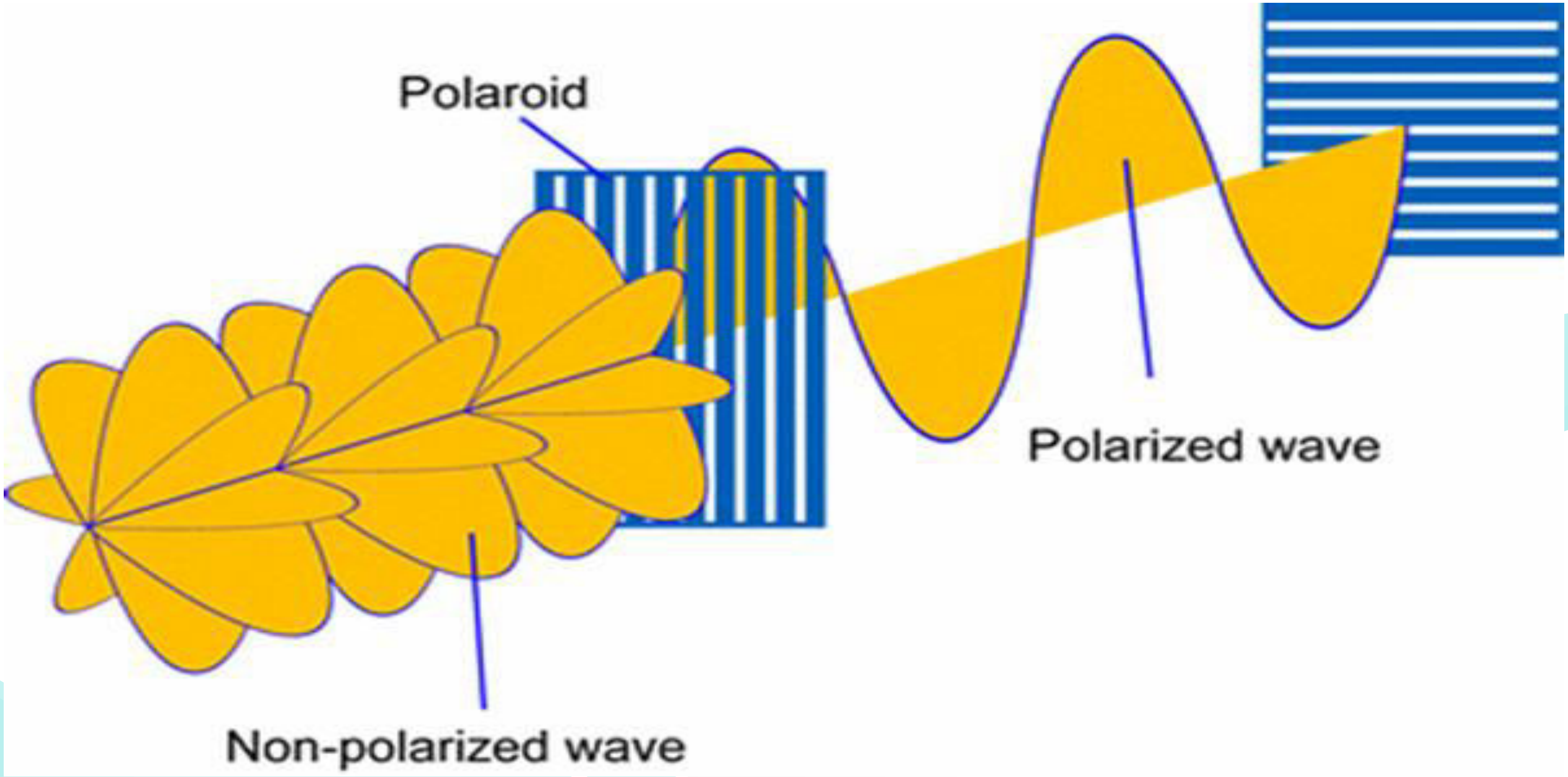
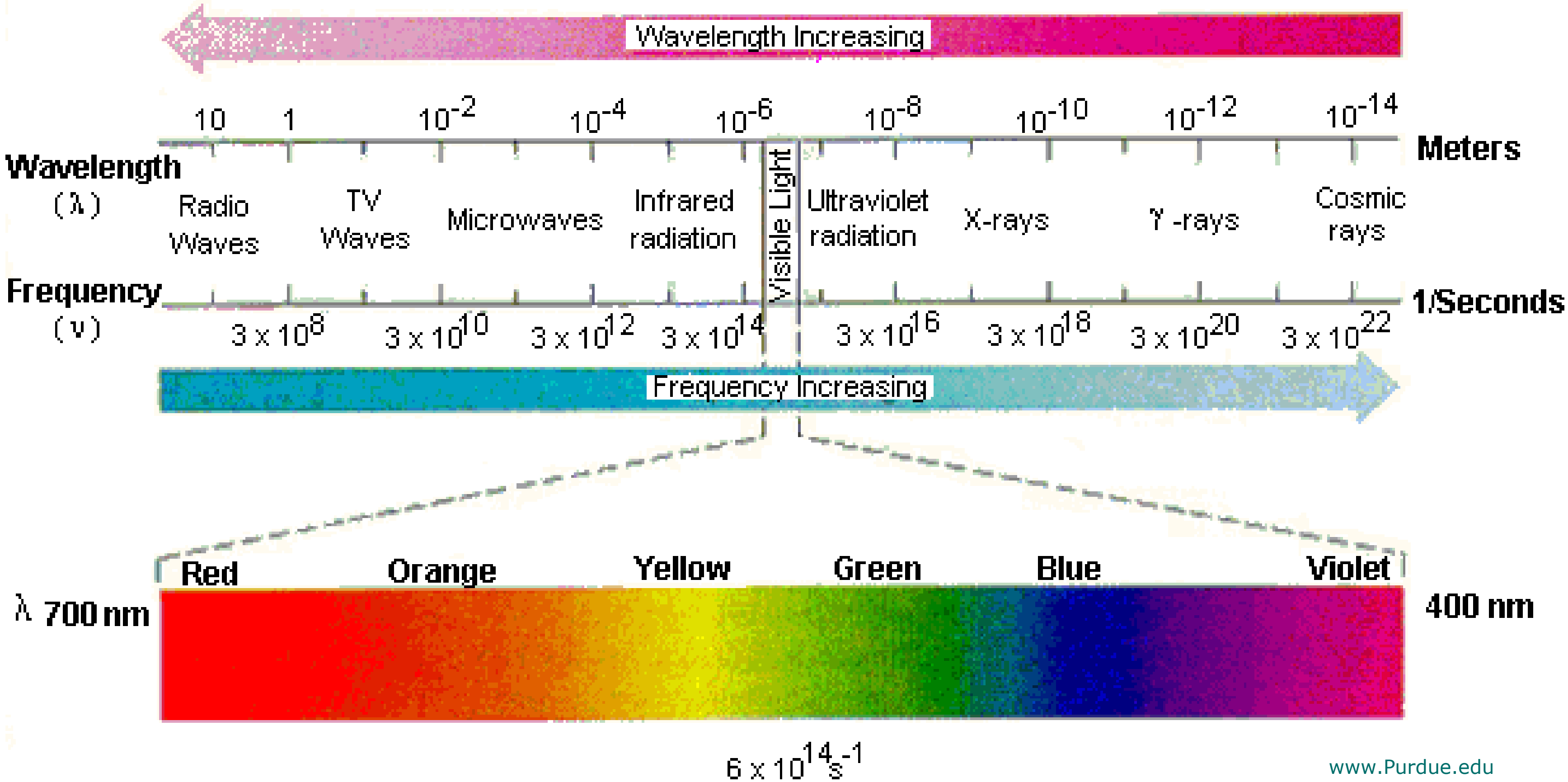
Polarization of Light



