Physics 123 - March 4, 2013

- Exam I - hope to have graded + returned Wed.
- If your grades show up on BB ... sort of meaningless until you see the distribution/mean

Last Time

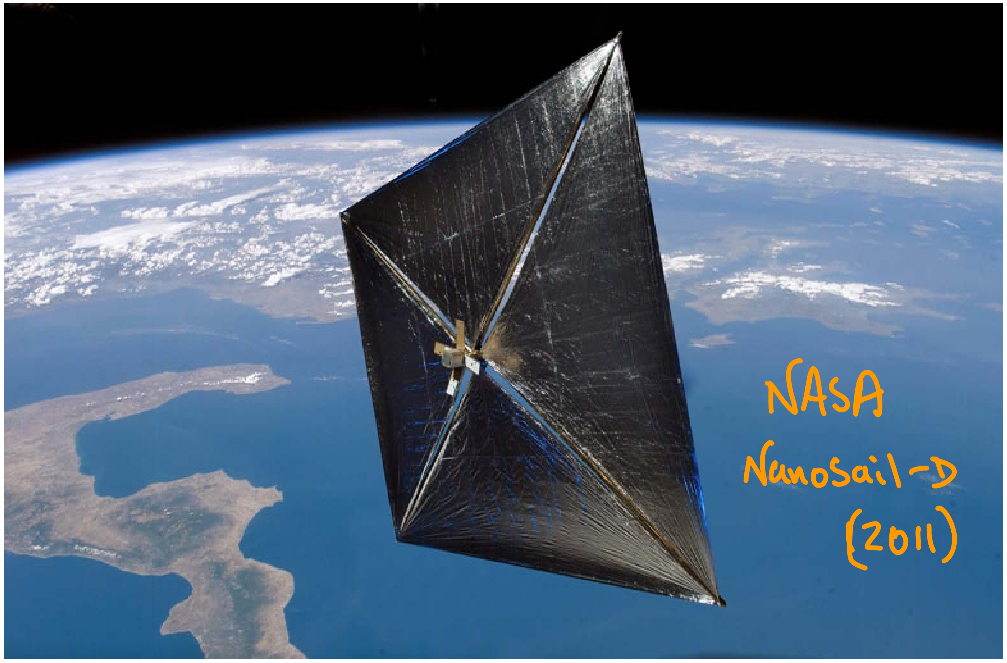
Energy flow in EM waves

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

Energy flux

$$\bar{S} = \langle s \rangle \equiv \text{Average intensity} = \frac{E_0^2}{2\mu_0 c} = \frac{cB_0^2}{2\mu_0} = \frac{E_0 B_0}{2\mu_0}$$

