

SUPPORT MANUAL FOR PRISM SPECTROMETER

In some of the optics experiments, we will use a spectrometer. The spectrometer is an instrument for studying the optical spectra. Light coming from a source is usually dispersed into its various constituent wavelengths by a dispersive element (prism or grating) and then the resulting spectrum is studied. A schematic diagram of a prism spectrometer is shown in Fig. 1. It consists of a collimator, a telescope, a circular prism table and a graduated circular scale along with two verniers. The collimator holds an aperture at one end that limits the light coming from the source to a narrow rectangular slit. A lens at the other end focuses the image of the slit onto the face of the prism. The telescope magnifies the light dispersed by the prism (the dispersive element for your experiments) and focuses it onto the eyepiece. The angle between the collimator and telescope are read off by the circular scale. The detail description of each part of the spectrometer is given below.

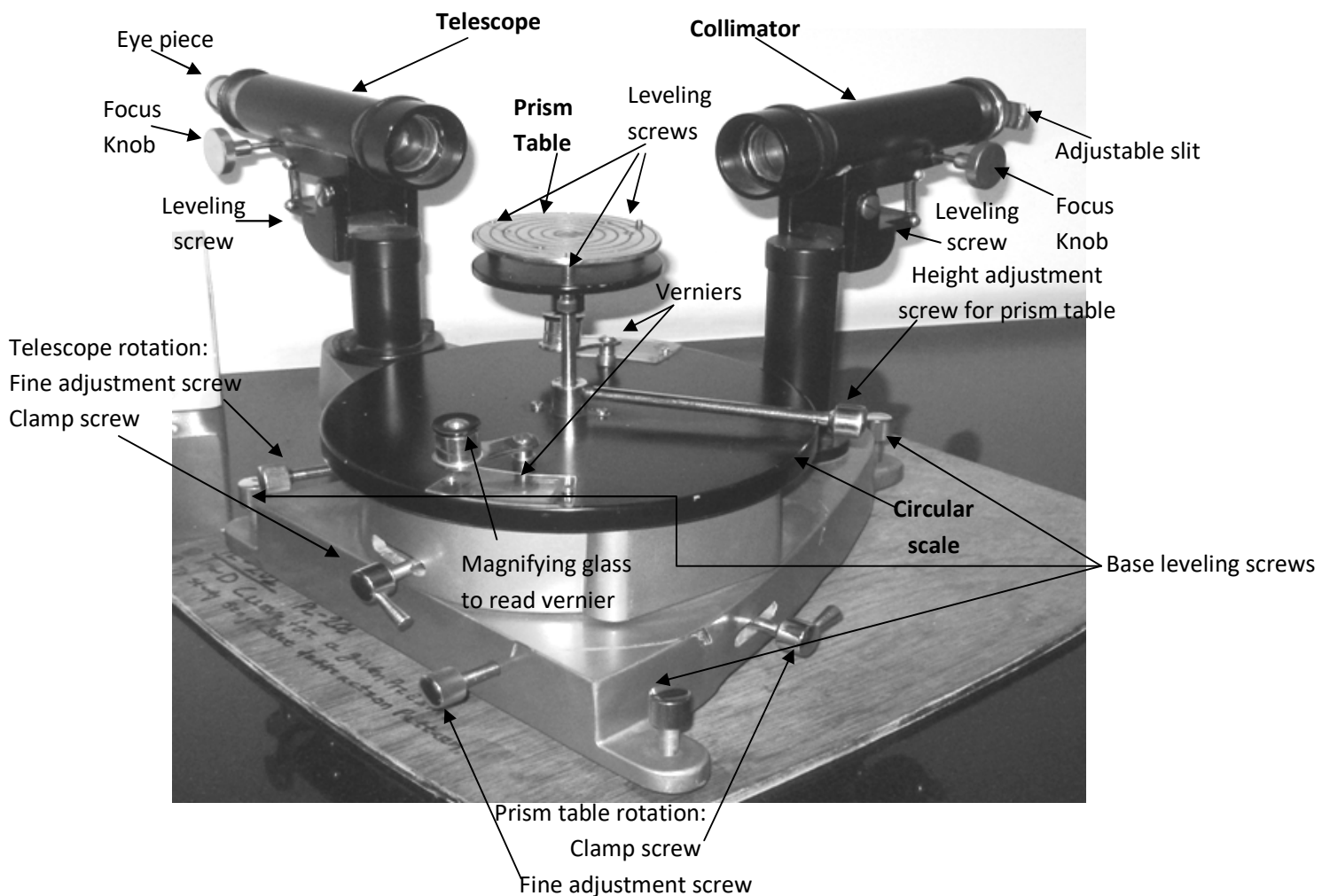


Fig. 1: Different parts of spectrometer

(i) **Collimator (C):** It consists of a horizontal tube with a converging achromatic lens at one end of the tube and a vertical slit of adjustable width at the other end. The slit can be moved in or out of the tube by a rack and pinion arrangement using the focus knob and its width can be adjusted by turning the screw attached to it. The collimator is rigidly fixed to the main part of the instrument and can be made exactly horizontal by adjusting the leveling screw provided below it. When properly focused, the slit lies in the focal plane of the lens. Thus the collimator provides a parallel beam of light.

