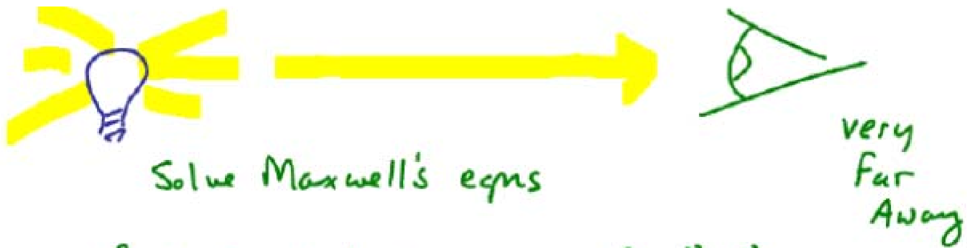
Physics 114 - April 7, 2015

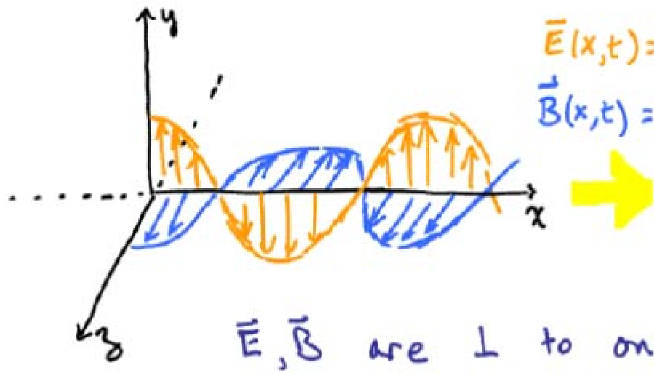
- Exam 2 ?
- Exam 3 – Week from Thursday
  - April 16 – Hoyt – During lecture Slot
  - Will cover: from last exam Through Chapt 31
    - EM waves (NOT polarization or optics)
    - Up Thru This week's workshop + Prob Set
- Q + A session Tuesday – Time + Place TBD

Last Time



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

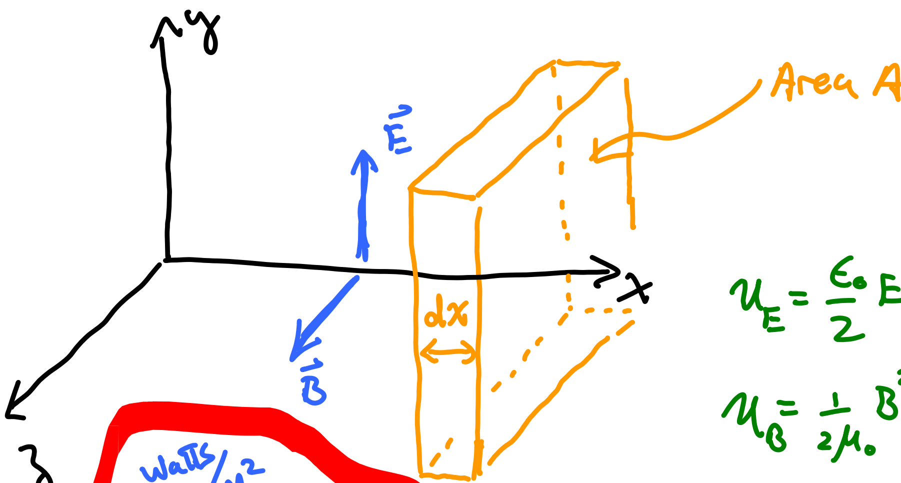
Wave Propagates in direction of $\vec{E} \times \vec{B}$

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

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

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

Energy flow for electromagnetic Plane waves



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

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

watts/m²

$$\frac{\text{Power}}{\text{Area}} \equiv \begin{matrix}\text{Instantaneous}\\ \text{Intensity}\\ \text{of}\\ \text{EM wave}\end{matrix} = \frac{EB}{\mu_0}$$

$$\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$$ Vector describing Energy floo = Poynting vector