Watts/m^2



Radiation Pressure

$$\frac{F}{\text{area}} = \text{Pressure} = \frac{S}{c}$$

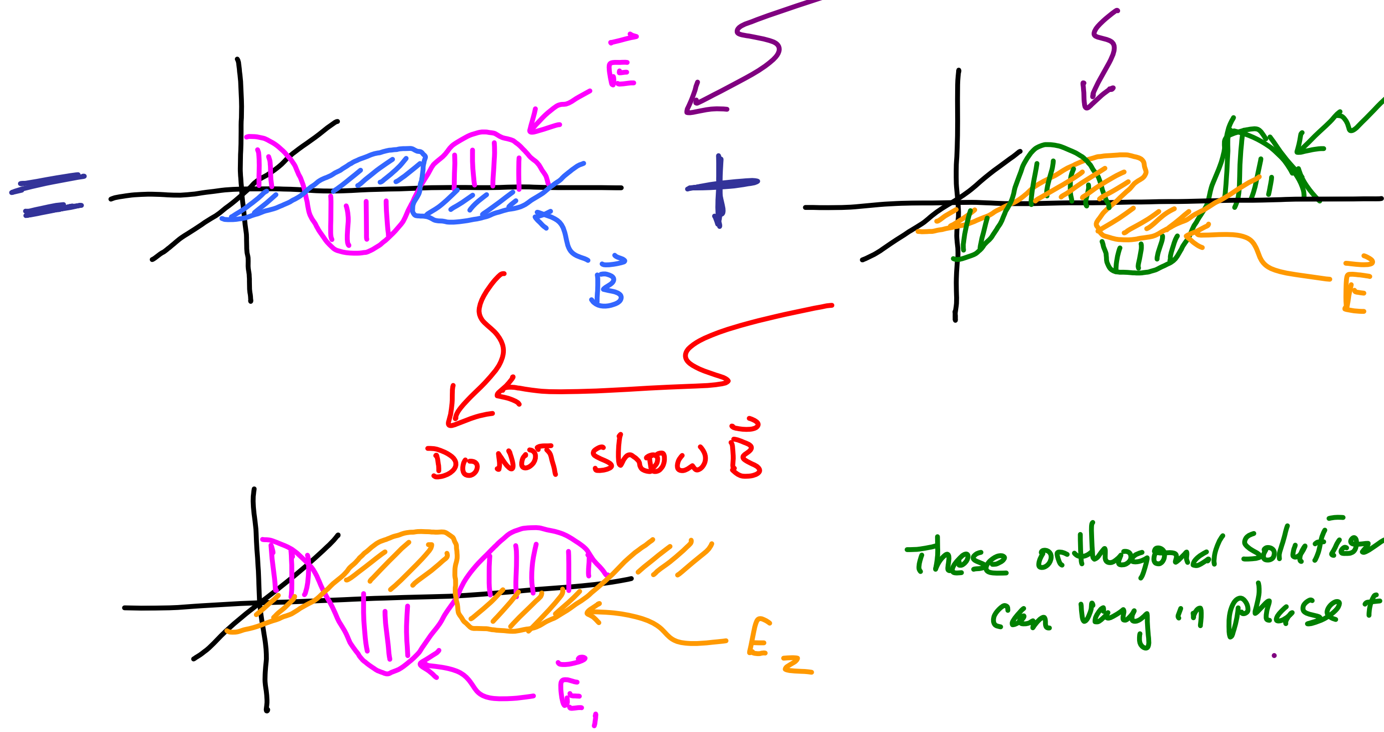
$$\langle \text{Pressure} \rangle = \frac{\langle S \rangle}{c}$$

