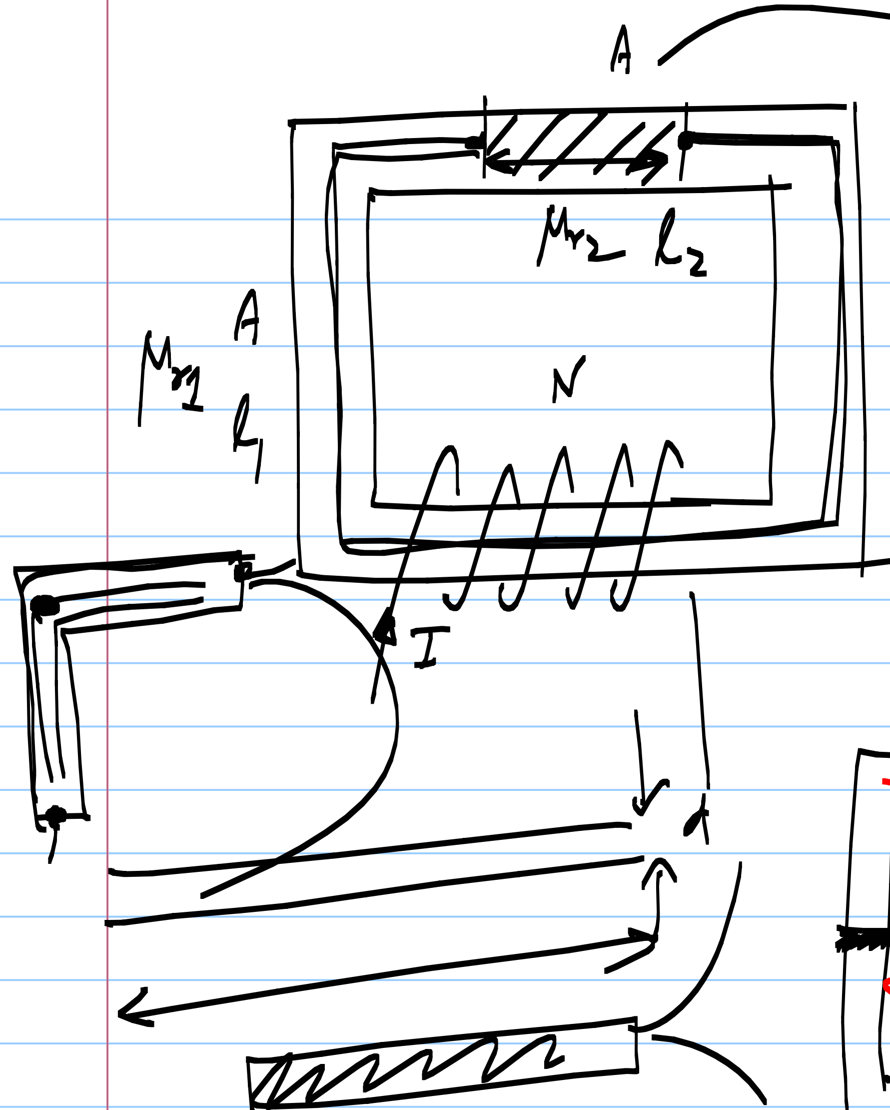
$M = \mu_r \mu_0 \frac{A}{l_{loop}} N_1 N_2$

