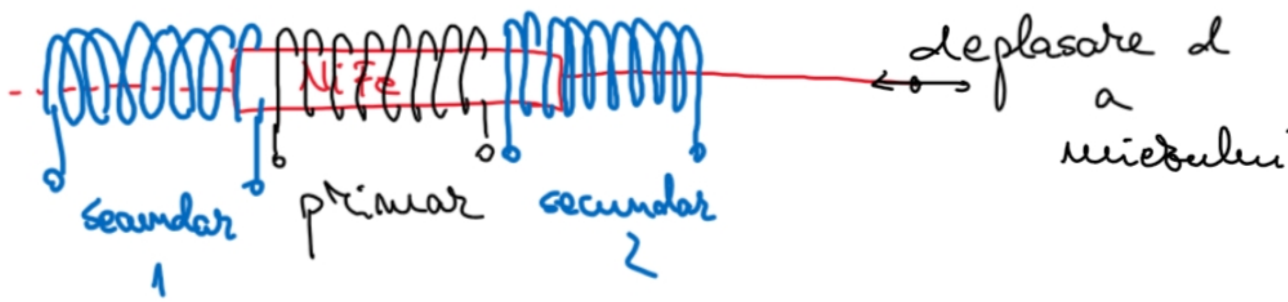
Curs 7:

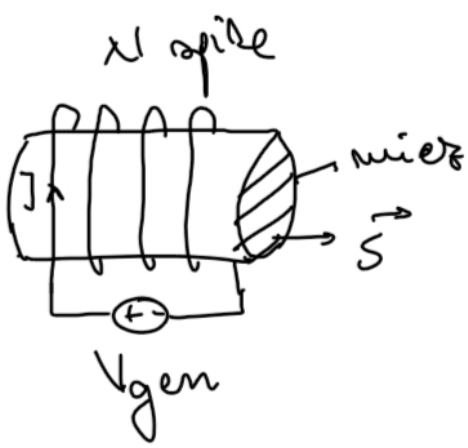
Transformatorul diferențial liniar variabil:

LVDT - „Linear Variable Differential Transformer"



Deplasarea miezului duce la variația factorului de cuplaj între primar și cei doi secundari. (implicit o variație a raportului de transformare).

Legea lui Faraday



tensiune electromotoare indusă

$$t.e.m. = -N\frac{d\phi}{dt}$$

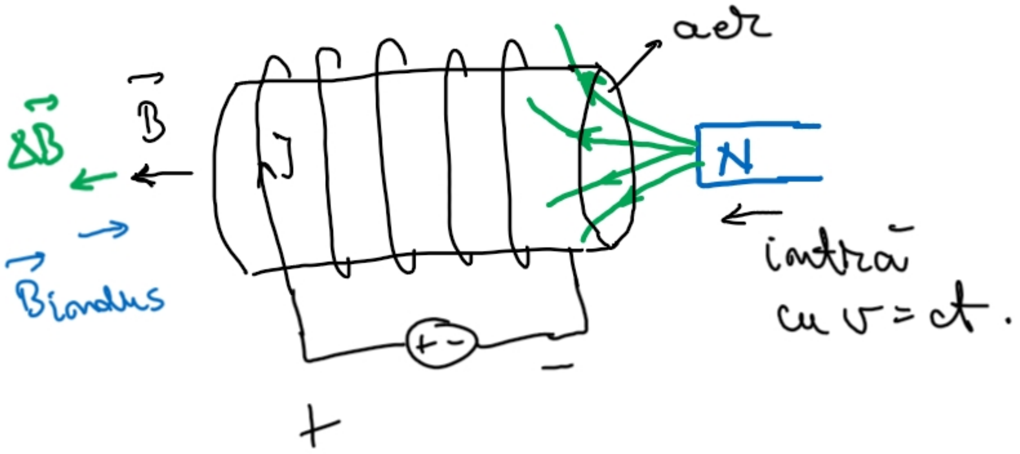
ϕ - fluxul magnetic (Wb)