(ii) **Prism table (P):** It is a small circular table and capable of rotation about a vertical axis. It is provided with three leveling screws. On the surface of the prism table, a set of parallel, equidistant lines parallel to the line joining two of the leveling screws, is ruled. Also, a series of concentric circles with the centre of the table as their common centre is ruled on the surface. A screw attached to the axis of the prism table fixes it with the two verniers and also keep it at a desired height. These two verniers rotate with the table over a circular scale graduated in fraction of a degree. The angle of rotation of the prism table can be recorded by these two verniers. A clamp and a fine adjustment screw are provided for the rotation of the prism table. It should be noted that a fine adjustment screw functions only after the corresponding fixing screw is tightened.

(iii) **Telescope (T):** It is a small astronomical telescope with an achromatic doublet as the objective and the Ramsden type eye-piece. The eye-piece is fitted with cross-wires and slides in a tube which carries the cross-wires. The tube carrying the cross wires in turn, slides in another tube which carries the objective. The distance between the objective and the cross-wires can be adjusted by a rack and pinion arrangement using the focus knob. The Telescope can be made exactly horizontal by the leveling screws. It can be rotated about the vertical axis of the instrument and may be fixed at a given position by means of the clamp screw and slow motion can be imparted to the telescope by the fine adjustment screw.

(iv) **Circular Scale (C.S.):** It is graduated in degrees and coaxial with the axis of rotation of the prism table and the telescope. The circular scale is rigidly attached to the telescope and turned with it. A separated circular plate mounted coaxially with the circular scale carries two verniers, V_1 and V_2 , 180° apart. When the prism table is clamped to the spindle of this circular plate, the prism table and the verniers turn together. The whole instrument is supported on a base provided with three leveling screws. One of these is situated below the collimator.

Adjustment of Spectrometer: The following essential adjustments are to be made step by step in a spectrometer experiment: Leveling the apparatus means making (a) the axis of rotation of the telescope vertical, (b) the axis of the telescope and that of the collimator horizontal, and (c) the top of the prism table horizontal. The following operations are performed for the purpose.

(i) **Leveling of telescope:** Place a spirit level on the telescope tube making its axis parallel to that of the telescope. Bring the air bubble of the spirit level halfway towards the centre by first turning the two base leveling screws (i.e. leaving the base leveling screw below collimator) and then turning the telescope leveling screw. Now rotate the telescope through 180° and adjust the base and telescope leveling screws. Repeat the operations several times so that the bubble remains at the centre for both positions of the telescope. Next place the telescope in the line with the collimator and bring the air bubble of the spirit level at the centre by turning the base leveling

screw below the collimator. Again check the first adjustment for the previous orientations of telescope. The axis of the rotation of the telescope has thus become vertical and the axis of the telescope has become horizontal.

(ii) Leveling of collimator: Remove the spirit level from the telescope. Place it on the collimator along its length. Bring the air bubble of the spirit level at the centre by adjusting the collimator leveling screw provided below the collimator. This makes the axis of the collimator horizontal.

(iii) Leveling of the prism table: Place a spirit level at the centre of the prism table and parallel to the line joining two of the leveling screws of the prism table. Bring the air bubble of the spirit level at the centre by turning these two screws in the opposite directions. Now place the spirit level perpendicular to the line joining the two screws and bring the bubble at the centre by adjusting the third screw. This makes the top of the prism table horizontal.

(iv) Adjusting cross wires and focusing image

Rotate the telescope towards any illuminated background. On looking through the eye-piece, you will probably find the cross-wires appear blurred. Move the eye-piece inwards or outwards until the cross-wire appears distinct.

Place the telescope in line with the collimator. Look into the eye-piece without any accommodation in the eyes. The image of the slit may appear blurred. Make the image very sharp by turning the focusing knob of the telescope and of the collimator, if necessary. If the image does not appear vertical, make it vertical by turning the slit in its own plane. Adjust the width of the slit to get an image of desired intensity.

