Lecture 6 - 10/9/07 Phys 375

Types of Polarization:

Linear:

Ex: $\vec{E}(\vec{r},t) = E_0 \hat{x} e^{i(\vec{k}\cdot\vec{r}-\omega t)}$

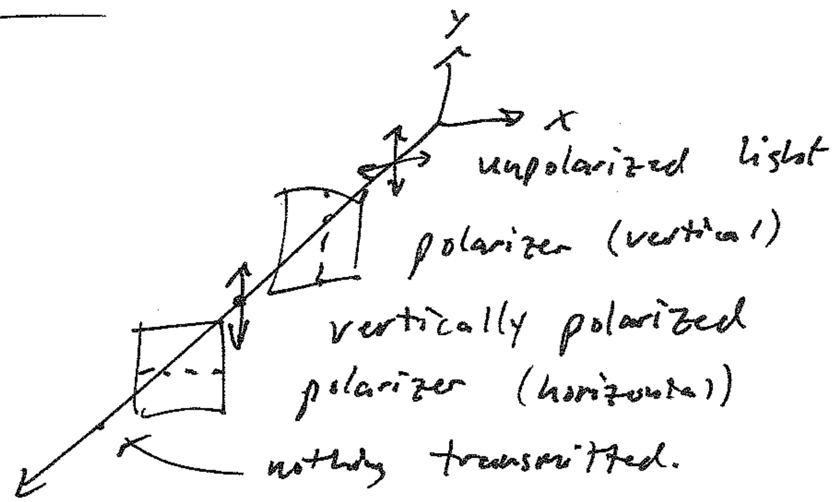
Circular:

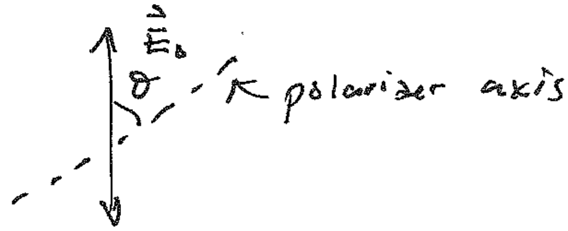
Ex: $\vec{E}(\vec{r},t) = E_0\left[\hat{x} e^{i(\vec{k}\cdot\vec{r}-\omega t)} + \hat{y} e^{i(\vec{k}\cdot\vec{r}-\omega t-\frac{\pi}{2})}\right]$

Elliptical:

Ex: $\vec{E}(\vec{r},t) = E_{0x}\hat{x} e^{i(\vec{k}\cdot\vec{r}-\omega t)} + E_{0y}\hat{y} e^{i(\vec{k}\cdot\vec{r}-\omega t-\frac{5\pi}{6})}$

Linear Polarizers:





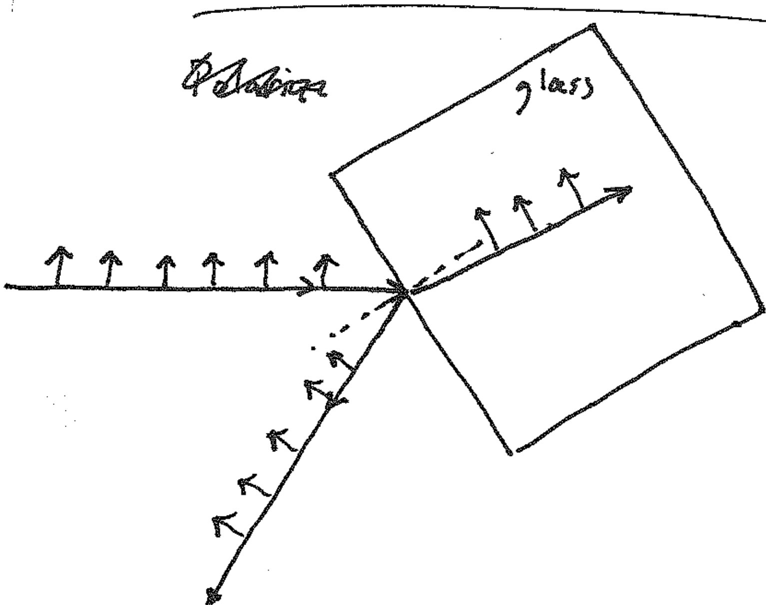
$|E_{transmitted}| = |\vec{E}_0| \cos\theta$

