PHY385H1F – "Introductory Optics"
Practicals Day 4 – The Wavelength of Light
October 17, 2011

Group Number (number on Intro Optics Kit): ____.

Facilitator Name:________________________________.

Record-Keeper Name:__________________________________. [Turn this sheet in for marks]

Time-keeper:______________________________.

Computer/Wiki-master:________________________________.

NOTE: The roles for the above must be *different* than the last two weeks!

Activity 4.1 – The Wavelength of Light

In two-slit interference, light falls on an opaque screen with two closely spaced, narrow slits. As Huygen's principle tells us, each slit acts as a new source of light. Since the slits are illuminated by the same wave front, these sources are in phase. Where the wave fronts from the two sources overlap, an interference pattern is formed.

The PASCO OS-8500 optics bench is shown in the figure. The light source, component holders, and ray table base all attach magnetically to the bench. For proper alignment, the edge of each of these components should be mounted flush to the alignment rail, which is the raised edge that runs along one side of the bench.

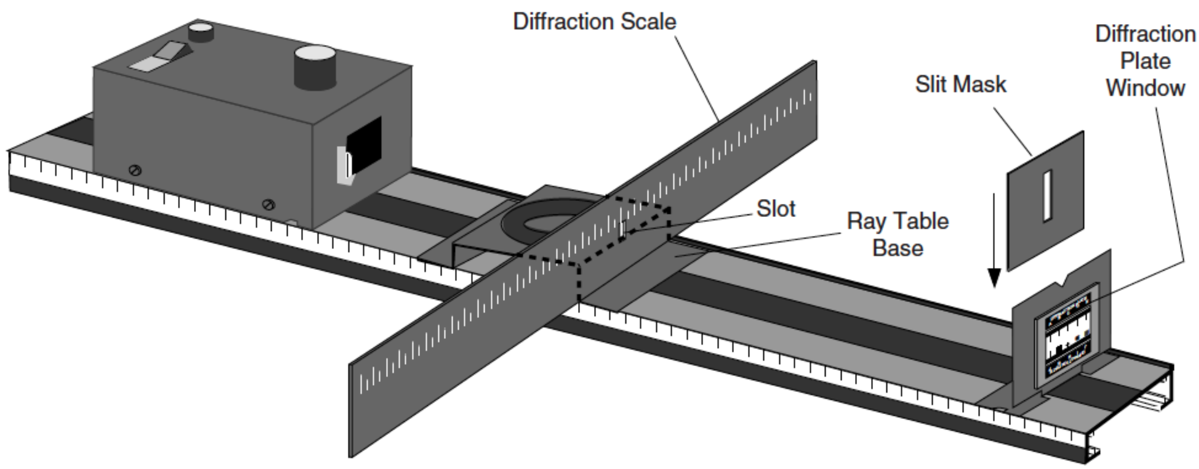
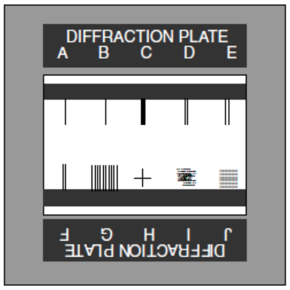


Figure 1. The setup. You need to put your head close to the optics bench on the right and look through the diffraction plate towards the light source in order to see the diffraction pattern.

The Slit Mask should be centred on the Component Holder. While looking through the Slit Mask, adjust the position of the Diffraction Scale so you can see the filament of the Light Source through the slot in the Diffraction Scale.

Attach the Diffraction Plate to the other side of the Component Holder, as shown. Centre pattern D, with the slits vertical, in the aperture of the Slit Mask. Look through the slits. By centring your eye so that you look through both the slits and the window of the Diffraction Plate, you should be able to see clearly both the interference pattern and the illuminated scale on the Diffraction Scale.

NOTE: *In this experiment, you look through the narrow slits at the light source, and the diffraction pattern is formed directly on the retina of your eye. You then see this diffraction pattern superimposed on your view of the illuminated diffraction scale. The geometry is therefore slightly more complicated than it would be if the pattern were projected onto a screen, as in most textbook examples. (A very strong light source, such as a laser, is required in order to project a sharp image of a diffraction pattern onto a screen.)*



Pattern	No. Slits	Slit Width (mm)	Slit Spacing center-to-center (mm)
A	1	0.04	
B	1	0.08	
C	1	0.16	
D	2	0.04	0.125
E	2	0.04	0.250
F	2	0.08	0.250
G	10	0.06	0.250
H	2 (crossed)	0.04	
I	225 Random Circular Apertures (.06 mm dia.)		
J	15 x 15 Array of Circular Apertures (.06 mm dia.)		

Figure 2. The patterns on the PASCO "Diffraction Plate". For pattern D, the slit spacing for the double slit is 0.125 mm.

