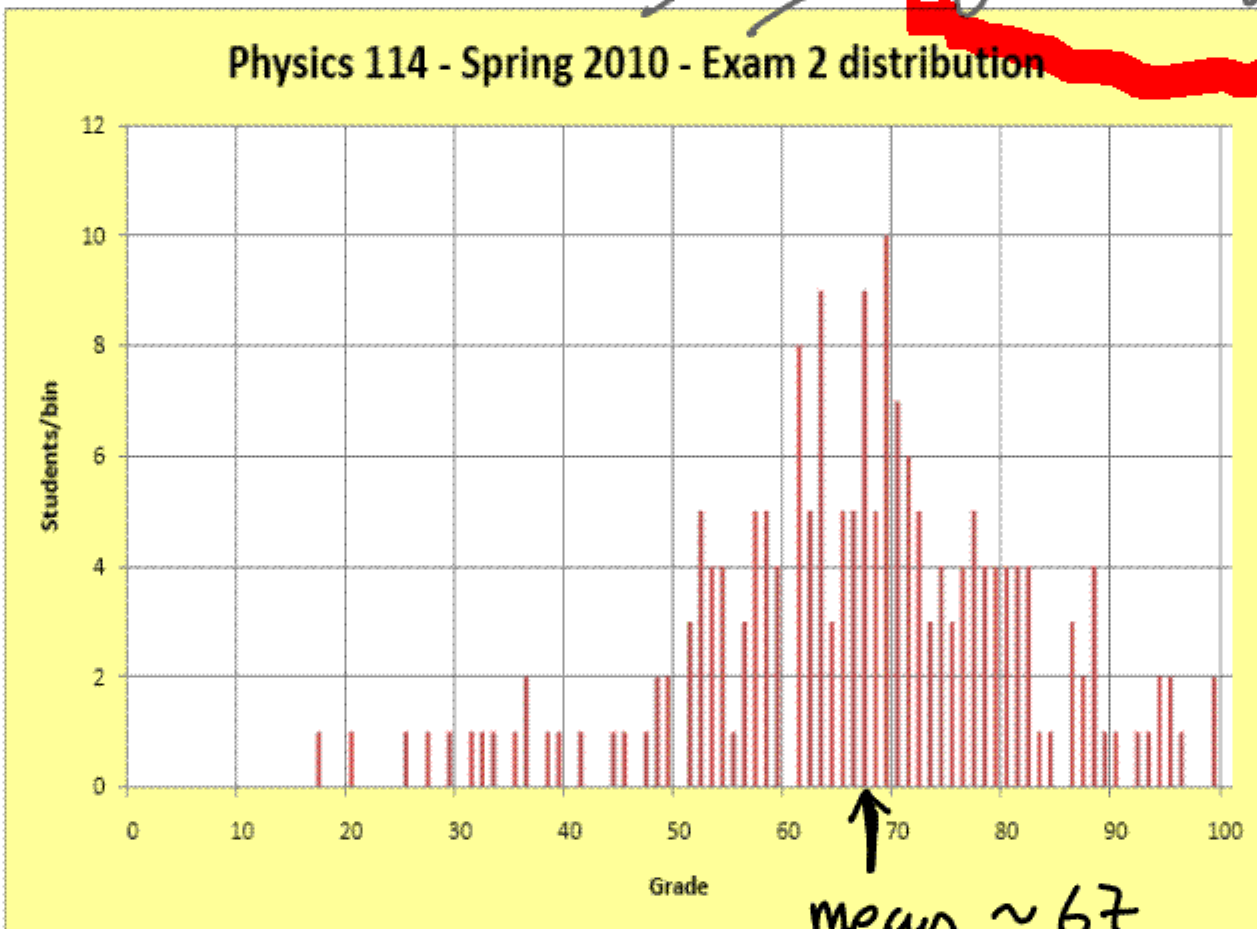
Physics 114 - March 30, 2010

- Exam 2 graded . . .