$(\times 2)$ if total reflection

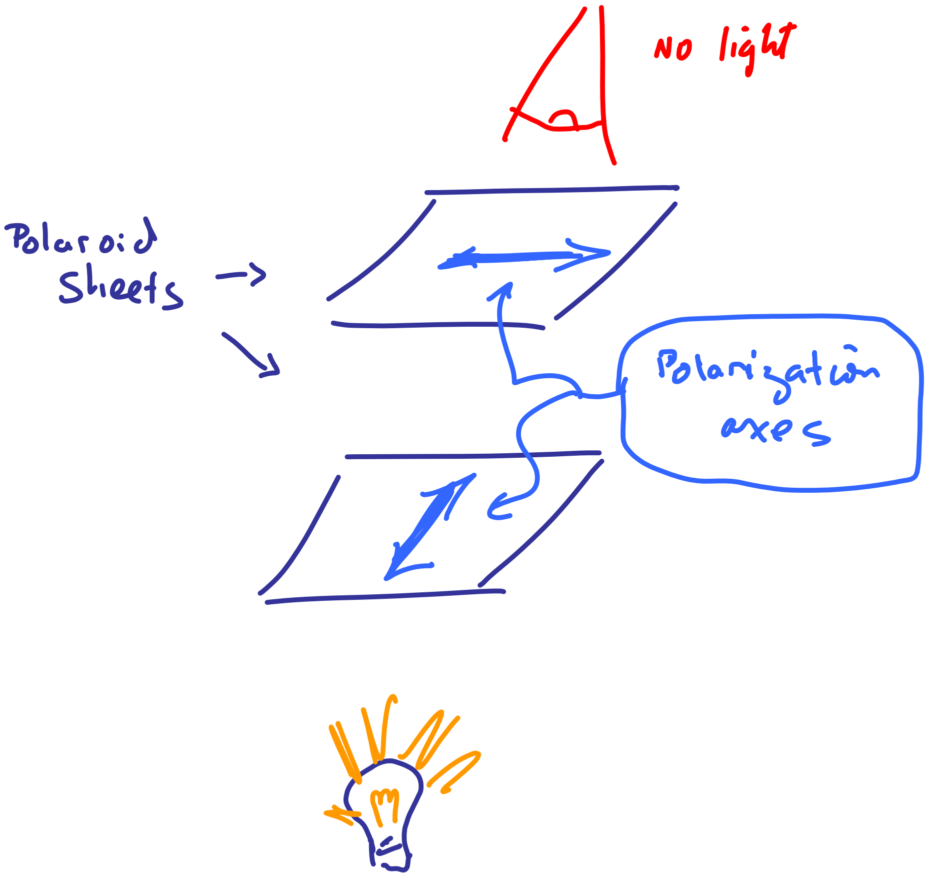
Polarization of EM waves

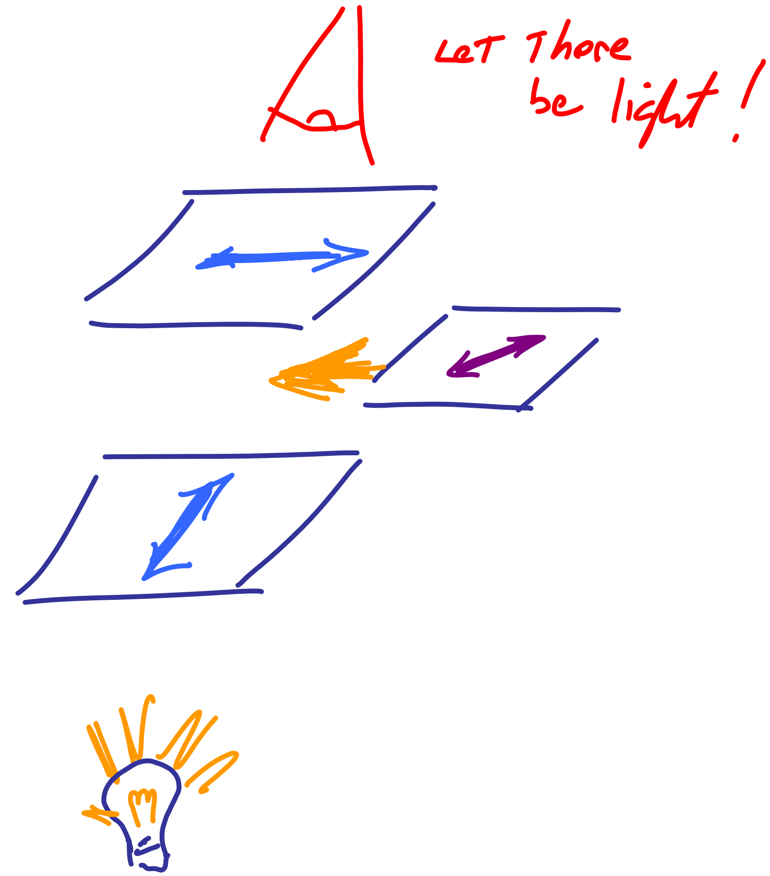
$E \perp B$, $\vec{E} \times \vec{B}$ in direction of wave
$B = E/c$, $\vec{E}, \vec{B}$ in phase

