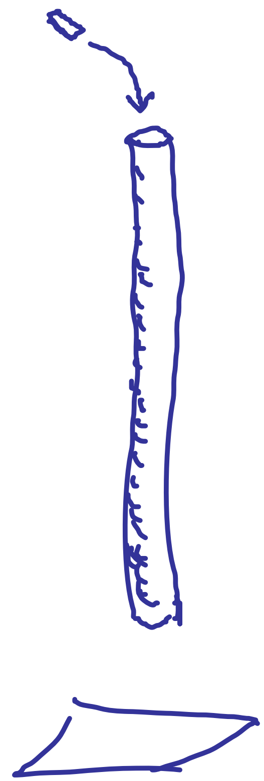
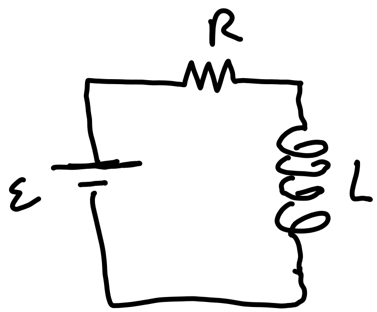
Physics 114 - March 31, 2015



The pellet drop challenge!



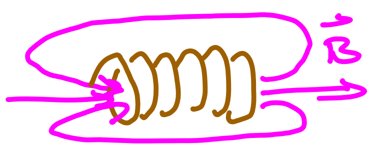
$$\mathcal{E} i = i^2 R + L i \frac{di}{dt}$$

- $\mathcal{E} i$: Power output of Battery
- $i^2 R$: Power dissipated in Resistor
- $L i \frac{di}{dt}$: Power going into the inductor

$$L i \, di/dt \rightarrow U_B = \tfrac{1}{2} L i^2$$

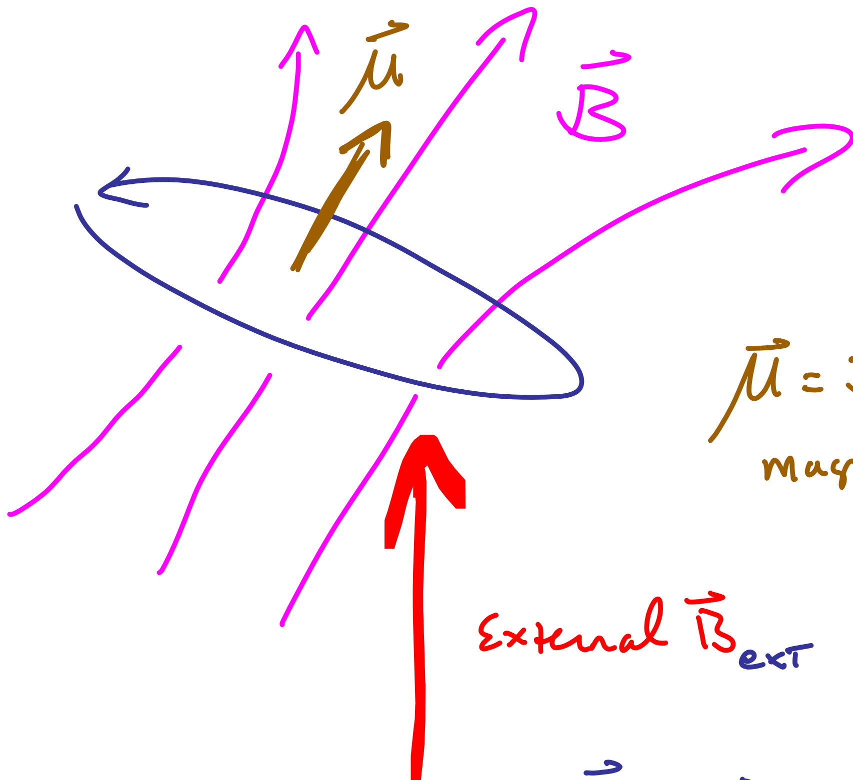
U_B: energy stored in B field in inductor