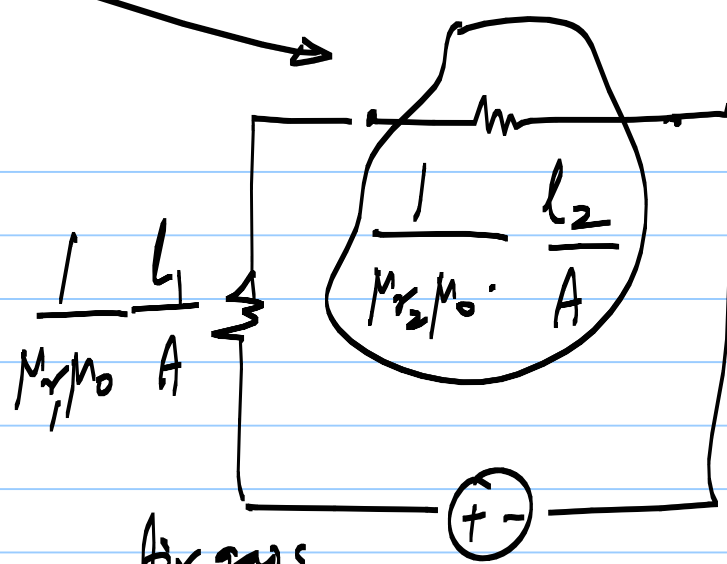


$\mathcal{F}_1 = N_1 I_1$

$\phi = \frac{\mathcal{F}_1 + \mathcal{F}_2}{\mathcal{R}_{tot}}$

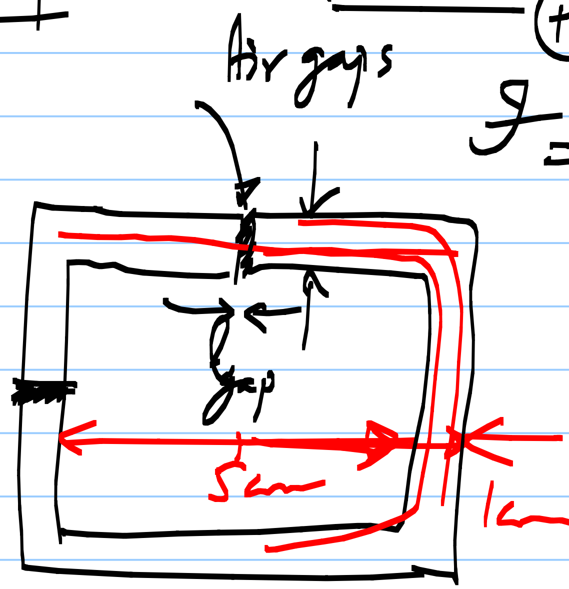

CW
CW
CW
CCW





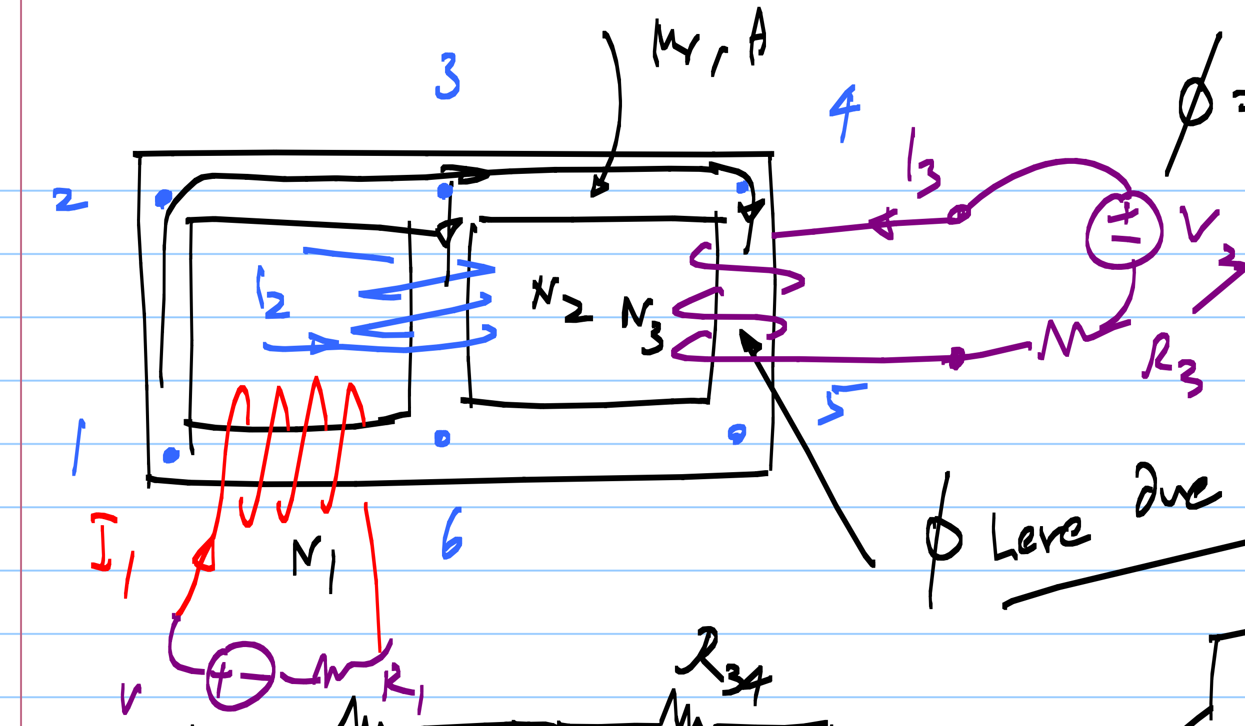
$\frac{1}{\mu_0}\frac{l_{gap}}{A}$

$\mathcal{F} = NI$



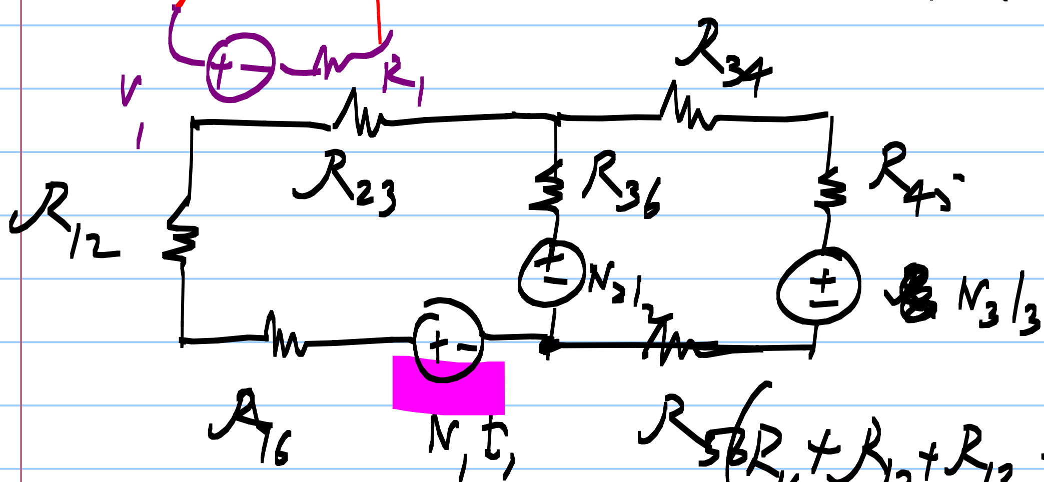
