Physics 114 - March 30, 2006

Important

Last Time:

Magnetic Induction

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

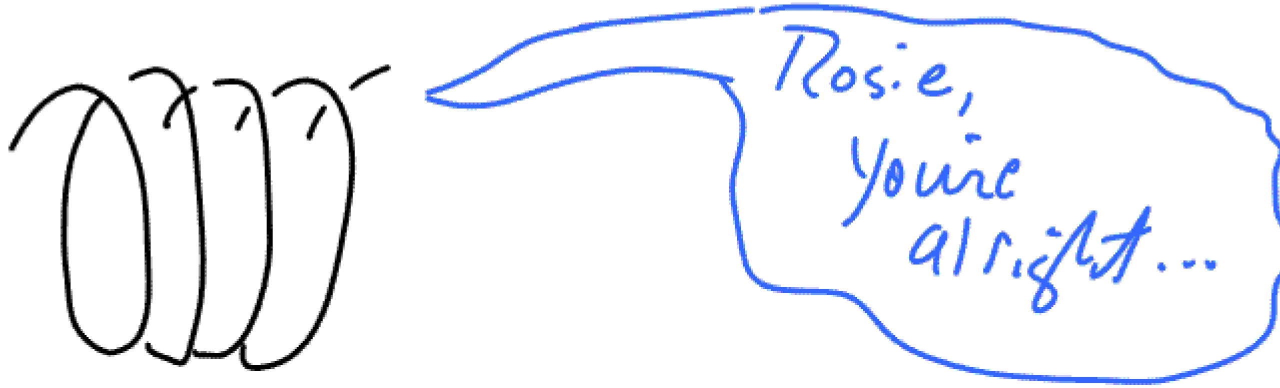
Also worked as an understudy in London production of Phantom of the Opera

