Refraction Through Prism

Objective

1.To determine the refractive index of glass prism.

2.To determine the refractive index of various liquids in a hollow prism.

Principle and Task

The refractive indices of liquids and glass are determined by refraction of light through the prism at minimum deviation.

Theory

A glass prism is a transparent object which has two plane surfaces, $XDEY$ and $XDFZ$, inclined to each other (Fig. 4.1).

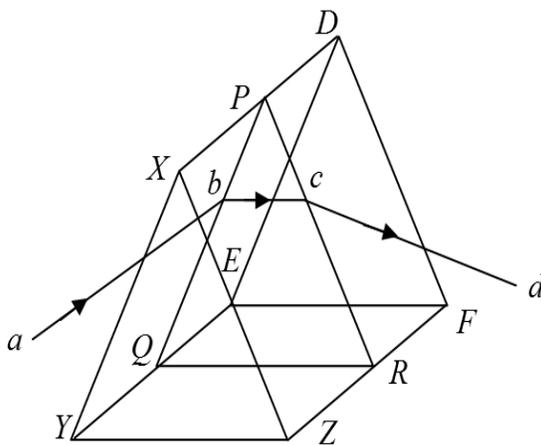The angle between the inclined plane surfaces $XDFZ$ and $XDEY$ is known as the angle of

Figure 1: **Prism.**

the prism, or the refracting angle, the line of the intersection XD of the planes is known as the refracting edge. A ray of light ab, incident on the prism at b in a direction perpendicular to XD, is refracted towards the normal along bc when it enters the prism, and is refracted away from the normal along cd when it emerges into the air. If the incident ray is directed towards the refracting angle, as in Fig. 4.1, the emersion light is always deviated by the prism towards its base.

Refraction Through a Prism

Consider a ray HM incident on a prism of refracting angle A (Fig. 4.2). If i_1, r_1 and i_2, r_2 are the angles of incidence and refraction at M and N as shown, and n is the refractive index of the prism then, by using the law of refraction,

$$\sin i_1 = n \sin r_1, \tag{1}$$

$$\sin i_2 = n \sin r_2. \tag{2}$$

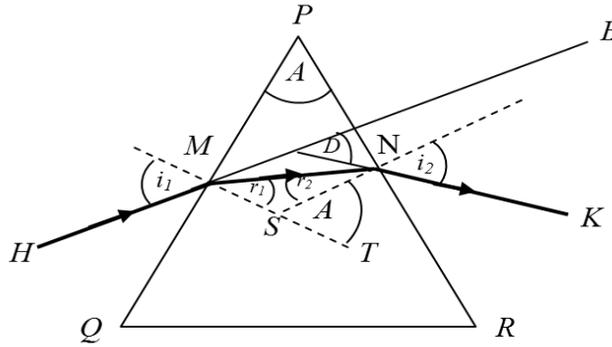From the geometry of Fig. 4.2 we can write:

Figure 2: **Refraction through prism.**

$$\therefore A = r_1 + r_2, \tag{3}$$

as angle NST is the exterior angle of the triangle MSN.
The deviation angle, D, of the light (angle BOK), is given by

$$D = (i_1 - r_1) + (i_2 - r_2). \tag{4}$$

Equations (1) - () are the general relations which hold for refraction through a prism.

Minimum Deviation

Experiment shows that as the angle of incidence i is increased from zero, the deviation D begins to decrease continuously to some value D_m, and then increases to a maximum as i is increased further to 90^0. A graph of D plotted against i has the appearance of the curve X, which has a minimum value at R, Fig. 4.3. Experiment and theory show that the minimum deviation, D_m, of the light occurs when $i_1 = i_2 = i$ and $r_1 = r_2 = r$.
Then, we can write Eqs. (1), (4.3) and (4.4) as
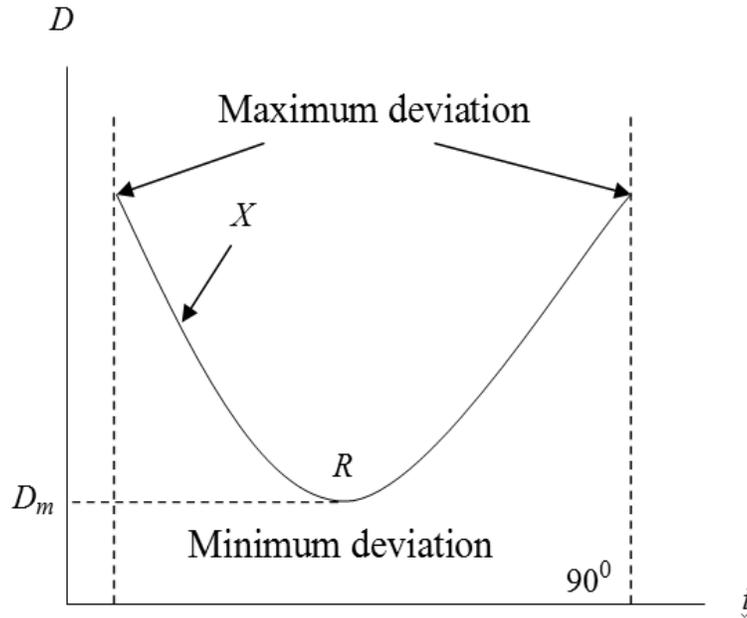
$$n = \frac{\sin i}{\sin r}, \tag{5}$$