$l_{gap} \ll W$

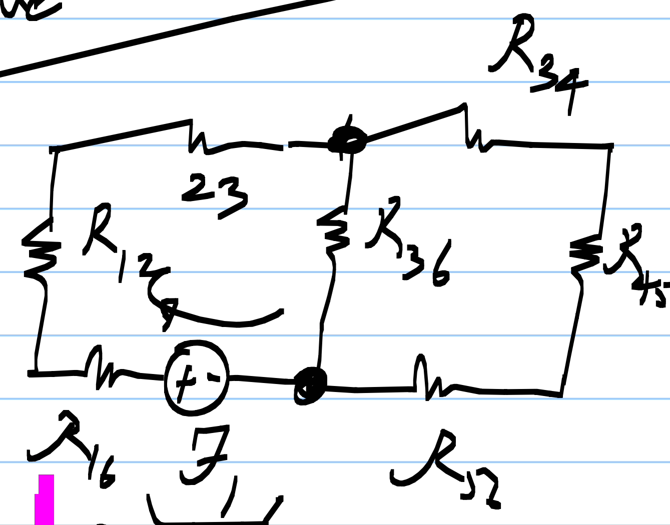
$l_{gap} < \frac{W}{10}$



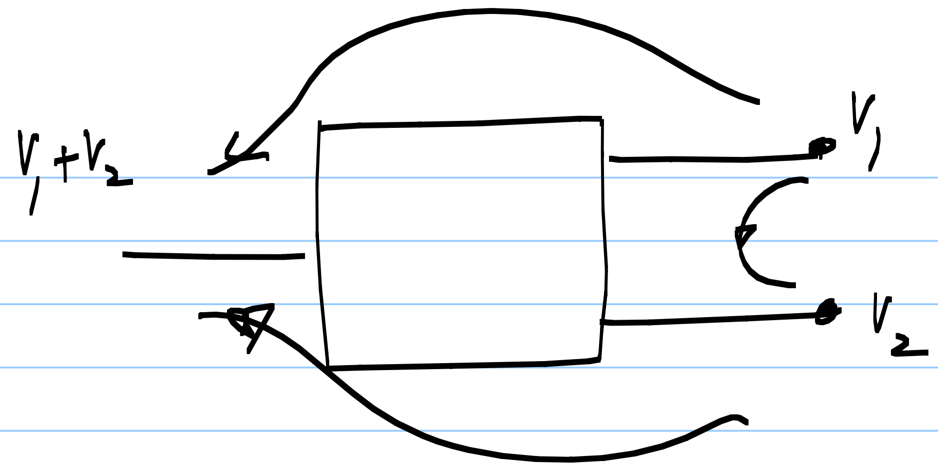
$$\phi = (\ )N_1 I_1 + (\ )N_2 I_2 + (\ )N_3 I_3$$

ϕ here due to $N_1 I_1$

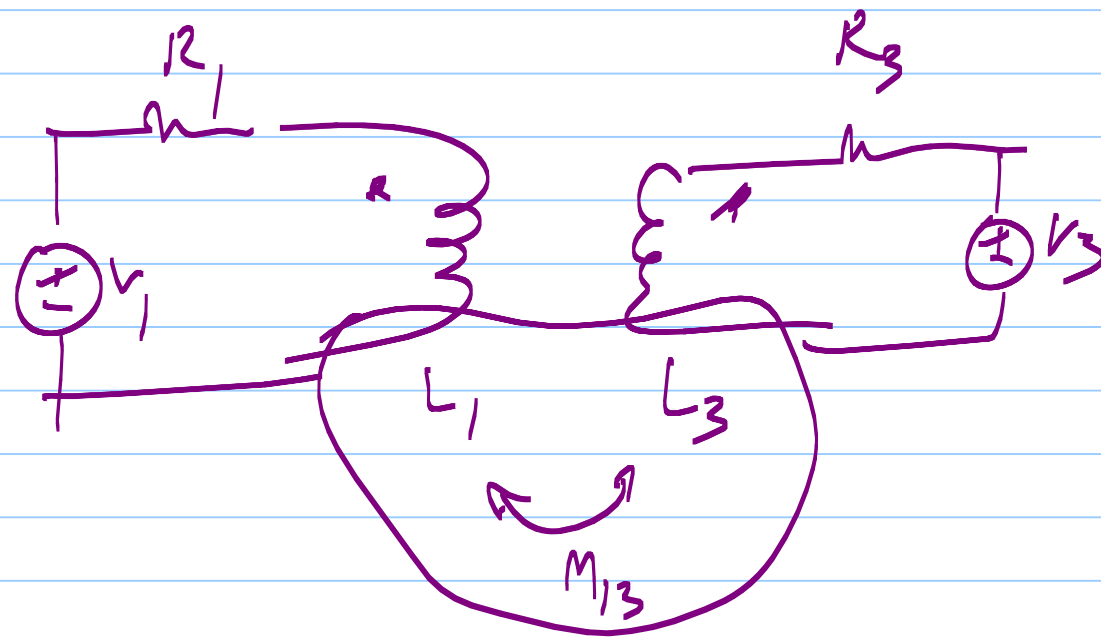




$$R_{5?}\left(R_{16} + R_{12} + R_{13} + R_{36} \parallel (R_{34} + R_{45} + R_{52})\right)$$



