EXPERIMENT 16

Object. *Verification of Fresnel's laws of reflection and refraction from a plane refracting surface.*

Following apparatus are required to perform the experiment : Spectrometer, two polaroids to fit collimator and telescope tubes, prism, sodium lamp etc.

The polarising angle $\varnothing_p$ is calculated by Brewster's relation ;

$$\varnothing_p = \tan^{-1} \mu \qquad ...(16.1)$$

where μ is the refractive index of prism material for monochromatic light (say sodium light having λ = 5893 Å).

The angle of refraction r is found by relation :

$$\sin r = \sin i/\mu \qquad ...(16.2)$$

Principle. Let A and B be the amplitudes of the electric vector of an electromagnetic wave in the plane and perpendicular to the plane of incidence respectively. If A is made equal to B, then the ratio of the reflected components A_r and B_r is given by

$$\frac{B_r}{A_r} = \frac{\cos(i+r)}{\cos(i-r)},$$

where i and r are the angles of incidence and refraction respectively.

The condition that vector A = B can be achieved by polarising a light at an angle of 45° to the plane of incidence (horizontal). The experimental way to achieve this condition is described in the procedure.

The ratios of vectors A and A_r in the plane of incidence and B and B_r in a plane perpendicular to the plane of incidence are given as below by electromagnetic theory of light :

$$\frac{A_r}{A}=\frac{\tan(i-r)}{\tan(i+r)}, \quad \text{I Law} \qquad ...(i)$$

The condition for complete transmission, *i.e.*, for $A_r = 0$ is that tan (i + r) = ∞ or, i + r = π/2. In this case no light will be reflected.

Also, $$\frac{B_r}{B}=\frac{\sin(i-r)}{\sin(i+r)}. \quad \text{II Law} \qquad ...(ii)$$

The equation shows that B_r minimum can never be zero. If condition i + r = π/2 is set for light, the part in the plane of incidence will be completely transmitted, but the reflected part will always be present because of the vectors B and B_r in a plane perpendicular to the plane of incidence. It shows that the reflected light in such a case is always plane polarized in a plane perpendicular to the plane of incidence. The expressions are mathematical forms of the Fresnel's laws. However if A = B, we obtain from (i) and (ii),

$$\frac{B_r}{A_r}=\frac{\cos(i+r)}{\cos(i-r)}. \qquad ...(iii)$$

Relation (iii) is experimentally verified. The angles of incidence, reflection and refraction are shown in Fig. (16.1). It is clear from figure that

$$\sin r = \cos i, \ \therefore \ \mu = (\sin i/\sin r) = \tan i.$$

At i = $\varnothing_p$, the polarizing angle the reflected light becomes plane polarised . Hence $\varnothing_p$ and i are found with the help of Brewster's law given below :

$$\mu = \tan \varnothing_p$$

The angle r is calculated by using Snell's law which gives sin r = sin i/μ. Knowing i and r, the value of (B_r/A_r) = cos (i + r)/cos (i-r) is found. The ratio (B_r/A_r) = tan θ too is found experimentally as described below and a graph plotted between tan θ and cos (i + r)/cos (i-r) must be straight line passing through the origin and inclined at an angle of 45° to the either axes.

Procedure. (1) Set up spectrometer with prism as decribed in Expt. (A-6) and find the refractive index of the prism material for monochromatic light, say sodium light. Now, use Brewster's law μ = tan ∅, *i.e.*, $\varnothing = \tan^{-1} \mu$, to find brewster's angle ∅. Its value comes out to be nearly 58°. The

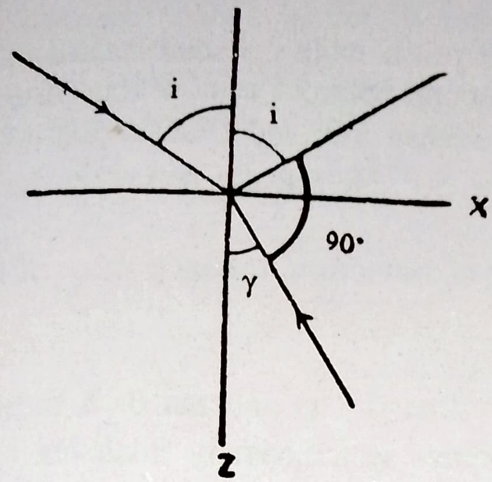

Fig. 16.1

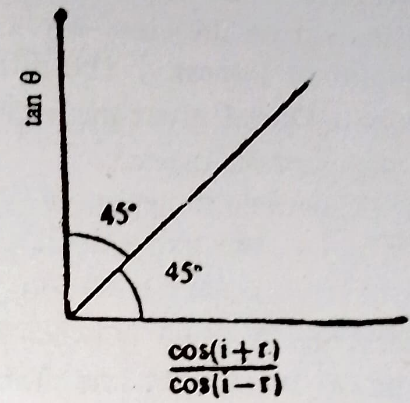

Fig. 16.2

light incident at this angle is reflected as plane polarised light from the face of the prism.