2

Figure 3: **Minimum deviation.**

$$A = 2r \quad \Rightarrow \quad r = \frac{A}{2}, \tag{6}$$

$$D_m = 2i - 2r = 2i - A \quad \Rightarrow \quad i = \frac{D_m + A}{2}. \tag{7}$$

Substituting Eqs. () and (0.0.1) into Eq. () gets the refractive index of the prism

$$n = \frac{\sin \frac{D_m + A}{2}}{\sin \frac{A}{2}}. \tag{8}$$

The Spectrometer

The spectrometer is an optical instrument used to measure accurately the refractive index of glass in the form of prism. It consists essentially of a collimator C, a telescope T, and a table R, on which a prism B can be placed. The collimator is fixed, but the table and the telescope can be rotated round a circular scale (Fig. 4.4). The collimator is used to obtain parallel rays, and the telescope to brought these rays to a focus at cross-wires. A vernier is also provided for this scale. The source of light S, used in the experiment is placed in front of a narrow slit at one end of the collimator.

Before the spectrometer can be used, however, three adjustments must be made:

(1) The collimator C must be adjusted so that parallel light emerges from it.

(2) The telescope T must be adjusted so that parallel rays entering it are brought to a focus at cross-wires near its eye-piece.
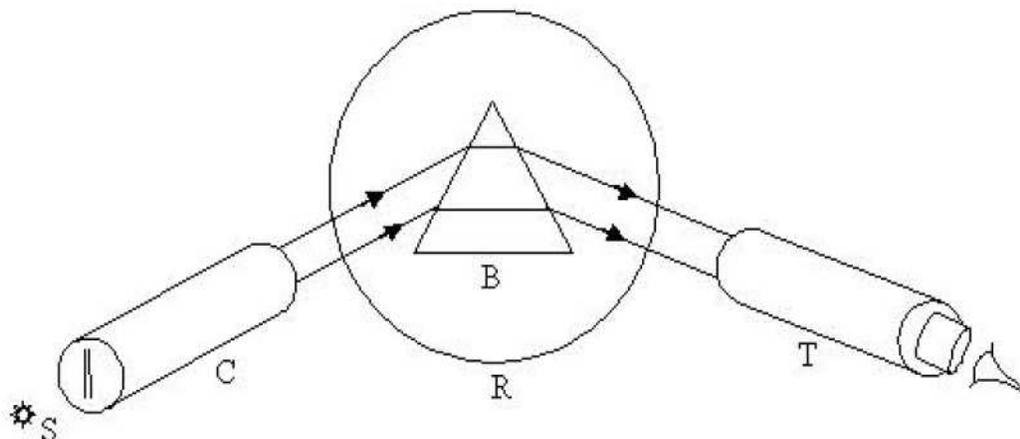
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Figure 4: **Spectrometer.**

(3) The refracting edge of the prism (which is the edge XD in Fig. 4.1) must be parallel to the axis of rotation of the telescope (this axis is perpendicular to the plane of the parer in Fig. 4.5), i.e., the table must be "levelled".

Measurement of the angle A, of a prism

The prism is placed so as to face the collimator lens. The incident light illuminates the two surfaces containing the refracting angle A with parallel light as in Fig. 4.5. The parallel rays will reflect, and an image of the collimator slit is hence observed with the telescope in positions T_1, T_2. The angle of rotation of the telescope from T_1 to T_2 is equal to $A_1 + A_2 = 2A$, and hence the angle of the prism, A, can be obtained.