Dr.S.R.Jigajeni

Electromagnetic Spectrum



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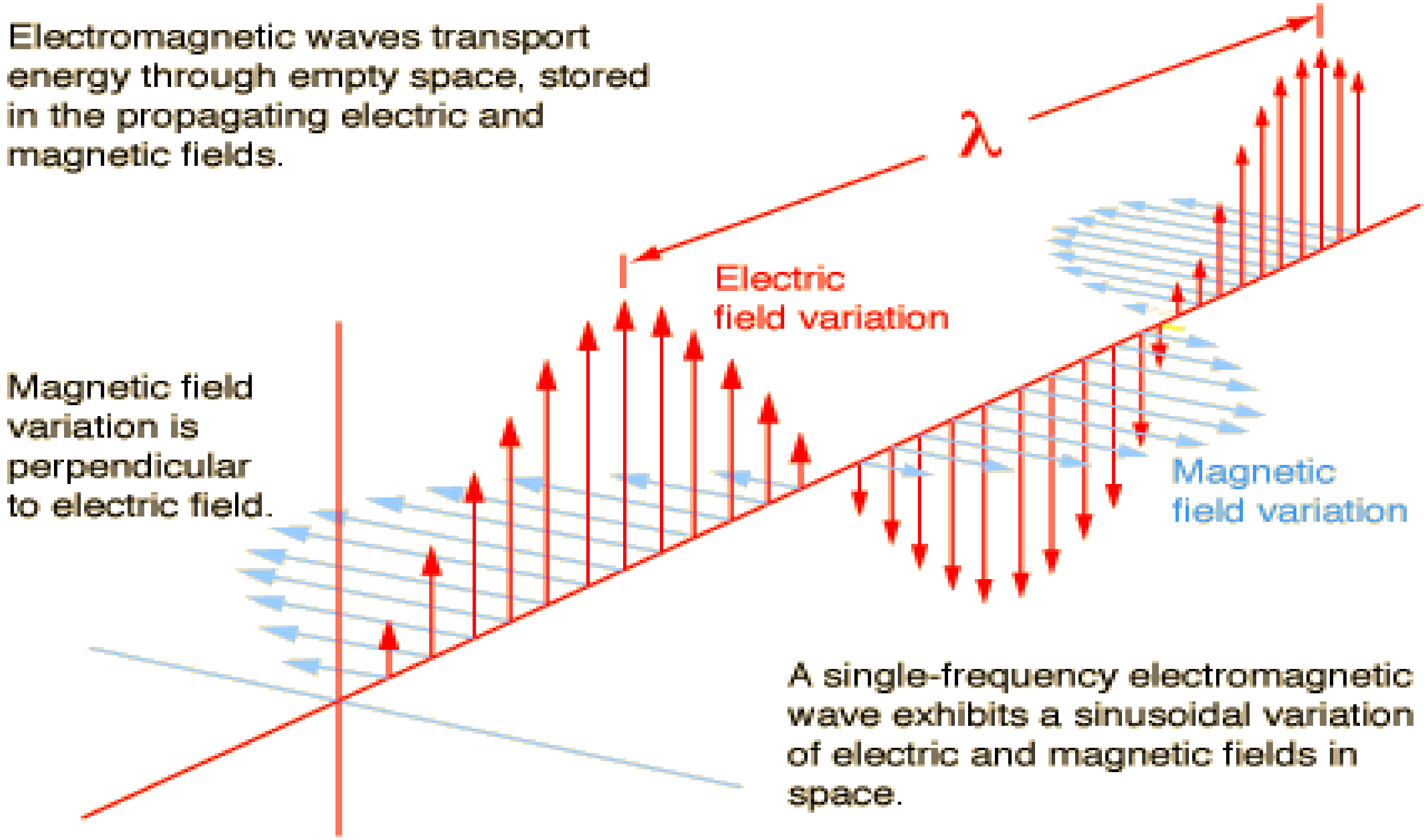
What are Light Waves?

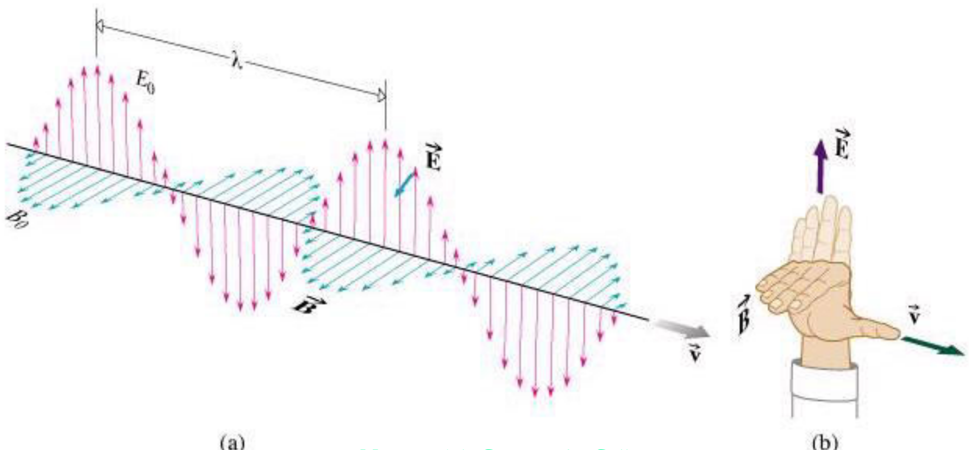
- A light wave is a comprised of electric and magnetic fields changing in space and time, i.e., they are electromagnetic waves.
- A light wave is a 3-dimensional transverse wave.
- Light waves do not need a medium to travel, i.e., they can travel in a vacuum.

Electromagnetic Waves (cont.)



Electromagnetic Waves (cont.)

- When the electric field is at a maximum, the magnetic field is also at a maximum.
- Use RHR to determine the direction of B relative E.



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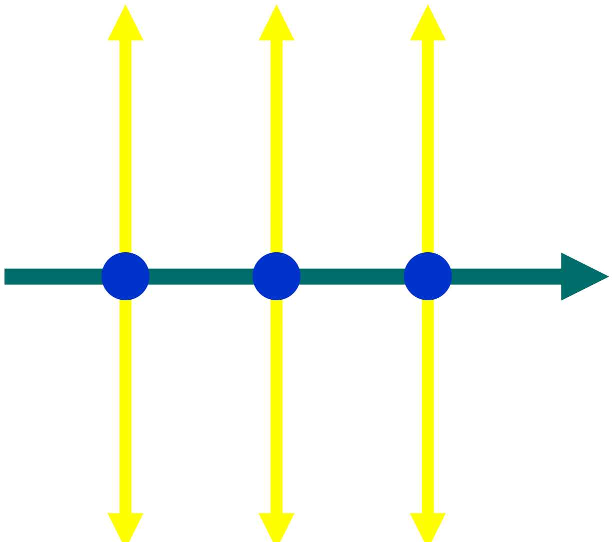
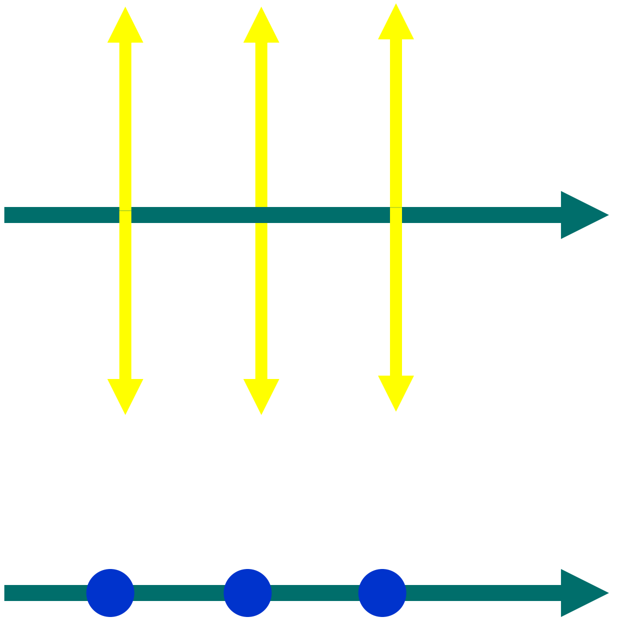
- The electric and magnetic fields are always perpendicular to one another.
- EM Radiation travels at the speed of light in a vacuum (3.00×10^8 m/s).

Representation . . .

