Physics 142 - November 1, 2007

- Exam 2 one week from Today
  - in Hoyt
  - reg. class time
  - welcome to bring formula sheet as last time
  - will try to set up a Q+A session

To be covered:

Topics

Potential
Capacitance
Energy in $\vec{E}$
$\vec{E}$ in materials
dielectrics
Kirchoff's Rules
DC circuits w/ R, RC
Special Relativity

Lorentz force law
Biot-Savart
Ampere's law

Lectures
Sept 27 - Oct 30

Prob Sets 4-7

Workshops 4-8

Chapters
25-30, 36

Induction

B NOT changing

magnetostatics

steady currents

Kirchoff

$$\sum V \Big|_{\text{closed loop}} = 0$$

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

Statement of Kirchoff's law in free space

Changing Magnetic field

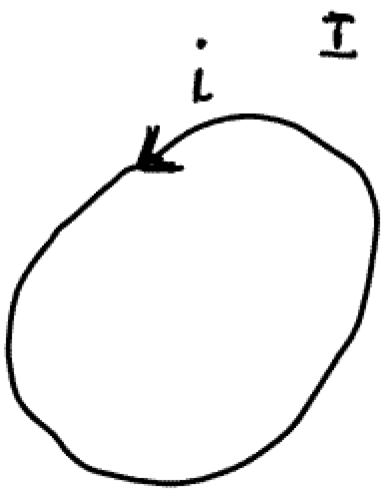
$$\boxed{\mathcal{E} = \oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_M}{dt} \qquad \Phi_M \equiv \int_{loop} \vec{B} \cdot d\vec{A}}$$

Induced EMF

Faraday's Law

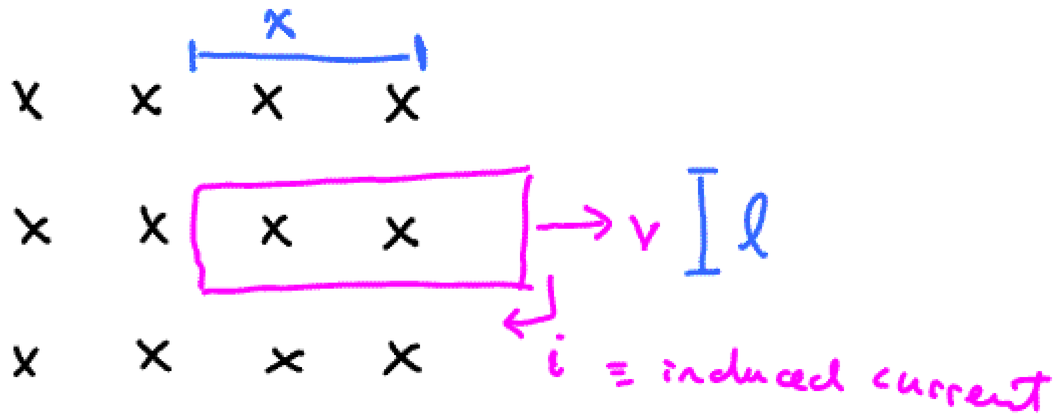
True in { free space, Materials, Wire

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.



i increasing with time

induce a counter-clockwise current in II



$\vec{B}$

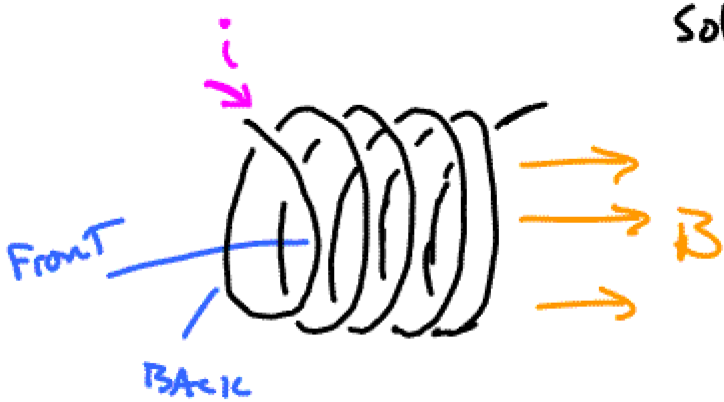
$$\mathcal{E} = -\frac{d\Phi_M}{dt} = -\frac{d(Bx\ell)}{dt} = -B\ell\frac{dx}{dt} = -B\ell v$$

loop has resistance R $\quad |i| = \frac{B\ell v}{R}$

$V = iR$

$\mathcal{E} = iR$

Be sure to check out the "Induction" Java Applet on the class website!



