LECTURE SERIES - 06

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* PHYSICS * E.M.W
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Fresnel's Rhomb: A mathematical treatment of the reflection of plane polarised light from the surface of a dielectric led Fresnel to the conclusion, that when a beam of plane polarised light is reflected internally from the surface of a glass plate, it is converted into elliptically polarised light when the plane of vibration of the incident light is inclined at an angle of 45° to the plane of incidence. This fact was first tested and confirmed by Fresnel who constructed a Rhomb of crown glass whose angle are 54° and 126° as shown in fig.(1) It is based upon the fact that a phase difference of $\pi/4$ is introduced between the component vibration. When light is totally internally reflected back at glass-air interface when the angle of incidence is 54°.

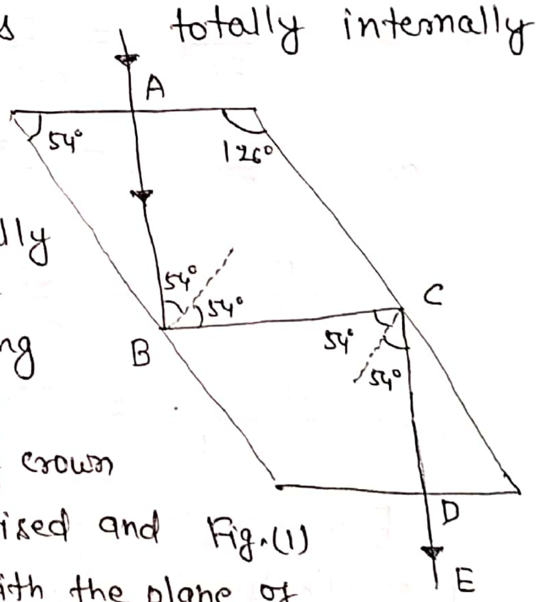

Fig.(1)

A ray of light enters normally at one end of the Rhomb and is totally internally reflected at the point B along BC. The angle of incidence at B is 54°, which is more than the critical angle of crown glass. Let the incident light be plane polarised and let the vibration make an angle of 45° with the plane of incidance. Its components (i) Parallel to plane of incidence and (ii) perpendicular to the plane of incidence are equal. These components after reflection at the point B undergo a phase difference of $\pi/4$ or a path difference of $\lambda/8$. A further phase difference of $\pi/4$ or a path difference of $\lambda/8$ is introduced between the components when the rays BC is totally internally reflected back along CD. Therefore, the final emergent ray DE has two components vibrating at right angle to each other and they have a path difference of $\lambda/4$. Therefore, emergent light DE is circularly polarised.

Fresnel's rhomb works similar to a Q.W.P. If the light enterning the Fresnel's rhomb is circularly polarised, a further path difference of $\lambda/4$ is introduced between the component vibrations. The total path difference between the component vibration is $\lambda/2$. Therefore the emergent light is plane polarised and its vibrations make an angle of 45° with the plane of incidence.

When an elliptically polarised light is passed through a Fresnel's rhomb, a further path difference of $\lambda/4$ is introduced between the component vibration. (Parallel and perpendicular to the plane of incidence.) The total path difference between the component vibration is $\lambda/2$ and emergent light is plane polarised.

Thus we see that Fresnel's rhomb behaves just similar to a Q.W.P; A Q.W.P. is used only for light of a particular wave-length. Whereas a Fresnel's rhomb can be used for light of all wavelength. In the Fresnel's rhomb the emergent beam is displaced to one side, and hence a rotation of the rhomb produces a movement of the image which is difficult to follow when used with an analyser.

Brewster's Law From Fresnel's formula

$$\left(\frac{E_T}{E_i}\right)_{\parallel} = \frac{\tan(\theta_i - \theta_T)}{\tan(\theta_i + \theta_T)}$$

From this relation, it is evident that $(E_R/E_i)_{\parallel} = 0$

When (i) $\tan(\theta_i - \theta_T) = 0$ i.e $\theta_i - \theta_T = 0$

or (ii) $\tan(\theta_i + \theta_T) = \infty$ i.e $\theta_i + \theta_T = \pi/2$

The first result is of little importance because it implies that the two media are optically identical (as $n_1 \sin\theta_i = n_2 \sin\theta_T$

So if $\theta_i = \theta_T$, $n_1 = n_2$ But the second result shows that when the reflected and refracted rays are perpendicular ($\theta_i = \theta_T$) there is no energy carried by the reflected ray. The angle of incidence for which this occurs is called Brewster's angle θ_B

i.e $\theta_i = \theta_B$

Now from Snell's Law, we know that

$$n_1 \sin\theta_i = n_2 \sin\theta_T$$

or $$\frac{\sin\theta_i}{\sin\theta_T} = \frac{n_2}{n_1}$$

or $$\frac{\sin\theta_B}{\sin(\frac{\pi}{2} - \theta_B)} = \frac{n_2}{n_1}$$

Since $\theta_B + \theta_T = \frac{\pi}{2}$

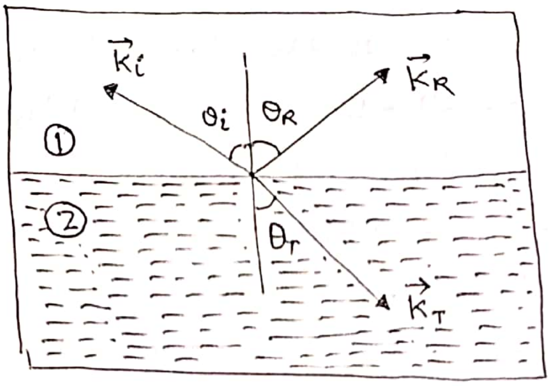

Fig. (1)

or $$\tan\theta_B = \frac{n_2}{n_1} = 1n_2$$

or $\theta_B = \tan^{-1} 1n_2$ Which is Brewsters Law

Thus, if an unpolarised wave is incident on the boundary surface with $\theta_i = \theta_B$ only the portion of the wave with electric vecter perpendicular to the plane of incidence will be reflected. This means that the reflected wave is linearly polarised with vibration perpendicular to the plane of incidence. Brewster's angle is also called polarising angle

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