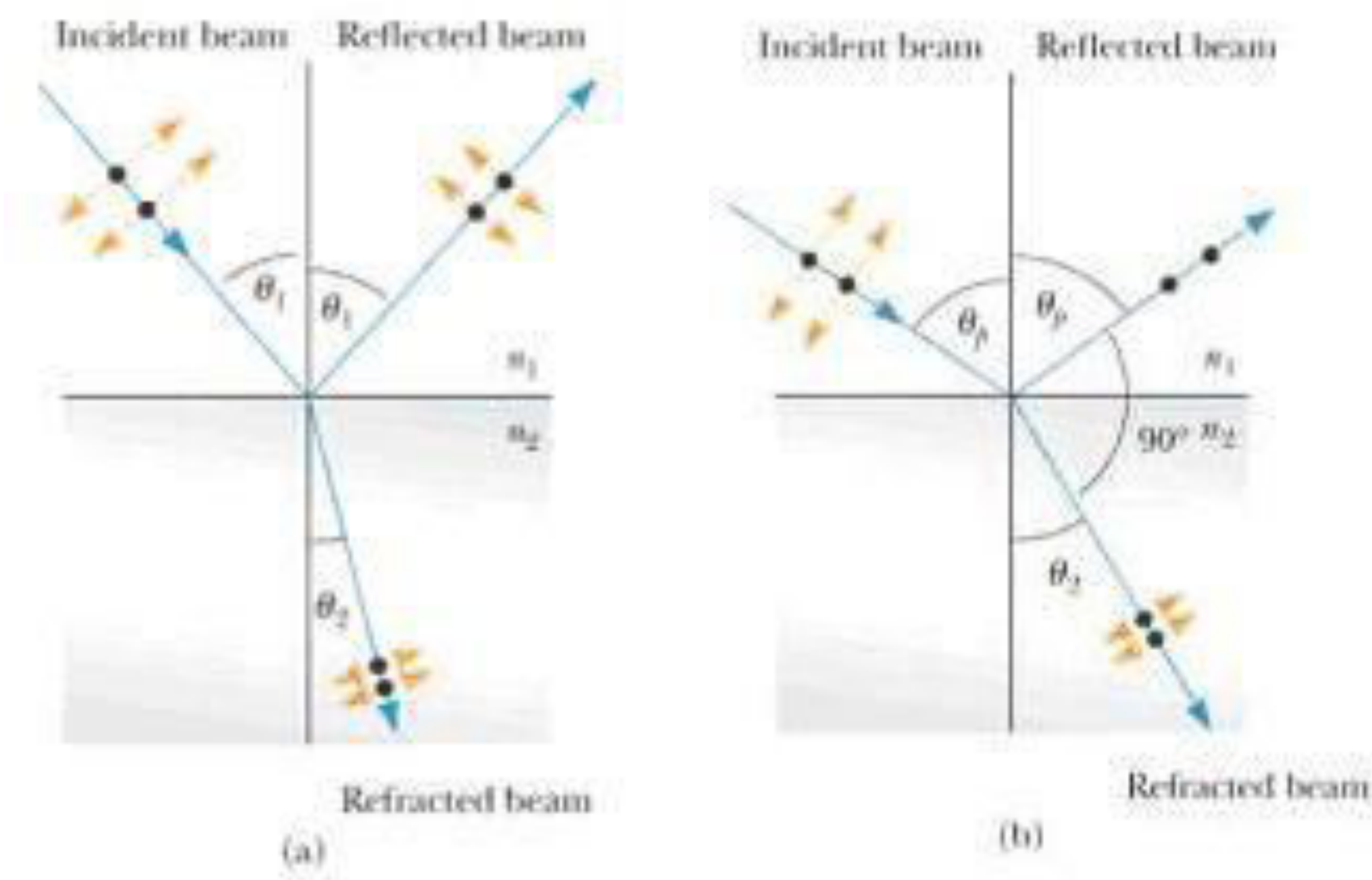


Unpolarized

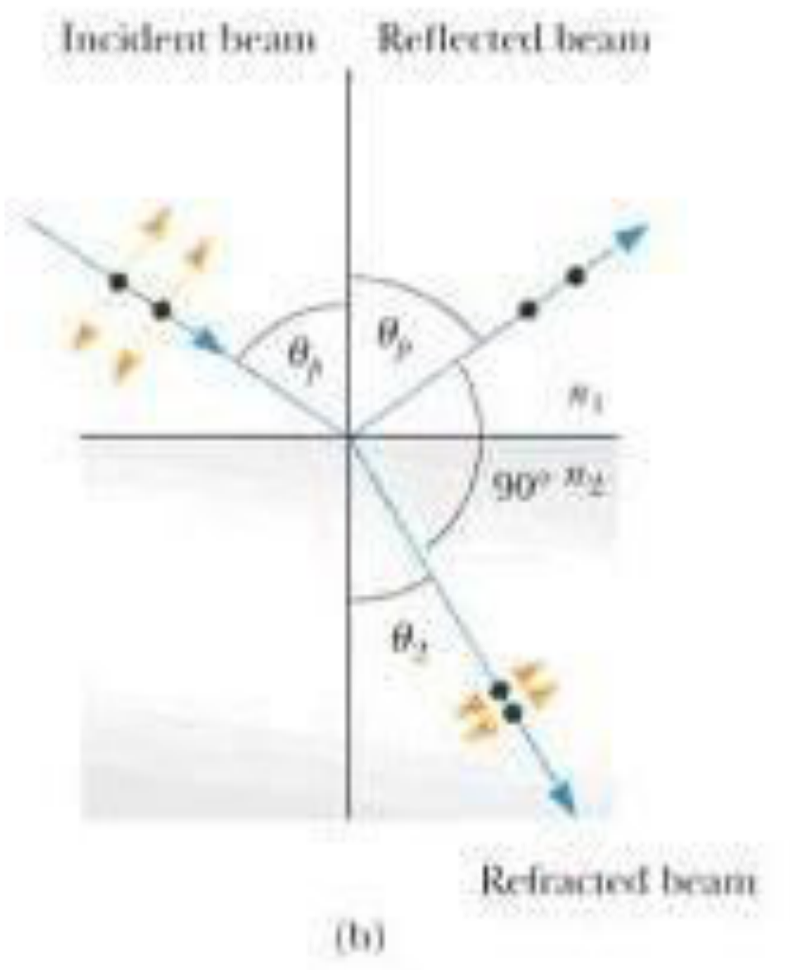


Polarized

Polarization by Reflection



Brewster's Angle



$$\angle i = \theta_P$$

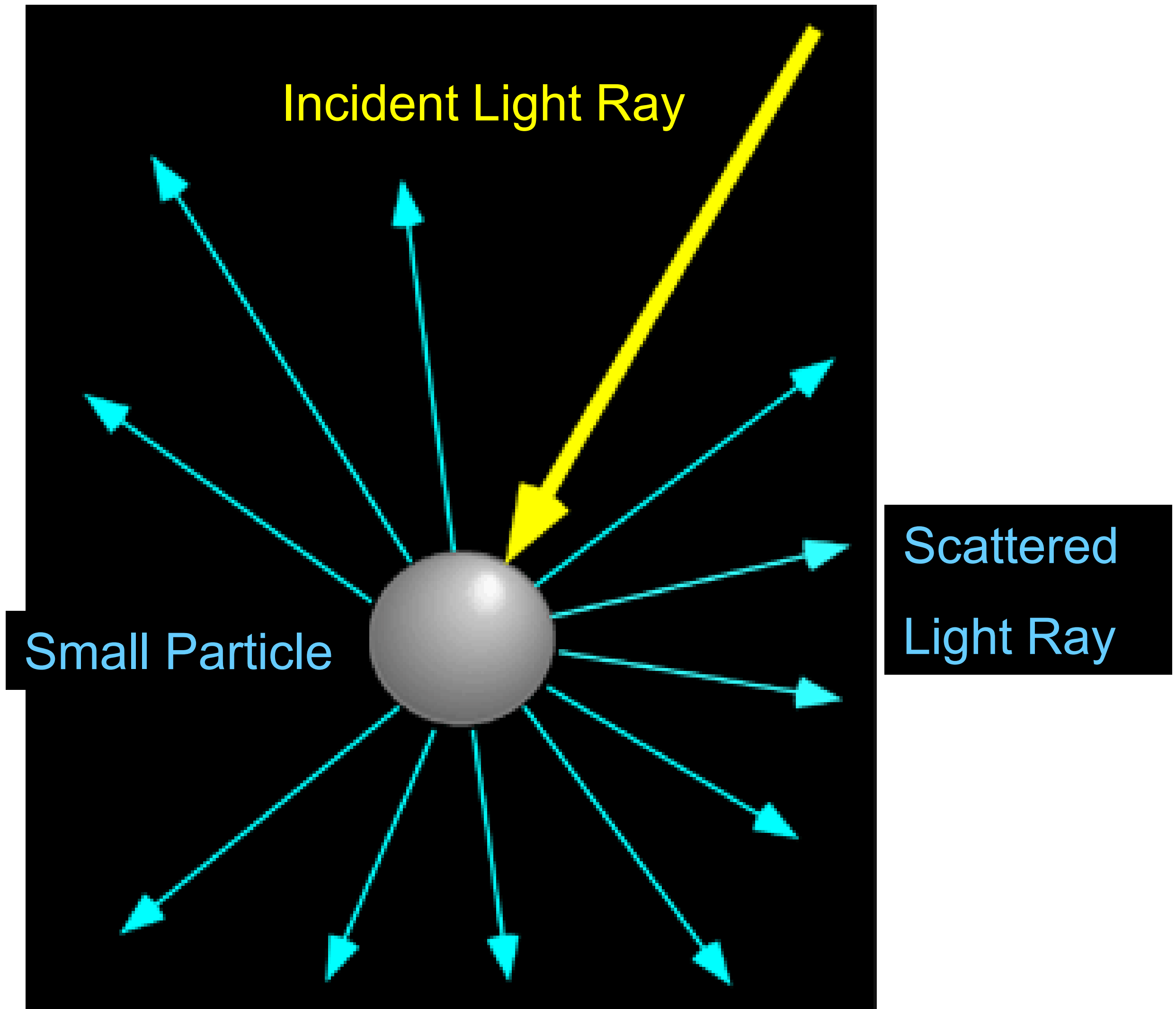
$$\angle r = 90° - \theta_P$$

$$n = \frac{\sin i}{\sin r}$$

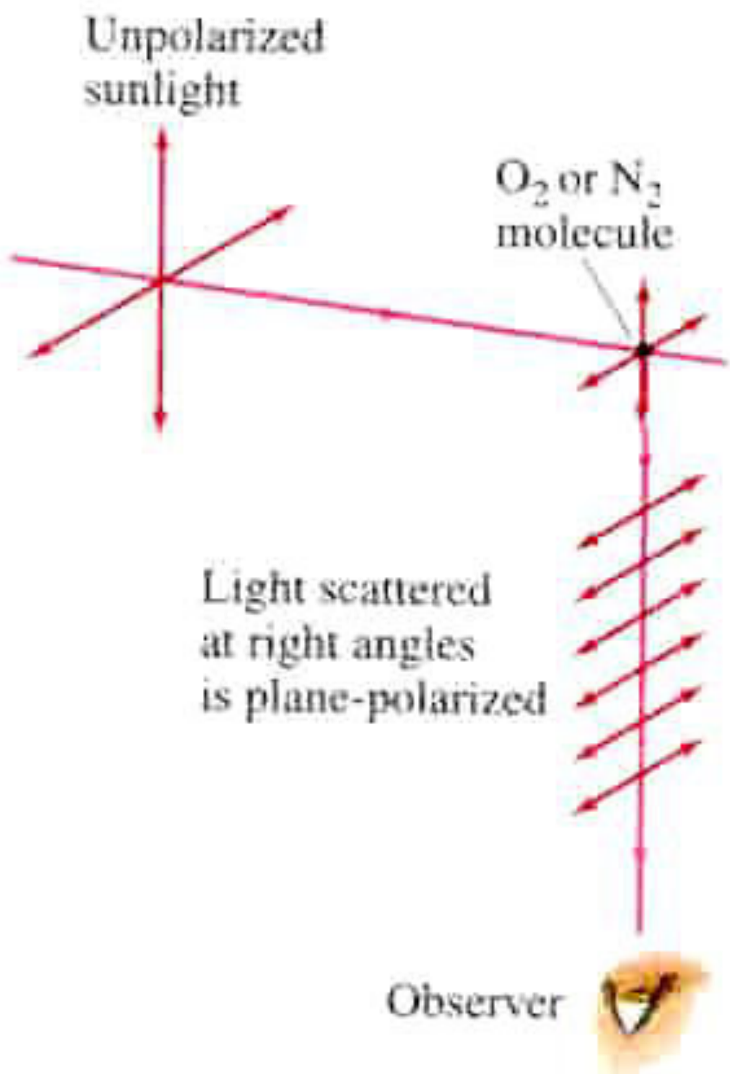
