Evaluated by . . . .

EXPERIMENT 10

SPECTRAL ANALYSIS USING A GRAT-ING SPECTROMETER

Structure

10. INTRODUCTION

You have used a **spectrometer** to determine the index of refraction of the material of the prism for various colours of light. In that process you have learned to adjust the prism and the telescope. You have also learned to make measurement of angles. This experiment, **using** a grating can be considered as a sequence to that experiment, where you bave used a prism.

Objective

After performing this experiment, you will be able to

- **standardise** a **grating**, and
- determine the wavelength of the various **colours** of light.

10.2 APPARATUS

Student spectrometer
Transmission grating
Mercury vapour lamp
Sodium vapour lamp
Spirit level
Reading lens

10.3 STUDY MATERIAL

10.3.1 Standardisation of Grating

The determination of number of lines per meter of the grating is called **standardisation** of the **grating**. Usually, this information is written on the grating. This information is sometimes given as certain number of lines per inch or centimeter, or meter.

What does this number denote? For this you must know how a grating is made and how it acts on the light falling on it. On a plane transparent glass, parallel lines are drawn with a very small **separation** between adjacent ones using diamond point. Through the tranparent portion between the two adjacent **lines, light** passes and the opaque portions stop the incident light. The gap between the opaque lines is so small that light is diffracted **by** it. Diffracted light from all such transparent slits interfere to form various interence orders.

The width of the transparent slit is a. The width of the opaque portion is *b*, **then** grating element is $e = a + b$. (See **Fig.** 10.1) The reciprocal N of e ($N = 1/e$) is called "number of **lines**" or equivalently number of slits per unit length. Measurement of N is known as standardisation of grating.

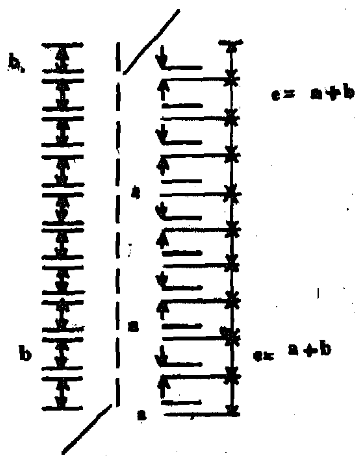

Fig.10.1

When you look at a source of light through a grating, you see that light **is pulled** to the sides into a patch of coloured light. **This** patch is due to the interference of diffracted light from **the** many **tiny** slits.

10.3.2 Interference Orders

The light coming from ,adjacent slits has a path difference $e * \sin\theta$ as shown in Fig. 10.2. If $e * \sin\theta = m *$ (wavelength of light), where θ is **the** angle of diffraction and *m* is the order of interference, then all the diffracted,light from the many slits interferes to form an image of **the** slit in **the** direction of θ. If $m = 1$, it is called first order, and if $m = 2$, it is called second order. The above equation can be written ast

$$\sin\theta = N * m * \text{(wavelength)}$$

where $N = 1/e$ = number of lines per meter.

If we are able to determine θ of a known wavelength of light, then N can be determined, by setting $m = 1$ or 2 for the order of the spectrum.

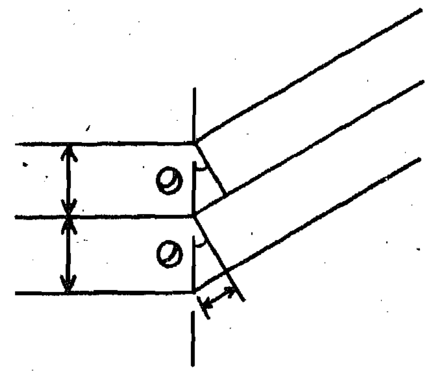

Fig.10.2

For the determination of N, the angle of difraction θ is determined for a monochromatic line of a spectrum. In the laboratory, sodium vapour light is used as a source of spectrum. With two lines at wavelengths 589.0 nm and 589.6nm, sodium vapour lamp is usually used to determine N. With mercury vapour lamp, we determine the angle θ for the green light which has a standard wavelength 546.1 nm, and thus we can determine N. In your laboratory if both sodium light and mercury light are avaliable, you can choose any one source to determine N.

It is interesting to note that determination of N and the determination of wavelength involves the same formula. For the determination of N, We assume wavelength while in the determination of wavelength we assume N,' which was already determined. In either case, we measure the angle of diffraction θ from the experiment.

