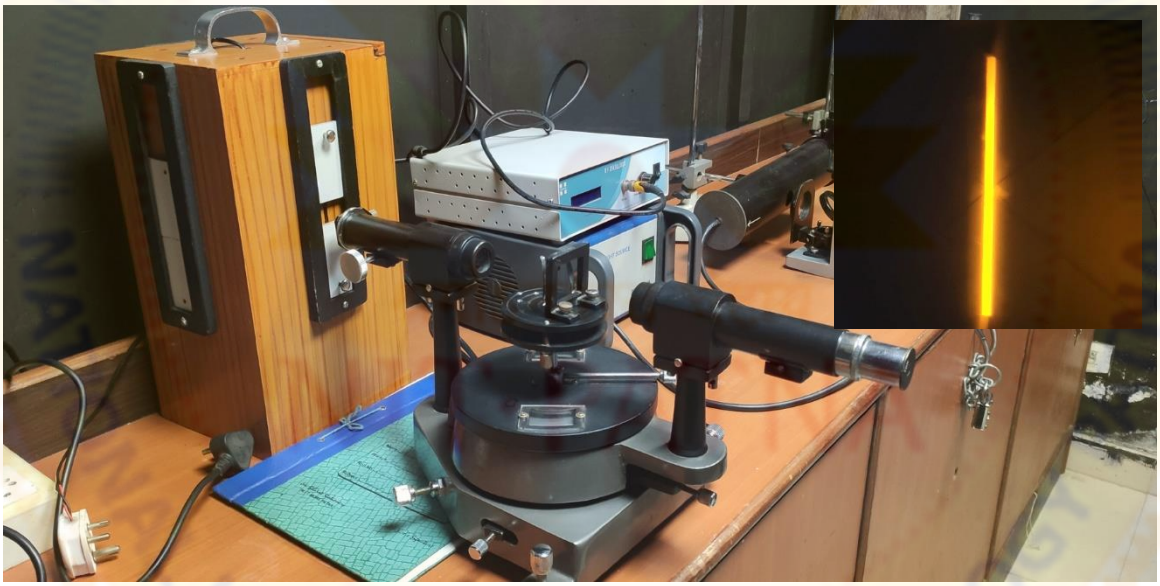
LABORATORY MANUAL FOR DIFFRACTION OF SODIUM LIGHT USING PLANE TRANSMISSION GRATING



EXPERIMENT

AIM

To determine the wavelength (λ) of sodium light using a plane transmission grating.

APPARATUS

1. Grating
2. Spectrometer
3. Sodium Lamp

THEORY

Diffraction of Light:
Light travels in straight lines in a transparent homogeneous medium, but when light is passing by the edge of an opaque obstacle it bends slightly into the geometric shadow that would be cast by the edge on a screen. This slight bending of light of light is called diffraction. This is similar to the bending of sound waves round corners but is on a much reduced scale due to the much shorter wavelength.

The formula for diffraction of light is given by,

$$(a+b)sin\theta_n = n\lambda$$

$$\therefore \lambda = \frac{(a+b)\sin\theta_n}{n}$$

Where, $(a+b)$ = grating element

θ_n = angle of diffraction for nth order (where $n = 1, 2$)

n = Order of spectrum

PROCEDURE

1. Level the prism table with the help of spirit level. Focus the eye-piece on cross-wires adjust the telescope and collimator for parallel rays with the help of Schuster's method as discussed in appendix.

2. Bring the telescope in line with collimator to have the sharp image of the slit coincident

with the vertical cross-wire as shown in Fig. 1(a) without placing the grating on the prism.

3. Adjust the reading of one of spectrometer windows (W_1 or W_2) to be 0° (i. e. , 360°) by rotating the prism table. Fix the prism table*.

   Note that only one i.e., either prism table or the telescope be moved at a time and not the both. If prism table is to be moved, keep the telescope fixed and vice-versa.