$$n = \frac{\sin \theta_P}{\sin (90° - \theta_P)} = \frac{\sin \theta_P}{\cos \theta_P}$$

$$n = \tan \theta_P$$

Scattering



Scattering of Sunlight

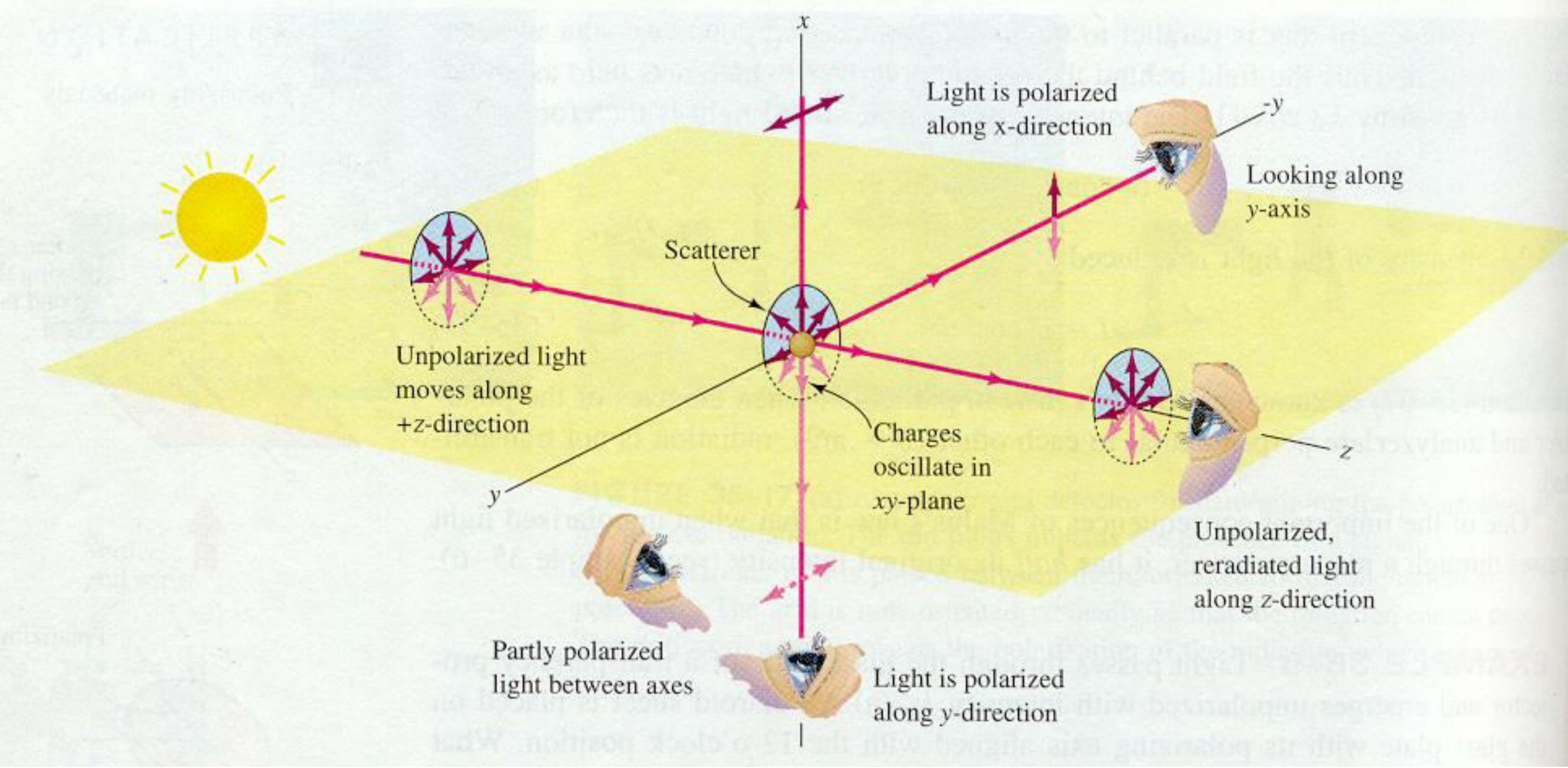


When unpolarised sunlight impinges on the molecules, the electric field of the EM wave sets the electric charges within the molecules into motion. The EM wave is **absorbed**.

