# Physics 114 - April 6, 2006

Poster Session Tomorrow — Hirst Lounge 3-5

Any grp need a Member?

April 13 in class

- 2 Optics
- 7 Beer run
- 16 Aurora
- 18 Diamonds
- 19 come-on lines

Does this work for you?

Test AV + come wT Backup

April 20 in class

- 1 van de Graff
- 10 Morning
- 12 Atom
- 17 Guitar
- 23 Bill Nye + Phy Ass

7 minute Time limit

# Maxwell's Equations

**Integral Form**

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

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

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

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

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

**Differential Form**

we will not use in this class

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

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

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

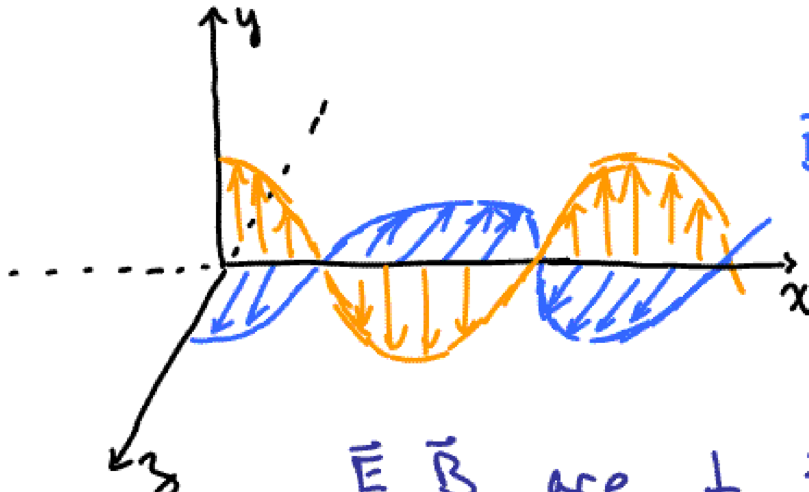
$$\vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$