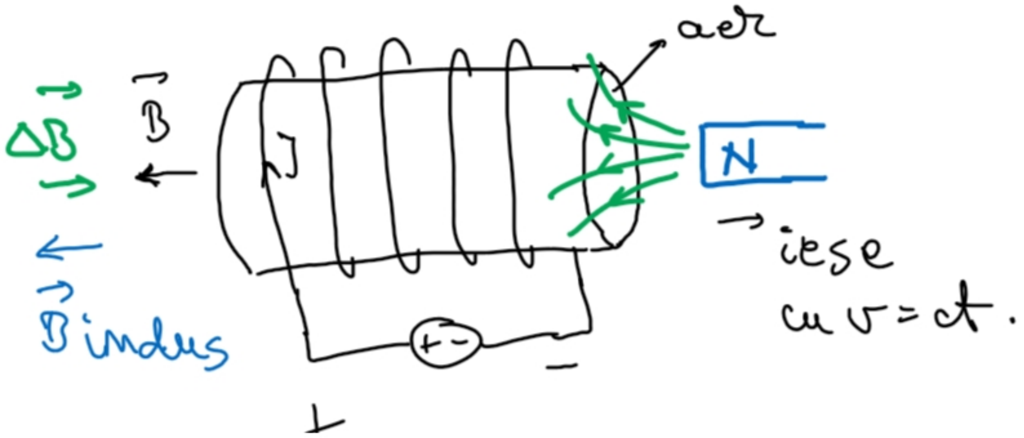
t - timpul (s)

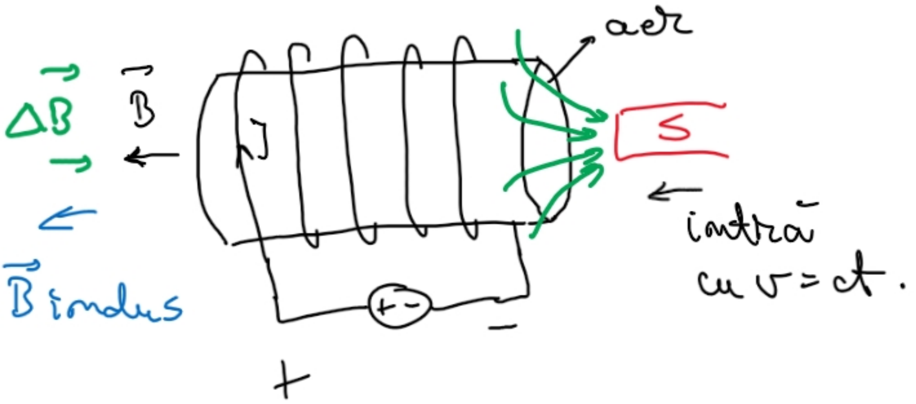
N - nr. de spire.

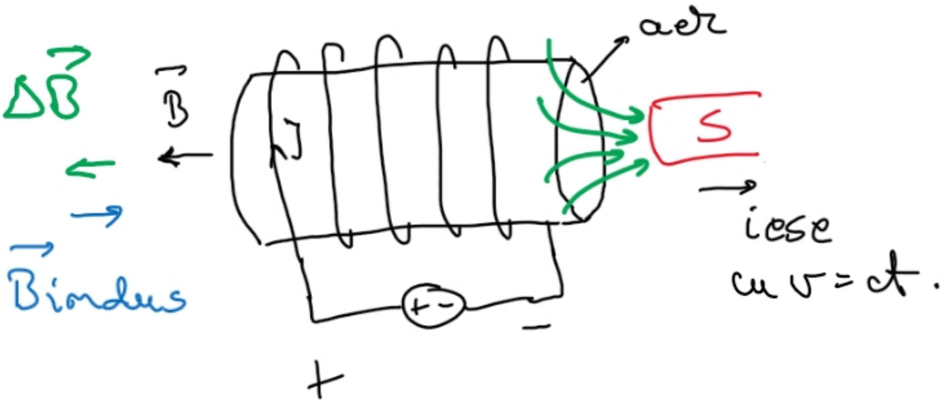
$-\frac{d\phi}{dt}$ → legea lui Lenz → $\phi = ct.$

