Wavelength of sodium light using diffraction grating

PURPOSE: In this experiment we will use the diffraction grating and the spectrometer to measure wavelengths in the sodium spectrum.

THEORY: A diffraction grating consists of a transparent material into which a very large number of uniformly spaced wires have been embedded. One section of such a grating is shown in figure 1. As the light impinges on the grating, the light waves that fall between the wires propagate straight on through. The light that impinges on the wires, however, is absorbed or reflected backward. At certain points in the forward direction the light passing through the spaces (or slits) in between the wires will be in phase, and will constructively interfere, following the **Huygens's principle**. The condition for constructive interference can be understood by studying figure 1: Whenever the difference in pathlength between the light passing through different slits is an integral number of wavelengths of the incident light, the light from each of these slits will be in phase, and the it will form an image at the specified location. Mathematically, the relation is simple

$$n\lambda = d \sin\theta \qquad \text{or} \qquad \lambda = (d \sin\theta)/n$$

This is known as diffraction grating equation. Where n =1, 2, 3…….is an integer , d is the distance between adjacent slits (which is the same is the distance between adjacent wires), θ is the angle the re-created image makes with the normal to the grating surface, λ is the wavelength of the light.

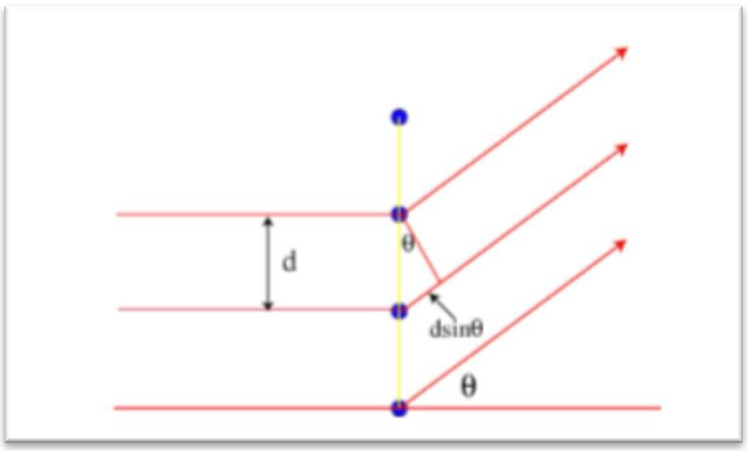

Fig. 1: Geometry determining the conditions for diffraction from a multi-wire grating

Diffraction gratings can be used to split light into its constituent wavelengths (colors). In general, it gives better wavelength separation than does a prism, although the output light intensity is usually much smaller.

By shining a light beam into a grating whose spacing d is known, and measuring the angle θ where the light is imaged, one can measure the wavelength λ. This is the manner in which the atomic spectra of various elements were first measured.

In this lab you will find the first and second order diffraction images of a laser and measuring its wavelength. The diffraction gratings that you will use have 6000 lines/cm, so that the grating spacing is

$$d = 1/6000 \text{ cm}$$

Apparatus: spectrometer, diffraction grating, sodium light source with power supply.

Spectrometer: It consists of three basic components; a collimator, diffraction grating, and a telescope.

