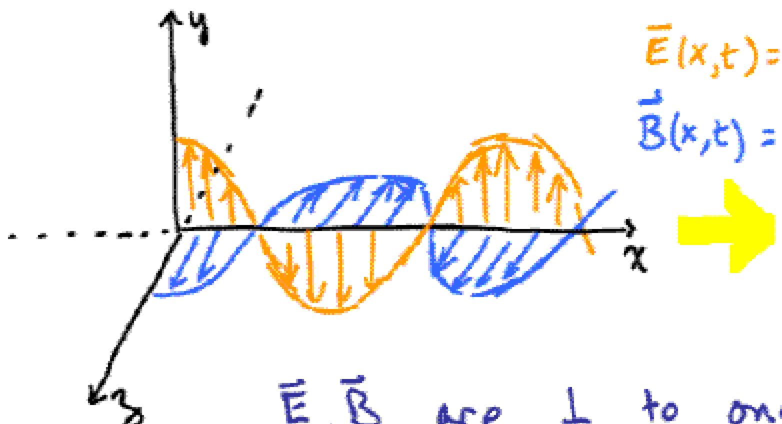
Physics 114 - April 1, 2010

Last Time

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

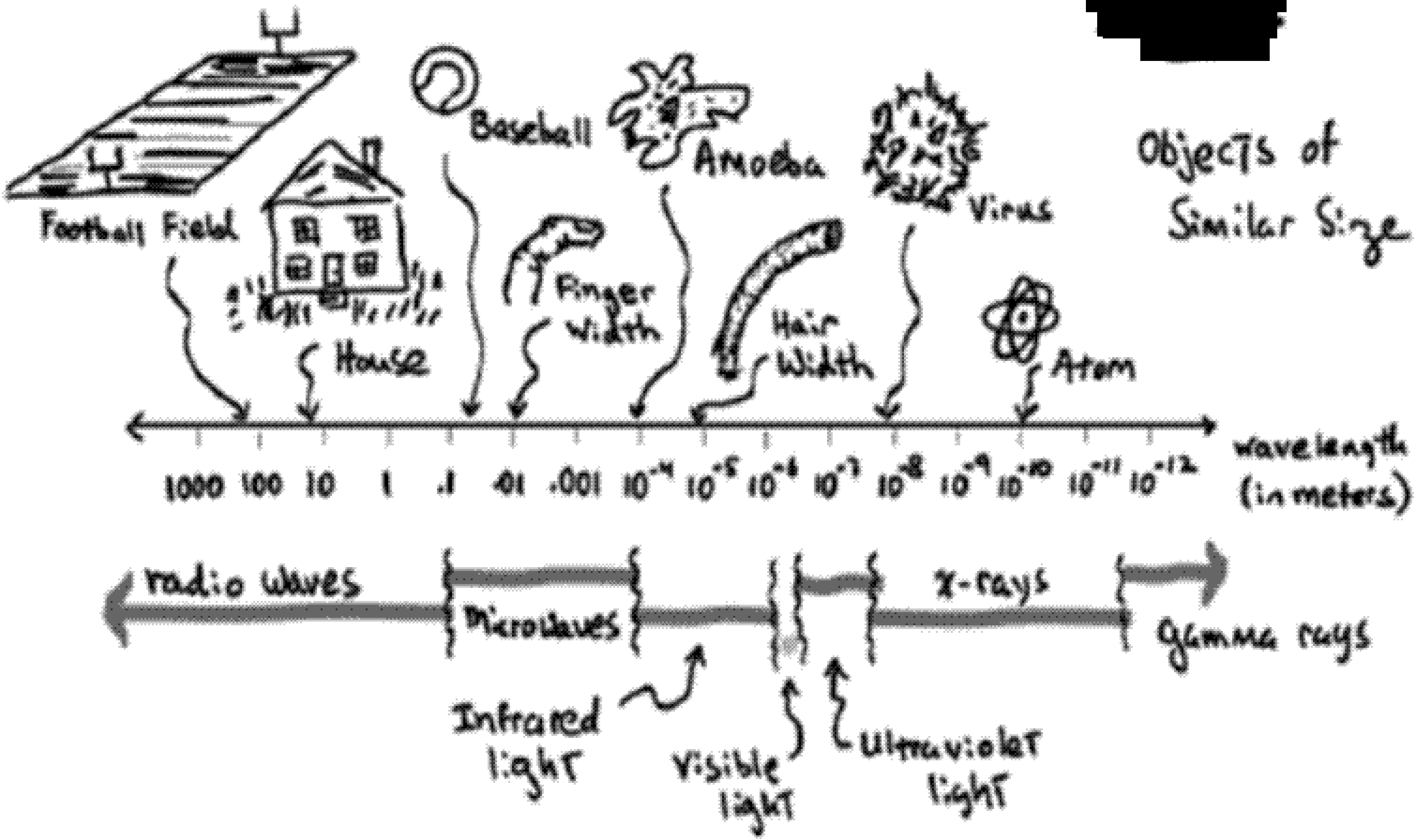
$|\vec{B}| = |\vec{E}|/c$