(v) Optical leveling of a prism: The leveling of a prism makes the refracting faces of the prism vertical only when the bottom face of the prism, which is placed on the prism table, is perpendicular to its three edges. But if the bottom face is not exactly perpendicular to the edges, which is actually the case, the prism should be leveled by the optical method, as described below:

- (a) Illuminate the slit by sodium light and place the telescope with its axis making an angle of about 90° with that of the collimator.
- (b) Place the prism on the prism table with its vertex coinciding with that of the table and with one of its faces (faces AB in Fig. 2) perpendicular to the line joining two of the leveling screws of the prism table.
- (c) Rotate the prism table till the light reflected from this face AB of the prism enters the telescope. Look through the telescope and bring the image at the centre of the field of the telescope by turning the two screws equally in the opposite directions.
- (d) Next rotate the prism table till the light reflected from the other face AC of the prism enters the telescope, and bring the image at the centre of the field by turning the third screw of the prism table.

(vi) Focusing for Parallel rays by Schuster's method: This is the best method of focusing the telescope and the collimator for parallel rays within the space available in the dark room. In order to focus the telescope parallel light rays are required and this in turn requires a properly adjusted collimator. For this reason the adjustment of the telescope and the collimator are usually done together.

Schuster's method is based on the fact that the effect of the prism on the divergence of the beam is different on opposite sides of this minimum deviation position (see Fig. 2). The emergent beam will be less divergent (or more divergent) than the incident beam as the angle of incidence is increased (or decreased) from the minimum deviation value (i.e. as the apex A in Fig.2 is rotated towards, or away from, the telescope). This property of the prism can be used to obtain an accurately collimated beam. The method is explained below:

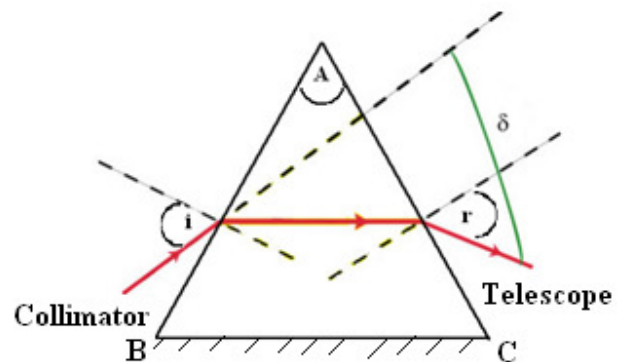
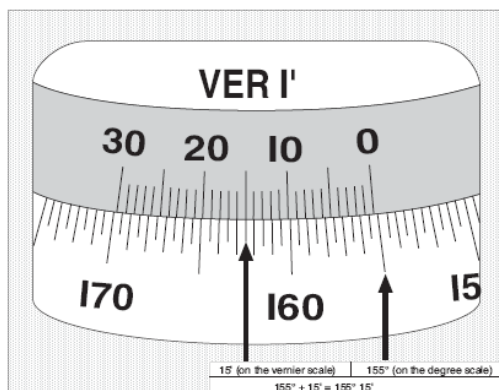


Fig. 2: Minimum deviation of light ray

- (a) Place the prism on the spectrometer table as shown in Fig.2.
- (b) For your prism the angle of minimum deviation is around 50° so set the telescope at an angle a few degrees greater than this ($\sim 55^\circ$).
- (c) Illuminate the slit of the spectrometer with light from a sodium lamp. Rotate the prism table and observe the images of the slit through the telescope as it passes through the minimum deviation position.
- (d) Lock the telescope at an angle a few degrees greater than this position.
- (e) Turn the prism table away from its minimum deviation position so that apex A moves towards the telescope and a spectral line is brought into the centre of the field of view of the telescope. Adjust the focus of the telescope until this line image is as sharp as possible.
- (f) Turn the prism table to the other side of the minimum deviation position until the same spectral line is again at the centre of the telescopes field of view. Now adjust the focus of the collimator until a sharp image is once more obtained.
- (g) Repeat this process until no further adjustment is required. If the same line image is sharply focused when viewed on either side of the minimum deviation position then the light beam through the prism is properly collimated.

Reading angles using a spectrometer:



Practice reading the angle from the circular scale. Use the vernier scale with the little magnifying glass to read the angle.

The following is an example: In the figure, the zero point on the vernier scale is between the 155° and $155^\circ 30'$ (or 155.5°) marks on the degree plate. So the main scale reading (M) is 155° . Now note the vernier reading (V) by finding the line on the vernier scale that aligns most closely

with any line on the main scale. From figure, $V=15$. Assuming the vernier constant (VC) = $1'$, the total reading (T) is $T = 155^\circ + (1' \times 15) = 155^\circ 15'$ or 155.4° . **For convenience convert all the readings to degrees.**