Physics 142 – November 18, 2010

- Presentations

  2 groups each of
  Dec 2
  Dec 7
  Dec 9

  Send me ordered list of date preference

Last Time —

Maxwell's eqns plus vector calc Identities

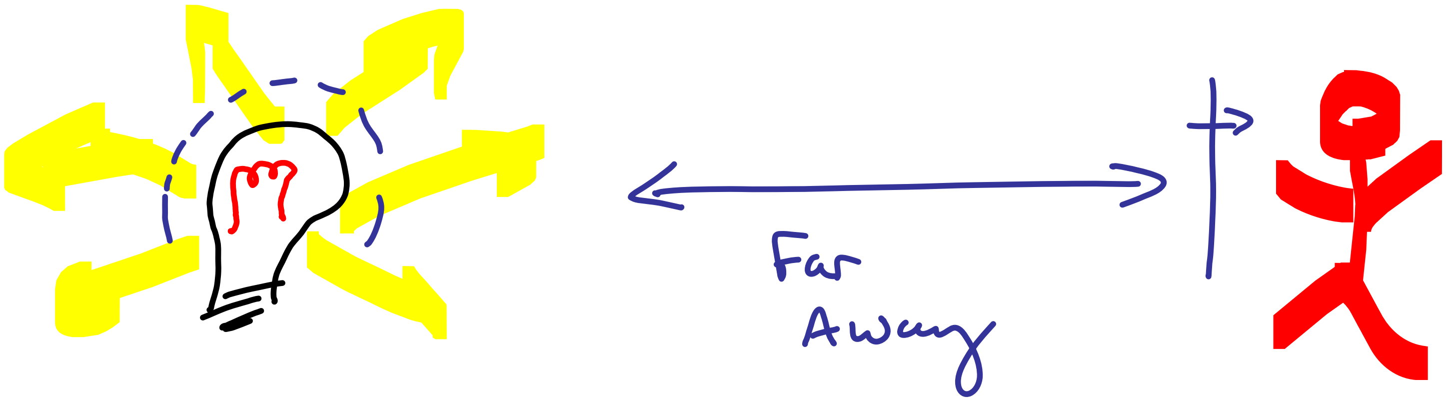
$$\nabla^2 \vec{B} = -\mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$

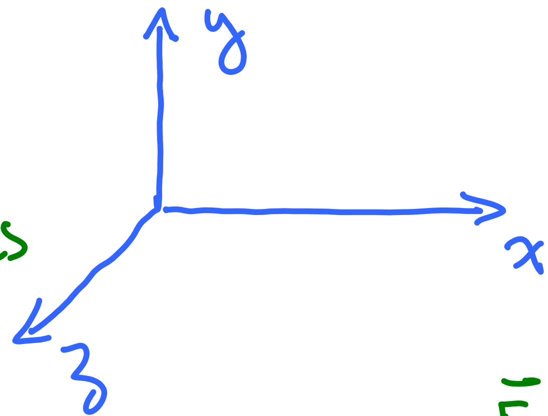
$$\nabla^2 \vec{E} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}$$

