(For Counsellor's use only)

Grade . . . . Name. . . . .

Evaluated by . . . . Enrolment Number . . . . .

EXPERIMENT 8

SPECTRAL ANALYSIS USING A PRISM SPECTROMETER

Structure

8.1 INTRODUCTION

You have already learned about the phenomena of dispersion, interference and diffraction in your school. These phenomena are beautiful to observe and give a lot of scientific information. Most of the informations gathered regarding heavenly bodies are due to the study of these phenomena. In the experiments you are going to perform, you observe these phenomena and determine values of some physical quantities such as refractive index of the material of the prism for different wavelengths of lines of various colours in the visible spectrum of some sources of light. You should be aware that the observation of the solar spectrum gives information regarding the constituents of the atmosphere of the sun.

Of course before you are able to determine the quantities you will learn to use the apparatus required. They are the spectrometer, prisms, and sources of light. The knowledge and skills you acquire in this experiment will form the basis of your future experiments in spectroscopy. The Experiment will be a sequential experiment with this experiment.

Objectives

After performing this experiment you should be able to

* Identify the various parts of spectrometer and make initial adjustments in order to obtain a clear and resolved spectrum.
* Determine the refractive indices of the material of the prism for different wavelengths.
* Observe and interpret the solar spectrum.

8.2 APPARATUS

Student spectrometer
Dense flint glass equilateral prism Mercury vapour lamp
Spirit level
Reading lens.

8.3 STUDY MATERIAL

8.3.1 Refractive Index

When a composite visible light is dispersed in a medium, the light of different colours are separated and propagated in different directions. The light of different colours travel with different speeds in a transparent medium. This phenomenon is called dispersion. The speed of light in vacuum is a constant equal to $3*10^8$m. The speed of blue light is less than that of the red light in the dispersive medium. The ratio of the speed of light in vacuum to the speed of light of a particular colour in the medium called refractive index.

$$n = \text{refractive index} = \frac{\text{speed of light in vacuum}}{\text{speed of light of a particular colour in the medium.}} \quad \ldots\ldots 1$$

These different colours of light also have different wavelengths: the wavelength of blue light is less than the wavelength of red light. There is a relation between the wavelength and refractive index.

$$n = A + (B/\lambda^2)$$

where λ = wavelength, and A and B are called the Cauchy's constants.

To determine the wavelength and the refractive index, we use a spectrometer. With a spectrometer and a prism we can determine the refractive indices of various colours of lights. With a spectrometer and a grating, we can determine the wavelengths of lights of different colours.

8.3.2 Light Sources

The source of light can be a white light source such as incandescent light, sunlight or mercury vapour light,

In the laboratory, we use two types of light, monochromatic light source; polychromatic light source. Sodium vapour lamp emits light of one wavelength (actually a doublet) at yellow region of spectrum. Its wavelength is 589.3nm. The low pressure mercury lamp emits lights of different colours. They are : two closely spaced lines (doublet) in yellow region, a few lines in bluish green region, a bright line in green region and a bright line in blue region.

Identification of elements by the **spectrum of emitted light** is a **part of** the study of spectroscopy.

8.4 PRECAUTIONS

1) Sometimes, it may happen ***that you are able to see the reflected light from one side of the prism and not from the other side. The slit might not have received light properly.***

2) ***Fix the prism table and the telescope firmly while taking readings.***

3) ***When the prism is fixed on the prism table, the refracting edge of the prism should be at the centre*** of the prism table while measuring the angle of the prism. This enables to get the reflected light from the slit, on both the sides of the prism.

SAQ's

1) The refractive indices of blue and red **colour** are denoted as nb and nr. **What** does (nb **- nr)** denote? what is its value in your observations?

2) The mean refractive index of the material of the prism is

$$n = \frac{(n_b + n_r)}{2}$$

Calculate its value.

3) The dispersive power of the **material of the prism** between the blue and yellow **colours** is

$$dw = \frac{(n_b - n_y)}{(n-1)}$$

Calculate its value.

4) How will you identify the **refracting angle of the** prism? From the geometry **of the** prism, what is its value?

