3. POLARIZATION

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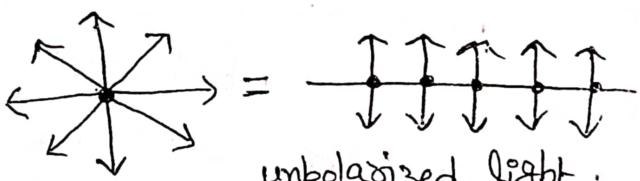
The phenomenon of interference and diffraction established the wave nature of light. this phenomenon do not reveal the character of wave motion i.e whether it is longitudinal or transverse. The phenomenon of polarization established that light waves are transverse waves.

According to Maxwell's e.m theory light waves are e.m waves which are transverse in nature. ~~It~~ Electric & magnetic field vectors vibrating perpendicular to the direction of wave propagation. Here the electric vector is responsible for the sensation of sight. Hence the electric vector vibration only are taken as light waves.

Unpolarized light :

"Light which has the same property in all directions (or) a light wave symmetrical about a direction is called unpolarized light (or) The light in which the electric field vector vibrates in all directions is referred as unpolarized light.



unpolarized light.

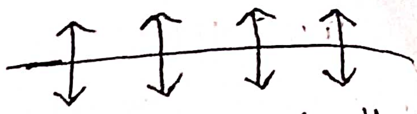
fig(a)

Ex: Light emitted by the sun, lamp, candle ....

Polarized light :-

"Light which has acquired the property of ~~one~~ one-sideness" (or) a light wave unsymmetrical about a direction is called polarized light". Shown in fig.(b)

a) If the direction of vibration (electric field vector direction) is parallel to the plane of paper, it is represented by a straight line arrow as shown in fig.



vibrations ||el to the plane of paper. (π components)

b) If the direction of vibration is $\perp^r$ to the plane of the paper, it is represented by dots as shown in fig.

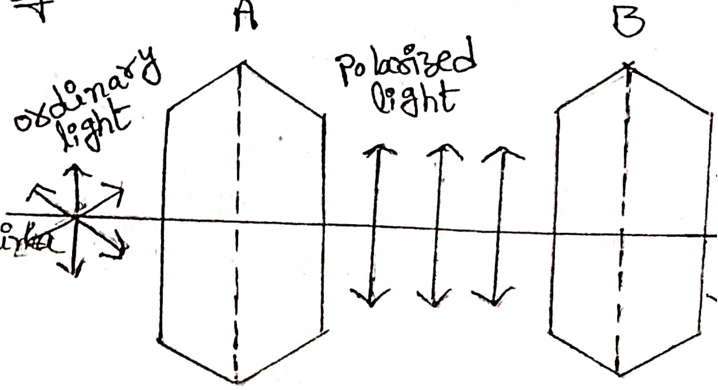
vibrations $\perp^r$ to the plane of paper. (σ components)

Polarization of light waves :-

The process of converting the unpolarized light into polarized light is called polarization.

To understand the concept of polarization, let us considering two identical tourmaline crystals A & B. These two are cut such that their planes parallel to their crystallographic axes.

When both are parallel to each other, the intensity of transmitted light from the second crystal is max. When the second crystal is rotating, the intensity of emergent light gradually decreases. When both crystals are $\perp^r$ to each other, the intensity of emergent light becomes zero.



In one complete rotation of second crystal we get two maxima and two minima.

From the above expt, it is clear that light undergoes some kind of change in its nature after passing through the crystal A. After passing through the crystal B, the light acquired the definite onesideness. This is possible, only when the waves are transverse. The Process of giving one-sideness is called Polarization.

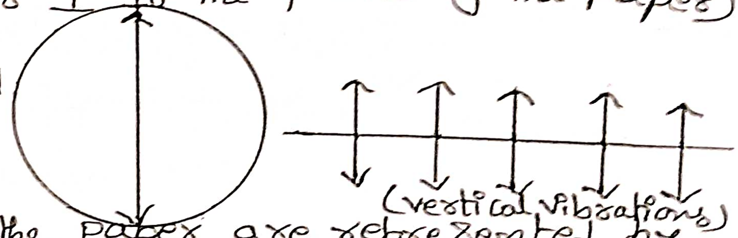
In the above expt first crystal is called Polarizer and second crystal is called Analyser.

