38.6 Polarization of Light Waves

- EM waves are transverse waves.
- The direction of polarization of the EM waves is defined as the direction $\mathbf{E}$ is vibrating.

- Ordinary light is *unpolarized*, i.e., $\mathbf{E}$ are randomly pointed in all directions.

**Linearly polarized light**: $\mathbf{E}$ vibrates in the same direction all the time.

**Ideal polarizer**: all light with $\mathbf{E} \parallel$ to the transmission axis is transmitted, and all light with $\mathbf{E} \perp$ to the transmission axis is absorbed. An unpolarized light passing through a polarizer becomes polarized.

The intensity of the polarized beam transmitted through the analyzer varies as (Malus’s law)

$$I = I_0 \cos^2 \theta$$

$I_0$ is the intensity of the polarized wave incident on the analyzer.

**Q**: At what angle, $I$ becomes maximum or minimum?
**Polarization by Reflection**

When an unpolarized light beam is reflected from a surface, the reflected light can be completely polarized, partially polarized, or unpolarized, depending on the incidence angle.

**Brewster’s angle** \( \theta_p \):

\[
\tan \theta_p = \frac{n_2}{n_1}
\]

At this particular angle of incidence, the reflected beam is completely polarized, with its vector parallel to the surface.

For water \( (n = 1.33) \), \( \theta_p = \tan^{-1}(1.33) = 53.06^\circ \)

**Q:** how to find out the transmission axis of a polarizer?

**Polarization by Double Refraction**

In certain crystalline structures, the speed of light is not the same in all directions. Two indices of refraction are needed. They are often called **double-refracting** or **birefringent** materials.

- The **ordinary** (O) ray is characterized by an index of refraction of \( n_o \). This is the same in all directions.

- The second ray is the **extraordinary** (E) ray which travels at different speeds in different directions. It is characterized by an index of refraction of \( n_E \) that varies with the direction of propagation.