# Physics 142 - October 28, 2010

- Presentation groups

Last Time

## Induction

Magnetostatics

Kirchoff

$$\sum_{\substack{\text{closed}\\ \text{loop}}} V = 0$$

$$\oint \vec{E} \cdot \vec{dl} = 0$$

We used for Circuits

Kirchoff's law in Free space

## Changing B Field

induced EMF

$$\mathcal{E} = \int_{\text{loop}} \vec{E} \cdot \vec{dl} = -\frac{d\phi_M}{dt}$$

Magnetic Flux $\equiv \phi_M = \int \vec{B} \cdot \vec{dA}$

True in Material (wire) and Free space

# Induction

$$\mathcal{E} = \int_{loop} \vec{E} \cdot d\vec{l} = -\frac{d\Phi_M}{dt}$$

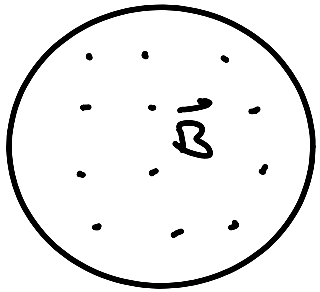
induced EMF

$$\Phi_M = \int_{loop} \vec{B} \cdot d\vec{A}$$

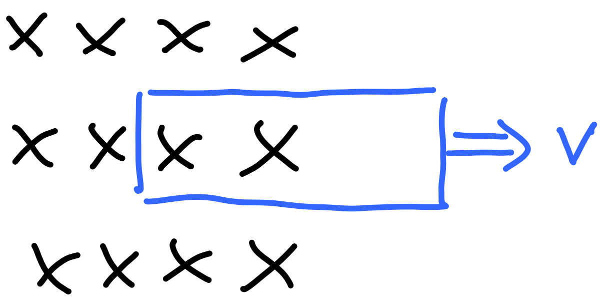
All very Important

**Lenz's Law** - An induced current in a closed conducting loop will appear in such a way as to oppose the change that created it

Gives the direction of induced effect



B is increasing in strength

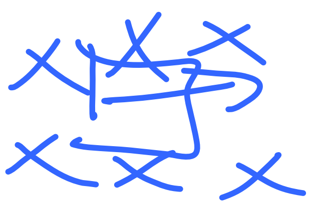


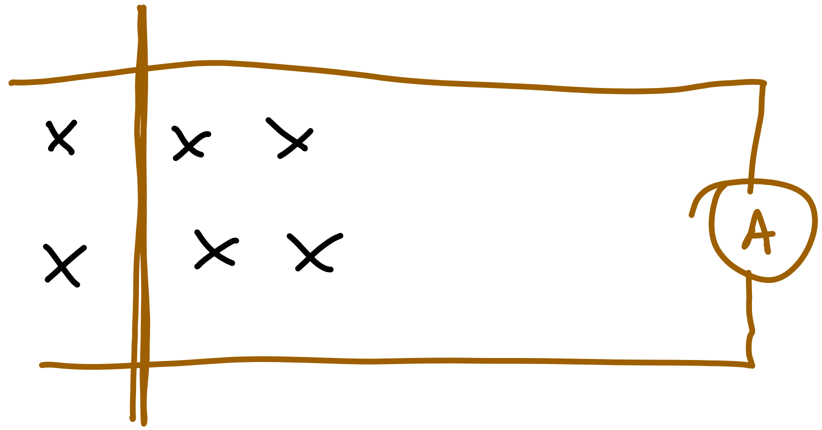
1) clockwise

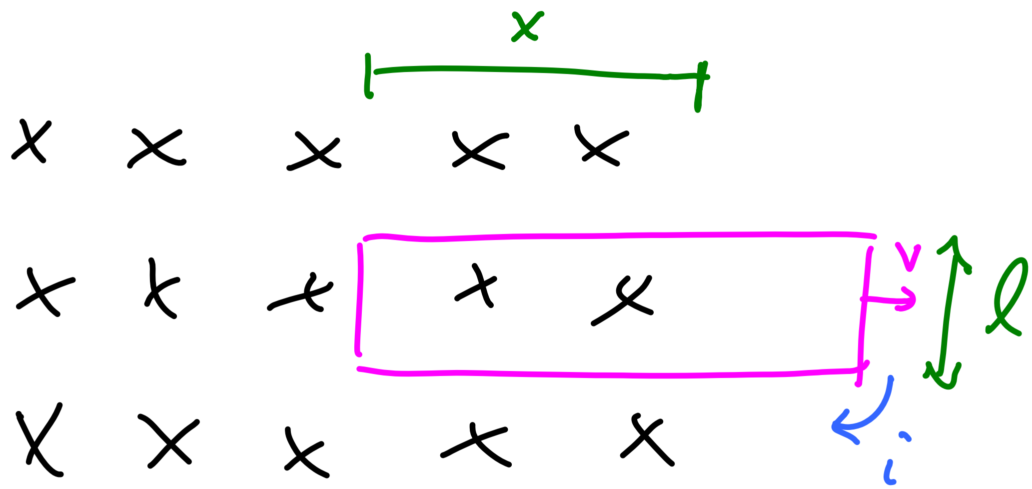
2) counter-clockwise

3) no induced current

Superconductor





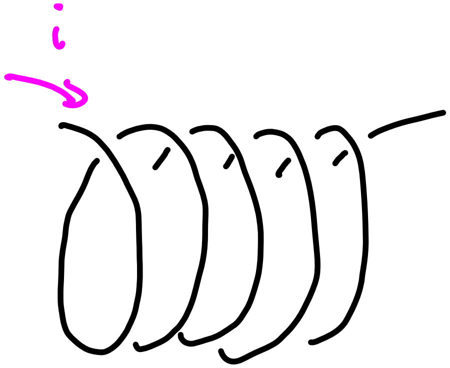

$$\mathcal{E} = -\frac{d\Phi_m}{dt} = -\frac{d}{dt}(B x \ell) = -B\ell \overbrace{\frac{dx}{dt}}^{v}$$