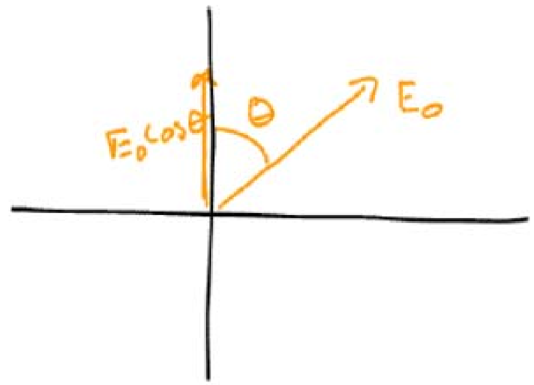
General Solution =

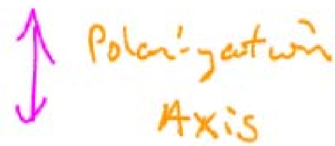


These orthogonal solutions
can vary in phase + Amplitude

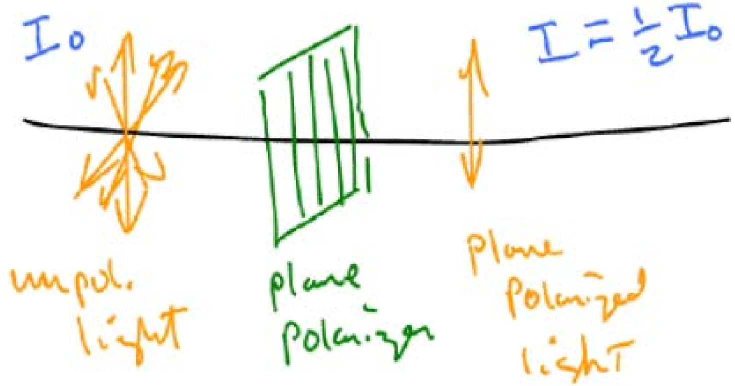

No light
Polaroid sheets
Polarization axes

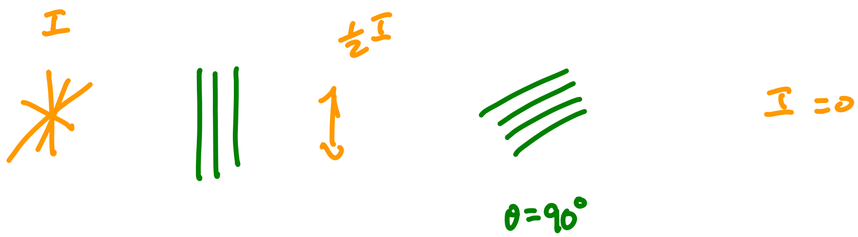

Let There be light!