The essential geometry of the experiment is shown in Figure 3. At the zeroth maxima, light rays from slits A and B have travelled the same distance from the slits to your eye, so they are in phase and interfere constructively on your retina. At the first order maxima (to the left of the viewer) light from slit B has travelled one wavelength farther than light from slit A, so the rays are again in phase, and constructive interference occurs at this position as well.

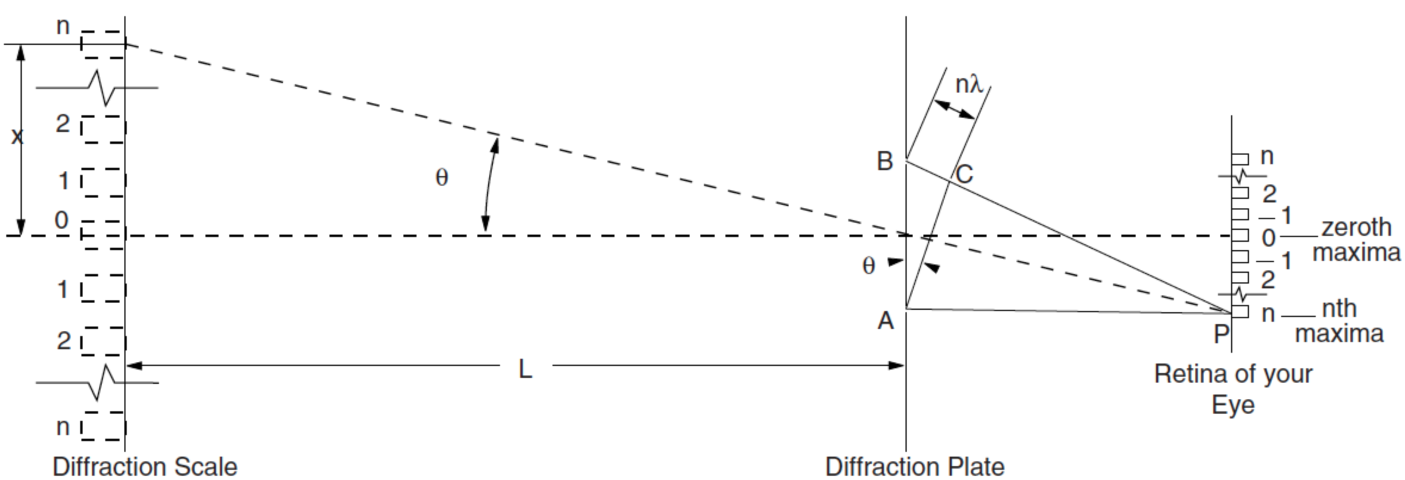


Figure 3. Geometry of two-slit interference.

At the n^{th} order maxima, the light from slit B has travelled n wavelengths farther than the light from slit A, so again, constructive interference occurs. In the diagram, the line AC is constructed perpendicular to the line PB. Since the slits are very close together (in the experiment, not the diagram), lines AP and BP are nearly parallel. Therefore, to a very close approximation, AP = CP. This means that, for constructive interference to occur at P, it must be true that $BC = n\lambda$.

From right triangle ACB, it can be seen that $BC = AB \sin \theta$, where AB is the distance between the two slits on the Diffraction Plate. Therefore, $AB \sin \theta = n\lambda$. (The spacing between the slits, AB, is listed in Figure 2.) Therefore, you need only measure the value of θ for a particular value of n to determine the wavelength of light.

To measure θ, notice that the dotted lines in the illustration show a projection of the interference pattern onto the Diffraction Scale (as it appears when looking through the slits). Notice that $\theta' = \arctan X/L$. It can also be shown from the diagram that, if BP is parallel to AP as we have already assumed, then $\theta' = \theta$. Therefore, $\theta = \arctan X/L$; and $AB \sin (\arctan X/L) = n\lambda$.

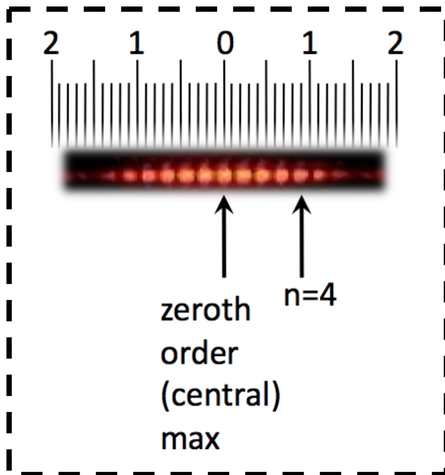


Figure 4. This is a drawing of approximately what you are supposed to see. It is difficult, but with one eye you should be able to see both the diffraction scale and the diffraction pattern at the same time, one just above the other. The zeroth order central maximum should always appear exactly at the 0 cm mark on the diffraction scale. In this drawing, it appears that the $n = 4$ order is a distance of $X = 9$ mm away from the central $n = 0$ maximum.