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

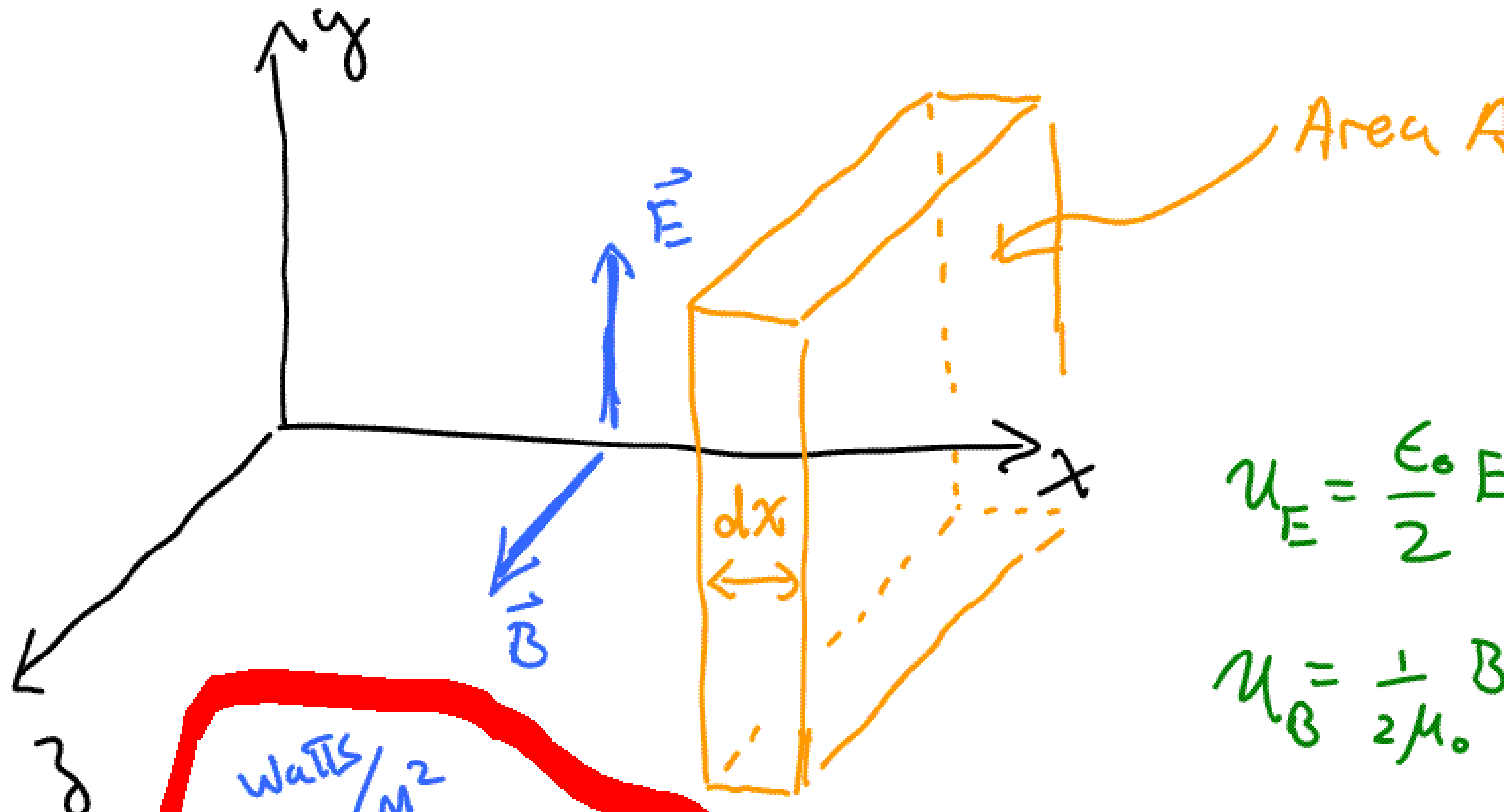
speed of propagation $\rightarrow c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$