Solenoid — each turn has area A

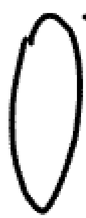
x-Sect Area

$$|\vec{B}| = \mu_0 n i$$

turns/length

$$\Phi_{m\,\text{single turn}} = BA = \mu_0 n i A$$

$$\Phi_{m\,st} \propto i$$



$BA = \Phi_m$

length l of solenoid

nl Turns

$$\Phi_{m\,\text{length } l} = \underbrace{\mu_0 n i A}_{\text{Single Turn}} \underbrace{n l}_{\#\text{ Turns}}$$

$$\Phi_{m\,\text{length } l} \propto i$$

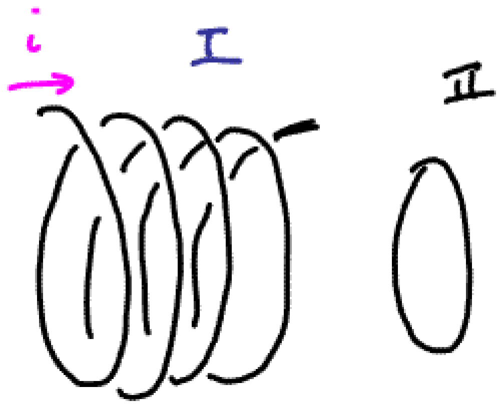
$$\phi_m = L\, i$$

Constant of self-inductance

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

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

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



Δi in I

ΔB in II

↳ induce $\mathcal{E}$ in II

$$\Phi_{m \text{ in II}} \propto i_{\text{I}}$$

$$\Phi_{m \text{ in II}} = L\, i$$

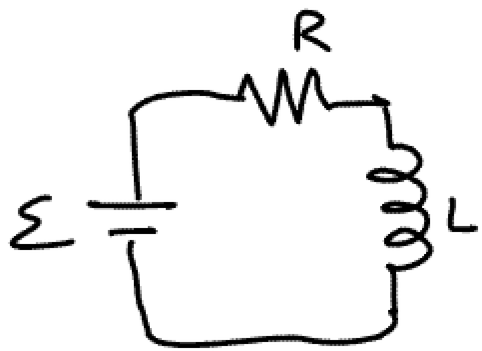
constant of Mutual Inductance

often see

M, L

Energy + Magnetic field

new circuit element → inductor



LR circuit

$$\sum \mathcal{E} = 0$$

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

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

mult by i

$$\mathcal{E} i = i^2 R + L i \frac{di}{dt}$$

L measured in Henry's

Power

Energy going in or out of B field

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

$U_B \equiv$ Energy in B field

$$dU_B = Li\,di$$

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

Energy stored in inductor in form of B

Analogous U in capacitor $= \frac{1}{2}CV^2$

Solenoid w/ i, n turns/length, consider length ℓ

$\Rightarrow$ find Energy density of Magnetic field

$$B_{solenoid} = \mu_0 n i \quad \text{(inside)}$$

$$= 0 \quad \text{(outside)}$$

$$u_B \equiv \text{Energy density in } B = \frac{U_B}{A\ell}$$

$$u_B = \frac{\frac{1}{2} L i^2}{A\ell}$$

$$\Phi_M = L i \qquad L = \frac{\Phi_M}{i} = \frac{(BA)(n\ell)}{i}$$

geometry

$$L = \frac{\mu_0 n i A \, n\ell}{i} = \mu_0 n^2 A \ell$$

$$u_B = \frac{\frac{1}{2} \mu_0 n^2 A \ell \, i^2}{A\ell} = \frac{1}{2} \mu_0 i^2 n^2 = \frac{B^2}{2\mu_0}$$

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

Energy density in magnetic field

Analogous to

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