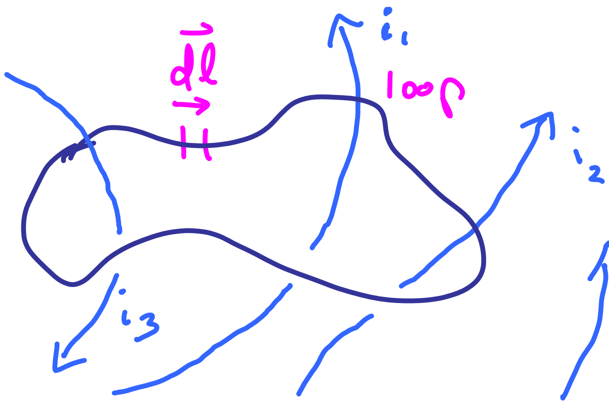
Physics 114 – March 26, 2015

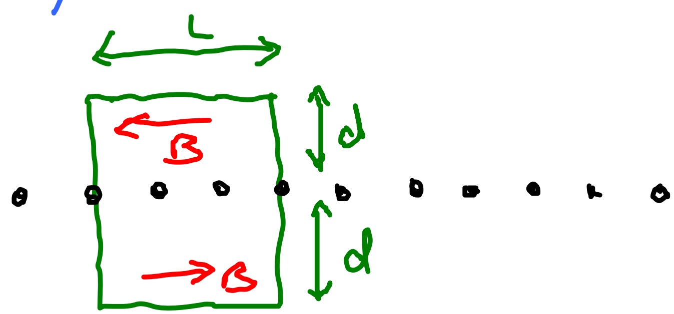
- 2 weeks exam 2 grading (TA Exams)
- Prob set due a week from Tomorrow
  LONG don't put it off until next week

Ampere's law



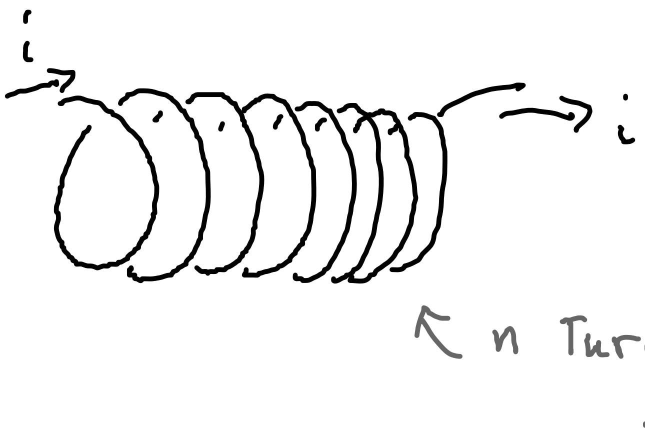
$$\oint_{\text{loop}} \vec{B}\cdot\vec{dl} = \mu_0 I_{encl}$$

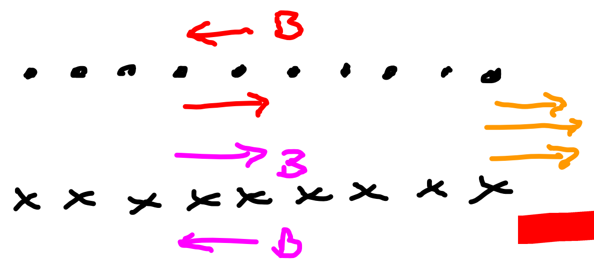
$$I = jL$$



$$\oint \vec{B}\cdot\vec{dl} = 2BL = \mu_0 j L \qquad |\vec{B}| = \frac{\mu_0 j}{2}$$

