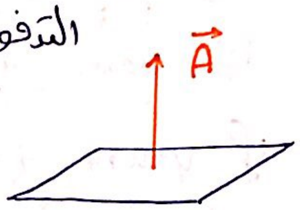
Chap 30: Induction & Inductance

- **Magnetic flux** : التدفق المغناطيسي



$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

$\vec{B}$ ← المجال المغناطيسي

$d\vec{A}$ ← المتجه العمودي على المساحة

يتم حساب التدفق عن طريق هذا التكامل

$[\Phi_B] = \text{Weber} = T \cdot m^2$

Faraday's law :-

- كمية المجال المغناطيسي يعبر عنها بعدد خطوط المجال العابرة للحلقات

Changing $|B|$ $\xrightarrow{\text{inducing}}$ emf ($\mathcal{E}$) & current i

Note: In a special case (A and B are parallel) and B is uniform :- $\Phi_B = BA$

- The magnitude of emf induced :-

$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

($-$) indicats opposition

→ If you have a Coil with N turns Then

$$\mathcal{E} = -N\frac{d\Phi_B}{dt}$$

- How can I change the Magnetic flux

By changing :- $|B|$ or A (expanding Coil or sliding it in or out) or θ (rotating)

Lenz's law :-

In a simple way :-

- If you're increasing I'm gonna oppose you
- If you're decreasing I'm gonna help you

meaning :

- If in a loop : external B is increasing the induced i will oppose this change By creating a B_{ind} that opposes B in direction

But :-

- If external B is decreasing, the induced i will oppose this decrease by Creating a B_{ind} that is in the same direction of B

page 795 fig 30-5 explains it really well

Induction & Energy transfer

- Remember : $\mathcal{E} = \frac{d\Phi_B}{dt}$ → If it's changing by moving the loop with $\vec{v}$ Then $\frac{d\Phi_B}{dt} = BLv$

$$\mathcal{E} = BLv$$

and $i = \frac{BLv}{R}$

And the force you applied to change it equals :- $F = iLB$

$$F = \frac{B^2L^2v}{R}$$

The thermal energy rate $P = \frac{B^2L^2v^2}{R}$

Alaa Etaiwi

Induced Electric fields

- A changing magnetic field produces an Electric field

- if B is changing (increasing or decreasing) $\rightarrow E_{ind}$
- if B is constant $\rightarrow$ No E_{ind}

$\rightsquigarrow$ Faraday's law :- $\underbrace{\oint \vec{E} \cdot d\vec{s}}_{= \mathcal{E}} = -\frac{d\Phi_B}{dt}$

Inductors & inductance

- An inductor : is a device used to produce a desired magnetic field

- The inductance of an inductor :- $L = \frac{N \Phi_B}{i}$
  (Depends only on Geometry)
  $[L] = \text{henry} = 1 \ T \cdot m^2/A$

- The inductance per unit length near the center of a long solenoid :-

$$\frac{L}{l} = \mu_0 n^2 A$$

A ← cross sectional Area of a Solenoid

n ← number of turns per unit length.

l ← a length near the middle of the Solenoid

Alaa Haiwi

• self induction

- If i is changing in a Coil Then An induced emf ($\mathcal{E}$) appears

This is Called self induction

and the self induced Emf $= -L \frac{di}{dt}$

→ direction of Emf induced opposes the change of i (lenz's law)

RL - CirCuits (lab physics 112 is back >:( )

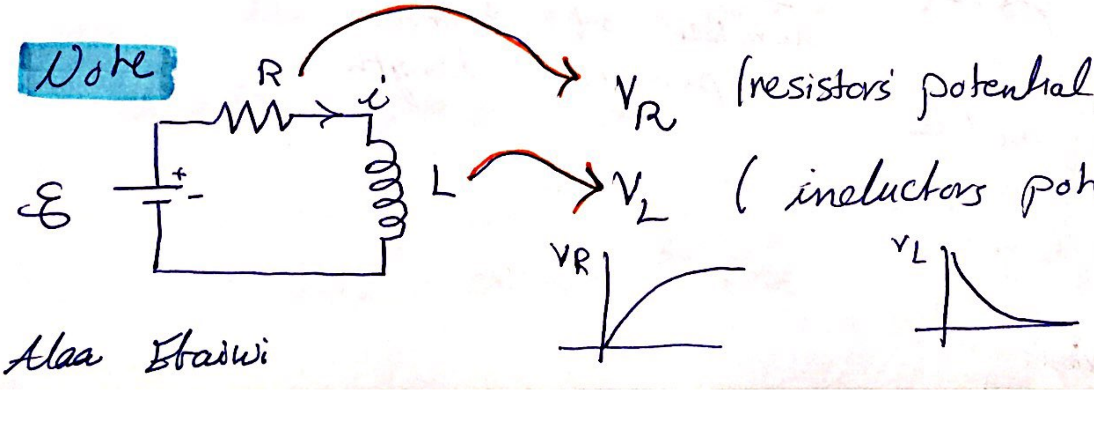
- Initially an inductor acts to oppose changes in the current through it, A long time later it acts like ordinary Connecting wire

- If you introduce a $\mathcal{E}$ in a R-L circuit current i rises ↑ according to $i = \frac{\mathcal{E}}{R}\left(1 - e^{-t/\tau_L}\right)$

  - $\tau_L = \frac{L}{R}$ is the inductive time Constant

- If you remove $\mathcal{E}$ the current i decays ↓ according to $i = i_0 e^{-t/\tau_L}$

Note



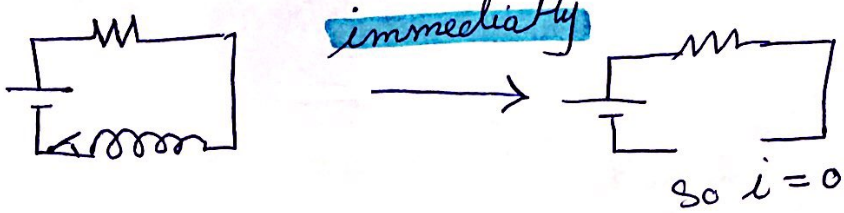
V_R (resistors' potential) Turns on

V_L (inductors potential) Turns off

Alaa Ebadwi

• If you have a RL-circuit

↳ when the switch is immedialty closed
L acts like a broken wires



↳ after a long time L acts like a conducting wire

Energy stored in a Magnetic force

if an inductor L carries current i
Then the Magnetic Energy that it carries is:-

$$U_B = \frac{1}{2} L i^2$$

← current that it carries

↑ inductance

↳ Magnetic energy density (at a point)

$$u_B = \frac{B^2}{2\mu_0}$$

$$= \frac{1}{2} \mu_0 n^2 i^2.$$

Alaa Itaiwi