EP13 Measurement of Angle of Prism --- Use of Spectrometer

A spectroscope is an instrument for producing and viewing spectra. When the instrument is graduated for measuring angles for refracted, reflected and diffracted beams, it is called a spectrometer.

OBJECTIVE

1. To study the principle of the reading of the angular vernier.
2. To learn how to measure the angle of a prism using a spectroscope.

THEORY

1. Description of the instrument

A spectrometer consists of three essential parts: a telescope, a platform, and a collimator (Figure 1). The collimator is a tube with a converging lens at one end and a fine slit of adjustable width at the other. The length of the tube is equal to the focal length of the lens so that the collimator renders the rays of light from the slit parallel (Figure 2). The source of light is placed just beyond the slit. The platform can support a prism which deviates these rays and disperses them into a spectrum. The telescope contains an objective lens, which brings the rays of light to a focus in its focal plane, and an eyepiece, through which the image of the spectrum is viewed.

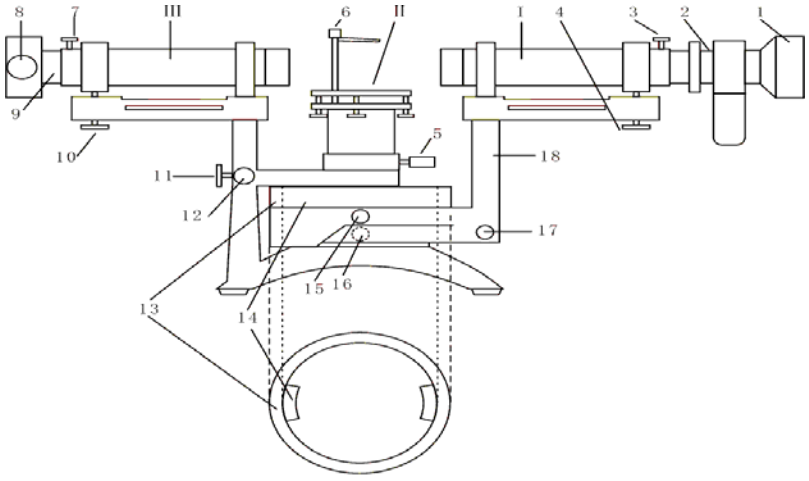

Figure 1. the planform of a spectrometer

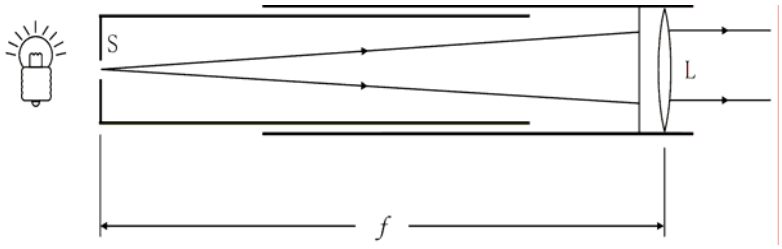

Figure 2. the collimator of a spectrometer

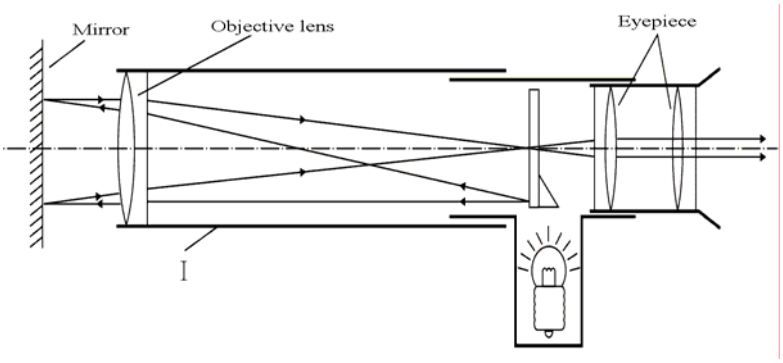

Figure 3. the telescope of a spectrometer

Spectrometers are used to measure angles for refracted, reflected and diffracted beams. They should be adjusted (Figure 4) so that:

1) the light rays emerging from the collimator are parallel.
2) the incident beams, refracted beams, reflected beams and diffracted beams are in the same plane.
3) the optical axis of the telescope is vertical to the spin axis of the spectrometer.

In general, the three parts of the spectrometer can be adjusted respectively. But if you have not any experience about optics experiment, and you have not learned any knowledge about optics, please do not disturb any of the adjustments. Much time is required to restore such adjustments.

