Quantum and Nuclear Physics

“Does light strike our eyes as particle form or as wave form?”

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IBDP EXTENDED ESSAY (PHYSICS)

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INTRODUCTION

Personal observation

Ever since I was young, quantum physics has been one of the biggest factors that played a leading role in my desire to learn physics and one day do physics-related studies. This desire started with the movies I watched when I was little, involving the transition between multiverses and quantum physics, and a book I read about the famous physicist Albert Einstein and quantum called “Einstein and the Quantum” [1]. Quantum physics constitutes one of the most fascinating and mysterious fields of science. The strange and complex behavior of particles goes beyond the rules of classical physics and therefore holds great appeal to me. Quantum physics also provides the basis for philosophical discussions, and in this sense, discussions have always attracted my observant personality to reach accurate information.

At the same time, since I am eager to learn new subjects and do research. I will also do research and calculations on the subject of Interference which I will use in my experiment. Also, in the past whether the light reaches our eyes in waves or in particles has been discussed between incredible physicists Isaac Newton and Christian Huygens, that’s why my curiosity came from what is the difference between they observations in the past.

BACKGROUND INFORMATION

It’s known that the wave-particle duality is significantly present in the nature. Particles are substances that have very small sizes and energies. Waves are a way of transporting energy or matter and also they carry energy or matter from a source to a distant another points. What these two have in common is the fact that both carry energies. In the past many researches have conducted experiments questioning these two share the same quality

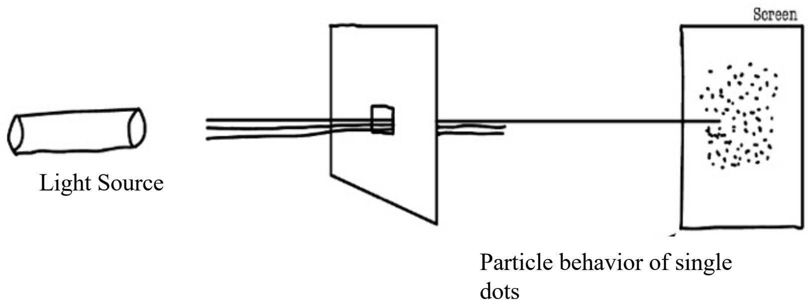


Figure 1: Wave behaviour

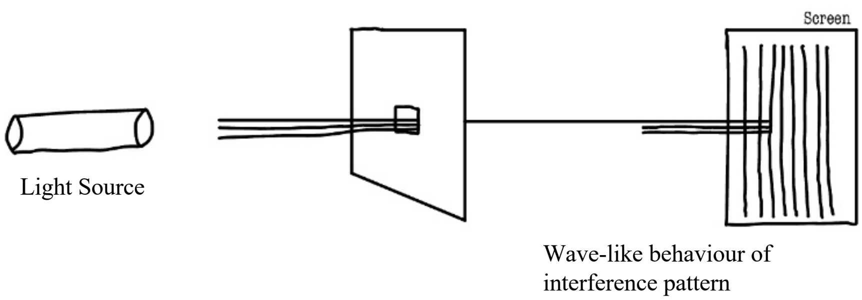


Figure 2: Particle behaviour

One example of these research was Isaac Newton's double-slit experiment where his purpose was to conclude whether sunlight travels in the shape of particles or waves and after the experiment he came to the conclusion that light transfer our eyes as particles. Alternatively, the same experiment was done by Christian Huygens which lead to another result, he proposed that light is carried to our eyes as waves rather than particles. First version was conducted by British scientist Thomas Young in 1801. In this case, light transfer our eyes in waves and that these waves can be perceived and selected by the human eye at certain intervals and It is also observed that the experiment results vary according to the development of the technological age (source of light: candle and laser). The equation as shown below for constructive double-slit interference is m $\lambda = d \sin(\theta)$ where m is an integer, λ is the wavelength of the beam, d is the distance between the slits, and θ is the angle of diffraction [2].

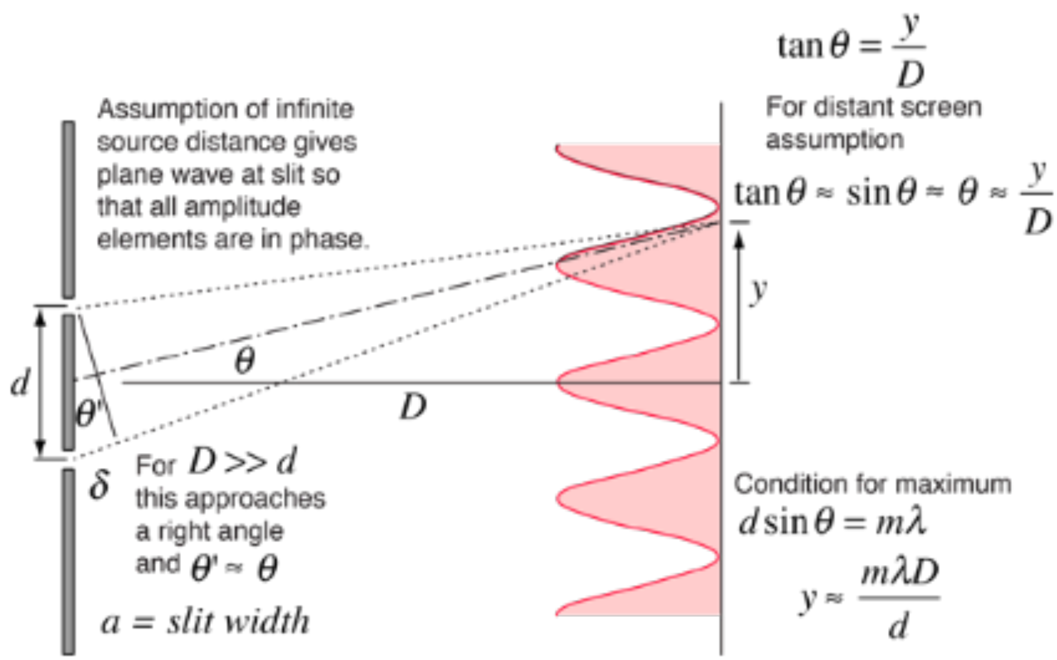


Figure 1: Double-slit interference

Thomas Young Double Slit Experiment

Thomas Young's double slit experiment is an experiment that plays a major role in guiding other scientists regarding the physics "quantum" experiment that reveals the behavior of light and the wave nature. This double slit experiment by Thomas Young was performed in the early 19th century and provided important evidence for the theory of propagation of light in waves, proposed by Christian Huygens and later elaborated by Augustin Jean Fresnel.

[2] Davis, C. L. (n.d.). *Light and Optics - Double Slit Interference - Physics 299.*

As a result of this experiment conducted by Thomas Young, he observed that the light reflected on the screen spread in waves and there were dark fringes on the screen. He named this situation he observed as "interference pattern" [3].

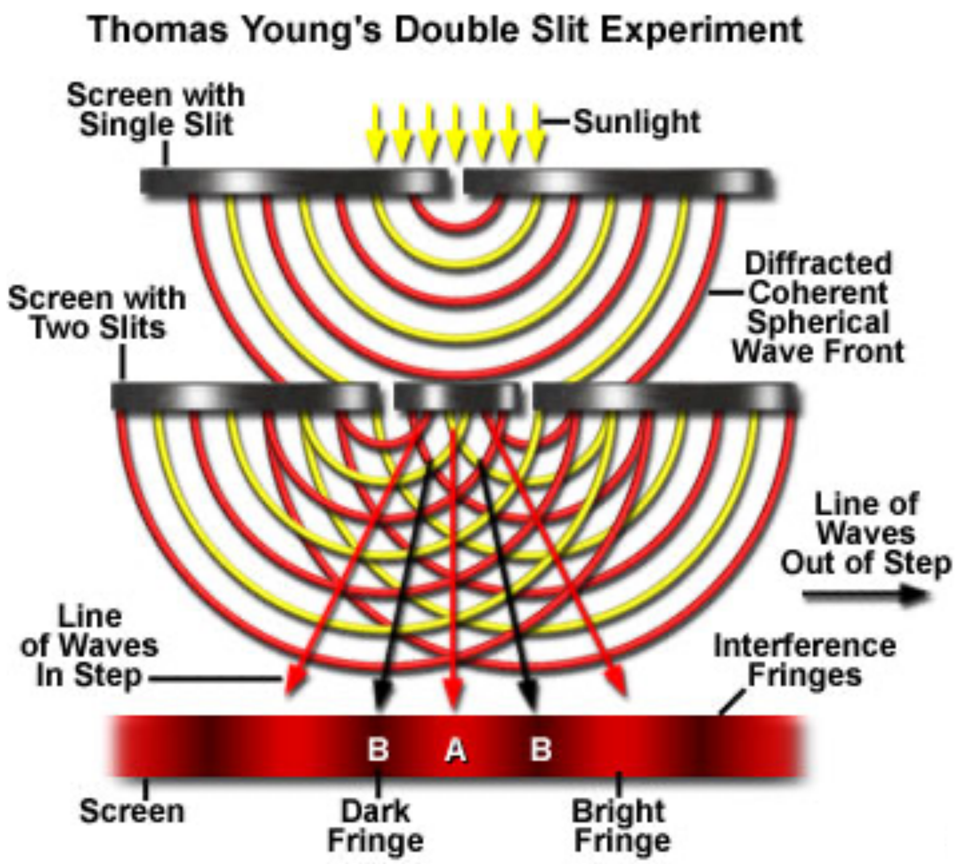


Figure 2: Thomas Young's Double Slit Experiment

Christiaan Huygens Theory

In 17[th] century Christian Huygens did not use a double slit in his experiment like Thomas Young, but Huygens put forward a theory explaining the relationship between light and waves, which is the main reason for Young's experiment. In this theory, Huygens proposed that light propagates as waves in a medium called luminiferous ether. Huygens' principle stated that all points on a wave front can be

[3] *Thomas Young's Double Slit Experiment - Java Tutorial | Olympus LS*. (n.d.).

considered as a source of secondary spherical waves, and the sum of these waves determines the shape of the new wave front. Although he did not conduct the double-slit experiment, he laid the foundation for understanding phenomena such as reflection, refraction and diffraction of light [4].

