polarization

The phenomenon of confining the vibration of light waves to a single plane perpendicular to its propagation is called polarization of wave.

Unpolarized light: The light having vibrations along all possible straight lines perpendicular to the direction of propagation of light is said to be unpolarized light. Light from the sun and other sources like glowing bulb, burning candle etc.

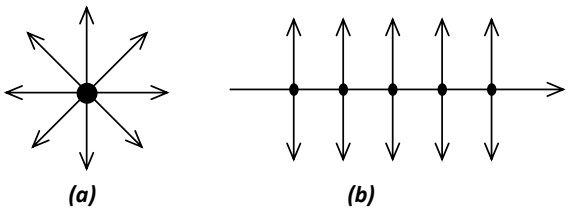

Fig-(a): *Vibration of ordinary (unpolarized) light*
(b) : *Representation of unpolarized light*

Polarized light: *the phenomenon in which the vibrations of ordinary or natural light are confined to a single plane is called* ***polarization of light*** *and such a light of one-sidedness is called* ***polarized light****.*

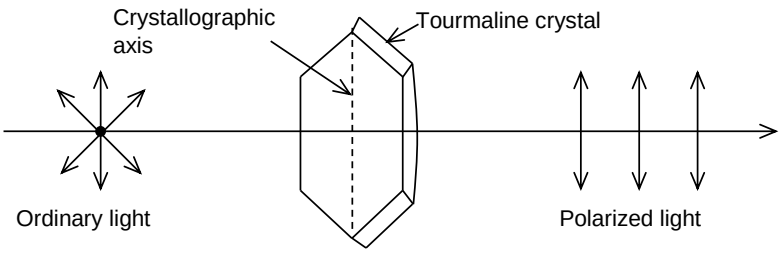

Fig-*Production of plane-polarized light*

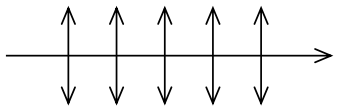

Fig- (a): *Polarized light vibrating in the plane of paper*

Fig-(b): *Polarized light vibrating perpendicular to the plane of paper*

Plane of vibration and plane of polarization:

The plane containing the optic axis in which the vibrations occur is known as plane of vibration. The plane which is at right angles to the plane of vibration and which contains the direction of propagation of the polarized light is known as the plane of polarization. Plane of polarization does not contain vibrations in it. In the Fig. PQRS represents the plane of vibration and EFGH represents the plane of polarization.

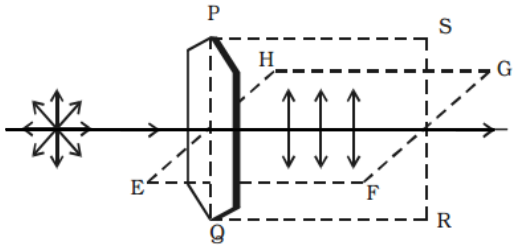

Fig.*Plane of vibration and plane of polarization*

Experimental Verification of Transverse Nature of Light

The phenomena of polarization of light proves that light waves are transverse wave. An experiment to illustrate the polarization of light is discussed below:

If we take a tourmaline crystal 'X' cut parallel to its crystallographic axis and allow a beam of unpolarized light to pass through it, the light is slightly coloured. If the crystal is rotated about the ray as an axis, the character of the transmitted light remains the same. If the emergent beam of light is further passed through a similar crystal 'Y' with its axis parallel to the 'X', light is almost completely transmitted through the crystal Y as shown in Fig-.When the crystal Y is rotated about an axis parallel to the incident light so that the axis of the two crystals are inclined to each other, the intensity of the emergent beam gradually decreases and when the axis of the two crystals X and Y are at right angles to each other, no light passes through the crystal Y as shown in Fig . If the second crystal Y is further rotated, light is again transmitted through it and attains maximum intensity when the axis of both crystals are again parallel. This experiment shows that light, after passing through the first crystal acquires a property which prevents it to pass through the second crystal, when it is in a definite position. It is because when a beam of light passes through the first crystal, the crystal absorbs vibrations in all directions except those parallel to its crystallographic axis. Hence, unabsorbed vibrations are transmitted and the transmitted light has vibrations in one direction only.