The variety of electromagnetic waves

[redacted]



Energy flow for electromagnetic Plane waves



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

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

Watts/m^2

$$\boxed{\frac{\text{Power}}{\text{Area}} = \text{Instantaneous Intensity of EM wave} = \frac{EB}{\mu_0}}$$

$$\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$$ Vector describing Energy flow

= Poynting vector

$$|\vec{S}| \equiv \text{Intensity}$$

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

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

makes use of

$E \sim E_0 \sin\omega t \qquad B \sim B_0 \sin\omega t$

$B_0 = E_0/c$

Momentum carried by EM wave $\equiv p = \dfrac{U}{c} \equiv \dfrac{(\text{Energy})}{c}$

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

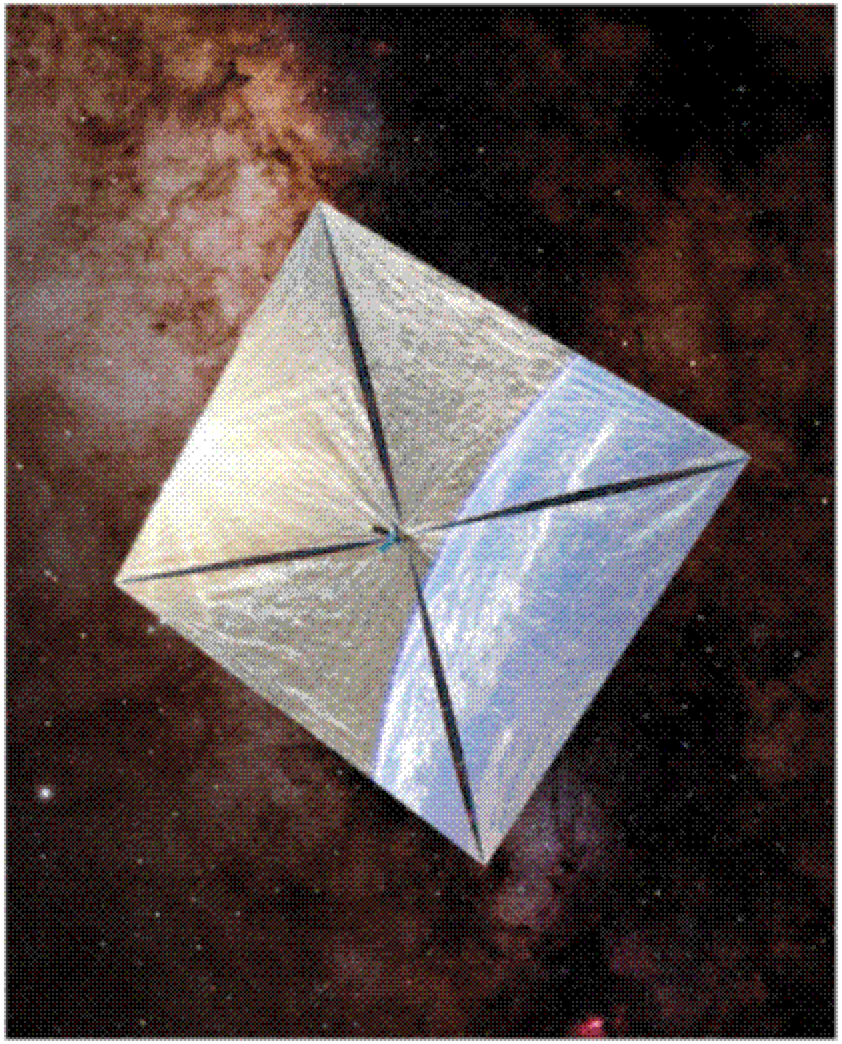
Force EM wave exerts if <u>Completely</u> <u>Absorbed</u>

