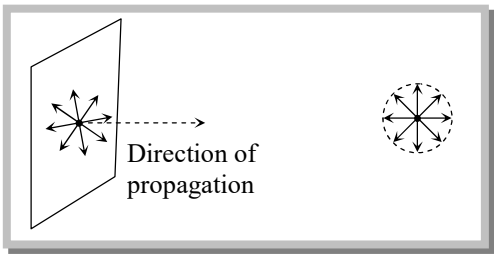
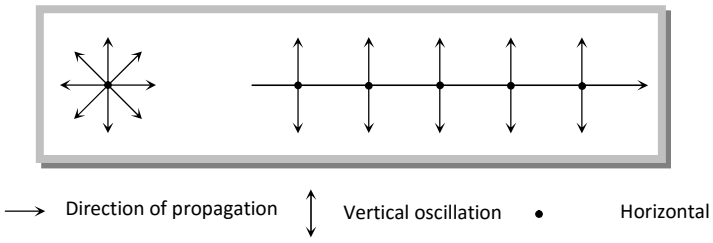
Polarization of Light.

Light propagates as transverse EM waves. The magnitude of electric field is much larger as compared to magnitude of magnetic field. We generally prefer to describe light as electric field oscillations.

(1) Unpolarised light

The light having electric field oscillations in all directions in the plane perpendicular to the direction of propagation is called unpolarised light. The oscillation may be resolved into horizontal and vertical component.





(2) Polarized light

The light having oscillations only in one plane is called Polarized or plane polarized light.

(i) The plane in which oscillation occurs in the polarized light is called plane of oscillation.

(ii) The plane perpendicular to the plane of oscillation is called plane of polarization.

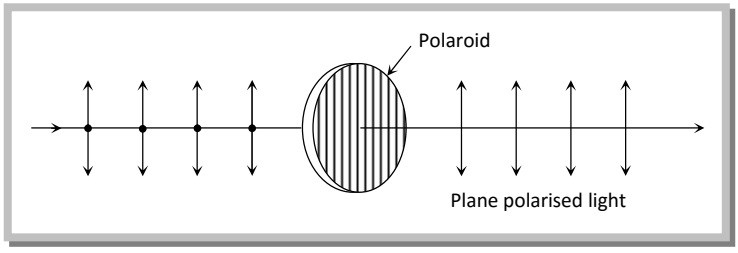
(iii) Light can be polarized by transmitting through certain crystals such as tourmaline or Polaroid's.

(3) Polaroid's

It is a device used to produce the plane polarized light. It is based on the principle of selective absorption and is more effective than the tourmaline crystal.

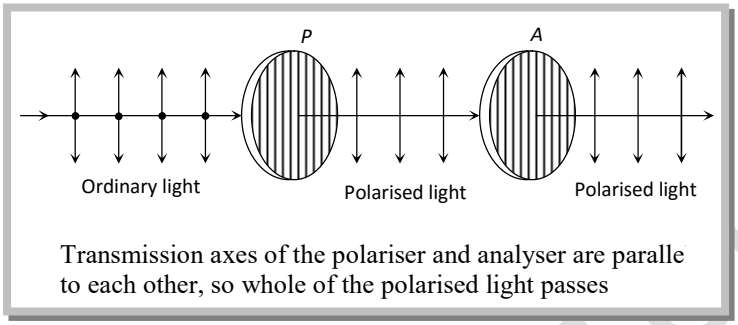
or

It is a thin film of ultramicroscopic crystals of quinine idosulphate with their optic axis parallel to each other.

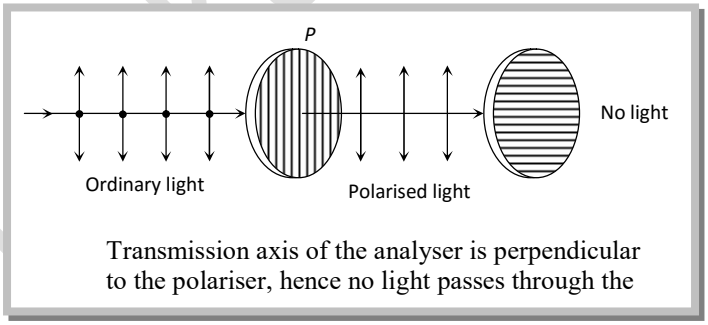


(i) Polaroid's allow the light oscillations parallel to the transmission axis pass through them.

(ii) The crystal or Polaroid on which unpolarised light is incident is called polarizer. Crystal or Polaroid on which polarized light is incident is called analyzer.



Transmission axes of the polariser and analyser are paralle to each other, so whole of the polarised light passes

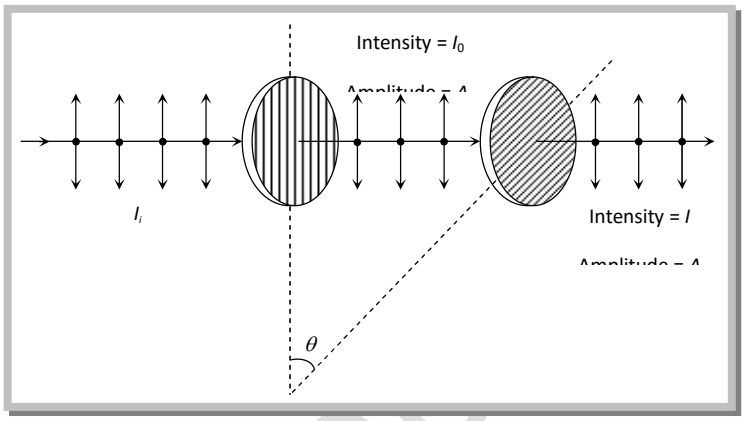


Transmission axis of the analyser is perpendicular to the polariser, hence no light passes through the

Note: When unpolarised light is incident on the polarizer, the intensity of the transmitted polarized light is half the intensity of unpolarised light.

