36A –Diffraction Intensity

At the end of module 35B, you were asked to note and discuss why the double slit interference pattern did not extend over the entire view screen. The reason is that interference can only occur where there is intensity from each of the single slit sources. These slit sources are not point sources, and the width of the intensity pattern due to one slit is governed by diffraction. Diffraction is the word used to describe the interference between the infinite number of infinitesimal (Huygens) sources that make up the slit itself.

You can find a relationship in the textbook that quantitatively describes the intensity as a function of angle on a far screen. One version of that relation is given here:

$$I(\theta) = I_0\left(\frac{\sin(\beta/2)}{\beta/2}\right)^2 \text{ with } \beta = \frac{2\pi}{\lambda}a\sin\theta$$

1) Describe in words what each of the terms in the above equation represents.
   a) I_0 input light intensity
   b) θ angle from center
   c) a apature diameter
   d) λ wavelength of light
   e) β angle of the phasor from the center

2) From the above equation determine the following:
   a) Find the numerical values of β (in radians) for which $\sin(\beta/2) = 0$.

   n*2pi for any integer n 0,+-1,+-2...

   $\beta =$ -2pi,0,2pi,4pi,6pi,...

   b) The intensity is zero at all but one of these points. What is the numerical value of β for this special point? Why is it not zero?

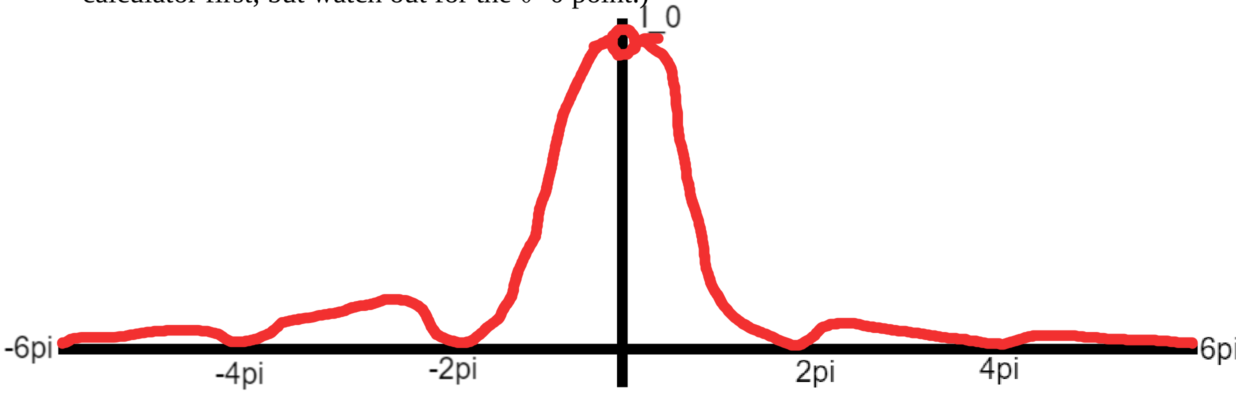
0 because I=sin(B/2)/(B/2),^{2} and at small x sinx=x, so sin(B/2)=B/2, and we have (B/2)/(B/2)=1 (in limit)

$\beta =$ 0

c) What is the value of the intensity at this special point in terms of I_0?

I=__I_0__________

3) Sketch $I(\beta)$ for $-6\pi < \beta < 6\pi$. (You might find it advantageous to plot this in Excel or on your calculator first, but watch out for the θ=0 point.)



4) What is the ratio $I(\beta)/I_0$ for $\beta = 3\pi$ to that for $\beta = 0$? Identify these two points on your sketch above.

$I(3\pi)/I(0)$=__0.04503________

Note that in two source interference the two maxima nearest the center of the pattern are nearly equal in intensity, whereas in diffraction the central maximum is much more intense than the next maximum from the center.

5) We sometimes take advantage of the "Small Angle Approximation" for diffraction and interference calculations. Fill in the table below.

θ (radians)	sinθ	tanθ	% difference Between sine and tan	θ(radians)	sinθ	tanθ	% difference Between sine and tan
0	0	0	0	0.3	0.296	0.309	4.466
0.10	0.100	0.100	0.5	0.35	0.343	0.365	6.063
0.15	0.149	0.151	1.123	0.4	0.389	0.423	7.894
0.2	0.199	0.203	1.993	0.45	0.435	0.483	9.995
0.25	0.247	0.255	3.109	0.50	0.479	0.546	12.242

used (tan-sin)/tan, wasn't specified, but they're close enough

a) For which angles above is the approximation $\theta \cong \sin\theta \cong \tan\theta$ good to within a few percent?