Looking through the pair of slits (pattern D) at the Light Source filament, make measurements to fill in the tables below. All of the team members should try this and record individual measurements of the apparent distance between two bright fringes (X) and the number of dark fringes between them (Δn). In this way you can make four independent determinations of λ. The error in the mean is $\sigma / \sqrt{4}$, where σ is the standard deviation of the four measurements. Alternately place the Red, Green, and Blue color filters over the Light Source aperture to make the measurements for the different colours of light. If you have time, make measurements with the other two-slit patterns as well (patterns E and F on the Diffraction Plate). Perform the calculations shown to determine the central wavelength of Red, Green, and Blue Light.

Central Wavelength of **RED** filter
Double-slit pattern **D**: $AB = 0.125$ mm $= 1.25 \times 10^{-4}$ m
Distance between slit-pattern and the diffraction scale: $L =$ ______________________.

Measurement #	Δn	X	$\lambda = \left(\frac{AB}{n}\right)\sin[\arctan(X/L)]$
1			
2			
3			
4			
Average λ			
Error in λ			

Central Wavelength of **GREEN** filter
Double-slit pattern **D**: $AB = 0.125$ mm $= 1.25 \times 10^{-4}$ m
Distance between slit-pattern and the diffraction scale: $L =$ ______________________.

Measurement #	Δn	X	$\lambda = \left(\frac{AB}{n}\right)\sin[\arctan(X/L)]$
1			
2			
3			
4			
Average λ			
Error in λ			

Central Wavelength of **BLUE** filter
Double-slit pattern **D**: AB = 0.125 mm = 1.25×10^{-4} m
Distance between slit-pattern and the diffraction scale: L = ______________________.

Measurement #	Δn	X	$\lambda = \left(\frac{AB}{n}\right)\sin[\arctan(X/L)]$
1			
2			
3			
4			
Average λ			
Error in λ			

Central Wavelength of **RED** filter
Double-slit pattern **E**: AB = 0.250 mm = 2.50×10^{-4} m
Distance between slit-pattern and the diffraction scale: L = ______________________.

Measurement #	Δn	X	$\lambda = \left(\frac{AB}{n}\right)\sin[\arctan(X/L)]$
1			
2			
3			
4			
Average λ			
Error in λ			

Central Wavelength of **GREEN** filter
Double-slit pattern **E**: AB = 0.250 mm = 2.50×10^{-4} m
Distance between slit-pattern and the diffraction scale: L = ______________________.

Measurement #	Δn	X	$\lambda = \left(\frac{AB}{n}\right)\sin[\arctan(X/L)]$
1			
2			
3			
4			
Average λ			
Error in λ			

Central Wavelength of **BLUE** filter
Double-slit pattern **E**: AB = 0.250 mm = 2.50×10^{-4} m
Distance between slit-pattern and the diffraction scale: L = ______________________.

Measurement #	Δn	X	$\lambda = \left(\frac{AB}{n}\right)\sin[\arctan(X/L)]$
1			
2			
3			
4			
Average λ			
Error in λ			

Central Wavelength of **RED** filter
Double-slit pattern **F**: AB = 0.125 mm = 1.25×10^{-4} m
Distance between slit-pattern and the diffraction scale: L = ______________________.

Measurement #	Δn	X	$\lambda = \left(\frac{AB}{n}\right)\sin[\arctan(X/L)]$
1			
2			
3			
4			
Average λ			
Error in λ			

Central Wavelength of **GREEN** filter
Double-slit pattern **F**: AB = 0.125 mm = 1.25×10^{-4} m
Distance between slit-pattern and the diffraction scale: L = ______________________.

Measurement #	Δn	X	$\lambda = \left(\frac{AB}{n}\right)\sin[\arctan(X/L)]$
1			
2			
3			
4			
Average λ			
Error in λ			

Central Wavelength of **BLUE** filter
Double-slit pattern **F**: $AB = 0.125$ mm $= 1.25 \times 10^{-4}$ m
Distance between slit-pattern and the diffraction scale: $L =$ ____________________.

Measurement #	Δn	X	$\lambda = \left(\frac{AB}{n}\right)\sin[\arctan(X/L)]$
1			
2			
3			
4			
Average λ			
Error in λ			

Activity 4.2 – Lab Tour: Institute of Optical Sciences Holography Lab

Take a tour of the IOS Holography Lab in MP331, as lead by Emanuel Istrate. Please ask questions, and record a brief answers or notes below. You might ask:

- Why does a hologram look transparent, and yet you can see an image inside?
- Why must you use a laser to shoot a hologram?
- If you need a laser to shoot, why is it better to use an LED to play back a hologram?

TOUR NOTES [or 'how to shoot a hologram']: