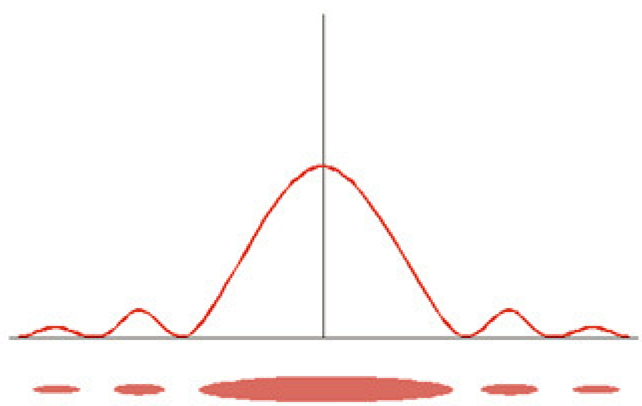
Introduction:

In this lab we will explore the wave nature of light. Visible light is an electromagnetic wave, with wave length λ between 400 and 750 nm, and it exhibits wave-like characteristics of interference, diffraction and refraction under certain circumstances.

Experiment 1: Interference and Diffraction

Diffraction Patterns:

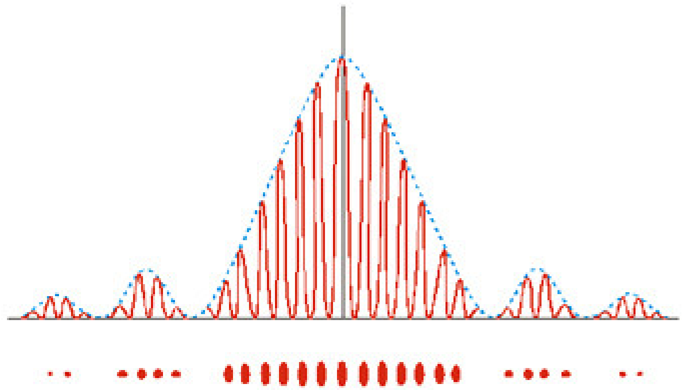
When light of wave length λ passes through a slit of width a and then strikes a screen which is a distance L from the slit, then a central bright beam of light forms opposite the slit, and then a series of secondary fringes form on either side as demonstrated in the diagram and graph below:



The width of the central beam, as measured from the centers of the two minima on either side, is $2L\lambda/a$. The width of the other fringes is $L\lambda/a$. Larger wavelengths give a larger separation. Smaller slit widths lead to a wider separation. If the slit width is very small it is possible that only a very wide central maximum is visible, and if the slit width is very large all the fringes may be so close together that only a single small spot will be visible.

Interference Patterns:

When light of wave length λ passes through two slits, each of width a, and separated by a distance d and then strikes a screen which is a distance L from the slits then a fringe pattern like the following may form:

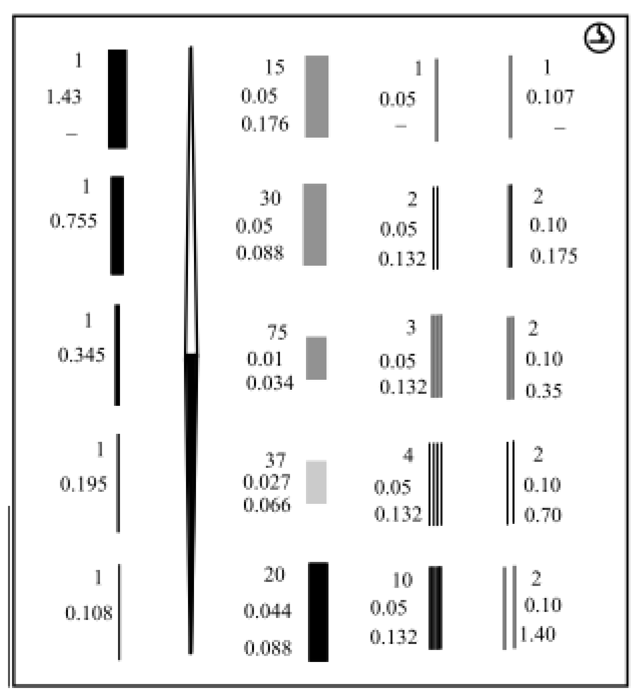


The separation between the small fringes is $L\lambda/d$.

When there are more than two slits the interference pattern is similar, although the fringes are narrower and brighter.