Vector Calculus Magic

very far Away

Solve Maxwell's eqns

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




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

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

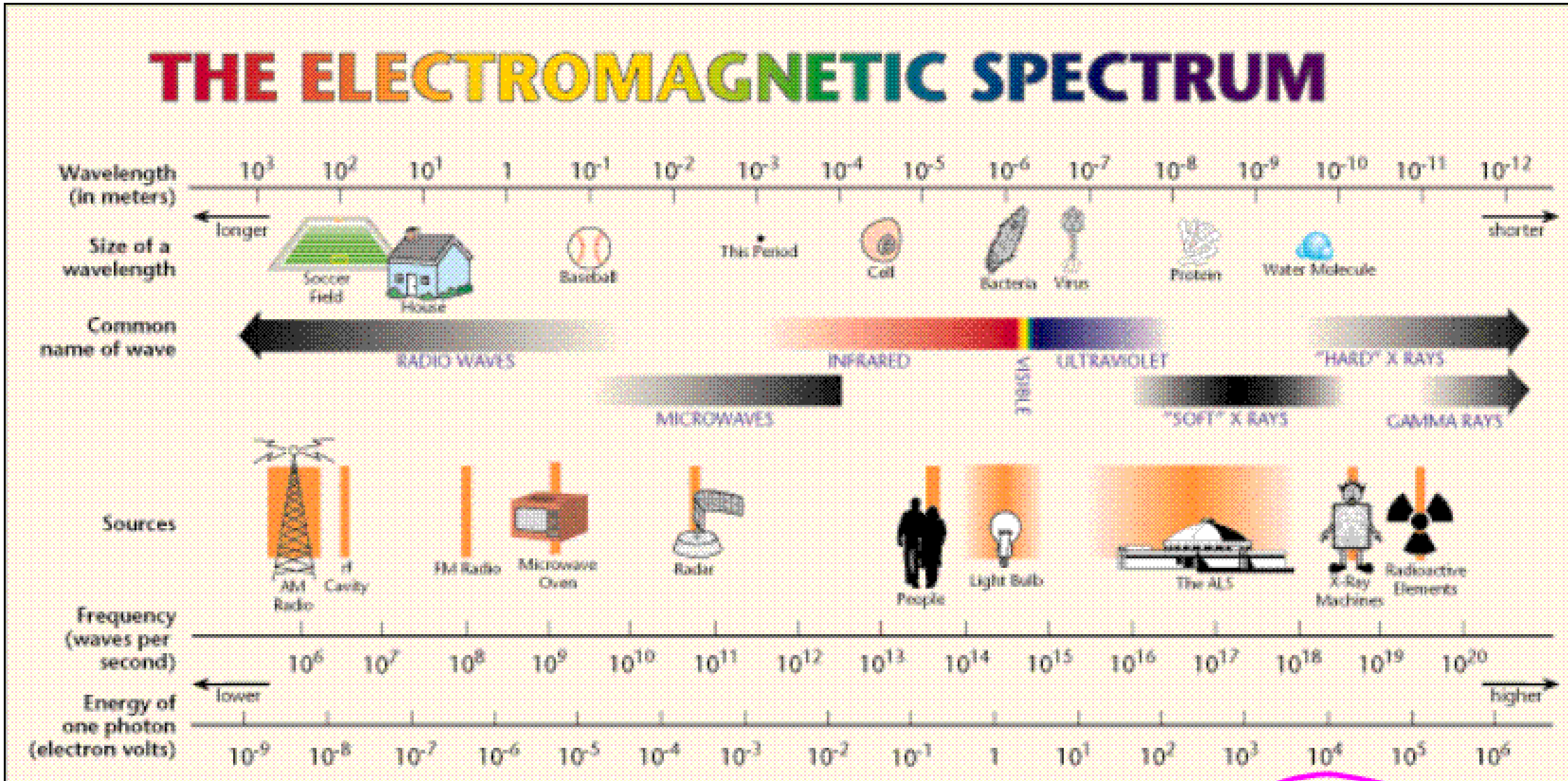
$\vec{E}$, $\vec{B}$ are $\perp$ to one another

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

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

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

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




$$\frac{\lambda}{T} = \lambda \nu = c$$

Energy flow of EM wave

Poynting vector $= \vec{S} = \dfrac{\vec{E} \times \vec{B}}{\mu_0}$ ← E/Time/Area

$|\vec{S}|$ = Intensity in WATTS$/m^2$

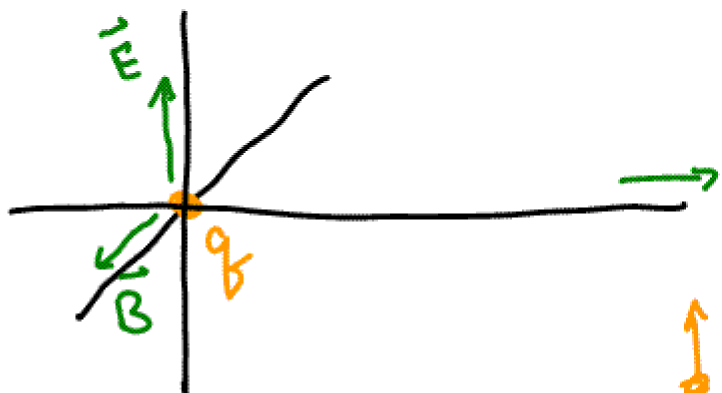
Time Average of $S \equiv \bar{S} \equiv \langle S \rangle$

