Physics 223
Experiment 8: Interference from Multiple Slits

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Double slit interference

In Young's double slit interference experiment, two infintely small slits are illuminated by a single plane wave (see Figure 1) of wavelength λ. The interference pattern which appears on a screen far away is a result of the different distance traveled by the light from the two slits. If the slit separation is d and the screen is at a distance $L \gg d$ from the two slits, the interference maxima and minima occur at angles θ such that

$$\begin{array}{lrcl} \text{maxima} & d\sin\theta & = & m\lambda \\ \text{minima} & d\sin\theta & = & (m+\frac{1}{2})\lambda \end{array} \qquad m = 0,1,2,3\ldots \tag{1}$$

This leads to a simple intensity function:

$$I(\theta) = \cos^2\left[\frac{\pi d}{\lambda}\sin\theta\right]. \tag{2}$$

However, when the slits have a finite aperture a, the resulting intensity pattern becomes a combination of the simple Young's experiment and the single slit diffraction derived above.

$$I(\theta) = \left|\frac{\sin(\pi a \sin\theta/\lambda)}{\pi a \sin\theta/\lambda}\right|^2 \cos^2\left[\frac{\pi d}{\lambda}\sin\theta\right]. \tag{3}$$

The second term is a simple two slit interference pattern with equally spaced minima and maxima while the first term, arising from single slit diffraction, is more slowly varying and modulates the intensity and introduces some additional minima.

Diffraction gratings

A diffraction grating is similar to an ideal double slit with the difference that instead of two sources interfering to give maxima, the diffraction grating contains many "slits". The angular position of the maxima is given by

$$n\lambda = d\sin\theta \tag{4}$$

where $\theta = \arctan(x/L)$, n is the order number (0,1,2...), x is the distance of the n^{th} maximum from the central maximum ($n = 0$), d is the spacing of the rulings in the grating, and L is the distance between the grating and the screen. The intensity of a diffraction grating appears to be very different from that of a simple double slit, however, because the superposition of many "slits" results in only the sharp maxima being visible.

You will have a red laser, a set of double slits with two different spacings, and at least three different diffraction gratings (including one with unknown spacing). Using the slits and the gratings, devise a procedure to measure the wavelength of the laser and the spacing of the unknown diffraction grating. Treat the results obtained from the double slits, and gratings separately and compare the results. Which one of these methods appears to give the most accurate results for the wavelength?

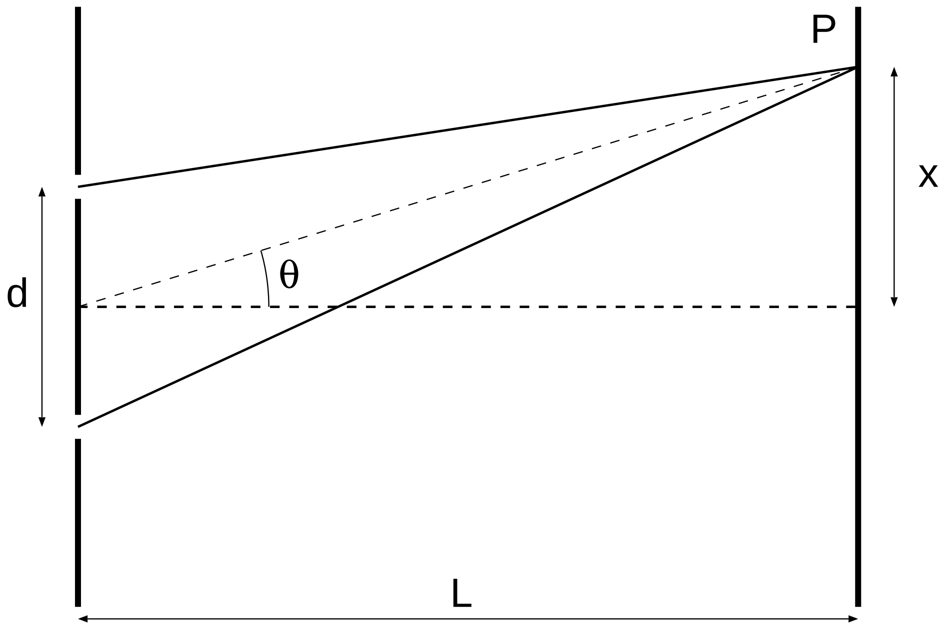

Figure 1: Double slit interference, maxima and minima