Solenoid





$B = \mu_0 i n$

Induction

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

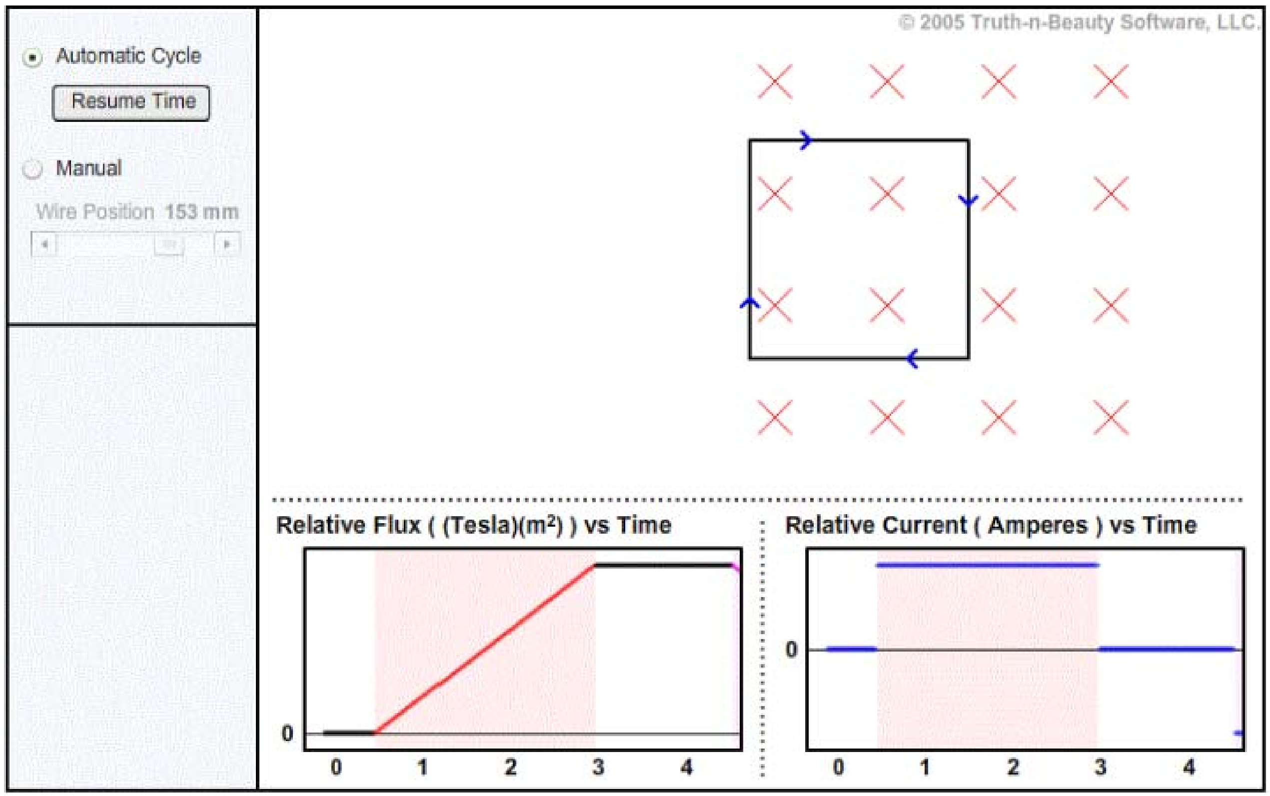
$$\mathcal{E} = \int_{loop} \vec{E} \cdot d\vec{\ell} = -\frac{d\phi_M}{dt}$$

induced EMF

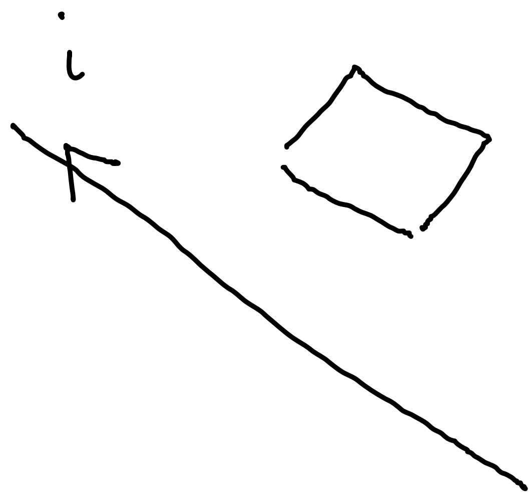
All very Important

<u>Lenz's</u> <u>Law</u> - 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


© 2005 Truth-n-Beauty Software, LLC.
Automatic Cycle
Resume Time
Manual
Wire Position 153 mm
Relative Flux ((Tesla)(m²)) vs Time
Relative Current (Amperes) vs Time
0
0 1 2 3 4
0
0 1 2 3 4