8.5 THE EXPERIMENT

PARTS OF A SPECTROMETER

1. Telescope
2. Collimator
3. Prism-table

8.5.1 Adjustments of a Spectrometer

ADJUSTMENT OF **THE** EYE-PIECE : Looking through the eyepiece of the telescope, you can see the cross wire. The cross wire can be clearly seen on a white back-ground when the eyepiece is moved in or away in the slot, for a particular position, the cross wire is clearly seen. After setting this, do not disturb the eye-piece. This adjustment has to be done by every person who uses a spectrometer as the eye-lens also plays a role in focusing the **crosswire.**

Turn the telescope towards the distant object like a building or a tree more than 20 metres away. Focus the telescope, so that the details of the distant objects are clearly seen; for example the leaves of the distant tree shall be clearly seen. You know that light rays coming from a distant object is parallel and the telescope is able to receive parallel beam of light and brings it into its focal plane. After doing this adjustment, do not disturb the telescope adjustment through out the experiment.

8.5.2 Adjustment of the Collimator

After the adjustment of the telescope, we turn towards the collimator and adjust the collimator. The collimator has a slit at one end of it. Keep the slit width minimum keeping good visibility. Look through the telescope, and focus it so that the slit is seen clearly. A parallel beam of light then emerges from the collimator. The telescope which is already set to receive parallel beam of light, is able to converge the light at its back focal plane, where the image of the slit is formed. Throughout the experiment the telescope that is adjusted to receive parallel rays and the collimator that is adjusted to produce paralled rays should not be altered.

8.5.3 Adjustment of the Prism Table:

Using the spirit level, adjust the prism table to be horizontal. There are three screws on the prism table rests. Keep the spirit level on the line joining two screws and turn the screws suitably to bring the bubble to the centre. Then keep the spirit level perpendicular to the original position and turn the third screw to keep the bubble at the centre. Repeat this alternatively till the bubble of the spirit level is always at the centre. Now if you keep the spirit level in any position on the prism table, the bubble is always at the centre. Then the prism table is horizontal.

Keep the prism on the prism table and clamp it. The base of the prism is against the clamp.

There is a facility to rotate the prism-table along with the vernier scale by releasing a mainscrew at the base of the instrument. By tightening the screw, the vernier scale can be fixed and the prism-table alone can be rotated.

The telescope can be rotated and 'fixed at any desired positions by fixing a main screw, which is also at the base of the instrument.

Any fine movements of the telescope or the vernier scale are possible by working the screws called vernier screw. Vernier screw can work only when the main screws are fixed.

The circular scale is graduated in degrees. The value of main scale divisions, is usually $1/2^\circ$ or 30'.

The number of divisions in the vernier scale is usually 30 **(VSD)**, which is equal to 29 main scale divisions. The least count of the vernier is usually 1'.

8.5.4 Measurement of Angle of the Prism

In ths case refractive indices of the various lines of the mercury vapour lamp by using an equilateral prism and a spectrometer,

APPARATUS **REQUIRED:**

- Prism (dense flint glass),
- Spirit level,
- Reading Lens,
- Mirrors,
- Mercury lamp,
- Spectrometer,

After making the adjustments of the spectrometer, the prism is mounted on the prism-table. The reflection edges are **kept symmetrically** on the prism table with respect to the collimator. Rotate the **telescope** to receive the reflected light from **one** side of the prism. Fix the **main** screw **of the** telescope and then turn the fine screw of the telescope so that the cross wire is **coinciding with image of** the slit, as shown below in Fig. 8.1.

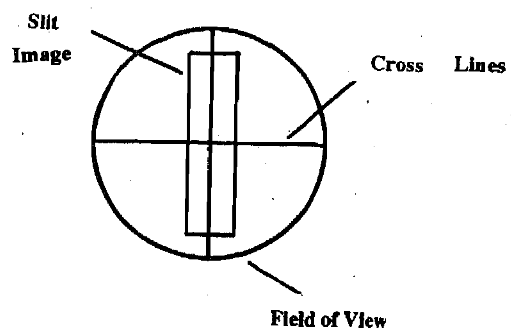

Fig 8.1

Refer to Rig. 8.2. Note the main scale readings and vernier scale coincidence on both scales, A and B. **Release** the telescope and rotate it to receive the reflected light from the second face and do exactly as before to take the **readings** on both scales. The difference in the two readings of scales **A** and B is equal to the angle through which the telescope is **rotated** and this is equal to twice the angle of the prism ($2A$). Hence we can determine A. Tabulate the **readings.** Repeat the experiment by keeping the vernier scale at other positions and fixing it. The mean value of a number **of trials** gives a better estime of A. Write your measurements in Table I.

