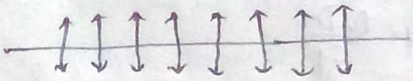
Polarisation

The light which has acquired the property of one sideness is called polarised light.

<u>plane polarised light</u>: when vibrations take place only in one direction parallel to the plane through the axis of ~~The beam~~ a beam, light is said to be plane polarised.

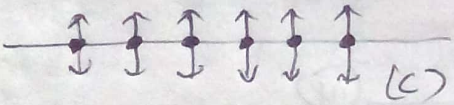


(a)

(i) when the plane polarised light has got vibrations in the plane of the paper they are represented in (a).

(b)

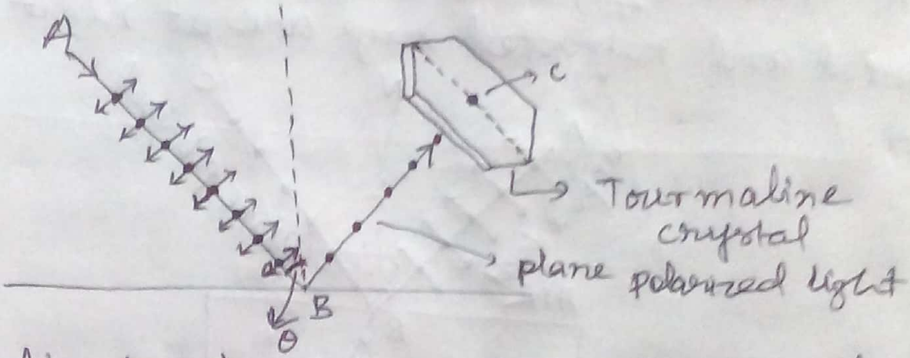
(ii) when the vibrations lie in a direction perpendicular to the plane of the paper. represented by (b).



(c)

(iii) unpolarised light is represented in (c)

Polarization by Reflection: Polarization of light by reflection from the surface of glass was discovered by Malus in 1808. consider the light incident along the path AB on the glass surface. Light is reflected along BC. In the path of BC, place a tourmaline crystal and rotate it slowly. It will be observed that light is completely extinguished only at one particular angle of incidence. This angle of incidence is equal to 57.5° for a glass surface and is known as the polarizing angle. Similarly polarized light by reflection can be produced from water surface also.



The production of polarized light by glass is explained as follows. The variations of the incident light can be resolved into components parallel to the glass surface and perpendicular to the glass surface. Light due to the components parallel to the glass surface is reflected whereas light due to the components perpendicular to the glass surface is transmitted.

Thus, the light reflected by glass is plane polarized and can be detected by a tourmaline crystal.

Brewster's law: Brewster found that ordinary light is completely polarized in the plane of incidence when it gets reflected from a transparent medium at a particular angle known as the angle of polarization.

Suppose, unpolarized light is incident at an angle equal to the polarizing angle on the glass surface. It is reflected along BC and refracted along BD.

From Snell's law $\mu = \frac{\sin i}{\sin r}$ —— (i)

Brewster able to prove that the tangent of the angle of polarization is numerically equal to the refractive index of the medium.

$$\mu = \tan i = \frac{\sin i}{\cos i} \quad \text{—— (ii)}$$

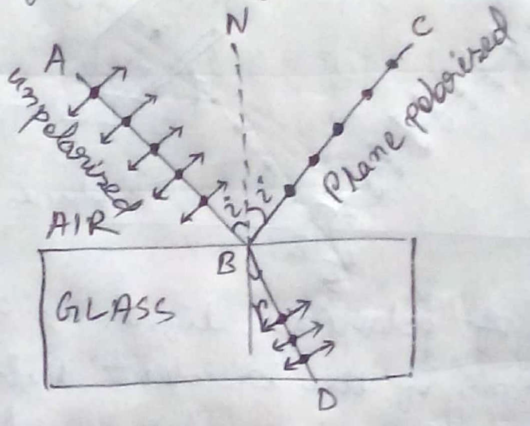
comparing (i) and (ii)

$$\cos i = \sin r = \cos\left(\frac{\pi}{2} - r\right)$$

$$i = \pi/2 - r$$

$$i + r = \pi/2$$

As $i + r = \pi/2$, $\angle CBD$ is also equal to $\pi/2$. Therefore, the reflected and refracted rays are at right angles to each other.