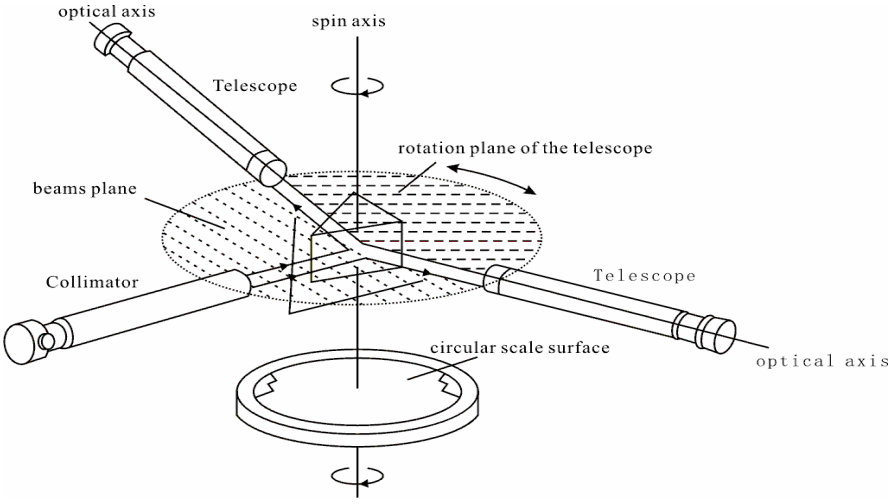

Figure 4 Adjustment of instrument

2. Angular verniers and the reading of an angle on a spectrometer

a. Angular verniers

The principle of the reading of the angular vernier is similar to that of the vernier caliper (see EP 01).

The reading device consists of two parts: one is the main scale circle and the other, called the angular vernier scale disc. The two parts can rotate round the same spin axis of the instrument. There are double verniers symmetrically arranged on both sides of the vernier scale disc in order to eliminate the eccentric difference due to the centers of the two parts not overlapping completely.

Suppose that Angular verniers have the arc length of n divisions on the vernier scale equal to the arc length of $n-1$ divisions on the main scale, and the divisions of the vernier scale and the main scale are β and α respectively (Figure 5), then we can

get:

$$n\beta = (n-1)\alpha$$

$$\alpha - \beta = \frac{\alpha}{n}$$

$\Delta\theta$ ($\Delta\theta = \alpha - \beta = \frac{\alpha}{n}$) is the *least counts of a spectrometer*.

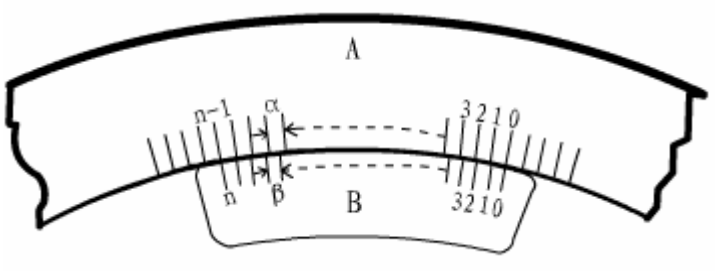

Figure 5 the angular vernier

In this lab, $\alpha = 0.5° = 30'$, n=30, so $\frac{\alpha}{n} = 1'$, that is, the least count is $1'$.

The method of determining the reading is similar to that of vernier caliper.

b. cross-zero reading (cross $360°$ *or* $180°$ reading).

The angle measured by the spectrometer is $\varphi = |\varphi_1 - \varphi_2|$, where φ_1 *and* φ_2 are the values read on both sides of the reading device.

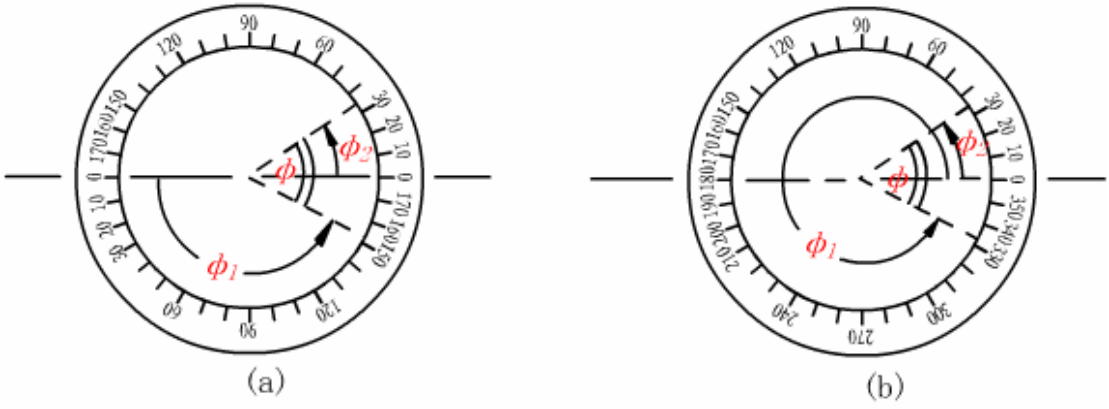

Figure 6 cross-zero reading

The main scale is divided along the circle(see Figure 6). The angle rotating from zero line one circle is two $180°$ or one $360°$. It is only marked $0°$ when $180°$ or $360°$, so if the angle just cross the zero it should be calculated by