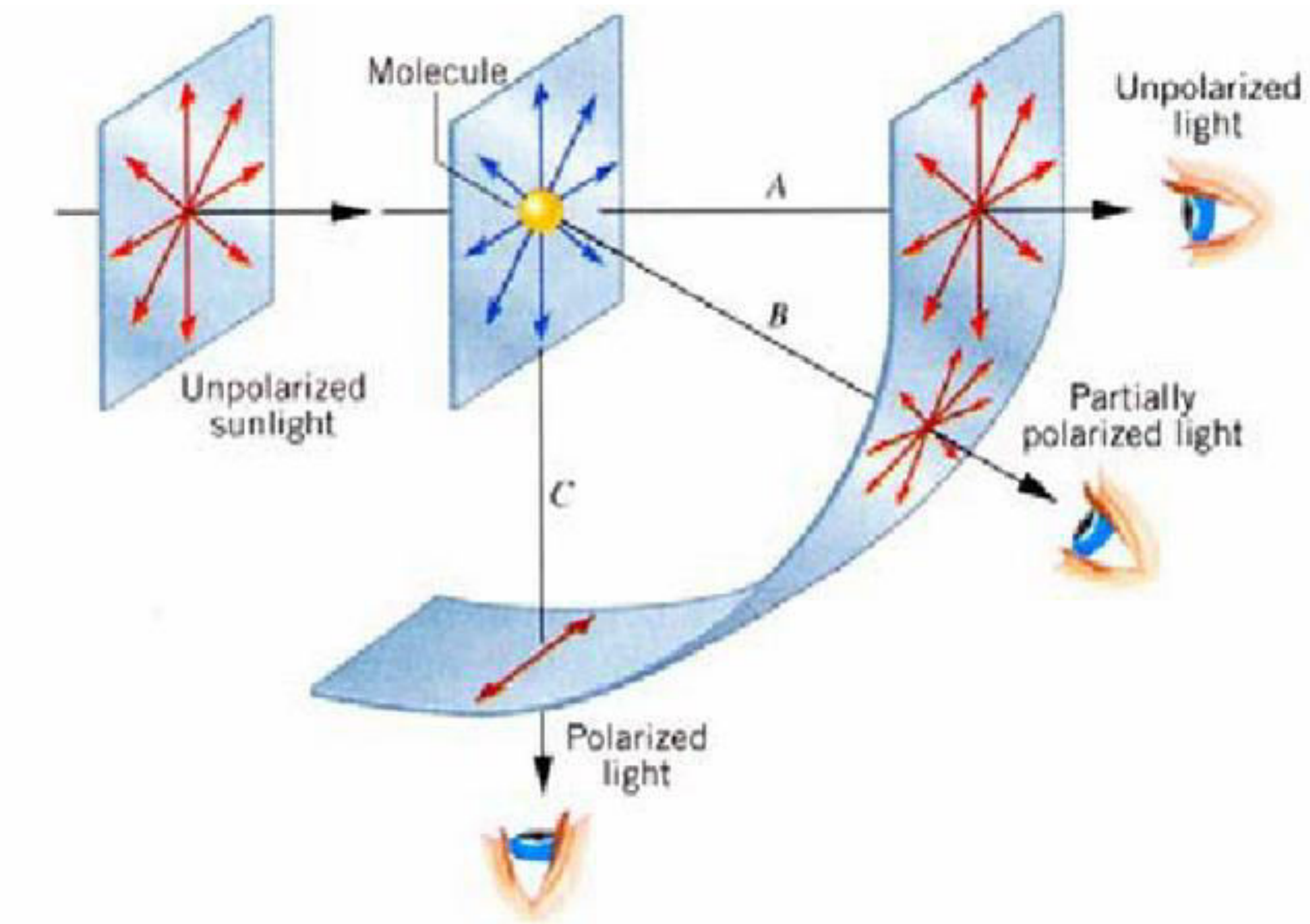
The molecules then quickly **re-emit light in all directions** since oscillating electric charges produce EM waves.

Because of the **transverse nature** of light, the electric field of the re-emitted waves should be in the plane that includes the line of oscillation, the **scattered light is completely plane polarized** with its electric vector in the direction shown.