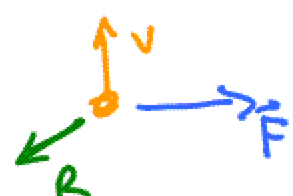
$$E = E_0 \sin \omega t$$

$$B = \frac{E_0}{c} \sin \omega t \qquad B_0 = E_0/c$$

$$S = \frac{1}{\mu_0 c} E_0^2 \sin^2 \omega t$$

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




EM waves can exert a force

$$F \sim \frac{dp}{dt} \sim qvB \sim qv\frac{E}{c} \sim \frac{1}{c}\frac{d(\text{work})}{dt}$$

$$\frac{d(\text{work})}{dt} \sim \frac{qE\,dx}{dt} = qEv$$

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

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

U — Energy

Momentum in EM wave

Em wave → Total Absorption

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

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

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

Total Reflection

$$\text{Pressure} = \frac{2S}{c}$$

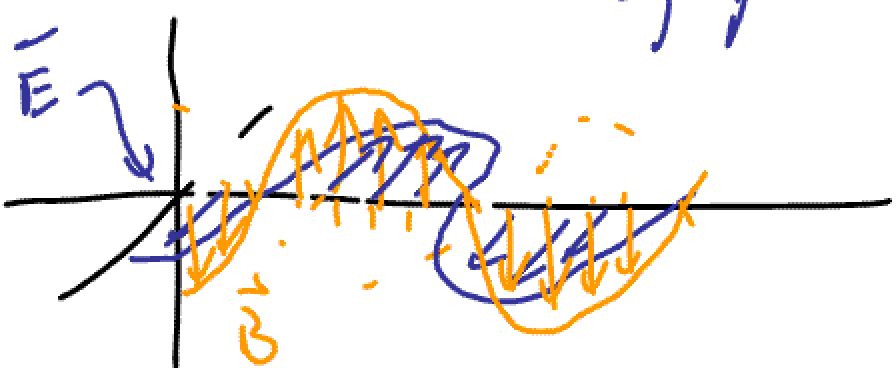
$$\langle P \rangle = \frac{\langle S \rangle}{c} \qquad \langle p \rangle = \frac{2\langle s \rangle}{c}$$