Solenoid



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

Energy Density in B field



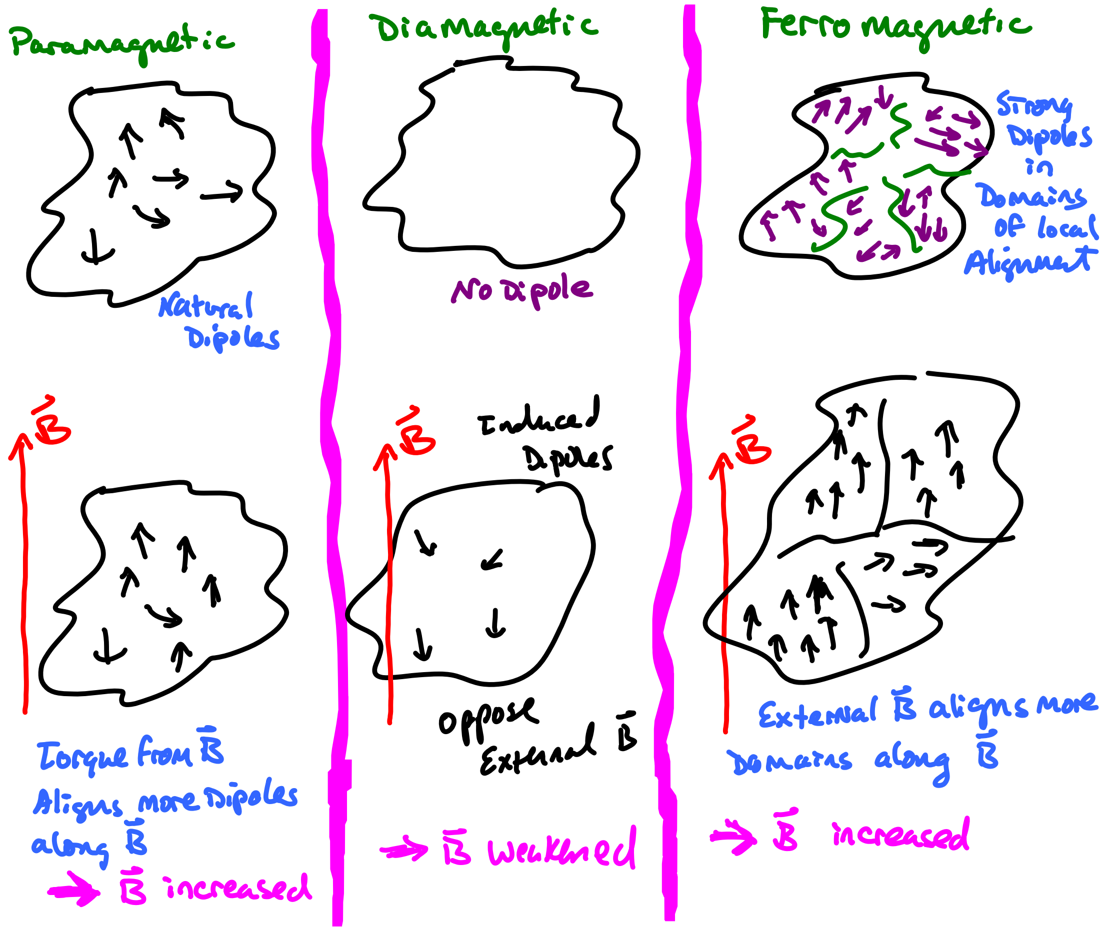
$$\vec{\mu} = \vec{B}A$$

magnetic Moment

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

Aligns $\vec{\mu}$ with $\vec{B}_{ext}$

Magnetism in Materials



$$B = \mu_0 (1 + \chi_M) B_{free}$$

χ_M: Magnetic Susceptibility

$(1 + \chi_M)$: relative permeability

B_{free}: External Field

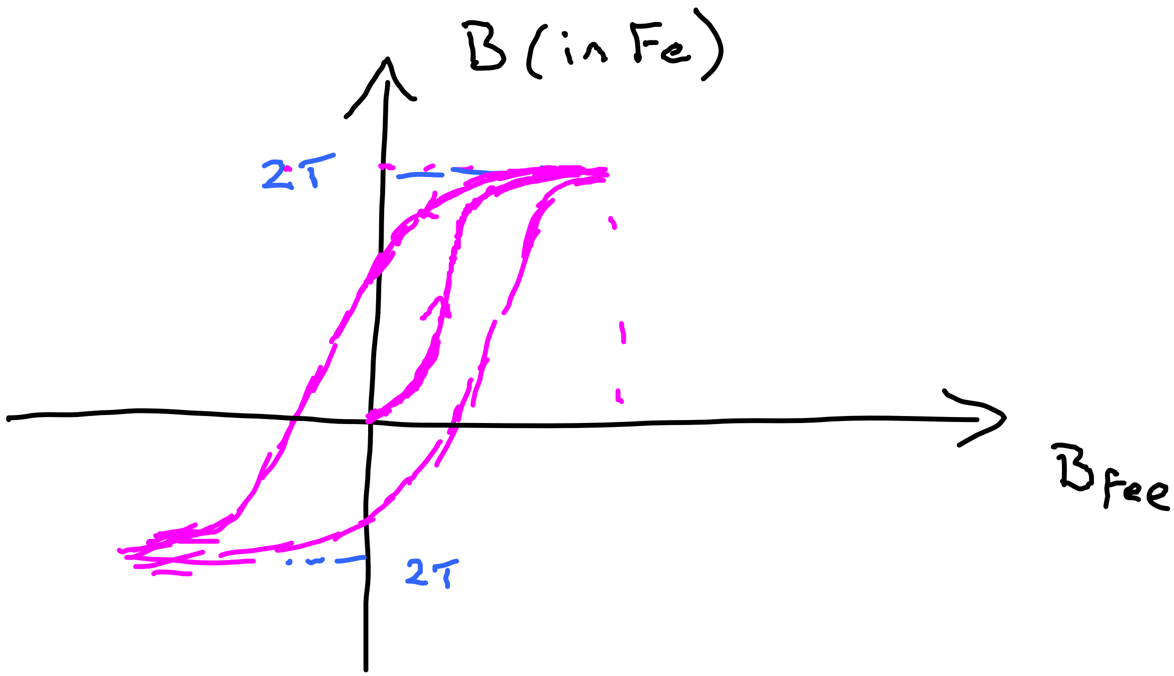
$$B = [\mu_0 + \mu_0 \chi_M] B_{free}$$

$\mu_0 \chi_M$: permeability

