Experiment No. 5

Object : *To study the polarisation of light by reflection and to verify the Brewster's law.*

Apparatus Required : A plane glass plate, 60 W electric bulb, polaroid, convex lens, photo cell and micro-ammeter.

Description of the Apparatus : Fig. 16 shows the experimental arrangement. It consists of a 60 W electric bulb S and a convex lens L. G is a plane glass plate mounted on a horizontal circular table. The plate can be rotated about a vertical axis passing through the centre of table and its position can be read on a circular scale labelled on the table with the help of a pin attached in the plate-holder perpendicular to the plane of the plate. P is a polaroid which can be rotated in its own plane and D is the photo-voltaic cell connected to a micro-ammeter (μA). The reading of micro-ammeter is proportional to the intensity of light incident on the photo cell. Polaroid and photo cell both are mounted on the same holder.

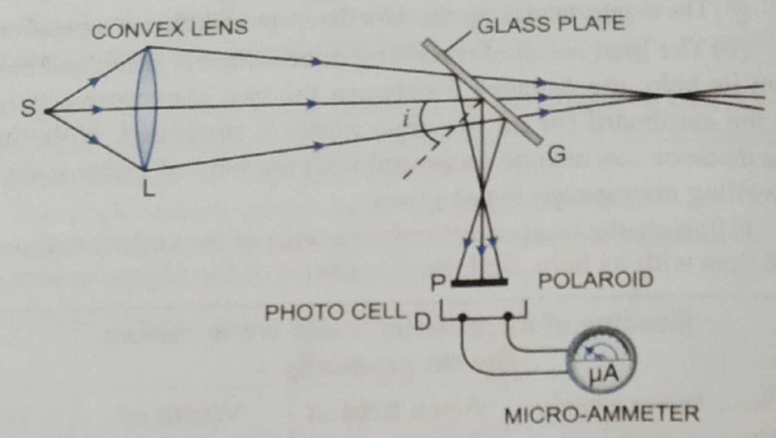

Fig. 16. Arrangement for polarisation by reflection

Theory : When an unpolarised light is reflected from a transparent reflecting surface (such as glass), the reflected light is partially polarised which contains more component of vibrations perpendicular to the plane of incidence and less component of vibrations parallel to the plane of incidence. In the reflected light the intensity of polarised light having vibrations perpendicular to the plane of incidence, depends on the angle of incidence. On gradually changing the angle of incidence, at a particular angle of incidence the reflected light becomes perfectly plane polarised (Fig. 17) with vibrations perpendicular to the plane of incidence. This angle of incidence is called the *polarising angle* or the *Brewster's angle* and it is represented by i_p. According to Brewster, polarising angle i_p depends on the refractive index μ of the medium. It is given as

$$\mu = \tan i_p$$

This is called *Brewster's law.* For air-glass, the value of polarising angle i_p is nearly 57° and for air-water, its value is nearly 53°.

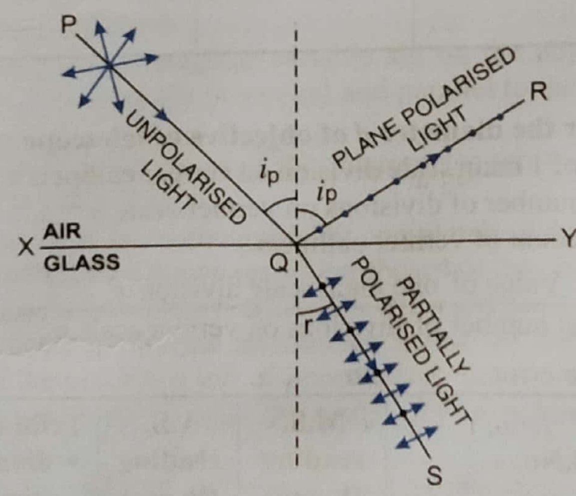

Fig. 17. Polarisation of light by reflection

It may be mentioned here that if the angle of incidence is less than or greater than the polarising angle (*i.e.*, $i < i_p$ or $i > i_p$), the reflected light is partially polarised with more vibrations perpendicular to the plane of incidence and less vibrations parallel to the plane of incidence. But when the angle of incidence becomes equal to the polarising angle (*i.e.*, $i = i_p$), the reflected light is completely plane polarised.

At different angle of incidence, in the reflected light the intensity of vibrations parallel to the plane of incidence and perpendicular to the plane of incidence, is measured with the polaroid and photo cell. If at an angle of incidence, I_{max} is the intensity of vibrations perpendicular to the plane of incidence and I_{min} is the intensity of vibrations parallel to the plane of incidence, then at that angle of incidence i, the degree of polarisation p is defined as

$$p = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

Thus a graph plotted for degree of polarisation p against the angle of incidence i is a curve in which the value of i at the peak of the curve is equal to the Brewster's angle i_p.