TABLE I

SIDE I VERI VERII	SIDE II VERI VERII	$2A$ VERI VERII DIFF. DIFF.	A MEAN
MEAN PRISM ANGLE = ...			

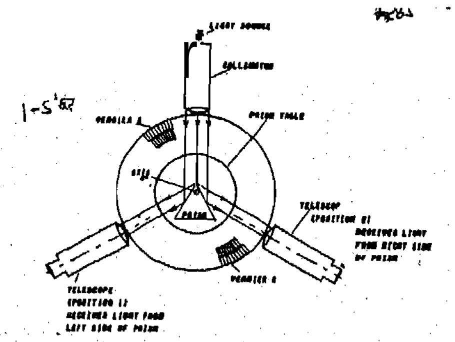

Fig. 8.2

8.5.5 Measurement of Angles of Minimum Deviatiod for various Colours of Light

After measuring the angle of the prism, let us turn the prism table so that the side of the prism is inclined to the collimator as shown in Fig. 8.3.

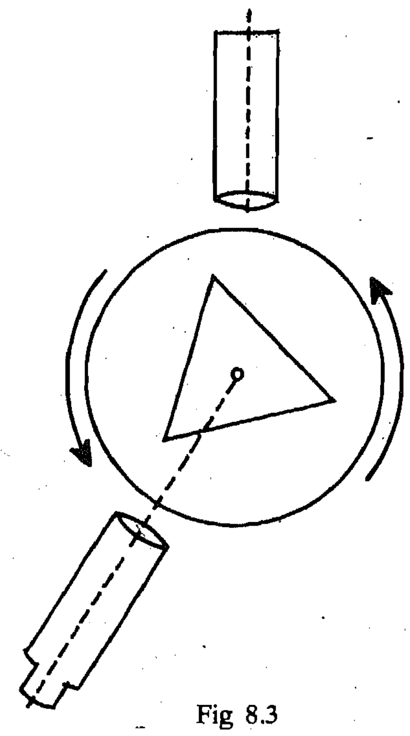

Fig 8.3

After refraction through the prism in which direction the emergent ray will come out?

The emergent ray will be deviated towards the base of the prism. Now rotate the telescope so that the emergent rays pass through the telescope. You can see the beautiful spectrum of the incident light. Refer to Fig.8.4.

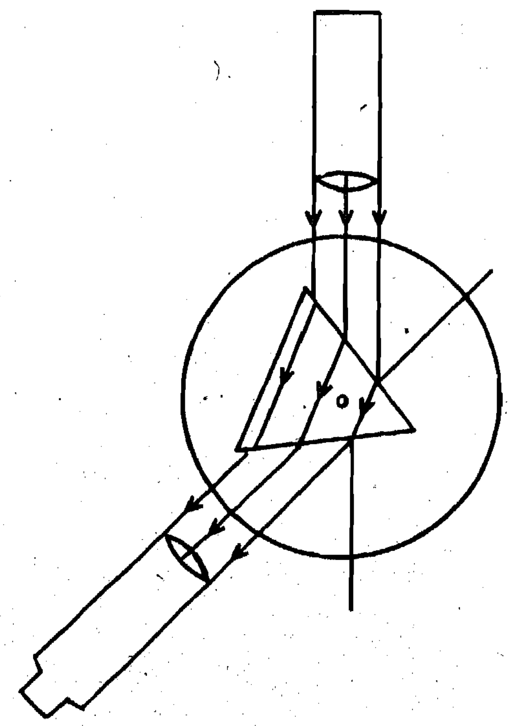

Fig 8.4

When the prism table is rotated, the angle of incidence changes and the angle of emergence also changes. Consequently the angle of deviation also changes, as shown in Fig. 8.5