4. **Arrangement for normal incidence:** To plane that grating perpendicular to the light coming from the collimator, proceed as follows:
   (i) Rotate the telescope through 90° in clockwise (or anticlockwise) direction and fix it. [(fig. 1 (b)].
   (ii) Now fix the grating G on the prism table so that it is perpendicular to the line joining two (of the three) levelling screws P and Q [Fig. 1 (g)]. Let the light from the collimator (i.e., fine illuminated slit) such that the fine slit becomes coincident with the vertical cross-wire of the telescope [fig. 1(c)]. This makes the angle of incidence 45° on the grating surface. In other words, the normal drawn to the grating makes an angle of 45° with the incident ray of light from the collimator. Take the reading of this position of the prism table, see that the image of the slit is symmetrical with respect to the horizontal cross-wire of the telescope. If not, make it so by suitably turning the screw R. This makes the plane of grating vertical fix the telescope firmly.
   (iii) Rotate the prism table from this position through 45° in the direction of arrow shown in Fig. 1 (c). The plane of grating is now perpendicular [Fig. 1(d)] to the incident light which falls on its back. Fix the prism table now firmly and release the telescope.

5. Rotate the telescope and bring it in a line with the collimator to receive the image of the slit on the cross-wire [Fig. 1 (e)]. Note the reading of the position of the telescope on both the windows. This corresponds to the direction O_1, O [Fig. 1(f)] i.e., direct ray.

6. Now turn the telescope to the left till the position OA is reached. The first order spectrum will be visible. See if the slit is symmetrical with respect to cross-wire in the diffracted image. If not, turn the screws P and Q for the purpose. This adjustments makes the lines on the grating vertical. Coincide the cross-wire of the telescope with the left of the yellow line. (If the two line D_1 and D_2 are both visible, coincide the cross-wire with the left of both lines, by turn) and read the position of the tele-scope on both verniers. Now turn the telescope to the right and when the spectrum is visible in the direction OB, make measurement as before. The angle[1] AOB= $2\theta_1$.

