EXPERIMENT – 8

Aim of the experiment: Determination of refractive index of the material of a prism using spectrometer and sodium light.

Apparatus required: College spectrometer, prism (equilateral), prism holder, sodium lamp with housing and power supply, spirit level, reading lens, torch.

Principle:
A labelled diagram of a glass prism is shown in figure-1. A ray of light when incident on one of the refracting faces of a prism of angle A, undergoes refraction at that surface as well as at the refracting face on the other side and consequently the emergent ray gets substantially deviated from its original path as shown in figure-2. This deviation depends upon the angle of the prism and the refractive index of its material. The deviation produced by the prism for various incident angles shows a dependence typically as in figure-3.

In order to determine the refractive index of a prism by the method of minimum deviation we may try to get the $\delta\ vs\ i$ curve as shown in figure-3. In this method the experimenter needs to acquire several data points so that the curve is fairly smooth, and the final result has acceptable accuracy. This method becomes quite elaborate and extensive and will be adopted in other courses.

Alternatively, we may choose to directly determine the minimum deviation angle and the angle of prism to get the refractive index of the prism material. In our case we would adopt this method.

It can be clearly seen that at a specific angle of incidence the plot of deviation attains a minimum δ_m . We will look for this angle directly in our experiment.

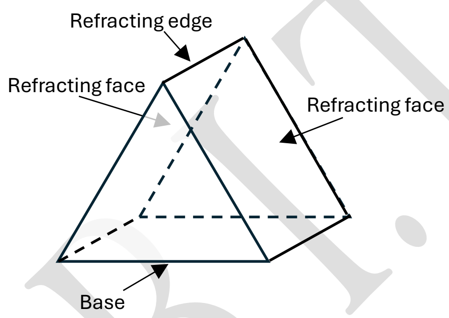

Fig-1. Diagram of a glass prism showing its faces

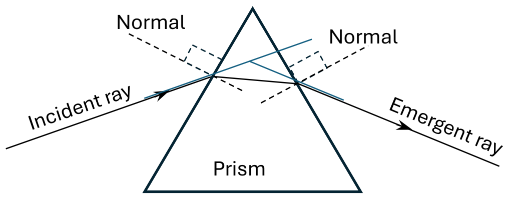

Fig-2. Diagram of a glass prism showing refraction

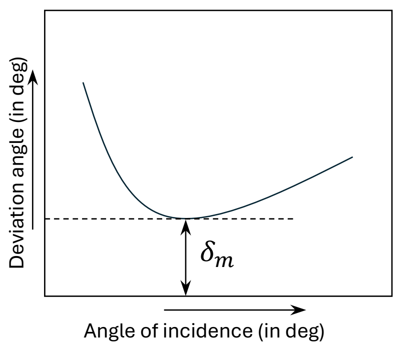

Fig-3. Typical plot of deviation angle versus angle of incidence for a prism

The refractive index μ, of the material used in the prism is related to its angle A, and the minimum deviation it can produce δ_m, according to the following relation:

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} \qquad (1)$$

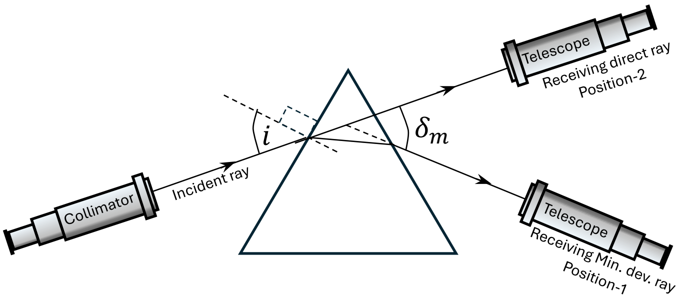

Fig.-4. Schematic diagram for the determination of angle of minimum deviation of light by the prism. (Top view)

