Investigating youngs double slit experiment

In the early 1800s, a great debate arose within the scientific community, was light a wave or a particle? The famous Isaac Newton, argued that light was in fact a particle. On the contrary, a scientist by the name of Thomas Young argued that light was not a particle but that it was a wave. To go along with his argument he devised an experiment to test his theory. Young performed his famous double slit experiment which seemed to prove that light was a wave. Though the experiment most often uses light, the fact is that this sort of experiment can be performed with any type of wave. Young allowed light from the sun to pass through the slit in a barrier so it expanded out in wave fronts from the slit as a light source. The light then passed through another barrier with a pair of slits. Each slit diffracted the light as if they were individual but yet identical light sources. The light impacted an observation screen as an interference pattern with bright spots and dark spots that spanned out on the screen. The light would only span a certain angle before disappearing, that angle is ninety degrees. The brightest part on the screen would be in the middle as it would fade out symmetrically. Light was proved to behave like a wave with this experiment simply because unlike particles waves are able to move through each other, and essentially form interference patterns. Of course, later on it was determined that light had both properties of particles and waves in what would be known as the Wave-Particle Duality. The truth is that both these scientist were correct in their theory. Light can refract, reflect, diffract just like a wave and light can also travel without a medium just like a particle.

Many different aspects of the double slit experiment could affect the results of the experiment. The distance the observation screen is from the source of light and the slits affect the results. The wavelength of the light shone through the slits also affects the results of the experiment. The distance between the two slits is another factor that affects the results. A formula is used when there is an unknown variable in a double slit experiment:

λ is the wavelength of the light

d is the distance between the two slits

x is the distance between the bands of light and the central maximum

L is the distance from the slits to the screen central maximum

The measurement of x can only be determined by actually experimenting. The wavelength will always be the same because wavelength can only be changed by changing the original light source. The color of the light also depends on the wavelength. Changing one of the variables will also change the results as the distance being more farther will have a wider diffraction on the observation screen.

Question:

How can the relationship for double slit interference allow us to predict an unknown variable based on known variables?

Purpose: To determine the relationships among the wavelengths of a light source and the distances from dark to dark of a double slit interference pattern in order to find the distance between the two double slits.

Hypothesis:

It is hypothesized that the relationship of double slit interference will allow us to predict unknown variables fairly accurately. Specifically, it is believed that as the wavelengths of the lasers decrease, the distances from dark to dark spots on the interference pattern will also decrease by a certain factor depending on the amount of decrease. The red laser (650 nm) should produce the widest distance between nodal points on the screen, while the green laser (532 nm) and purple laser (405 nm) should produce smaller distances between the nodal points. Since we kept the distances between the screen and the light source at a constant, it is hypothesized that the wider the wavelengths are, the wider the distances between the nodal points will be. In addition, the distances between the slits are predicted to have approximately the same width for all three of the lasers. Based on the fact that we will be using the same slit for all three of the lasers, the calculated widths between the slits should be more or less the same. Based on our knowledge of the formula for destructive interference, we believe that the distance between dark to dark will be directly proportional to the wavelengths of the lasers.

Lab Design:

Materials:

· Meter stick

· Two Retort Stands

· Two Utility Clamps

· Double Slit Plate

· Blank piece of paper

· Red Laser (λ = 650 nm)

· Green Laser (λ = 532 nm)

· Purple Laser (λ = 405 nm)

· Plastic Ruler

· Tissue Paper

Procedure:

1. The required materials were gathered.

2. A piece of blank paper was taped against the wall, which acted as a screen.

3. The double slit plate was partially wrapped in tissue paper and attached to a utility clamp.

4. The utility clamp was then attached to the retort stand.

5. The retort stand was placed at a distance of one meter from the screen.

6. The red laser was placed on to a second utility clamp and the utility clamp was clamped onto a second retort stand. Then, it was placed behind the retort stand holding the double slit plate.

7. The red laser was shined through the double slits and the distances between the dark nodes of the interference pattern on the blank paper was marked with a pencil.