Pressure exerted by Fully absorbed EM wave $= \dfrac{\text{Force}}{\text{Area}} = \dfrac{S}{c}$

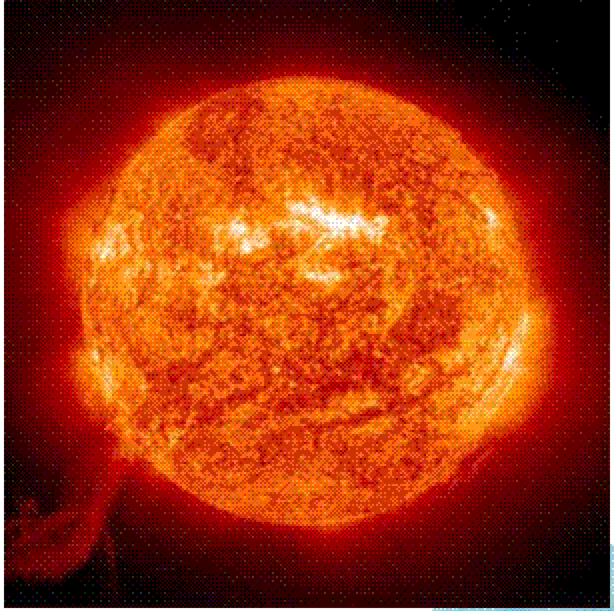
Radiation Pressure

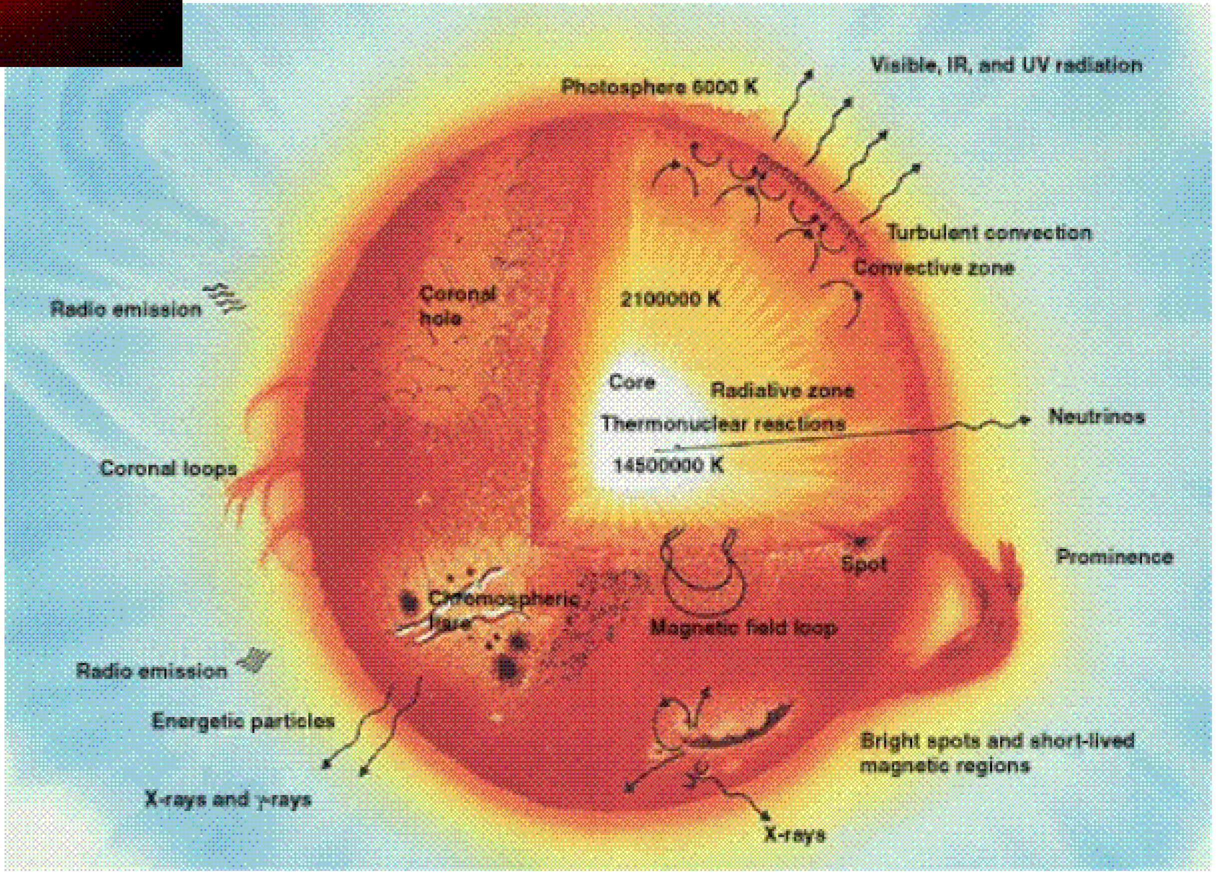
What happens if EM wave Totally Reflected ?