Discovered Magnetic induction

Farad named after Faraday

Also invented the Bunsen Burner

Inductor w/out a date



$$\phi = L\, i$$

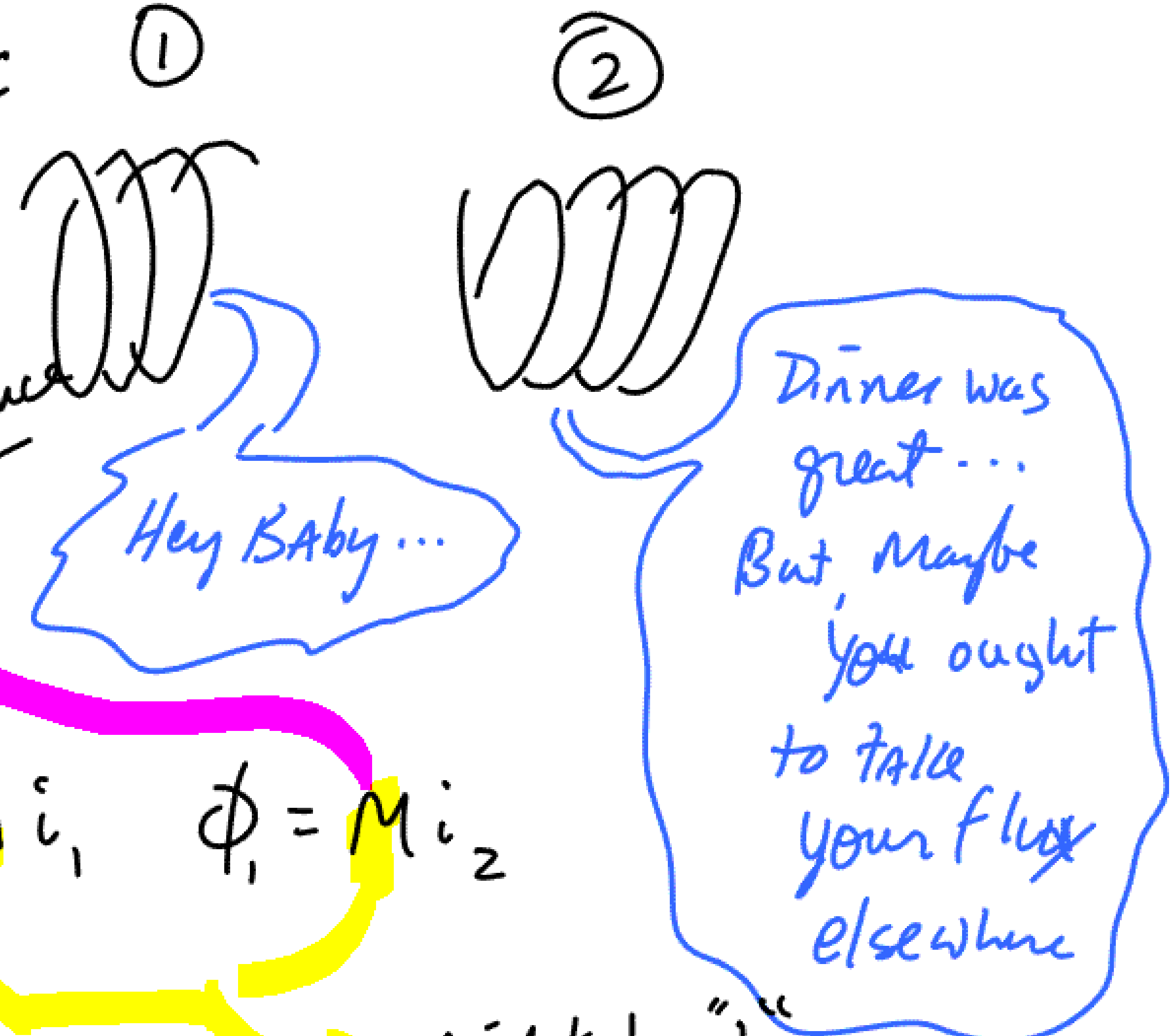
L → Const of Self inductance

Faraday's law

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

Circuit symbol

Inductor with a date



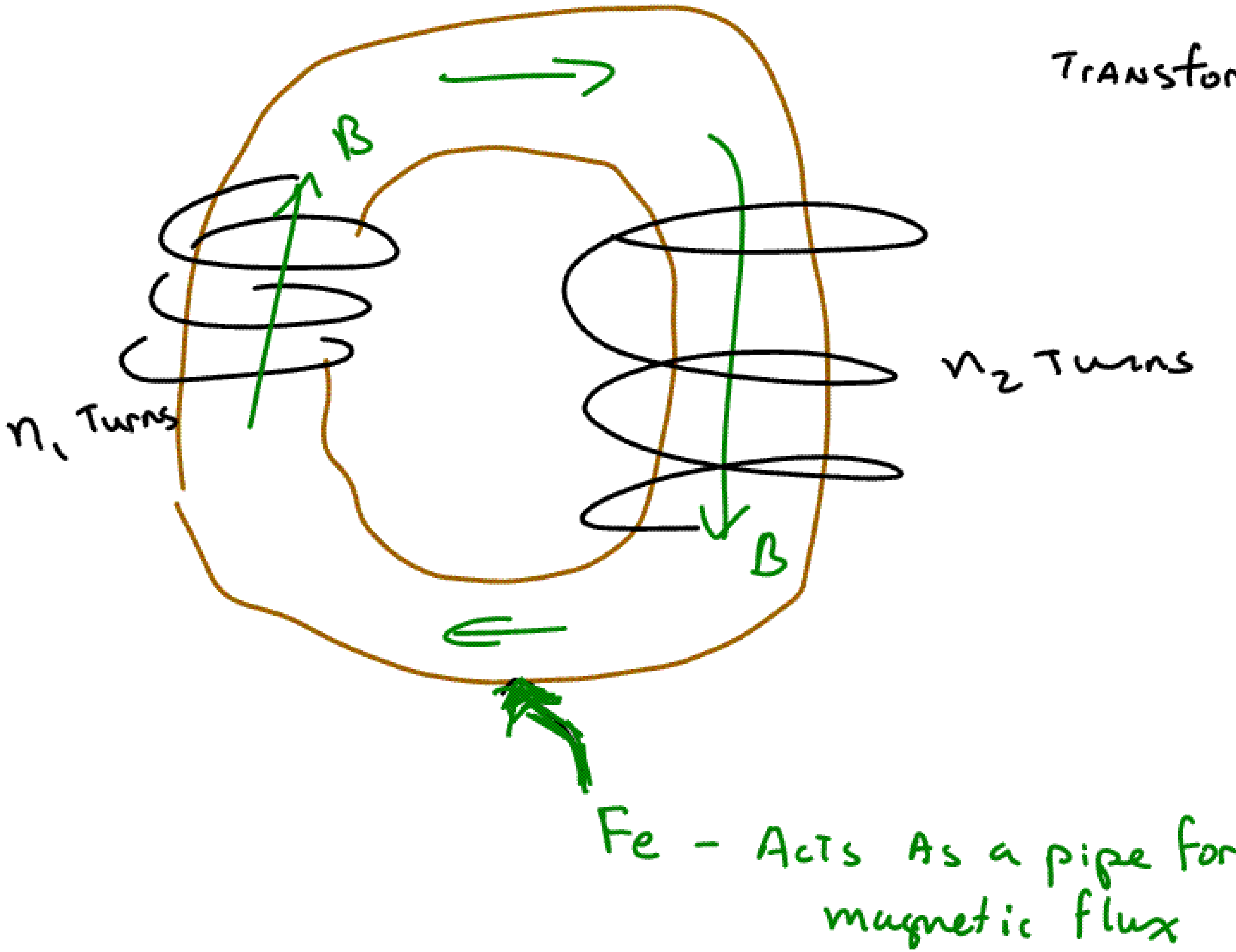
const. of Mutual inductance

$$\phi_2 = M i_1 \qquad \phi_1 = M i_2$$

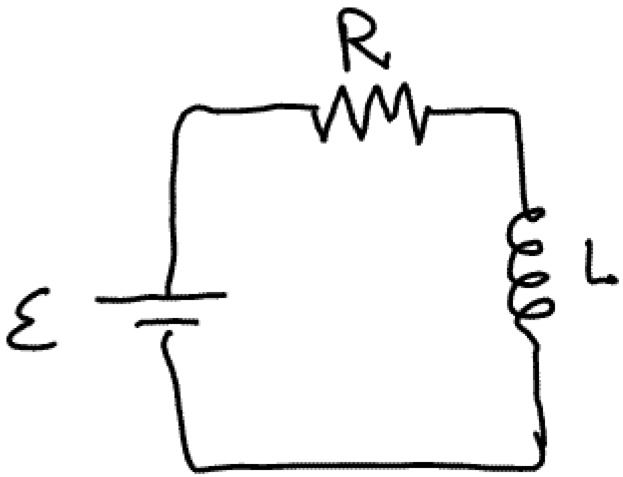
Might be "L" too

$$\mathcal{E}_2 = -M \frac{di_1}{dt} \qquad \mathcal{E}_1 = -M \frac{di_2}{dt}$$

Transformer



Energy + The Magnetic Field



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

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

$\mathcal{E}i$: Power output of Battery

i^2R: Power dissipated in Resistors

$Li\frac{di}{dt}$: Power in or out of inductor

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 → $U_E = \frac{1}{2} C V^2$