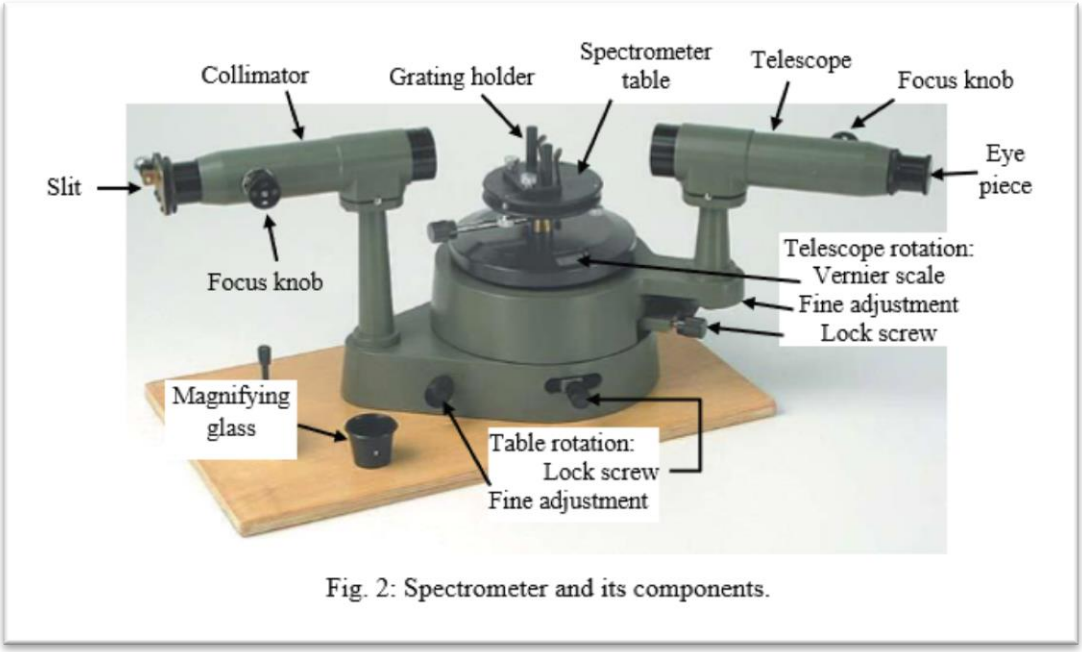

Fig. 2: Spectrometer and its components.

Light enters through a narrow slit positioned at the focal point of the collimating lens. The light leaving the collimator is therefore a thin, parallel beam, which ensures that all the light from the slit strikes the diffraction grating at the same angle of incidence. The grating diffracts the light of different color light at different angles. The telescope is focused at infinity to collect the parallel diffracted beam of light and can be rotated at very precisely measured angles. There are two Vernier readings on two opposite sides on the table, Vernier A and B. You can treat these two reading as measured by two different scales.

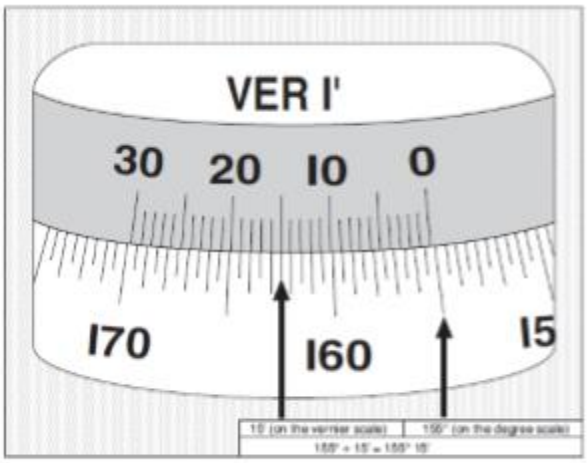

Fig. 3: Reading the Vernier Scale.

The Vernier reading has least count of 1' [(1/60)˚]. To aid viewing the Vernier scale reading a magnifying glass is provided. The table and the telescope can be fine adjusted by tightening the lock screw and rotating the fine adjustment knobs.

Calibrating the spectrometer:

Turn the telescope towards a distant object (e.g. a far off building) and adjust the telescope to see a clear well-defined image of the distant object. If the initial adjustment of the cross hairs was good, the image of the distant object will remain fixed against the image of cross hairs as the eye is moved slightly from side to side. That is, there is no parallax between the images of the cross hairs and the distant object, and thus the two coincide with the focal plane of the telescope. Otherwise there is relative motion between the image of the cross hairs and that of the distant object and the adjustments must be repeated. This method of focusing by the elimination of parallax is universal in the use of optical instruments.

Measuring:

Place the grating on the center of the table with its scratches running vertically, and with the base material (glass) facing the light source. In this way, one can study diffraction without the compilation of refraction. Place the grating in the center of the table and fix it using screw. Rotate the table to make the grating perpendicular to the incident beam by eye. This is not critical since the average of θ_R and θ_L accommodates a minor misalignment.

Affirm maximum brightness for the straight through beam by adjusting the source-slit alignment. At this step, the slit should be narrow, perhaps a few times wider than the hairline. Move telescope on one side and place the naked eye in front of the collimator and move it gradually towards the telescope till the first order diffracted image is visible. Bring the telescope in this position and observe the image through it. Clamp the telescope in this position. If the resolving power of the grating is sufficiently high, two distinct narrow lines corresponding to the

wavelength 5890 Å and 5896Å will be seen side by side in the field of view. Ordinarily, the two will appear as one in the first order position. Turn the tangent screws of the telescope till the vertical cross-wire coincides with the center of the image of the slit. Note the reading of the scale on the two verniers V_1 and V_2. Similarly, observe the first order spectrum on the other side of the direct image and note the reading on the two verniers.

Repeat and note the reading on the verniers by setting the telescope on the second order diffracted image on either side of the direct image.

Order of the spectrum		Vernier reading			Angle of diffraction			Sin θ	λ=(d sinθ)/n
		Left	Direct	Right	Left θ_L	Right θ_R	Average θ		
First order	V_1								
	V_2								
Second order	V_1								
	V_2								

Mean value of sodium light wavelength (for first order)=…….

(for second order)=……

Average λ=……Å

Actual value=…….Å

Percentage error= ……

Precaution: The Diffraction Grating is a delicate component. It has a large number of lines per (cm) drawn on it. Be careful not to touch or scratch the surface of the grating.