Physics 114 - April 4, 2006

- Exams graded — remind me before end of class + I will return them

- Project Poster session this Friday
  April 7   3-5 pm   Hirst Lounge in Wilson Commons

- April 13 in-class presentations

  groups:
  2 optics
  7 Beer run
  16 Aurora Borealis
  18 Diamonds

April 20?

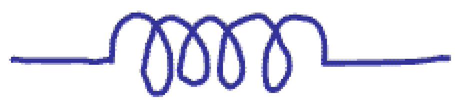
1 van de Graff, 10 morning w/ physics, 12 ATOM, 17 Guitar
19 come online

Last time:

$\phi = Li$

$\phi = Mi$

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



in a circuit

use w/ Kirchoff's Law $\Rightarrow$ get differential eqn

Solve for $q(t)$, $i(t)$

etc. ...

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

Energy density of Magnetic field

Magnetism in Materials

Paramagnetic materials $K_m > 1$

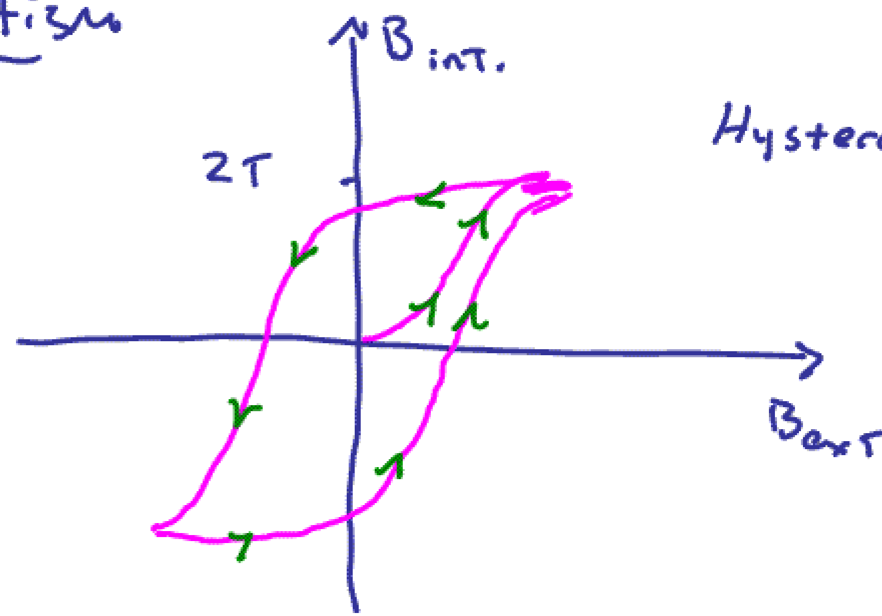
DiaMagnetic Materials $K_m < 1$

μ/μ_0

$$|\vec{B}_{int}| = K_m |\vec{B}_{ext}|$$

Const of magnetic permeability

FerroMagnetism



Hysteresis

Maxwell's Equations

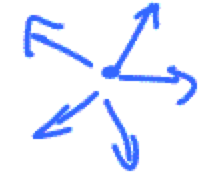
1873

James Clerk Maxwell

1831 - 1879 (Edinburgh)

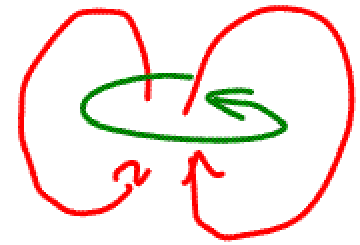
$$\oint_S \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\epsilon_0}$$

Gauss' Law



$$\oint_S \vec{B}\cdot d\vec{A} = 0$$

No Magnetic Monopole



$$\oint_C \vec{B}\cdot d\vec{l} = \mu_0 I_{encl}$$

Ampere's Law

Amperian loop

$$\oint_C \vec{E}\cdot d\vec{l} = -\frac{d\Phi_m}{dt} = \frac{d}{dt}\int_S \vec{B}\cdot d\vec{A}$$

