Polarization :-

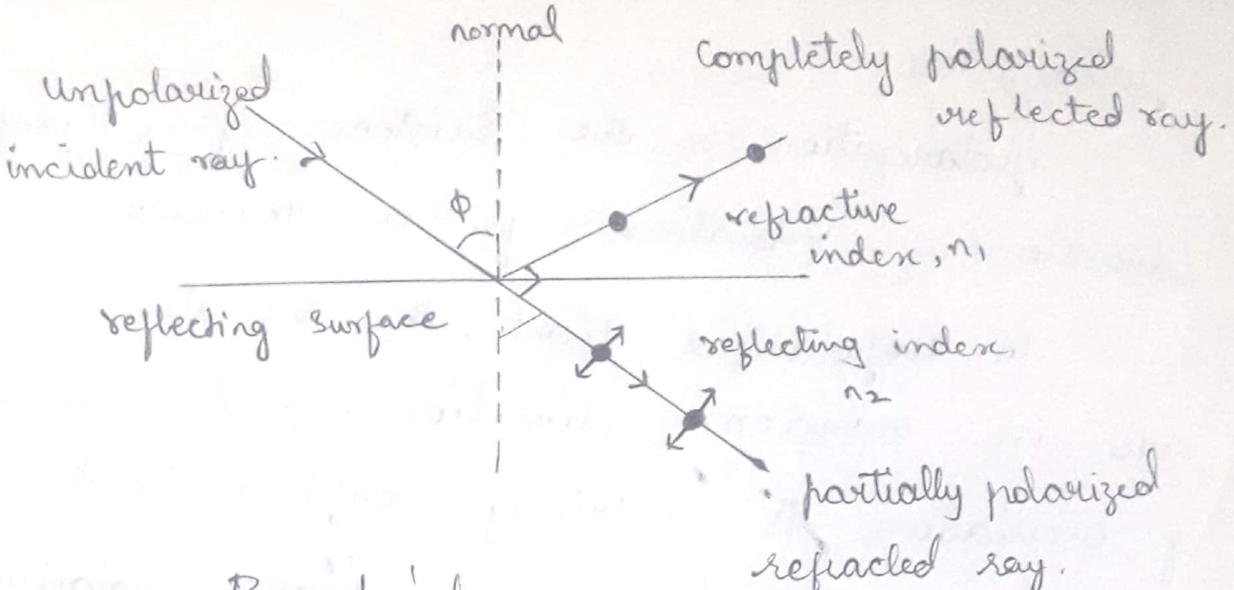
Polarization is the Existence of a preferred directions of vibration for a transverse wave.

In unpolarized light, the vibration of $\bar{E}$ or $\bar{B}$ are in random direction. If the direction of oscillation is strictly confined to the plane the wave is said to be plane polarized or linearly polarized. The plane containing $\bar{E}$ and $\bar{K}$ is called the plane of vibration and the plane containing $\bar{H}$ and $\bar{K}$ is called the plane of polarization.

Production of polarized light.

Polarized light may be produced from unpolarized light by four phenomena.

1. Reflection.
2. Selective absorption / Transmission.
3. Double Refraction.
4. Scattering



Brewster's law.

When unpolarized light is incident on a reflecting surface, the light can be resolved in two components. The component of the electric field parallel to this plane is termed p-like (parallel) and the component prependicular to this plane is termed s-like (perpendicular).

At Brewster's angle, the reflected ray has only s-component which is 15% and the refracted ray is a mixture of both s and p components.

From snells law

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{\sin \theta}{\sin r}$$

we know

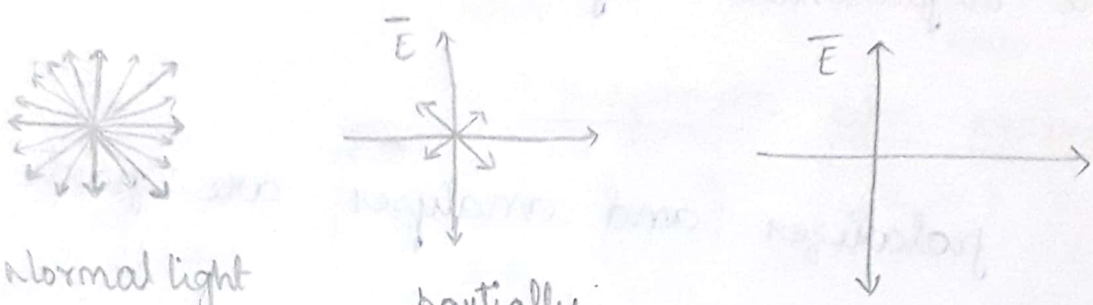
$$\theta_p + 90 + r = 180,$$

$$r = 90 - \theta_p$$

$$\frac{\sin \theta_p}{\sin(90 - \theta_p)} = \frac{n_2}{n_1} = \frac{\sin \theta_p}{\cos \theta_p}$$