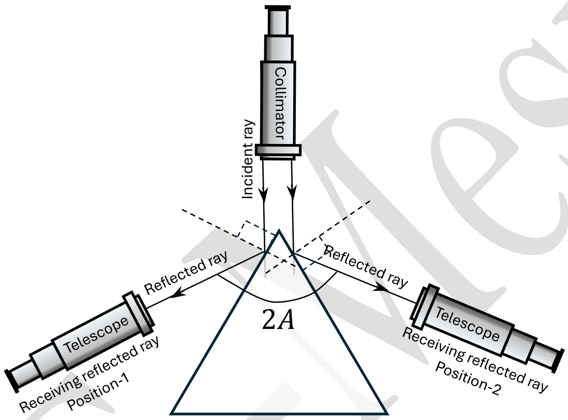

Fig.-5. Schematic diagram for the determination of angle of prism. (Top view)

Procedure and precautions:

In order to determine the refractive index μ of the prism we need to determine the angle of the prism A and the minimum deviation δ_m of light ray that it can produce. So first we choose to determine the minimum deviation.

A. Determining the minimum deviation produced by the prism.

1. Place your spectrometer outside the dark room on a table adjacent to a window and focus the telescope to a very distant object, preferably, at the leaves of a distant tree. Bring them to sharp focus by adjusting the telescope focusing knob. Once done, your telescope is adjusted for receiving parallel rays. DO NOT DISTURB THIS KNOB ANY FURTHER, THROUGHOUT THE EXPERIMENT. If at all focusing is required, use the collimator focusing knob.
2. Now, bring your spectrometer to an appropriate location in the dark room. Note that there is a fairly wide slit in the housing of a sodium vapor discharge lamp.
3. Place your spectrometer in front of this slit in such a way that the adjustable slit of the collimator receives enough light. Ensure that the collimator is exactly in line with the light source by looking directly through the collimator objective.
4. Follow the process for rough levelling, alignment and optical levelling as outlined in the relevant section of the *appendix*.
5. Bring the telescope in line with the collimator directly facing each other.

6. View through the eyepiece of the telescope and adjust its position so that the slit image is at the center of the field of view. Make the collimator slit as thin as possible so that you see just a sharp thin line, and if need be, focus the instrument using the collimator focusing knob.
7. Place the prism on the prism table such that the refracting edge coincides with the center of the prism table and its base parallel to the line joining the collimator and the telescope. Push the prism 2 to 3 mm in the direction perpendicular to its base and rotate the prism table approximately 20 degrees such that the base goes towards the collimator. Clamp the prism gently using its attachment so that it does not shake, shift from its position or fall off.
8. Adjust the height of the prism table appropriately so that the prism is able to intercept the incoming light.
9. Position your telescope to receive the ray deviated by the prism. For this you may need to move the telescope a little, to and fro, while looking through the eyepiece.
10. Now, rotate the prism table in a direction, that shifts the image of the slit towards the direct ray. Do this until it starts coming back. The point from where it starts to retrace is the minimum deviation possible.
11. If needed reposition your telescope a little so that the telescope crosshair is coincident with the slit image at its minimum deviation position. If required, you may use the collimator focusing knob to get a better focused image. Record this position of the telescope using the two Vernier windows.
12. Remove the prism from the prism table and position your telescope to receive direct ray. Adjust precisely to make the crosshair coincident. Record your observations for the new position of telescope, once again in the same fashion using the two Vernier windows.
13. The difference between the observations for deviated ray and the direct ray would be the minimum deviation, δ_m.

This experiment is usually done in a darkroom. However, it can be done in a lighted room as well as the light from the sodium lamp is intense enough to be visible.

Note:

1. Make sure not to mix up the observations of the two Vernier windows. Reading of Vernier window-1 is to be processed with those of the same window, for any position of the telescope. Same will hold for Vernier window-2.
2. During this experiment you do not have to record deviation angles corresponding to different angles of incidence, rather, look for the minimum deviation angle directly and record the angle (five times, to improve the precision of result).