Solns Posted

check over your Exam!!



$$B = \mu_0 (1 + \underbrace{\chi_m}_{\text{Magnetic Susceptibility}}) \underbrace{B_{free}}_{\text{External B field}}$$

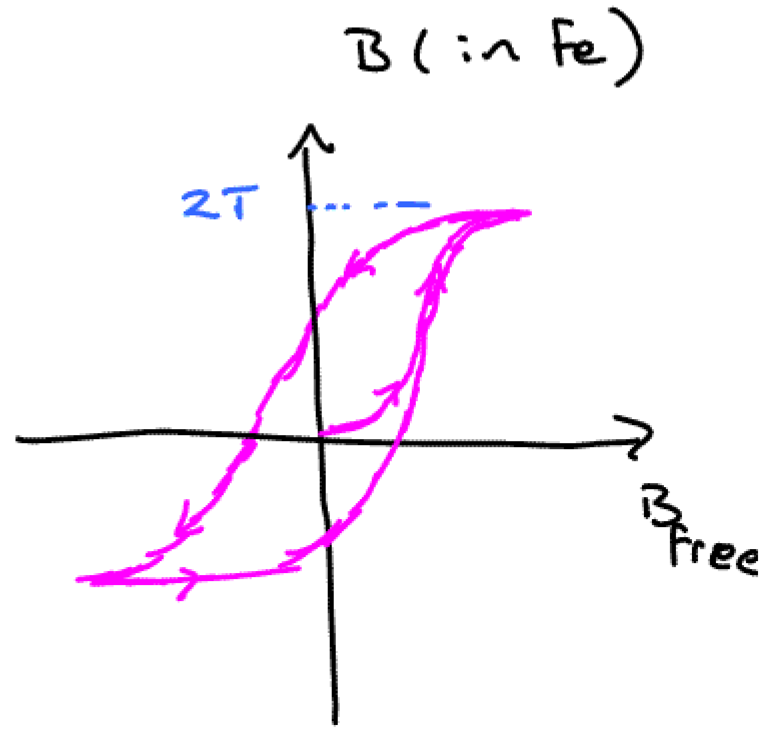
relative permeability

$\mu_0 K_m \sim$ permeability $\rightarrow \mu$

$\chi_m \gtrsim 1$ Paramagnetism

$\gg 1$ Ferromagnetism

< 1 Diamagnetism



Hysteresis loop

Integral form of Maxwell's equations

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

No magnetic monopole $$\oint_S \vec{B}\cdot d\vec{A} = 0$$

Ampere $$\oint_C \vec{B}\cdot d\vec{l} = \mu_0 \int_S \vec{J}\cdot d\vec{A} + \boxed{\mu_0 \epsilon_0 \frac{d}{dt}\int \vec{E}\cdot d\vec{A}}$$

new term – "Maxwell's Displacement current"

Faraday $$\oint_C \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\int \vec{B}\cdot d\vec{a}$$

Integral form

(what you've seen except for Maxwell's displacement current term)

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

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

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

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

Vector Calculus Magic

Differential form

[We will not use in this class]

called the "divergence"

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

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

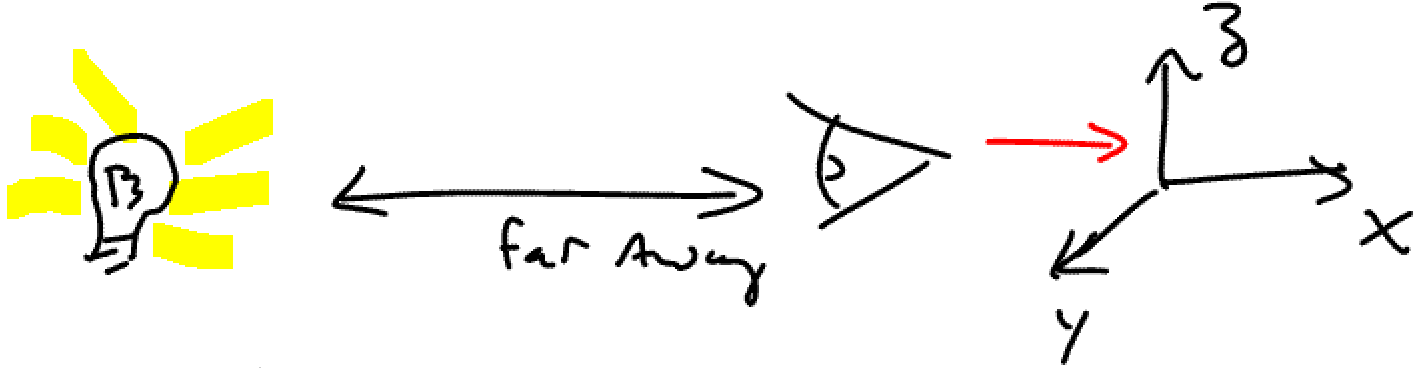
$$\vec{\nabla}\times\vec{B} = \mu_0\vec{J} + \mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t}$$