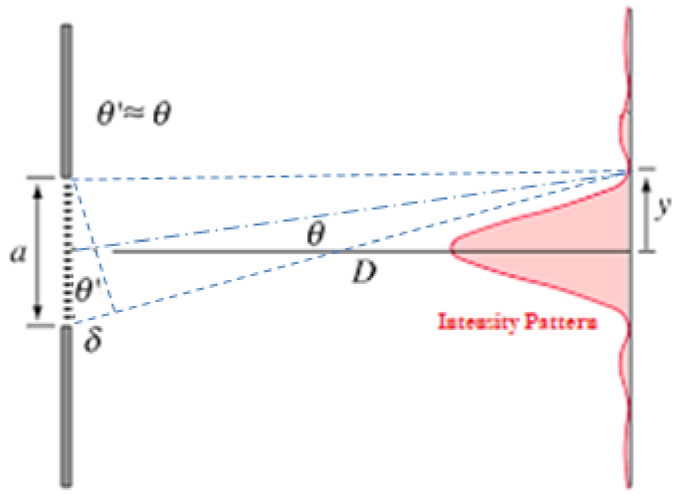
(within 5%) theta~=sin theta up to 0.56, theta~=tan theta up to 0.39, and tan theta ~= sin theta up to 0.32
so about .3 if assuming all three are "equal"

b) In the small angle approximation, for two-slit interference, what is the position y_1 of the first bright band measured from the center of the central maximum when the view screen is a distance D from the slit mask. Write your answer in terms of the following symbols: λ, *D*, *d*, and constants.

y*d=D*m*l

y=D*lambda/d

6) In classroom experiments, the light passing through a single slit is projected onto a flat viewing screen and the position y of a dark and bright band on the screen is measured relative to the center of the pattern, rather than the angle.



a) In the small angle approximation, what is the position y_1 of the first dark band measured from the center of the central maximum when the view screen is a distance D from the slit mask. Write your answer in terms of the following symbols: $\lambda, D, a,$ and constants.

y=D tan theta, a*sin theta = m lambda, theta=arcsin m*lambda/a
y=D*tan(arcsin(m*lambda/a)
y=D*tan(arcsin(lambda/a))

b) In the small angle approximation for single slit diffraction, what is the distance between the two dark bands on both sides, and closest to, the center of the pattern? Express your results in terms of the following symbols: $\lambda, D, a,$ and constants.

=2y=D*tan(arcsin(lambda/a))-D*tan(arcsin(-lambda/a))
=2*D*tan(arcsin(lambda/a))

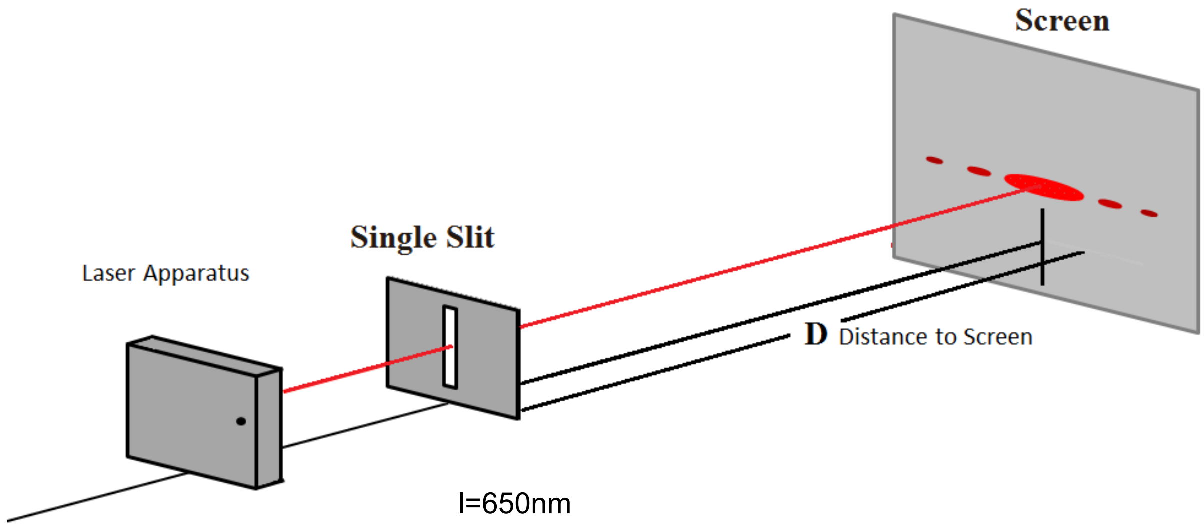
c) In the small angle approximation, what is the distance between the y_1 and y_2 dark bands? Express your results in terms of the following symbols: $\lambda, D, a,$ and constants.