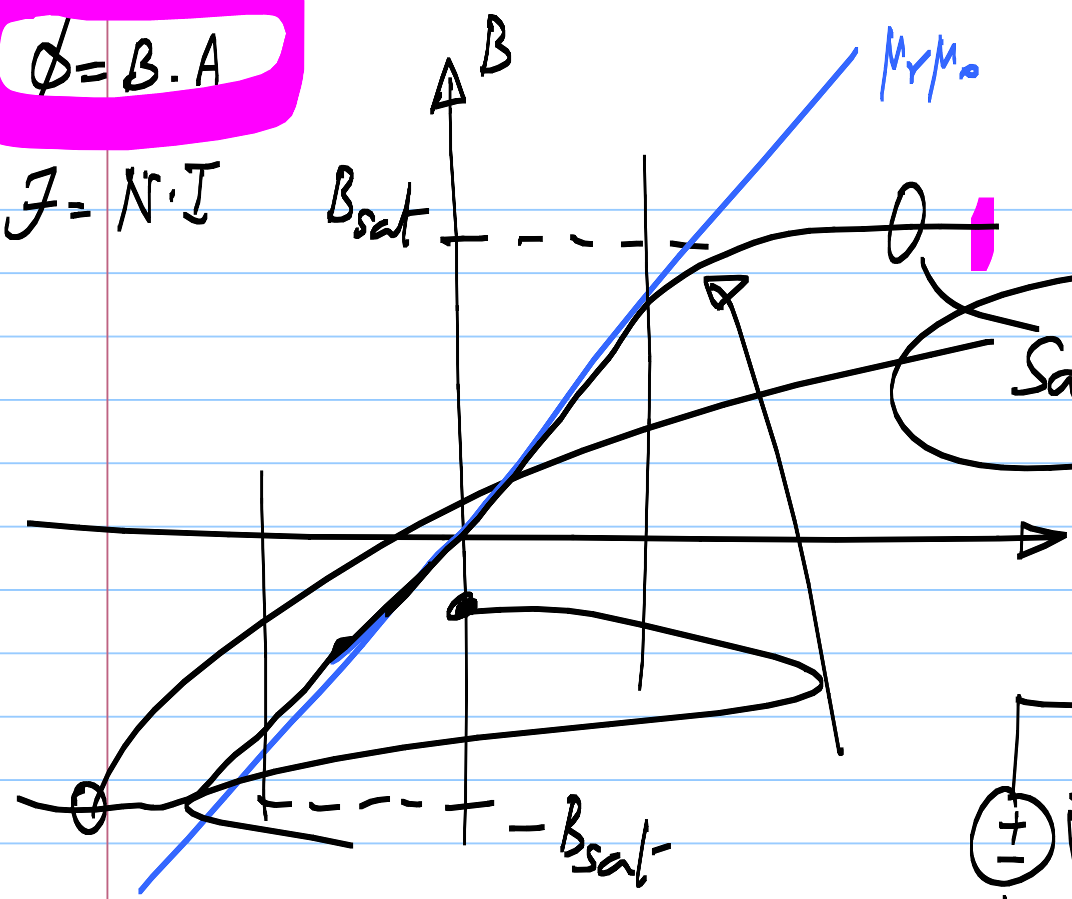
V1+V2
V1
V2



R1
R3
V1
V3
L1
L3
M13

$\Phi = B \cdot A$

$\mathcal{F} = N \cdot I$



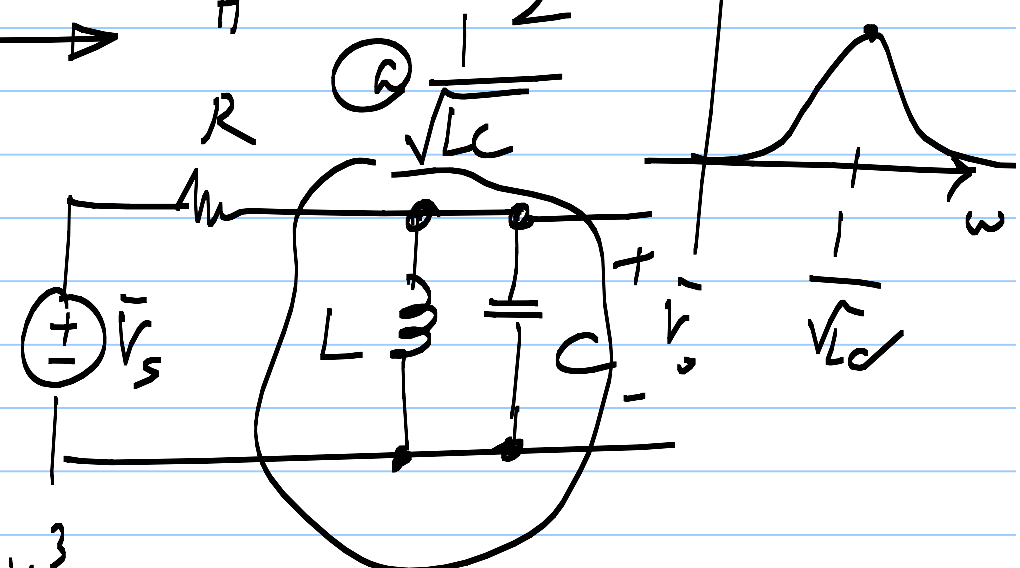
$B = \mu_r \mu_0 H$