# Polarization Crap


Polarization of light

→ direction of $\vec{E}$ vector

→ linearly polarized light



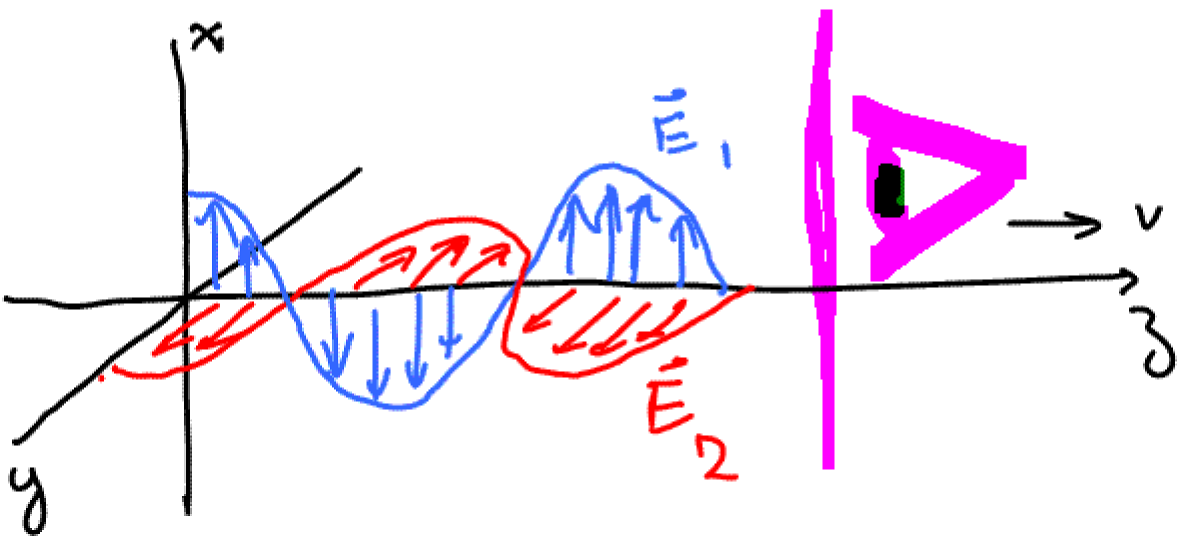

Gen. Soln
Max. Eqns
2 $^{nd}$ Soln

General Soln → 2 orthogonal waves

basis

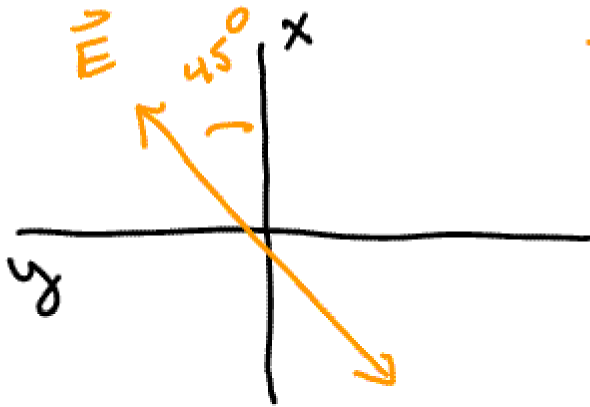
1 – plane polarized along x-axis

2 – " " " y-axis




$$\vec{E}_1 = E_{0x} \cos(kx - \omega t)\ \hat{x}$$

$$\vec{E}_2 = E_{0x} \cos(kx - \omega t)\ \hat{y}$$



