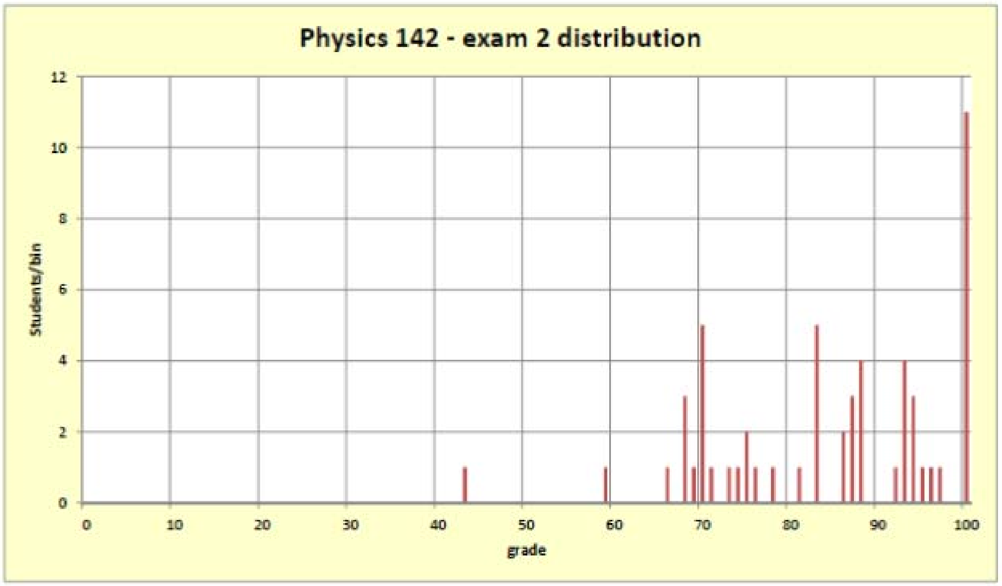
Physics 142 - November 20, 2014

- Presentation date Preferences   Dec 4, 9, 11

- Exam 2 graded

uh... clearly a high mutant density...



Last Time —

Maxwell's eqns plus vector calc Identities

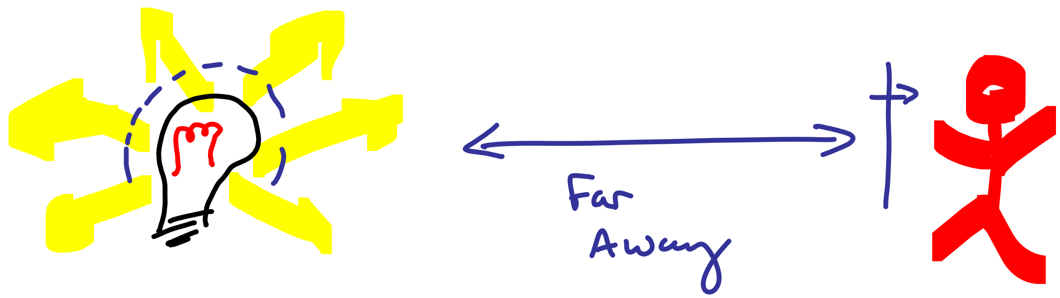
$$\nabla^2 \vec{B} = -\mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$

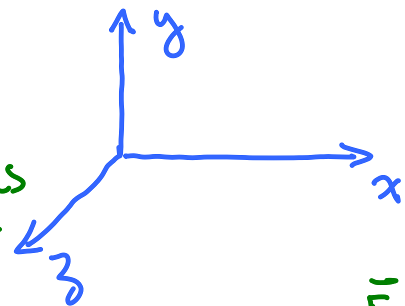
$$\nabla^2 \vec{E} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}$$

- Wave equations for $\vec{E}$, $\vec{B}$
- Coupled equations because of mixing of $\vec{E}, \vec{B}$ in Maxwell's eqns

what can we learn?