(4) Malus law

This law states that the intensity of the polarized light transmitted through the analyzer varies as the square of the cosine of the angle between the plane of transmission of the analyzer and the plane of the polarizer.



(i) $I = I_0 \cos^2\theta$ and $A^2 = A_0^2 \cos^2\theta \Rightarrow A = A_0 \cos\theta$

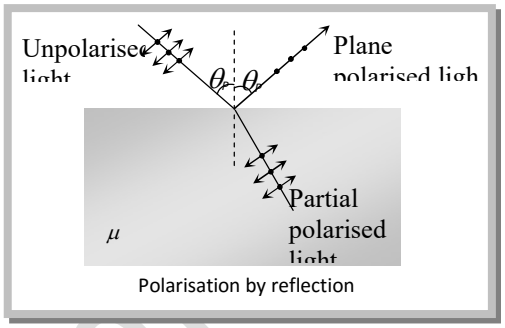
If $\theta = 0^o$, $I = I_0$, $A = A_0$, If $\theta = 45^o$, $I = \frac{I_0}{2}$, $A = \frac{A_0}{\sqrt{2}}$, If $\theta = 90^o$, $I = 0$, $A = 0$

(ii) If $I_i =$ Intensity of unpolarised light.

So $I_0 = \frac{I_i}{2}$ i.e. if an unpolarised light is converted into plane polarized light (say by passing it through a plaroid or a Nicol-prism), its intensity becomes half. and $I = \frac{I_i}{2}\cos^2\theta$

Note: Percentage of polarization $= \frac{(I_{max} - I_{min})}{(I_{max} + I_{min})} \times 100$

(5) Brewster's law: Brewster discovered that when a beam of unpolarised light is reflected from a transparent medium (refractive index =μ), the reflected light is completely plane polarized at a certain angle of incidence (called the angle of polarization θ_p).



Polarisation by reflection

Also $\mu = \tan\theta_p$ Brewster's law

(i) For i <θP or i >θP

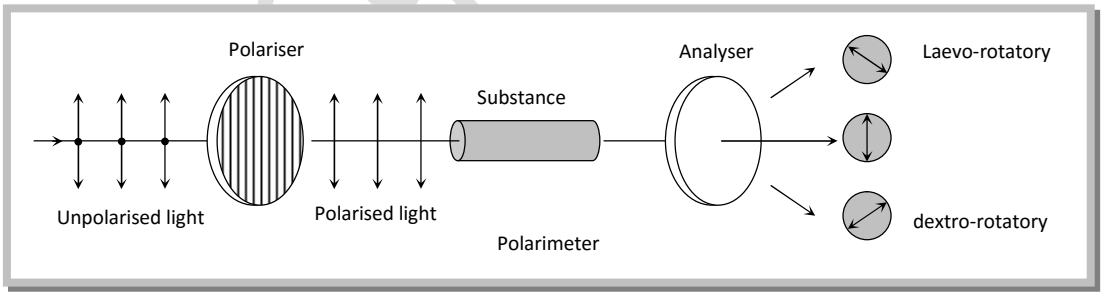
Both reflected and refracted rays becomes partially polarized

(ii) For glass $\theta_P \approx 57^o$, for water $\theta_P \approx 53^o$

(6) Optical activity and specific rotation

When plane polarized light passes through certain substances, the plane of polarization of the light is rotated about the direction of propagation of light through a certain angle. This phenomenon is called optical activity or optical rotation and the substances optically active.

If the optically active substance rotates the plane of polarization clockwise (looking against the direction of light), it is said to be dextro-rotatory or right-handed. However, if the substance rotates the plane of polarization anti-clockwise, it is called laevo-rotatory or left-handed.



The optical activity of a substance is related to the asymmetry of the molecule or crystal as a whole, e.g., a solution of cane-sugar is dextro-rotatory due to asymmetrical molecular structure while crystals of quartz are dextro or laevo-rotatory due to structural asymmetry which vanishes when quartz is fused.

Optical activity of a substance is measured with help of polarimeter in terms of 'specific rotation' which is defined as the rotation produced by a solution of length 10 cm (1 dm) and of unit concentration (i.e. 1

g/cc) for a given wavelength of light at a given temperature. i.e. $[\alpha]^{\lambda}_{t^{o}C} = \frac{\theta}{L \times C}$ Whereθ is the rotation in length L at concentration C.

(7) Applications and uses of polarization

(i) By determining the polarizing angle and using Brewster's law, i.e. $\mu = \tan\theta P$, refractive index of dark transparent substance can be determined.

(ii) It is used to reduce glare.

(iii) In calculators and watches, numbers and letters are formed by liquid crystals through polarization of light called liquid crystal display (LCD).

(iv) In CD player polarized laser beam acts as needle for producing sound from compact disc which is an encoded digital format.

(v) It has also been used in recording and reproducing three-dimensional pictures.

(vi) Polarization of scattered sunlight is used for navigation in solar-compass in Polar Regions.

(vii) Polarized light is used in optical stress analysis known as 'photo elasticity'.

(viii) Polarization is also used to study asymmetries in molecules and crystals through the phenomenon of 'optical activity'.