Experiment No. 7

Object : *To determine the refractive index and dispersive power of the material of prism with the help of spectrometer.*

Apparatus Required : Spectrometer, prism, spirit level, reading lens, mercury vapour lamp and reading lamp.

Description of the Apparatus : Spectrometer : Refer Experiment No. 3 for the description of spectrometer.

Theory : When a monochromatic ray of light QP is incident at the point P of the surface AB of the prism ABC, it follows the path PR after refraction through the surface AB (from air to glass), bending towards the normal NOM. The refracted ray is PR. This ray again suffers refraction from glass to air at the surface AC and bends away from the normal N'DM' (*i.e.*, bends towards the base BC) and follows the path RS. The emergent ray is RS. The angle of incidence i is $\angle$QPN, the angle of refraction r is $\angle$MPR at the first surface and angle of emergence e is $\angle$SRN' at the second surface.

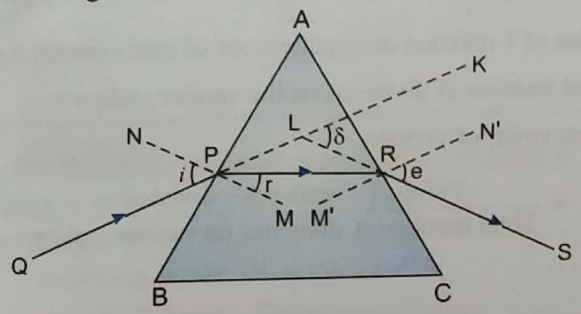

Fig. 24. Reflection through a prism

If the angle of incidence i of the incident ray on the prism is gradually increased, the angle of deviation δ first decreases, then at a particular angle of incidence, the angle of deviation becomes minimum equal to δ_m. With further increase in angle of incidence, the angle of deviation again starts increasing. The minimum value of angle of deviation δ_m is called the *angle of minimum deviation.*

If the refracting angle of prism $\angle BAC = A$, in the position of minimum deviation, the refractive index of the material of prism is

$$\mu = \frac{\sin[(A + \delta_m)/2]}{\sin(A/2)}$$

Now if white light is made incident on the prism, the angle of minimum deviation corresponding to different constituent colours of white light is different. Hence a spectrum is obtained in the light emerging out of the prism. If the refractive indices of material of prism for the violet, yellow and red light be respectively μ_V, μ_Y and μ_R, the dispersive power of the material of prism is then

$$\omega = \frac{\mu_V - \mu_R}{\mu_Y - 1}$$

Formula Used : The refractive index of material of prism for the monochromatic light is

$$\mu = \frac{\sin[(A + \delta_m)/2]}{\sin(A/2)}$$

where A is the refracting angle of prism and δ_m is the angle of minimum deviation for the light of that colour.

Dispersive power of the material of prism $\omega = \frac{\mu_V - \mu_R}{\mu_Y - 1}$

where μ_V, μ_R and μ_Y are respectively the refractive indices of material of prism for light of violet, red and yellow colours.

Procedure : The experiment is done in the following three steps :

(1) Adjustment of Spectrometer : Before the experiment, the spectrometer is adjusted by the method described in Experiment no. 3 so that (a) the axes of collimator and telescope intersect each other on the vertical axis of the telescope, (b) the prism table is horizontal, and (c) telescope and collimator are focused for the parallel rays.

(2) Determination of refracting angle A of the prism : (i) First find the least count of the scale provided on the spectrometer.

(ii) Now the prism is kept on the prism table such that the vertex A of the prism is at the centre of prism table and its base is normal to the direction of incident light (Fig. 25). In this position, the parallel rays coming from the collimator fall on the faces AB and AC of the prism and they get reflected from these faces.

(iii) Illuminate the slit of collimator with the mercury lamp.

(iv) Now the telescope is turned towards the face AB of the prism and the image of slit formed by the light reflected from this face is brought on the cross-wires of telescope. The telescope is then clamped with the help of screw and it is moved slowly with the help of tangential screw to obtain the image of slit on the vertical cross-wire. This position of telescope is read with the help of both vernier scales on the circular scale.

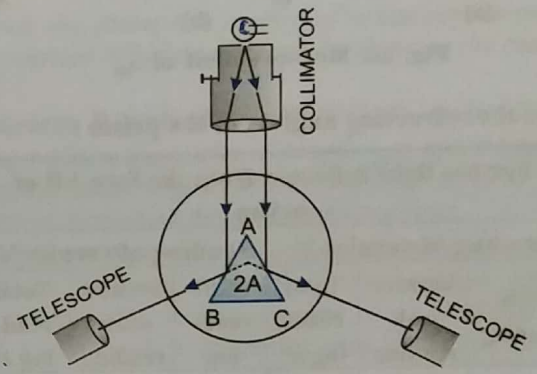

Fig. 25. Measurement of A

(v) Then the telescope is turned towards the face AC of the prism and again the image of the slit formed by the light reflected from this face is brought on the vertical cross-wire of the telescope. This position of telescope is again read with the help of both verniers.

(vi) Find the difference in both readings of each vernier separately. This difference is twice the refracting angle of the prism (*i.e.*, 2A). Taking half of this, the refracting angle A of the prism is obtained.

(3) Determination of angle of minimum deviation δ_m : (i)The prism is placed on the prism table such that light from collimator falls obliquely on one refracting face AB of the prism (Fig. 26).

(ii) On lighting the mercury lamp, it is kept near the slit of collimator and the spectrum is seen by bringing the telescope towards the other refracting face AC of the prism.

