Diffraction

***Available equipment**: laser pointer, CD (or DVD) disc, ruler, protractor(optional), large paper clips or clothespins to fix CD.*

Introduction:

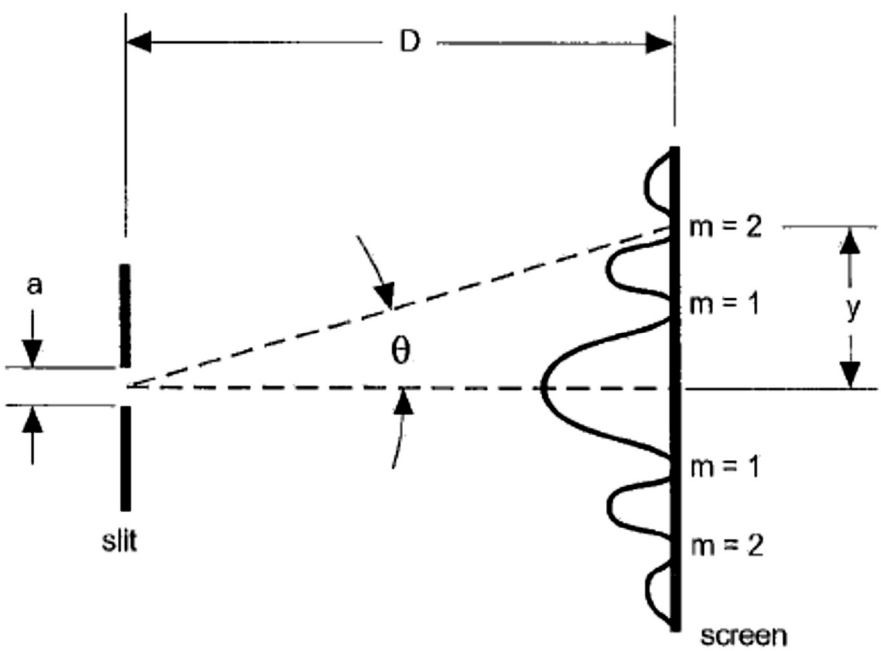
Single Slit

The figure below shows light of wavelength λ shining on a slit of width a, and the time-averaged intensity $I(\theta)$ pattern on a screen. The minima in the diffraction pattern occur where $I(\theta) = 0$, and the angular position θ_m of the mth minima is related to λ and a by:

$$m\lambda = a \cdot \sin(\theta_m) \approx a \cdot \tan(\theta_m) = \frac{a \cdot y_m}{L}$$

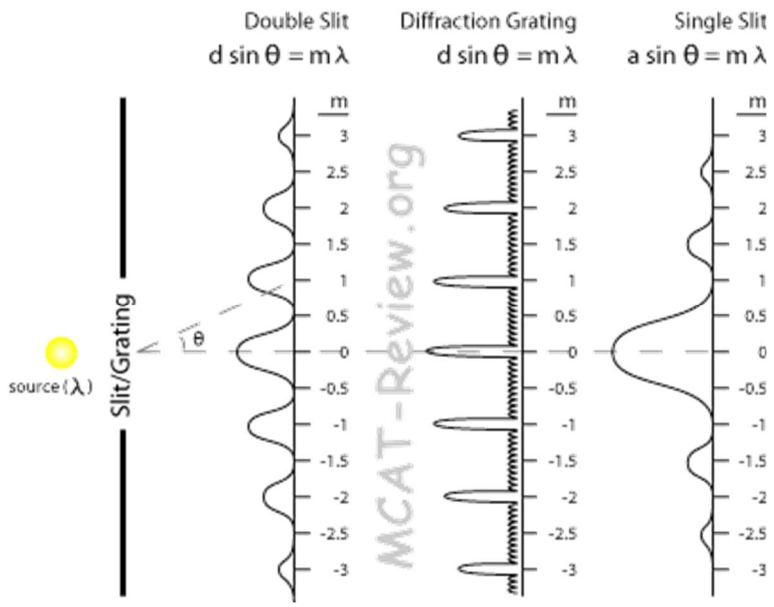
where $m = 1,2,3,\ldots$ *(for dark)* (1)

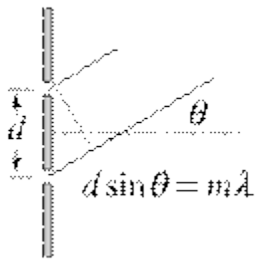
That means that the central bright line is twice wide than other bright lines that spaced at equal distances from each other. Note the condition for a diffraction minimum: for $m = 1$, $\lambda = a \sin \theta_1 \leq a$, since $\sin \theta_1 \leq 1$, hence the wavelength of light λ must be less than or equal to the aperture dimension a for diffraction to occur.



