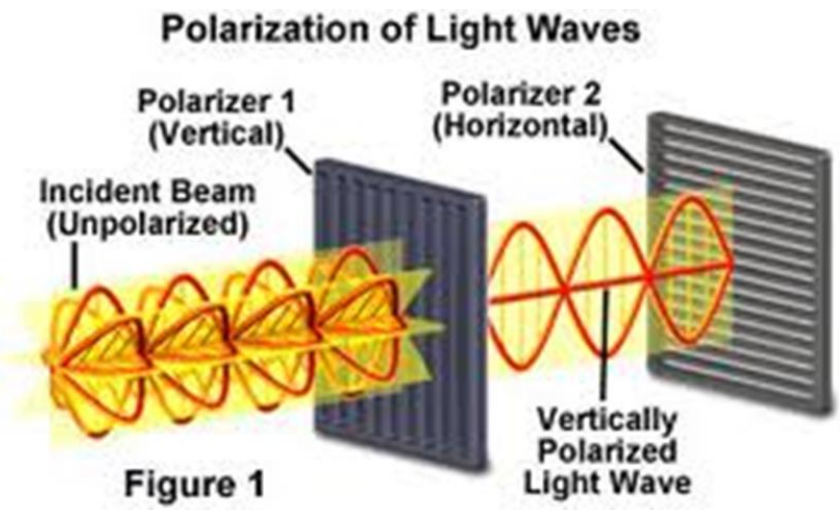
Polarization of Light

Polarization of a light wave

- Normal light is unpolarized: that is, an equal mixture of light waves with all of these different directions for the $\vec{E}$ field
- Linearly polarized light has its electric field oscillating along only one of these possible directions

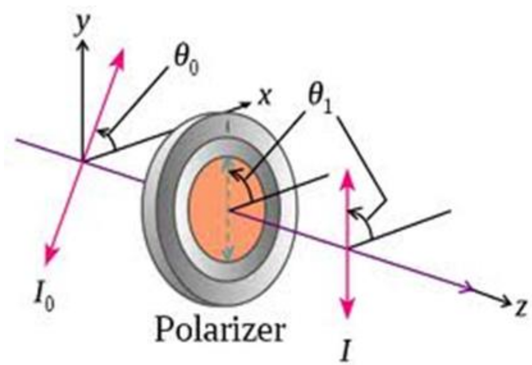


There are many directions of the electric field consistent with a given direction of propagation of a light wave (Remember the right-hand-rule for light propagation)

Polarization by dichroism

- Certain materials (the natural crystal tourmaline, the synthetic Polaroid) restrict electron conduction along one direction within the material. Only light linearly polarized parallel to this direction emerges from the material.
- Light intensity I measures the power per unit area (SI unit: $\mathrm{Watt/m^2}$)
- Unpolarized light through polarizer (the result is linearly polarized light):
$$I' = I_0/2$$
- Linearly polarized light through polarizer:
$$I' = I_0 \cos^2 \theta$$

tourmaline



$$\theta = \theta_1 - \theta_0$$

Quickuiz

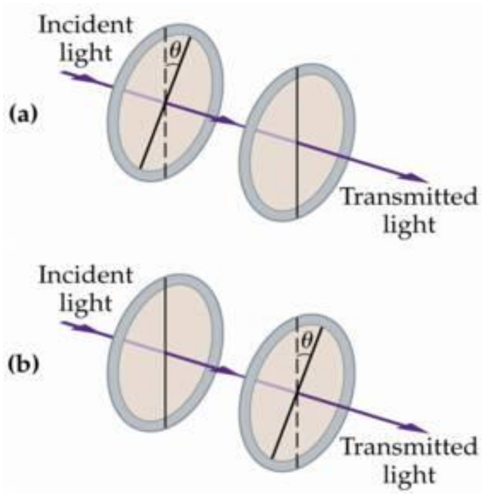
Consider the two situations shown in the figure. In the upper case (a), the first polarizer is at an angle theta to the vertical, while the second polarizer is vertical. In the lower case (b), the first polarizer is vertical, while the second polarizer is at the same angle theta to the vertical.

Suppose the light incident on the first polarizer is unpolarized. In which case is the intensity of the transmitted light the greatest?

A. Case (a)

B. Case (b)

C. The two cases have equal intensities.



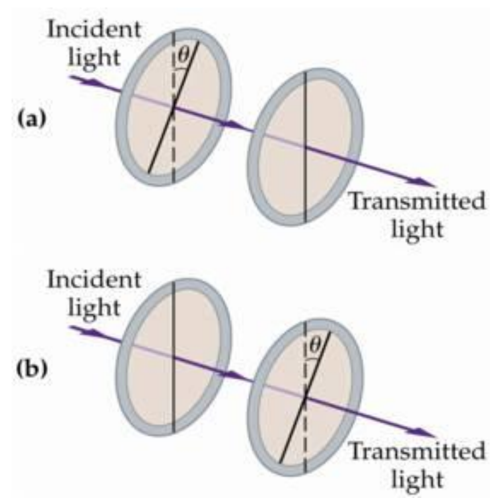
Quickuiz

The polarizers are arranged in the same setup as in the previous question. Now suppose the light incident on the first polarizer is linearly polarized in the vertical direction. In which case is the intensity of the transmitted light greater?