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

Current = I

$$\mu_0\epsilon_0\frac{d}{dt}\int_S \vec{E}\cdot d\vec{A}$$

Maxwell's "Displacement Current"

$$\oint \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\epsilon_0}$$

Divergence

$$\vec{\nabla}\cdot\vec{E} = \rho/\epsilon_0$$

$$\oint \vec{B}\cdot d\vec{A} = 0$$

$$\vec{\nabla}\cdot\vec{B} = 0$$

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

curl

$$\vec{\nabla}\times\vec{B} = \mu_0\vec{J} + \mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t}$$

$$\oint \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\int \vec{B}\cdot d\vec{A}$$

$$\vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$

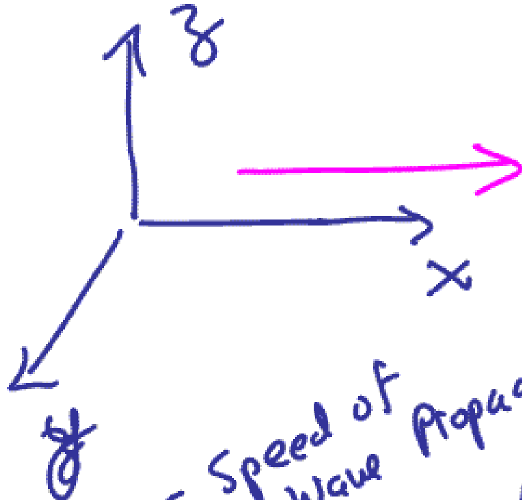
differential form

Integral form Maxwell's eqns

Will NOT use in this class ... but just wanted to show it to you

$$\vec{\nabla} = \frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}$$

Can expand differential form of Maxwell's eqns and look at "plane wave" solution far away from source ... We will skip derivation because intellectual gain/pain ratio is low