- Harmonic Wave Solutions to eqns above
- Maxwell's equations
- Boundary conditions





Impose
Boundary
Conditions

$\vec{E} = \vec{E}(x,t)$

$\vec{E} = E(x,t)\,\hat{j}$

"polarization"

with no loss in generality

We Find

- $\vec{E}, \vec{B}$ are transverse and mutually $\perp$
- $\vec{E}, \vec{B}$ are in phase
- $|\vec{E}| = c\,|\vec{B}|$

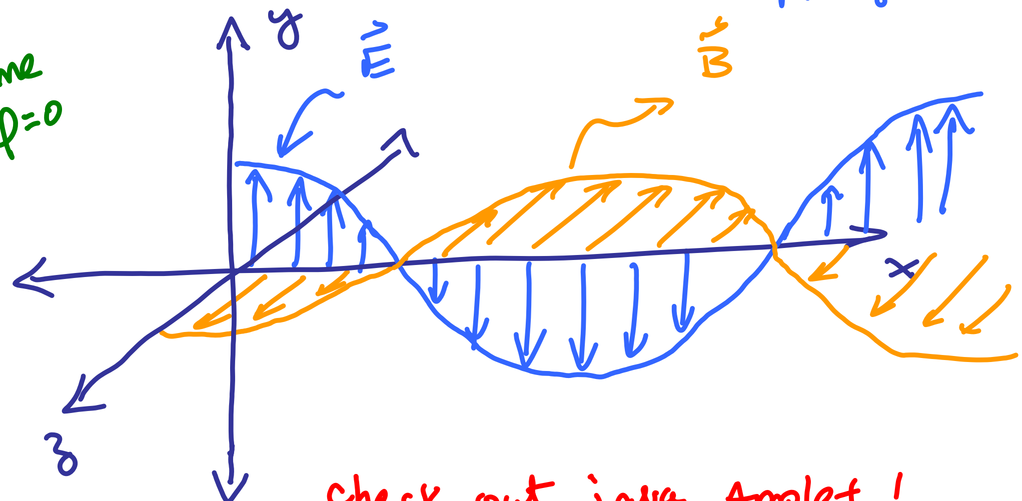
$$E_y(x,t) = E_{0y}\cos(kx - \omega t + \phi)$$

$\frac{2\pi}{\lambda}$ $\frac{2\pi}{T}$ Phase (initial condition)

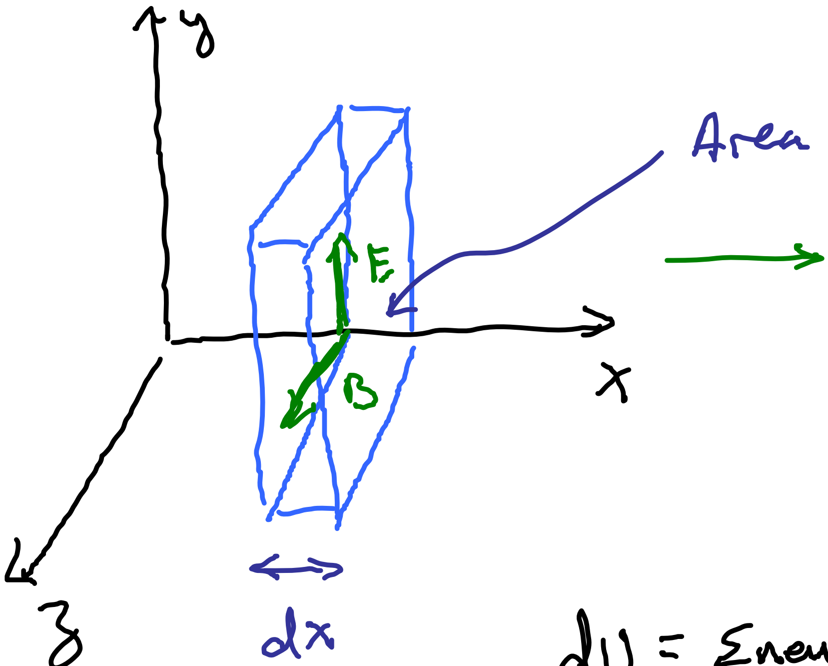
$$B_z = \frac{k}{\omega} E_{0y}\cos(kx - \omega t + \phi)$$

Freeze time

Assume $\phi = 0$



Check out java Applet!