Fig. 10.3 shows how light of one color is diffmcted at each of the slits. Some light from ecede slit reaches each order.

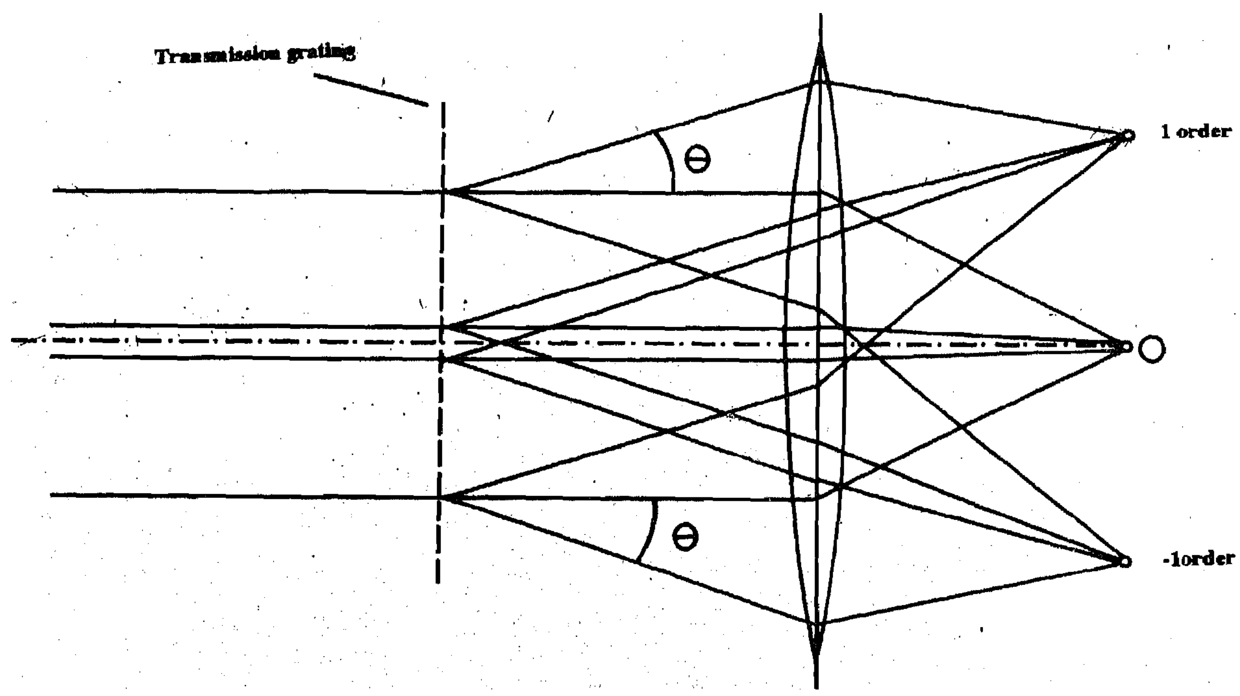

Fig.10.3

10.4 PRECAUTIONS

1) Fix the grating on the central round table called the "prism table", in a vertical position in between the clips.
2) Perform all adjustments as in the prism experiment before taking readings.
3) Fix the telescope firmly while taking readings.
4) Carefully note the readings on vernier I and vernier II in their respective places in tabular column.

10.5 THE EXPERIMENT

10.5.1 Normal Incidence

TO SET THE PLANE TRANSMISSSION GRATING FOR NORMAL INCIDENCE OF LIGHT.

The light incident on the grating from the collimator is a plane wave and there is no phase difference between waves from adjacent slits. If you have not already performed the Experiment 8 "Spectral Analysis using a Prism Spectrometer", read it now. Then carry out the spectrometer adjustments described. After having done all the adjustments of the spectrometer, keep the telescope so as to receive the light from collimator directly. Note the readings on the verniers.

The telescope is then released and turned exactly through 90° and held fixed. Thus the axis of the telescope and the collimator axis are perpendicular to each other.