$B = \mu_r \mu_0 H$

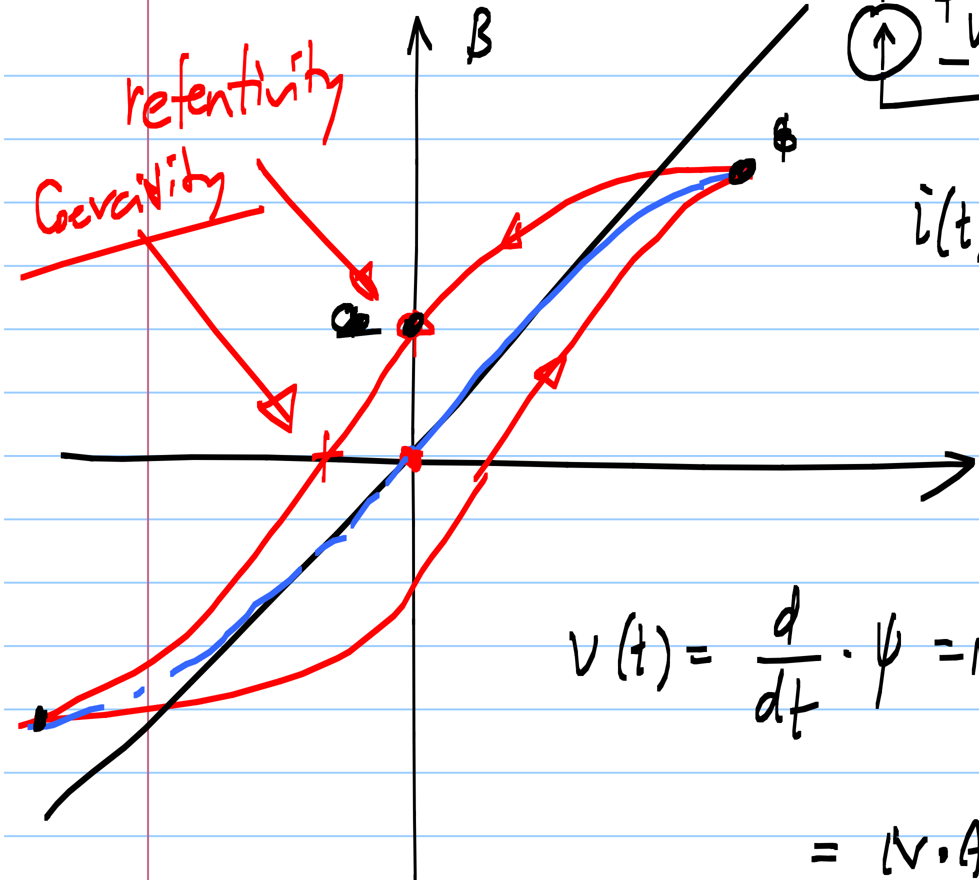
$+ \quad H^2 + H^3 + \ldots$

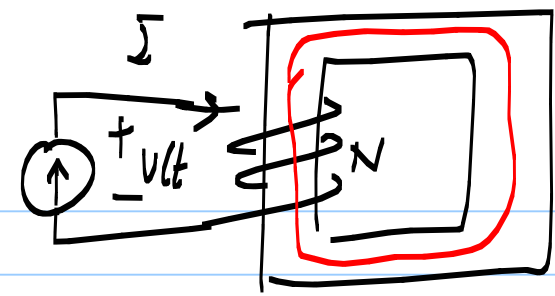
B–H nonlinearity

$\frac{1}{2} L I^2$!!