7. Make similar measurements on the second order spectrum and measure the angle EOD = $2\theta_2$.

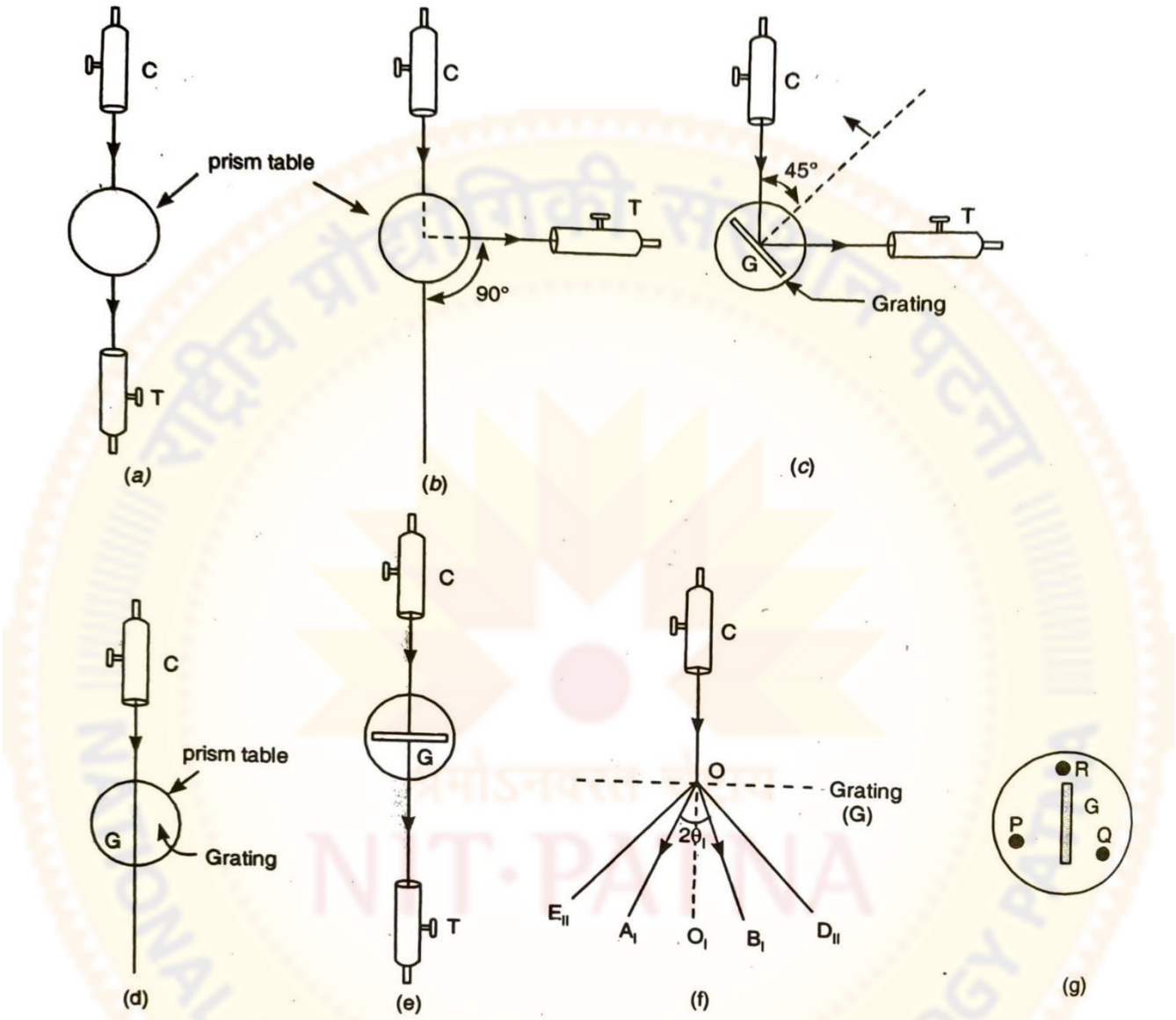
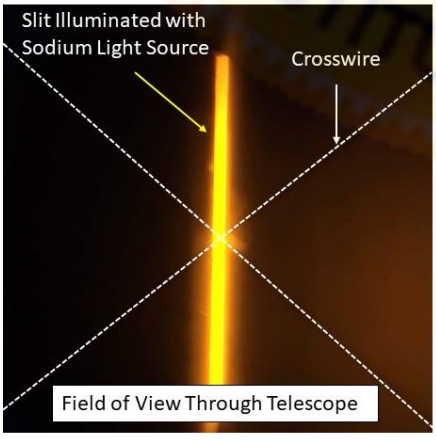
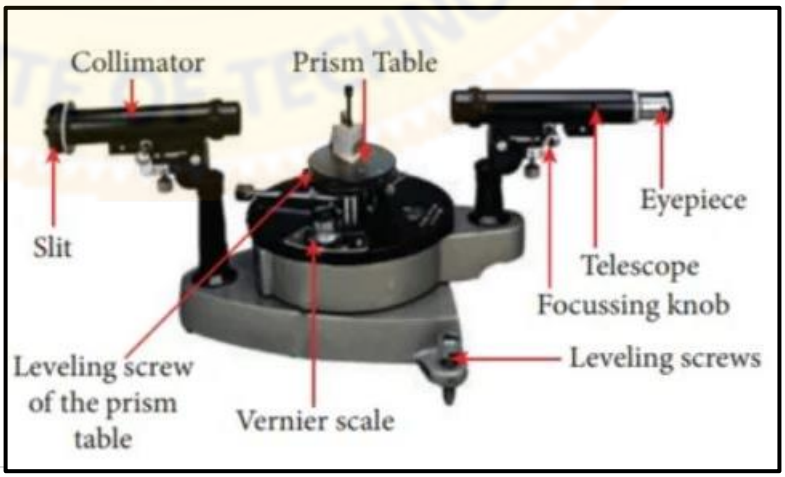


Fig. 1: Positions of telescope in different cases to measure angle of diffraction.