$$\varphi = |180° + \varphi_2 - \varphi_1|$$

as shown in figure 6 (a), $\varphi = |180° - 151.25° + 32.75°| = 61.50°$

or $\varphi = |360° + \varphi_2 - \varphi_1|$

as shown in figure 6 (b), $\varphi = \left|360° - 331°20' + 32°55'\right| = 61°35'$

(Here the values of φ_1 *and* φ_2 only for examples)

3. PRISM

A prism is an important optical instrument. It can make the incoming lights deviate, and then disperse them into a spectrum. There is a method to measure the angle of the prism:

Arrange the prism like figure 7:

we can obtain:

$$2i_1 + 2i_2 + \theta = 360° \qquad \text{(i)}$$

since $(90° - i_1) + (90° - i_2) = \angle A$ (ii)

combine expression (i) and (ii) we have:

$$\angle A = \frac{\theta}{2} \qquad \text{(iii)}$$

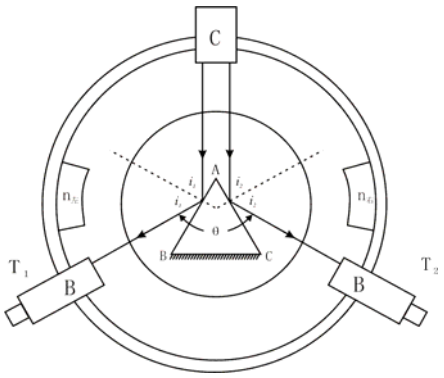

Figure7 Measurement of angle of prism

CAUTION

1. The prism or other optical instruments should be gently handled, and you should avoid touching the optical surfaces of such apparatus with your naked hands (you can touch the gross surfaces of these instruments).
2. A spectrometer is a precision instrument. It wound be damaged if you forcibly rotate the telescope or platform when they are locked..
3. Before you record the data you should be sure that the related screws have been locked so that the data you will record are right.

PROCEDURE

1. The spectrometer should be already adjusted when you come to the laboratory, with the collimator and telescope properly focused. CAUTION: Do not handle the spectrometer until the instructor has demonstrated its operation to you. This instrument is easily thrown out of adjustment, and needless delay or even permanent damage can be caused by careless handling. Be extremely careful when using it.
2. Turn on the sodium light source and mount it near the slit, the slit being at the principal focus of the collimating lens. While viewing the slit image with the unaided eye, move the telescope in the line of sight and adjust for sharp, clear image. Now narrow the slit, if adjustable, so that the very best setting can be made.
3. Now mount the prism in the center of the platform and orient it so that the ground glass face is roughly perpendicular to the collimator tube. This arrangement makes angle A face the collimator tube (see Figure 7). In this position the prism splits the parallel beam of light from the collimator and reflects a portion of it from each of the smooth faces
4. With the unaided eye, locate the image of the slit as reflected from either face of the prism. If you are unable to see either image, try moving the prism a small distance toward or away from the collimator. While viewing the image from face AB (see Figure 7), move the telescope in front of the eye and adjust the cross hairs on the center of the image. This may

best be done with the slow-motion screw (see Figure 1, screw 17). Read the angle for position T_1 and record it. Repeat the procedure for the image from the other face AC of the prism.

5. It may be shown that the angle between positions T_1 and T_2 is equal to 2A. Hence, you have the information for determining the refracting angle A of the prism.

DATA RECORDING AND PROCESSING

Measurement times	viewing image of the slit from face AB		viewing image of the slit from face AC		θ_1	θ_2	θ	$\angle A$
	φ_{left1}	φ_{right1}	φ_{left2}	φ_{right2}				
1								
2								
3								
4								

in the table:

$$\theta_1 = \varphi_{left1} - \varphi_{left2}$$

$$\theta_2 = \varphi_{right1} - \varphi_{right2}$$

$$\theta = \frac{1}{2}(\theta_1 + \theta_2)$$

$$\angle A = \frac{1}{2}\theta$$

calculate the uncertainty of the angle, and expression the result as:

$$\angle A = \overline{\angle A} \pm U_{\angle A}$$

QUESTION

1. Do you have any other method to measure the angle of prism?
2. What are the double verniers on the division circle of the spectrometer for?