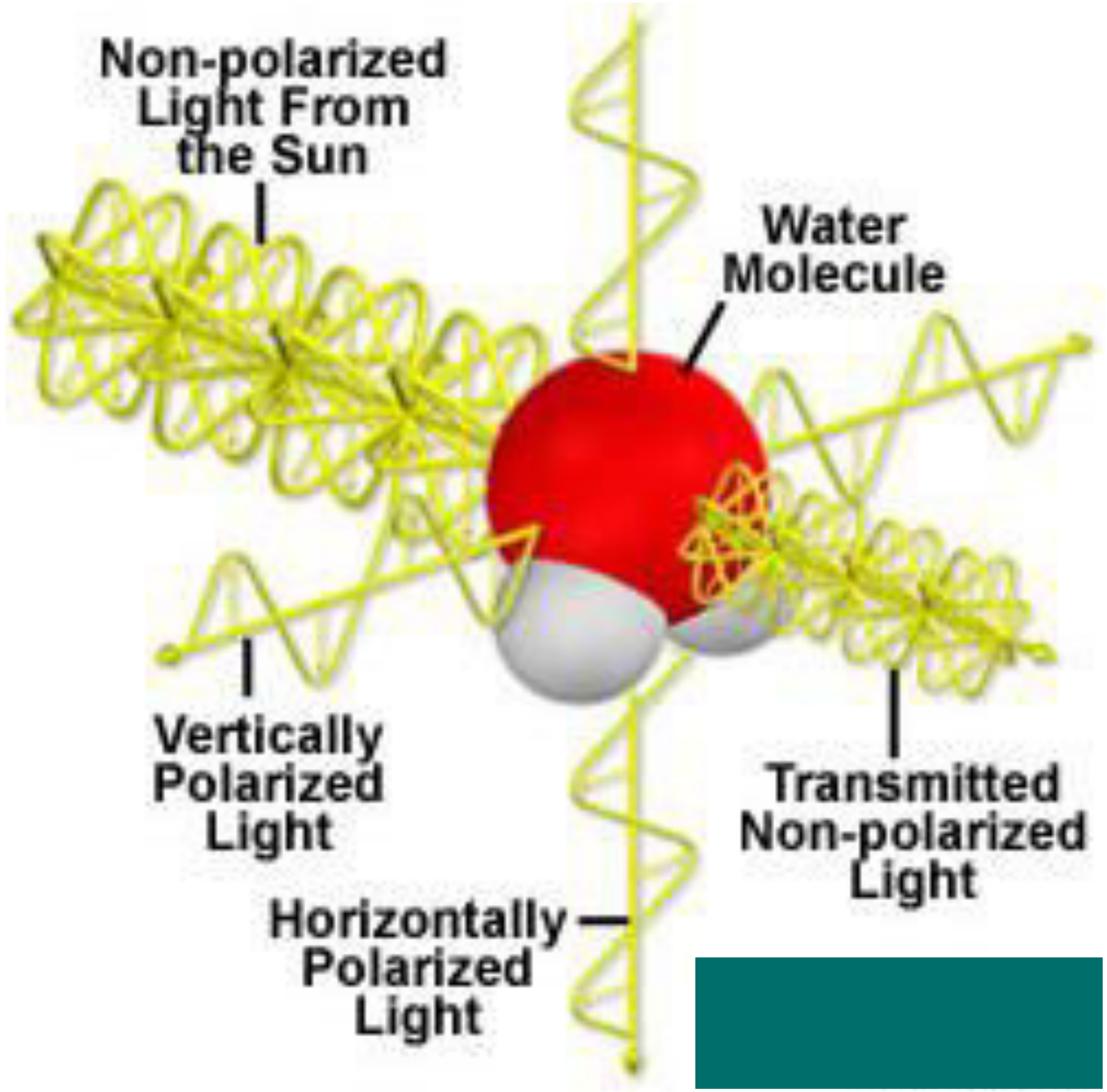
Scattering of Sunlight



Polarization by Scatterings

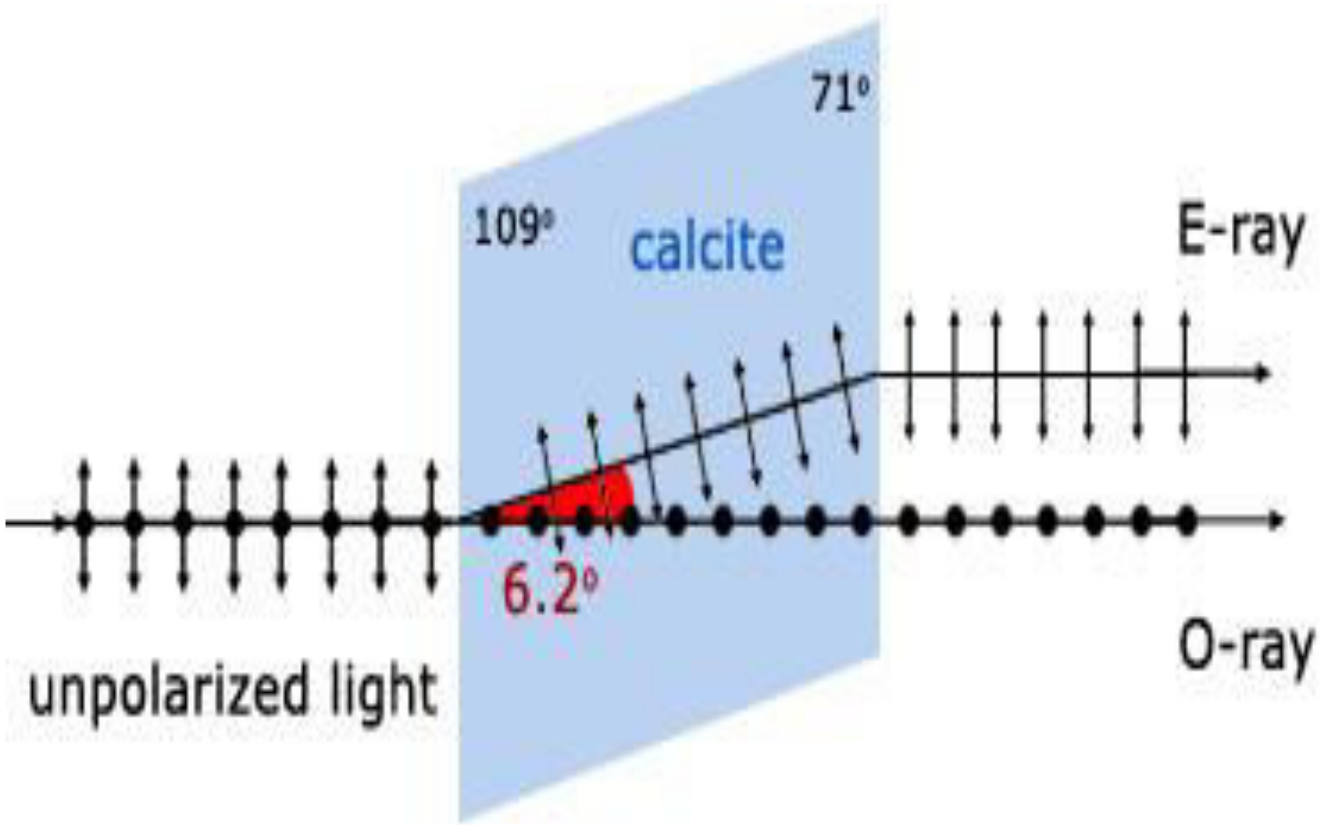


Polarized Light by Scattering



Polarisation by double refraction

- Two refracted beams emerge instead of one
- Two images instead of one



Polarisation by double refraction

Isotropic Medium : Velocity Spherical

Anisotropic Medium : Velocity ellipsoid

Uniaxial and Biaxial Crystals

Uniaxial : Calcite, Quartz

Biaxial: Mica

e-ray : Plane of polarisation is same as principal plane

e-ray in general does not obey the laws of refraction except in case of special cut of crystal (optic axis)