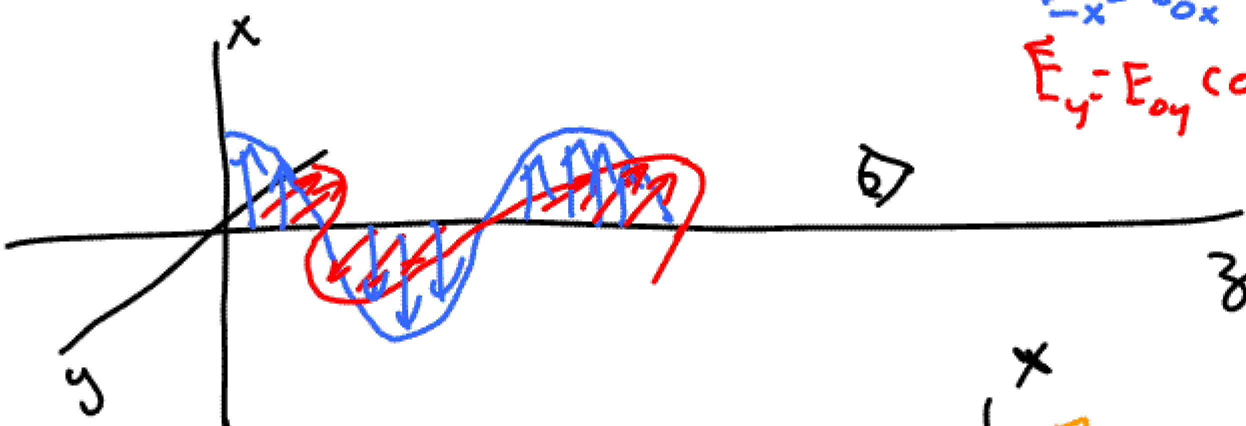

what you see

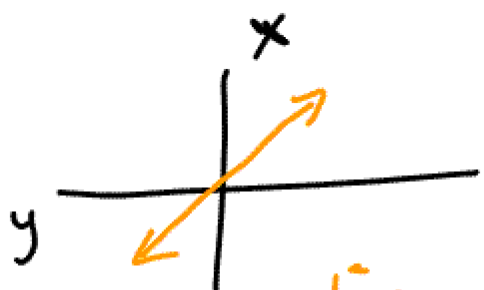
linear polarization

$\vec{E}_x = E_{0x}\cos(kx-\omega t)\hat{x}$

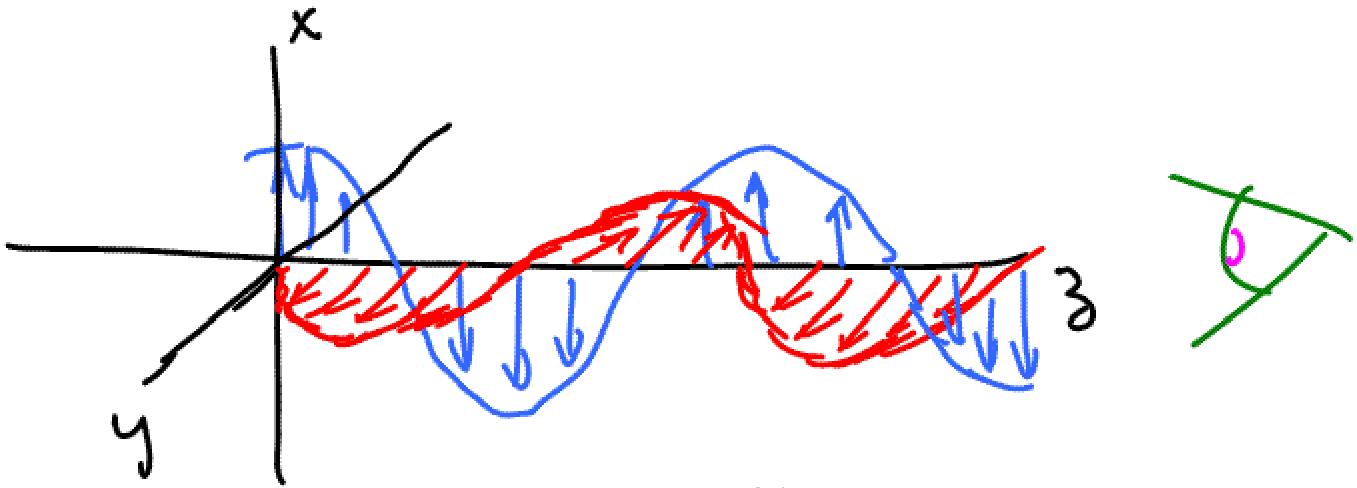
$\vec{E}_y = E_{0y}\cos(kx-\omega t+\pi)\hat{y}$

$\phi$

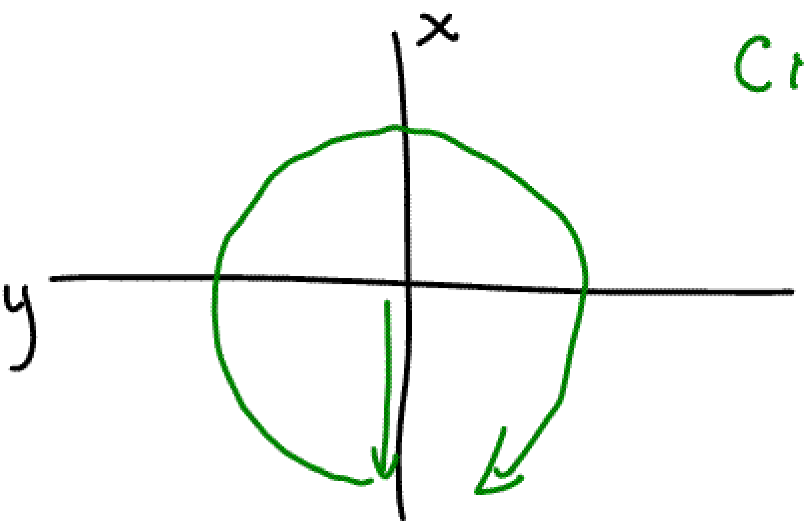



linear polarization again




## Circular polarization




Clockwise $\vec{E}$ rotation as wave travels toward you

Right handed circular pol.