LABORATORY MANUAL FOR

REFRACTIVE INDEX OF PRISM USING A SPECTROMETER

**Aim:** To determine the refractive index of the material of a given prism using a spectrometer.

**Apparatus:** A spectrometer, a spirit level, a source of monochromatic light (sodium vapour lamp), a glass prism, a magnifying lens and a reading lamp.

**Theory:** When a beam of light strikes on the surface of transparent material (glass, water, quartz crystal, etc.), the portion of the light is transmitted and and other portion is reflected. The transmitted light ray has small deviation of the path from the incident angle. This is called refraction.

Refraction is due to the change in speed of light while passing through the medium. It is given by snell's law

$$\frac{sin(i_1)}{sin(r_1)} = \frac{n_2}{n_1}, \tag{1}$$

where $i$ is the angle of incident, $r$ is the angle of refraction, $n_1$ is the refractive index of the first medium and $n_2$ is the refractive index of the second medium.

When a ray of light passes through a prism, it suffers refraction as shown in fig. 1.

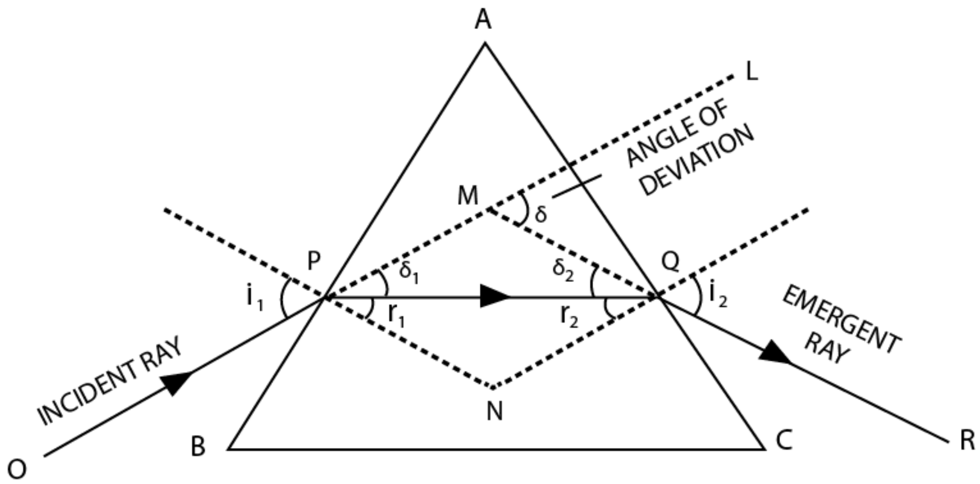


Figure 1: Refraction of light by prism.

We can apply Snell's Law to the ray of light at each surface. This leads to the two equations,

$$sini_1 = nsinr_1 \tag{2}$$

$$nsinr_2 = sini_2 \tag{3}$$

The angle $r_1$ and $r_2$ are not independent, being related by the equation,

$$A = r_1 + r_2, \tag{4}$$

where $A$ is angle of prism.

Applying the exterior angle theorem we get,

$$\delta = (i_1 - r_1) + (i_2 - r_2). \tag{5}$$

Combining eq.(4) and (5), we have

$$\delta = i_1 + i_2 - A. \tag{6}$$

Solving eq.(2) and (3) for $i_1$ and $i_2$, respectively, we get

$$i_1 = sin^{-1}(nsinr_1), \tag{7}$$

$$i_2 = sin^{-1}(nsin(A - r_1)). \tag{8}$$

Finally, substituting these two equations into eq.(6) we get,

$$\delta = sin^{-1}(nsinr_1) + sin^{-1}(nsin(A - r_1)) - A. \tag{9}$$

In minimum deviation position, $\angle i_1 = \angle i_2$ and so $\angle r_1 = \angle r_2 = \angle r$ or

$$\angle i = \frac{A}{2} \tag{10}$$

Then from eq.(6) we have,

$$i_2 = (\delta_m + A)/2 \tag{11}$$

Substituting this into eq.(3) and solving for the index of refraction gives,

$$n = \frac{sin((\delta_m + A)/2)}{sin(A/2)} \tag{12}$$

The angle $\delta_m$ is known as the minimum angle of deviation for the prism at the wavelength $\lambda$.

**Procedure:**

**(A) Telescope adjustment:**

1. The spectrometer and the prism table are arranged in horizontal position by using the levelling screws (as shown in fig. 2).