O-ray-Plane of polarisation is perpendicular to the principal plane

o-ray always obeys the laws of refraction

Linear polarisation by double refraction

Positive and Negative uniaxial crystals

Quartz - Positive $(n_e - n_o) > 0$

$n_o = 1.5443$ $n_e = 1.5534$

$n_e > n_o$

$v_e < v_o$

For sodium D lines

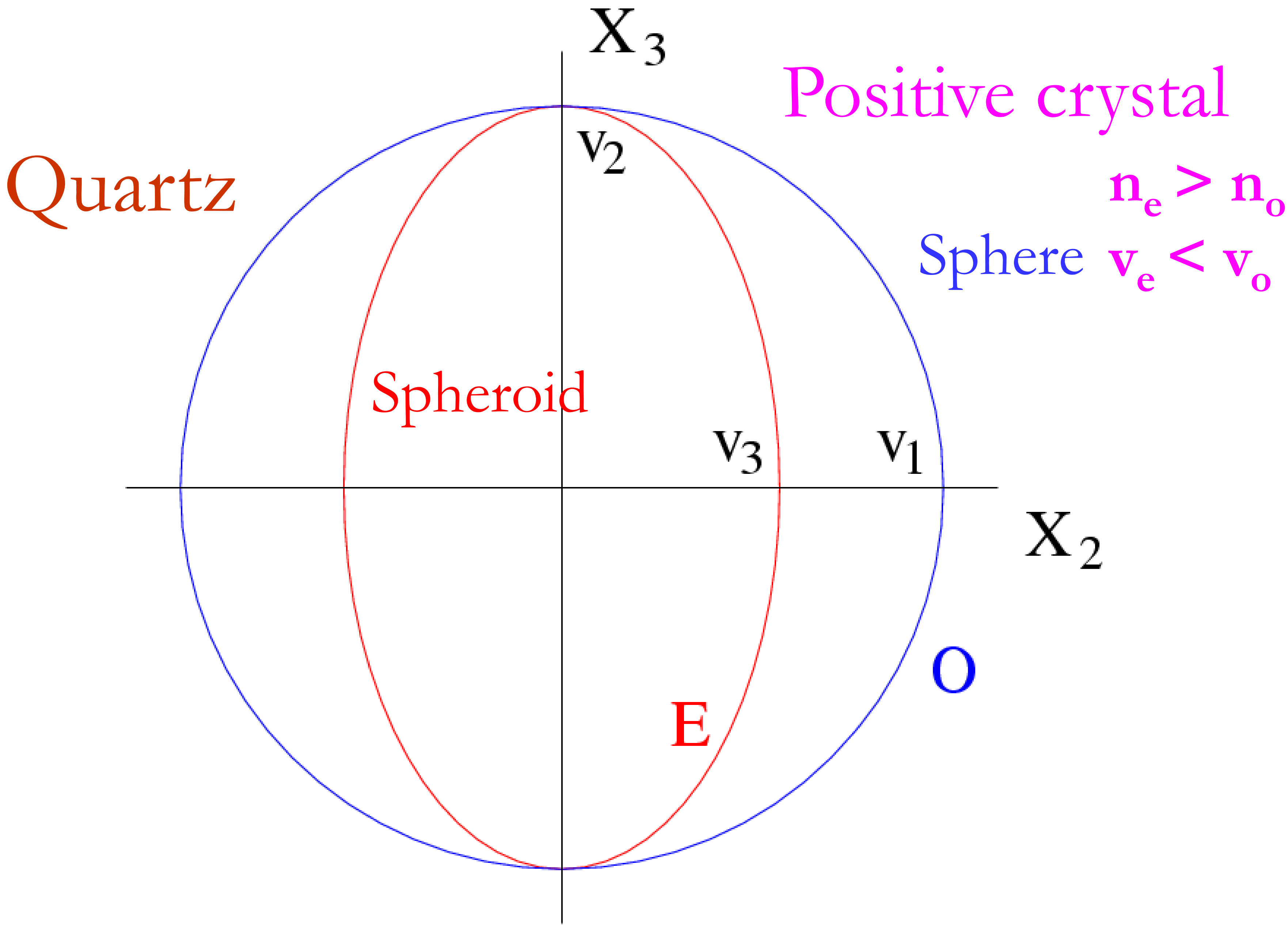
Calcite - Negative $(n_e - n_o) < 0$

$n_o = 1.6584$ $n_e = 1.4864$

$n_e < n_o$

$v_e > v_o$

Velocity or Refractive index is the same along the OPTIC AXIS for o-ray and e-ray.



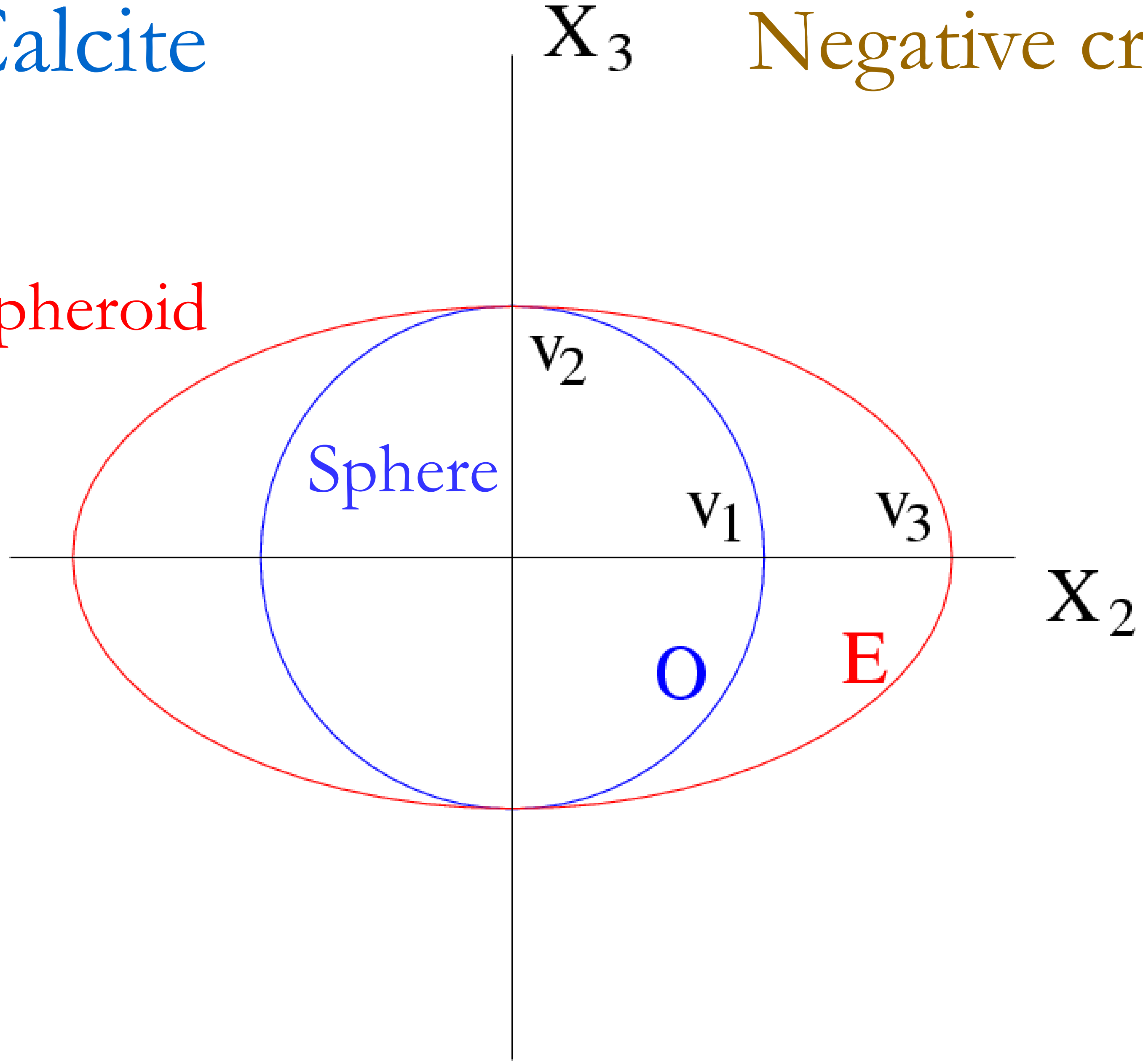
Quartz
Positive crystal
$n_e > n_o$
Sphere $v_e < v_o$
X_3
v_2
Spheroid
v_3
v_1
X_2
O
E