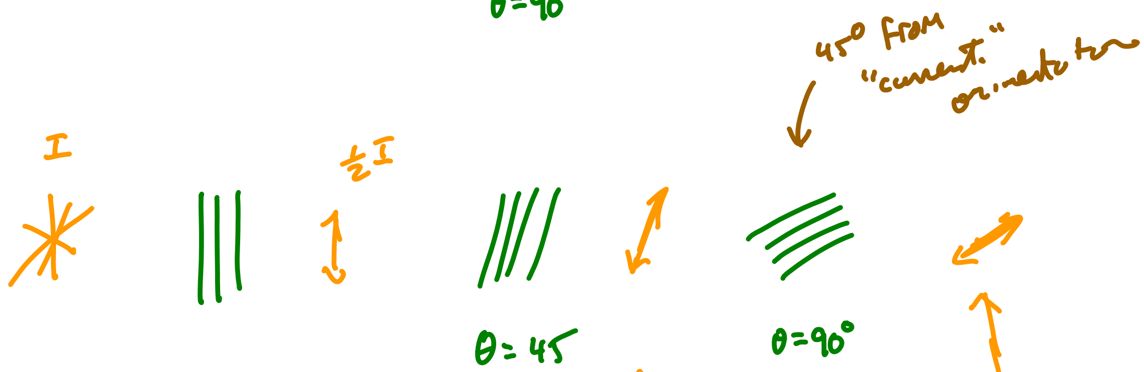




$$I_{New} \sim E_0^2 \cos^2\theta \sim I_{init} \cos^2\theta$$







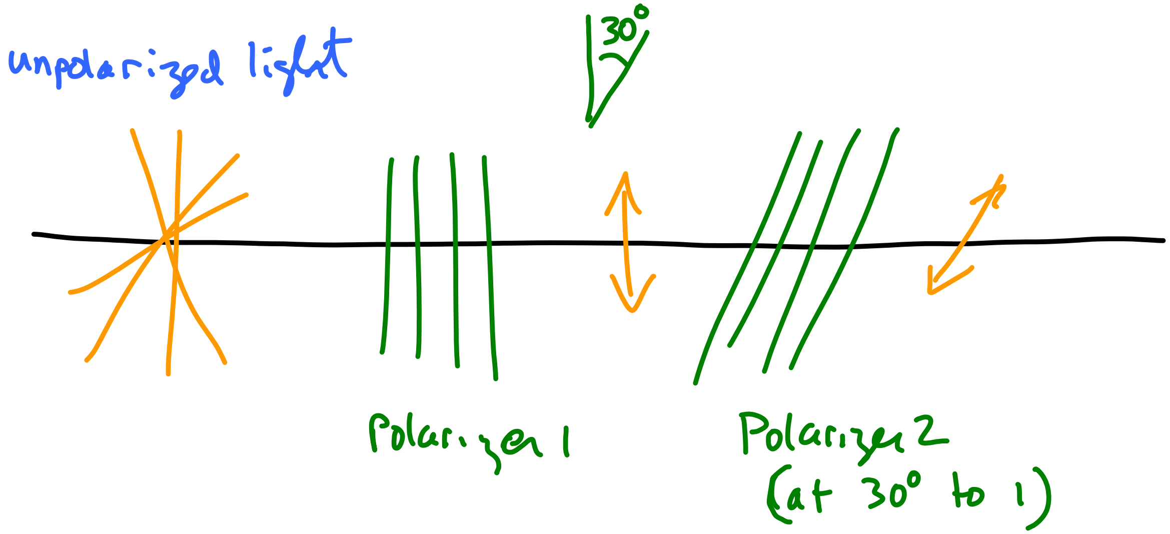
$I = (\frac{1}{2}I)\cos^2 45$

$I = [(\frac{1}{2}I)\cos^2 45]\cos^2 45$

NOT zero !

Example

Initially unpolarized light is incident on a polarizer with the polarizer axis oriented vertically. This light then passes through a second polarizer with polarizer axis oriented at 30° to the vertical. What is the intensity of the light transmitted through both polarizers relative to the intensity of the incident light?



I_0 $\qquad\qquad$ $\frac{1}{2} I_0$ $\qquad\qquad$ $\frac{1}{2} I_0 \cos^2 30$

Intensity ratio is $\dfrac{\frac{1}{2}\cos^2 30}{1} = \dfrac{I}{I_0} = 37.5\ \%$

Things change in materials:

$\epsilon_0 \equiv$ permittivity of free space → $\epsilon \equiv$ permittivity of material

$\mu_0 \equiv$ permeability of free space → $\mu \equiv$ permeability of material

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} \rightarrow v = \frac{1}{\sqrt{\epsilon \mu}}$$

$$v < c$$

$\frac{c}{v} \equiv n \equiv$ index of refraction

$n \geq 1$

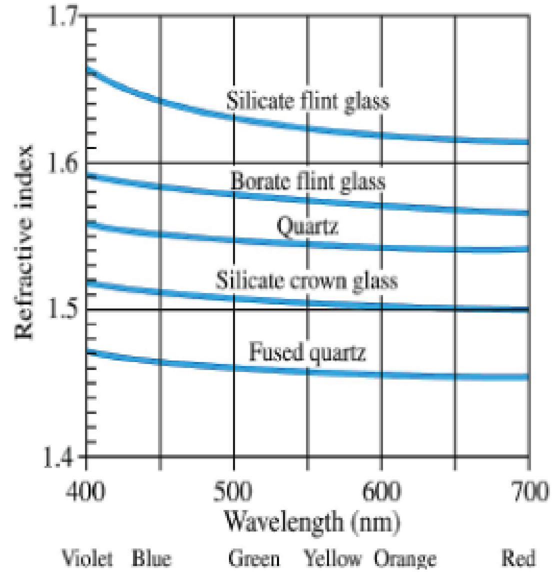
TABLE 32–1 Indices of Refraction[†]

Material	$n = \frac{c}{v}$
Vacuum	1.0000
Air (at STP)	1.0003
Water	1.33
Ethyl alcohol	1.36
Glass	
Fused quartz	1.46
Crown glass	1.52
Light flint	1.58
Lucite or Plexiglas	1.51
Sodium chloride	1.53
Diamond	2.42

[†] $\lambda = 589$ nm.