·) exemple pt. Legea lui Lenz



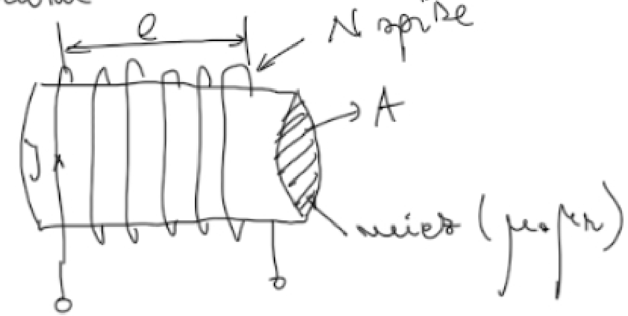




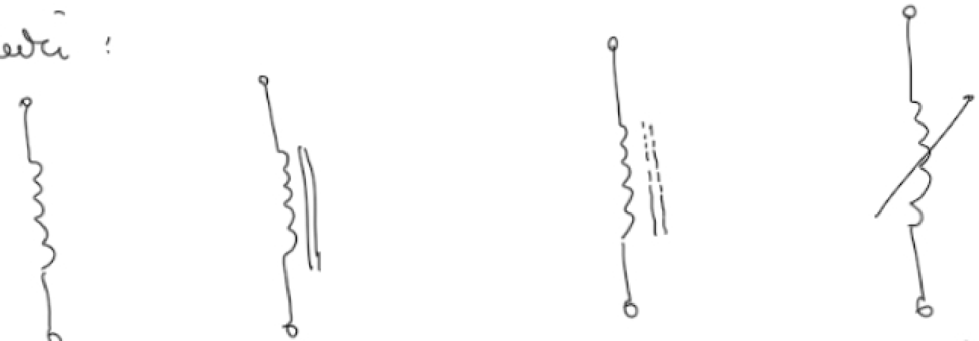


Inductanța („self-inductance"):

Considerăm:



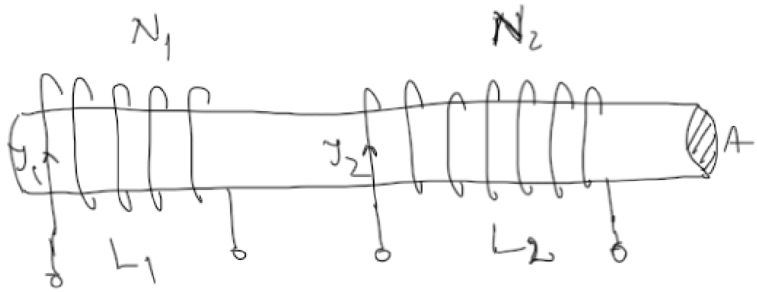
simboluri:



Legea lui Faraday: $V_L = -N \dfrac{d\phi}{dt}$, $N\phi = Li$ $\Rightarrow$ $V_L = -L \cdot \dfrac{di}{dt}$ → Faraday (Lenz)

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

Inductanța mutuală („mutual inductance")



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

Dacă avem curent prin L_1:

$$M_{12} = \frac{N_2 \phi_{12}}{I_1}$$

$$M_{21} = \frac{N_1 \phi_{21}}{I_2}$$

Dacă $I_1 = I_2 \Rightarrow M_{12} = M_{21} = M$

$$L_1 = \frac{\mu_0 \mu_r N_1^2 A}{l} \quad ; \quad L_2 = \frac{\mu_0 \mu_r N_2^2 A}{l}$$

$$M^2 = L_1 L_2$$

$M = \sqrt{L_1 L_2}$ pentru cuplaj perfect.