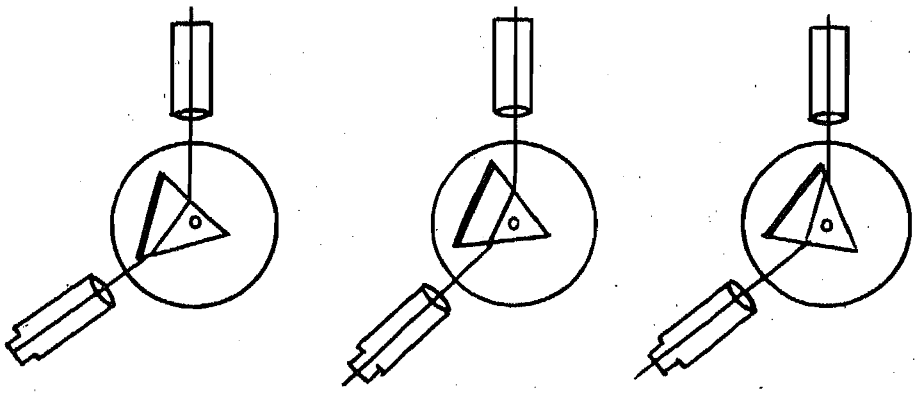

Fig 8.5

Our aim is to fix the prism-table at the minimum deviatian position. For this, you observe **the spectrum** through the telescope and simultaneously rotate the prism-table and follow the spectrum. If you rotate the prism table in one direction the spectrum will move **towards** one end. As you **rotated** prism more in the same direction you will see the spectrum halt its motion and **then** move in the opposite direction. Fix the prismtable **at** the "halt' position. This is the position of minimum deviation.

TABLE **II**

DIRECT RAY READING - VERNIER I ....
- VERNIER **II** ....

COLOURS	**MIN.DEV.POS.**		ANGLE OF **MIN.DEV.**			n
	VER I	**VER** II	**VERI** DIFF.	**VERII** DIFF.	**MEAN** D	

SAQ: Do you need to adjust the prismtable for **each line of the spectrum?** Does the adjustment of the prism table for one line in minimum deviation **position automatically** guarantees minimum deviations for all the other lines? Do the experiment and the answer in Table II.

After taking the readings of the minimun deviation position for all the lines, remove the prism. Release the telescope and turn it in line with the axis of the collimator and take the direct ray reading on both verniers.

Calculate the difference in the readings on the same vernier for the two positions of the telescope, that is the positions to receive the deviated and the direct rays. Take the mean of the two difference readings. It gives D, the angle of minimum deviation.

Using the formula n = sin ((A+D)/2) / sin (A/2) and substituting the values for A and D, calculate the refractive index can be calculated.

8.5.6 Observations:

1 msd	=	$1/2^{\circ}$
30 vsd	=	29 msd
1 vsd	=	29/30 msd
Least count	=	1 msd - 1 vsd= (1-29/30)msd = 1/30 msd
	=	1/30 * 1/2 = 1/60 =1'

Least Count = 1' Angle of the prism = A =

Set the prism and prism table at minimum deviation position for the green line in the mercury spectrum. Now adjust the telescope so that the cross-wire falls on the prominent lines, one by one. Record the scales for each line in Table III, which you should draw in the space below.

8.4.7 Solar Spectrum:

In observing solar spectrum in the visible region, instead of the laboratory sources, we use the sun light. Keep the prism position the same as for 8.4.6. Adjust a small mirror to reflect sunlight straight into the Spectrometer through the slit. Adjust the slit to the narrowest possible, while letting through appreciable light.

The procedure of taking readings is the same as before. Here one observes dark lines on a continuous background spectrum. These dark lines correspond to absorption lines of elements which are in vapour state on the Sun. So these absorption lines appear as dark lines. The H-alpha and H-beta lines arc prominently seen as dark lines.

Measure the angles at which very prominent (dark) absorption lines are seen. Enter your scale readings in Table IV, which you should draw in the space below.

8.6 CALCULATIONS

Make a graph in which you plot the calculated indexes of refraction forvarious colours (Table II). The wavelength (nm) of the colours (see the chart below).

Colour	Red	Yellow	Green	Blue1	Blue2	Violet	
wavelength (nm)	690.72	546.07	491.61		435.83	404.66	

8.7 CONCLUSIONS

The angle of the prism is determined. The refractive indices of the material of the prism are determined for various colours of the spectrum of light emitted froma–source., The spectrometer is calibrated for the mercury lines using green-light minimum deirators. The prominent solar absorptions lines are observed and their wavelength calculated.

Make a graph in which you plot the wavelengths of prominent mercury lines or telescope angle readings (Table III).

From the telescope angle readings of prominent 'solar absorptions lines (Table IV) and by use of the above graph, find the wavelength of the solar lines. Enter in Table V.