Formula Used : The degree of polarisation p due to reflection from a plane glass plate at a certain angle of incidence is given as

$$p = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

where I_{max} = intenstiy of vibrations perpendicular to the plane of incidence in the reflected light and I_{min} = intensity of vibrations parallel to the plane of incidence in the reflected light.

According to Brewster's law, the angle of incidence when $I_{min} = 0$ or $p = 1$ is called angle of polarisation or Brewster's angle, *i.e.*, at $i = i_p$, $p = 1$ and $\tan i_p = \mu$ where μ is the refractive index of the reflecting surface.

Procedure : (1) First the glass plate is withdrawn from the plate holder and light from the bulb is made incident directly on the polaroid. Now the polaroid is rotated in its own plane and it is seen whether there is variation in the reading of micro-ammeter connected with the photo cell or not. If there is no variation, the light from the bulb is unpolarised.

(2) Now glass plate is mounted in the plate holder. The polaroid and the photo cell are rotated and kept such that the light reflected from the plate falls on the entire surface of photo cell through the polaroid (Fig. 16). Take care that the plane of plate is normal to the incident light. This position of plate is read on the circular table with the help of pin attached on it. This is the angle of incidence i.

(3) Then the polaroid is rotated in its own plane till the reading of micro-ammeter connected with the photo cell becomes maximum. Now the position of polaroid θ_1 and the reading of micro-ammeter I_{max} are noted. Then the polaroid is turned through 90° from this position and it is so adjusted that the reading of micro-ammeter becomes minimum. This position of polaroid θ_2 and the reading of micro-ammeter I_{min} are noted.

(4) Now the plate is gradually rotated and corresponding to different angle of incidence, above experiment is repeated to note the values of I_{max} and I_{min}. Take care that each time, the position of polaroid is θ_1 for I_{max} and position of polaroid is θ_2 for I_{min}.

(5) From the above observations, that value of i ($= i_p$) is noted for which I_{min} is nearly zero. This is the polarising angle or Brewster's angle.

Observations :

For the polarising angle (or Brewster's angle) and degree of polarisation :

S. No.	Angle of incidence i (in °)	Reading of micro-ammeter (in μA)		Degree of polarisation $p = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$
		I_{max} When vibrations are perpendicular to the plane of incidence	I_{min} When vibrations are parallel to the plane of incidence	
1.				
2.				
3.				
4.				
5.				
6.				

From the above observations,

Angle of polarisation i_p = ...°. when $p = 1$ (or $I_{min} = 0$ nearly)

Calculations : (1) In the first observation table, for each angle of incidence i, the value of p is calculated using the formula

$$p = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

(2) A graph is plotted by taking the angle of incidence i on X-axis; I_{min} and I_{max} on Y-axis. We get a curve as shown in Fig. 18. From the graph that value of angle of incidence i_p is read where the value of I_{min} is zero.

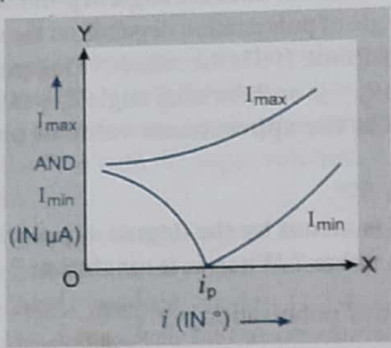

Fig. 18. Graph for I_{max} and I_{min} against i

(3) A graph is plotted for the degree of polarisation p on Y-axis and the angle of incidence i on X-axis, which is a curve as shown in Fig. 19. From this graph, read that value of angle of incidence i_p for which the value of p is nearly equal to 1.

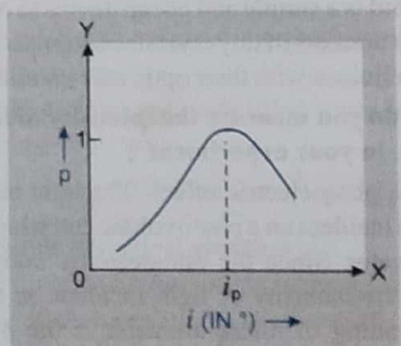

Fig. 19. p-i graph

Result : From graph (Fig. 18), Brewster's angle i_p = ...°

From graph (Fig. 19), Brewster's angle i_p = ...°

Mean value of Brewster's angle i_p = ...°

From $\tan i_p = \mu$, the theoretical value of i_p = ...°

Percentage error :

Percentage error in the value of Brewster's angle

$$= \frac{\text{Experimental value} \sim \text{Theoretical value}}{\text{Theoretical value}} \times 100\ \%$$

= .....%

Precautions : (1) The light incident on the glass plate from the bulb should be unpolarised.

(2) The light emerging out of polaroid should be incident on the entire surface of photo cell.

(3) The readings of I_{max} and I_{min} are taken at mutually perpendicular angular positions of polaroid and for each angle of incidence, the angular position of polaroid should be kept same.

(4) No exterior light should fall on the photo cell. For this, the entire apparatus should be placed closed inside a wooden box painted black from inside.