n varies w/ λ

Dispersion



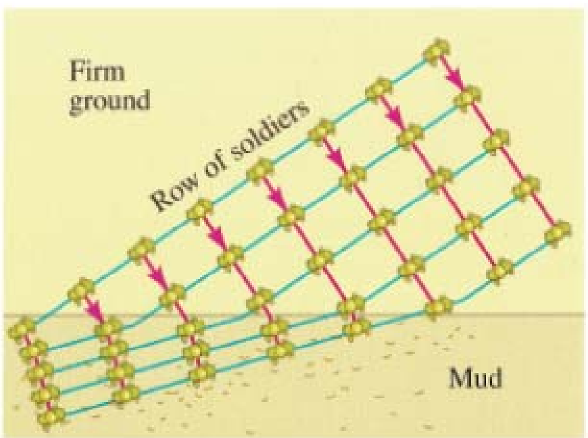
Law of refraction

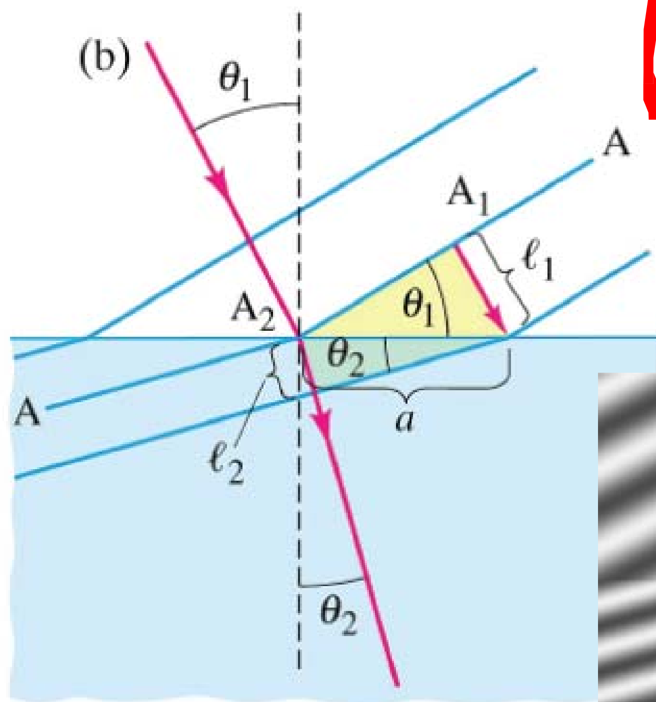
$$\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$$

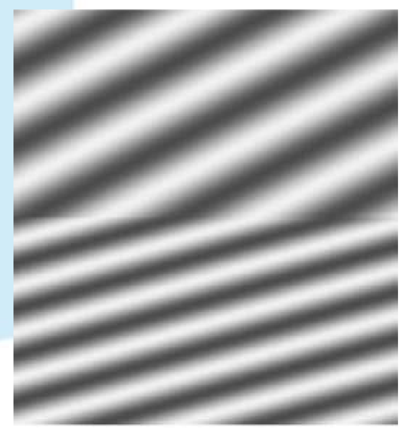
$n = c/v$

$$\frac{\sin\theta_2}{\sin\theta_1} = \frac{c/n_2}{c/n_1} = \frac{n_1}{n_2}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$