Hysteresis





l_{loop} , A

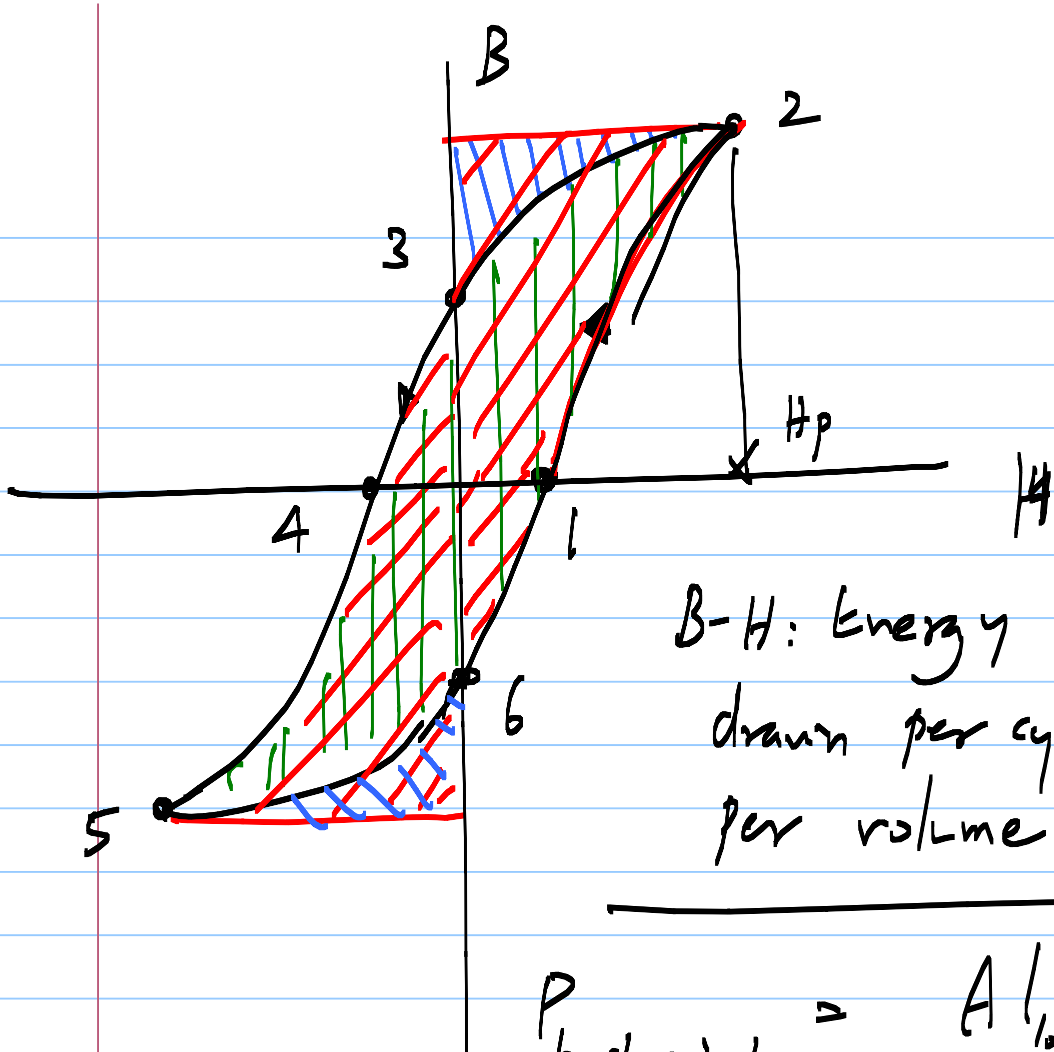
$$H = \frac{N \cdot i}{l_{loop}}$$

$i(t)$ $v(t)$

$$\int v(t) \cdot i(t)\, dt$$

$$v(t) = \frac{d}{dt} \cdot \psi = N \frac{d}{dt} \phi = \int N A \cdot \frac{dB}{dt} H \cdot \frac{l_{loop}}{N} \cdot dt$$

$$= N \cdot A \frac{dB}{dt} \qquad = A \cdot l_{loop} \int H \cdot dB$$



$$\int_{t_1}^{t_2} v \cdot i \, dt = \underbrace{A \cdot l_{loop}} \int_{B_1}^{B_2} H \cdot dB$$