$\chi_M \gtrsim 0$ Paramagnetic Material

$\chi_m \gg 0$ FerroMagnetic

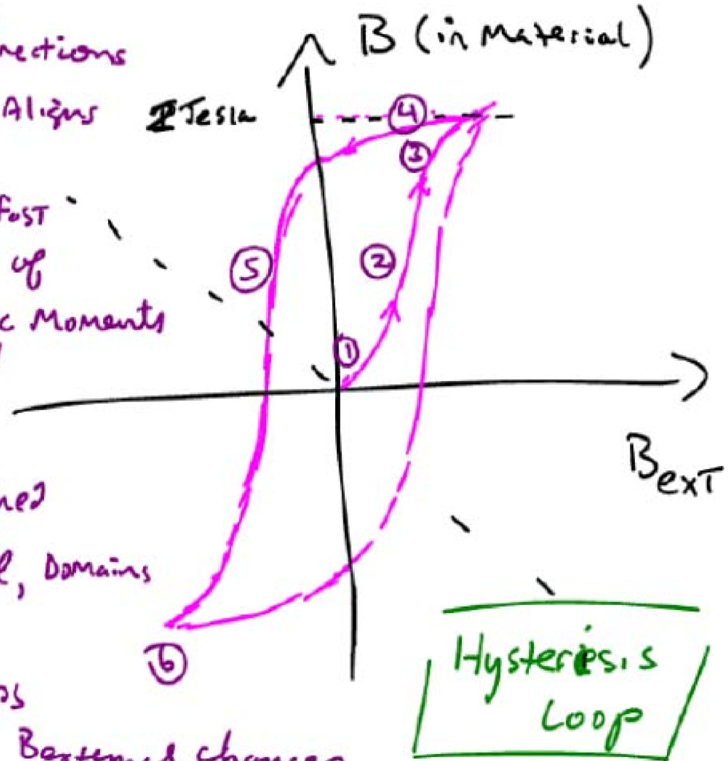
$\chi_m < 0$ Diamagnetic Material



B (in Fe)
2T
2T
Bfree

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

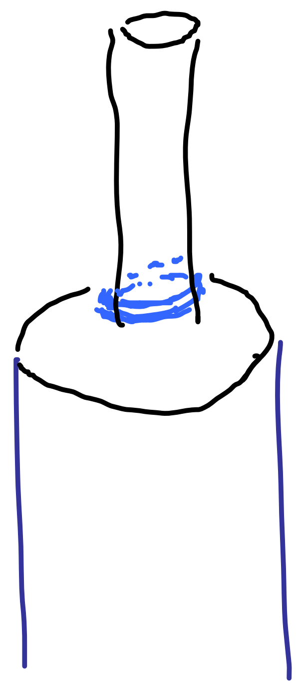


③ saturation All domains Aligned

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



Demo

Maxwell's Equations

1873

James Clerk Maxwell

1831-1879 (Edinburgh)

$$\oint_S \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\epsilon_0}$$ Gauss' law

