

Physics 114 - March 30, 2006

Last Time:

Magnetic Induction

Important

Faraday's Law

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

Magnetic Flux

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

Lenz's Law

Induced Current opposes the change that creates it!

Michael Faraday
(1791-1867)

British Physicist
+
Chemist



Discovered
Magnetic induction

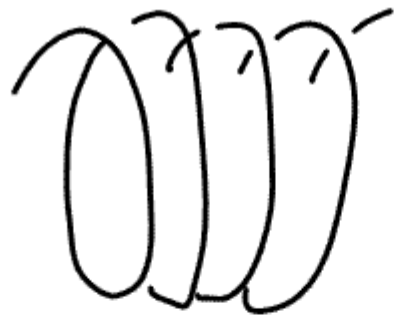
Farad named
after Faraday

Also invented the
Bunsen Burner



Also worked as an
understudy in
London production
of Phantom of
the Opera

Inductor w/out
a core



Rosie,
you're
alright...

Faraday's
Law

$$\phi = L i$$



Const of
Self inductance

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

Circuit symbol



Inductor with a date

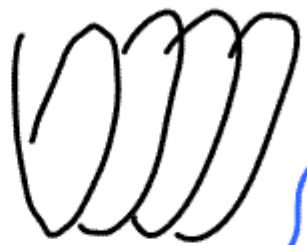
const. of Mutual inductance

①



Hey Baby...

