SPECTRA EXPERIMENT

The Diffraction Grating

Apparatus: Spectrometer, Mercury discharge lamp, incandescent lamp, diffraction grating with 600 lines per millimeter. (HeNe laser if calibration of the grating spacing is included.)

Introduction:

A transmission diffraction grating spectrometer will be used to study the discrete bright line spectra from mercury atoms in discharge lamps. In addition, the limits of vision will be measured using the continuous emission spectrum from an incandescent bulb.

The major parts of the spectrometer are labeled in figure 1.

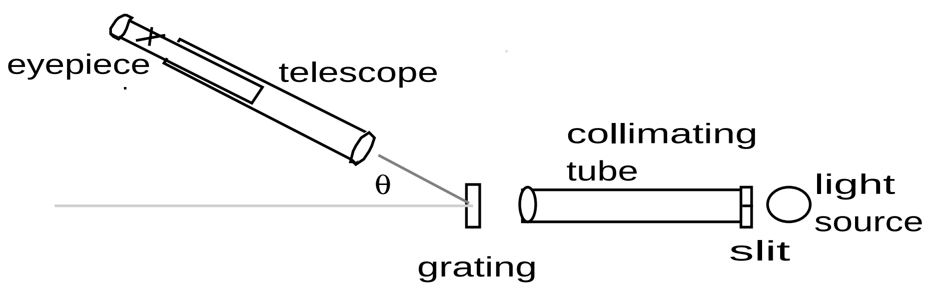

Figure 1

The diffraction grating applies the principles of diffraction and interference to separate by wavelength (color) the light from the source so that each wavelength is sent out at a different angle θ . Because a vertical slit is placed in front of the light source, an image of this slit is seen through the telescope for each wavelength present unless the wavelengths are so close together that the slit images overlap. In this case a broadened image or band is observed. Two discrete close wavelengths with overlapping images cannot be resolved by the spectrometer.

Each line or groove in the diffraction grating acts as a separate source according to Huygens' principle sending out secondary waves. These secondary waves will exhibit constructive interference whenever the path length from an adjacent line differs by an integral number of wavelengths. This is when

$$m \lambda = d \sin\theta \qquad \text{(eqn 1)}$$

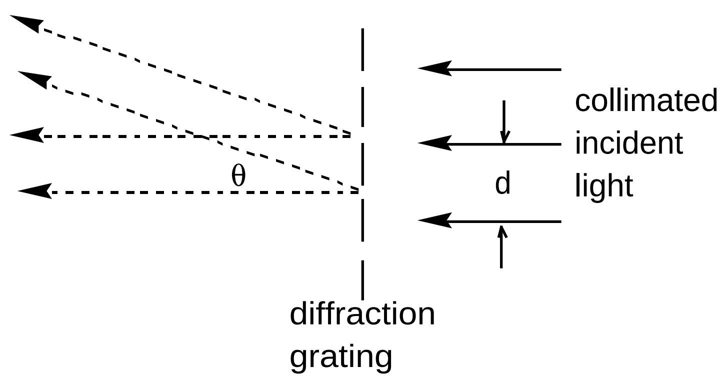

Figure 2

where m is called the order of the spectrum, λ is the wavelength, d is the spacing between the grooves or lines in the grating, and the angle θ is defined in figures 1 and 2. Normally the reciprocal of d, the number of lines per length is supplied by the manufacturer. A common unit of length used for visible wavelengths is the nanometer (1 nm = 10^{-9} meter). The computed wavelengths will have units of nanometers if d is expressed in nanometers. Since d is known and the angle θ can be measured with the aid of the spectrometer, the wavelengths emitted by a light source can be determined.

Procedure and Calculations:

For optimum operation the telescope and collimating tube must be properly adjusted. The following adjustments must be checked by the experimenter:

1. Adjust the eyepiece so the crosshairs are in clear focus.
2. Remove and focus the telescope on a distant object (one at "infinity).
3. The slit must be moved in the collimating tube so the image is sharp.
4. The slit must be vertical and narrow.

With these adjustments one should see a sharp image of the slit through the telescope.

The "white" light seen in the straight ahead direction is the zero order and defines where the angle θ is zero. The spectrum of different colors should be seen to the left and right of zero. Before taking data, check to see if the spectrum is symmetrical. That is, the same color line should be measured at the same angle to the left and right of zero. If this is not the case then the grating must be rotated.

You will work with two light sources. The first is the Mercury (Hg) lamp which gives off light from an electrical discharge of the gas. The light from the Hg lamp provides a discrete or line spectrum. The second is the incandescent lamp that provides a continuous spectrum like the rainbow.

Mercury lamp

As seen by the eye alone or in zero order, the Hg lamp appears bluish white. This suggests the Hg spectrum has several lines over the range of the visible spectrum with a slight dominance in the shorter wavelengths. Don't stare at the Hg lamp. Some uv (ultraviolet) rays are present and can "sunburn" the cornea of the eye.

1. Measure the angular location of at least 5 spectral lines in first order and compute the corresponding wavelengths. Compare to the values listed below that other experimenters have found. Compute the percent difference.
2. Also measure one of the above spectral lines (colors) in second order. Compute its wavelength and compare to the first order result. For second order, m=2.

Some Hg wavelengths from the Handbook of Chemistry and Physics:

violet	404.7 nm
violet	407.8 nm
blue violet	435.8 nm
blue	491.6 nm
green	546.1 nm
yellow	577.0 nm
yellow	579.1 nm

Incandescent lamp

1. Using the spectrometer, measure the angles corresponding to your limits of vision at short wavelengths (violet edge) and at long wavelengths (red edge). Use these angles to compute the limiting wavelengths of your vision.
2. Also, measure the angle corresponding to the color that you judge to be "pure" green and compute its wavelength.