A. Case (a)

B. Case (b)

C. The two cases have equal intensities.



Polarization by Reflection

- When light is incident on a planar interface between two media, the reflected and refracted rays are at least partially polarized. If the reflected and refracted rays are perpendicular, then the reflected ray is fully (linearly) polarized, with the axis of polarization parallel to the planar interface. This occurs at Brewster's angle θ_B:

$$\tan\theta_B = \frac{n_2}{n_1}$$

n_1, n_2 are refractive indices of first and second media, respectively.

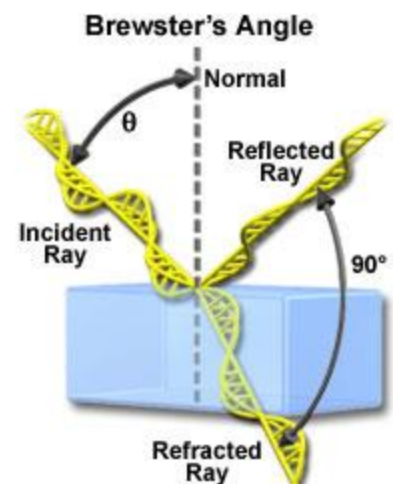


Figure 1

Polarizing filter simulation:

http://www.colorado.edu/physics/2000/applets/polarized.html

Example

- What's the Brewster's angle for light moving from air, $n_{air} = 1.00$ to water $n_{water} = 1.33$?

$$\tan\theta_B = \frac{n_2}{n_1}$$

$$\theta_B = \tan^{-1}\left(\frac{1.33}{1}\right) = 53.1°$$

What about from water to air?

$$\theta_B = \tan^{-1}\left(\frac{1}{1.33}\right) = 36.9°$$

LCD display

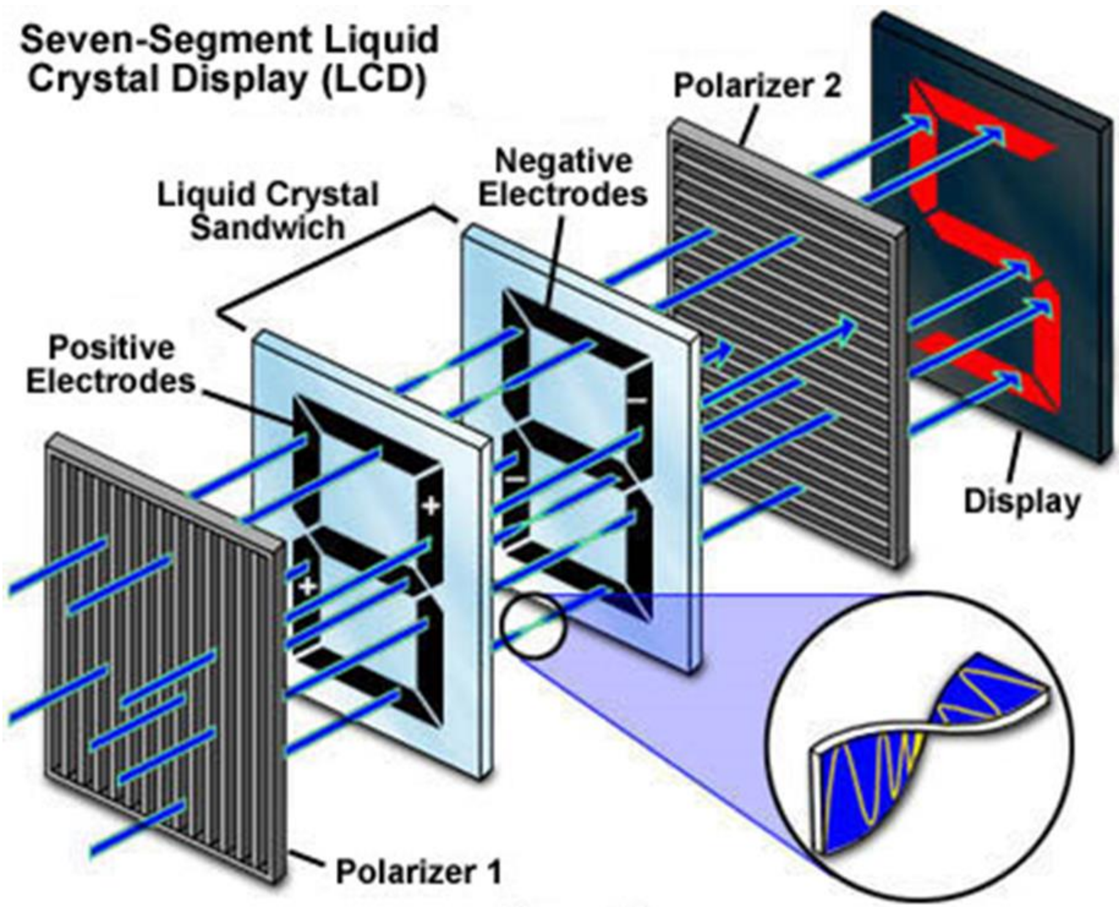


Figure 3