8. The distances of three successive dark spots were measured using a ruler and recorded.

9. Steps 7 and 8 were repeated 3 times for the red laser.

10. Steps 6-9 were repeated, but with the green laser and purple laser.

11. All of the materials were returned to their respective places.

Variable Selection:

Table 1: Use of the variables

Independent variable:

λ

The lasers were changed, thus changing the wavelength.

Dependant Variable

Δx

The distance between the successive nodes (Δx) changed as the wavelength changed.

Controlled Variable:

L

The distance from the source or slit to the screen was kept the same throughout the experiment.

d

The D3 slit was used for the entire experiment.

Observations:

Quantitative Observations:

Table 2: Distance between Bright and Dark Spots for each laser

Laser

(λ nm)

Δx #1

(± 0. 5mm)

Δx #2 (± 0. 5mm)

Δx #3 (± 0. 5mm)

Red (650)

9. 0

9. 0

10. 0

Green (532)

7. 5

8. 0

8. 0

Purple (405)

4. 5

5. 5

5

Qualitative Observations:

Red Laser: The red laser seemed like a typical everyday laser. The point the laser made was quite tiny and precise. During the testing, we observed that the red laser diffracted the most out all the other lasers. The actual interference pattern that appeared on the screen was wider than the interference pattern created by the other two lasers.

Green Laser: The green laser was brighter than the red laser. In addition, the point that the laser made was noticeably larger than that of the red laser. We also noticed that the laser appeared to be a bit pixelated when shined at the wall. The green laser pointer itself was noticeably heavier than the red laser. From the actual testing of the laser we observed that the interference pattern produced by the green laser was not as wide as that of the red laser.

Purple Laser: The purple laser was quite fascinating. The point it made on a surface when testing it out was quite noticeably larger than that of the red and green laser. Instead of producing a precise end point like the red laser, the purple laser produced a rather large point on the wall. The color of the purple laser also appeared to go from light to darker as it extended from the middle of the point. In addition, we noticed that the purple laser was extremely bright and difficult to look at as it would hurt our eyes. During the testing the purple laser produced an interference pattern that was not as wide as the previous two lasers.

Analysis:

During our testing we performed 3 trials for each laser to insure that our results were accurate. Obviously, we found that our results varied between all three trials for each laser. To find the most accurate representation of , an average of all the trials were be taken.

Formula:

Table 3: Average of Δx for each Laser

Laser Color

Average Δx (± 0. 5mm)

Red

9. 3

Green

7. 8

Purple

5. 0

Using these averages we created Graph 1 showing the relationship between the wavelength of the laser and the resulting value. This graph is very useful because it can be used to calculate d (the distance between double slits).

Graph 1: Shows the relation between the wavelength and distance between the successive nodes.

This graph shows the relationship between the change in x and wavelength. It shows that the relationship is linear and that as the x decreases wavelength decreases. The relationship that the graph shows makes sense since x and wavelength are known to be proportional to each other, as one changes the other changes in the same way. The slope of the line is -17478x. Since this graph shows the relationship between wavelength and x the slope is actually also equivalent to .

Calculating d using Graph 1:

Equation of the slope:

Since the slope is taken from the graph that shows the relationship:

∴

, L = 1000 mm

± 0. 5mm

∴ the distance between the double slits is

Percent Error:

Experimental value = 0. 0572 mm ± 0. 5mm

Actual value = 0. 2636 mm ± 0. 5mm

∴ there is an error of 78. 3%.

A percentage error of 78. 3% makes sense considering the amount of error present in our experiment. Along the way we must have accumulated a lot of error thus contributing to the rather high error percentage.

Evaluation of investigation:

Although, initially we were quite confident with our results it turned out that our results were very in accurate. We followed the procedure step by step. We converted all of our observations correctly. We were able to create a graph to ultimately find d. However, in the end we were still very in accurate. We did everything necessary however we believe that our weakness was that we had several sources of error that had a very large impact on the accuracy of our results. That is our only logical explanation for our error percentage of 78. 3%.