Types of Polarized light and their representation:-

The Polarized light can be classified into

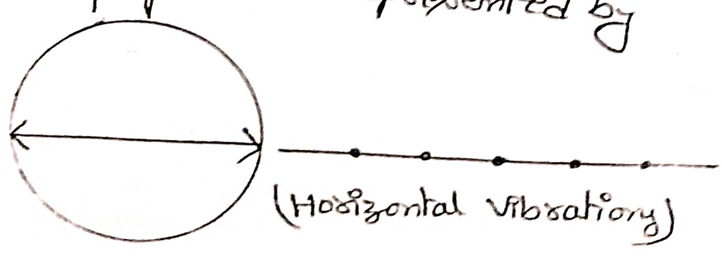
i) Plane polarized light (or) linearly plane polarized light:

It the vibrations are confined to a single plane (either in ||el to the plane of the paper or $\perp^{r}$ to the plane of the paper) then it is called plane polarised light.



The vibrations along the plane of the paper are represented by arrows shown in above fig(a).

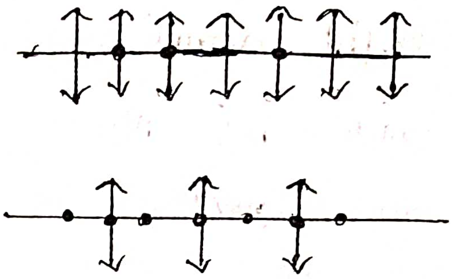
The vibrations $\perp^{r}$ to the plane of the paper are represented by dots shown in fig(b)



Plane

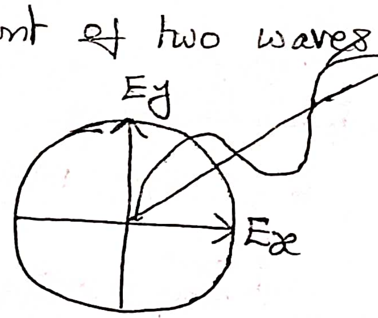
ii) Partially plane polarized light :

It the linearly polarized light contains small additional compo.. of ~~of~~ unpolarized light, it becomes partially plane polarized light. Then it is represented by ~~m~~ either more arrows and less dots (or) less arrows and more dots.



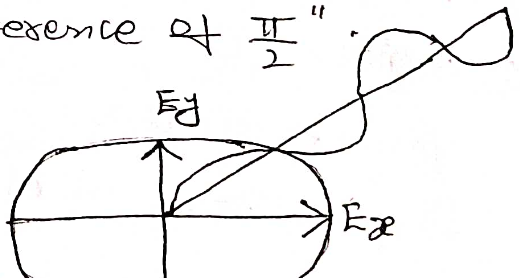
iii) circular Polarized light :

" circularly polarized light is the resultant of two waves of equal amplitudes, vibrating at right angles to each other and having a phase difference of $\frac{\pi}{2}$ ".



iv) Elliptically Polarized light :

" Elliptically polarized light is the resultant of two waves of unequal amplitudes vibrating at right angles to each other and having a phase difference of $\frac{\pi}{2}$ ".



NOTE:

Plane of vibration;

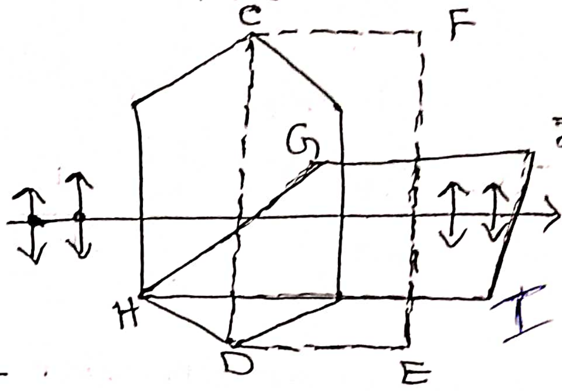
The vibrating electric vector E & the direction of wave propagation constitute a plane called the plane of vibration.

Plane of polarization;

The magnetic vector B & the direction of wave propagation ~~from~~ form a plane and is called the plane of ~~pb~~ polarization.

Plane of vibration and plane of Polarization:

When ordinary light passed through a tourmaline crystals the light is polarized and the vibrations are confined to a single plane. There are two planes in a crystal. "The plane in which the vibrations are confined is known as plane of vibration". This plane contains the direction of vibration as well as direction of propagation of light. Here CDEF plane of vibration.



