Expt - 2
Grating Spectrometer

I. OBJECTIVE

To determine the wavelengths of spectral lines of mercury and the angular dispersive power of a diffraction grating.

II. PRINCIPLE

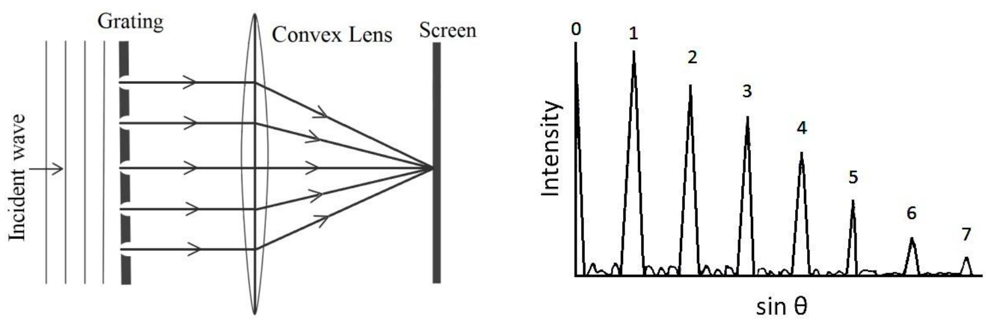
An arrangement consisting of a large number of parallel slits of the same width, which are separated by equal opaque spaces is known as a diffraction grating. For N parallel silts, each having width a, separated by opaque spaces of width b, the diffraction pattern consists of diffraction modulated interference fringes. The quantity g (= a+b) is called the grating constant and N (=1/g) is the number of slits per unit length.

If monochromatic light of wavelength λ from a narrow slit (parallel to the slits/rulings of a grating) is incident normally on the diffraction grating, the diffraction pattern consists of extremely sharp narrow lines parallel to the rulings. These sharp lines are called principal maxima and are given by

$$g \sin \theta = \pm n \lambda \qquad (1)$$

where, θ is the diffraction angle and n is the order of diffraction.

A grating schematic and typical, Intensity *vs*. $\sin \theta$ variation (for 5 slits) are shown in *Fig. 1*. Notice that there are weak secondary maxima in between the principal maxima of different orders.



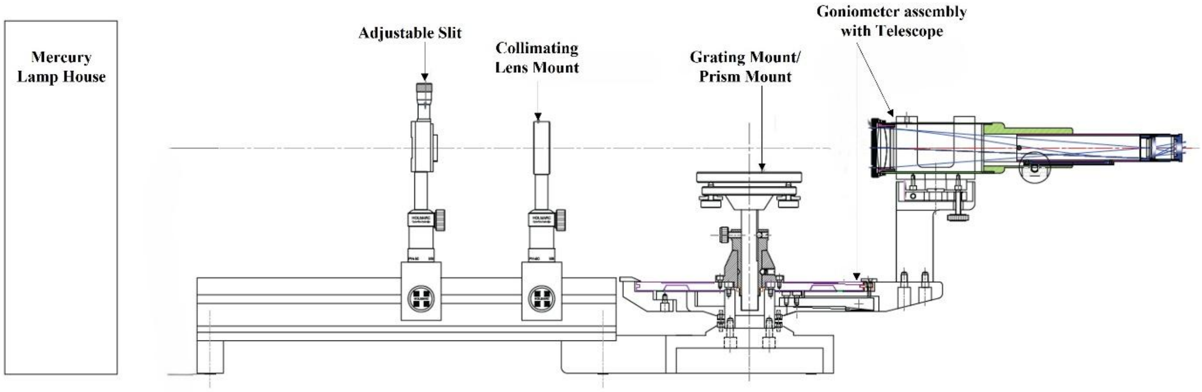
(a) **Figure 1** **(b)**

It is clear from *Eqn. 1* that the diffraction angle θ depends on wavelength λ. Hence if the source of light is polychromatic, then for each order of diffraction (except for n = 0), there will be as many lines in the diffraction pattern, as there are different wavelengths in the light source. Thus, the diffraction grating (like a prism) enables us to observe and analyse the spectrum of a polychromatic light source and forms the basis of modern-day high-resolution mono-chromators and spectro-photometers.