Sources of Error:

Systematic Error:

One source of systematic error present in our lab has to do with the actual tool we used to take our measurements. We actually used a very cheap dollar store ruler to take our measurements. It was used to measure the distance between successive nodal lines (Δ x). The problem with this ruler was that it had a lot of tiny chips and scrapes on it which made it difficult to read the measurement on it. In addition, the end of the ruler had a piece of it actually chipped off. Overall, it was just in very poor condition. This source of error had a definite effect on the results of our lab. Since it was so difficult to take accurate measurements, our measurements of Δx are most likely slightly inaccurate. This inaccuracy also affects our calculation because the variable Δx is an important part of the calculation.

Random Error:

From the very beginning of our lab, it was clear that there would be many sources of random error. We were unsure at first of what to do and on top of that we had to perform the delicate experiment in a rush to meet time constraints. The first of the random errors began when we had to point the laser through the slits. The laser itself was set up in the right position using a clamp and retort stand. However, when it came to actually pressing the laser we ran into a problem. The problem was that it was difficult to hold the laser steady while pressing the button at the same time. Often the operator of the laser could not hold it steady for the period of time that it took to measure the distances between bright and dark spots. This made it difficult to measure the distances between bright spots since the interference pattern projected on the screen was constantly jittering around the screen. Before we could finish measuring the distances accurately the pattern would move and we would have to remeasure once again. Once again, the fact that it was difficult to accurately measure Δx likely had a large impact of error.

Another random error occurred because we were not able to perform the entire experiment within the given time period. We were able to collect the results for only two of the lasers in the time given. Because of this we had to complete the experiment at a later date. This meant that we had to set up the experiment a second time. The potential of error was certainly high. In order to eliminate this source of error, we would have to perfectly replicate the original lab set up from a few days before. Obviously, we were not able to replicate the exact conditions of the original lab set up. First of all, we were not able to use the same lab bench to set up our experiment. We had to use a lab bench on the other side of the class which may or may not have had a slight difference.

Furthermore, we were tasked with positioning the retort stand the exact same distance from the screen as the original lab set up. We knew we originally positioned the retort stand at a distance of 1 m away from the screen. However, it was impossible to know how accurate our original measurement was and even if we knew the exact measurement it would be difficult to position the stand at that exact distance. This source of error definitely had some sort of effect on our results. The reason being that depending on the distance from the source to the screen the interference pattern may appear either larger or smaller on the screen than the other lasers which were tested under different conditions. In other words, the distance between the source and the screen was not kept constant even though we were supposed to keep it constant. The fact that ' L' was not kept constant definitely contributed to the inaccuracy of our results.

Improvements to the Lab Procedure:

As shown by the inaccuracy of our results, we definitely had a lot of room for improvement. To be honest, there were several sources of error present in our lab. One way to improve the lab would be actually take more time to do the lab more carefully. If we had more time we would have been able to take our time and be as precise as possible in our experiment. We would have also been able to finish the lab in one complete sitting so that there was no need to re-setup the lab again. To be honest, that one improvement alone would have eliminated a lot of the sources of error present in our lab. In addition, to improve this lab we could find a way to keep the laser completely steady while being pressed. For example, the button could be taped down so that there would be no need for an operator of the laser which eliminates the shaking involved caused by unsteady hands.

Conclusion:

In conclusion, Young's double slit experiment showed many unsuspecting things. The hypothesis stated that by interpreting the different aspects of the interference pattern created by the double slit would allow the prediction of the unknown variables, d. Although our results weren't as accurate we found that our hypothesis was correct since we were in fact able to find the unknown variable d using the other known variables. We also hypothesized that as the wavelength increased or decreased, Δx would do the same. This hypothesis was also correct since we observed that as the wavelength of a source decreased, the distance between successive nodes also decreased. In addition, we found that our hypothesis that the distance between double slits would be equal to be correct even though we had a percent error of 78. 3%. It is evident that systematic and random error contributed to this rather high percent of error. Although, our lab was not completely successful the experiment taught us several things. From the experiment we learned how the double slit equation applied to real life, that Δx and wavelength are proportional to each other and most importantly, to try to take more care with our experiments in order to get more accurate results.