Procedure:
In this experiment we will use two different lasers with different wavelengths and a variety of different slit combinations to explore the qualitative and quantitative features of these diffraction and interference patterns.

For the different slits we will use a Cornell slit plate which is illustrated below. The first column shows a series of different single slits, the second column shows a slit of variable width, the other columns show 2 or more slits, with different separations and widths. The numbers to the left of the slits show properties of the slits. The first number is the number of slits, the second is, a, the width of the slits in mm, and the third, when present, is, d, the distance between two slits.

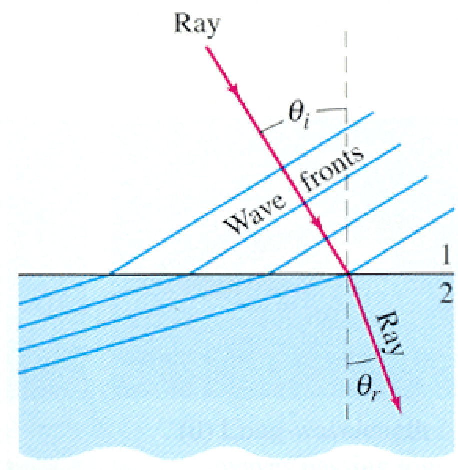


1. Set the slit plate on the stand and one of the lasers opposite it. Make sure the whole apparatus is a distance of about 4 meters from the screen. Measure this distance. When it is safe to do so turn on the laser (do not look directly into the laser, it can damage your retina).
2. First aim the laser through a few of the single slits and qualitatively compare the diffraction patterns you see. Sketch a few of the patterns. For the narrowest slit measure the separation of the fringes and use the formula to determine the wave length of the light. Repeat for the other laser. Confirm that the larger wavelength corresponds to larger fringe separation. (Note: the red laser is reported to have wavelength 632.8 nm and the green has wavelength 532 nm. Find the percentage error between your measured value and the reported value.)
3. Now aim the laser through some of the double slits in the right most column and qualitatively compare these interference patterns. Sketch the pattern for a few of these. For the double slit with the smallest separation distance measure the distance between the fringes and check the formula to see if you obtain the same value of the wave length of light. Repeat for the other laser.
4. Now aim the laser through some of the multiple slits. In particular, use the slits in the second column from the right in the diagram above. As you go down the column the number of slits increases from 1 to 2 to 3, up to 10. Draw sketches of the full diffraction pattern for 1, 2 and 10 slits next to each other. What are the differences and similarities?
5. Finally, obtain a diffraction grating, which has 600 slits per mm. Place this diffraction grating in the holder and place a white screen about a 1 meter from the grating. Turn on your laser and measure the separation between the fringes that you see. Because the slit separation in this grating is so small the fringe separation is quite large. What is the separation between two slits if there are 600 slits per mm? The interference formula given above is actually only an approximation to the formula that applies when the fringe separation is small compared to the distance from the screen. The correct formula is $d\sin\theta = \lambda$, where θ is the angle between the line from the grating to the central fringe and the line form the grating to next fringe. You can determine the angle with trigonometry by measuring the distance between the fringes on the screen, y, and the distance between the screen and the grading, L. Then

$$\theta = \tan^{-1}(y/L)$$

Experiment 2: Refraction

Light travels at different speeds in different media. As a consequence, light can change its direction as it passes across an interface between two different media, as shown below.



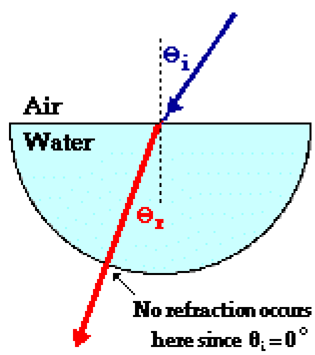
The relationship between the angle of incidence θ_i and the angle of refraction θ_r is given by Snell's Law:

$$n_i \sin\theta_i = n_r \sin\theta_r$$

Where n is the refractive index of the medium.

Procedure

1. Fill the refractive circular container until it is half full with water.
2. Adjust the laser so that it is incident on the water from above as shown:



3. Choose 6 different incident angles and for each measure the corresponding refraction angle.
4. Plot $\sin\theta_r$ vs $\sin\theta_i$ and verify Snell's Law. Use the slope of the graph to determine the index of refraction of water.
5. Now adjust the incident beam so is incident on the water from below and passes up from water to air. Adjust the incident angle until the angle of refraction is as close as possible to 90 degrees. Hence determine the critical angle.