Solenoid, n turns/length, i

$B = \mu_0 n i$ inside, $= 0$ outside

$u_B \equiv$ Energy density in Magnetic field

$$u_B = \frac{U_B}{A\ell} = \frac{\frac{1}{2}Li^2}{A\ell}$$

$$\phi_m = Li \qquad L = \frac{\phi_m}{i} = \frac{BAn\ell}{i}$$

B2

$$L = \frac{(\mu_0 n i)An\ell}{i} = \mu_0 n^2 A\ell$$

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

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

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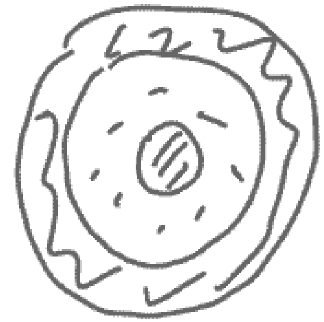
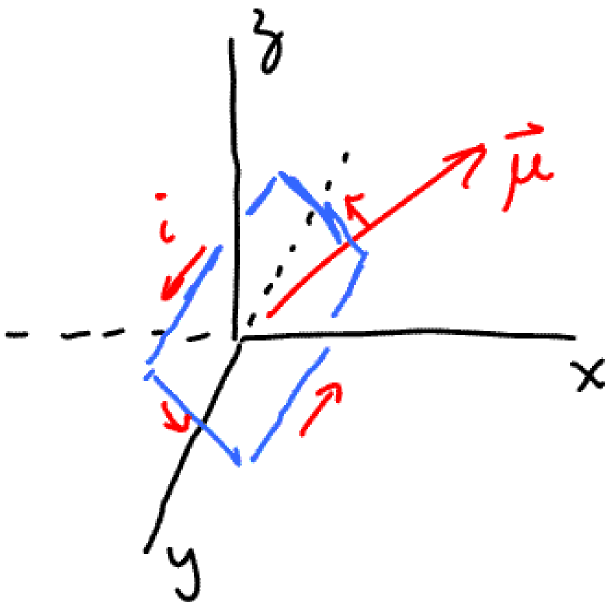
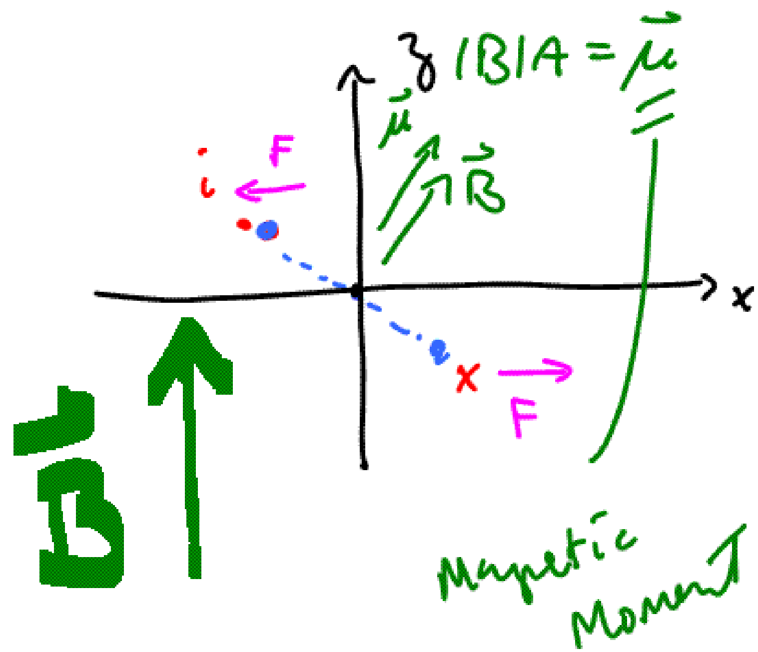


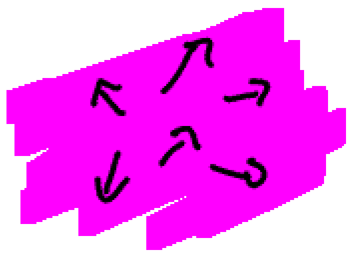
Magnetic fields in Matter



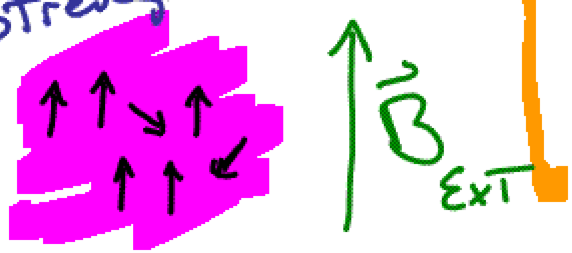


Torque on Magnetic Dipole $= \vec{\mu} \times \vec{B}$

Paramagnetism



Strengthen B



Diamagnetism

No Dipoles

Weakens B

Ferromagnetism

Fe = iron

Regions called Domains

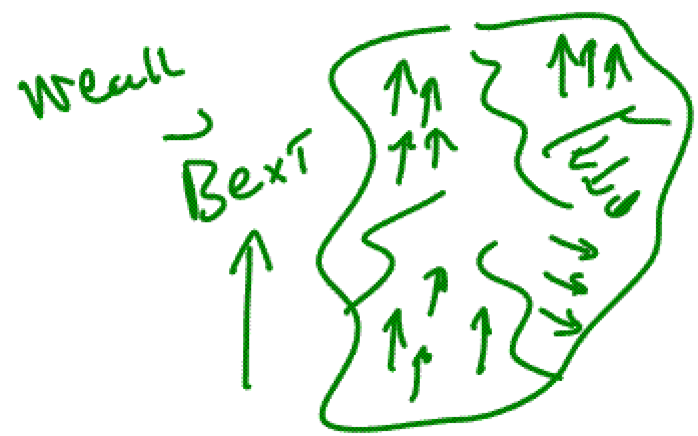
$$|\vec{B}| = \mu_0(1+\chi_m)|\vec{B}_{ExT}|$$