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

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

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

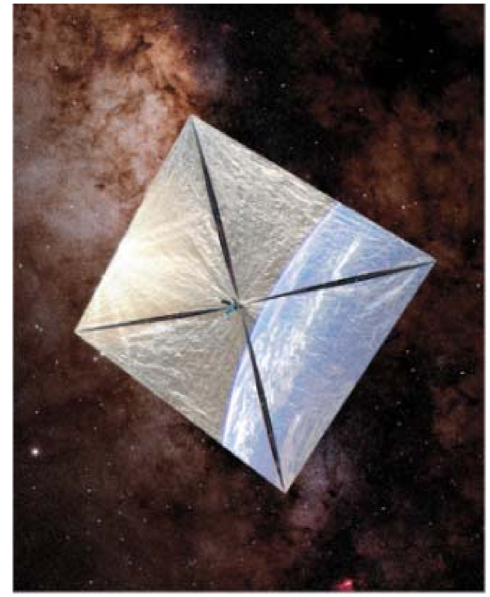
makes use of: $E \sim E_0 \sin\omega t$ $\quad B \sim B_0 \sin\omega t$

$B_0 = E_0/c$

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

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

↑ Force EM wave exerts if Completely Absorbed



"Solar Sail" Spacecraft

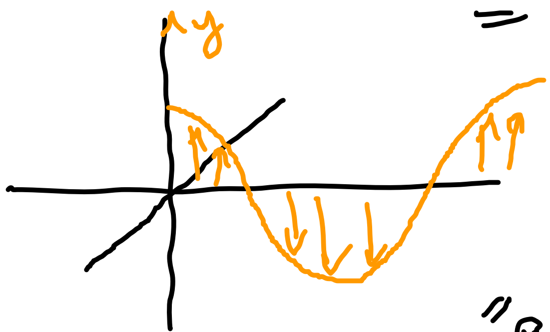
Pressure exerted by Fully absorbed EM wave $= \frac{\text{Force}}{\text{Area}} = \frac{S}{c}$

Radiation Pressure

What happens if EM wave Totally Reflected? Rad Pressure $= \frac{2S}{c}$

End of Material for Exam 3

$\vec{E}$ = only of two orthogonal solns to EM plane wave



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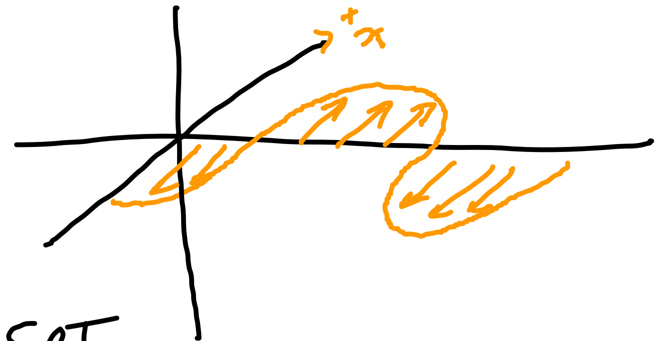
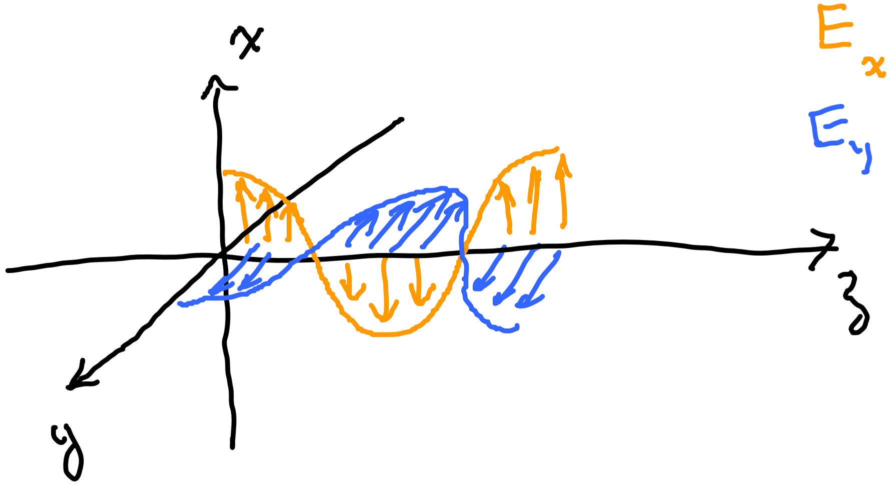
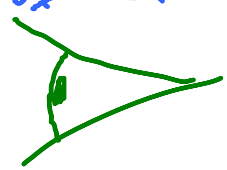