From Brewster's law it is clear that for crown glass of refractive index 1.52, the value i is given by

$$i = \tan^{-1}(1.52) \Rightarrow i = 56.7^\circ.$$

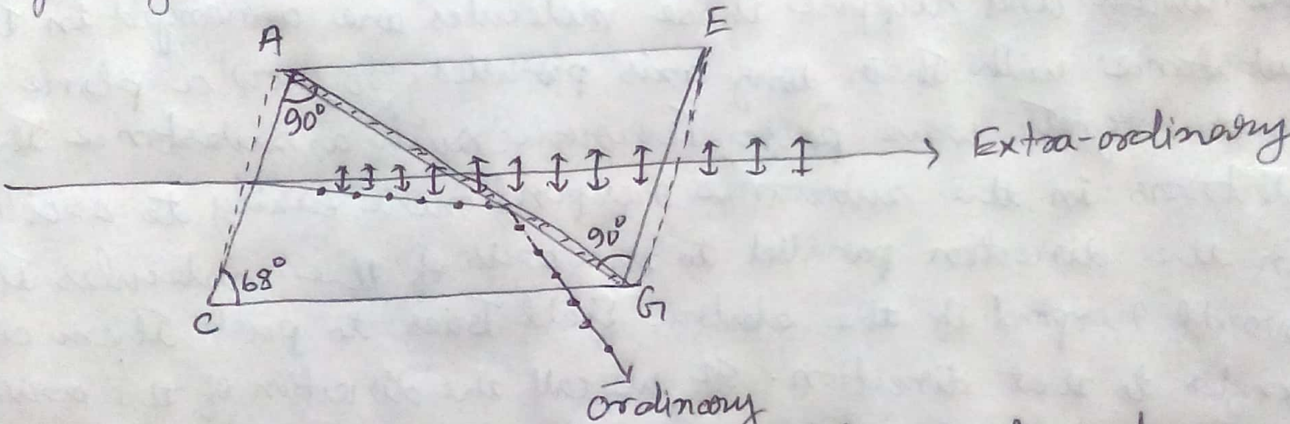
<u>Double refraction:</u> we have so far assume that velocity of light and hence the refractive index is independent of the direction of propagation of electromagnetic wave and state of polarisation of the wave. Amorphous solids like glass, crystalline solids and certain liquids show this behaviour. These are said to be optically isotropic. The progress of wave trains in isotropic substances can be found out by Huygen's construction. The secondary wave trains are spherical surfaces

There are other crystalline substances which are optically anistropic. Consider a substance which is composed of non-spherical molecules which are longer in length than the width and suppose these molecules are arranged in the substance with their long axis parallel. If now a plane polarised electro-magnetic wave passes through such a substance the ~~etc~~ electrons in the substance respond more easily to oscillations in the direction parallel to the axis of the molecules than they would respond if the electric field tries to push them at right angles to that direction. If we call the direction of the axis of molecules as optic axis, then refractive index in the direction of optic axis will be different than that in the direction perpendicular to the direction of optic axis. Such substances are called bi-refringent. If polarised light beam is incident on such a substance and if polarisation is parallel to the optic axis, the light will pass through with one velocity and if polarisation is perpendicular to the optic axis, the light is transmitted with a different velocity. Hence a birefringent substance will have two refractive indices. Thus a ray of light passing through such substances will suffer double refraction and on emergence will give rise to two images of the same object. This phenomenon is also known as double refraction and the substances are called doubly refracting substances.

The applications of double refraction are photo-elasticity; construction of full wave plate, half wave plate and quater waveplate; Kerr effect.

Nicol Prism:- It is an optical device used for producing and analysing plane polarized light. It was invented by william Nicol. when a beam of light is transmitted through a calcite crystal, it breaks up into two rays: (1) the ordinary ray which has its vibrations perpendicular to the principal section of the crystal and (2) the extraordinary ray which has its vibrations parallel to the principal section.

The Nicol prism is made in such a way that it eliminates one of the two rays by total internal reflection. It is generally found that the ordinary ray is eliminated and only the extraordinary ray is transmitted through the prism.



AG diagonal represent the ~~canad~~ canada balsam in the plane ALGK. It is clear that canada balsam acts as as a rarer medium for an ordinary ray and it acts as a denser medium for the extraordinary ray. when the ordinary ray passes from a portion of the crystal into the layer of canada balsam it passes from a denser to a rarer medium. when the angle of incidence is greater than the critical angle, the ray is totally internally reflected and is not transmitted. The extraordinary ray is not affected and is therefore transmitted through the prism.