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

called the "curl"

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

vector operator



speed of prop

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

phase

$$E_y(x,t) = E_{0y} \cos\left(\underbrace{k}_{2\pi/\lambda}x - \underbrace{\omega}_{2\pi/T} t + \phi\right)$$

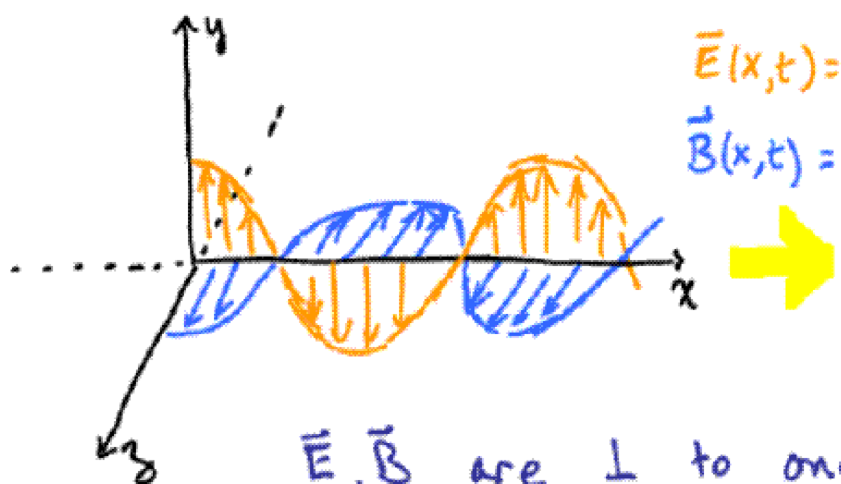
$$B_z(x,t) = \frac{k}{\omega} E_{0y} \cos(kx - \omega t + \phi)$$

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

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 propagates in direction of $\vec{E} \times \vec{B}$