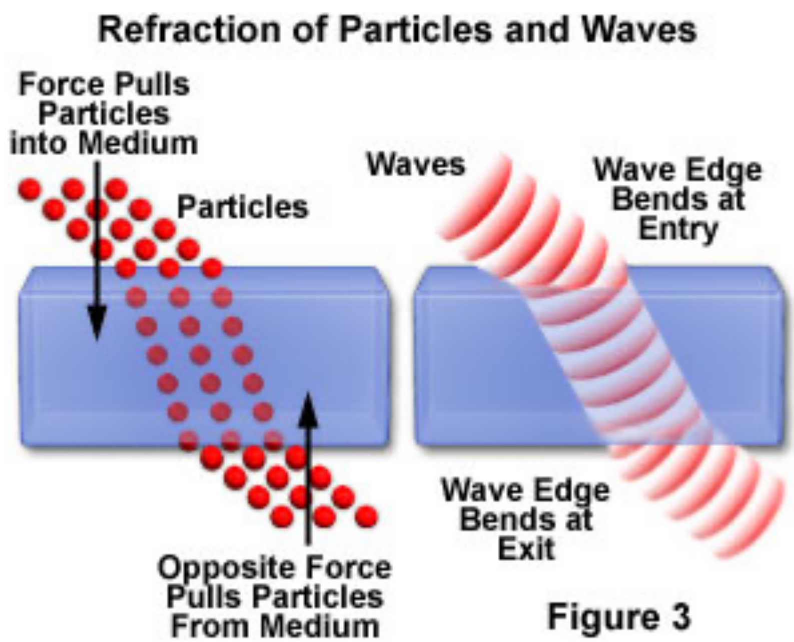


Figure 3: Christiaan Huygens Theory

What is "Double Slit"?

Double slits are a tool used in experiments primarily for the study of wave behavior, especially in the context of light waves.

They consist of two narrow, closely spaced slits or openings that pass waves through them. Like waves of light, they are refracted or spread out as they pass through and exit the double slit. If the slits are close enough to each other and the wavelength of the waves is comparable to the slit width, an interference pattern will form on the screen on the other side of the slits. The interference pattern formed on this screen consists of varying brightness and dark fringes [5]

[4] *Is Light a Particle or Wave? | Olympus LS*. (n.d.).
[5] Contributor, T. (2023, June 13). *double-slit experiment*.

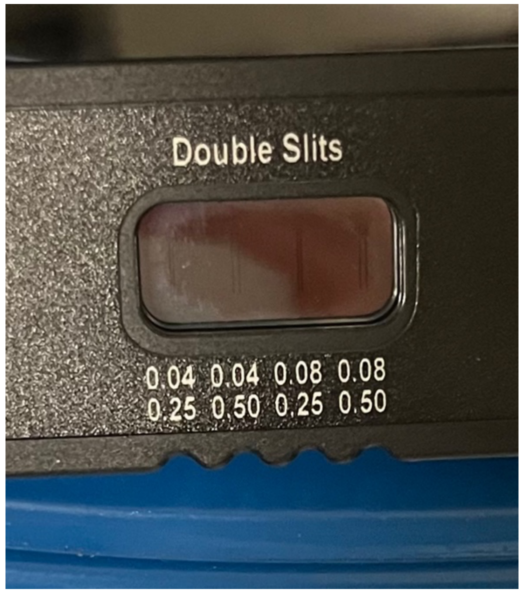


Figure 4: Double Slits (used in experiment)

RESEARCH QUESTION

"How do the slit separation, width of slits ((0.04,0.25), (0.04,0.50), (0.08,0.25), (0.08,0.50) ± 0.01 mm) and distance between slits and screen (10, 15, 20, 25, 30, 35, 40, 45 ± 0.1 cm) effect fringe separation on the screen?"

In this research, I investigate the effects of 3 independent variables (distance between slits and screen, slit separation, and slit width) separately on the interference pattern formed in the screen. I started the experiment with 1 green laser and 4 double slits ((0.04,0.25), (0.04,0.50), (0.08,0.25), (0.08,0.50) ± 0.01 mm), after that I changed the distance for 8 times for each double slit and took all the data by my phone. I need to use a laser because in the experiment to show whether the laser can transmit light in the form of waves or particles in the experiment where the transfer occurring because of the candlelight used by Isaac Newton in his experiment is in the form of particles. However, it has been observed that with the development of technology over the years, the results also change, that is, they spread in waves.

HYPOTHESIS

The behavior of the light transmitted by the laser will be reflected on the screen in waves, and as the distance between the slit and the screen increases, the distance between the fringes will increase in direct proportion. In (0.04, 0.25 ± 0.01 mm), when the distance between them is 10 ± 0.1 cm, the distance between the fringes will be the minimum, and when the distance between them is 45 ± 0.1 cm, the distance between the fringes will be the maximum.

METHODOLOGY

Variables

Independent Variable (IV):

During the experiment I changed 3 independent variables which are "(10, 15, 20, 25, 30, 35, 40, 45 ± 0.1 cm), slit separation (0.04 and 0.08 ± 0.01 mm), slit width (0.25 and 0.50 ± 0.1 mm)". My method of measurement of these 3 independent variables, I checked the distance of my slit from the screen with a ruler (100 ± 0.1 cm) and used 4 different slits with different separation and width ((0.04,0.25), (0.04,0.50), (0.08,0.25), (0.08,0.50) ± 0.01 mm) at every 8 different distances.

Dependent Variable (DP):

I have 2 dependent variables that I will observe as dependent variables in the experiment and I will calculate them as "length distance between fringes (x ± 0.01 mm) and Length of the total length of fringes (x ± 0.1 cm)". Before each calculation, I will observe the fringe length and total length of fringes that will change by increasing the distance between my slits and the screen in a controlled manner with the help of a ruler.

Controlled Variable (CV):

In order to minimize my margin of error during the experiment, I controlled some of my variables: Light source (laser) with the color of green, slit type (double slit), ruler lengths and type (30 ± 0.1 cm) and (100 ± 0.1 cm), distance between light source and double slits, darkness in the room (closed all the lights in the room and closed the curtains). The reasons and method of controlling these variables are related with the error percentage because I want to minimize the uncertainty. Related to this I used a single powerful green laser and all 4 slit types as double slits; this made the experience more precise and helped me control my procedure. Also controlling the darkness of the room and turning off all the lights made the experience clearer. To avoid different results while measuring, I kept my laser fixed at the same distance from my double slit without angling it.

Materials:

- Light source (green laser)
- A barrier with two slits (these mirrors must have reflecting and transmitting properties) ((0.04,0.25), (0.04,0.50), (0.08,0.25), (0.08,0.50) ± 0.01 mm)
- Screen
- Ruler 1 (30 ± 0.1 cm) (to observe the distance more precise and calculating more specific data)
- Ruler 2 (100 ± 0.1 cm) (to observe the whole length in interference)
- Ruler 3 (100 ± 0.1 cm) (to measure and control the distance between screen and double slits)
- Pen (for drawing the minimum and maximum points of fringes observed on the screen)
- Mobile phone (for taking photos of screen)
- Notebook (for taking notes of the each trial)
- TI-84 Plus CE-T calculator (for calculating the data)

Procedure:

1. First separate the 4 different double slits according to their ranges ((0.04,0.25), (0.04,0.50), (0.08,0.25), (0.08,0.50) ± 0.01 mm).
2. Stick Ruler 1 to your screen, Ruler 2 under Ruler 1 with a tape, then tape the remaining Ruler 3 to the ground for measuring and controlling the distance between your screen and your double slit.
3. Control your double slit so that it cannot move with a slit holder stand to prevent it from slipping or angling during the experiment.
4. During the experiment, control your laser in every trial to your double slit at the same distance and at the same angle so that the angle and distance of your laser remains constant every trial.
5. After setting up the experimental setup, make sure the lights in the room are off and the curtains are drawn because a dark environment is required.
6. After completing all the checks, check from ruler 3 and bring your first double slit range 10 cm closer to the screen.
7. And start your measurements by holding the green laser at 8 different distances (10, 15, 20, 25, 30, 35, 40, 45 ± 0.1 cm) respectively.
8. Do not forget to make 10 trials for each distance (to having more precise results)
9. Draw the fringes that appear on the screen both among themselves and with the help of a pen to mark the total length of the fringes in order to see and calculate them more easily.
10. After each drawing take photos with a phone as you change the distance for all double slit spacings, this will help you calculate.
11. For calculating each measurement take note to the notebook the results by checking with the photos in phone
12. Calculate the data in your notebook with the calculator “TI-84 Plus CE-T”.