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

where θ_p is Called Brewster's angle.



Normal light

partially polarized light

plane polarized light

polarization. Fig: 2.

Selective Absorption / Transmission.

~~The plate P is polari~~

Ordinary light also Called as unpolarized light, Consists of a very large number of vibration in all planes with equal probablity at right angles to the direction of propagation. Hence, the plane polarized is represented ~~as~~ by a star or arrows and dots as shown fig: 2 plane polarized light has the vibrations along a straight line.

If the direction q vibration is parallel to the plane q paper, it is represented by a straight line arrow. If the ~~Vibrate~~ direction q vibration is prependicular to the plane q the paper, it is represented by dot.

polarizer and analyser.

polarizer and analyser are parts q optical instrument.

A polarizer Can filter light waves in order to generate polarization q light. In other words a polarizer Can generate plane polarized light from light waves Coming from a normal light source.

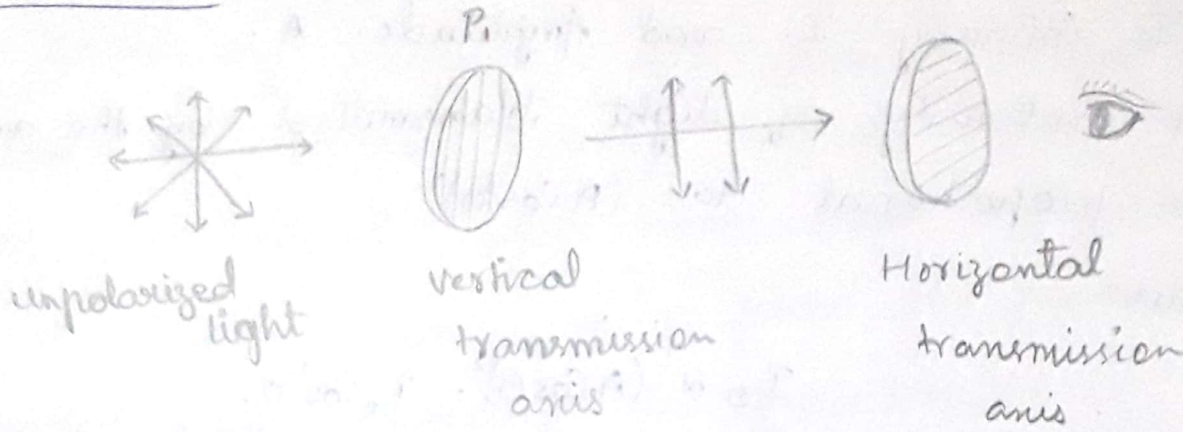
The analyser act as a second polarizer.

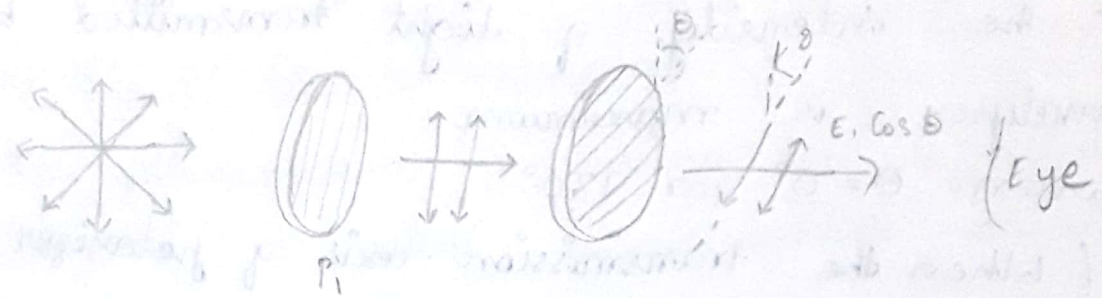
Although both are use as light filters, but difference in their application

Main difference b/w polarizer and analyser is that polarizer produces plane polarized light whereas analyzer Can be use to check whether the light has been polarized or not.