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

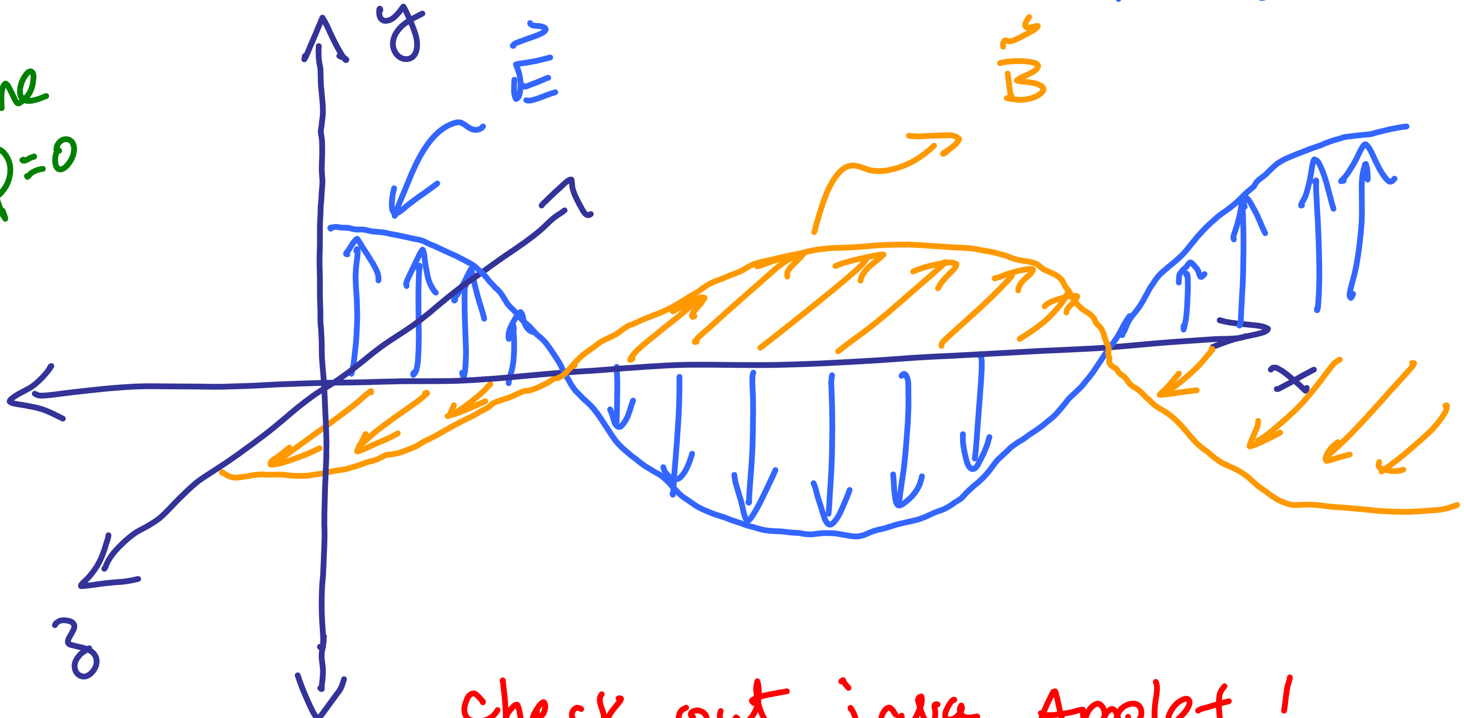
$$E_y(x,t) = E_{0y}\cos(kx - \omega t + \phi)$$

$k = \dfrac{2\pi}{\lambda}$ $\qquad$ $\omega = \dfrac{2\pi}{T}$ $\qquad$ ϕ: Phase (initial condition)

