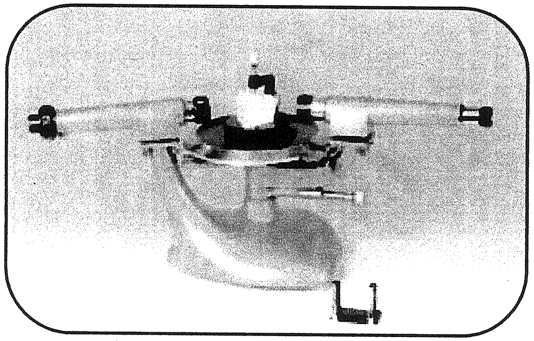
Standard Spectrometer



Introduction:

It is an inexpensive spectrometer having good performance with which the composition of light can be examined and refractive index of a transparent solid or liquid measured. The essential parts are as follows:

a) Collimator : It consists of a main tube at the one end of which there is a small draw tube fitted with a well corrected achromatic convergent lens with f. 1,=178 mm, and the other end carries an adjustable slit. The draw tube can be moved helically inside the main tube by hand, in order to place the slit in the focal plane of the lens so as to give parallel rays. The collimator is mounted on a spring loaded support. The support is integral with the base.

b) Prism Table : The prism table is supported on a 175 mm. Diameter circular scale graduated in degrees. The circular scale is rotatable about the central axis and is provided with a clamping screw. The fully adjustable prism table with three leveling screws has screwed holes for fixing the prism and grating holders.

c) Telescope : The telescope is astronomical type consisting of main tube at one end of which there is draw tube fitted with an achromatic objective, and the other end carries a Ramsden's eye piece with cross wires. The draw tube can slide inside the main tube helically by hand. The telescope mounted on heavy bearings can be rotated about the vertical central axis of the scale. A vernier reading to 0.1^0 is fixed to telescope arm. There is one clamping screw to fix the telescope and a tangent screw for slow motion of the telescope.

PRELIMINARY ADJUSTMENTS OF THE SPECTROMETER :

First focus the cross wires by moving the eye piece in and out. This fixes the position of the eye piece, relative to the cross wires. Next pointing the telescope through an open window at some distant object lying at infinity such as an electric pole, adjust the distance between the eye piece and the objective with the help of helical arrangement, until there is no parallax between distinct image of distant object (at infinity) and the cross wire. When this is done the telescope must not be readjusted again during the experiment. It may happen that a second observer whose sight differs from that of the first is unable to focus the cross wires easily. He may readjust the eye piece provided that he does not alter any other part of the telescope.

The telescope is now turned towards the collimator with its slit illuminated with a monochromatic source of light. The collimator lens is then, adjusted with the help of helical arrangement until a distinct image of the slit falls on the cross wires and there is no parallax between the two. The instrument is now ready so that parallel rays pass from the collimator to the telescope.

Schuster' Method : In the absence of a distant object this method may be used. After focusing the eye piece on cross wires the prism is so placed on the prism table that it has maximum illumination from the collimator. The prism table is then rotated slowly, following the refracted image with the telescope until the position of minimum deviation is found. Now the table is so rotated, so that the refracting edge is slightly turned towards the telescope causing the rotation of the image. The telescope is adjusted to give the distinct image. Again the prism table is turned to the other side of the minimum deviation i.e. the refracting edge towards the collimator and the collimator is adjusted to give a fine and distinct image of the slit. This procedure is repeated a number of times (usually three to four alternate focusing are sufficient) till the image does not blur on rotation.

Levelling of the Table: Place the prism on the table of the spectrometer, so that its refracting edge is at the center and parallel to the slit of the collimator and one of its clear faces say **AC** is perpendicular to the line joining two of the levelling screws **P & Q**. Adjust the prism table so that parallel beam of light illuminates both the faces surrounding the edge, as shown in the Fig. 1.

Receive the light in the telescope in the position T_1. Adjust the levelling screws **P & Q** to bring the reflected image in the middle of the field of view of the telescope. Next turn the telescope to face **AB** in the position T_2 and adjust the screw **R** to bring the image again in the center of the field of view.

Expt. 1 : To determine the angle of the prism by any of the following two methods:

a) By turning the Telescope : Having adjusted the image symmetrical in the field of view of the telescope, on either face, allow the telescope to receive rays along AT_1 from the face **AC** and along AT_2 from the face **AB** each time the slit falling upon the across wires. The

Difference between the two readings (angle T_1AT_2) is equal to twice the angle of prism i.e, 2A where **A** is angle of the prism. Half this difference gives the angles A.

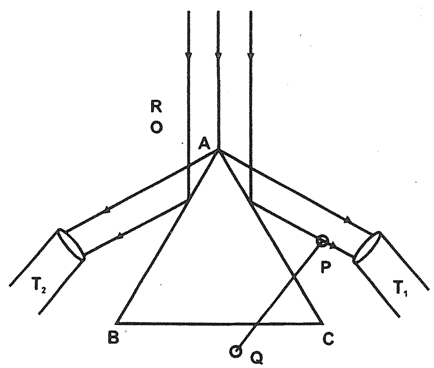


Fig. 1

b) By Turning the Table : Focus the telescope on the image of the slit by reflection from **AB** as shown. Note this reading. Keeping the telescope fixed rotate the prism table until the face **AC** is in position of **AB**, then **AC** has trough an angle i.e. the rays once again be reflected in the original direction. The difference between the two reading is equal to θ i.e. the angle A = $(180^\circ - \theta)$.