wave # $\frac{2\pi}{\lambda}$

$2\pi f$

$2\pi\nu = 2\pi/T$

phase Angle

$$E_y(x,t) = E_{0y}\cos(kx - \omega t + \varphi)$$

$$B_z(x,t) = \frac{k}{\omega} E_{0y}\cos(kx - \omega t + \varphi)$$

$$= \frac{1}{c} E_y$$

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3\times 10^8\ m/s$$

= speed of wave propagation

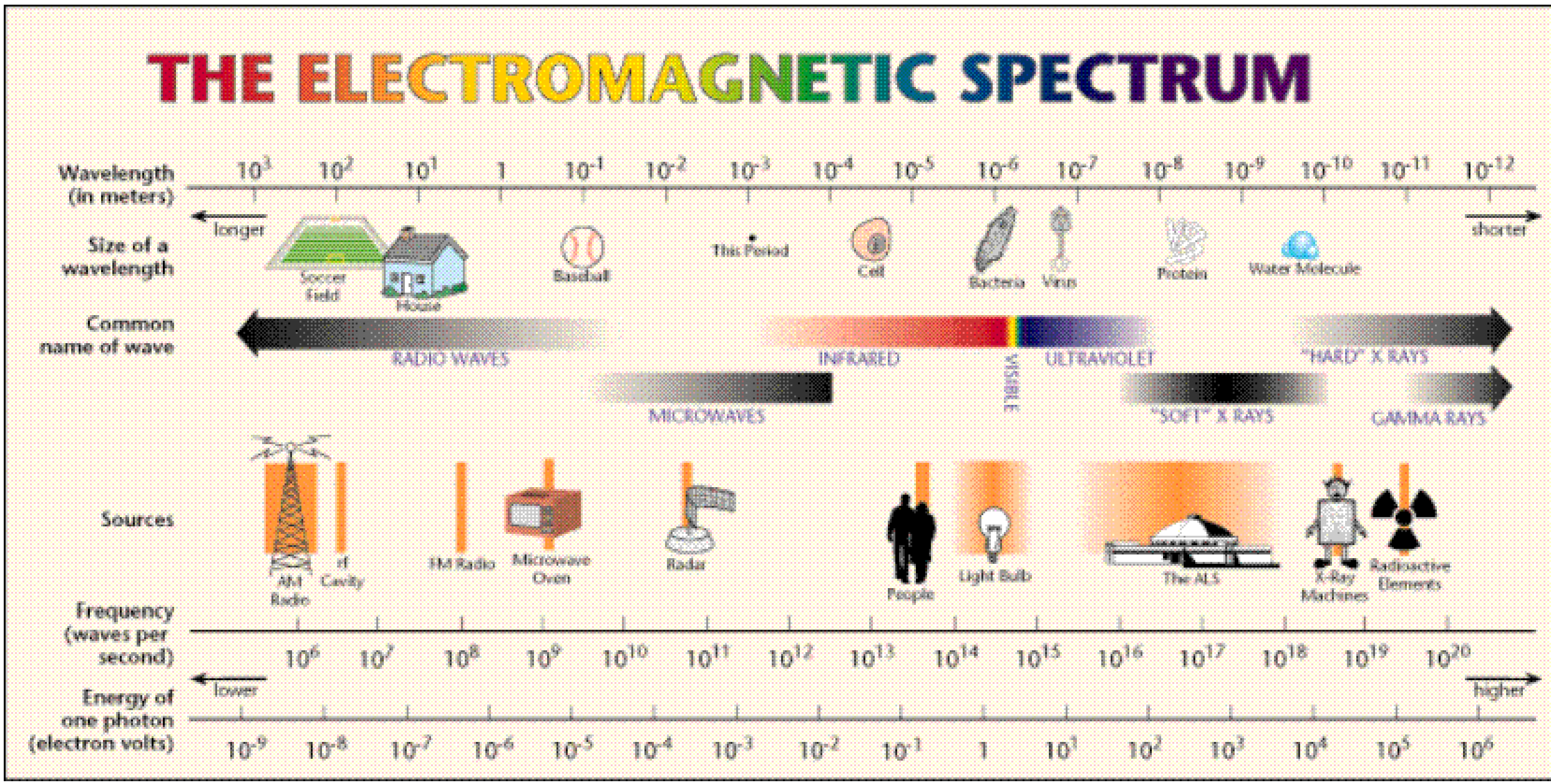
E, B coupled together

E, B $\perp$ to each other and $\perp$ to direction of propagation of wave

E, B are in phase

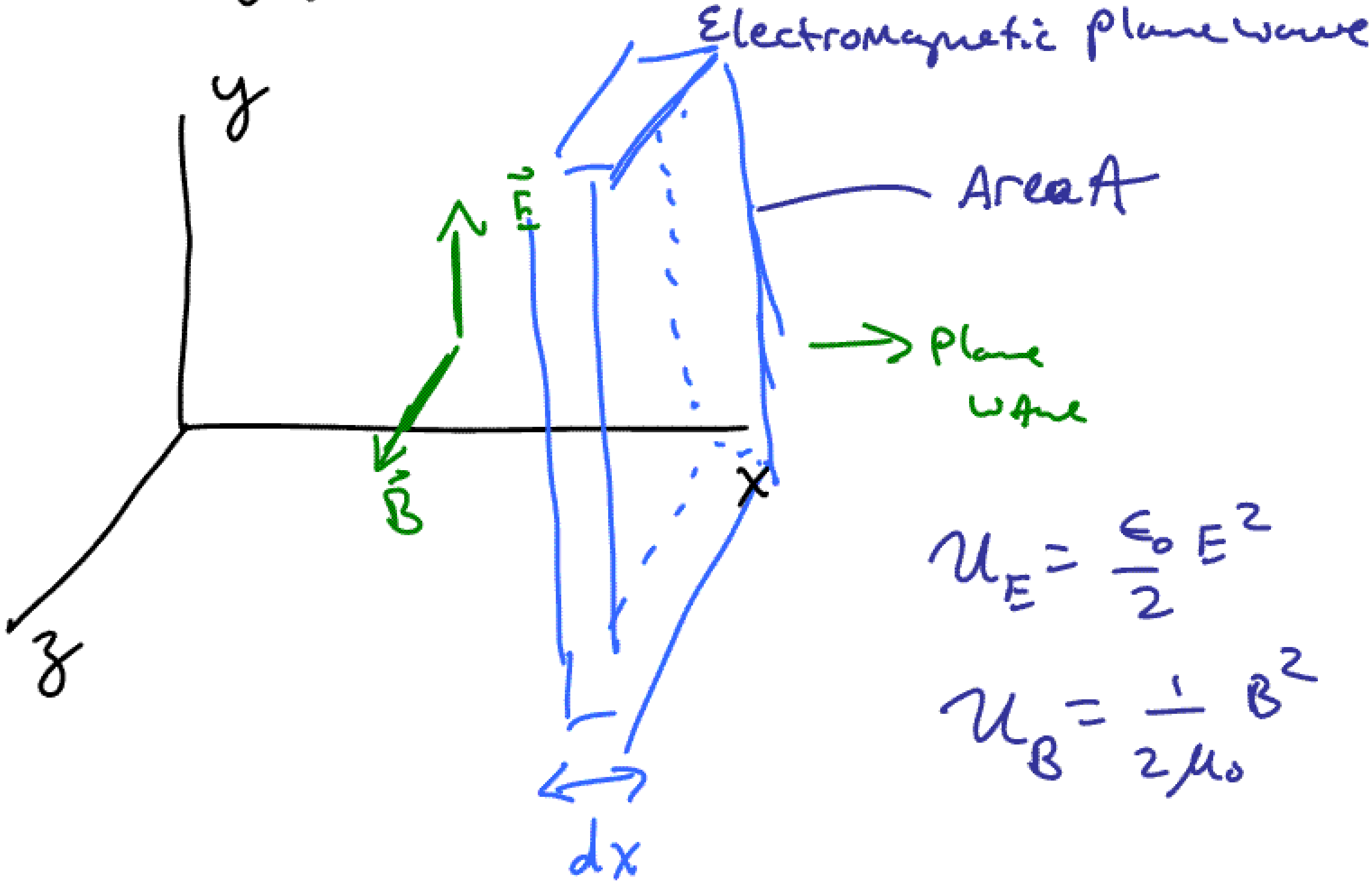
$E = h\nu$ → high frequency means high Energy (short wavelength)

Electromagnetic Radiation



- figure from www.lbl.gov
LBNL

Energy flow in EM Waves



$$u_E = \frac{\epsilon_0}{2} E^2$$

$$u_B = \frac{1}{2\mu_0} B^2$$

$$du = (u_E + u_B) \text{ vol. Box}$$

$$du = \left(\frac{\epsilon_0}{2} E^2 + \frac{1}{2\mu_0} B^2\right) A\, dx$$

$$E = cB \qquad c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} \qquad \epsilon_0 = \frac{1}{\mu_0 c^2}$$

$$du = \left[\frac{1}{2\mu_0 c^2} E c B + \frac{1}{2\mu_0} B \frac{E}{c}\right] A\, dx$$

differential Energy moving thru box in time $dt = \frac{dx}{c}$

$$du = \left(\frac{1}{\mu_0 c} EB\right) dx\, A$$

$$\frac{du}{dt} = \frac{EB}{\mu_0} (\text{Area})$$

$$\frac{dU}{dt}\frac{1}{(\text{Area})} = \frac{EB}{\mu_0} = \frac{\text{WATTS}}{m^2} \equiv \text{Intensity}$$

Energy flux

$\vec{S} \equiv$ vector energy flow

Poynting vector

$$\vec{S} = \frac{\vec{E}\times\vec{B}}{\mu_0}$$

→ represents the Energy flow of an EM wave

$|\vec{S}|$ = Intensity of the light

direction of $\vec{S}$ is direction of propugation of EM wave