2. The telescope is turned towards a distant object to receive a clear and sharp image.

3. The slit is illuminated by a sodium vapour lamp and the slit and the collimator are suitably adjusted to receive a narrow, vertical image of the slit.

4. The telescope is turned to receive the direct ray, so that the vertical slit coincides with the vertical crosswire.

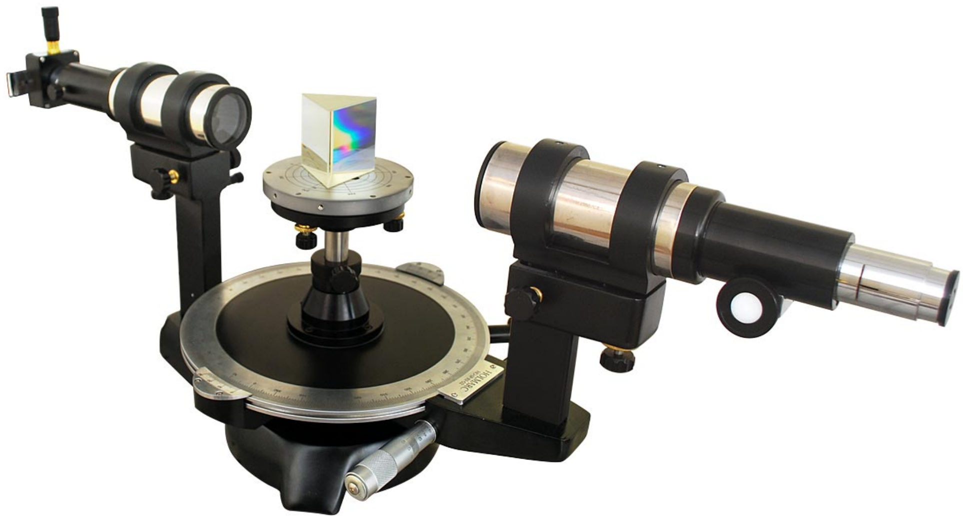

Figure 2: Spectrometer.

**(B) Measurement of the angle of the prism:**

1. Determine the least count of the spectrometer.

2. Place the prism on the prism table with its refracting angle A towards the collimator and with its refracting edge A at the centre. In this case some of the light falling on each face will be reflected and can be received with the help of the telescope (as shown in fig. 3).

3. The telescope is moved to one side to receive the light reflected from the face AB and the cross wires are focused on the image of the slit. The readings of the two verniers are taken.

4. The telescope is moved in other side to receive the light reflected from the face AC and again the cross wires are focused on the image of the slit. The readings of the two verniers are taken.

5. The angle through which the telescope is moved; or the difference in the two positions gives twice of the refracting angle A of the prism. Therefore half of this angle gives the refracting angle of the prism.

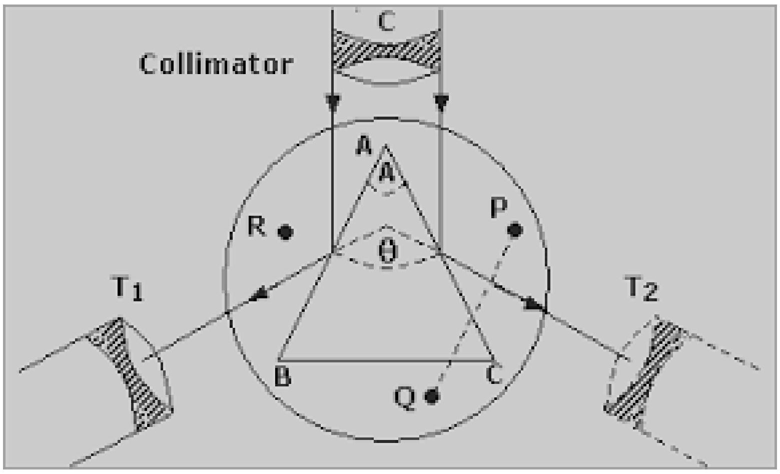


Figure 3: Arrangement to determine the angle of prism.

**(B) Measurement of the angle of minimum deviation:**

1. Place the prism so that its centre coincides with the centre of the prism table and light falls on one of the polished faces and emerges out of the other polished face, after refraction. The telescope is turned to view the refracted image of the slit on the other face (as shown in fig. 4).

2. The vernier table is slowly turned in such a direction that the image of slit is move directed towards the directed ray; ie., in the direction of decreasing angle of deviation.

