6.1 Polarization

Polarized Light
Polarization by absorption
Polarization by reflection
Polarization by scattering

Wave Optics

- Geometric Optics – Light rays move in straight lines.
  - Okay for interaction with objects much larger than the wavelength
- Wave Optics – Light propagates as spherical waves.
  - Describes interactions with objects with the same size as the wavelength.

Wave Properties of Light

Wave optics or Physical optics is the study of the wave properties of light.

Some wave properties are:

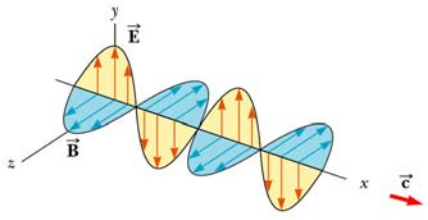
Interference, diffraction, and polarization.

These properties have useful applications in optical devices such as compact discs, diffraction gratings, polarizers.

Polarization

- Polarized light has it E field along one direction.
- Light can be polarized by several different processes
  - Absorption – Polaroid filter
  - Reflection – Brewster's angle
  - Scattering – Light from the sky
- Polarized light has many applications
  - Polaroid sunglasses, Polarization microscopy, liquid crystal display.

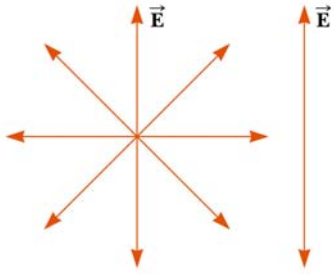
Light is a transverse wave



A plane wave with Electric field in the y direction

There is no E field in the direction of propagation

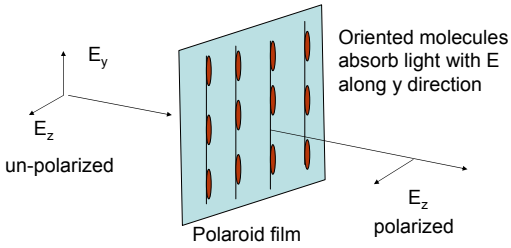
Polarized and un-polarized light



Unpolarized Light has E field at any instant can have E in any direction.

Polarized Light has E field in a certain direction

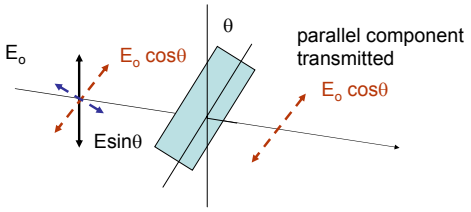
Polarization by absorption



for an ideal polarizer the intensity is reduced by 1/2

$$I_{polarized} = \frac{1}{2} I_{unpolarized}$$

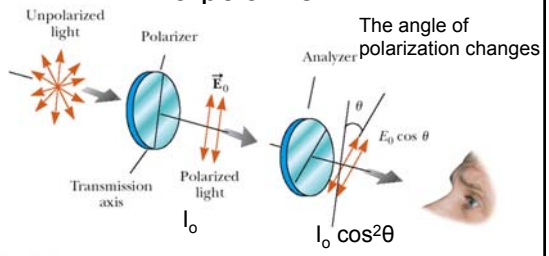
Polarized light passing through a polarizer at angle θ



But $I \propto E^2$

Therefore transmitted intensity
$I = I_o \cos^2\theta$

Polarized light passing though a polarizer



The angle of polarization changes

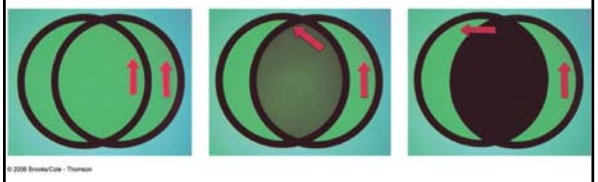
Decrease in intensity when polarized light passes through a polarizer

Law of Malus

$I = I_o \cos^2\theta$

Two polarizers

$I = I_o \cos^2\theta$

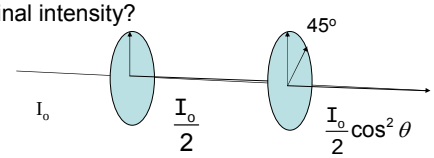


θ=0 θ=45° θ=90°

"Crossed-polarizers"