Scanned with CamScanner

Malus law





Malus law.

In 1809, Malus discovered a law regarding the intensity of light transmitted by the analyzer. According to ~~mauls~~ Malus, when a completely plane polarized light is incident on the analyzer, 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.

Let a beam of unpolarized light having intensity I_0 pass through a polarizer. The emerging beam is linearly polarized in the direction of transmission axis of the polarizer with intensity I and Amplitude. A.

The intensity of light transmitted by the analyzer is proportional to $(A \cos\theta)^2$

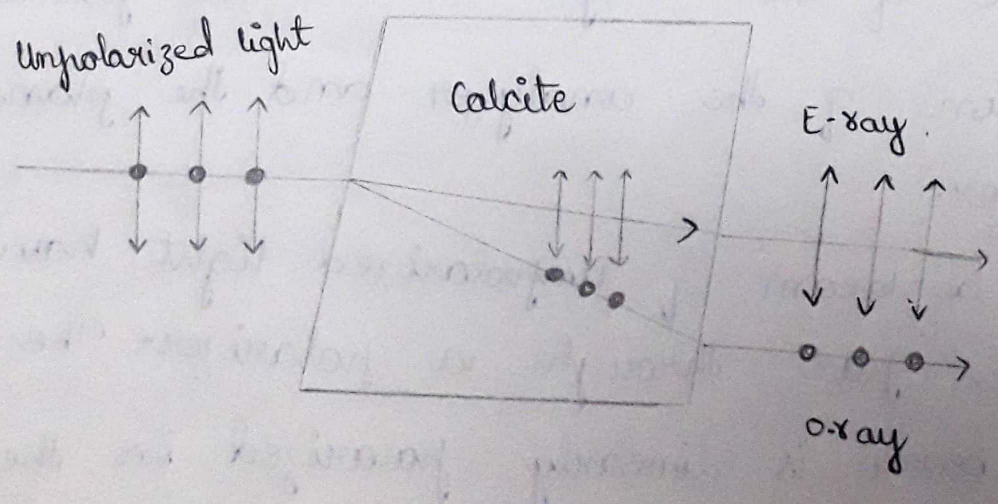
Thus

$$I_\theta \propto (A\cos\theta)^2 = I_0 \cos^2\theta.$$

∴ The intensity of light transmitted by the analyser is maximum when $\theta = 0°$ or $180°$ (When the transmission axis of polarizer and analyzer are parallel).

∴ The intensity of the light transmitted by the analyzer is zero when $\theta = 90°$ or $270°$ (When the transmission axis of polarizer & analyzer are perpendicular (⊥) to each other)

Double Refraction.



The double refraction phenomenon was discovered in 1669 by Erasmus Bartholines during his studies on Calcite ($CaCO_3$) crystal which is known more as Iceland spar. When light is incident on a Calcite Crystal, it is found to produce two refracted rays differing in properties.

Birefringence or Double refraction:-

The phenomenon of Causing two refracted rays by a Crystal is Called birefringence or double refraction.

The two rays formed in double refraction are linearly polarized in mutually perpendicular directions. One of them obey Snell's law of refraction and hence is Called an ordinary ray or O-ray and has an index of refraction μ_o.

The other ray which doesn't obey Snell's law is Called an extraordinary ray or e-ray and has an index of refraction μ_e.

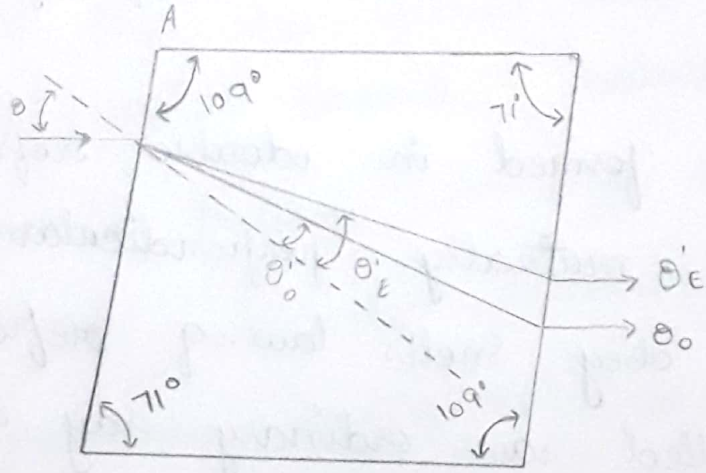
They Emerge together from the crystal and hence the light is Unpolarized. But, if one of the rays is eliminated, the light transmitted by the crystal will be a linearly polarized light.