Diffraction gratings

A diffraction grating is the tool of choice for separating the colors in incident light. The condition for maximum intensity is the same as that for the double slit or multiple slits, but with a large number of slits the intensity maximum is very sharp and narrow, providing the high resolution for spectroscopic applications. The peak intensities are also much higher for the grating than for the double slit.



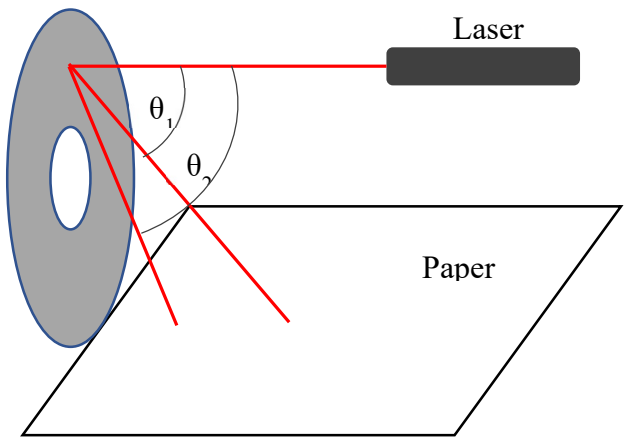


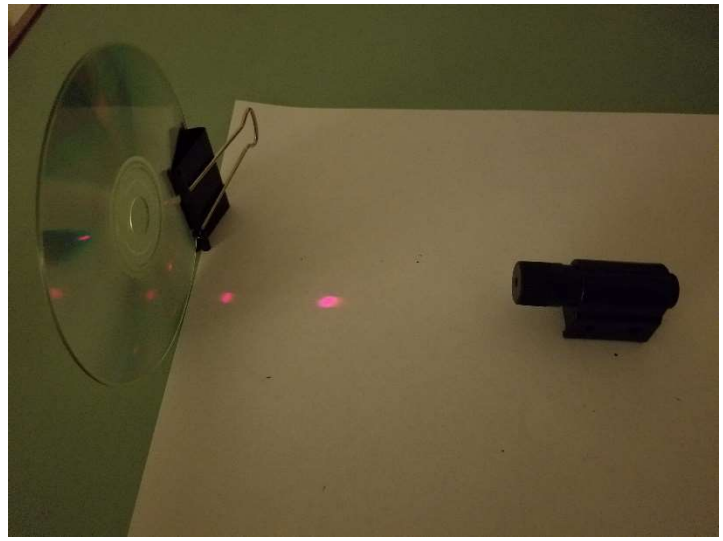
Babinet's principle states that the diffraction pattern produced by an opaque object is the same as the pattern produced by a hole with the same size and shape. For example, a single slit and a thin wire will produce the same diffraction pattern, as will a circular hole and an opaque disk.

Task1. Size of CD or DVD disc's tracks.

The digital information stored on CD discs form closely spaced rows acting like a reflecting diffraction grating. Use a laser pointer to determine the distance between the disc's grooves.

One of the possible configurations is shown in the figure, but you can do it differently. Just remember that it is easier to calculate angles when the laser beam is perpendicular to the CD disc and aimed to a point on the central vertical line above or below the disc's center (the grooves at such a spot are horizontal). You may fix the CD disc with a large paper clip.





Red laser has a wavelength 670nm

1. You will see the two bright spots. These are two diffraction orders (m = 1, 2)
2. Decide how you will measure the diffraction angles
3. Use these angles to determine the tracks spacing.
4. Do the calculations for both angles match each other?
5. Estimate the uncertainty of your measurements.
6. Record your result including the uncertainty range.
7. Usual value for CD spacing is 1.6μm (for DVD it is different). Does it match your results? If not, find the possible reason and revise your experiment or check your calculations.

Task 2. Thickness of a Human Hair

Use Babinet's principle to determine the width of a strand of your hair.

1. Pluck a hair and tape it across the hole in a cardboard. Position the laser so that the beam is centered on the hair.
2. Determine the thickness, *a*.
3. What is your value for the hair diameter *a* in μm?
4. Usually the thickness of human hair is from 17μm to 180μm. Is your result within this range?