$$\frac{c}{v} = n$$

$$\lambda_0 \nu = c$$

$$\lambda \nu = v$$

ν does not change

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

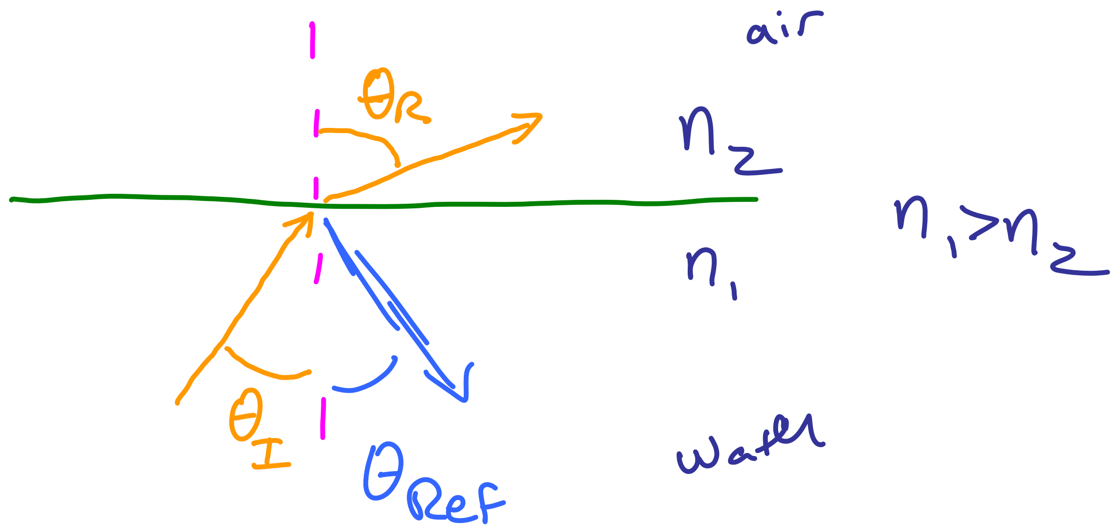
$$\lambda n = \frac{c}{\nu} = \lambda_0$$

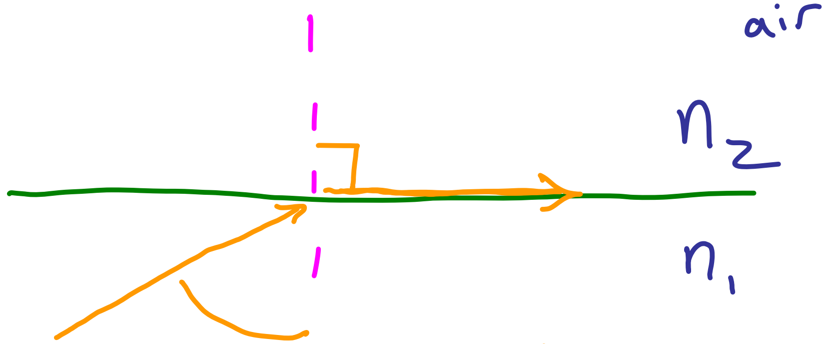
λn: in material (shorter)

λ_0: in vacuum

Critical Angle

$n_1 \sin\theta_1 = n_2 \sin\theta_2$





$\theta_I = \theta_c =$ critical Angle

water

$n_1 > n_2$

$n_1 \sin\theta_I = n_2 \sin\theta_R$

$\theta_R = 90^\circ$

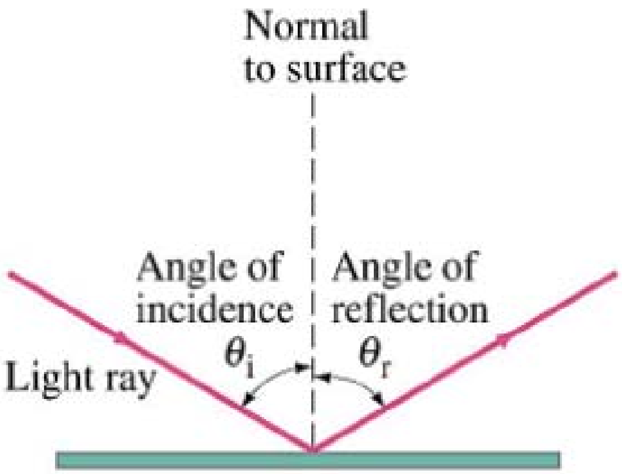
$\sin\theta_R = 1$

$$\sin\theta_c = \frac{n_2}{n_1}$$

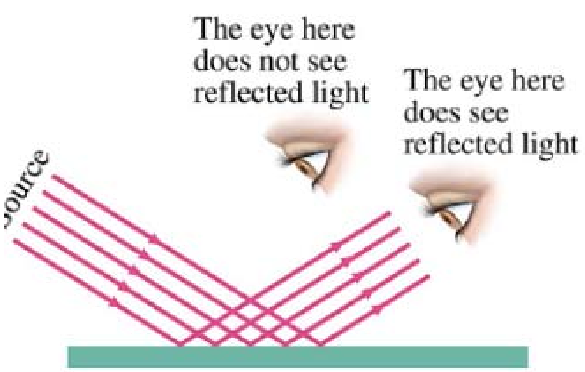
If $\theta_I > \theta_c$ all light is "internally" reflected