Rad pressure $= \frac{2S}{c}$



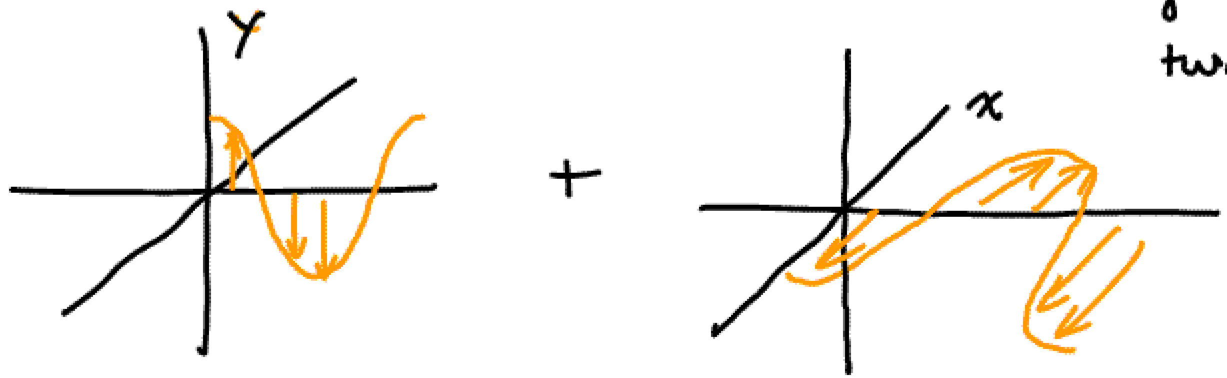
Artist's conception of light sail 1 spacecraft



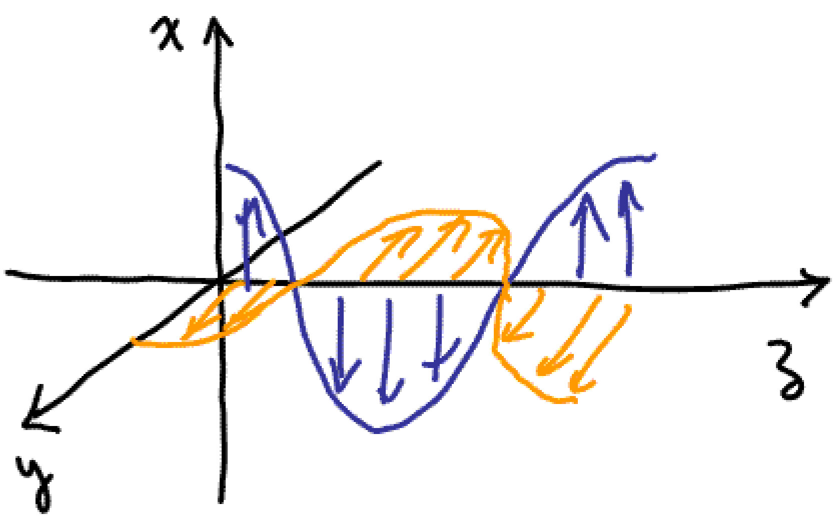

Visible, IR, and UV radiation
Photosphere 6000 K
Turbulent convection
Convective zone
Radio emission
Coronal hole
2100000 K
Core
Radiative zone
Thermonuclear reactions
Neutrinos
14500000 K
Coronal loops
Prominence
Spot
Chromospheric flare
Magnetic field loop
Radio emission
Energetic particles
Bright spots and short-lived magnetic regions
X-rays and γ-rays
X-rays

$\vec{E}$ only

look at two orthogonal solutions of plane wave ... look at only $\vec{E}$ for the two "orthogonal" solutions.