Example

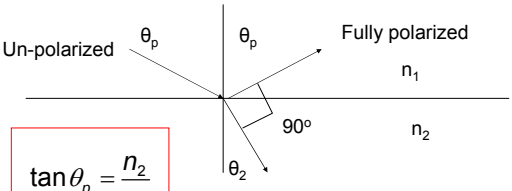
Un-polarized light is incident upon two polarizers that have their polarization axes at an angle of 45°. If the incident light intensity is I_o what is the final intensity?



$$I = \frac{I_o}{2}\cos^2 45 = \frac{I_o}{2}\left(\frac{1}{2}\right) = \frac{I_o}{4}$$

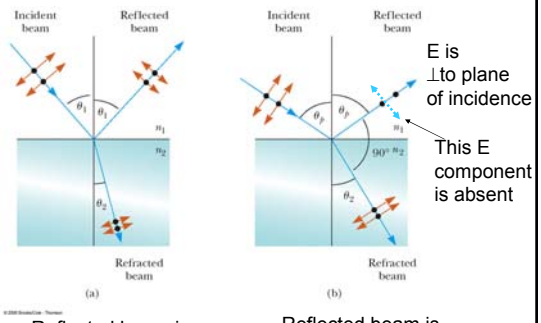
Polarization by reflection

Un-polarized light can be polarized by reflection at a specific polarization angle θ_p (Brewster's angle)



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

Polarization by reflection



E is ⊥to plane of incidence

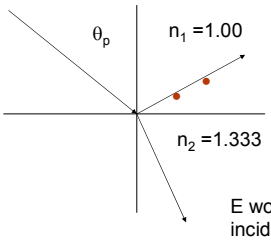
This E component is absent

Reflected beam is Partially polarized

Reflected beam is Fully polarized

Example

Suppose you wanted to have fully polarized light by reflection at the air water interface. What conditions would you use? What would be the direction of the polarized E field?



Angle of incidence equal to the polarizing angle

$\tan\theta_p = \frac{n_2}{n_1} = 1.333$

$\theta_p = 53^o$

E would be ⊥ to the plane of incidence.

Polarization by reflection

no filter

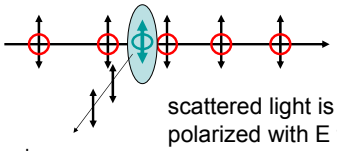
polarizing filter

The reflected light is polarized -

Polarization by scattering

Plane wave has no E field in the direction of propagation

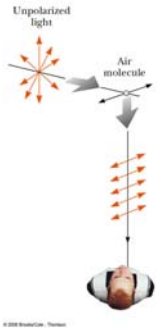
Scattering particle has oscillations partially polarized in the plane ⊥ to the direction of propagation



observer

scattered light is partially polarized with E field ⊥ to the direction of propagation of the incident light

Polarization of light by air



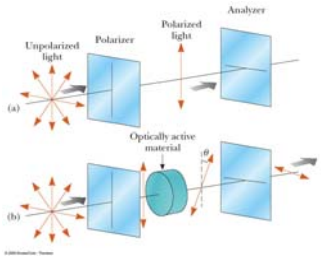
Polarization of scattered light

Light from the sky is partially polarized

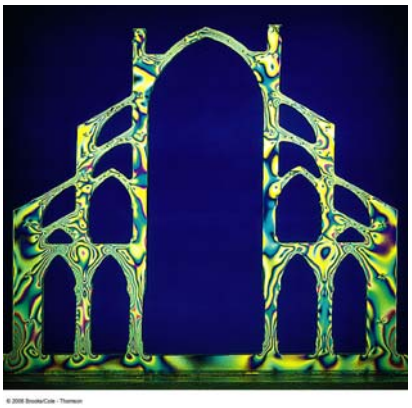
no filter

polarizing filter

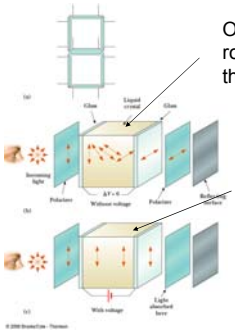
Applications- Crossed Polarizers



Crossed polarizers used to detect materials that rotate the plane of polarized light (optically active materials) including many biological materials and materials under mechanical stress



Applications – Liquid crystal display (LCD)



Oriented molecules rotate the plane of the polarized light

When an electric field is applied the molecules reorient so that the light is not rotated.

LCD displays