POLARISATION

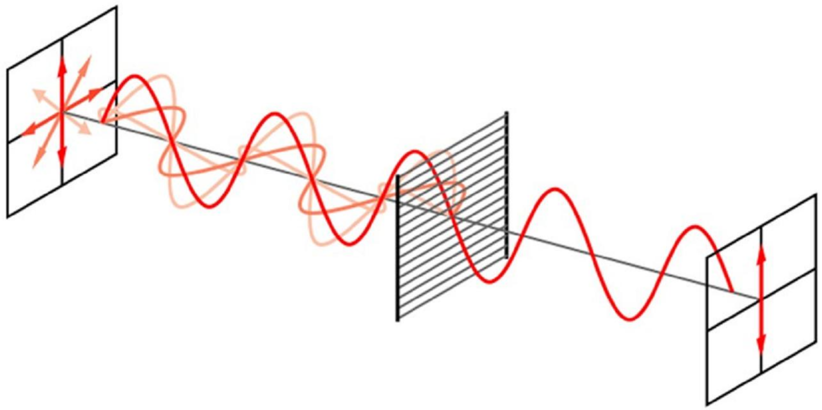
Polarisation

The phenomenon due to which vibrations of light waves are restricted in a particular plane is called polarisation.

In an ordinary beam of light from a source, the vibrations occur normal to the direction of propagation in all possible planes. Such beam of light called unpolarised light.

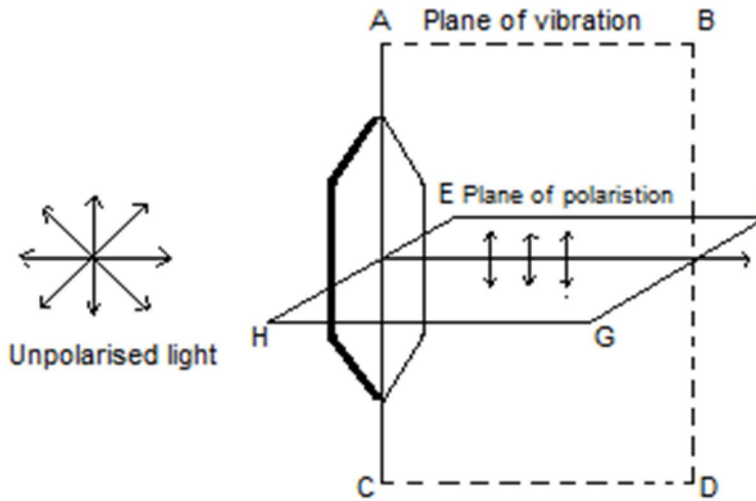
If by some methods (reflection, refraction or scattering) a beam of light is produced in which vibrations are confined to only one plane, then it is called as plane polarised light.

Hence, polarisation is the phenomenon of producing plane polarised light from unpolarised light.



In plane polarised light, the plane containing the direction of vibration and propagation of light is called plane of vibration.

Plane which is perpendicular to the plane of vibration is called plane of polarisation.



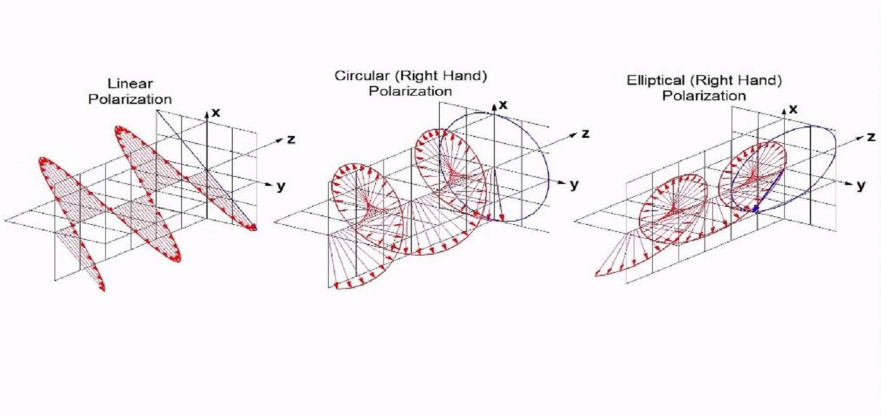
In above diagram plane ABCD represents the plane of vibration and EFGH represents the plane of polarisation.

There are three type of polarized light

1) Plane Polarized Light

2) Circularly Polarized Light

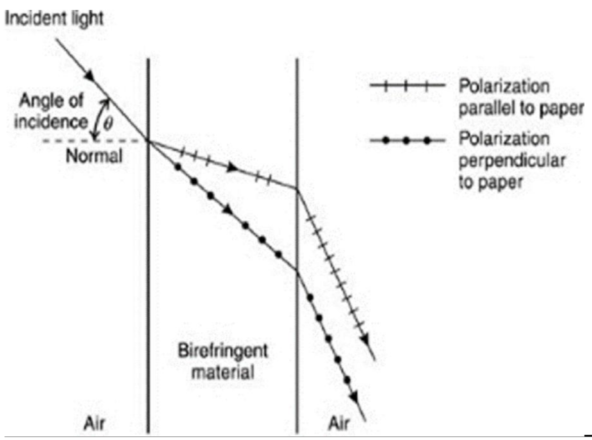
3) Elliptically Polarized Light



Polarised light can be produced by either reflection, refraction, selective absorption, scattering or by double reflection

Double refraction or birefringence

When ordinary light is allowed to pass through a calcite or quartz , it splits into two refracted beams(O-ray &E –ray) and both are plane polarized lights.