The angular dispersive power (DP) of a grating is defined as the rate of change of diffraction angle with change in wavelength. Obtained by differentiating Eqn. 1, it is given by

$$\text{D.P.} = \frac{d\theta}{d\lambda} = \frac{n}{g\ \cos\theta} \tag{2}$$

III. EXPERIMENTAL SET-UP AND APPARATUS DETAILS



Safety Instructions

- Care must be taken while handling the Optical components since this experiment uses precision optical lenses and other high-quality components.
- Please don't put your fingers on the main optical surfaces but hold components by their edge.

Grating Spectrometer

a. Preliminary adjustments of the spectrometer

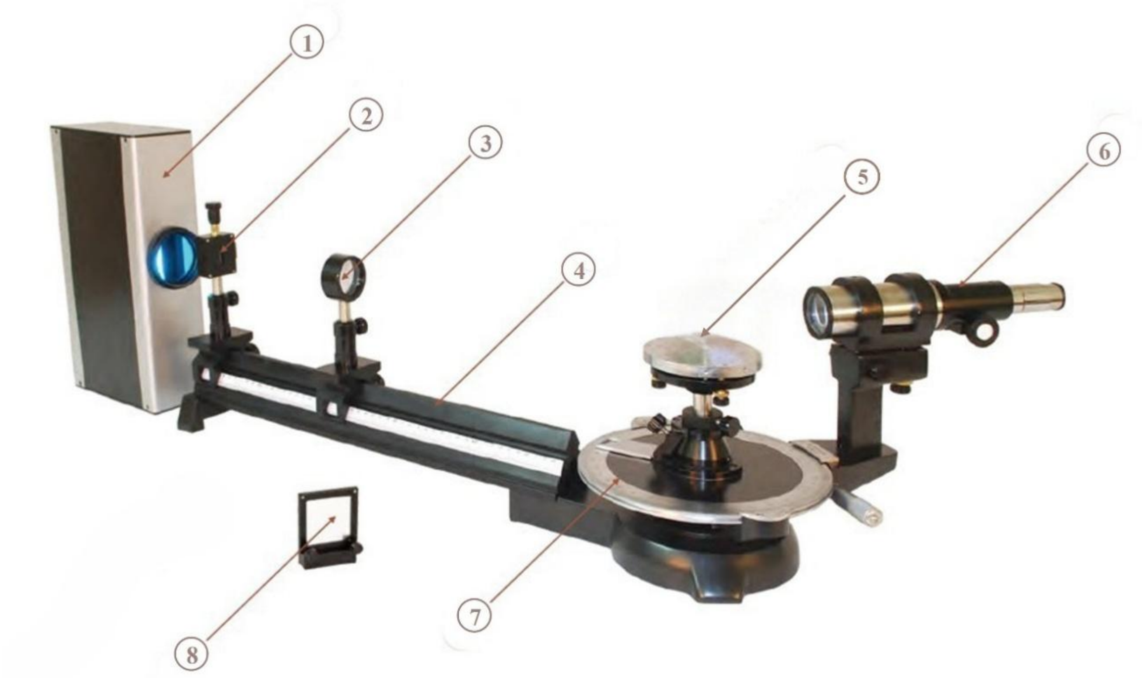
For accurate results, the diffracting element must be properly aligned with the optical axes of the telescope and collimator. This requires that both the spectrometer and the spectrometer table be in the same level.

In the case of telescope, slide the eyepiece in and out until the cross-wire come into sharp focus. Loosen the graticule lock ring, and rotate the graticule until one of the cross-wires is vertical. Retighten the lock ring and then refocus if necessary.

The telescope is directed towards a white wall and the eye piece is adjusted to make the cross-wire clear. The telescope is turned towards a distant object to get a clear image without parallax with the cross-wire.