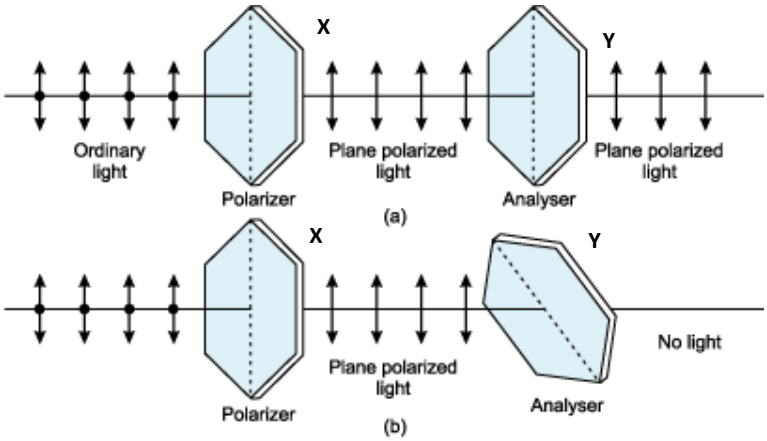

Fig- : *Experimental verification of transverse nature of light*

The light which has acquired the property of one-sidedness is called polarized light. Thus, we find that the intensity of light transmitted through 'Y' is maximum when axis of X and Y are parallel and minimum when they are at 90°. This experiment leads to the conclusion that light waves are transverse and not longitudinal. If light waves were longitudinal, there would not be any change in the intensity of light due to the rotation of crystal 'Y'.

Malus's Law

"When completely plane polarized light is incident on the analyzer, the intensity I of the light transmitted by the analyzer is directly proportional to the square of the cosine of angle between the transmission axes of the analyzer and the polarizer."

i.e $I \propto \cos^2\theta$.

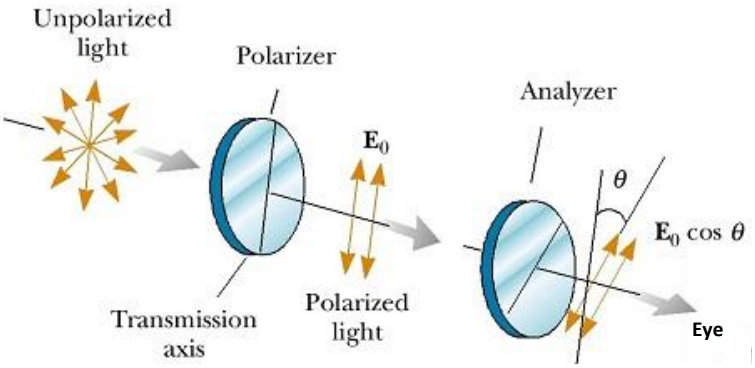

***Fig**-Polarization by selective absorption*

Polarization by Reflection: Brewster's Law

Whenever light is incident on the boundary between two media, some light is reflected in same medium and some is transmitted (undergoing refraction) into the second medium. At particular angle of incidence, called the *polarizing angle* θ_p, the reflected light is completely polarized in the direction perpendicular to the plane of incidence. when the angle of incidence is equal to the polarizing angle θ_p, the reflected ray and the refracted ray are perpendicular to each other; and this polarizing angle is also called *Brewster's angle*. the relation between polarizing angle and refractive index of the medium is called *Brewster's law* as:

"The tangent of angle of polarization is numerically equal to the refractive index of the medium."

If θ_p is the angle of polarization and 'μ' is the refractive index of the medium, then

$$\mu = \tan \theta_p$$

Proof: Let XY be the surface separating a transparent medium of refractive index 'μ' and air. A ray PO incident at the polarizing angle θ_p gets reflected along OQ and refracted along OR so that 'r' is the angle of refraction as shown in Fig

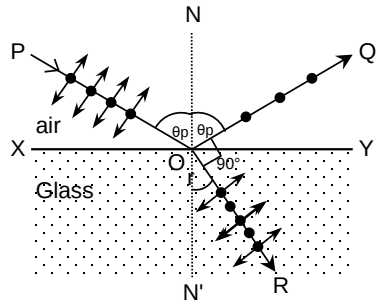

***Fig**-Polarization of light reflected from a transparent medium*

For polarizing angle (i.e. $i = \theta_p$) we get,

$\angle QOR = 90°$

From Fig We get

$$\theta_p + r = 90°$$

$$\therefore \quad r = 90° - \theta_p$$

By using snell's law, $\mu = \dfrac{\sin i}{\sin r} = \dfrac{\sin \theta_p}{\sin (90° - \theta_p)} = \dfrac{\sin \theta_p}{\cos \theta_p} = \tan \theta_p$

$$\therefore \quad \mu = \tan \theta_p$$

This shows the tangent of angle of polarization is numerically equal to refractive index of the material at which reflection takes place.

Short questions

1. Can sound waves be polarized? Explain.
2. Is polarization possible for longitudinal waves? Why?
3. Longitudinal waves cannot be polarized. Why?
4. Light waves can be polarized. What about sound waves? Explain.
5. What is polarizing angle? does it depend on the wavelength of light?
6. The polarising angle for a transparent medium is 60^{o}. What is the refractive index of the medium?
7. Is polarization possible for longitudinal waves? Explain.
8. Is there any difference between an analyzer and a polarizer? Explain.
9. What is polarizing angle? Does it depends on the wavelength of light used?
10. In which medium is the angle of polarization greater, rarer or denser?