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

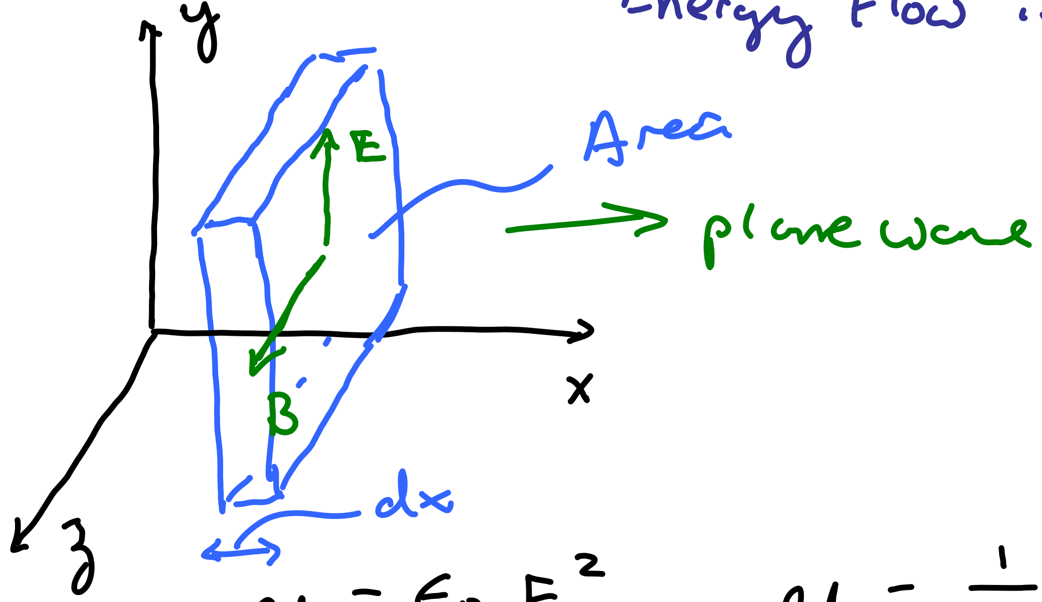
Freez time

Assume $\phi = 0$



Check out java Applet!

Energy flow in EM waves



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

dU = energy in box = $(u_E + u_B)$(volume box)

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

$E = cB$

$$\epsilon_0 = \frac{1}{\mu_0 c^2}$$

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

$$dU = \left[\frac{1}{2\mu_0 c^2} E c B + \frac{1}{2\mu_0} B \frac{E}{c}\right] (\text{Area})\, dx$$

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

$$dU = \left[\frac{1}{\mu_0 c} E B\right] \text{Area}\, dx$$

$$\underbrace{\frac{dU}{dt}}_{\text{power}} \frac{1}{\text{Area}} = \frac{1}{\mu_0 c} E B \overbrace{\frac{dx}{dt}}^{c}$$

$$\underbrace{\frac{dU}{dt}\frac{1}{\text{Area}}}_{\text{Intensity}} = \frac{EB}{\mu_0} = \frac{\text{Watts}}{m^2}$$

Energy flux

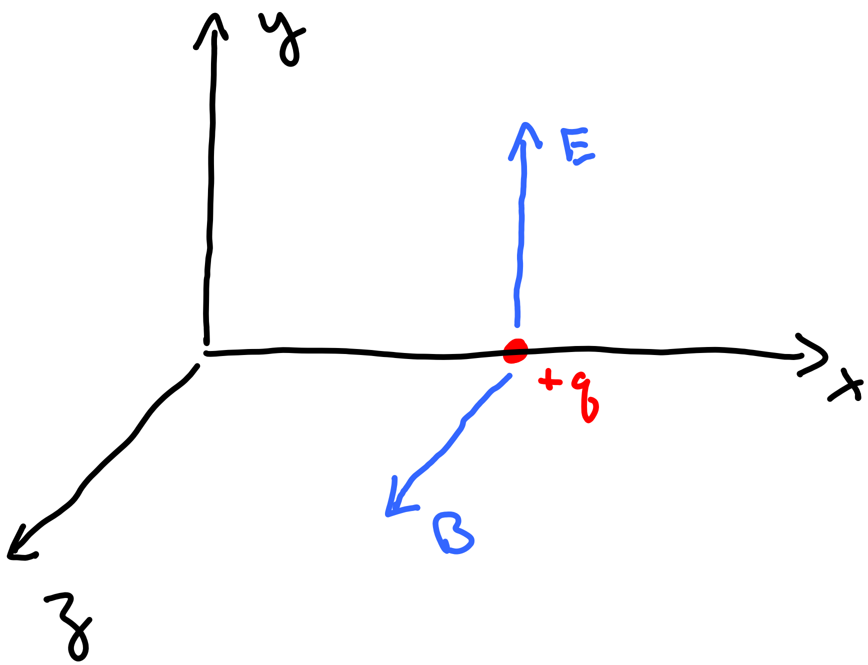
$$\boxed{\text{Poynting vector} \equiv \vec{S} \equiv \frac{\vec{E} \times \vec{B}}{\mu_0}}$$

