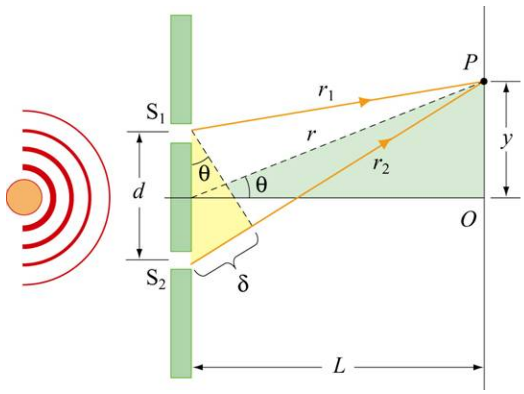
Diffraction
Challenge Problems

Problem 1:

Measuring the Wavelength of Laser Light
Suppose you shine a red laser through a pair of narrow slits (a = 40 μm) separated by a known distance and allow the resulting interference pattern to fall on a screen a distance L away (L ~ 40 cm).



(a) Will the center of the pattern (directly between the two holes) be an interference minimum or maximum?

(b) You should be able to easily mark and then measure the locations of the interference maxima. For the sizes given above, will these maxima be roughly equally spaced, or will they spread out away from the central peak? If you find that they are equally spaced, note that you can use this to your advantage by measuring the distance between distance maxima and dividing by the number of intermediate maxima to get an average spacing. If they spread out, which spacing should you use in your measurement to get the most accurate results, one close to the center or one farther away?

(c) Approximately how many interference maxima will you see on one side of the pattern before their intensity is significantly reduced by diffraction due to the finite width a of the slit?

(d) Derive an equation for calculating the wavelength λ of the laser light from your measurement of the distance Δy between interference maxima. Make sure that you keep a copy of this equation in your notes! You will need it for the lab.

(e) In order to most accurately measure the distance between maxima Δy, it helps to have them as far apart as possible. (Why?) Assuming that the slit parameters and light wavelength are fixed, what can we do in order to make Δy bigger? What are some reasons that can we not do this ad infinitum?

Problem 2:

Single Slit Interference

Now that you have measured the wavelength λ of the light you are using, you will want to measure the width of some slits from their diffraction pattern. When measuring diffraction patterns (as opposed to the interference patterns of problem 1) it is typically easiest to measure between diffraction minima.

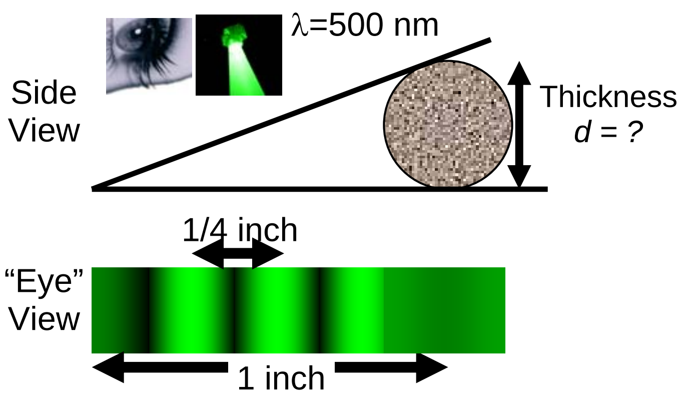
(a) Derive an equation for calculating the width a of a slit from your measurement of the distance Δy between diffraction minima. Make sure that you keep a copy of this equation in your notes! You will need it for the lab. Note that this same equation will be used for measuring the thickness of your hair.

(b) What is the width of the central maximum (the distance on the screen between the m=-1 and m=1 minima)? How does this compare to the distance Δy between other adjacent minima?

Problem 3:

Another Way to Measure Hair

In addition to using hair as a thin object for diffraction, you can also measure its thickness using an interferometer. In fact, you can use this to measure even smaller objects. Its use on a small fiber is pictured at left. The fiber is placed between two glass slides, lifting one at an angle relative to the other. The slides are illuminated with green light from above, and when the set-up is viewed from above, an interference pattern, pictured in the "Eye View", appears.



What is the thickness *d* of the fiber?

Problem 4:

CD

Suppose you reflect light off of a CD and measure the resulting interference pattern on a screen a distance L ~ 5 cm away.

(a) A CD has a number of tracks, each of width d (this is what you are going to measure). Each track contains a number of bits, of length $l \sim d/3$. Approximately how many bits are there on a CD? In case you didn't know, CDs sample two channels (left and right) at a rate of 44100 samples/second, with a resolution of 16 bits/sample. In addition to the actual data bits, there are error correction and packing bits that roughly double the number of bits on the CD.

(b) What, approximately, must the track width be in order to accommodate this number of bits on a CD? In case you don't have a ruler, a CD has an inner diameter of 40 mm and an outer diameter of 120 mm.

(c) Derive an equation for calculating the width d of the tracks from your measurement of the distance Δy between interference maxima.

(d) Using the previous results, what approximately will the distance between interference maxima Δy be on the screen?

Problem 5:

Light with a wavelength of λ = 587.5 nm illuminates a single slit which has a width of 0.750 mm.

(a) At what distance from the slit should a screen be located if the first minimum in the diffraction pattern is to be 0.850 mm from the center of the screen?

(b) What is the width of the central maximum?

Problem 6:

In a single-slit diffraction, the second-order bright fringe is at a distance1.40 mm from the center of the central maximum. The screen is 80.0 cm from a slit of width 0.800 mm. Assuming that the incident light is monochromatic, calculate the approximate wavelength of the incident light.

Problem 7:

Coherent light with a wavelength of λ = 501.5 nm is sent through two parallel slits in a large flat wall. Each slit has a width a = 0.700 μm, and the centers of the slits are at a distance d = 2.80 μm apart. The light falls on a semi-cylindrical screen, with its axis at the midline between the slits.

(a) Predict the direction of each interference maximum on the screen, as an angle away from the bisector of the line joining the slits.

(b) Describe the pattern of light on the screen, specifying the number of bright fringes and the location of each.

(c) Find the intensity of light on the screen at the center of each bright fringe, expressed as a fraction of the light intensity I_0 at the center of the pattern.