Calcite

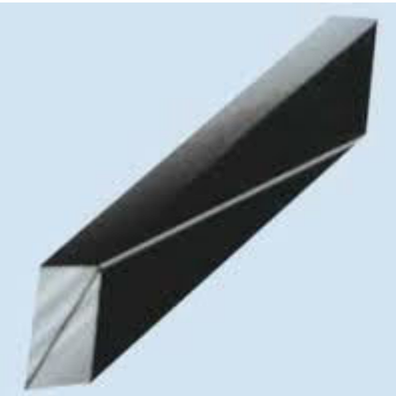
Negative crystal

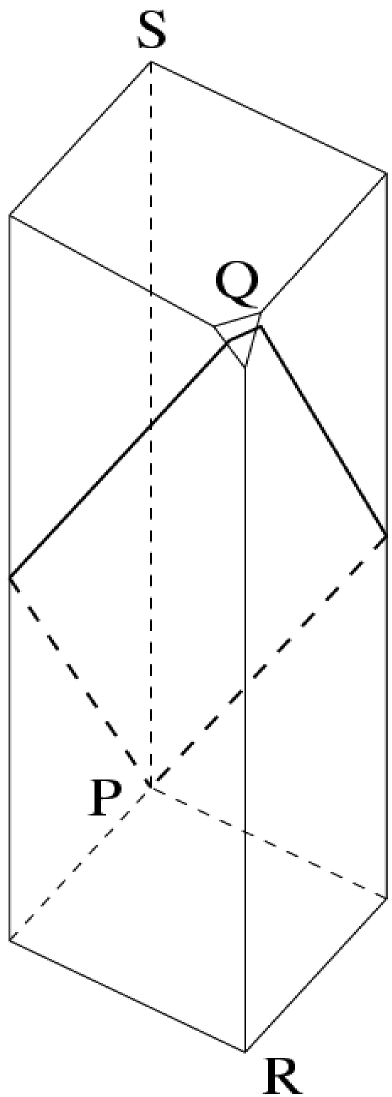
$n_e < n_o$

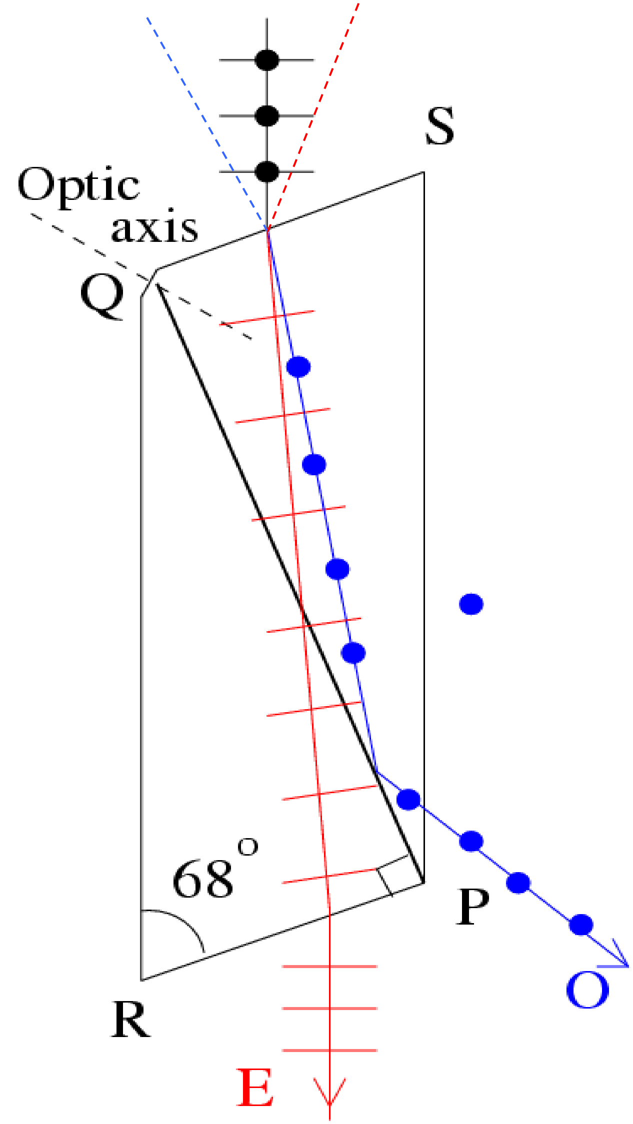
$v_e > v_o$



Nicol prism







Calcite

$n_o = 1.6584$

$n_e = 1.4864$

Canada balsam

$n = 1.55$

Question ?

- Why is the sky blue in the day and red at sunsets?

The sky is blue because . . .

- The tiny particles in the atmosphere (dust, clumps of air molecules, microscopic water droplets) are better at scattering shorter wavelength blue light than the longer wavelength red light.
- As sunlight passes through the atmosphere, the scattered blue light give the atmosphere an overall blue glow.

The sunset is red because . . .

- At sunrise and sunset, sunlight enters our atmosphere at a shallow angle and travels a long distance before reaching our eyes.
- During this long passage, most of the blue light is scattered away and virtually all that we see coming to us from the sun is its red and orange wavelengths.

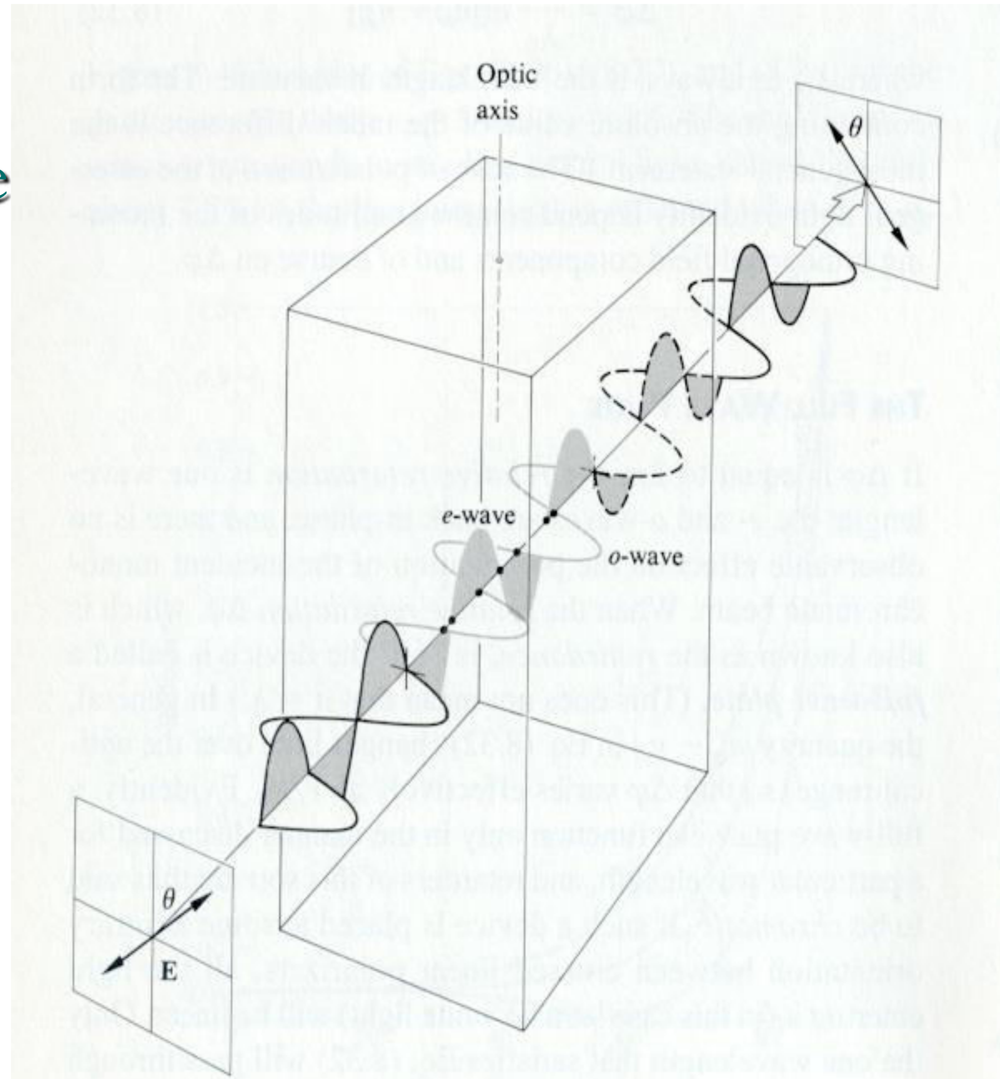
Retarders

- In retarders, one polarization gets ‘retarded’, or delayed, with respect to the other one. There is a final phase difference between the 2 components of the polarization. Therefore, the polarization is changed.

- Most retarders are based on birefringent materials (quartz, mica, polymers) that have different indices of refraction depending on the polarization of the incoming light.

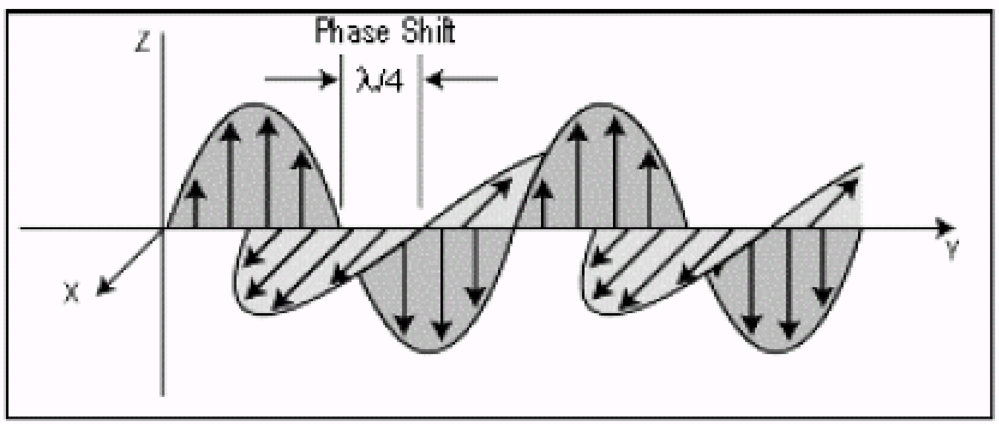
Half-Wave plate (I)

- Retardation of ½ wave or 180º for one of the polarizations.
- Used to flip the linear polarization or change the handedness of circular polarization.



Quarter-Wave plate (I)

- Retardation of ¼ wave or 90° for one of the polarizations



C. Circularly Polarized Light

- Used to convert linear polarization to elliptical.