

The Double Slit Experiment

Caution: Class IV lasers (mostly harmless) are used in this experiment. Under no circumstances should you look directly into the laser, even if it seems like a really good idea at the time and your lab partners bet you a quarter it won't hurt. Laser light reflected from non-metallic surfaces is safe, but be careful with reflective surfaces. Please help save batteries and turn them off if you're doing calculations for any length of time.

You've just heard the theory on Young's diffraction pattern arising from two slits, so you've been briefed on what should be measured here. Setup the laser and slit dial on an optical track and prepare to **carefully** measure the parameters, along with all accompanying uncertainties.

(a) Sketch the bright and dark spots you see on the screen for a clear double slit pattern that you've made with the laser. Pick one where the pattern is large and easy to measure. You should have a fairly large distance to the screen or wall to minimize the uncertainties. Use your pen/pencil to make it darker on the paper where it is brighter on the screen. (Pencil mark = bright spot on screen and white paper = dark spot on screen). The sketching-challenged can try tracing it right over the pattern projected onto this sheet.

(b) Sketch a graph of intensity as a function of position for the pattern you have drawn above. Match the horizontal scales so the two sketches line up. Try to capture the overall larger pattern as well as the fine fringes and label the features due to the slit separation d and the slit width a .

(c) **Carefully** measure the separation of the bright spots on the screen and the distance from the slits to the screen. Calculate the wavelength of the red light, and **include an uncertainty in the result**. This uncertainty should be based on the uncertainties you measured for the three measurements needed for the calculation. (Use the product/quotient rule for relative errors). Triple check your numbers and spend some time making sure you're doing everything as carefully as possible. You'll have to estimate what you think the error in d would be, but it's probably safe to assume it's manufactured to within a percent or so at least.

Measurements:

$$Y_{\max} = \underline{\hspace{2cm}} \pm \underline{\hspace{2cm}}$$

$$D = \underline{\hspace{2cm}} \pm \underline{\hspace{2cm}}$$

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(d) Which error in the things you measured had the greatest relative error? Which had the smallest?

If your total error below is a little large, try increasing D and measuring the setup again. This should help decrease the relative error in two of your quantities.

Calculations:

Wavelength Result:

$$\lambda = (\text{_____} \pm \text{_____}) \text{ nm}$$

(Remember, always: 1 sig. fig. on error, placement of cutoff on digits matching)

(e) Does your result agree with the range printed on the laser, within uncertainties?

(If not, better go back and check things because this is one of those beautifully elegant experiments that yields very accurate results from just a few measurements)

(f) What general conclusions could you make about the fundamental nature of light even if you had not made any measurements and just examined the pattern? (If you had set this up 200 years ago with monochromatic light (no lasers back then), you'd have won shiny awards, and been invited to all the right parties.) Why don't we see diffraction of light more in everyday life?

(g) Use the numbers you recorded above, and find the wavelength without using the small angle approximations for $\sin(\theta)$ and $\tan(\theta)$ that we used in the derivation, and be careful not to round off in the middle of calculations. At what number of significant digits does using the approximations start to matter? Is this well within the uncertainty range, so we didn't really have to worry about using the approximations?

Calculations:

(h) Notice that although the laser beams all look like basically the same color of red, different groups are getting slightly different wavelengths. This is to be expected because the lasers 'drift' slightly with age, and variations in manufacturing, etc, and your eyes can't discriminate between pure wavelengths very well. Now, two lasers at slightly different wavelengths should make a beat frequency, so try aiming your laser and another group's at the same spot. Can you see a beat frequency?

Estimate what this beat frequency should be using the two λ values. Does this explain things?

Calculations:

(i) Return to the set-up with the laser, a slit, and a screen. You have many choices of different types and numbers of slits on the slides, including variable ones. Examine all of them to understand how they are labeled.

Use the wheel with the double slits. Carefully sketch the pattern on the screen for several (at least three) pairs of slits, and record the slit width ("a") and space ("d") next to the sketch below.

Sketches:

Use your sketches to answer the following questions:

Q1. What happens if the slit separation increases, but the slit width is constant?

Q2. What happens if the slit separation is constant, but the slit width increases?

Q3. Explain the two cases above in terms of the formulas we derived in class.