4 4

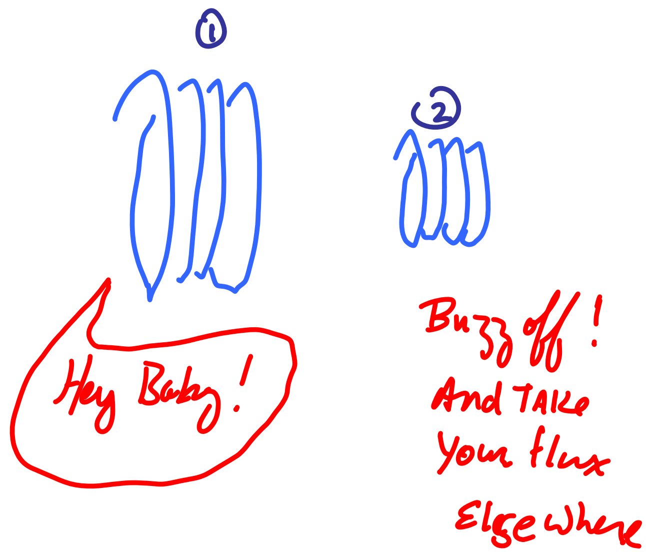

i

Self inductance

$\phi_M \propto i$

$EMF \propto \frac{d\phi_M}{dt} \propto \frac{di}{dt}$

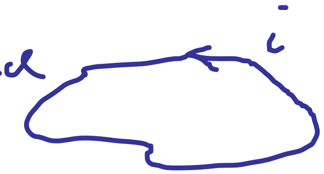
Mutual inductance



$\phi_{M_{2\,\text{due to}\,1}} \propto i_1$

$EMF_{\substack{\text{in 2} \\ \text{due to 1}}} \propto \frac{di_1}{dt}$

Self Inductance

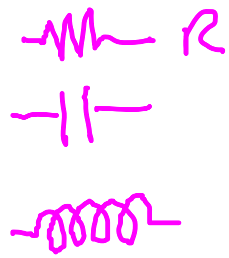


$$\phi_M = L i$$

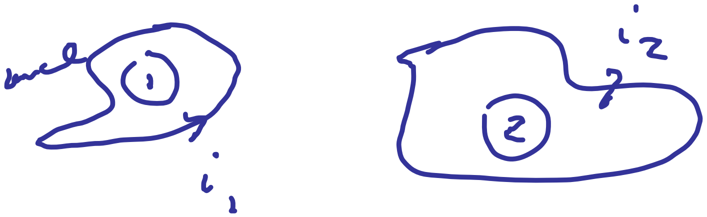
L ≡ const of self inductance

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

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



Mutual Inductance



$$\phi_{M\,(2)} = M\, i_{(1)}$$

M ≡ constant of Mutual inductance

$$\phi_{M\,(1)} = M\, i_{(2)}$$

| Symmetric |

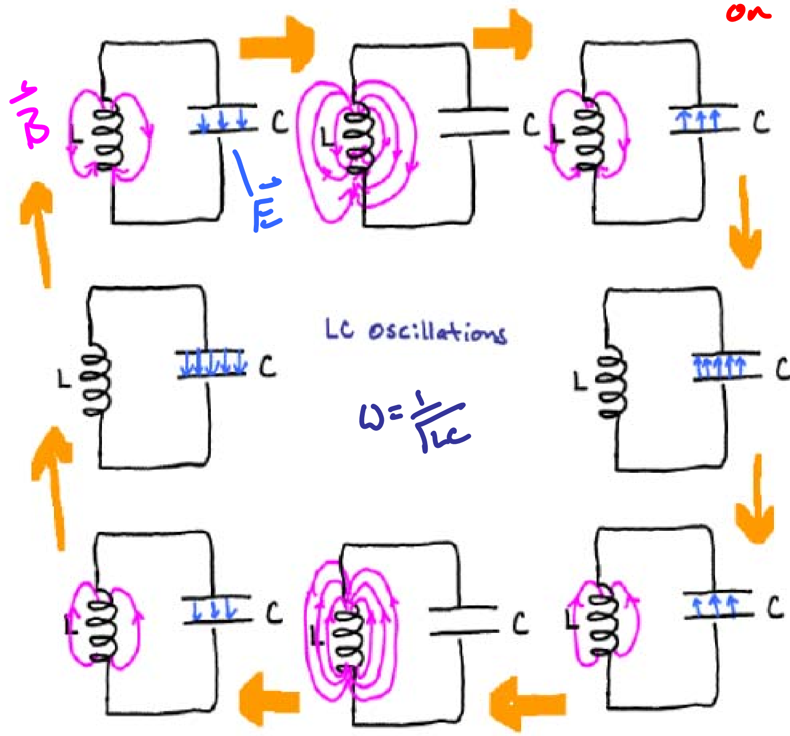
$$\mathcal{E}_{(2)\text{ by }(1)} = -M\frac{di_{(1)}}{dt}$$

$$\mathcal{E}_{(1)\text{ by }(2)} = -M\frac{di_{(2)}}{dt}$$

We won't spend time studying circuits with inductors. Too many other things to do ... but interesting things can happen. For example

NO - you are NOT responsible for LC circuits on test

Energy oscillating back + forth between $\vec{B}$ in inductor and $\vec{E}$ in capacitor in an LC circuit.