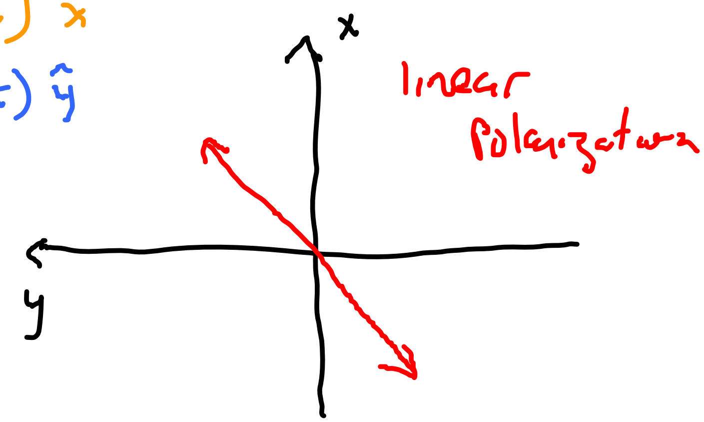
"Basis" set

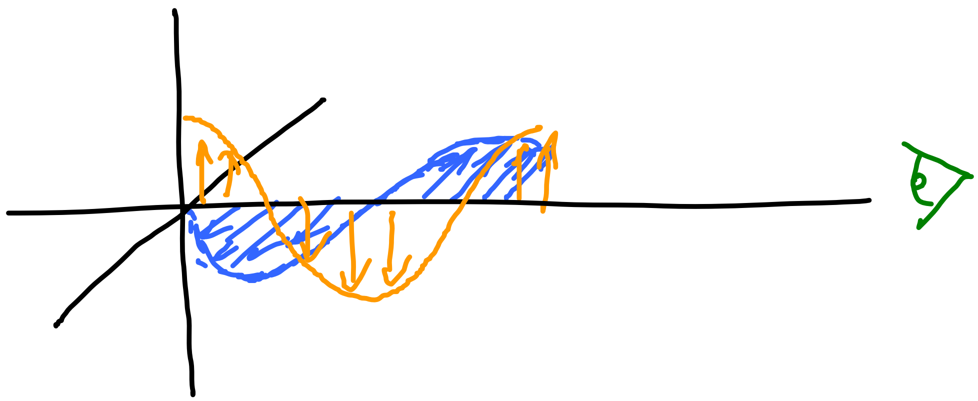


$E_x = E_{ox}\cos(kx-\omega t)\,\hat{x}$

$E_y = E_{ox}\cos(kx-\omega t)\,\hat{y}$