- Using the geometry of Fig. 4.5 show that

$$A(= \alpha + \beta) = \frac{A_1 + A_2}{2}$$

Measurement of the minimum deviation D_m

To measure the minimum deviation D_m, the prism is placed with its refracting angle A pointing away from the collimator, as shown in Fig. 4.6. The telescope is then turned until an image of the slit is obtained on the cross-wires at the position T_1. The table is now slowly rotated so that the angle of incidence decreases, and the image of the slit is kept on the cross-wires by moving the telescope at the same time. The image of the slit, and the telescope, then slowly approach the fixed line XY. But at one position (T_2), the image of the slit begins to move away from XY. If the table is now turned in the opposite direction the image of the slit again moves back when the telescope reaches the position T_2. The angle between the emergent ray CH and the line XY is hence the smallest angle of deviation, and is thus equal to D_m.
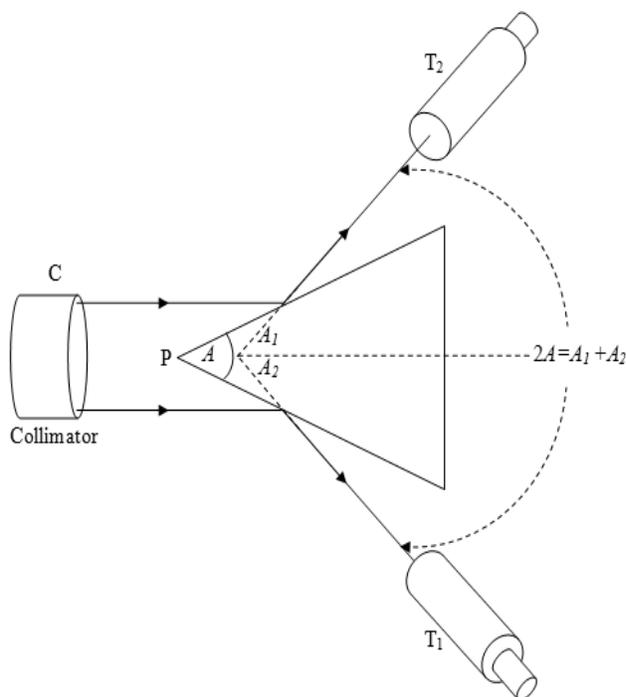
Figure 5: **Measurement of angle of prism.**

Equipment

Spectrometer, lamp holder, Spectral lamp Hg, Power supply for spectral lamps, glass Prism , hollow prism filled with paraffin and hollow prism filled with glycerin.

0.0.1 Set up and procedure

The experiment is set up as shown in Fig. 4.7. The spectrometer and the prism should be adjusted in accordance with the operating instructions.
The aperture, or slit, is projected into the plane of the cross-wires with the telescope set to infinity and observed with the eyepiece which is used as a magnifier.

Determination of the refracting angle A

1. Place the prism on the table of the spectrometer with the angle to be measured directed toward the lens of the collimator.

2. Turn the telescope till you get an image formed by reflection on the surface of the prism.

3. Determine the position of the telescope (A_1) by reading the scale.

4. Turn the telescope in the opposite direction to get another image of the slit reflected on the second face of the prism, and determine the position (A_2) in this case.
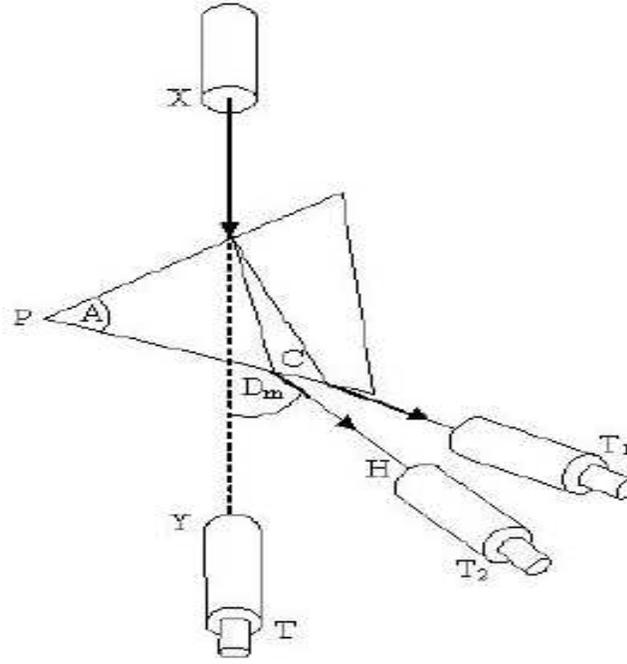
Figure 6: **Measurement of minimum deviation.**

Determination of the angle of minimum deviation D_m

1. Place the glass prism on the table so that the angle (A) which was measured serves as the refracting angle.

2. Turn the telescope till you gets spectral lines and measure the minimum deviation angle (D_m) for each spectral line, and record the results in Table 4.1.
   ● The position of minimum deviation can be detected by looking to the spectrum through the telescope and rotating it until the spectrum reverse its direction.

2. Repeat the steps in sections **4.5.1** and **4.5.2**, for the liquid prism, and record the results in Table 4.2.

Measurements and calculations

(a)In the first parts of the experiment, determine the angle A of the prism from the relation:

$$A = \frac{A_1 + A_2}{2} .$$

Figure 7: **Experimental set-up for determining dispersion in prism.**

Table 1: **Typical measurements for determining the refractive index of the glass prism.**

	Yellow	Green	Blue	Violet
D_m				
n				

(b) In the second part, Calculate the refractive index (n) for each spectrum from the relation:

$$n = \frac{\sin \frac{A+D_m}{2}}{\sin \frac{A}{2}} \ .$$

Table 2: **Typical measurements for determining the refractive index of the liquid prism.**

	Yellow	Green	Blue	Violet
D_m				
n				