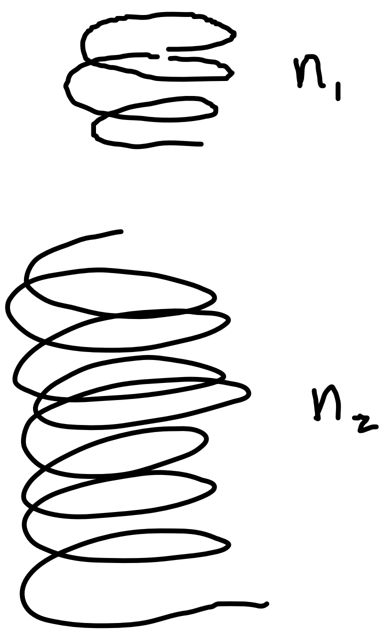


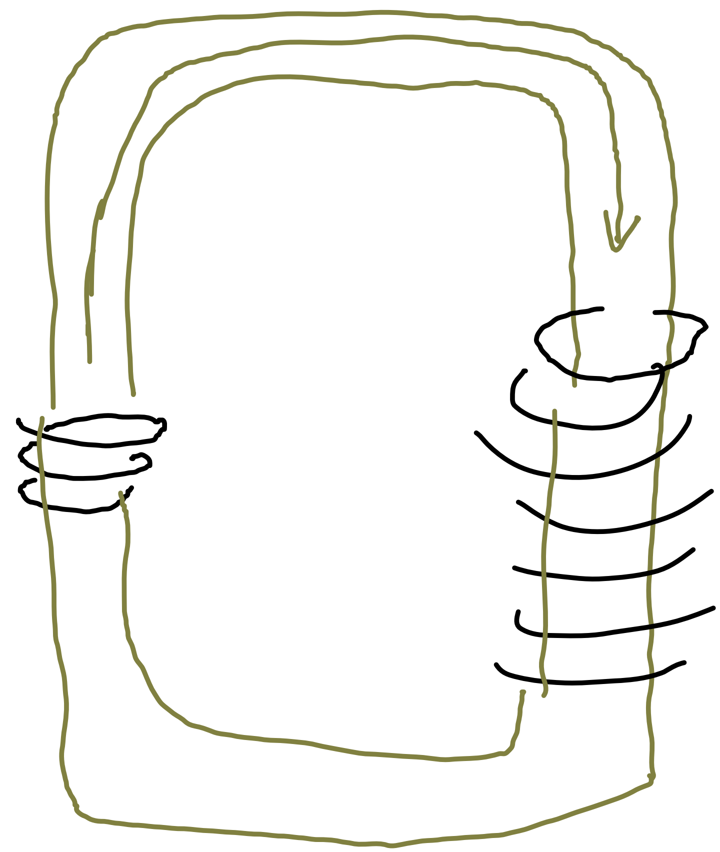
Transformers

Step up or

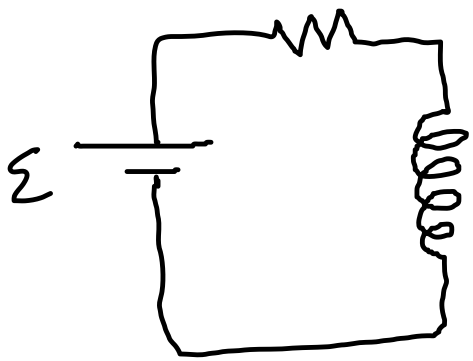
Step down

voltage





Energy and the Magnetic Field



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

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

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

Power output of EMF

Power dissapated by resistor

Power into inductor

$$\frac{dU_B}{dt} = \text{Power in inductor} = L i \frac{di}{dt}$$

$$dU_B = L i \, di$$

Total Energy in B in inductor $\quad U_B = \int_0^I L i \, di = \frac{1}{2} L I^2$

Take ∞ solenoid as our inductor

i, n turns/length length l

Area A

$B = \mu_0 n i$ (inside)

$= 0$ (outside)