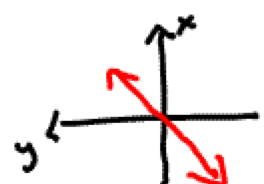


"Basis" of wave solns

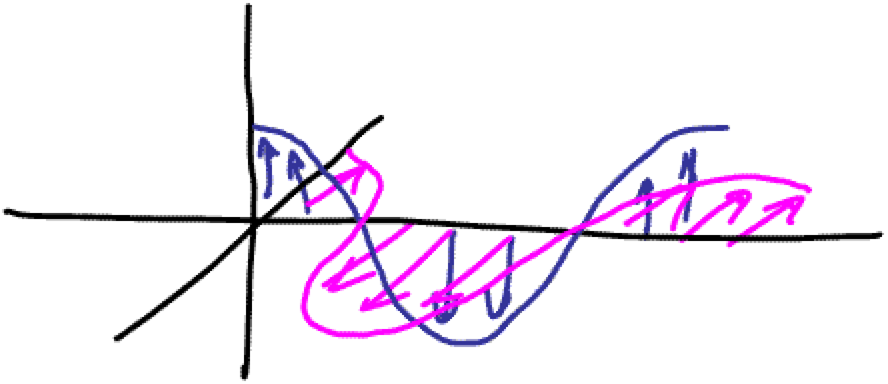


1 $\vec{E}$ plane polarized along y

1 $\vec{E}$ plane polarized along x

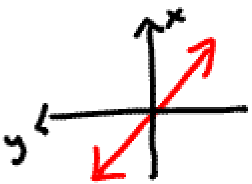


linear polarization

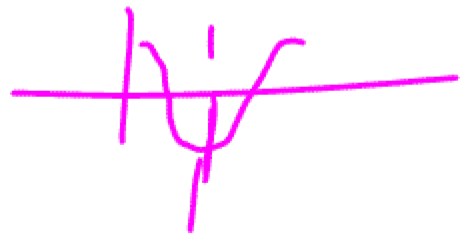


$$E_x = E_{ox}\cos(kx-\omega t)$$

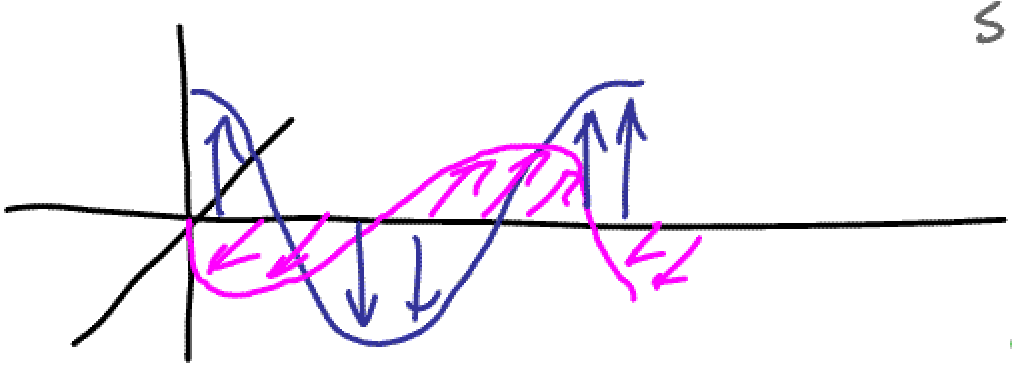