Justification

Double slits are mostly used for demonstrating the phenomenon of interference because the light waves passing through the double slits are closely spaced slit interfere with each other and resulting in an observable interference pattern on a screen placed behind them and fringes are formed in this interference pattern. The results of the experiments are always consisting of alternating bright and dark fringes indicative of constructive and destructive interference and these results are related with changing the slit width and separation because changing the width and separation directly effects to the fringe length. Along with that, the double-slit experiment has far-reaching implications in the domain of quantum mechanics, and it gives the dual behavior of light since it can be either a particle or a wave. The interference pattern originates from the wavelike propagation of light, and the detection and registration of discrete photons on the screen (which represents the particle-like nature of the photons) demonstrate the wavelike-particle duality nature of light.

Risk assessment and Ethical issues

During the experiment, I performed the experiment in an empty room to avoid damaging the surroundings while working with a very powerful laser. At the same time, I wore gloves to prevent damage to my skin and I used glasses because I am sensitive to light. After the experience, I turned off my laser by turning the laser switch and saved money without wasting battery. Also, I wiped the wall I drew with a pen to make measurements and calculations with a cloth after the experiment and left it clean.

Experimental Setup

The slits consisting of 4 different slits that I used in my experiment and my laser and rulers to measure the interference in my experimental setup.

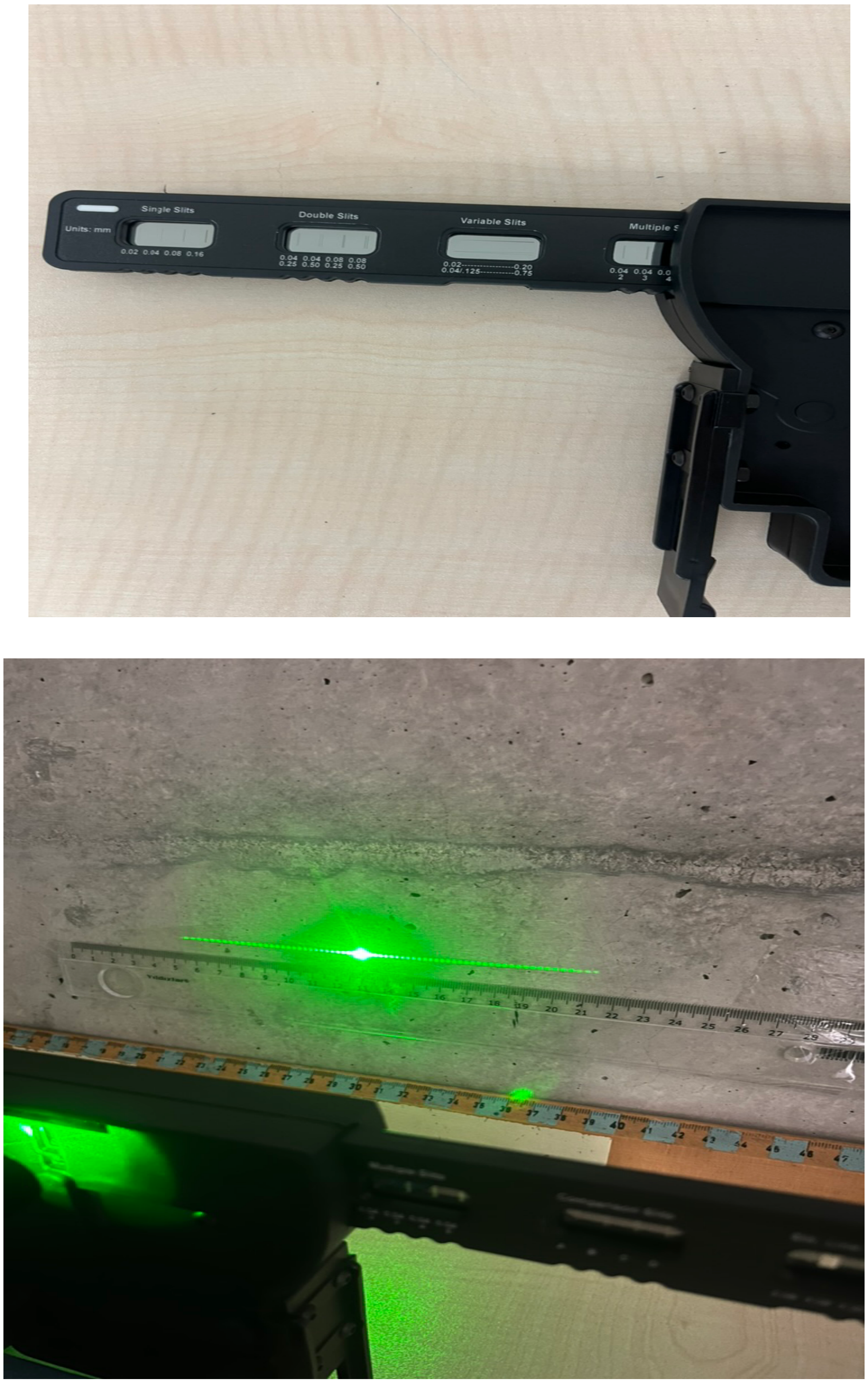


Figure 5: The experimental setup

Results and Analysis

Raw Data Table for total length of all Fringes

Double Slit range (x ± 0.01 mm)	Distance (x ± 0.1 cm)	Total length of all Fringes (x ± 1 cm)									
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10
0.04, 0.25	10	16.5	17.2	16.3	16.8	17.4	16.6	17.4	16.5	16.9	17.5
	15	21.5	22.1	21.4	21.3	22.0	21.6	22.2	21.5	21.4	22.1
	20	27.1	27.5	28.2	27.3	27.4	27.2	27.6	28.3	27.4	27.5
	25	33.4	33.5	34.2	33.3	33.4	33.5	33.6	34.3	33.4	33.5
	30	38.3	38.5	39.2	38.3	38.4	38.4	38.6	39.3	38.4	38.5
	35	43.6	43.5	44.2	43.3	43.4	43.7	43.6	44.3	43.4	43.5
	40	47.2	47.5	48.2	47.3	47.4	47.3	47.6	48.3	47.4	47.5
	45	54.3	54.5	55.2	54.3	54.4	54.4	54.6	55.3	54.4	54.5
0.04, 0.50	10	17.1	17.3	16.4	16.9	17.5	17.2	17.4	16.5	17.0	17.6
	15	22.5	22.2	21.5	21.4	22.5	22.6	22.3	21.6	21.5	22.6
	20	28.3	27.6	28.3	27.4	27.5	28.4	27.7	28.4	27.5	27.6
	25	30.5	33.6	34.3	33.4	33.5	30.6	33.7	34.4	33.5	33.6
	30	39.9	38.6	39.3	38.4	38.5	40.0	38.7	39.4	38.5	38.6
	35	46.1	43.6	44.3	43.4	43.5	46.2	43.7	44.4	43.5	43.6
	40	50.8	47.6	48.3	47.4	47.5	50.9	47.7	48.4	47.5	47.6
	45	55.4	54.6	55.3	54.4	54.5	55.5	54.7	55.4	54.5	54.6
0.08, 0.25	10	16.2	16.3	16.4	16.9	17.0	16.3	16.4	16.4	17.0	17.1
	15	22.3	22.2	21.8	21.9	22.5	22.4	22.3	21.9	22.0	22.6
	20	27.2	27.6	28.3	27.4	27.5	27.4	27.7	28.4	27.5	27.6
	25	33.5	33.6	34.3	33.4	33.5	33.6	33.7	34.4	33.5	33.6
	30	38.3	38.6	39.3	38.4	38.5	38.4	38.7	39.4	38.5	38.6
	35	44.2	44.6	44.3	44.4	43.5	44.3	44.7	44.4	44.5	43.6
	40	48.7	48.6	48.3	48.4	48.5	48.8	48.7	48.4	48.5	48.6
	45	56.3	55.6	56.3	56.4	56.5	56.4	55.7	56.4	56.5	56.6
0.08, 0.50	10	18.2	18.3	17.9	18.4	18.5	18.3	18.4	18.0	18.5	18.6
	15	24.6	24.2	24.5	24.4	24.5	24.7	24.3	24.4	24.5	24.6
	20	30.2	30.6	30.3	30.4	30.5	30.3	30.7	30.4	30.5	30.6
	25	35.3	35.6	35.3	35.4	35.5	35.4	35.7	35.4	35.5	35.6
	30	41.1	41.6	41.3	41.4	41.5	41.2	41.7	41.4	41.5	41.6
	35	46.7	46.6	46.3	46.4	46.5	46.8	46.7	46.4	46.5	46.6
	40	51.3	51.6	51.3	51.4	51.5	51.4	51.7	51.4	51.5	51.6
	45	57.1	57.6	57.3	57.4	57.5	57.2	57.7	57.4	57.5	57.6