Huygen's theory of double refraction

According to Huygen's theory, a point in a doubly refracting or birefringent crystal produces 2 types of wavefronts.

The wavefront corresponding to the O-ray is spherical wavefront. The ordinary wave travels with same velocity in all directions and so the corresponding wavefront is spherical.

The wavefront corresponding to the E-ray is ellipsoidal wavefront. Extraordinary waves have different velocities in different directions, so the corresponding wavefront is elliptical.

Negative crystals

Negative crystals are crystals in which refractive index corresponding to E-Ray (n_E) is less than the refractive index corresponding to O-Ray (n_O) in all directions except for Optic axis.

The E-Ray travels faster than O-Ray except along the Optic axis.

The spherical O-Wavefront is entirely within the ellipsoidal E -Wavefront.

Ex: Calcite , Tourmaline ,Ruby ...

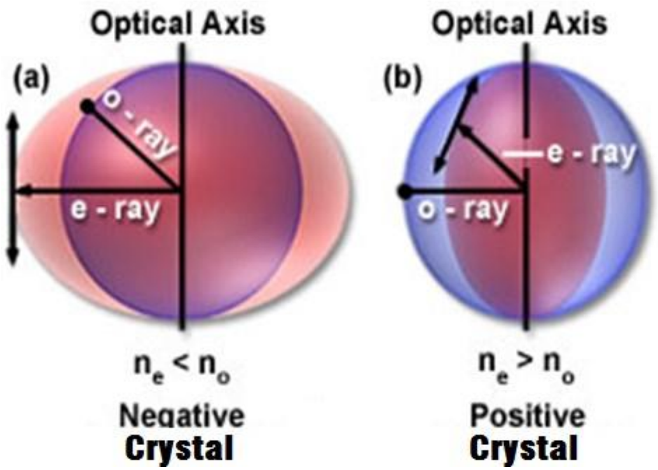
Positive crystals

Positive crystals are crystals in which refractive for O-Ray is less than that for E-Ray(n_0<n_E).

The velocity of O-Ray is greater than or equal to the velocity of E-Ray.

The ellipsoidal E-wavefront is entirely within the spherical O-wavefront.

Example : Quartz (SiO_2), Sellaite (MgF_2),Rutile (TiO_2),...



Optic axis

Optic axis of a crystal is the direction along which a ray of transmitted light suffers no birefringence (double refraction).

Light propagates along optic axis with a speed independent of its polarization.

According to number of optic axes crystals are divided as : Uniaxial and Biaxial crystals.

Phase retardation plate

A doubly refracting uniaxial crystal plate of uniform thickness having refracting surfaces parallel to direction of optic axis and capable of producing a definite phase difference between the ordinary and the extraordinary ray, is called phase retardation plate.

A retardation plate is an optically transparent material which resolves a beam of polarized light into two orthogonal components; retards the phase of one component relative to the other; then recombines the components into a single beam with new polarization characteristics.

If n_O & n_E are refractive indices of O-ray & E- ray respectively, λ is wavelength of light and t is the thickness of retardation plate.

Then,

Path difference between O-ray & E- ray can be given by

$$\Delta = t\,(n_O - n_E)$$

And phase difference between O-ray & E- ray can be given by

$$\delta = \frac{2\pi}{\lambda} t\,(n_O - n_E)$$

Types of retardation plates

1) Quarter wave plate
2) Half wave plate

1) Quarter wave plate

A doubly refracting uniaxial crystal plate having refracting faces parallel to the direction of the optic axis, having a thickness such that it creates a path difference of $\lambda/4$ or a phase difference of $\pi/2$ between the O-ray and the E-ray is called Quarter wave plate.

For quarter wave plate :

Path difference, $\Delta = t\,(n_O - n_E) = \lambda/4$

where λ is the wavelength of the incident light.

Thickness, $t = \frac{\lambda}{4(n_O - n_E)}$

Uses of quarter wave plate

If linearly polarized light is incident on a quarter-wave plate at 45° to the optic axis, then the light is divided into two equal electric field components. One of these is retarded by a quarter wavelength. This produces circularly polarized light.

If circularly polarized light is incident on quarter wave plate at 45° to the optic axis then it produces linearly polarized light.

If linearly polarized light is incident on quarter wave plate other than 45° to the optic axis then it produces elliptical polarized light.

2) Half wave plate

A doubly refracting uniaxial crystal plate having refractive faces parallel to the direction of the optic axis ,having a thickness such that it creates a path difference of $\lambda/2$ or a phase difference of π between the O-ray and the E-ray is called a Half wave plate.

For quarter wave plate:

Path difference, $\Delta = t(n_O - n_E) = \lambda/2$

where λ is the wavelength of the incident light.

Thickness, $t = \frac{\lambda}{2(n_O - n_E)}$

A retarder that produces a $\lambda/2$ phase shift is known as a half wave retarder.