plane wave

$$u_E = \frac{\epsilon_0}{2} E^2 \qquad u_B = \frac{1}{2\mu_0} B^2$$

$$dU = \underset{\text{Box}}{\text{Energy in}} = (u_E + u_B)(\text{Volume box})$$

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

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

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

du in energy moves $\frac{dx}{c}$ in dt

$$du = \left[\frac{1}{\mu_0 c} EB\right] \text{Area}\ dx$$

$$\underbrace{\frac{du}{dt}}_{\text{Power}} \frac{1}{\text{Area}} = \frac{1}{\mu_0 c} EB \underbrace{\frac{dx}{dt}}_{c}$$

$$\text{Power}/\text{Area} \equiv \text{intensity} = \frac{EB}{\mu_0} = \text{Watts}/m^2$$

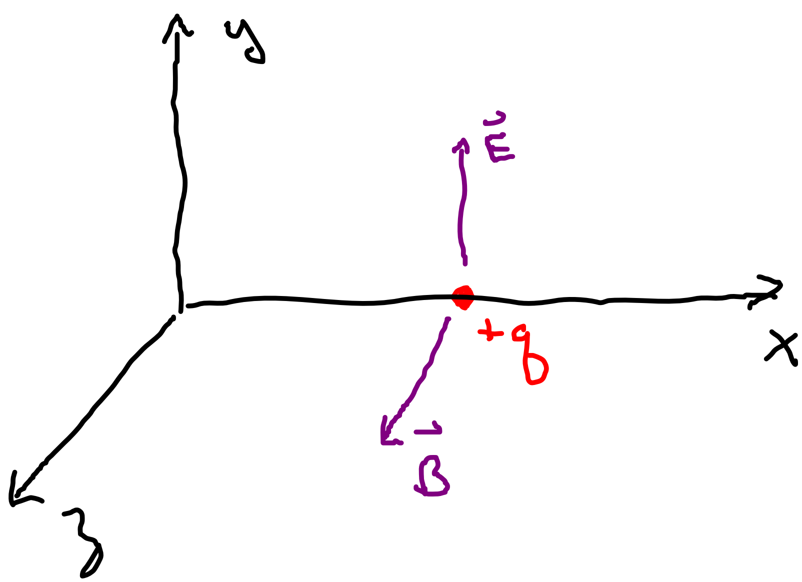
Energy Flux

$$\text{Energy flow vector} \simeq \text{Poynting vector} \equiv \boxed{\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}}$$

$|\vec{S}|$ varies w/ time

$$\left.\begin{aligned} E &= E_0 \sin \omega t \\ B &= \frac{E_0}{c} \sin \omega t \end{aligned}\right\} \longrightarrow S = \frac{E_0^2 \overbrace{\sin^2 \omega t}^{\text{Time Ave} = \frac{1}{2}}}{\mu_0 c}$$

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



$$F_x = \frac{dP_x}{dt} = q(\vec{V}\times\vec{B})_x = q(v_y B_z - \underbrace{v_z}_{0} B_y)$$

$$\frac{dP_x}{dt} = q\,V_y B_z = \frac{q}{c} V_y E_y$$

made use of $B_z = E_y/c$

$$W \sim F \cdot d \sim qE \cdot \frac{d}{t}\, t$$

$$\frac{dW}{dt} = q\,\vec{E} \cdot \vec{V} = q\, V_y E_y$$

$$F_x = \frac{dP_x}{dt} = \frac{1}{c}\frac{dW}{dt} \qquad dP_x = \frac{1}{c}\, dW$$

Energy

Momentum

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

Momentum of EM wave

Let EM wave be Absorbed

$$\vec{F} = \frac{d\vec{p}}{dt} = \frac{dU}{dt}\frac{1}{c} = \frac{1}{c}\,\frac{\frac{\text{Energy}}{\text{Area}}}{\text{time}}\ \text{Area}$$

$$|\vec{F}| = \frac{1}{c} S \ \text{Area}$$

Fully Absorbing.

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

radiation pressure

Fully reflecting

$$\boxed{\frac{F}{\text{Area}} = \text{Pressure} = \frac{2S}{c}}$$

$$\langle \text{pressure} \rangle = \frac{\langle S \rangle}{c}$$

absorption