Table 1: Total length of all fringes

Raw Data Table for Fringes

Double Slit range (x ± 0.01 mm)	Distance (x ± 0.1 cm)	Fringe spacing length (x ± 0.01 mm)									
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10
0.04, 0.25	10	1.0	1.1	1.1	1.0	1.2	1.1	1.2	1.0	1.1	1.0
	15	1.2	1.3	1.3	1.2	1.4	1.3	1.4	1.2	1.3	1.2
	20	1.5	1.6	1.6	1.5	1.7	1.6	1.7	1.5	1.6	1.5
	25	1.8	1.9	1.9	1.8	2.0	1.9	2.0	1.8	1.9	1.8
	30	2.0	2.1	2.1	2.0	2.2	2.1	2.2	2.0	2.1	2.0
	35	2.3	2.4	2.4	2.3	2.5	2.4	2.5	2.3	2.4	2.3
	40	2.5	2.6	2.6	2.5	2.7	2.6	2.7	2.5	2.6	2.5
	45	2.6	2.7	2.7	2.6	2.8	2.7	2.8	2.6	2.7	2.6
0.04, 0.50	10	1.1	1.2	1.2	1.1	1.3	1.2	1.3	1.1	1.2	1.1
	15	1.3	1.4	1.4	1.3	1.5	1.4	1.5	1.3	1.4	1.3
	20	1.6	1.7	1.7	1.6	1.8	1.7	1.8	1.6	1.7	1.6
	25	1.9	2.0	2.0	1.9	2.1	2.0	2.1	1.9	2.0	1.9
	30	2.1	2.2	2.2	2.1	2.3	2.2	2.3	2.1	2.2	2.1
	35	2.5	2.6	2.6	2.5	2.7	2.6	2.7	2.5	2.6	2.5
	40	2.6	2.7	2.7	2.6	2.8	2.7	2.8	2.6	2.7	2.6
	45	2.7	2.8	2.8	2.7	2.9	2.8	2.9	2.7	2.8	2.7
0.08, 0.25	10	1.2	1.3	1.3	1.2	1.4	1.3	1.4	1.2	1.3	1.2
	15	1.6	1.7	1.7	1.6	1.8	1.7	1.8	1.6	1.7	1.6
	20	1.7	1.8	1.8	1.7	1.9	1.8	1.9	1.7	1.8	1.7
	25	1.9	2.0	2.0	1.9	2.1	2.0	2.1	1.9	2.0	1.9
	30	2.1	2.2	2.2	2.1	2.3	2.2	2.3	2.1	2.2	2.1
	35	2.3	2.4	2.4	2.3	2.5	2.4	2.5	2.3	2.4	2.3
	40	2.5	2.6	2.6	2.5	2.7	2.6	2.7	2.5	2.6	2.5
	45	2.6	2.7	2.7	2.6	2.8	2.7	2.8	2.6	2.7	2.6
0.08, 0.50	10	1.3	1.4	1.4	1.3	1.5	1.4	1.5	1.3	1.4	1.3
	15	1.5	1.6	1.6	1.5	1.7	1.6	1.7	1.5	1.6	1.5
	20	1.7	1.8	1.8	1.7	1.9	1.8	1.9	1.7	1.8	1.7
	25	2.0	2.1	2.1	2.0	2.2	2.1	2.2	2.0	2.1	2.0
	30	2.3	2.4	2.4	2.3	2.5	2.4	2.5	2.3	2.4	2.3
	35	2.5	2.6	2.6	2.5	2.7	2.6	2.7	2.5	2.6	2.5
	40	2.7	2.8	2.8	2.7	2.9	2.8	2.9	2.7	2.8	2.7
	45	2.9	3.0	3.0	2.9	3.1	3.0	3.1	2.9	3.0	2.9

Table 2: Fringe spacing length

Table Analyze for Table 1 & 2

Considering the possibility of error rates and uncertainties when entering all data, the total fringe lengths were calculated as (x ± 1 cm) and the distance between the fringes was calculated as (x ± 0.01 mm). The reason for this was kept under control to minimize human errors in the calculation and to obtain precise results.

Table 1:

These data were used to measure the total length of all fringes with a table of 10 trials for each distance. The 10 trials for each distance consisted of a total of 80 trials since 8 different distances were used at 1 slit interval. A total of 320 total fringe lengths were taken during the experiment. With the data, it was seen that the length increased as the distance between the slit and the screen increased, width and separation variability had a minor effect on this length, not much difference was seen.

Table 2:

The lengths between two fringes were measured in Table 2 for the fringes whose total length was measured in Table 1, and it was seen that they were directly proportional to each other with the data taken. As we increased the distance between the slit and the screen, the distances between the fringes also increased and at the same time, when the slit width increased, there were small increases in the lengths due to the growth of the elites, but there were no major changes in the slit separation, on the contrary, small shortening occurred.

Sample Calculation

Mean Formula

Calculate mean with the formula:

$\bar{X} = \frac{\sum X}{N}$

For example, "slit range (0.04,0.25) in 10 cm":

$$\frac{(16.5\ + 17.2\ + 16.3\ + 16.8\ + 17.4\ + 16.6\ + 17.4\ + 16.5\ + 16.9\ + 17.5)}{10} = 16.91\ cm$$

Standard deviation Formula

Calculate the standard deviation with its formula:

1. Find the mean
2. Calculate the squared difference between each number and the mean
3. Calculate the average of the squared differences

$$\sigma\ = \sqrt{\frac{\sum(X\ -\ \bar{x})^2}{N}}$$

For example, "slit range (0.04,0.25) in 10 cm":

$(16.5 - 16.9)^2 = 0.16$

$(17.2 - 16.9)^2 = 0.09$

$(16.3 - 16.9)^2 = 0.36$

$(16.8 - 16.9)^2 = 0.01$

$(17.4 - 16.9)^2 = 0.25$

$(16.6 - 16.9)^2 = 0.09$

$(17.4 - 16.9)^2 = 0.25$

$(16.5 - 16.9)^2 = 0.16$

$(16.9 - 16.9)^2 = 0$

$(17.5 - 16.9)^2 = 0.36$

Sum the squared differences and then divide it with the total number of values (7) after these steps take the square root of the result

$0.16\ +\ 0.09\ +\ 0.36\ +\ 0.01\ +\ 0.25\ +\ 0.09\ +\ 0.25 + 0.16 + 0 + 0.36\ \ =\ 1.57$

$\frac{1.57}{10} = 0.157$

$\sigma\ = \sqrt{0.157}\ \approx 0.396$

Processed Data Table for all Fringes Length

Double Slit range (x ± 0.01 mm)	Distance (x ± 0.1 cm)	Average of all Fringes Length (x ± 1 cm)	Standard deviation
0.04, 0.25	10	16.91	0.402
	15	21.71	0.587
	20	27.05	0.432
	25	33.46	0.330
	30	38.34	0.357
	35	43.65	0.409
	40	47.37	0.361
	45	54.34	0.417
0.04, 0.50	10	17.09	0.405
	15	22.07	0.588
	20	28.07	0.435
	25	33.51	0.332
	30	39.19	0.359
	35	43.83	0.411
	40	47.57	0.363
	45	54.85	0.419
0.08, 0.25	10	16.90	0.411
	15	22.00	0.589
	20	27.60	0.432
	25	33.61	0.337
	30	38.57	0.353
	35	44.15	0.405
	40	48.65	0.366
	45	56.32	0.417
0.08, 0.50	10	18.47	0.409
	15	24.57	0.586
	20	30.55	0.433
	25	35.57	0.335
	30	41.63	0.356
	35	46.71	0.407
	40	51.67	0.361
	45	57.63	0.419

Table 3: Average of all Fringes Length

In table 3, the total fringe lengths taken in table 1 were divided by the number of trials (10) for each of the total fringe lengths taken in table 1 and the average was found, this allowed the experiment to reach a clearer result and by calculating the standard deviation, it was seen how much error rate was less. With the calculated results, it has been proven once again that there is an increase in direct proportion to the increase in the changed variables.