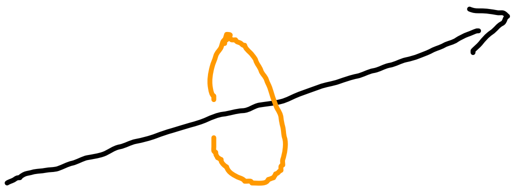
$$\oint_S \vec{B}\cdot d\vec{A} = 0$$ No Magnetic point Sources (Mono poles)

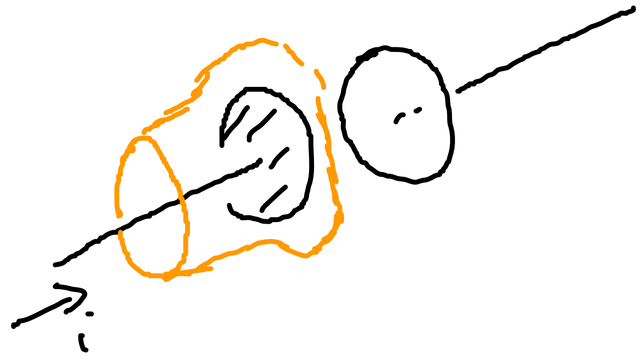
$$\oint_C \vec{B}\cdot d\vec{l} = \mu_0 I_{encl}$$ Ampere's Law

$$\oint_C \vec{E}\cdot d\vec{l} = -\frac{d\Phi_M}{dt} = -\frac{d}{dt}\oint_S \vec{B}\cdot d\vec{A}$$ Faradays Law

$$\oint_C \vec{B}\cdot d\vec{l} = \mu_0 I_{encl} + \mu_0\epsilon_0 \frac{d}{dt}\oint_S \vec{E}\cdot d\vec{A}$$

Maxwell's displacement current




i

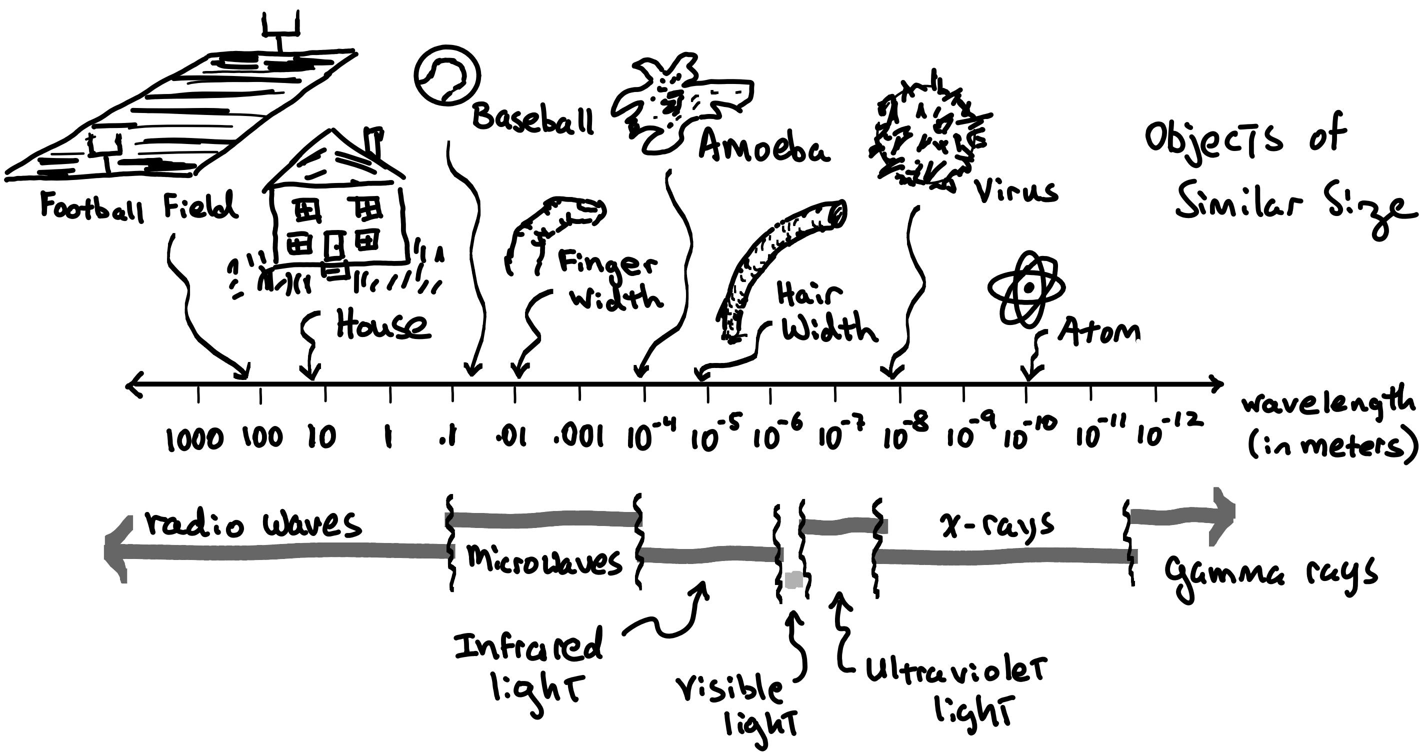
$$\oint_S \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\epsilon_0}$$ Gauss' law