$I_{trans} = I_0 \cos^2\theta$

Malus' Law

Polarization of Reflected Light

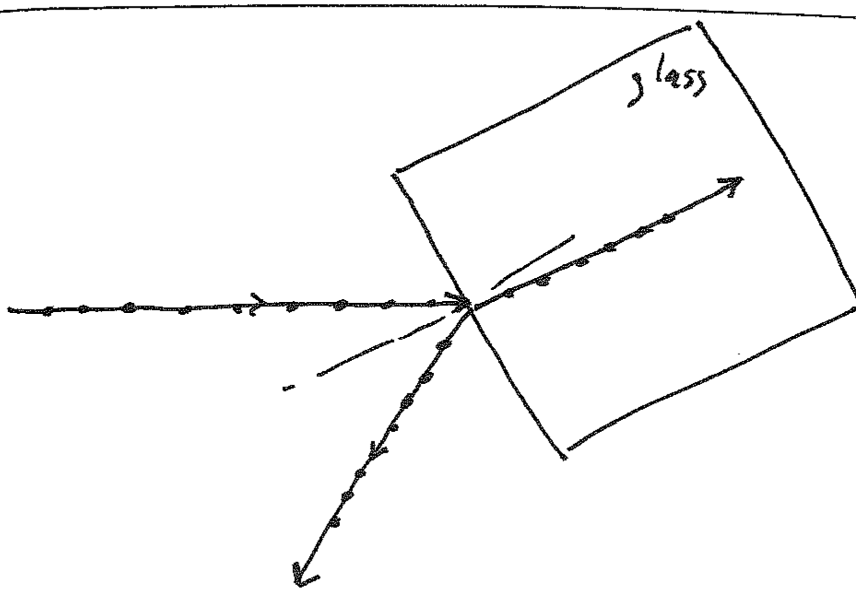
~~Polarize~~



"p-wave"

"Parallel to the plane of incidence"

Also called TM wave, and parallel wave



"s-wave"

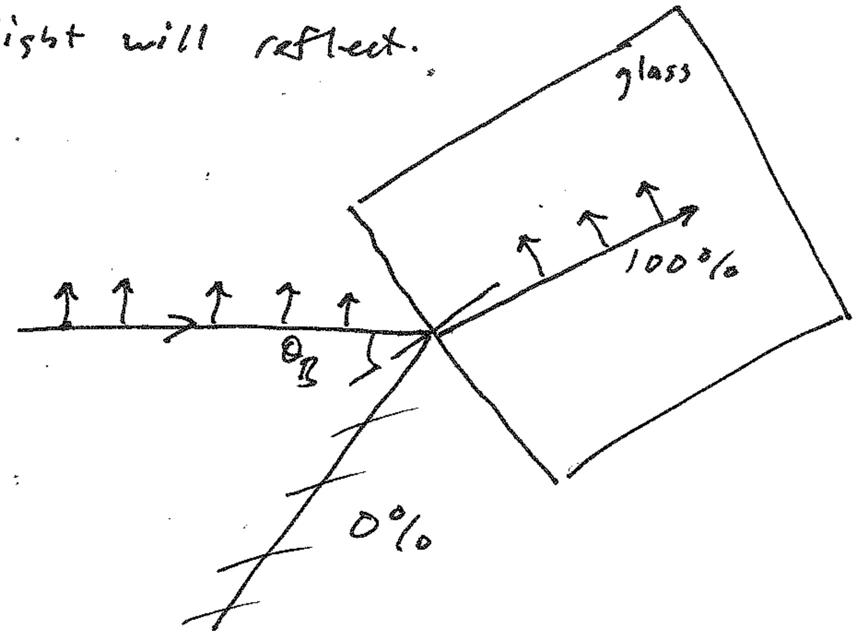
"Parallel to the glass surface"

Also called TE wave

and perpendicular wave.

Brewster's Angle

At a special angle of incidence – Brewster's Angle, no p-wave light will reflect.



This happens when the reflected ray would have been 90° from the refracted ray:

$$n_1 \sin\theta_B = n_2 \sin\left(\frac{\pi}{2} - \theta_B\right) = n_2 \cos\theta_B$$