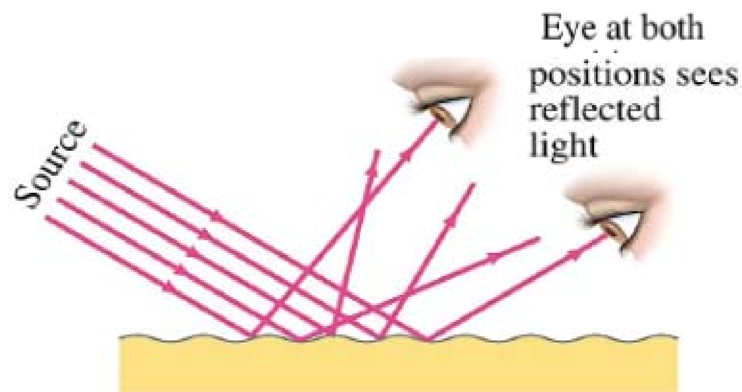
Law of reflection

$\theta_i = \theta_r$

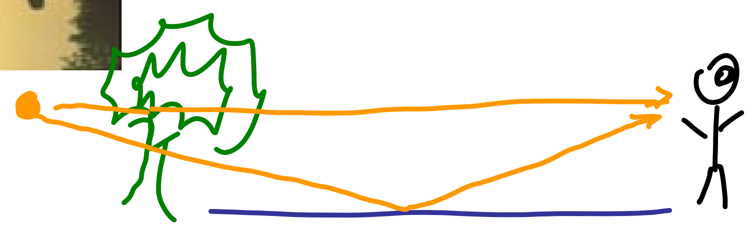


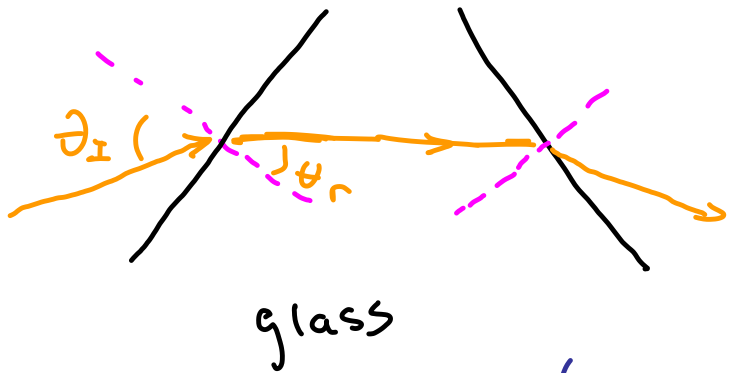
Specular reflection



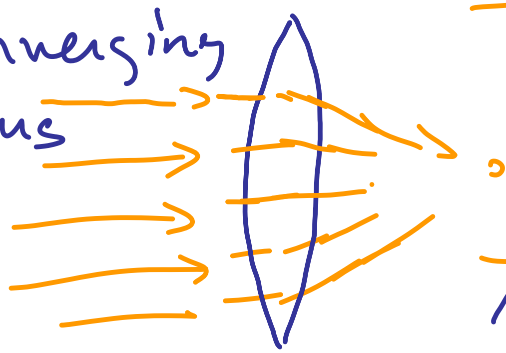


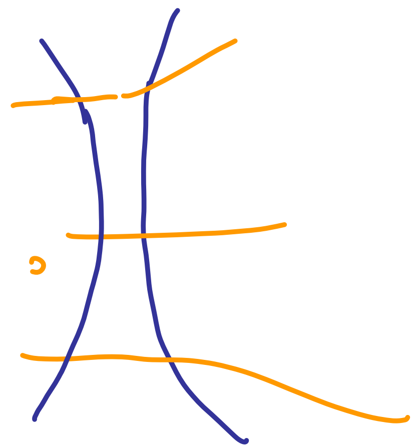
Diffuse reflection





Convex
converging
lens





concave (little cave) — Diverging