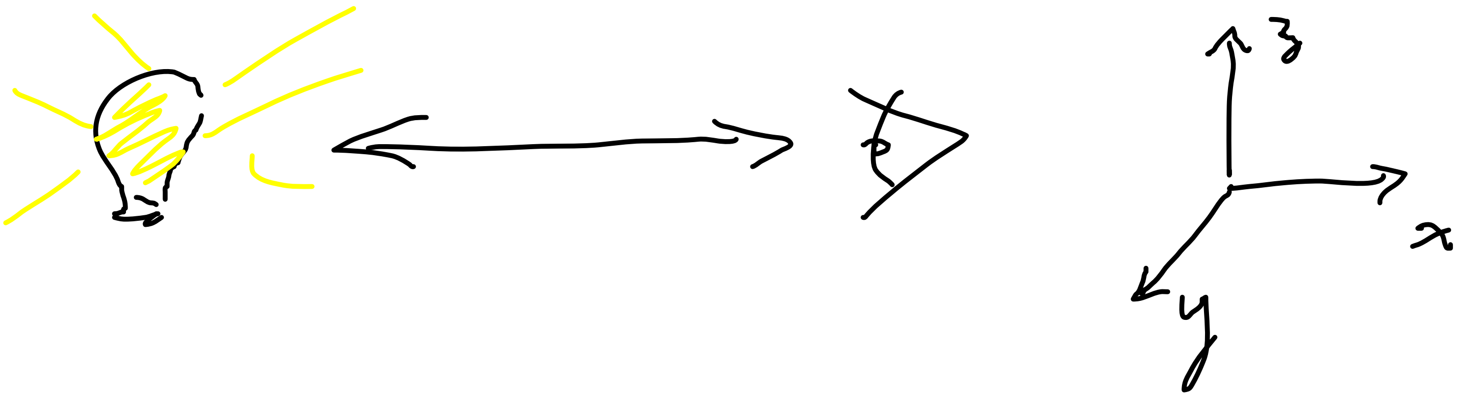
$$\oint_S \vec{B}\cdot d\vec{A} = 0$$ No Magnetic point Sources (Mono poles)

$$\oint_C \vec{B}\cdot d\vec{l} = \mu_0 \epsilon_0 \frac{d}{dt}\oint \vec{E}\cdot d\vec{A}$$ Ampere + Maxwell

$$\oint_C \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\oint_S \vec{B}\cdot d\vec{A}$$ Faradays Law

The variety of electromagnetic waves

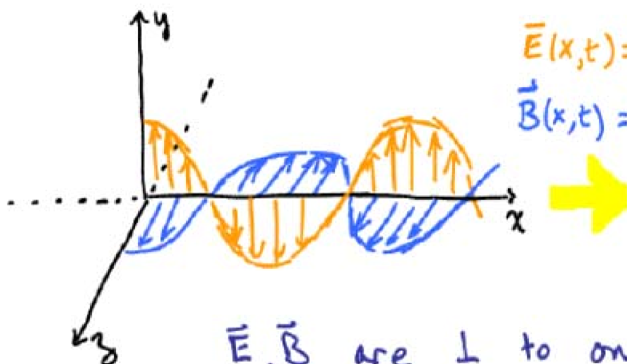



z
x
y

very Far Away

Solve Maxwell's eqns

Get Coupled wave eqns for $\vec{E}, \vec{B}$



$\vec{E}(x,t) = E_0 \cos(kx - \omega t + \varphi)\,\hat{y}$

$\vec{B}(x,t) = \frac{E_0}{c} \cos(kx - \omega t + \varphi)\,\hat{z}$

$\vec{E}, \vec{B}$ are $\perp$ to one another

Wave propogates in direction of $\vec{E} \times \vec{B}$

$|\vec{B}| = |\vec{E}|/c$

$\vec{E}, \vec{B}$ in phase

speed of propagation $\rightarrow c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$