Processed Data Table for Fringes

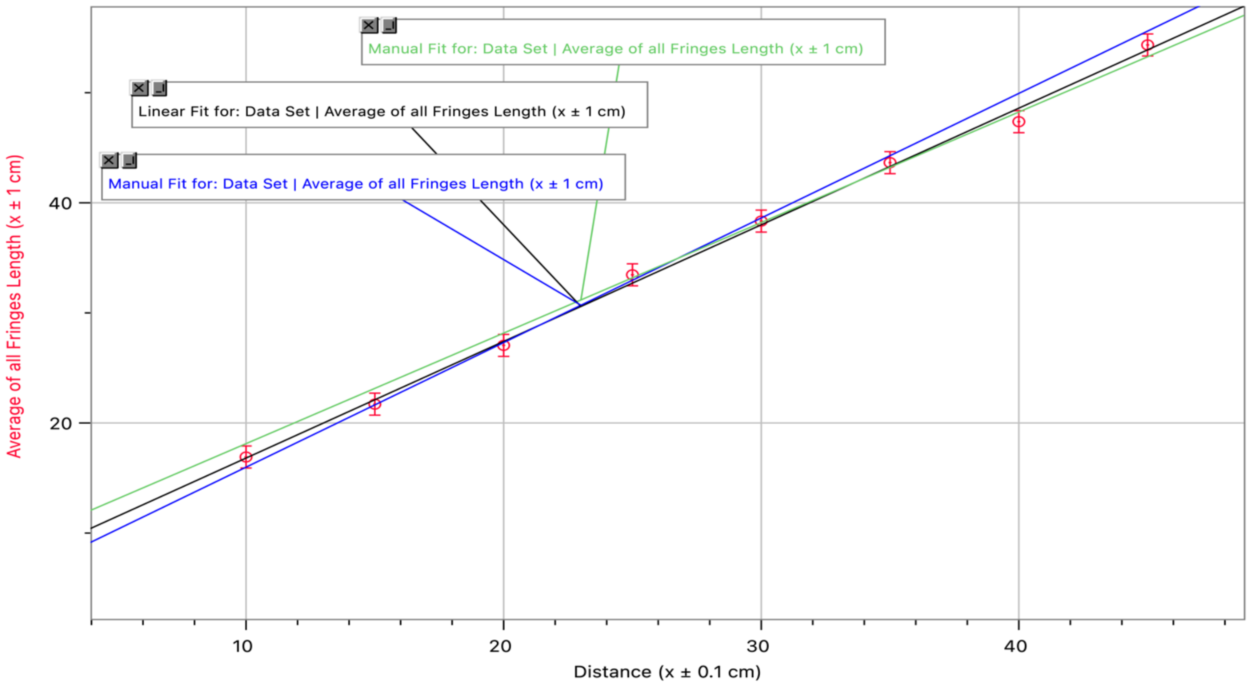
Double Slit range (x ± 0.01 mm)	Distance (x ± 0.1 cm)	Average Fringe Spacing Length (x ± 0.01 mm)	Standard deviation
0.04, 0.25	10	1.18	0.124
	15	1.36	0.014
	20	1.60	0.077
	25	1.88	0.070
	30	2.18	0.070
	35	2.40	0.067
	40	2.64	0.063
	45	2.72	0.063
0.04, 0.50	10	1.18	0.126
	15	1.38	0.017
	20	1.68	0.073
	25	1.98	0.070
	30	2.17	0.070
	35	2.54	0.070
	40	2.68	0.070
	45	2.79	0.070
0.08, 0.25	10	1.38	0.124
	15	1.69	0.014
	20	1.71	0.077
	25	1.98	0.070
	30	2.17	0.070
	35	2.38	0.067
	40	2.54	0.070
	45	2.68	0.063
0.08, 0.50	10	1.38	0.124
	15	1.58	0.014
	20	1.79	0.070
	25	2.08	0.070
	30	2.38	0.070
	35	2.54	0.067
	40	2.79	0.070
	45	2.98	0.063

Table 4: Average Fringe Spacing length

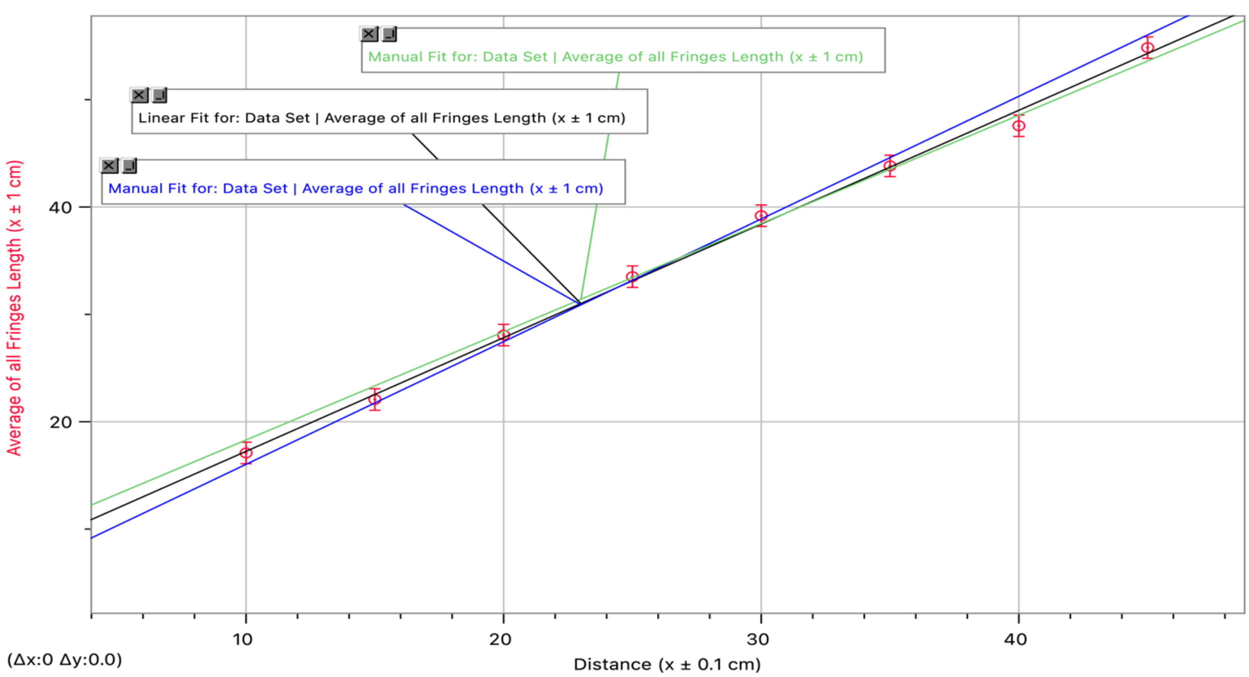
In table 4, the values in table 2 were averaged for each distance and it was seen more clearly how much length they showed at each distance. Taking the average and taking the standard deviation was done to reduce human errors, and the fact that the standard deviation was low in this table showed that the uncertainty taken reduced human error. It was observed that as the distance, slit spacing and slit width increased, the fringe separation was more affected and increased more.

Graphs and Trends for Average of all Fringes Length

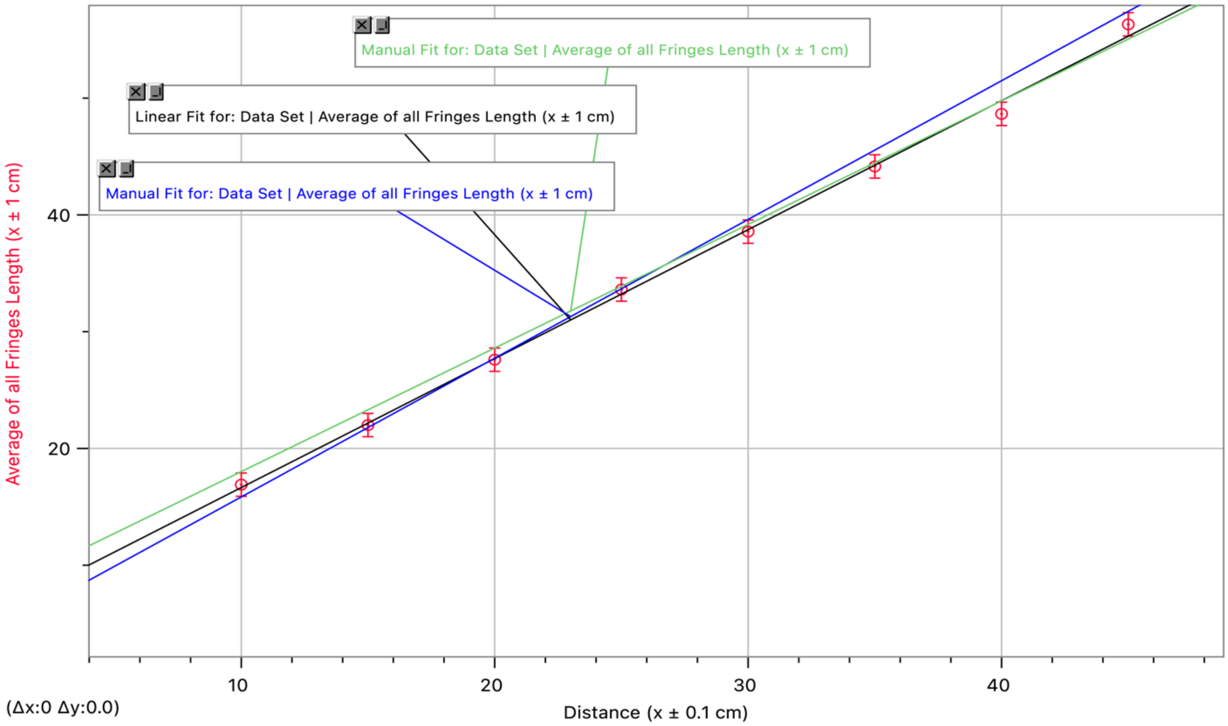
Graph 1: (0.04, 0.25 ± 0.01 mm)



