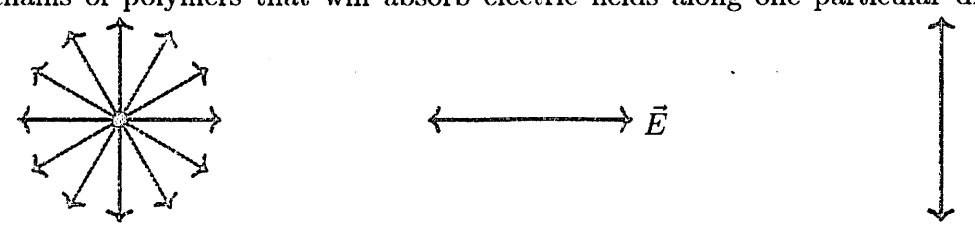
Light consists of an electromagnetic wave. This has both an oscillating electric field and an oscillating magnetic field. We know that the wave travels in the $\vec{E} \times \vec{B}$ direction: the direction of oscillation for each of the two fields is necessarily perpendicular the direction of the wave's travel. In our em wave equations we assume that the electric oscillates along the y direction for a wave moving along the $+x$ direction, but that is just a choice. For a wave moving (for example) out of the page, the electric field could be oscillating in any direction in the plane of the page. In fact, light will generally consist of many pieces with a random distribution of these directions. This is called unpolarized light. If light passes through a polarizer only oscillating electric fields along a particular direction will pass through, yielding polarized light. (Typically, a polarizer consist of chains of polymers that will absorb electric fields along one particular direction.)



Unpolarized Light | Horizontally polarized | Vertically polarized

- When unpolarized light of intensity I_0 passes through a polarizer exactly half of the light will pass through: $I = \frac{1}{2}I_0$. The light passing through will be polarized, with its polarization direction matching the polarization axis of the polarizer.
- When polarized light of intensity I_0 passes through a polarizer the intensity of the light making it through will be $I = I_0 \cos^2\theta$ where θ is the angle between the polarization direction of the initial light and the polarizer axis. The light passing through will still be polarized, but its direction will change so as the match the polarization axis.

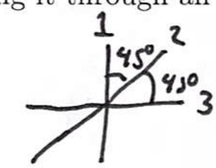
It is also the case that when light reflects and refracts at an interface between two materials the resulting beams can become (at least partially) polarized. In particular, suppose that a ray of light traveling in a material with index n_1 strikes an interface with a material of index n_2. When the incident angle θ_1 is equal to the Brewster angle, $\theta_p = \tan^{-1}\frac{n_2}{n_1}$, the resulting reflected ray will be completely polarized. It will be polarized in the direction such that only electric fields in the plane where the two materials met are allowed. (The refracted ray will be partially polarized.) Interesting, whenever this occurs (when $\theta_1 = \theta_p$) the reflected and refracted rays will be perpendicular to each other.

Unpolarized light of intensity $I_0 = 100\ \mathrm{W/m^2}$ passes three polarizer. The first has an axis oriented vertically; the second has an axis 45° from vertical; the third has an axis oriented horizontally. What intensity of light passes through all three polarizers? What is the polarization direction for light making it through all three?

1st: Factor of 1/2

2nd: Factor of $\cos^2(45°)$

3rd: Factor of $\cos^2(45°)$

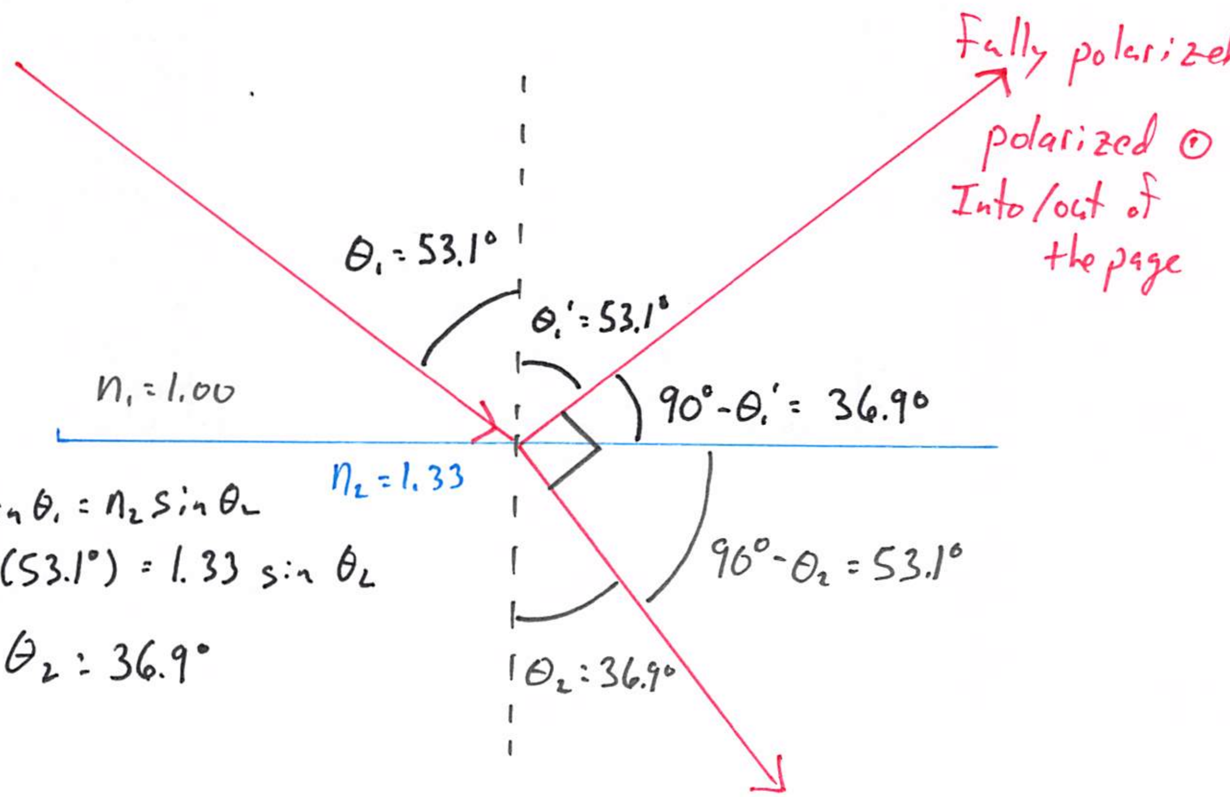


$$I = (100\ \mathrm{W/m^2}) \cdot \frac{1}{2} \cdot \cos^2(45°) \cdot \cos^2(45°)$$

$$= 12.5\ \frac{\mathrm{W}}{\mathrm{m}^2}$$

What is the polarizing angle (Brewster angle) when light traveling in air ($n = 1.00$) reflects off of water ($n = 1.33$)? What is the refracted angle (θ_2) when this happens? Sketch this and shown that the reflected and refracted angles will be 90° apart.

$$\theta_p = \tan^{-1}\left(\frac{n_2}{n_1}\right) = \tan^{-1}\left(\frac{1.33}{1.00}\right) = 53.1°$$



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

$$1 \sin(53.1°) = 1.33 \sin\theta_2$$

$$\theta_2 = 36.9°$$