Now rotate the prism-table such that the reflected image of the slit from the plane surface of the grating is received at the cross wire of the fixed telescope. You move only the prism table for achieving this coincidence and not the telescope. The situation is described in Fig.10.4 below:

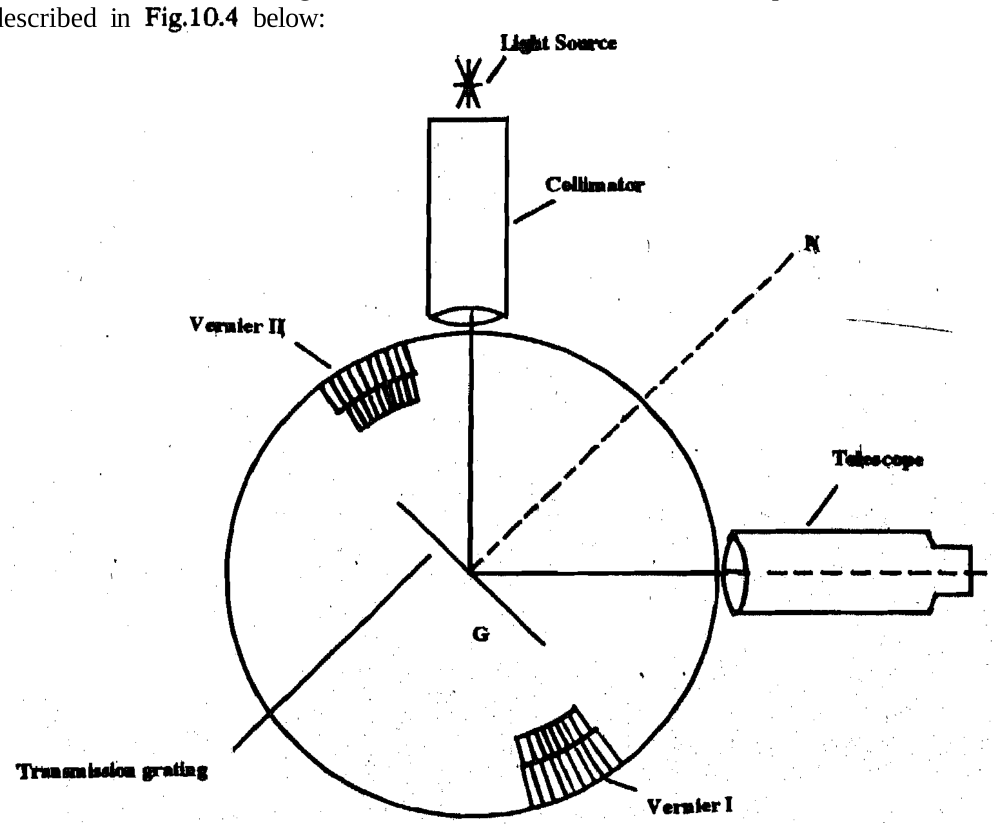

Fig.10.4

The angle between the collimator and normal GN to the grating is 45o. If the grating is **turned** exactly through 450 towards the collimator, then the parallel light from the collimator will be incident normally on the grating surface. How to rotate the grating exactly through **45°** ? Since the mere rotation of the prism-table can not determine the angle of rotation precisely, the prism-table has to be rotated **along** with the vernier scale through **45°.** Thus the grating is set at normal incidence, as shown in Fig. 10.5.