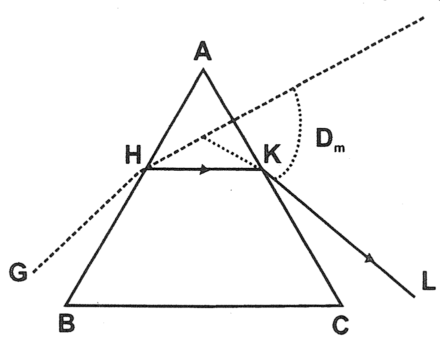


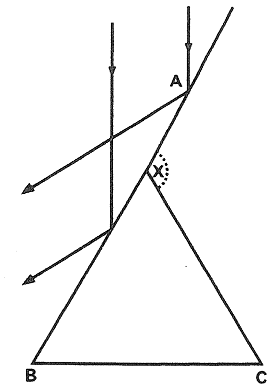
Fig. 2

Expt. 2: **To find the angle of minimum deviation and the refractive index of the material of the prism:**

To find the angle of minimum deviation D_m set the prism on the table with its center at the center of the table so that the light is refracting through is along **HK** as shown in the Fig. :

And the image of the slit is seen with naked eye along KI. Direct the telescope in this direction. Slowly rotate the prism table in such a direction that the deviation of the ray decreases and also rotate the telescope so as to keep the image of the slit in the field of view till the image of

the slit comes to momentary rest and on further rotation of the prism table in the same direction it turns back.



The position of the prism table at which the image becomes stationary corresponds to minimum deviation position. This image is coincided with the vertical cross wire. Note the position of the telescope on the graduated scale.

Remove the prism and turn the telescope to coincide the direct image of the slit with the vertical cross wire directly. Note the position of the Telescope again. The difference between the two readings is the angle D_m (angle of minimum deviation). The refractive index is given by:

$$\mu = \frac{\sin \frac{A + D_m}{2}}{\sin A/2}$$

Where A is the angle of prism. It may be pointed out here that when light passes through a prism, deviation occurs and the amount of deviation depends upon its refractive index, angle of incidence and the colour of the light used, Hence to find the refractive index, light of one colour or monochromatic light must be used. It is very conveniently obtained by soaking a piece of abestos in common salt solution and inserting it in the edge of non luminous Bunsen flame or by using a sodium lamp.

Exercise : To find the refractive index of a transparent liquid using a hollow prism.

HINT : A Hollow prism of glass is filled with a liquid whose refractive index is required. One of the prism is marked as the refractive edge. One of the edge of this prism is marked as the refracting edge. The angle subtended by the two faces here is the angle of the prism. This angle and the angle of minimum deviation are determined and here the refractive index is found as in the above experiment.

Expt. 3 : To measure the dispersive power of a prism :

The dispersive power of a medium is given by :

$$W = \frac{\mu v - \mu r}{\mu - 1}$$

Where μv and μr are the refractive indices for the violet and red rays and

$\mu = \frac{\mu v - \mu r}{\mu - 2}$ Being the refractive index for the mean ray.

PROCEDURE : Take a hydrogen discharge tube or mercury lamp as a source of red and blue rays. Illuminate the slit by it directly, and in the line spectrum three well marked spectral lines can easily be seen one in the red region a second in the blue and green region, and third in the violet. These lines are known as C, F and H lines and the value of refractive indices of the prism corresponding to these lines represent fairly μr, μ and μv Respectively.

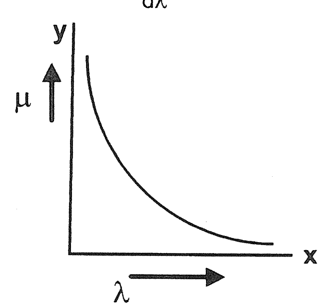
Proceed to calculate these as in the earlier expt. Calculate dispersive power, using the above relation.

Expt. 4 : Resolving power of the prism : or calibration of the Prism Spectrometer :

Light from a mercury tube is found to consist of seven bright lines of different colours. If the angle of minimum deviation for each line is found and the corresponding value of μ is calculated, a graph between wave length of each (from the tables for wave length) and μ is obtained. The calibration curve will be as shown. If the slope of the graph for any

particular wave length is found the resolving power $t = \frac{d\mu}{d\lambda}$ of the prism can be calculated

Where t = length of the base of the prism and $\frac{d\mu}{d\lambda}$ is tangent of the angle of the slope.



Expt. 5 : Determination of wave length of sodium light with a plane transmission grating :

The diffraction grating in the holder is placed in the proper position on the table so that it lies at the centre of the table of the spectrometer. Set the telescope at right angle to the collimator. Now set the grating for normal incidence.

To achieve this, first take the reading when the direct image of the slit coincides with the vertical cross wire. Turn the telescope through 90° from this reading and fix it here. Now rotate the table so that brightest reflected image of the slit after reflection from the grating surface coincides with the same cross wire in the telescope. Note this reading and rotate the through 45° to make the grating normal to the parallel beam of light coming from the collimator.

View the Ist order diffracted images on either side of the central maximum making the slit as narrow as possible.

Find the angle 2θ between the diffracted images in the first and then in the 2^{nd} order spectra. Half of this angle is the angle of diffraction in each case. If (a + b) is the width of the grating element then :

$(a + b) \sin\theta = n\lambda$ (For details see some Theory book)

Where n = order of the spectrum. For 1^{st} order n=1, and for 2^{nd} order n=2, and

$(a + b) = \frac{1}{N}$ where **N** is the no. of lines ruled on the grating surface per cm.

and λ = Wave length of the light used.