=D*tan(arcsin(2*lambda/a))-D*tan(arcsin(lambda/a))

36B – Experiment: Single Slit Diffraction

Equipment: PASCO Magnetic Rail; Red Semiconductor Laser and Power Supply; Single Slit Mask; Multiple Slit Mask; Black metal safety screen; Small ruler.

- Set up the diode laser to point through the apertures in the Single Slit mask and project onto the viewing screen. The laser and mask should be only 1-10 cm apart while the viewing screen should be 70-100 cm away (more if you can).
- Set the Single Slit mask so that the laser passes through the *a*=0.04 slit and is incident on the white viewing screen. The intensity on the screen should look like the intensity you sketched in the previous section. If you don't think so, consult with a TA.



l=650nm

t=Dl/a

1) Measure the distance $\Delta y = y_{+1} - y_{-1}$ between the two dark bands on either side of the central maximum and record it in the table below. Also record the distance *D* between the mask and the view screen for each measurement. The wavelength for these experiments is 650 nm.

Slit width *a* (mm)	*D* (mm)	θ_1 (radians) Calculated from *a*, *D*, λ	$\Delta y = y_{+1} - y_{-1}$ (mm)	Measured θ_1 (radians) (from Δy and *D*)
0.04	800	0.01625	28	0.0175
0.08	800	0.008125	14	0.00875

2) Use *a*, *D*, and λ to predict the angular position of the first dark band to one side of the central maximum and record it in the table above.

3) Use Δy and *D* to for each measurement to calculate the angle from the center at which the first dark band appears. Add this to your table.

4) Are your two approaches to finding θ_1 in agreement? If not, why do think they disagree?

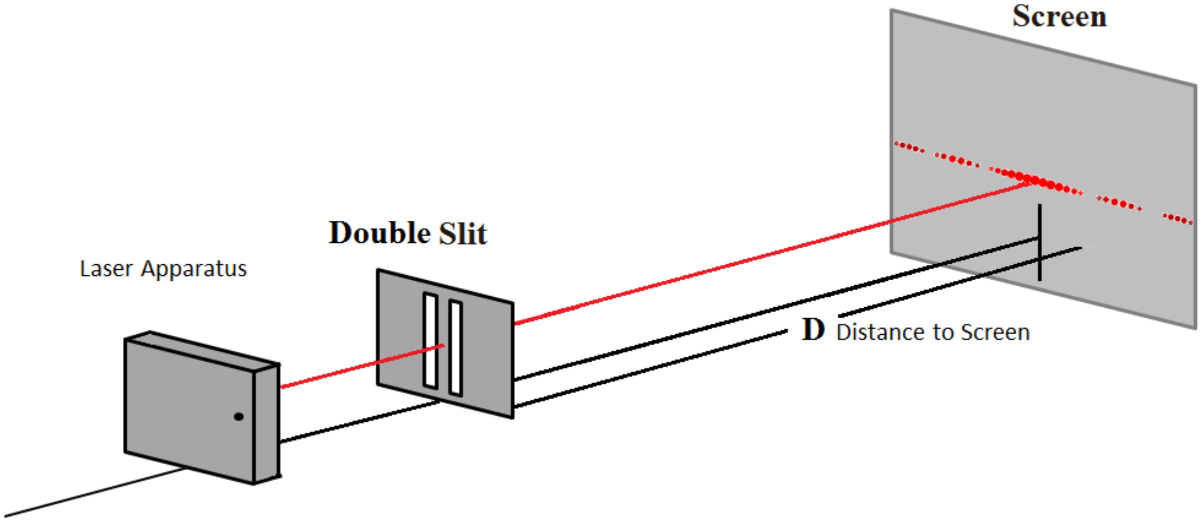
Yes, they're off by a very small margin

5) Can you observe additional bright and dark bands for the 0.16 mm slit? If so how does the intensity of the first bright band from the center compare with the intensity at the center of the pattern? (Much less intense. Slightly less intense. About equal. More intense.)