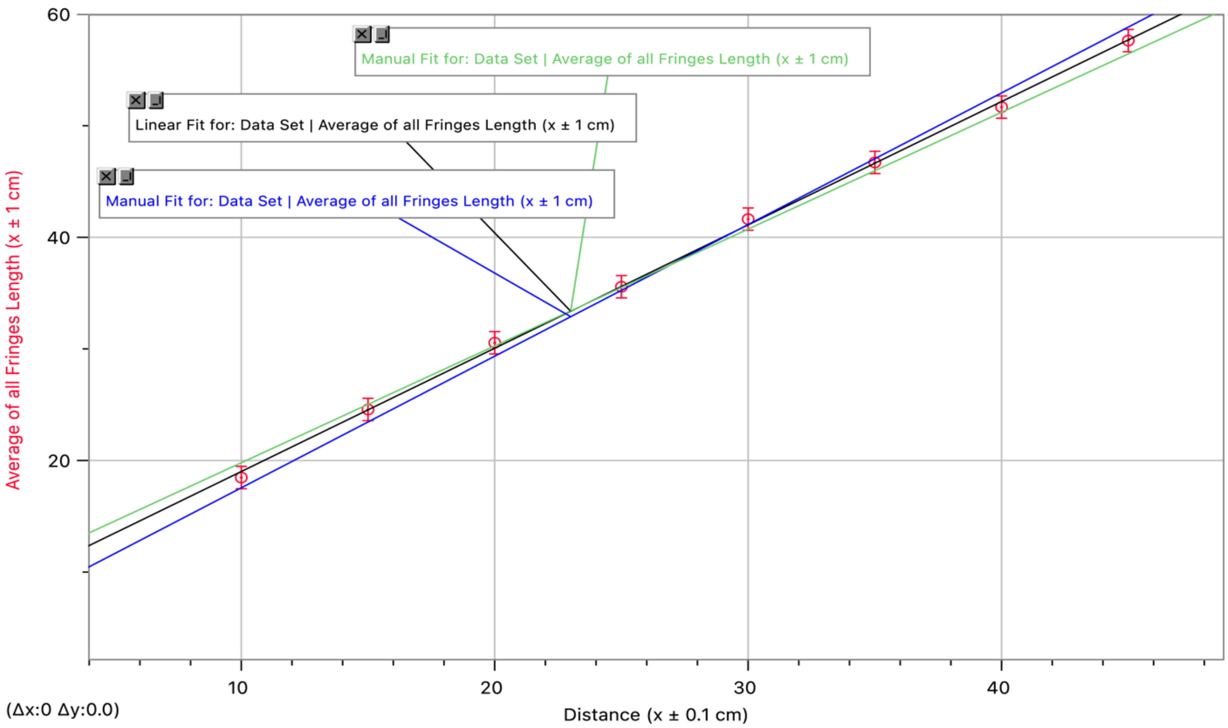
Graph 2: (0.04, 0.50 ± 0.01 mm)



Graph 3: (0.08, 0.25 ± 0.01 mm)

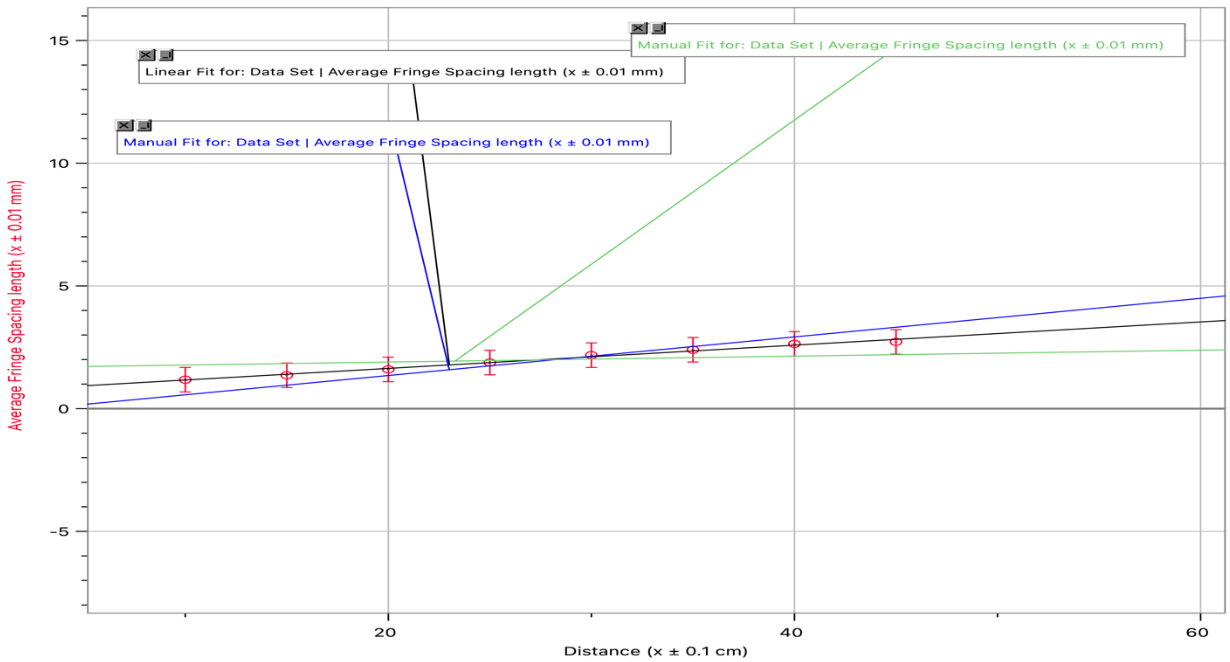


Graph 4: (0.08, 0.50 ± 0.01 mm)