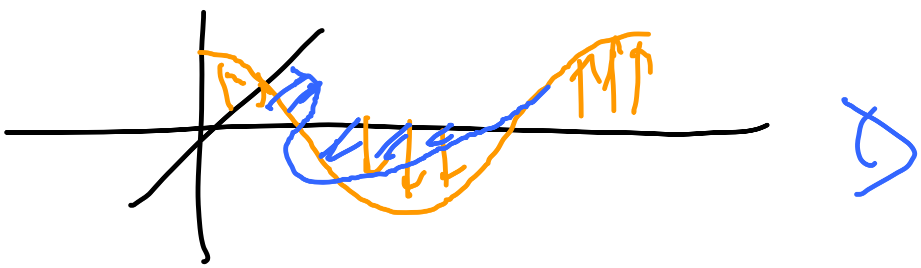


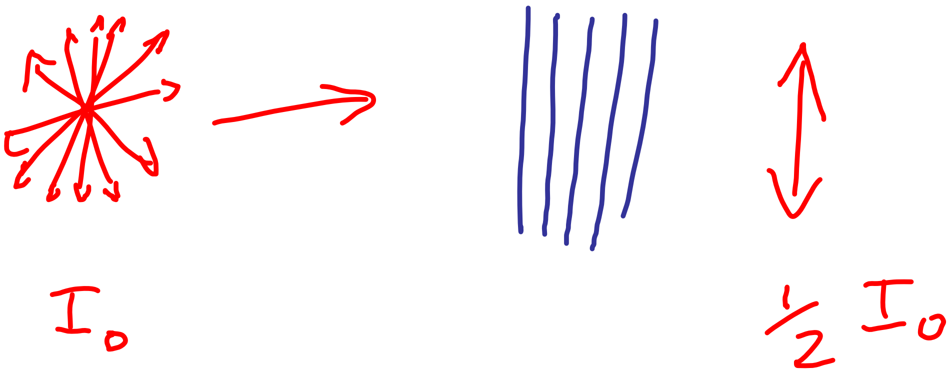


$E_x = E_{0x} \cos(kx - \omega t)\ \hat{x}$

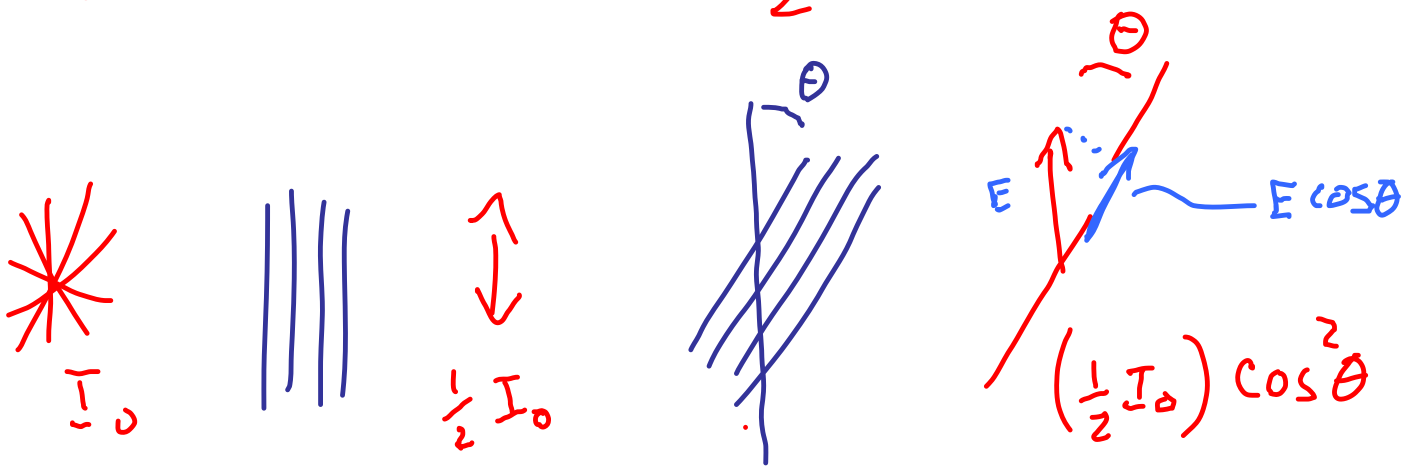
$E_y = E_{0x} \cos(kx - \omega t + \pi/2)\ \hat{y}$