χ_m → Magnetic Susceptibility

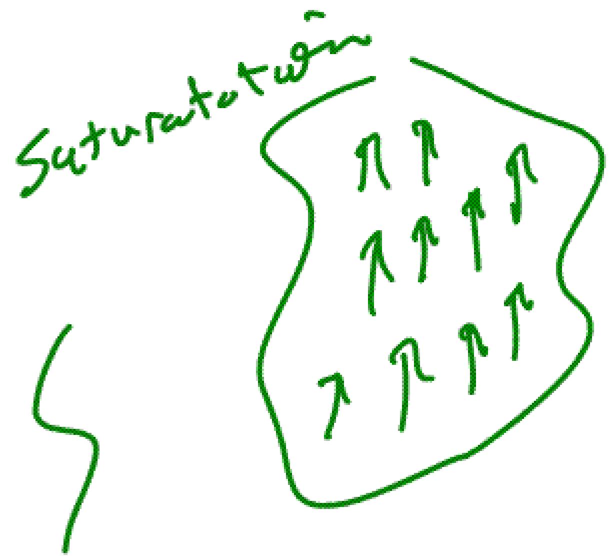
$$B = K_m B_{exT}$$

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

const. of Relative Permeability



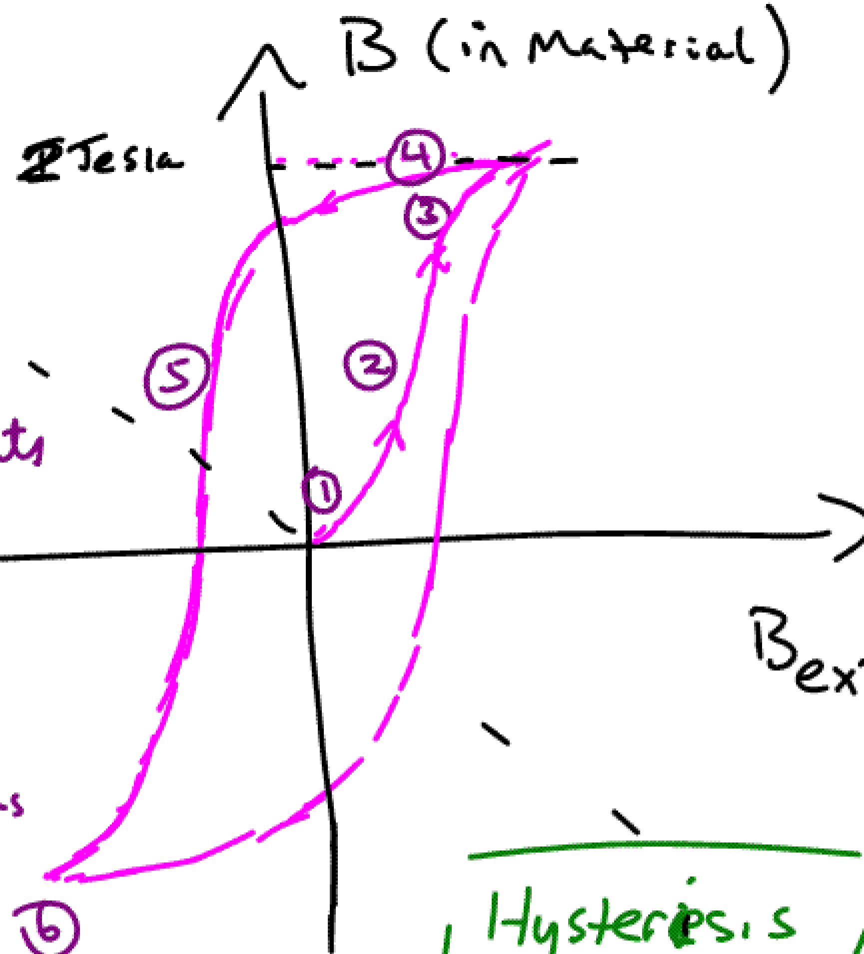
Partial Alignment



2 Tesla

① Domains oriented in random directions

② provide B_{ext}, Aligns domains, B internal grows fast due to addition of Domain magnetic Moments to external field



Hysteresis Loop

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