Without altering the above adjustments, the telescope is directed towards the collimator and the slit is opened. The slit is illuminated by the mercury light and the length of the collimator is adjusted to get a clear image of the slit. The prism table is levelled using a spirit level and the levelling screws.

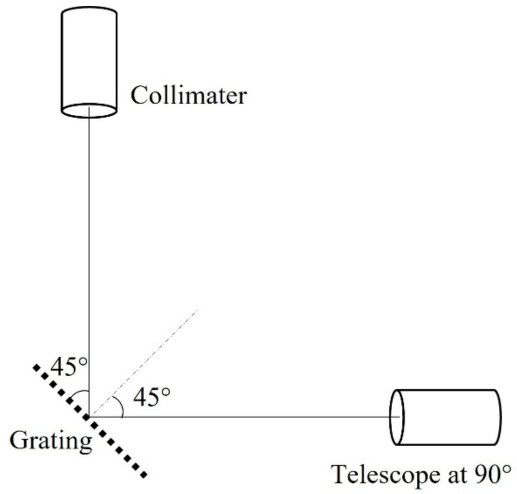
To read the angle, first find where the zero point of the vernier scale aligns with the degree plate and record the value. If the zero point is between two lines, use the smaller value.



1. Mercury lamp house　2. Slit with mount　3. Collimating lens with mount　4. Optical rail

5. Prism table　6. Telescope　7. Goniometer　8. Grating

b. Setting the grating for normal incidence



It is essential that the grating is to be set on the prism table with its plane normal to the axis of the collimator. The setting is achieved through the following steps.

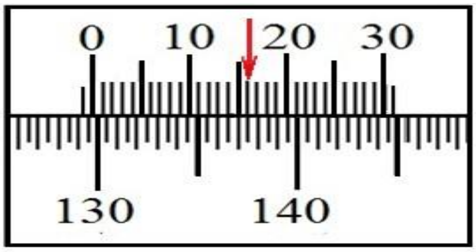
The telescope is brought in line with the collimator to have image of the slit on the vertical cross wire. It is locked in that position. The lower screw of the spectrometer is unlocked and the prism table is rotated till the reading on one vernier is exactly 360 degrees. The screw is locked. Now the telescope arm is unlocked and rotated through 90 degrees in clockwise or anticlockwise direction. It is locked in that position.

The grating stand is mounted on the prism table and the grating is placed in it with its ruled surface towards the telescope. Care is taken that the grating stands at the centre of the prism table. Then the prism table is rotated slowly so that a reflected image is seen in the field of view of the telescope. Rotating the prism table very slowly the reflected image to coincide exactly with the vertical cross-wire. In this position, the angle of incidence of light on the grating surface is 45 degrees. The reading of the position of the prism table is noted down. The prism table is rotated from the above position through 45 degrees more so that the grating plane becomes normal to the direction of light. The prism table is locked in this position. This is the normal incidence position. The telescope is then unlocked and rotated to bring it in line with the collimator to receive the white image of the slit on the cross wires. The reading of the position of the telescope is noted.

c. Measuring angle using Vernier

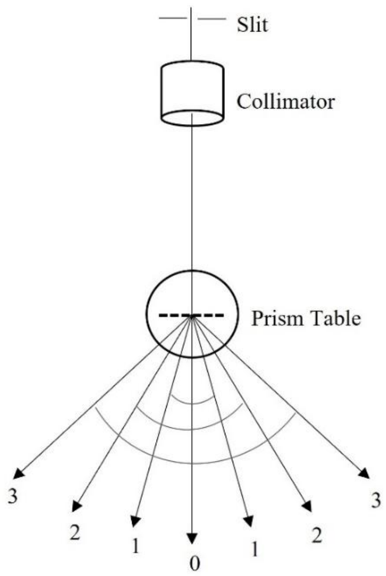
Inspect the angular verniers. Record the value of each main scale division and calculate the least count (L.C.) of the vernier in arc minutes (1′ = 1/60 degrees).