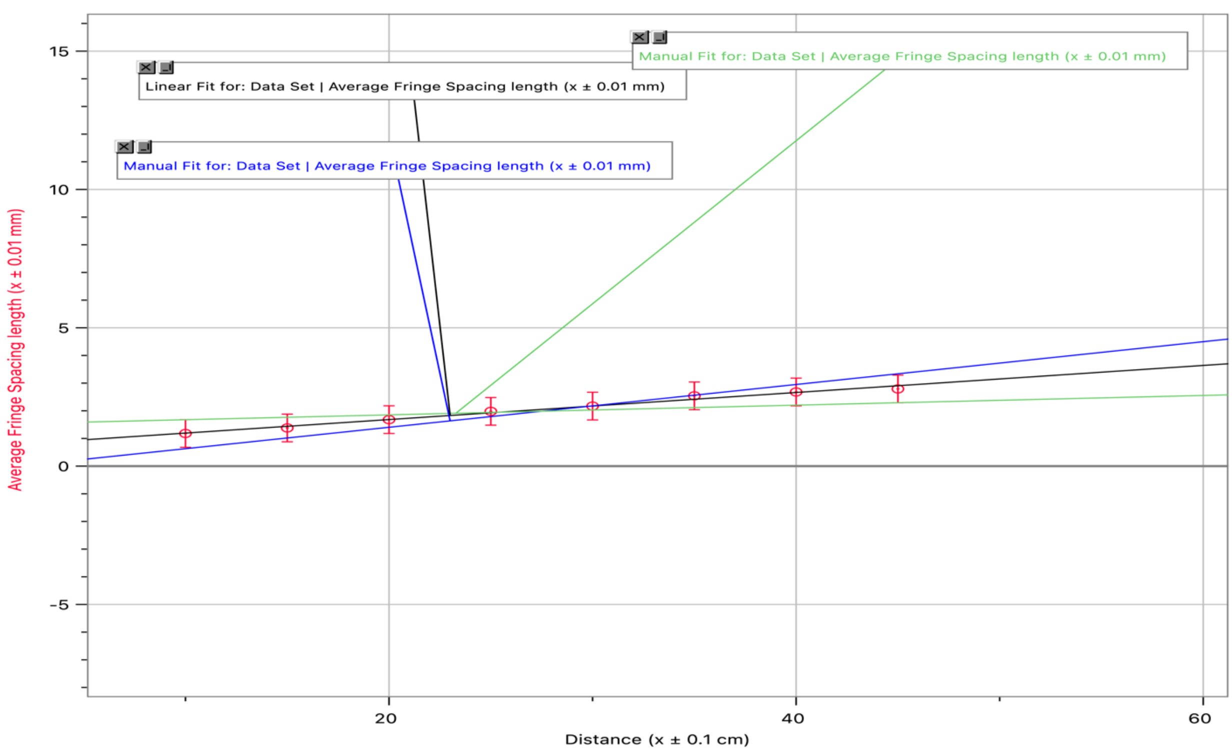


Graphs and Trends for Average Fringe spacing length

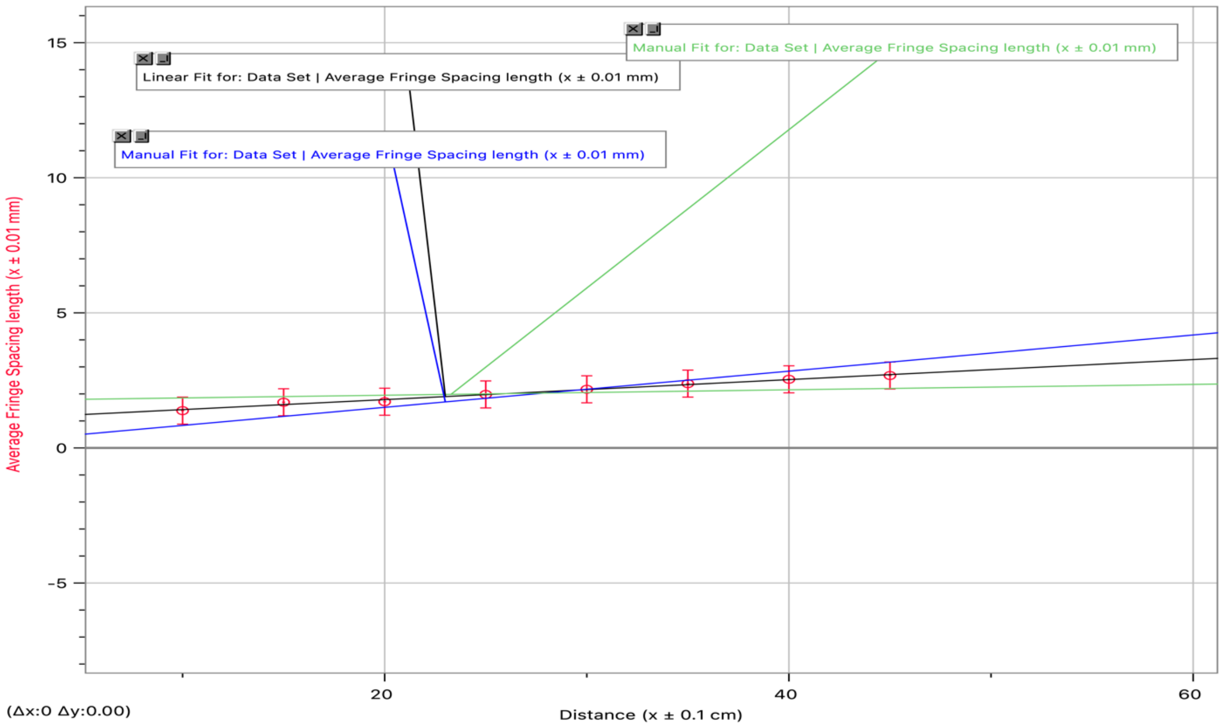
Graph 5: (0.04, 0.25 ± 0.01 mm)



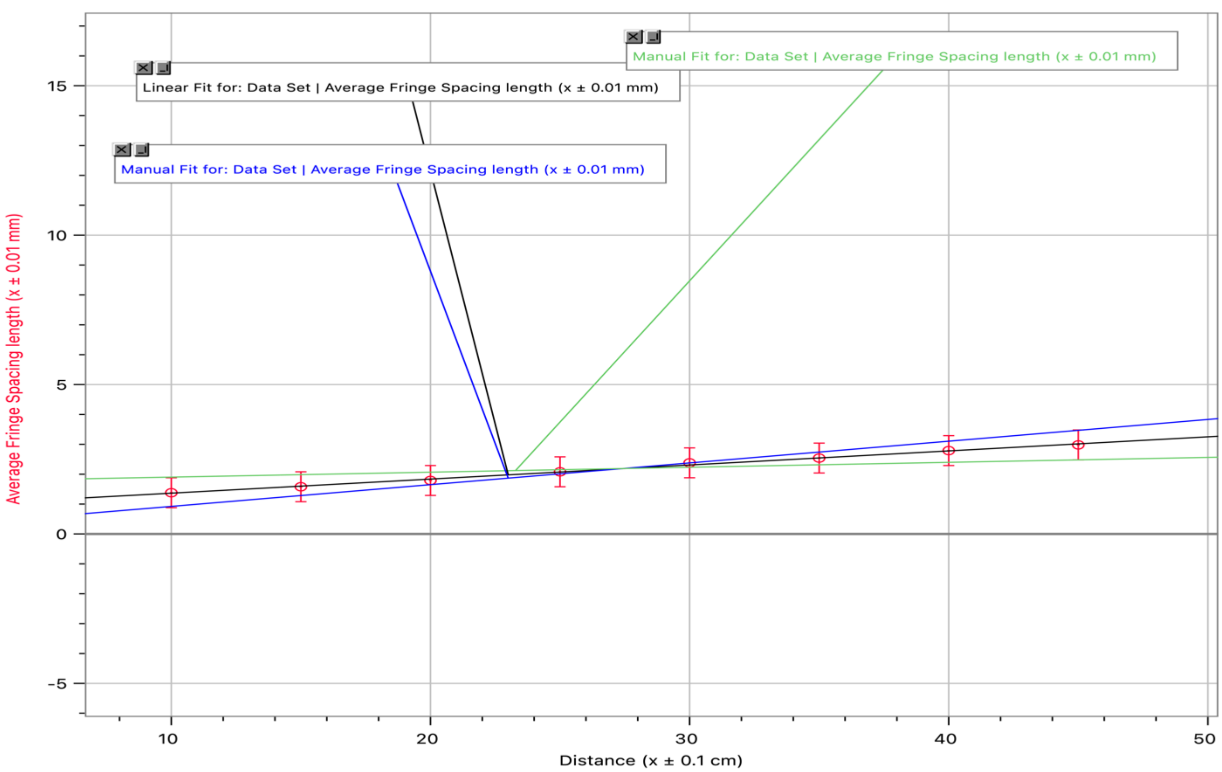
Graph 6: (0.04, 0.50 ± 0.01 mm)



Graph 7: (0.08, 0.25 ± 0.01 mm)



Graph 8: (0.08, 0.50 ± 0.01 mm)



Conclusion

Addressing the research question of "*"How do the slit separation, width of slits ((0.04,0.25), (0.04,0.50), (0.08,0.25), (0.08,0.50) ± 0.01 mm) and distance between slits and screen (10, 15, 20, 25, 30, 35, 40, 45 ± 0.1 cm) effect fringe separation on the screen?*", the experiment is aimed that observing the behavior of light and the difference between length ratio according to the 3 independent variable; distance between slit range and screen, slit separation and slit width. As a result of the observed light behavior, it was observed that all the light reflected on the screen spreads in waves. Of the 3 independent variables I used during the experiment, it was observed that as the distance between the slit and the screen increased, the length and total length of the fringes formed on the screen increased. The slit width was very effective in making the fringes sharper and darker as I increased it. This allowed to calculate the data of the fringes that observed in the screen more clearly. The last variable, which is increasing the slit separation, decreased the spacing of the fringes reflected on the screen and reduced the intensity contrast in fringes.

With the data obtained and graphs, as the distance between the screen and the double slit increased and the slit width increased, the length of the fringes and the lengths between the fringes increased proportionally. However, increasing the slit separation decreased minor the length of the fringes. In the double slits with spacings of (0.04,0.25 ± 0.01 mm), (0.04,0.50 ± 0.01 mm), (0.8,0.25 ± 0.01 mm), (0.8,0.50 ± 0.01 mm), the inter-fringe length and total length of fringes are least seen at a distance of (10 ± 0.1 cm), respectively (16.91 ± 1 cm / 1.0 ± 0.01 mm), (17.09 ± 1 cm / 1.1 ± 0.01 mm), (16.90 ± 1 cm / 1.2 ± 0.01 mm), (18.47 ± 1 cm / 1.3 ± 0.01 mm). At the distance of (45 ± 0.1 cm), the maximum values were (54.34 ± 1 cm / 2.6 ± 0.01 mm), (54.85 ± 1 cm / 2.7 ± 0.01 mm), (56.32 ± 1 cm / 2.6 ± 0.01 mm), (57.63 ± 1 cm / 2.9 ± 0.01 mm), respectively. Considering the standard deviations of the data taken, it was generally calculated that it was between 0.330 at (10 ± 0.1 cm) distance and 0.589 and 0.417 at (45 ± 0.1 cm) distance. This was seen as a low standard deviation because the margin of error was small, and the standard deviation was low, and it shows the how reliability relation with my taken data and my hypothesis.