Circular polarization





I₀
½ I₀



I₀
½ I₀
θ
θ
E
E cosθ
(½ I₀) cos²θ

Geometric Optics

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

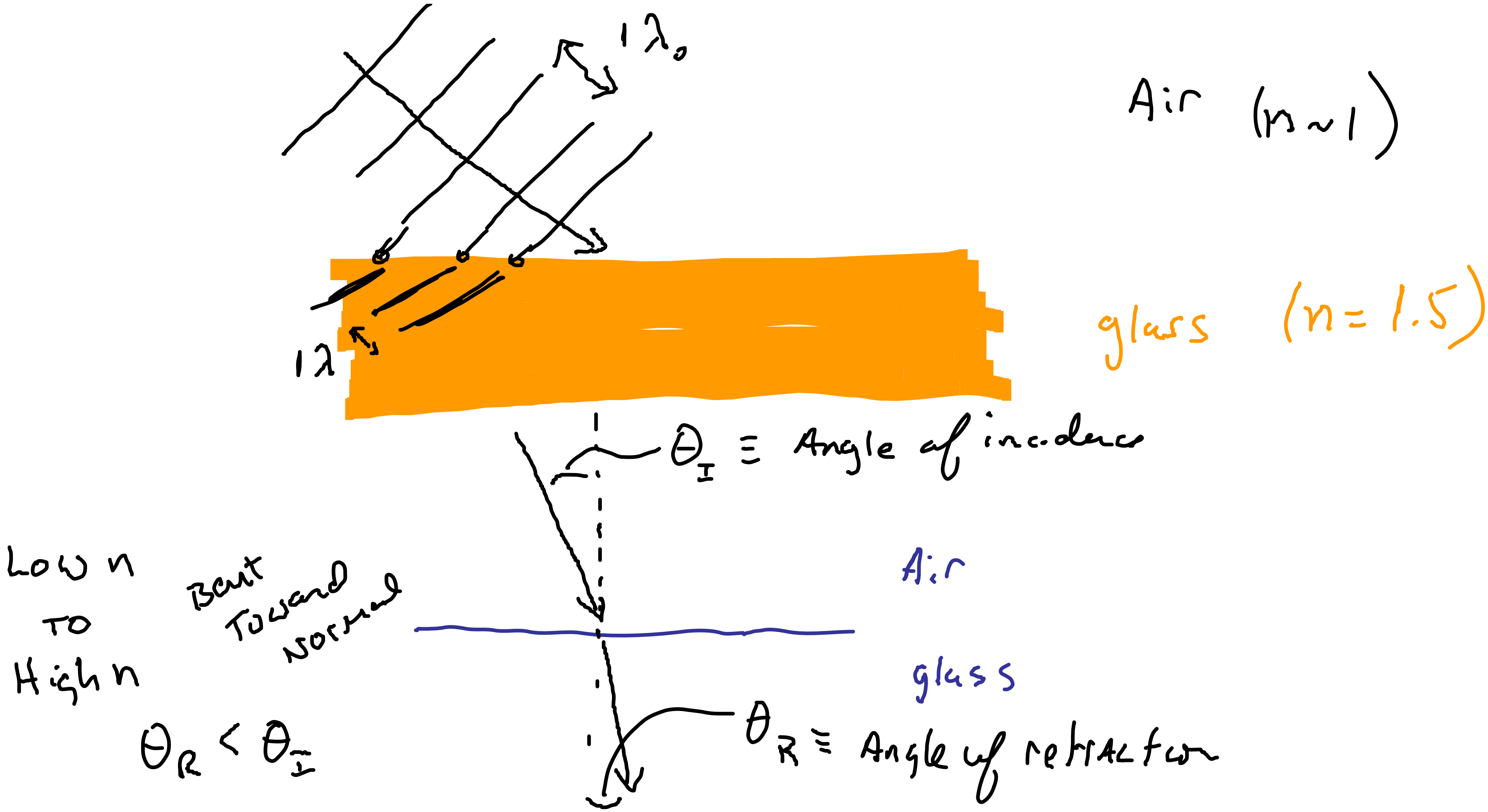
$$v = \frac{1}{\sqrt{\epsilon \mu}} < c \quad \text{in material}$$