Factor de cuplaj k

$M = k\sqrt{L_1 L_2}$ [H]

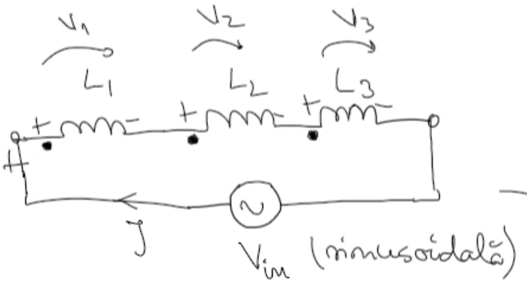
$k = 0 - 1$ (0 - 100%)

$k = 1$ - cuplaj perfect

$k > 0.5$ „tight coupling"

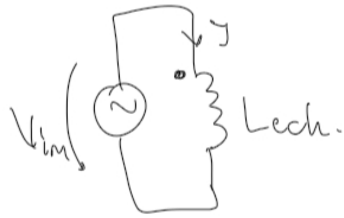
$k < 0.5$ „loose coupling"

Inductori în serie fără cuplaj:



Legea lui Ohm pt. inductori

$$V = L \cdot \frac{dI}{dt}$$



$$V_{in} = V_1 + V_2 + V_3$$

$$V_{in} = L_{ech} \cdot \frac{dI}{dt}$$

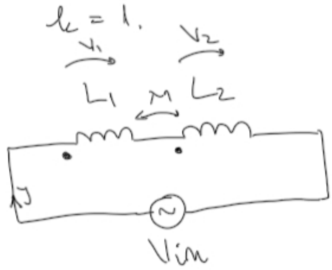
$$L_{ech} \cdot \frac{dI}{dt} = L_1 \cdot \frac{dI}{dt} + L_2 \cdot \frac{dI}{dt} + L_3 \frac{dI}{dt}$$

$$L_{ech} \frac{dI}{dt} = (L_1 + L_2 + L_3) \frac{dI}{dt}$$

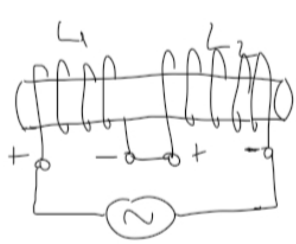
$$\boxed{L_{ech} = L_1 + L_2 + L_3}$$

Inductori în serie cuplați:

•) cuplaj în fază („aiding")



$L_{ech} = ?$



$$V_{in} = V_1 + V_2$$

$$V_{in} = L_{ech} \cdot \frac{dI}{dt}$$

$$V_1 = L_1 \cdot \frac{dI}{dt} + M \cdot \frac{dI}{dt}$$

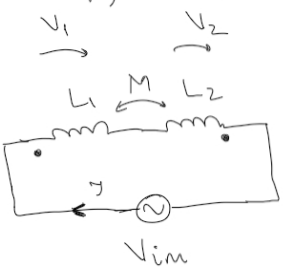
$$V_2 = L_2 \frac{dI}{dt} + M \cdot \frac{dI}{dt}$$

$$\Rightarrow L_{ech} \cdot \frac{dI}{dt} = L_1 \frac{dI}{dt} + M \frac{dI}{dt} + L_2 \frac{dI}{dt} + M \frac{dI}{dt}$$

$$L_{ech} \cdot \frac{dI}{dt} = (L_1 + L_2 + 2M) \frac{dI}{dt}$$

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

Inductori cuplaţi în opoziţie („opposing")



$$V_{in} = V_1 + V_2$$

$$V_{in} = L_{ech} \cdot \frac{dI}{dt}$$

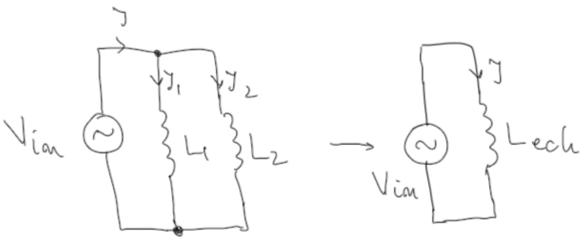
$$V_1 = L_1 \frac{dI}{dt} - M \frac{dI}{dt}$$

$$V_2 = L_2 \frac{dI}{dt} - M \frac{dI}{dt}$$

$$\Rightarrow L_{ech} \cdot \frac{dI}{dt} = (L_1 - M)\frac{dI}{dt} + (L_2 - M)\frac{dI}{dt}$$