$$E_y = E_{ox}\cos(kx-\omega t+\pi)$$

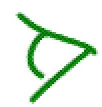


linear polarization



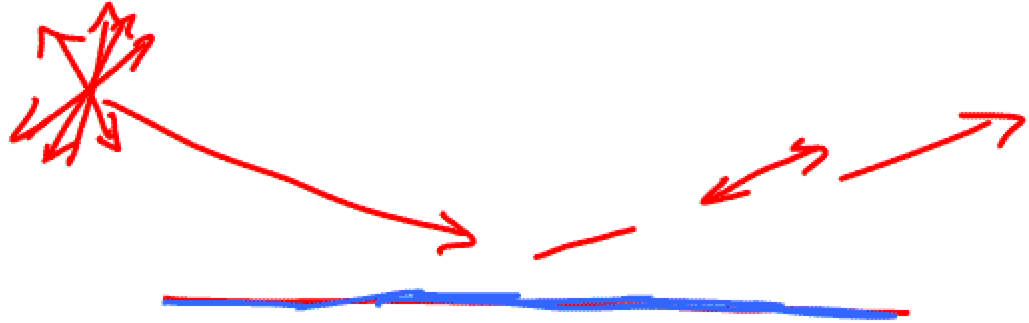
Shift by $\pi/2$

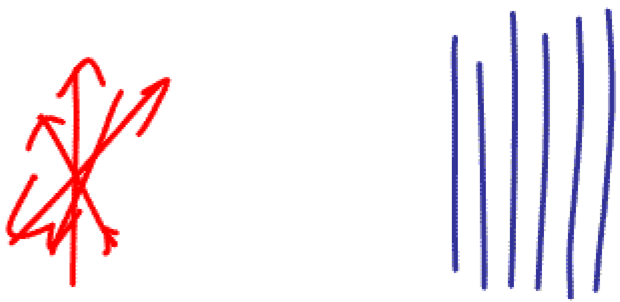




circular polarization

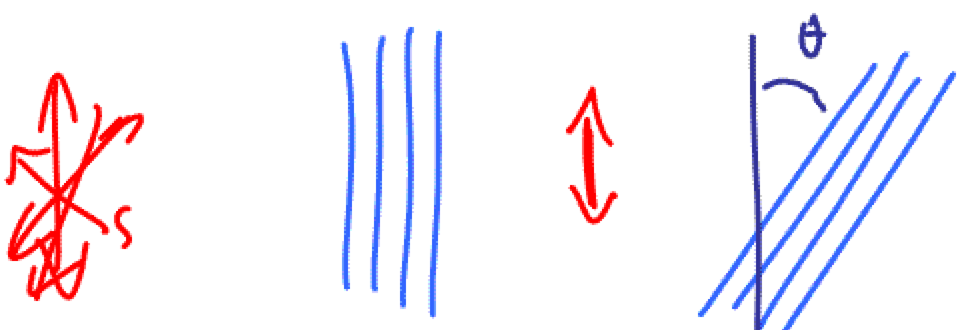
See EM Wave Polarization java applet on class website