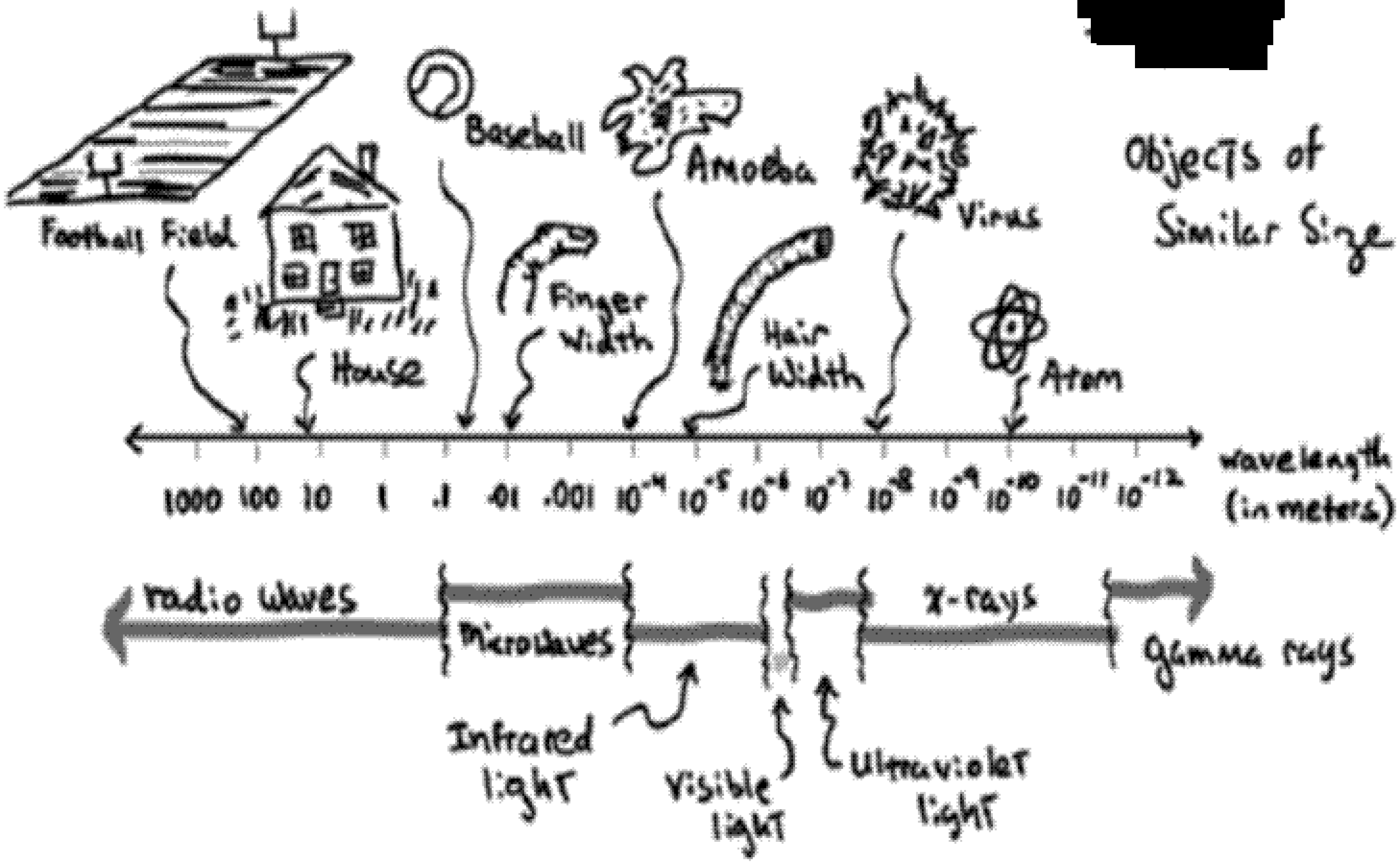
$|\vec{B}| = |\vec{E}|/c$

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

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

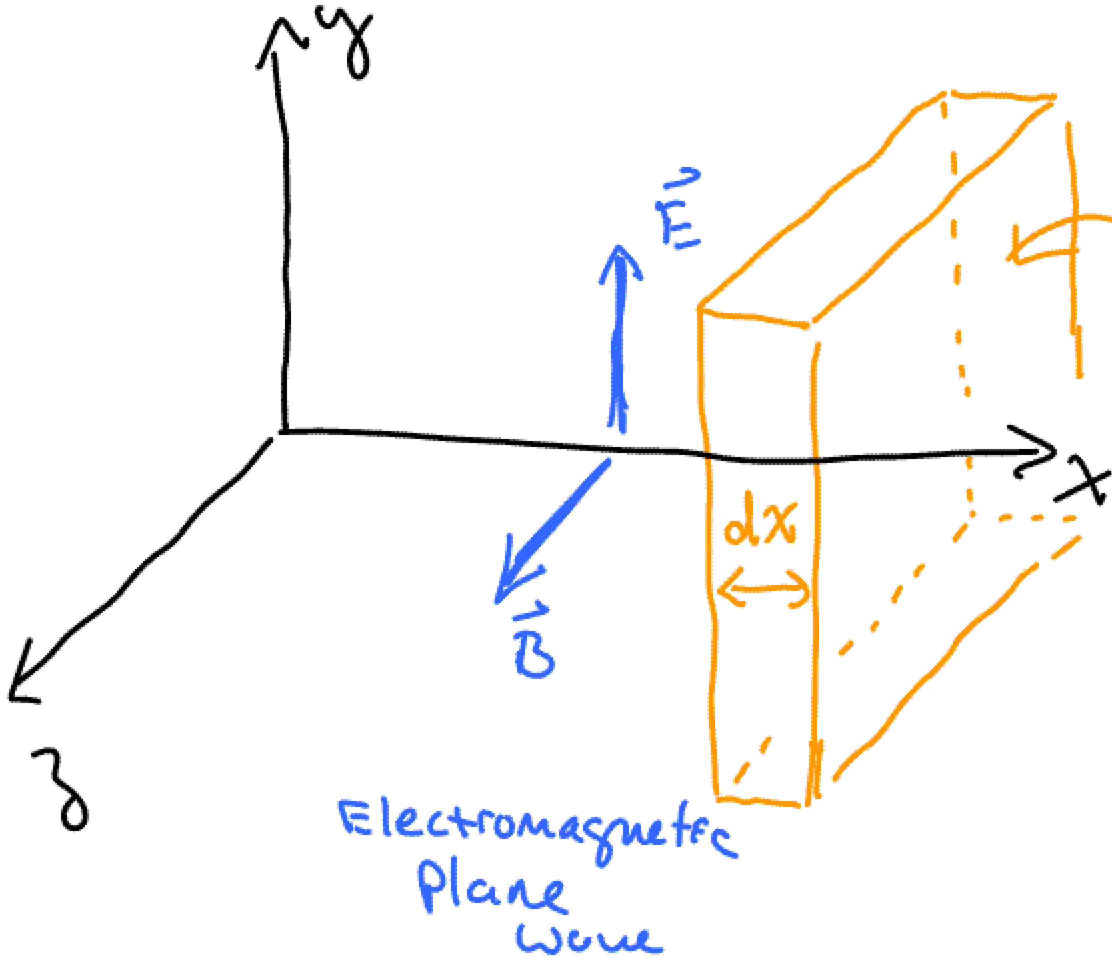
The variety of electromagnetic waves

[redacted]



$V = \lambda \nu$ $\qquad$ $E = h\nu$

Energy flow in EM waves



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

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

$$du = (u_E + u_B)\,\text{Volume} = (u_E + u_B)\,A\,dx$$

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

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

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

$$\frac{du/dt}{(\text{Area})} = \begin{array}{c}\text{Power}\\\text{Thru}\\\text{Box}\end{array} = \frac{EB}{\mu_0} \quad \frac{\text{WATTS}}{m^2}$$

Intensity of EM wave

$\vec{S} \equiv$ Vector Energy flow $\equiv \dfrac{\vec{E} \times \vec{B}}{\mu_0}$

Poynting vector