1-2 : ~~Power~~ Energy drawn

2-3 : Energy returned

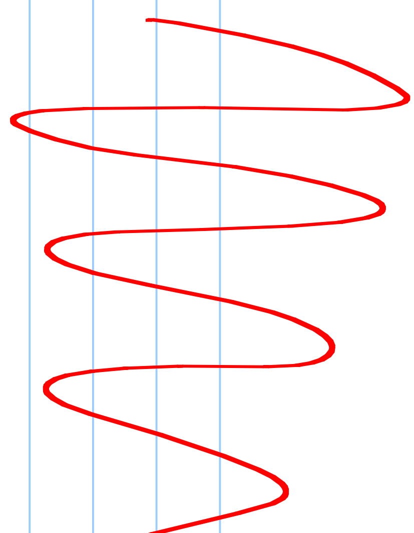
3-4-5 : Energy drawn

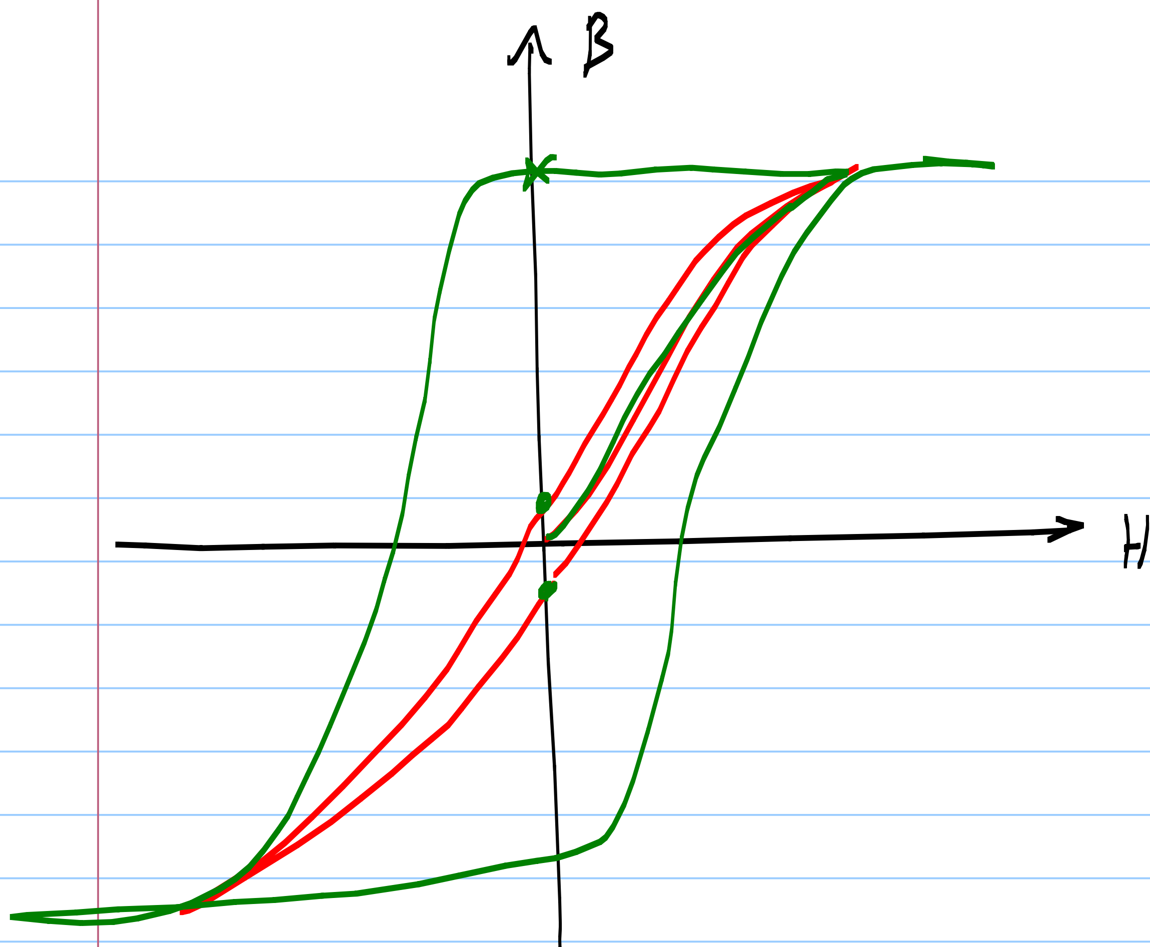
5-6 : Energy returned

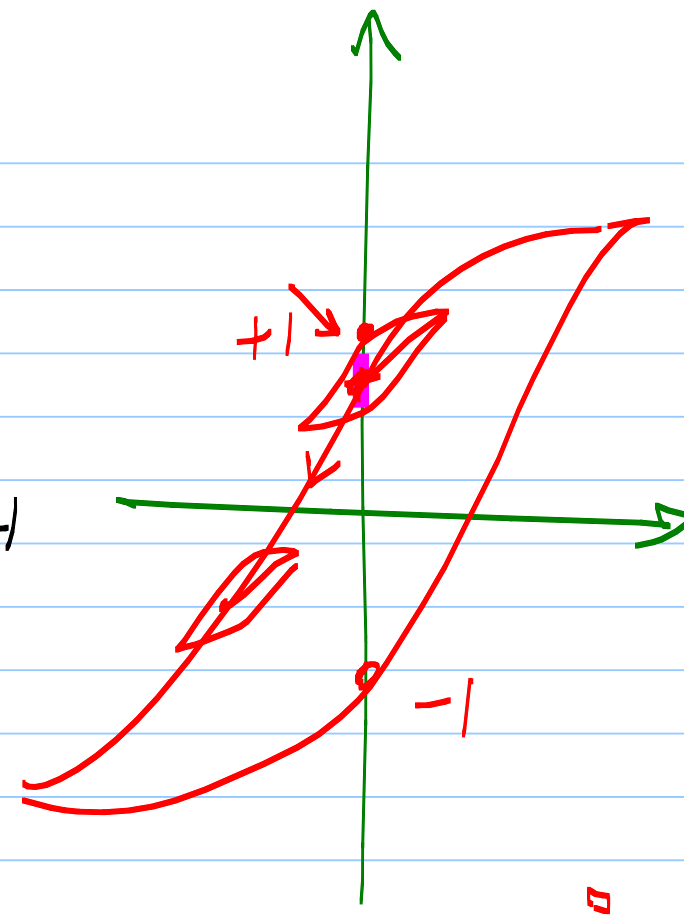
6-1 :