The plane which has no vibrations is known as plane of polarization. It is $\perp^r$ to the plane of vibration. GHIJ represents the plane of polarization.

MALUS LAW:

Malus discovered one law. It gives the intensity of light which is transmitted by the analyzer.

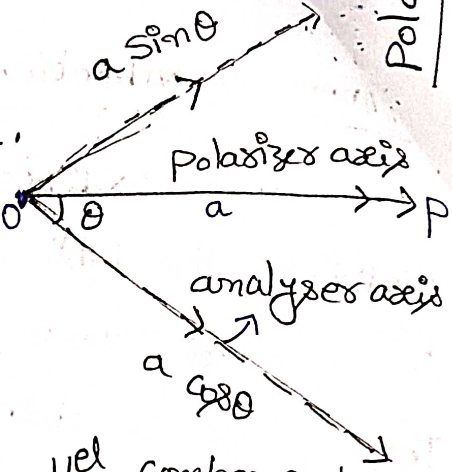
"This law states that the intensity of light transmitted by the analyzer is proportional to the square of the cosine of the angle between polarizer and analyzer axes".

i.e $\boxed{I \propto \cos^2\theta}$ $\boxed{I \propto \cos^2\theta}$

'θ' is the angle between polarizer and analyzer axes.

Let OP represents the amplitude of emergent light from the polarizer. 'a' is its amplitude.

This amplitude can be resolved into two components. $a\cos\theta$ & $a\sin\theta$. $a\cos\theta$ is component along the plane of analyser. $a\sin\theta$ is $\perp^r$ to the plane of analyser. Here the $\perp^r$ component $a\sin\theta$ is reflected and $\parallel^{el}$ component $a\cos\theta$ is transmitted by the analyser.



$\therefore$ The intensity of transmitted light through the analyser is

$$I = (a\cos\theta)^2$$

$$I = a^2\cos^2\theta$$

$$\therefore I = I_0\cos^2\theta \rightarrow (1)$$

I_0 is the intensity of plane polarised light incident on the analyser.

case i; when $\theta = 0$ i.e polariser & analyser axes are $\parallel^{el}$, the transmitted light is max i.e $I = I_0$.

case ii; when $\theta = 90°$ i.e P & A axes are $\perp^r$, the transmitted light is min i.e $I = 0$.

Production of Polarized light:

These are five methods to produce polarised light.

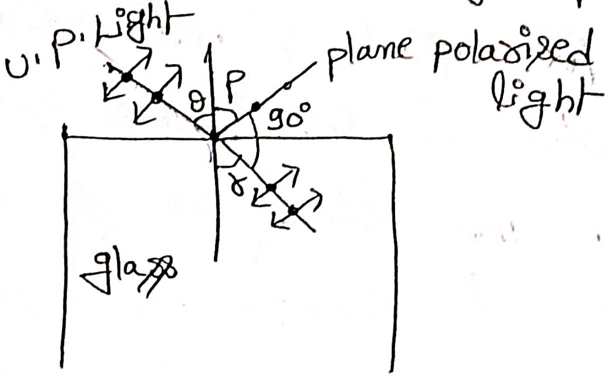
1. Polarization by reflection.
2. Polarization by refraction
3. Polarization by double refraction.
4. Polarization by selective absorption
5. Polarization by scattering.

Polarization by Reflection (Brewster's Law):-

This is the simplest way to produce plane polarised light according to this method.

"When ordinary light is reflected from the surface of a transparent medium like glass, it becomes partially polarised".

The degree of polarisation depends on angle of incidence. At certain angle of incidence the reflected light is completely polarised. The angle at which the light is completely polarized is called angle of polarization.



Brewster proved that the tangent of the angle of Polarization P is numerically equal to the refractive index of the medium.

$$\mu = \tan p \longrightarrow (1)$$

Proof:

From Brewster's law $\mu = \tan p = \dfrac{\sin P}{\cos P} \longrightarrow (1)$

From Snell's law $\mu = \dfrac{\sin i}{\sin r} = \dfrac{\sin P}{\sin r} \longrightarrow (2)$

(1) = (2)

$$\frac{\sin p}{\cos P} = \frac{\sin P}{\sin r}$$

$$\therefore \sin r = \cos P$$

$$\sin r = \sin(90^\circ - P)$$

$$\therefore r = 90^\circ - P$$

$$\boxed{r + P = 90^\circ}$$