Energy density in B field as $= u_B$

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

$$\Phi_M = Li = \underbrace{B\overset{\mu_0 n i}{A}}_{\substack{\Phi_m \\ \text{single loop}}} n \ell$$

lenth

loops

lenth

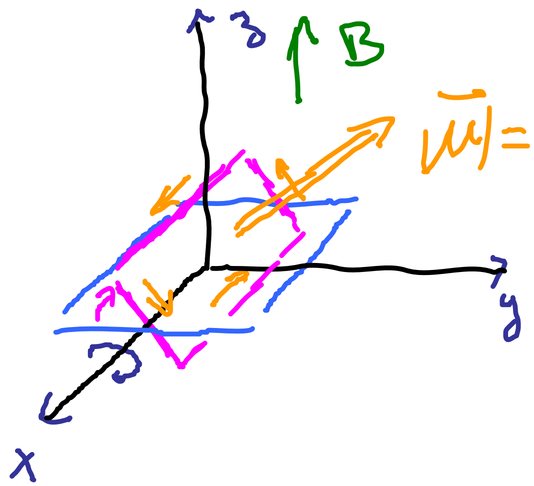
$$u_B = \frac{\tfrac{1}{2}(\overbrace{\mu_0 n A n \ell}^{L})\,i}{A\ell} \sim \frac{1}{2}\mu_0 i^2 n^2 = \frac{B^2}{2\mu_0}$$

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

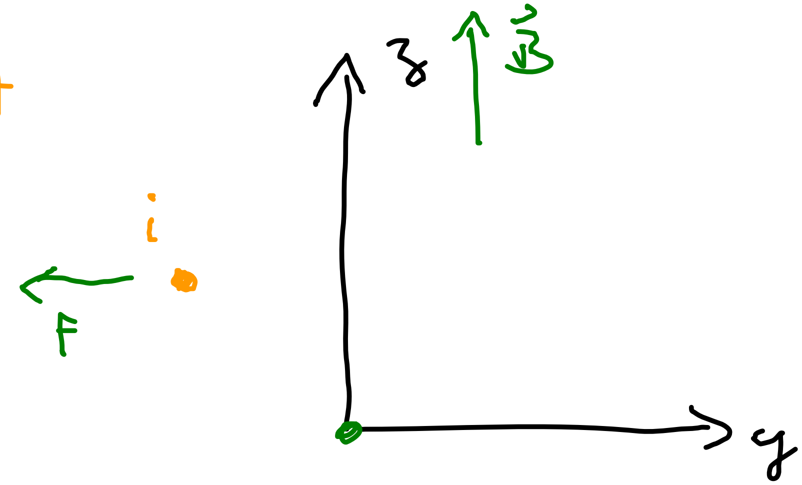
Energy density in B field

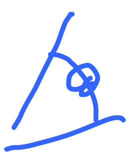
→ general

Magnetic Moment = $|\vec{\mu}| = |B|A$



$|\vec{\mu}| = |\vec{B}_{loop}|\,A$





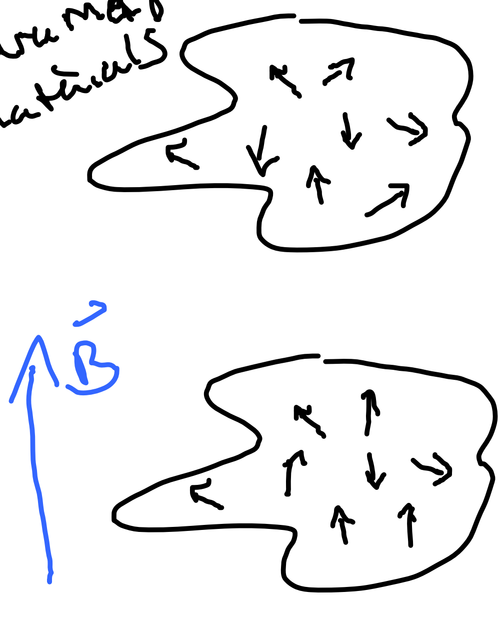
x i →

Torque on Magnetic Moment in $\vec{B}$

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

Magnetism in Materials

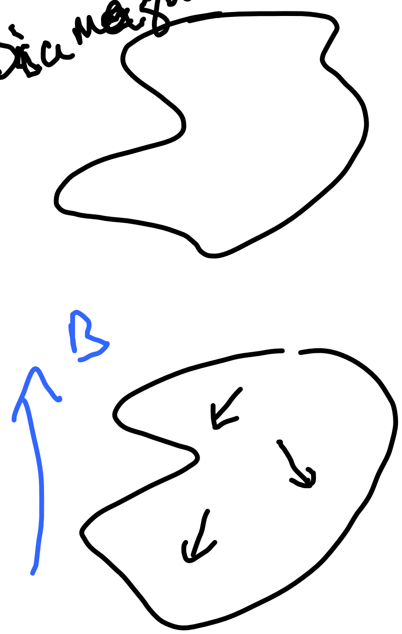
Paramagnetic Materials



$\vec{B}_{ext}$ increases

$\vec{B}$ inside material increase

Diamagnetic



$\vec{B}$ in material weakened