much less intense than the center, but more intense than the second band with the other slits

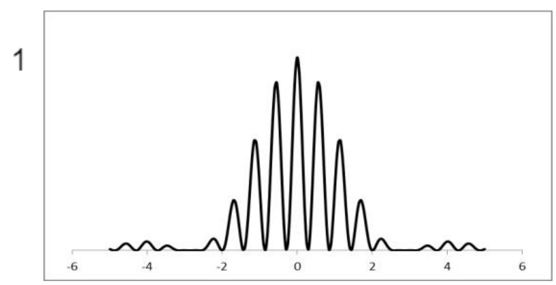
36C – Experiment: Double Slits of Finite Width

Equipment: PASCO Magnetic Rail; Red Semiconductor Laser and Power Supply; Multiple Slit Mask; black metal safety screen; Small ruler.

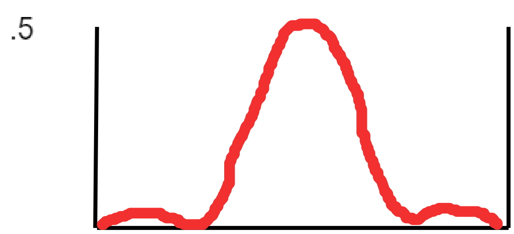


1) The figure to the right shows the intensity pattern on a distant screen due to light passing through two narrow slits. The intensity at the central peak is 1W/m^2.

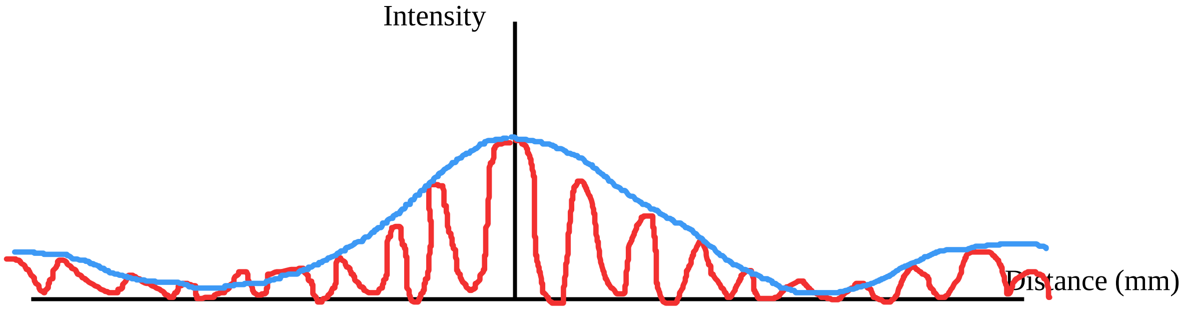
a) Draw a graph of the intensity pattern one would observe if one of the slits were blocked. (Include an intensity scale.)



b) Explain your logic in drawing it this way.



2) Set up the laser and Multiple Slit mask with the beam passing through the a= 0.04 and d = 0.25 mm set of slits. Sketch the intensity pattern you observe as a function of distance from the center. Include a length scale on your sketch.



(***Remote students only***: *image can be found in the LMS-posted image file associated with this Module*.)

We use the term "envelope" to describe the shape of a line that connects the closely spaced bright maxima ("fringes") in the intensity pattern. The envelope shape is controlled by the width of the individual slits. The spacing of the closely spaced bright maxima ("fringes") is controlled by the distance between the slits.

l=625nm

3) Fill in the table below.

y=22mm y=2mm,1mm

Slit width a (mm)	d (mm)	D m	Slit width a calculated from experimental measurement of Δy from min to min of the envelope, D, and λ (mm)	Slit separation d calculated from experimental measurement of Δy from max to max of the fringe pattern, D, and λ (mm)
0.04	0.25	.8	0.045mm	0.25mm
0.04	0.50	.8	0.045mm	0.50mm

4) How do the broad minima in the envelope you observe here compare with the positions of the first minima in the single slit experiment 36B?

approximately the same, between our two measurements in B

5) How does the spacing of the sharp bright maxima you observe here compare with the spacing you observed in experiment 35B?

exactly the same, it's the exact same setup