I_0

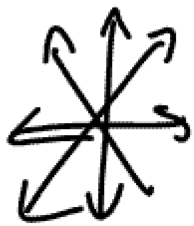
$\frac{1}{2}I$

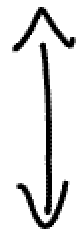


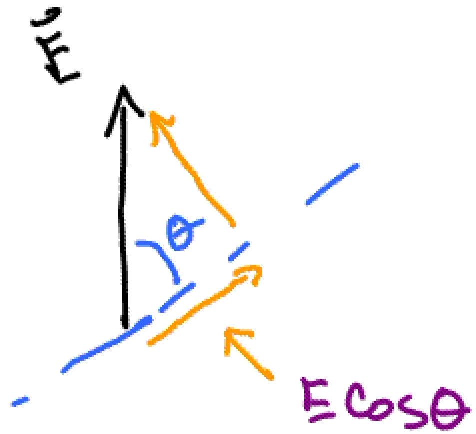
I_0

$\frac{1}{2}I_0$

$\frac{1}{2}I_0\cos^2\theta$







$$I \sim E^2\cos^2\theta$$

end of Material for Exam 3

Geometric Optics

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

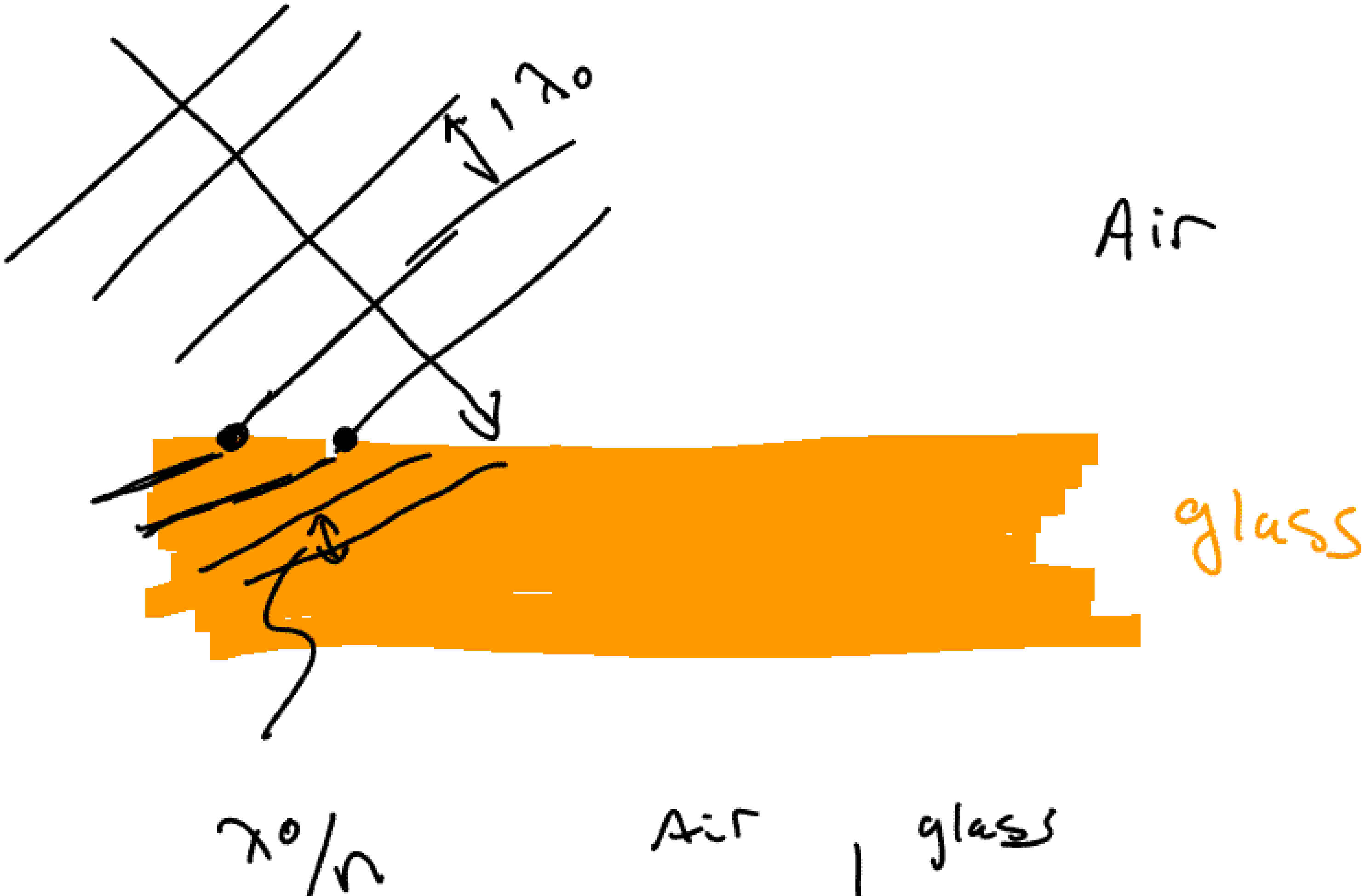
in a material $\quad V < C$

$n \equiv$ index of refraction $\qquad n > 1$

$$n \equiv \frac{c}{V_{\text{in material}}}$$

$$\lambda_0 \nu = c \qquad\qquad \lambda \nu = v = \frac{c}{n}$$

$$\lambda n = \frac{c}{\nu} = \lambda_0$$



Refraction:

bending of wave
at interface
between two Materials