(iii) When spectrum is seen [Fig. 26 (a)], the prism table is turned such that the spectrum begins to shift towards the axis of collimator. In doing so, if the spectrum goes beyond the field of view, the telescope is turned so as to bring the spectrum within the field of view. With this, the angle of incidence gradually increases and the angle of deviation gradually decreases. On turning the

prism table, a stage is reached when the angle of incidence is such that the angle of deviation becomes minimum. This position is shown in Fig. 26 (b). In this position, the telescope will be near the axis of collimator. If the prism table is further rotated, the angle of deviation will increase and to see the yellow spectral line, the telescope will have to be turned away from the axis of collimator. The position of prism from where the spectrum begins to shift in opposite direction is called the position of minimum deviation.

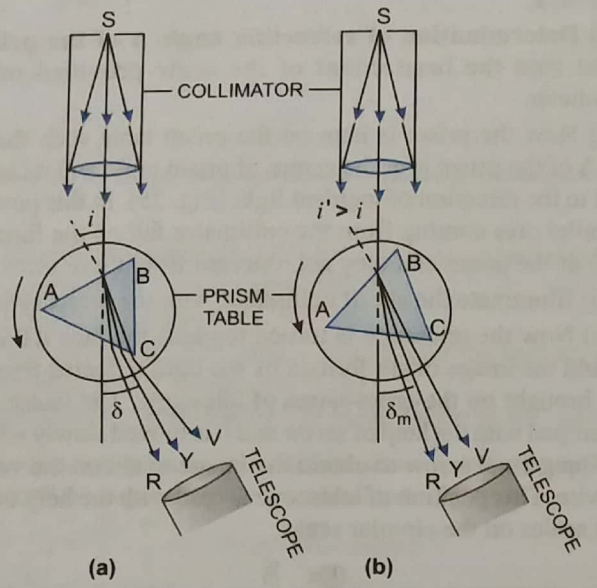

Fig. 26. Measurement of δ_m

(iv) In the position of minimum deviation, the yellow spectral line is made to coincide with the vertical cross-wire by turning the telescope and then the position of telescope is noted by taking the readings of both verniers on the circular scale.

(v) Now the prism is removed from the prism table and the telescope is brought just in front of the axis of collimator and the image of slit is made to coincide with the vertical cross-wire of the telescope. This position of telescope is again noted by taking the readings of both verniers on the circular scale.

(vi) Then taking the difference in the two readings of each vernier separately, find their mean value. This will give the angle of minimum deviation δ_m for the yellow colour.

(vii) Similarly, find the angle of minimum deviation for other colours (violet and red).

Observations :

Value of 1 division of circular scale of spectrometer x = ...°

Total number of divisions on the vernier scale n =.....

Least count of vernier

$$= \frac{\text{Value of 1 main scale division } x}{\text{Total number of divisions on vernier scale } n} = ...^\circ$$

(1) For the refracting angle A of the prism :

S. No.	For the light reflected from the face AB of prism						For the light reflected from the face AC of prism						Difference in readings of two verniers 2A		
	Reading of vernier V_1			Reading of vernier V_2			Reading of vernier V_1			Reading of vernier V_2					
	M.S. reading	Vernier scale reading	Total reading a°	M.S. reading	Vernier scale reading	Total reading b°	M.S. reading	Vernier scale reading	Total reading a°	M.S. reading	Vernier scale reading	Total reading b°	a~a' (in °)	b~b' (in °)	Mean 2A (in °)
1.															
2.															
3.															

Mean value of 2A = ...°

∴ A = ...°

(2) For the angle of minimum deviation :

S. No.	Colour of light	After refraction from prism						In line with the axis of collimator						Difference in readings of two verniers δ_m		
		Reading of vernier V_1			Reading of vernier V_2			Reading of vernier V_1			Reading of vernier V_2					
		M.S. reading	V.S. reading	Total reading a°	M.S. reading	V.S. reading	Total reading b°	M.S. reading	V.S. reading	Total reading a°	M.S. reading	V.S. reading	Total reading b°	a~a' (in °)	b~b' (in °)	Mean δ_m (in °)
1.	Yellow															
2.	Violet															
3.	Red															

From the above table :

Angle of minimum deviation for yellow colour δ_{m_1} =.....°

Angle of minimum deviation for violet colour δ_{m_2} =.....°

Angle of minimum deviation for red colour δ_{m_3} =.....°

Calculations :

Refractive index for yellow colour $\mu_Y = \dfrac{\sin[(A+\delta_{m_1})/2]}{\sin(A/2)} = ...$

Refractive index for violet colour $\mu_V = \dfrac{\sin[(A+\delta_{m_2})/2]}{\sin(A/2)} = ...$

Refractive index for red colour $\mu_R = \dfrac{\sin[(A+\delta_{m_3})/2]}{\sin(A/2)} = ...$

Dispersive power of material of prism $\omega = \dfrac{\mu_V - \mu_R}{\mu_Y - 1} = ...$

Result : (i) The refractive index of material (.....) of prism for light of different colours is given in the following table :

Colour of light	Calculated value of refractive index μ	Standard value	Percentage error %
Yellow			
Violet			
Red			

(ii) The dispersive power of material (.....) of prism ω = ...

Standard value : ω = ...

Percentage error :

Percentage error

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

= .....%

Precautions : (1) Before the experiment, the spectrometer must be well adjusted.

(2) The reading in the position of minimum deviation must be taken only when on turning the prism table in one direction, the spectral line of given colour (say, yellow) begins to return back after coinciding exactly with the vertical cross-wire of the telescope.

(3) While finding either the refracting angle of prism or the angle of minimum deviation, we must take the difference in two readings of the same vernier.