Physics 223
Experiment 7: Diffraction from a Single Slit

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When light passes through a small aperture or near sharp edges, it "spreads" in a phenomenon called diffraction. This is due to interference from Huygens wavelets originating from different parts of the aperture.

Suppose we have a beam of monochromatic light incident on a single small slit of width a. If the slit dimension is on the order of the wavelength of the light, it will be diffracted and form a pattern of maxima and minima. In order to see how this can happen, imagine that the slit is divided into two portions as shown in Figure 1, an upper half and a lower half. For every point **A** in the top half, there is a corresponding point **B** in the lower half of the slit. Consider the light from each of these two corresponding points impinging on the screen at point **P**. If the distance to the screen L is sufficiently large ($L \gg a$), the light traveling along **BP** will travel further than that along **AP** by an amount

$$\Delta x = \frac{a}{2}\sin\theta. \tag{1}$$

When this path length difference is exactly $\lambda/2$ then waves from each point in the upper half of the slit will destructively interfere at the screen with their corresponding wave from the lower half of the slit, resulting in a minimum in intensity. This will be the first minimum in the diffraction pattern (with the central maximum being at $\theta = 0$). The second minimum can be found in a similar way by dividing the slit into 4 equal portions and the third minimum by dividing the slit into 6 pieces. In general, we find that

$$\frac{a}{2n}\sin\theta = \frac{\lambda}{2} \longrightarrow a\sin\theta = n\lambda \qquad n = 1,2,3\ldots \tag{2}$$

Between each pair of minima there will be a maximum, however unlike simple double slit interference, these maxima are not equidistant from the minima. The intensity of a diffraction pattern can be derived by using the phasor construction and is given by:

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

You will be provided with a red laser, an optical rail, a photometer with several different aperture slits, and several single slits of differing aperture. Devise a procedure to measure the wavelength of the red laser by measuring the locations of the diffraction minima. Are all the expected maxima present, in the expected positions? Take the slit with the broadest central maximum and use the light meter and slit assembly to measure the intensity of the diffraction pattern as a function of angle from the center. In order to do this experiment you will need to calibrate the motion of the optical sensor and you will have to choose a suitable combination of aperture slit and relative positioning for the components to give you the best results. What happens if your aperture is too large? Too small?

Determine how well your results conform to the expected intensity values in Equation 3. Can you see secondary diffraction maxima? Are your measurements consistent with what you know about the wavelength of the laser and the slit size?

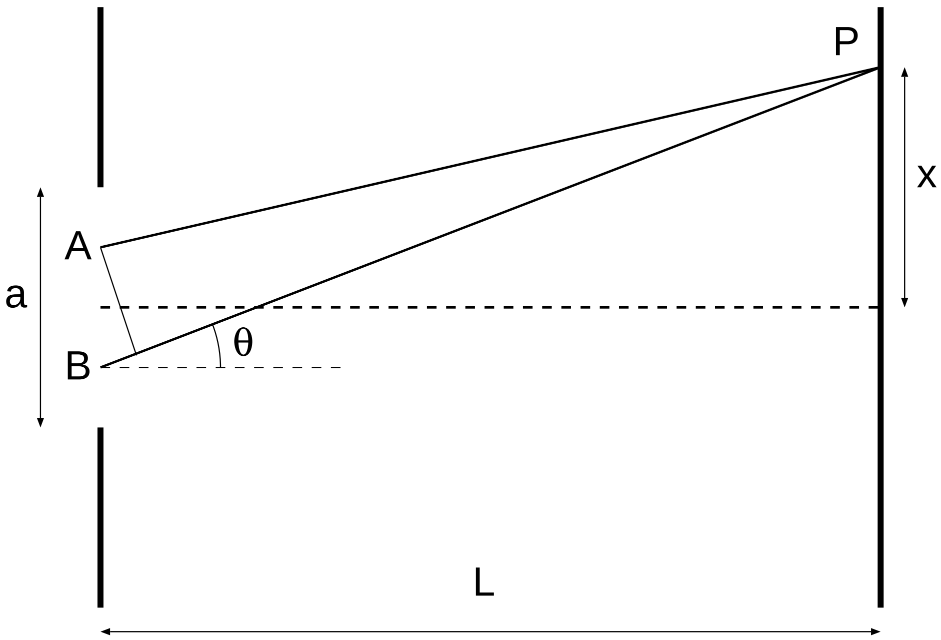

Figure 1: Single slit diffraction, finding the minima

CAUTION : Even though the lasers used in the laboratory are of low power and do not require special eyewear, serious injury may still occur. The following precautions MUST be observed at all times:

- **keep the laser turned off when not in use;**
- **do not move the laser around when it is on;**
- **do not mount the laser at eye level;**
- **do not look head on at the beam or at its reflection from a mirror or other shiny surfaces;**
- **never aim a laser at another person.**