B. Determining the angle of prism.

1. Place the prism on the prism table such that its refracting edge is towards the collimator and its base is towards the telescope. Place it in such a way the refracting edge is coincident with the center of the prism table. Push the prism a little (2 to 3 mm) towards the collimator.
2. Move the telescope to one side of the prism and receive the image of the slit, reflected from one of the faces.
3. Bring the image exactly at the crosshair using the fine-motion screw of the telescope. Record the observations for this position of the image using both the Vernier windows, in the observation table - 2.
4. Move the telescope to the other side of the prism and receive the image of the slit, reflected from this side.
5. Once again bring the image exactly at the crosshair using the fine-motion screw of the telescope and record the observations of this position of the image as well in the same way, on your observation table.

6. The difference of these two observations is $2A$.
7. Use the values of A and δ_m in equation-1 to obtain μ, the refractive index of the prism.

Observations:
Obtaining the LC of the spectrometer that we are using:

$1 \text{ MSD is } = 0.5 \text{ deg}$

$60 \; VSD \; coincide \; with \; 59 \; MSD$

$\therefore 1 \; VSD = \frac{59}{60} \; MSD$

$30 \; VSD \; coincide \; with \; 29 \; MSD$

$\therefore 1 \; VSD = \frac{29}{30} \; MSD$

By definition, the least count or the Vernier constant of an instrument is defined as:

$LC = 1 \; MSD - 1 \; VSD$

$\therefore LC = 1 \; MSD - \frac{59}{60} \; MSD$

$or, \quad LC = \left(1 - \frac{59}{60}\right) \; MSD$

$or, \quad LC = \left(1 - \frac{59}{60}\right) 0.5 \text{ deg}$

$or, \quad LC = \left(\frac{1}{120}\right) \text{deg}$

$LC = 1 \; MSD - 1 \; VSD$

$\therefore LC = 1 \; MSD - \frac{29}{30} \; MSD$

$or, \quad LC = \left(1 - \frac{29}{30}\right) \; MSD$

$or, \quad LC = \left(1 - \frac{29}{30}\right) 0.5 \text{ deg}$

$or, \quad LC = \left(\frac{1}{60}\right) \text{deg}$

Note that there are some spectrometers having 60 VSD coinciding with 59 MSD and others having 30 VSD coinciding with 29 MSD. Hence, exercise due care while determining the least count of your instrument, in particular.

Table-1: Readings of the positions of telescope of a spectrometer for the direct determination of minimum deviation angle produced by the prism.

S.No.	Readings for the telescope position								$\delta\ (= M - N)$
	for deviated ray				for direct ray				
	MSR (deg) B	VSR	VSR x LC (deg) C	Total (M=B+C) (deg)	MSR (deg) D	VSR	VSR x LC (deg) E	Total (N=D+E) (deg)	
1									
2									
3									
4									
5									

Table-2: Readings of the positions of telescope of a spectrometer for the direct determination of angle of the prism.

S.No.	Readings for the telescope position								$A\ (= P - Q)$
	for ray reflected towards the left				for ray reflected towards the right				
	MSR (deg) F	VSR	VSR x LC (deg) G	Total (P=F+G) (deg)	MSR (deg) H	VSR	VSR x LC (deg) J	Total (Q=H+J) (deg)	
1									
2									
3									
4									
5									

Calculations:
Using the relation in equation-1

Result and discussion:
The refractive index of the glass prism as obtained in this experiment is:

$$\mu = (1.65 \pm 0.03)$$

Conclusion:

This method of determining the refractive index is fairly direct and is quite accurate provided the measurements are carried out using spectrometer is setup methodically.

Bibliography:

1. Hecht – Optics
2. A K Ghatak - Optics

Viva questions:

1. What will happen if we have a hollow prism with water filled in it?
2. What will happen if prism surrounding is optically denser?
3. Advantage and applications of this experiment?
4. Can a glass prism have a refractive index larger than 1.5?
5. What is the speed of light of different wavelengths in glass / prism?
6. Is the graph of $\delta\ vs\ i$ symmetrical about the lowest point?
7. For A = 15, 30, 45, 60, 90 deg. What will happen?
8. Condition for only red light coming out of the prism?
9. What will happen if we keep another inverted prism alongside?
10. Ultra-thin beam of light?
11. What factors does the angle of deviation depend upon?
12. What are the factor(s) upon which the dispersive power of a prism depends?
13. Which color has the largest and smallest refractive index?