OBSERVATIONS

Least count of the spectrometer vernier = …
No. of lines ruled on the grating (say) = 15000 per inch

$$= \frac{15000}{2.54} \text{ per cm}$$

$$\therefore \text{ grating element, } (a + b) = \frac{2.54}{15000} \text{ cm}$$

[A] Table for determination of angle of diffraction ($\boldsymbol{\theta}$)

S. No.	Order	Window	I position of telescope			II position of telescope			2θ = (a~b)	θ
			MSR	VSR	Total (a)	MSR	VSR	Total (b)		
1	I	W_1			(a_1)			(b_1)	$2\theta_1$	θ_1
2		W_2			(a_2)			(b_2)		
3	II	W_1			(a_3)			(b_3)		
4		W_2			(a_4)			(b_4)	$2\theta_2$	θ_2

CALCULATIONS

First order: here n =1

$(\boldsymbol{a + b})\ \boldsymbol{sin\ \theta_1} = \mathbf{1} \cdot \boldsymbol{\lambda}$

For, second order: here n= 2

$(\boldsymbol{a + b})\ \boldsymbol{sin\ \theta_2} = \mathbf{2} \cdot \boldsymbol{\lambda}$

Find, λ in both cases in angstrom.

ERROR CALCULATIONS

- **For maximum Error in λ :**

  $\therefore \frac{\Delta\lambda}{\lambda} = \frac{\cos\theta}{\sin\theta} \cdot \Delta\theta = \cot\theta \cdot \Delta\theta$

  Least count of the spectrometer $= \mathbf{1'}$

  $$\therefore \Delta\theta = 1' = \frac{1}{60} \times \frac{3.14}{180} = 0.003\ rad$$

  Find $\Delta\lambda$.

RESULT

$\therefore Wavelength\ of\ the\ D-line(\text{I-}order) = \cdots$

$$Wavelength\ of\ the\ D-line(\text{II-}order) = \cdots$$

SOURCES OF ERROR AND PRECAUTIONS

1. All adjustments of the spectrometer must be correctly made.
2. The grating must be adjusted so that its plane is vertical and the rulings on it must also be made vertical.
3. In measuring angles, the left side of the image must be made to coincide with the vertical cross-wire for positions of telescope on either side of the central image.
4. The light must be incident on that side of the grating on which there are no rulings. This is done to secure that no refraction occurs after diffraction has taken place.

Appendix:

Schuster's Method: (i) Adjust the spectrometer with its collimator towards a monochromatic source (Sodium light) receive light. Bring the telescope in line with the collimator and adjust the slit as well as level the Spectrometer to get a narrow and bright image of the slit at the centre of the field of view of the telescope. Adjust the telescope position so that vertical cross-wire coincides with the slit. Adjust the eye piece so that cross-wires are distinctly visible. Keep the prism on prism table and adjust the height of the prism table to get the refracted rays. See that the prism table is also levelled. Adjust approximately the minimum deviation position which is indicated by the movement of the slit to only one side of the vertical cross-wire even if the prism table is rotated in either direction. Fix the telescope. (i) Set the prism so that it makes an angle with the incident beam greater than that corresponding to the minimum deviation position. Set the telescope on the emergent beam and focus it till the image of the slit is sharp. (ii) Now turn the prism so that it makes with the incident

beam an angle less than that corresponding to minimum deviation position and now focus the collimator by turning the screw S_1 till the image of the slit as seen through telescope (whose focussing is not now disturbed) is sharp. Now come back to the first position and repeat the two steps in that order. By repeating the process 3 or 4 times both collimator and telescope are focussed for parallel light simultaneously and the image of the slit is sharp in both positions of the prism. If a mistake is made in the order of focussing the image will get worse and worse.