B-H: Energy drawn per cycle per volume

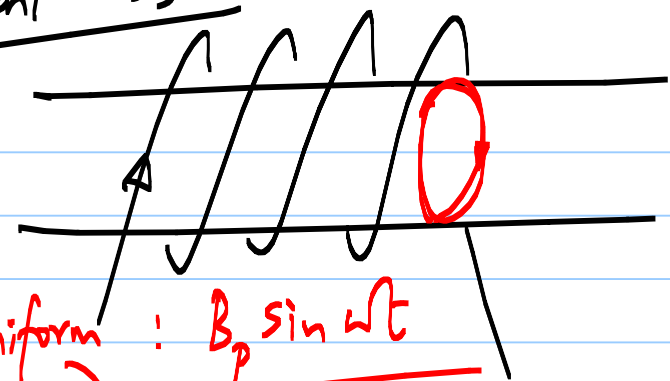
$$P_{hysteresis\ loss} = \underbrace{A\, l_{loop}}_{\text{Core volume}} \cdot (\text{BH loop area}) \cdot f$$



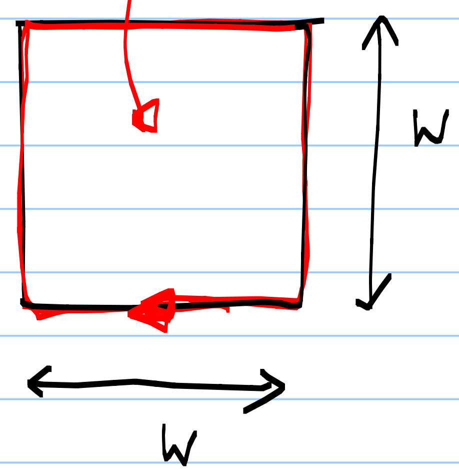

B
H

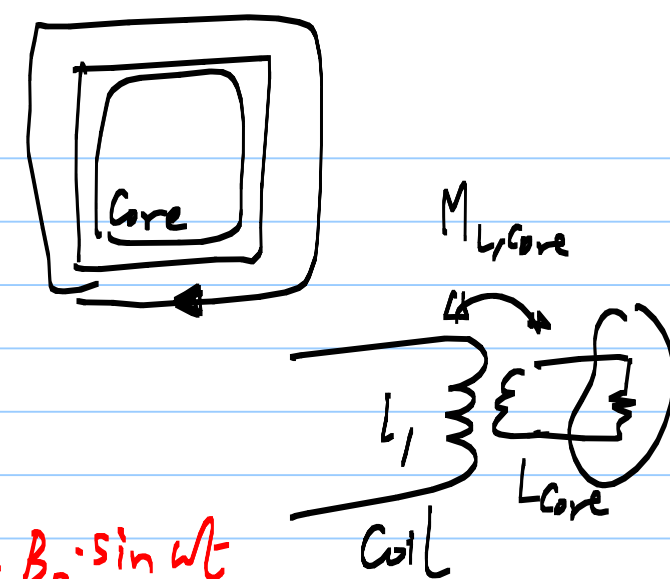

+1
−1

Eddy current loss:



B: uniform : $B_p \sin \omega t$



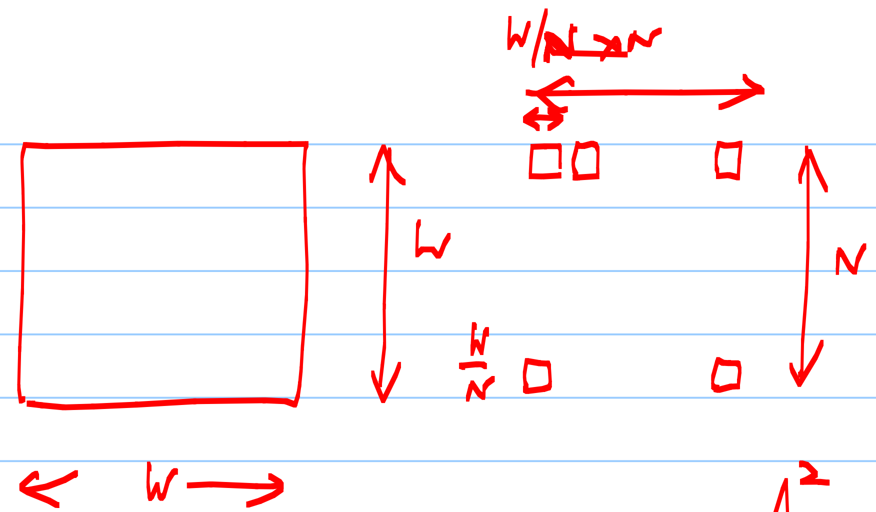


R_{loop}

$\phi = A \cdot B_p \cdot \sin \omega t$

$v(t) = \underbrace{A B_p \cdot \omega}_{V_p} \cdot \cos \omega t$

$$\frac{V_p^2}{2 \cdot R_{loop}} = \frac{A^2 B_p^2 \omega^2}{2 \cdot R_{loop}}$$



$$\frac{A}{N^2} \; ; \quad R_{loop}/N$$

$$A \cdot \quad R_{loop}$$

$$\frac{A^2 B_p^2 w^2}{2 R_{loop}}$$

$$N^2 \cdot \frac{\frac{A^2}{N^4} \cdot B_p^2 w^2}{2 \cdot \frac{R_{loop}}{N}} = \frac{1}{N} \cdot \frac{A^2 B_p^2 w^2}{2 R_{loop}}$$

Lamination