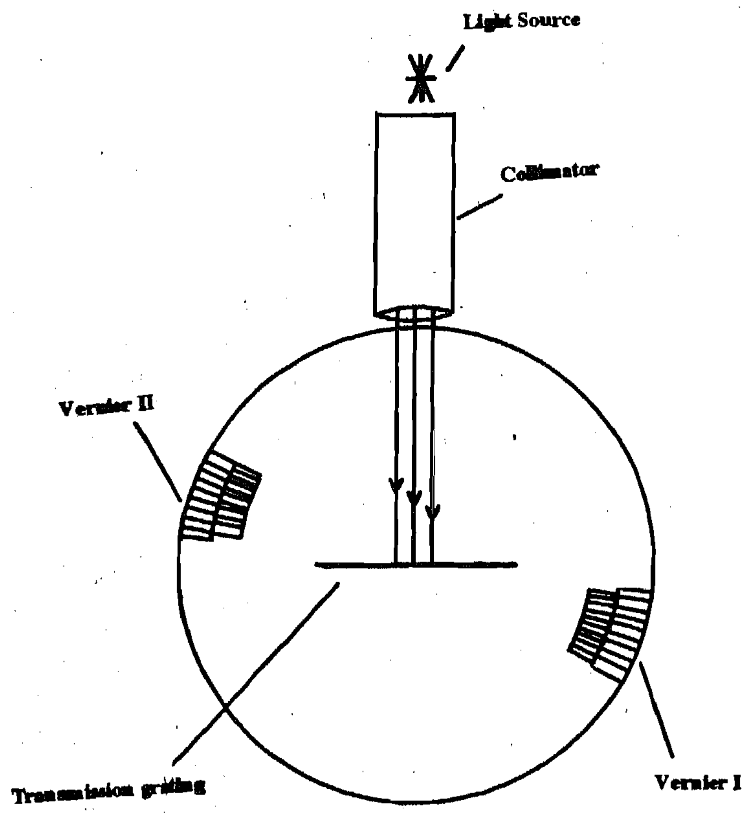

Fig. 10.5

10.5.2 TO MEASURE THE ANGLES OF DIFFRACTION CORRESPONDING TO THE LINES OF VARIOUS COLOURS OF THE SPECTRUM IN THE FIRST AND SECOND ORDERS.

The incident composite light the from mercury **vapour** lamp can be considered as composed of **many** discrete **monochromatic** lines or wavelengths. Due to diffraction, these **lines** are deviated away **from** the direction of incidence, after incidence on the grating.

By. rotating the telescope on one side, you **can** observe the **images** of the slit in blue, bluish green, green and yellow regions. Again you see the images of the slits in the same **series** for even larger angles of diffraction. They are called **the** first and second order spectra. **They** art **also** observed on the other side of **the** direct beam.

The direct beam suffers no diffraction. All the wavelengths present in the source of light reinforce together and so the direct light has the same resultant colour as the source itself.

The cross wire of the telescope is made to coincidence with of the image of the slit and the readings of vernier I and vernier II are noted. In the same way, the readings for all the prominent lines in the blue, bluish green, green and yellow are noted. Enter your readings in the table.

After all the readings are taken on one side, the readings of the direct ray is noted down. You have already noted the direct ray reading before you turned the telescope to 90^0. Then why is it necessary to take this readings for a second time? Yes, you have turned the prism table along with the vernier through 45^0 and this has changed the direct ray reading. So you have to once again determine the direct ray reading. The difference between the direct ray and the various deviated rays gives the angles of diffraction.

TABLE FOR STANDARDISATION

SIDE 1		SIDE 2		ANGLE OF DIFFR.					WAVELENGTH
VNI	VNII	VNI	VNII	θ_1	θ_2	θ_3	θ_4	θ_{mean}	(nm) Dir. Beam

NUMBER OF LINES PER METER = ...

TABLE FOR WAVELENGTH

SIDE 1		SIDE 2		ANGLE OF DIFFR.					WAVELENGTH
VNI	VNII	VNI	VNII	θ_1	θ_2	θ_3	θ_4	θ_{mean}	(nm) Dir. Beam

10.5.3 Calculations

In general the grating produces many orders of visible spectrum. Usually there are two orders of spectrum corresponding to $m = 1$ and $m = 2$. They are seen on either side of the direct image. Tbe angles of diffraction for $m = 2$ can should be taken and tabulated.

Using the formula $\sin\theta = N * m *$(wavelength), wavelength is calculated as θ and N are known. Put $m = 1$ for first order and $m = 2$ for second order. The results are tabulated, and compared with "standard" values.

Answer the following questions:

1. In the grating experiments you are using a standard grating with 7000 lines /cm. Supposing I have only a grating with 700 lines /cm, how would the spectrum appear.

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2. If I break the grating by mistake & only one cm width of the piece of it avaliable
   (a) Can one still see the diffraction pattern?
   (b) If so how does it differ from that of a grating of larger size?

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3. Draw the diagram of a spectrometer and identify its parts.

4. Using a spectrometer, one observes coloured lines both by using a prism and a grating. You have observed the angles of deviation for each coloured line with respect to the direct light. What are the differences between these two spectra observed? List as many differences as you can.

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5. While you are doing an experiment with the grating, a mischievous student slightly pushes the grating in its plane. Will this affect your reading? Explain.

10.6 CONCLUSIONS

You have determined the wavelengths of various colours of light using a transmission grating and a spectrometer. You have observed the first and the second order spectra on either side of the direct light, and compared your results with standard values.