Read the angular vernier scale to get the angular position in a manner described by the example as shown in following figure.



In this example, the least count of the vernier is 1′. As the zero of the angular vernier scale (upper scale) is between 129.5º and 130º of the main scale (lower scale), the angle is somewhere between these two values. You can take the main-scale reading as 129° 30’ or 129.5º. Next check for the graduation on the angular vernier scale which lines up with a main scale graduation below it. In this case, it is the 16th graduation on the angular vernier scale, hence the vernier reading is 16 (≈ 0.27°). So, the required angular position is 129.77º.

d. Measuring the Diffraction Angles



Move the telescope arm to left side of the direct image and make the vertical cross-wire coincide with the extreme red line of the first order spectrum. Use tangent screw to get to the exact angular position. Note down the two angle values α_1, α_2 using V_1 and V_2, respectively in this position.

In a similar manner, record the angular positions of the two lines of the yellow doublet, the green line and the violet line at the other end of the spectrum, in that sequence.

After crossing the direct image, continue to move the telescope arm in the same direction to measure the angular positions β_1, β_2 corresponding to V_1 and V_2 respectively, for all the corresponding spectral lines on the other side of the direct image.

The observations are recorded in table. Using the formula, the wavelengths of various spectral lines are calculated.

e. Closing the experiment

Switch OFF the mercury lamp. Remove the grating from its holder and keep it in its box.

The grating used in this experiment consists of 600 lines/mm.

IV. RESULTS AND CALCULATIONS

1. Record and tabulate for all first order spectral lines, the colour, (α_1, α_2) and (β_1, β_2).
2. Calculate and tabulate separately (in degrees) for all the first order spectral lines:

   $\theta_1 = \frac{\alpha_1 \sim \beta_1}{2}$, $\theta_2 = \frac{\alpha_2 \sim \beta_2}{2}$, $\theta = \frac{\theta_1 + \theta_2}{2}$ and $\Delta\theta = \left| \frac{\theta_1 - \theta_2}{2} \right|$

   Take $\Delta\theta = \frac{L.C.}{2}$ if, $\theta_1 = \theta_2$.
3. Using Eqn.1, calculate the wavelength (λ) for all the spectral lines.

   Take N = 600 lines/mm.
4. Estimate the uncertainties ($\Delta\lambda$) for all the λ's by using $\Delta\lambda = (\cos\theta/N)\Delta\theta$, where $\Delta\theta$ is in radians.
5. Using Eqn. 2, calculate the values of angular dispersive power (D.P.) for all the spectral lines and also obtain the respective uncertainties, Δ(D.P.) by using the equation $\Delta(D.P.) = (N.\sec\theta.\tan\theta)\ \Delta\theta$.
6. Tabulate all the values of $\lambda \pm \Delta\lambda$ and $DP \pm \Delta(DP)$ in a separate Table of Results.

V. PRECAUTIONS

- The prism table should be properly levelled.
- Grating surface is never touched while handling it.
- Grating should be mounted with its lines parallel to the slit or vertical wire of the cross wires.
- Prism table should not be disturbed while rotating the telescope to receive images of different orders.
- Telescope should be rotated slowly, otherwise there is a possibility of missing an order.

- Once the collimator and the telescope are adjusted for parallel rays (steps A and B), their focusing should not be disturbed.
- Make sure that the telescope arm is locked while taking vernier readings at different angular positions.
- While rotating the telescope arm from one angular position to another, if the vernier crosses over 0º (360º) on the circular scale, take the angular difference appropriately in calculations step IV.2.

Observation table for reference

Sr.. No.	Colour	Vernier 1						Vernier 2					
		M.S.R.	V.S.R.	α_1 (deg.)	M.S.R.	V.S.R.	β_1 (deg.)	M.S.R.	V.S.R.	α_2 (deg.)	M.S.R.	V.S.R.	β_2 (deg.)