f

ν

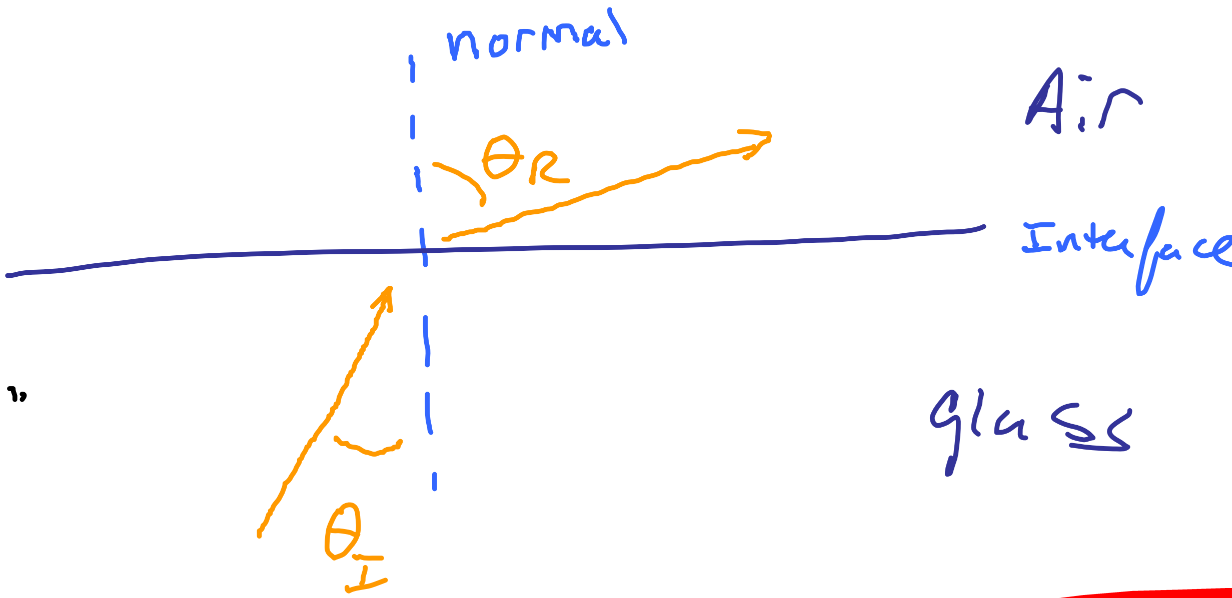
$$n \equiv \text{index of refraction} \equiv \frac{c}{v_{material}}$$

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



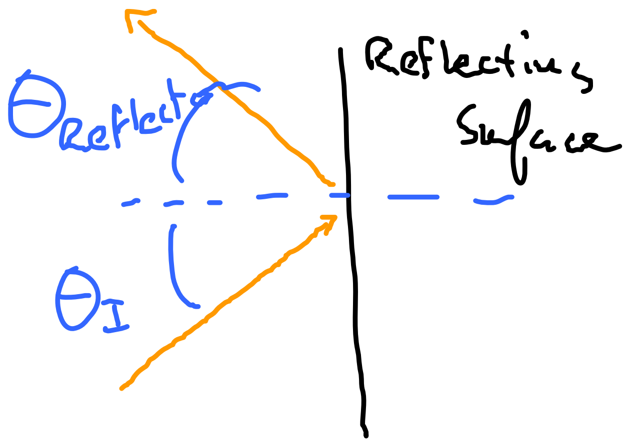
1 λ_0
Air ($n \sim 1$)
glass ($n = 1.5$)
1 λ
$\theta_I \equiv$ Angle of incidence
Air
glass
Low n
To
High n
Bent
Toward
Normal
$\theta_R < \theta_I$
$\theta_R \equiv$ Angle of refraction