②



Dinner was great...
But, maybe you ought to take your flux elsewhere

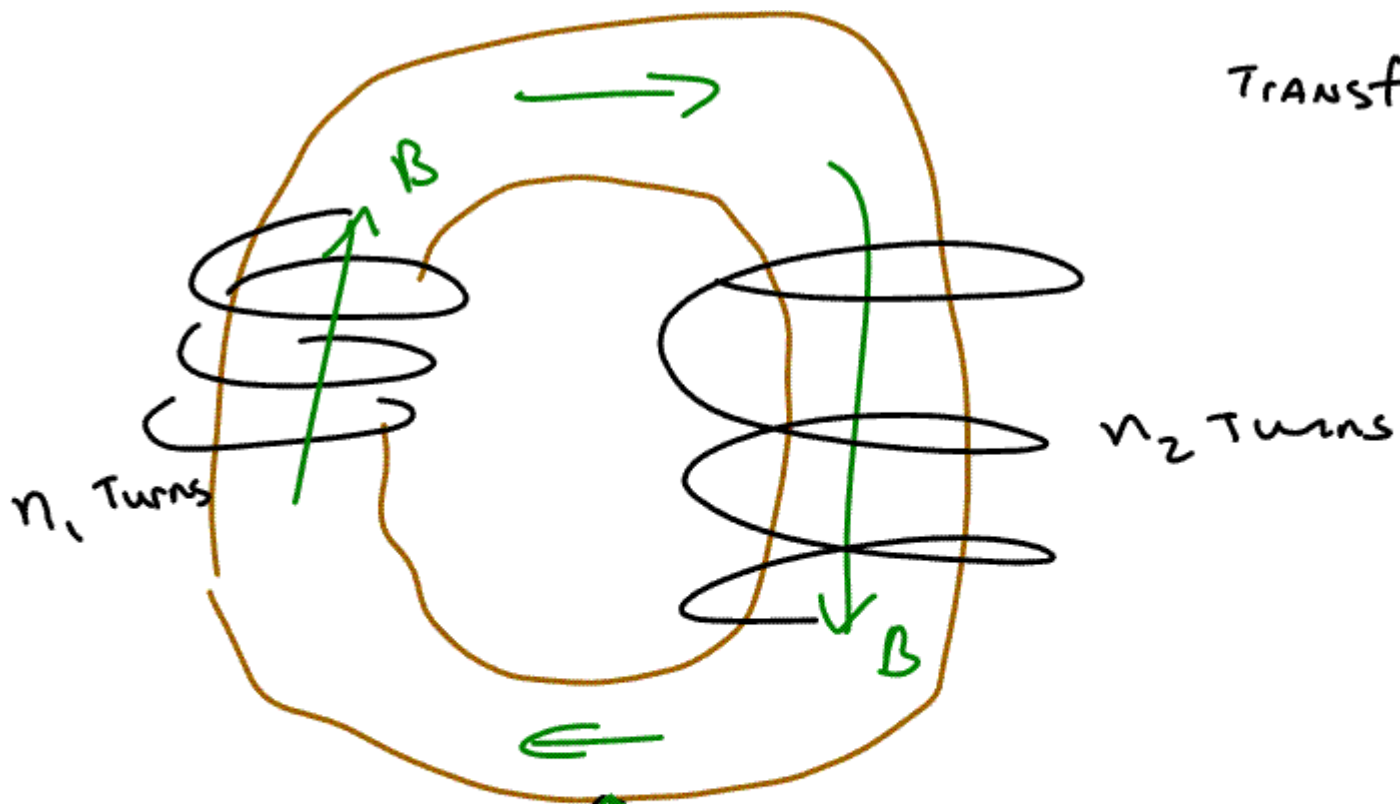
$$\Phi_2 = M i_1 \quad \Phi_1 = M i_2$$

might be "L" too

$$\mathcal{E}_2 = -M \frac{di_1}{dt}$$

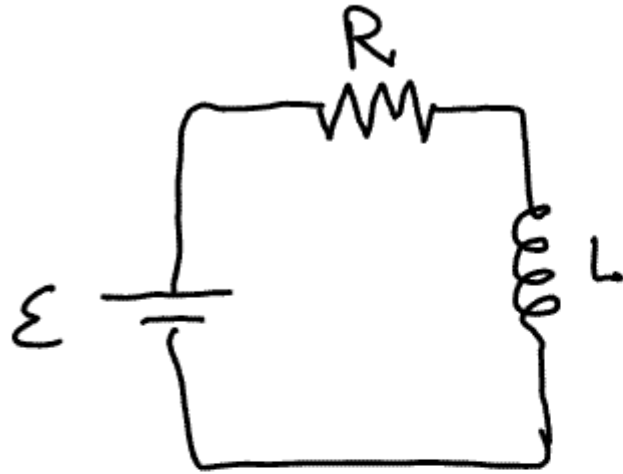
$$\mathcal{E}_1 = -M \frac{di_2}{dt}$$

Transformer



Fe - Acts As a pipe for magnetic flux

Energy + The Magnetic Field



$$\epsilon = iR + L \frac{di}{dt}$$

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

The equation above is annotated with colored circles and arrows. A green circle surrounds ϵi with a green arrow pointing down to the text 'Power output of Battery'. An orange circle surrounds $i^2 R$ with an orange arrow pointing down to the text 'Power dissipated in resistors'. A blue circle surrounds $L i \frac{di}{dt}$ with a blue arrow pointing down to the text 'Power in or out of inductor'. A blue line also connects the blue circle to the text 'Energy storage in B field'.

Power output
of Battery

Power
dissipated
in resistors

Energy
storage in
B field

Power in or out
of inductor

$$\frac{dU_B}{dt} = L i \frac{di}{dt}$$

$$dU_B = L i di$$

$$U_B = \int_0^I L i di = \frac{1}{2} L I^2$$

recall for capacitor $\rightarrow U_E = \frac{1}{2} C V^2$

Solenoid, n turns/length, i

$$B = \mu_0 n i \quad \text{inside, } = 0 \text{ outside}$$

$U_B \equiv$ Energy density in Magnetic field

$$U_B = \frac{U_B}{Al} = \frac{\frac{1}{2} Li^2}{Al}$$

$$\Phi_m = Li \quad L = \frac{\Phi_m}{i} = \frac{BA nl}{i}$$

$$L = \frac{\overset{B^2}{\mu_0 n^2} Al}{i} = \mu_0 n^2 Al$$

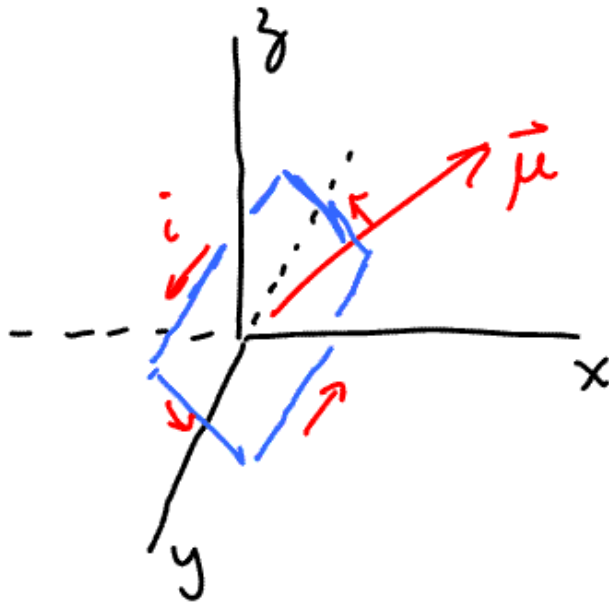
$$U_B = \frac{\frac{1}{2} Li^2}{Al} = \frac{\frac{1}{2} \mu_0 n^2 Al i^2}{Al} = \frac{1}{2} \mu_0 i^2 n^2$$