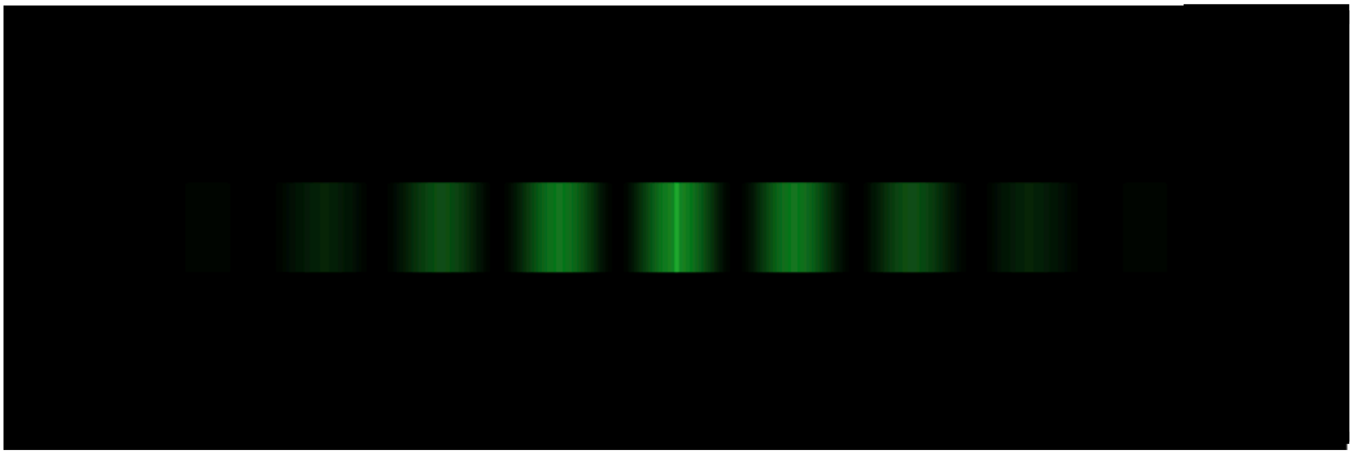


Figure 6: The result in simulation

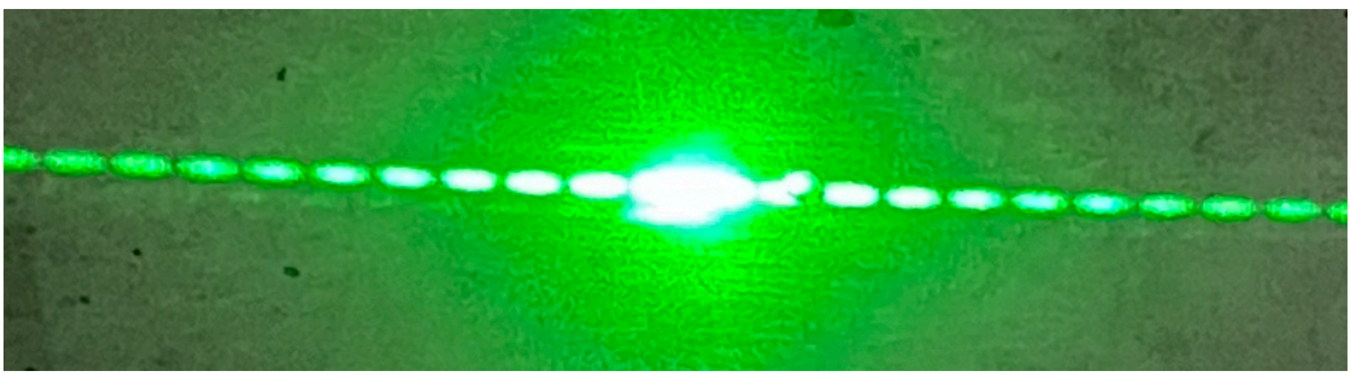


Figure 7: The result in actual experiment

Discussion & Evaluation

Discussion

The problem of the behavior of light and its reflection in our eyes has been debated for many years. This adventure, which started with Sir Isaac Newton claiming that light comes to our eyes as particles, has led to more and more opposing views over the years. Later, in the 17th century, Christiaan Huygens claimed that light comes to our eyes as waves and that these waves are called "luminous ether". Christiaan Huygens, who could not perform a double slit experiment due to the conditions of the time, would later pioneer Thomas Young's double slit experiment with his theory. By performing the first double slit experiment, Thomas Young proved that light propagates in waves and forms an interference pattern. In my experiment, I proved this once again and made calculations by going into finer details. In the future, scientists or teachers can use this experiment as the simplest basic building block in their courses or careers because it is an easy experiment to do in the laboratory.

During the experiment, there were some very interesting growths in the length ratio as the distances increased. For example, the slit in the range of 0.04,0.25 ± 0.01 mm was 16.91 cm long at 10 ± 0.1 cm, while at 45 ± 0.1 cm it was 54.34 cm, showing an initial length change of 37.43 cm.

Evaluation

As a result of my experiment, It was noticed that the 3 different variables used in the fringe separation observed in the experiment, distance between the slit and the screen, slit separation, slit width, were in agreement with the data received, because when the distance increased, the length between the fringes and the total length increased, minor decreases in lengths were seen as the slit separation increased, and when the slit width increased, clearer and darker fringes appeared on the fringes on the screen, thus revealing larger fringes, which again caused the length to increase. Also, it was seen that there were not major differences between the results obtained in the simulation and the results obtained after the actual experiment was performed, and it was seen that the error rate was the least with the calculated low standard deviation in the processed data table.

The error rates and standard deviations of the experimental results can vary depending on the experimental materials used and the professionalism of the environment, and the error rate calculated from the data taken in an experiment changes all the possibilities in the smallest detail up to the course of the experiment. In this experiment, the materials used, such as a powerful laser, resulted in darker fringes and a clear reflected interference pattern.

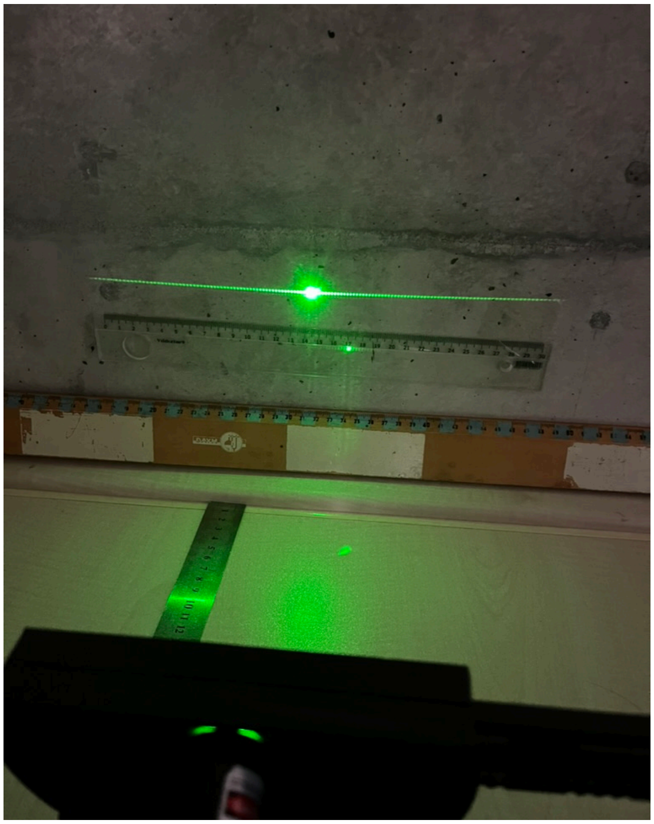


Figure 8: Interference pattern in experiment

In this way, it contributed to a more precise and more comfortable measurement of the experiment because it could have varied depending on the beam power and the darkness of the room, but the fact that the experiment was carried out in a professional laboratory environment contributed to minimizing the error rate of the experiment. A more sophisticated experiment could have used different laser colors and a wider range of slit widths, which would have provided more comprehensive results with a lower error rate.

Experimenting with different colored lasers could have taken different measurements with the colors that our eyes can see at certain intervals, such as the colors that human beings can see (red, orange, yellow, blue, purple) lights, which are related to the real life of the experiment.

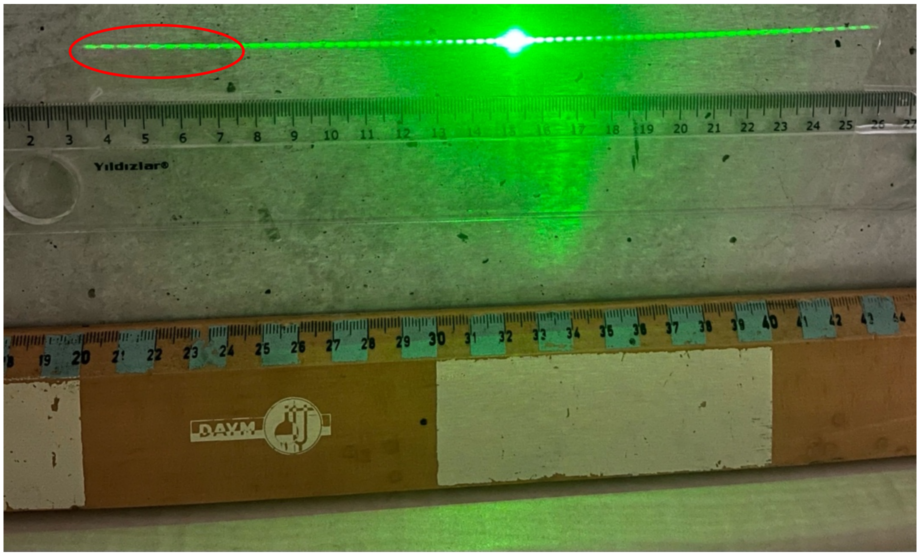


Figure 9: Zoomed photo of fringes

More detailed and more striking results could have been obtained by shooting every moment of the experiment with millimeter slow-motion cameras, and at the same time the error rate could have been minimized with more detailed measurement tools instead of rulers, which are used as measurement tools. The error rate in this experiment occurred when measuring the distance between the dark fringes, because if more advanced and professional measuring instruments and cameras had been used, more millimeter results and more detailed observations could have been obtained, and the error rate would have been less than ± 0.01mm.

EXTENSION

The aim of the experiment was to observe once again the debate on the behavior of light that has been going on for years, and thus, it became an extra experiment by measuring the fringe spacing and total length of fringes of the interference pattern reflected on the screen. The error rate of the experiment had as low an error rate and standard deviation as possible, proving the reliability of the experiment. While the error rate can be minimized with the materials used in this experiment, better measurements with more comprehensive and more millimetric measurement tools may be beneficial in future studies. With the power of the green laser used in the experiment, experiments can be made with other different lasers and the effect of colors on this situation can be investigated in future experiments.

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