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

Inductori în paralel fără cuplaj:



$$V_{in} = L_{ech} \cdot \frac{dI}{dt}$$

$$I = I_1 + I_2$$

$$\frac{dI}{dt} = \frac{dI_1}{dt} + \frac{dI_2}{dt}$$

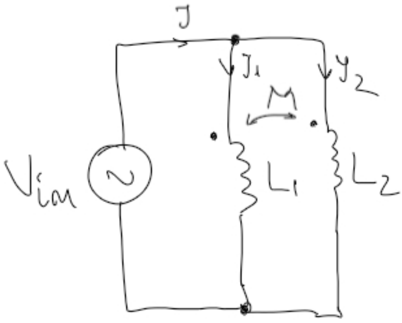
$$V_{in} = \underbrace{L_1 \cdot \frac{dI_1}{dt}}_{\frac{dI_1}{dt} = \frac{V_{in}}{L_1}} = \underbrace{L_2 \cdot \frac{dI_2}{dt}}_{\frac{dI_2}{dt} = \frac{V_{in}}{L_2}} = \underbrace{L_{ech} \cdot \frac{dI}{dt}}_{\frac{dI}{dt} = \frac{V_{in}}{L_{ech}}}$$

$$\frac{\cancel{V_{in}}}{L_{ech}} = \frac{\cancel{V_{in}}}{L_1} + \frac{\cancel{V_{in}}}{L_2}$$

$$\frac{1}{L_{ech}} = \frac{1}{L_1} + \frac{1}{L_2}$$

$$\boxed{L_{ech} = \frac{L_1 L_2}{L_1 + L_2}}$$

Inductori în paralel cuplați în fază:



$$\frac{dI}{dt} = \frac{dI_1}{dt} + \frac{dI_2}{dt}$$

$$V_{in} = L_{ech}\frac{dI}{dt}$$

$$V_{in} = L_1 \cdot \frac{dI_1}{dt} + M \cdot \frac{dI_2}{dt}$$

$$V_{in} = L_2 \cdot \frac{dI_2}{dt} + M \cdot \frac{dI_1}{dt}$$

$$L_2 \frac{dI_2}{dt} + M \frac{dI_1}{dt} = L_1 \frac{dI_1}{dt} + M \cdot \frac{dI_2}{dt}$$

$$(L_2 - M)\frac{dI_2}{dt} = (L_1 - M)\frac{dI_1}{dt}$$

$$V_{in} = L_1 \frac{dI_1}{dt} + M \cdot \frac{L_1 - M}{L_2 - M} \cdot \frac{dI_1}{dt}$$

$$V_{in} = \frac{dI_1}{dt}\left(L_1 + \frac{M(L_1 - M)}{L_2 - M}\right)$$

$$V_{in} = L_2 \cdot \frac{dI_2}{dt} + M \cdot \left(\frac{L_2 - M}{L_1 - M}\right)\frac{dI_2}{dt}$$

$$V_{in} = \frac{dI_2}{dt}\left(L_2 + M \cdot \frac{L_2 - M}{L_1 - M}\right)$$

$$L_{ech} = L_1 + \frac{M(L_1 - M)}{L_2 - M} + L_2 + \frac{M(L_2 - M)}{L_1 - M} =$$

$$= \frac{L_1(L_2 - M) + M(L_1 - M)}{L_2 - M} + \frac{L_2(L_1 - M) + M(L_2 - M)}{L_1 - M} =$$

$$= \frac{(L_1 - M)\left[L_1(L_2 - M) + M(L_1 - M)\right] + (L_2 - M)\left[L_2(L_1 - M) + M(L_2 - M)\right]}{(L_1 - M)(L_2 - M)} =$$

$$= \frac{(L_1 - M)\left[L_1 L_2 \cancel{- L_1 M} \cancel{+ L_1 M} - M^2\right] + (L_2 - M)\left[L_1 L_2 \cancel{- L_2 M} \cancel{+ L_2 M} - M^2\right]}{(L_1 - M)(L_2 - M)} =$$

$$= \frac{(L_1 L_2 - M^2)(L_1 - M + L_2 - M)}{(L_1 - M)(L_2 - M)} = \frac{L_1^2 L_2 + L_2^2 L_1 - 2ML_1 L_2 - L_1 M^2 - L_2^2 M_2 + 2M^3}{(L_1 - M)(L_2 - M)}$$