$|\vec{S}| =$ Intensity

$\hat{S} \equiv$ direction of EM wave

Time Average of $\vec{S} \equiv \langle \vec{S} \rangle$ or $\bar{S}$

$E = E_0 \sin \omega t$

$B = \frac{E_0}{c} \sin \omega t$

$$S \sim \frac{1}{\mu_0 c} E_0^2 \underbrace{\sin^2 \omega t}_{\text{Time Averages to } 1/2}$$

$$\bar{S} = \langle S \rangle = \frac{E_0^2}{2\mu_0 c} = \frac{c}{2\mu_0} B_0^2 = \frac{E_0 B_0}{2\mu_0 c}$$

Momentum of ch. particle

F

dist / time

$$F \sim \frac{dp}{dt} \sim q v B \sim q v \frac{E}{c} \sim \frac{1}{c} \frac{d(\text{work})}{dt}$$

$$dp \sim \frac{d(\text{work})}{c} \sim \frac{\text{Energy}}{c}$$

$$\boxed{P = \frac{U}{c}}$$

Momentum
in EM wave

$$F = \frac{dp}{dt} = \frac{dU}{dt}\frac{1}{c} = \frac{1}{c}\,\frac{\text{Energy}}{\text{Time}} =$$

$$F = \frac{1}{c}\,\frac{\text{Energy}/\text{Area}}{\text{Time}}\,\text{Area} = \frac{S}{c}\,\text{Area}$$

$$\text{Pressure} = \frac{F}{\text{Area}} = \frac{S}{c} = \text{Radiation pressure}$$