E, B vary w/ time

$|\vec{S}|$ varies

$$\left.\begin{aligned} E &= E_0 \sin \omega t \\ B &= \frac{E_0}{c} \sin \omega t \end{aligned}\right\} \Rightarrow S = \frac{E_0^2 \sin^2 \omega t}{\mu_0 c}$$

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



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

$$\frac{dP_x}{dt} = q v_y B_z = \frac{q}{c} v_y E_y \qquad B_z = \frac{E_y}{c}$$

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

$$\sim v$$

$$\frac{dW}{dt} = q\vec{E}\cdot\vec{v} = q\,v_y E_y$$

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

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

EM Wave is Absorbed

$$\vec{F} = \frac{d\vec{p}}{dt} = \frac{dU}{dt}\frac{1}{c} = \frac{1}{c}\overbrace{\frac{\text{Energy}/\text{Area}}{\text{time}}}^{\text{Poynting vector}}\,\text{Area}$$

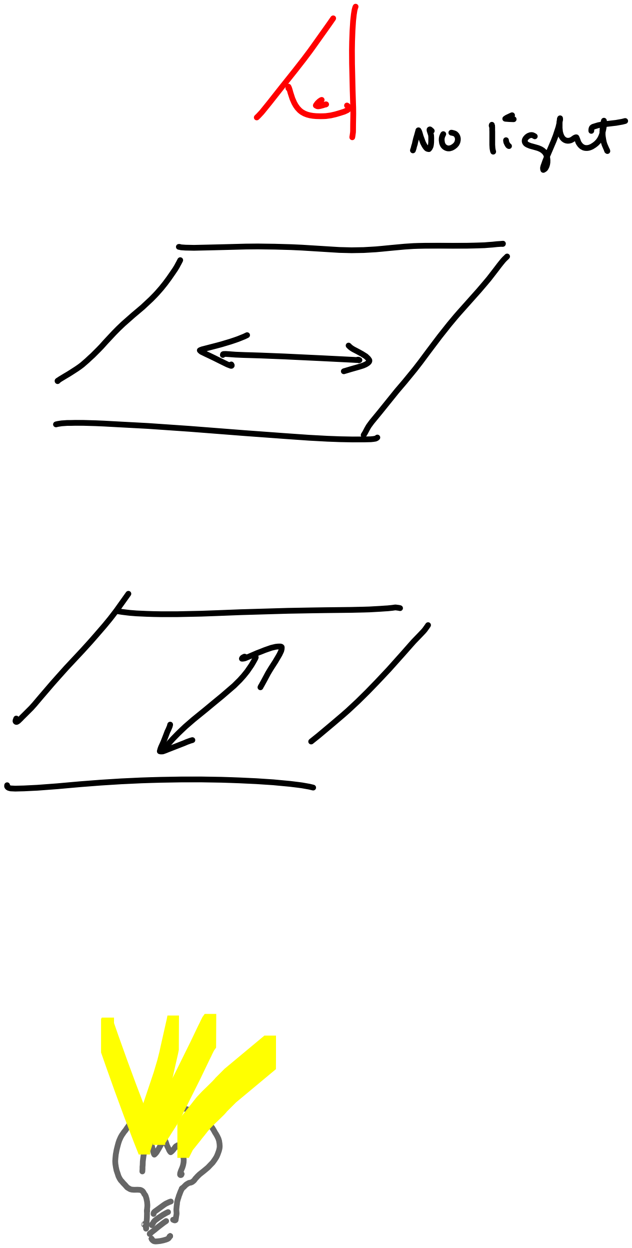
$$F = \frac{1}{c} S \,\text{Area}$$

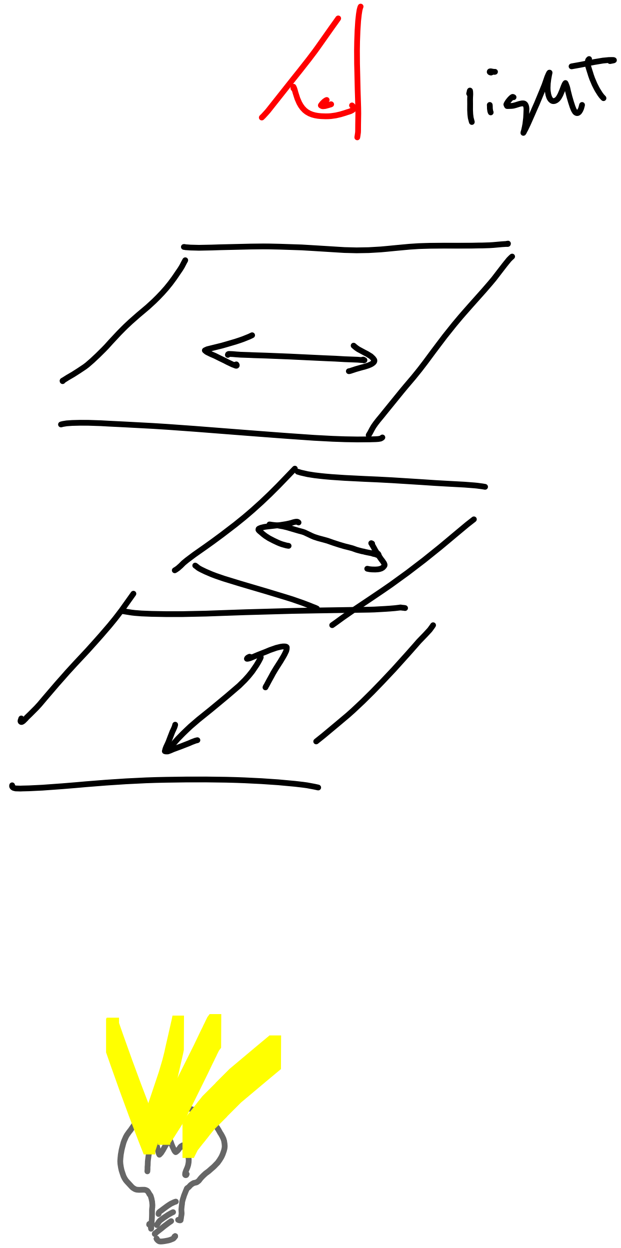
$$\boxed{\frac{F}{\text{Area}} = \text{Pressure} = \frac{S}{c}}$$

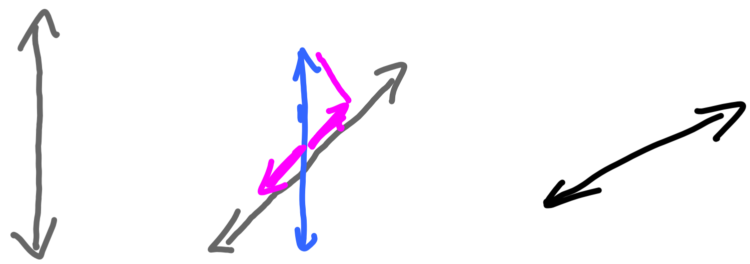
radiation pressure

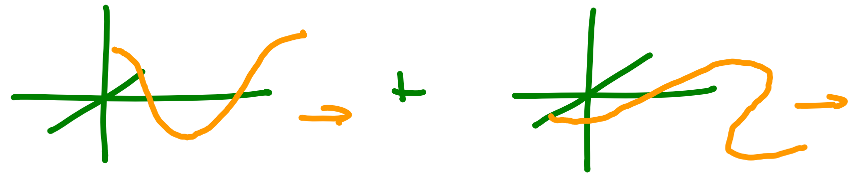
x 2 if wave is reflected

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


No light


light



General Soln → 

Superposition of two orthogonal waves

(Form a basis)

1 - plane polarized y Axis $\bar{E}$ along y

1 - plane polarized z axis $\vec{E}$ along z