$$\boxed{\tan\theta_B = \frac{n_2}{n_1}}$$ Brewster's Angle

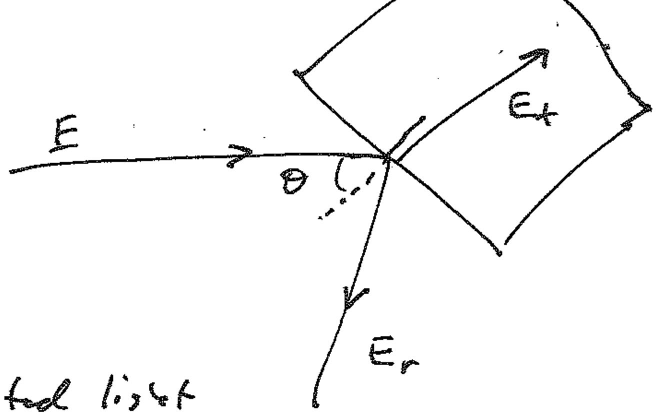
~~Fresnel Equations~~

Brewster's Angle is also called the "Polarizing Angle", since the reflected ray must be 100% s-wave.

⟹ One way to make polarized light from un-polarized light.

Fresnel Equations

Magnitude of reflected ~~and transmitted~~ Electric field for any angle of incidence, for both s-wave and p-wave

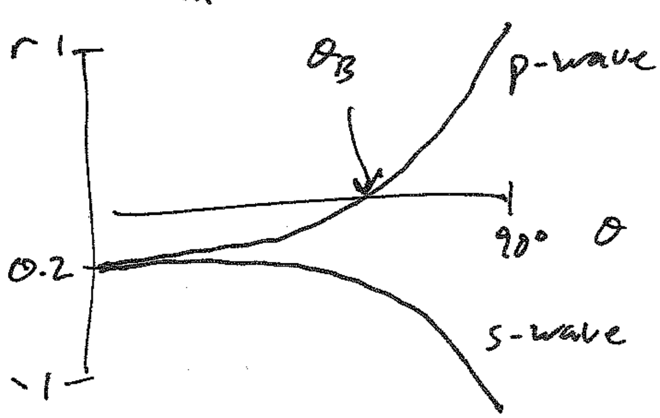


Reflected light

$$r_s = \text{s-wave} \equiv \frac{E_r}{E} = \frac{\cos\theta - \sqrt{n^2 - \sin^2\theta}}{\cos\theta + \sqrt{n^2 - \sin^2\theta}}, \quad n \equiv \frac{n_2}{n_1}$$

$$r_p = \text{p-wave} = \frac{E_r}{E} = \frac{-n^2\cos\theta + \sqrt{n^2 - \sin^2\theta}}{n^2\cos\theta + \sqrt{n^2 - \sin^2\theta}}, \quad n \equiv \frac{n_2}{n_1}$$

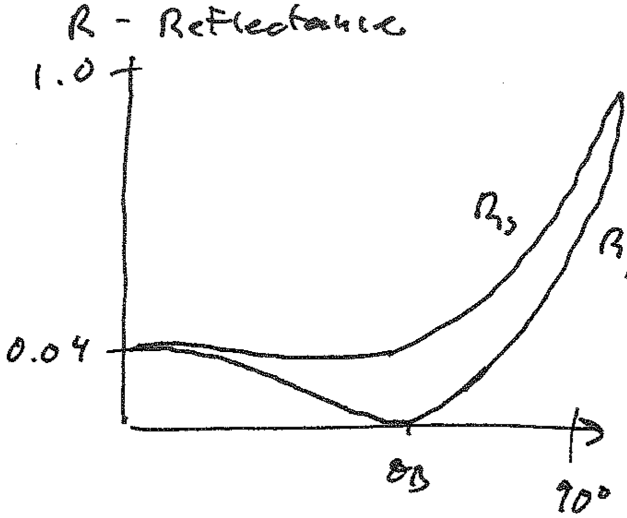
Ex: $\frac{n_2}{n_1} = 1.5$ (glass)



For $r < 0$, E_r has opposite sign from E (phase shift of π).

Reflected Intensity $I \propto E^2$

$$\text{Reflectance} = R \equiv \frac{I_r}{I} = \left(\frac{E_r}{E}\right)^2 = r^2$$



$$R_p = \left(\frac{\tan(\theta_i - \theta_t)}{\tan(\theta_i + \theta_t)} \right)^2$$

$$R_s = \left(\frac{\sin(\theta_i - \theta_t)}{\sin(\theta_i + \theta_t)} \right)^2$$

Special Case: Angle of Incidence = ϕ:

$$r_p = r_s = \frac{1-n}{1+n}$$

$$R_p = R_s = \left(\frac{1-n}{1+n} \right)^2$$

Since $R_p \neq R_s$ otherwise, unpolarized light becomes partially polarized upon reflection. At θ_B, it becomes 100% polarized

Polarized Sunglasses & eliminate glare