3. It will be found that at a certain position, the image is stationary for some moment. Vernier table is fixed at the position where the image remains stationary. Using telescope fine adjusting slider, make coincide the slit with cross wire.

4. Note corresponding main scale and vernier scale reading in both vernier (vernier I and vernier II).

5. Carefully remove the prism from the prism table. Turn the telescope parallel to collimator, and note the direct ray readings.

6. Find the difference between the direct ray readings and deviated readings. This angle is called angle of minimum deviation ($\delta_m$). Refractive index of the material of the prism is determined by using eq.(12)

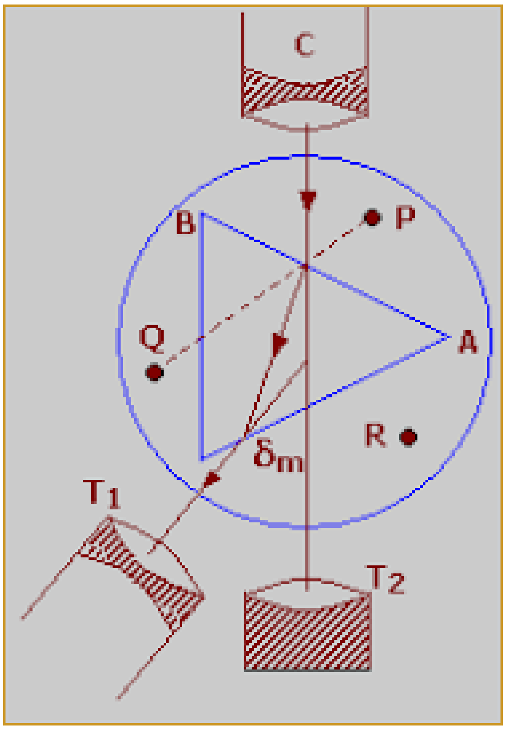


Figure 4: Arrangement to determine the angle of minimum deviation.

**Observations:**

1. **Least count of spectrometer**

   One main scale division, $N =$. . . . . .degrees

   No. of divisions on vernier, $v =$. . . . . .

   Least count$=\frac{N}{v}$ =. . . . . .degrees =. . . . . .seconds

2. **Wavelength of light used** = . . . . . . . . . .

3. **Table for the angle of the prism (A):**

| **S.No.** | **Vernier** | ***Telescope reading for reflection*** | | | | | | **Difference** $\theta = a - b$ | $A = \theta/2$ |
|---|---|---|---|---|---|---|---|---|---|
| | | **First face** | | | **Second face** | | | | |
| | | **MSR** | **VSR** | **TR(a)** | **MSR** | **VSR** | **TR(b)** | | |
| **1.** | $V_1$ | | | | | | | | |
| | $V_2$ | | | | | | | | |
| **2.** | $V_1$ | | | | | | | | |
| | $V_2$ | | | | | | | | |
| **3.** | $V_1$ | | | | | | | | |
| | $V_2$ | | | | | | | | |

$*$ MSR = Main Scale Reading, VSR = Vernier Scale Reading, TR = MSR+VSR$\times$LC = Total Reading

4. **Table for the angle of minimum deviation:**

| S.No. | Vernier $V_1$ | | | Vernier$V_2$ | | |
|---|---|---|---|---|---|---|
| | Telescope reading | | Difference $\delta_m$ | Telescope reading | | Difference $\delta_m$ |
| | Minimum deviation | Direct reading | | Minimum deviation | Direct reading | |
| 1. | | | | | | |
| 2. | | | | | | |

**Results:**

1. **Angle of prism :** . . . . . . . . . . .degrees
2. **Angle of minimum deviation of the prism :** . . . . . . . . . . .
3. **Refractive index of the material of the prism :** . . . . . . . . . . .
4. **Percentage Error :**

**Precautions:**

1. The telescope and collimator should be individually set for parallel rays.
2. Slit should be as narrow as possible.
3. Both verniers should be read.
4. The prism should be properly placed on the prism table for the measurement of angle of the prism as well as for the angle of minimum deviation.

**Sample viva voca questions :**

1. What is monochromatic light?
2. What is angle of prism?
3. What is angle of minimum deviation?
4. What is refractive index? What are its units?
5. What is the relation between the angle of incidence and the angle of deviation?

6. How does the angle of deviation vary with the wavelength?
7. On what factor or factors does the angle of deviation depend?
8. Which eyepiece is used in the telescope of a spectrometer?
9. Will the angle of minimum deviation change, if the prism is immersed in water?

**References:** • Optics by A. Ghatak