(2) Focus the direct slit in telescope and note the verniers. Rotate the telescope at an angle of 90° from this position. Place the prism on the prism table. Rotate the prism table so that the slit image falls on the telescope cross wires. The light is reflected from the prism face at angle of 45° in this setting. In order to make the reflection at Brewster's angle (Ø ≃ 58°), clamp the prism table and rotate the telescope by an angle equal to double the difference of Ø and 45° (*i.e.*, 2 (58-45) = 26°). Now, clamp the telescope and rotate the prism table so that slit is again focussed on the cross wires. The reflection is at Brewster's angle in this setting and reflected light is plane polarised.

(3) Now, fit a polaroid on the telescope objective. Rotate the polaroid so that the intensity of slit appears minimum. This is known as tint of passage. Note the reading of the polaroid pointer.

(4) Remove the prism. Observe the direct slit in the telescope. Fit another polaroid on the collimator lens and rotate it to get minimum intensity of the slit. Rotate the collimator polaroid at an angle of 45° from this setting. This setting makes the vibration of incident light at an angle of 45° to the plane of incidence. The condition is necessary to make A = B. Do not disturb this position of the collimator polaroid.

(5) Now, place the prism on the prism table. Rotate the telescope through 90° from the first setting. Next, rotate the prism table so that slit is focussed on the cross wires. The refraction is at an angle of 45° in this setting. The intensity of the slit won't be minimum. Therefore rotate the telescope polaroid to get minimum intensity. Note the reading of this

polaroid. The difference between first and this reading of telescope polaroid gives the value θ for 45° incidence.

(6) Rotate the telescope by 10°. The prism table is then rotated to focus the slit on the cross-wires. The telescope polaroid is now rotated to get minimum intensity. The difference between this and first reading of telescope polaroid gives the value of θ for 50°. Repeat the procedure for other angles of incidence.

(7) Calculate the value of r, the angle of refraction, for each value of i (45°, 50°, ...) by using Snell's law :

$$\sin r = \sin i/\mu.$$

(8) Plot a graph between cos (i + r)/cos (i - r) and tan θ. It must come out to be straight line. Tabulate readings systematically finalising in a table giving i, r, θ to plot variation shown in Fig. (16.2).

A plot of tan θ against $\frac{\cos(i+r)}{\cos(i-r)}$ gives a straight line passing through origin and at angle of 45° to either of the axes. It establishes and verifies Fresnel's laws. Recording the least count of the spectrometer used, the observation in a proper tabular form and findings in a systematic way is an individuality and may be made as shown ahead. However refer to Expt. (A.6) to perform an experiment with a spectrometer. Interpret results theoretically.

Record of observations :

(I) L.C. of the spectrometer used =...

N. B. Use tables of type shown in Expt. (6) to record the angle of prism A and the angle of minimum deviation D for mean sodium wavelength 5893 Å.

Table 1. Determination of polarising angle $\varnothing_p$.

Std. wavelength used λ	Angle prism A	Angle of min. deviation for wavelength λ D	Refractive index of prism $\mu = \sin(A+D)/2 / \sin(A/2)$	Polarising angle $\varnothing_p = \tan^{-1}\mu$
...cm	...°	...°	...	...°

Table 2. Polaroids readings to polarize incident light at 45° to the plane of incidence.

Telescope polaroid for min. intensity on receiving reflected light at Brewter's angle (a)	Collimater polaroid for min. intensity in direct observation with telescope polaroid set to position (a) . (b)	Collimator polaroid after rotating it through 45° from its setting (b) (c) → fixed	Remarks
...°	...°	...°	...

Table 3. Obervations to verify Fresnel's laws.

S. No.	Angle of incidence	Telescopic polaroid				Angle of refraction		
		Initial	Final	Diff. θ	tan θ	sin i	sin r = sin i/μ	r
[illegible]	45°, 50°,...	...°	...°	...°	...	...	...	...°

Table 4. Sorted out values to plot graph.

Telescope polaroid		Angle of incidence	Angle of refraction	i + r	i - r	cos (i+r)	cos (i - r)
θ	tan θ	i	r				
° ...	...	° ...	° ...	° ...	° ...	...	...