Physics 2054 Lab: Interference and the Diffraction Grating

In this experiment, you will explore some of the wave properties of light. We will send light waves at various frequencies (and therefore various wavelengths) through an item called a diffraction grating. A diffraction grating is an array of a very large number of closely spaced slits. When held to your eye, it will seem essentially transparent, but there will be "rainbow" patterns everywhere in your field of view. The rainbow patterns are the result of the white light (really a combination of all colors of light) being broken up into its *spectrum*, or individual constituent wavelengths.

When light passes through a diffraction grating two things occur; diffraction and interference. Diffraction occurs whenever a wave passes through an aperture (such as a slit or hole) that has dimensions comparable with the wavelength of the wave phenomenon. In the case of light, its wavelengths are centered around 500 nm (1 nm $=10^{-9}$m). The exact bounds of visible light will be one of the things you determine in this experiment.

Interference of light waves is just a special case of this phenomenon which is dealt with in Chapters 13 and 14 of your text. If two light waves *destructively* interfere, one's maxima coincide with the other's minima and the result is darkness. If two light waves *constructively* interfere, one's maxima coincide with the other's maxima and the result is a bright region. For a diffraction grating, the bending of light as it passes through any slit works together with the interference of light waves passing through different slits to produce well-defined bright and dark regions. The location of the bright regions is given by:

$$m\lambda = d\sin\theta\ ,$$

where $m=0,\pm1, \pm2, \pm3,.....$, d is the width of one of the slits, and λ is the wavelength of the light. (In this lab, we'll be using diffraction gratings for which d can be determined from the known number of lines, or slits, per mm; see the grating for that data.) Note that d must be in meters (or nm) to yield a wavelength in meter (or nm). The angle θ is measured from a line perpendicular to the grating (see diagram). For m=1 or -1, the image seen is called the *first order* image. There are higher order images, and if you try hard you may be able to see the second order image of the light source.

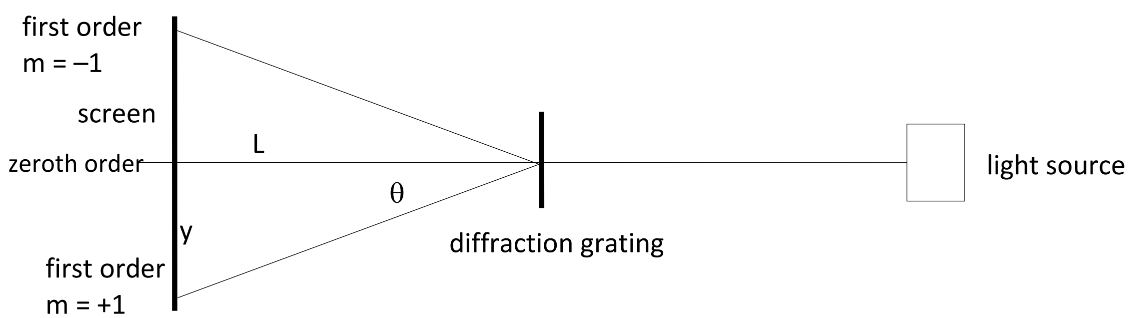

Figure 1. The arrangement of the grating and light source for use with the incandescent light or the laser ("light source"), as seen from above.

The angle θ will be determined by measuring the distance from the center of the screen (y) and the distance from the grating to the screen (L), and using a bit of trigonometry. When measuring the screen-to-diffraction grating length, it is important to note any offset between the grating and its mount.

$$\tan\theta = \frac{y}{L}$$

You will measure the spectra of two light sources; a common incandescent bulb (the light box used in the thin lens lab) and a laser. You must be very careful when using the laser, as directly viewing the laser light can cause eye damage.

Part 0: Alignment and Set-up

A. Mount the apparatus to the optics bench as shown in the diagram above and as demonstrated by your instructor. Set the distance L to be approximately 15 cm, but adjust it for maximum separation of the spectra. You will use the back of the light source, which can be set for single or multiple white slits or different colors. You will slide the selector until just one thin slit is visible.

B. Check the alignment of your apparatus to ensure that the $m = 1$ and the $m = -1$ spectra are symmetric (equidistant on either side of the slit). If it is not, make the necessary adjustments before proceeding to Part 1.

Part 1: Incandescent light

A. Set up the incandescent light bulb as the light source. At the center of the screen, you should be able to see the zeroth order image which will be an uninteresting rectangle of white light. If you can see this, you are ready to take your first data.

B. Find the first order image of the slit; it should appear as a smeared-out “rainbow” of color superimposed on either side of the screen. Note the locations (y-values) of the extrema of the spectrum (the red and the violet ends) and record their apparent locations. In your lab report, calculate θ and therefore λ for each of these extremes. See the table below. Use either $m = +1$ or $m = -1$.

C. Also, approximately determine the boundaries between the various colors. It is important that each student make independent observations, as eyesight varies among individuals.

L =

Boundary	red/dark	red/orange	orange/yellow	yellow/green	green/blue	blue/violet	violet/dark
Y							
θ							
λ (nm)							

Discussion Question:

1. The wavelengths you found in Part B represent the extremes and nature of light visible to human beings, assuming you are one. How do these values compare to the expected values?
2. Estimate the error (in ± some number of nm) in the extreme wavelength calculations for the red/dark and violet/dark boundaries. Consider only the errors associated with actually viewing the observed features on the screen. (How precisely can you determine the boundaries?) Ignore the minor errors associated with measuring the distance between the grating and the screen.

Part 2: Diode Laser

A. Next, you will measure the wavelength of the light coming from an LED (diode) laser. At all times, be careful not to look directly into the laser or directly at reflections coming from the laser; as with looking at any very bright source of light, prolonged exposure can permanently damage your eyes. Move the incandescent light source out of the way and insert the laser onto the optical bench.

B. Using the same procedure as Part 1, determine the wavelength of the laser light.

Discussion Questions:

1. Estimate the error (in ± some number of nm) in the laser wavelength calculation. Consider only the errors associated with actually viewing the observed diffraction maxima (bright areas). (e.g. how wide are they?) Ignore the minor errors associated with measuring the distance between the grating and the screen.
2. Is your wavelength consistent with what you measured for the region of visible light of the same color as the laser? How does it compare with the wavelength data printed on the laser itself?