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

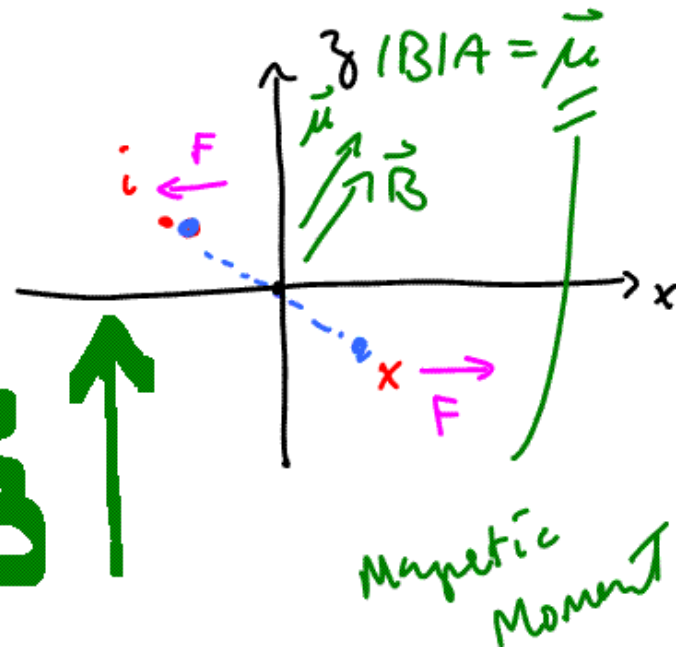
$$u_B = \frac{B^2}{2\mu_0}$$



Magnetic fields in matter

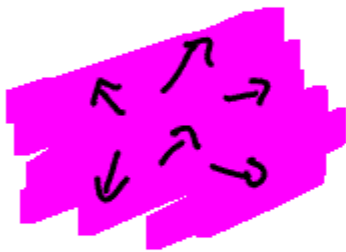


B ↑



Torque on
Magnetic
Dipole $= \vec{\mu} \times \vec{B}$

Paramagnetism



Strengthens B

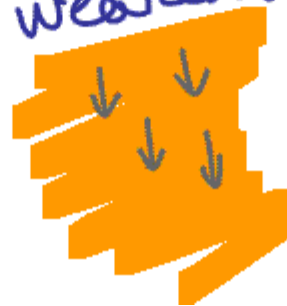


Diamagnetism



No dipoles

Weakens B



Ferromagnetism



Regions
called
Domains

Fe = iron

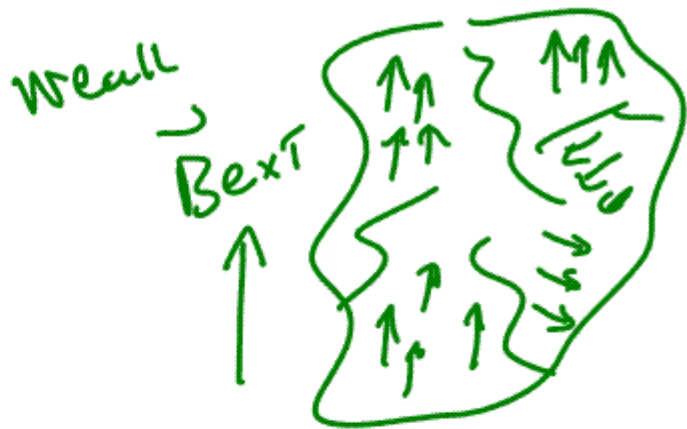
$$|\vec{B}| = \mu_0(1 + \chi_m) |\vec{B}_{EXT}|$$

Magnetic Susceptibility

$$B = K_m B_{EXT}$$

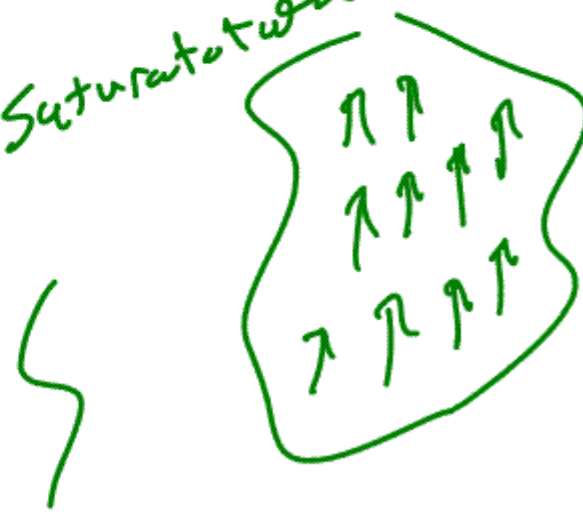
$$= \frac{\mu}{\mu_0}$$

const. of Relative Permeability



Partial Alignment

Saturation



2 Tesla

- ① Domains orientated in random directions
- ② provide B_{ext} , Aligns domains, $B_{internal}$ grows fast due to addition of Domain magnetic Moments to external field
- ③ SATURATION All domains Aligned
- ④ reduce $B_{external}$, Domains stay aligned
- ⑤ $B_{internal}$ drops quickly when $B_{external}$ changes direction and causes domains to orient in other direction
- ⑥ Saturation with domains pointed opposite the direction at position ③-④