High n
to
low n
"Bent away from normal"



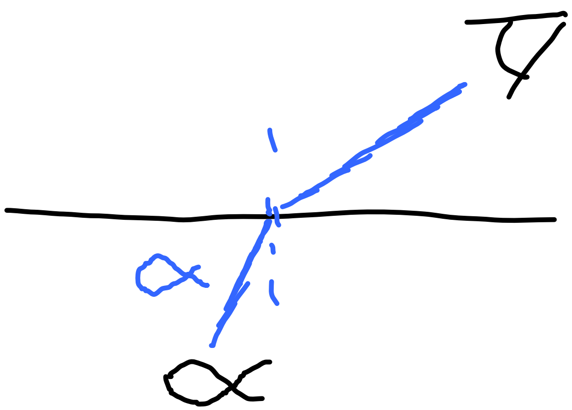
$$n_1 \sin\theta_I = n_2 \sin\theta_R$$

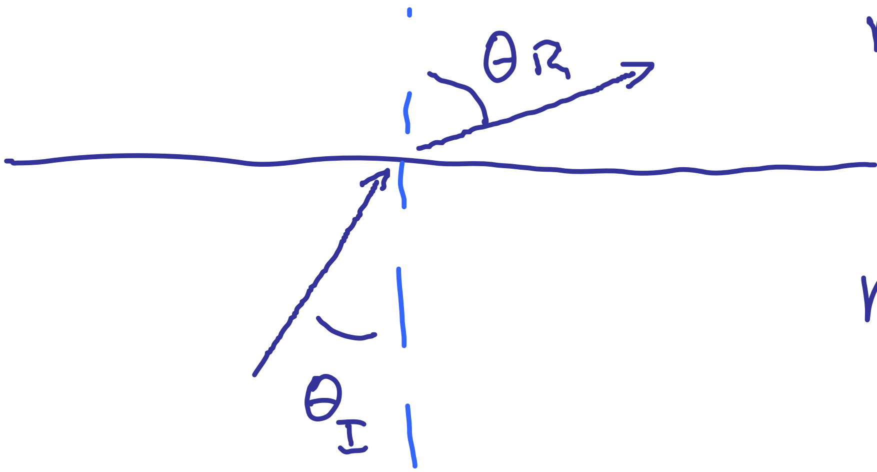
Snell's Law
of
Refraction



$$\theta_I = \theta_{Refl.}$$

Law of reflection

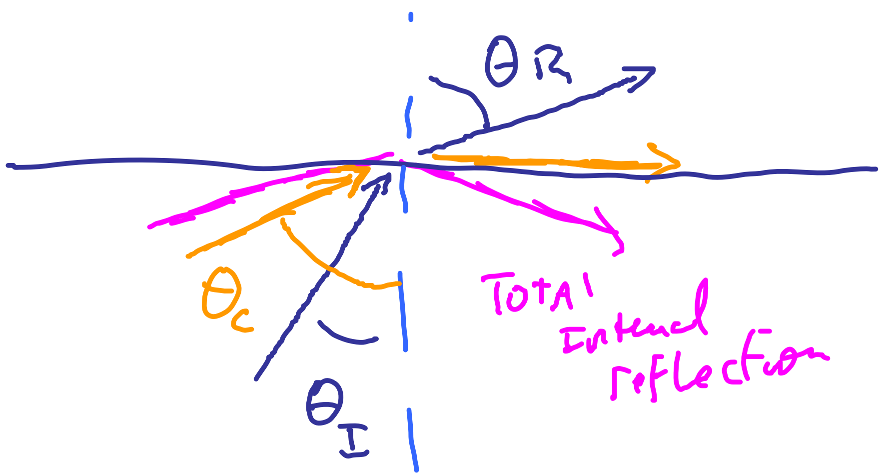




n_2 air

n_1 water

$n_1 > n_2$



when $\theta_1 = \theta_c$

$\theta_2 = 90°$

$\theta_c \equiv$ critical Angle