Double refraction is exhibited by all transparent anistropic materials. The crystal showing this phenomenon are called birefringent or doubly refracting crystals. The bifringence of a crystal is defined as

$$\Delta \mu = \mu_e - \mu_o$$

In (+ve) crystals, $\mu_e > \mu_o$ and the reverse for negative crystals.

Nicol prism.



Nicol prism.

principle: We know that when an ordinary light is transmitted through a calcite crystal, it splits in ordinary and extraordinary beams which are completely plane polarized with vibration in two mutually perpendicular planes.

In 1828, Nicol eliminated the ordinary beam by utilizing the phenomenon of total interna reflection at thin flim of Canada balsam separated the two pieces of Calcite. This device is known as Nicol prism.

Construction: A Calcite Crystal whose length is three times as its width is taken. the end faces of this crystal are grounded in such a way that the angles in the principal Section become 68° and 112° instead of 71° and 109°. This is done to increase the field of view.

The Crystal is Cut into two pieces along the line PR and then two pieces are Cemented along the same line using Canada balsam. The refractive index of Canada balsam ($\mu = 1.55$) which lies between refractive indices for the ordinary ($\mu_o = 1.65$) and extraordinary ($\mu_e = 1.45$) ray for Calcite.

Working:- When a beam of light AB enters the face PS in direction parallel to the longside; it is doubly refracted into ordinary plane polarized beam BO and extraordinary plane polarized beam BE. From the value of refractive indices given above, it is clear that Canada balsam act as a rarer medium for an ordinary ray and denser medium for extraordinary ray.

Moreover, the dimensions of the Crystal are so chosen that the angle of incidence of ordinary ray at the Calcite - Canada balsam surface becomes greater than the corresponding critical angle ~~68~~. 69°. Under these conditions ordinary ray is completely reflected at Calcite - Canada balsam surface and is absorbed by the tube containing the Nicol prism.

Thus, only extraordinary plane polarized ray is transmitted.

<u>Limitations</u>:- The Nicol prism acts as a polarizing device effectively when the incident beam is confined within the angle of 14° on either side of AB.

<u>Uses</u>: Nicol prism can be used both as polarizer and an analyser. When two Nicol are arranged co-axially then the first Nicol which produces plane polarized light is known as polarizer while the second which analyses the polarized

which analyses the polarized light is known as analyser.

Quarter wave plane (QWP)-

A quarter wave plate is a thin plate of birefringent crystal having its refracting faces parallel to the direction of optic axis and its thickness is adjusted such that it introduces a quarter wave ($\lambda/4$) path difference between the e-ray and o-ray propagating through it. The optical path difference between the e-ray and o-ray is given by

$$t(\mu_e - \mu_o) = \lambda/4$$

This gives the thickness of the plate.

$$t = \frac{\lambda}{4(\mu_e - \mu_o)}$$

A path difference of $\lambda/4$ is equivalent to a phase difference of $\pi/2$ or $90°$. It means that a quarter wave plate producing elliptically or circularly polarized light.

Half wave plate (HWP)

A half wave plate is a thin plate of ~~bir~~ birefringent crystal having its refracting faces parallel to the direction of optic axis and its thickness is adjusted such that it introduces a half wave ($\lambda/2$) path difference between the e-ray & o-ray propagating through it. The O.P.D b/w e-ray and o-ray is given by

$$t(\mu_e - \mu_o) = \lambda/2$$

This give the thickness of the plate.

$$t = \frac{\lambda}{2(\mu_e - \mu_o)}$$

A path difference of $\lambda/2$ is equivalent to a phase difference of π or 180°. It means that a half wave plate introduces a phase differences of 180° between the e-ray and o-ray.

Consequently, a half wave plate rotates the plane of polarization of the incident polarized light.