$$\mathcal{E} = -B\ell v$$

if $R$ in loop

$V = iR$

$$|i| = \frac{\mathcal{E}}{R} = \frac{B\ell v}{R}$$




$n$ Turns/length

Each turn has Area $A$

$$\phi_m = BA = \mu_0 n i A \quad \text{single turn}$$

length $\ell$ of solenoid

$$\phi_M = \overbrace{\underbrace{\mu_0 n i A}_{\phi_M \text{ single Turn}}\, \ell n}^{\phi_M \text{ Thru length } \ell \text{ of solenoid}}$$

$\propto i$

$\phi_M \propto i$

$$\phi_m \propto i$$

$$\phi_m = \underbrace{L}_{\text{CONSTANT of Self inductance}} i$$

change $i$ $\rightarrow$ change $\phi_m$ $\rightarrow$ $\frac{d\phi_m}{dt}$ $\rightarrow$ $\mathcal{E}$

$$\mathcal{E} = -\frac{d\phi_m}{dt} = -L\frac{di}{dt}$$

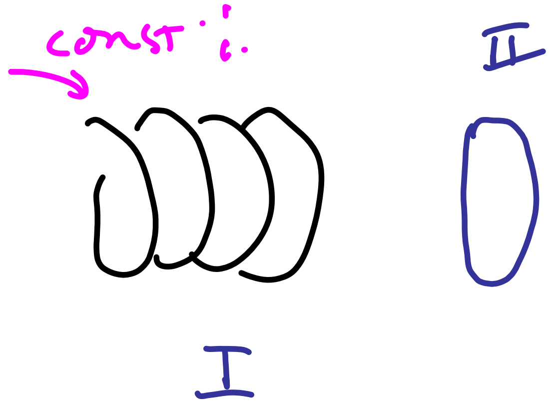
$$\boxed{\mathcal{E} = -L\frac{di}{dt}}$$

geometry only

self-inductance

units Henrys

(MKS




change $i$ in I $\rightarrow$ changing $\phi_M$ in II

induces $\varepsilon$ in II

$\phi_M$ in II $\propto$ $i$ in I

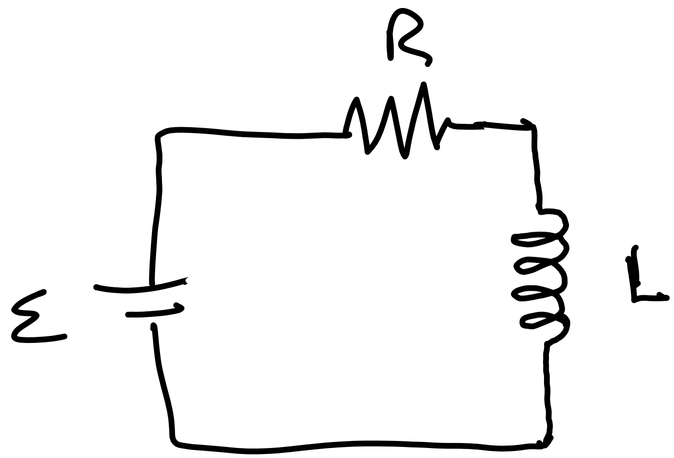
$$\phi_{M_{\text{in II}}} = L\, i_{\text{in I}}$$

$$L \equiv M$$

$\rightarrow$ CONSTANT of Mutual inductance

$$\varepsilon_{\text{in II}} = -L \frac{di_{\text{I}}}{dt}$$

# Energy in Magnetic field




$$\Sigma V = 0$$

$$\mathcal{E} - iR - L\frac{di}{dt} = 0$$

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

mult $i$

$$\underbrace{\mathcal{E} i}_{\text{Power output by } \mathcal{E}} = \underbrace{i^2 R}_{\text{Power Diss in } R} + \underbrace{L i \frac{di}{dt}}_{\text{Power}}$$

Rate of change of E in B field

$$\frac{dU_B}{dt} = Li\frac{di}{dt}$$

$U_B$ = Energy stored in B

$$dU_B = Li\,di$$

$V_{cap} = \frac{1}{2}CV^2$

$i \rightarrow 0 \rightarrow I$

$$U_B = \int_0^I Li\,di = \frac{LI^2}{2} = \frac{1}{2}LI^2$$

Solenoid $\quad B = \begin{cases} \mu_0 n i & \text{inside} \\ 0 & \text{outside} \end{cases}$

$i$, $n$ turns/length, $\ell$

$u_B \equiv$ Energy density in B

$$u_B = \frac{U_B}{A\ell} = \frac{\frac{1}{2} L i^2}{A\ell} = \frac{1}{2}\,\frac{\overbrace{n^2 \mu_0 \ell A}^{\text{earlier}}\, i^2}{A\ell}$$

$$u_B = \frac{1}{2}\mu_0 i^2 n^2 = \frac{|B|^2}{2\mu_0}$$

$B = \mu_0 n i$

$$u_E = \frac{\varepsilon_0}{2} E^2$$

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