Young Experiment Report

Testable question:

How is the separation between nodal lines (or dark fringes) affected by the wavelength of the light (λ), separation of the light sources (d) and the amplitude/intensity of the light?

Hypothesis:

The double-slit experiment is a fundamental experiment in physics that demonstrates the wave-particle duality of particles. It involves passing a beam of particles or waves through two closely spaced slits and observing the resulting pattern on a screen. The separation between the nodal lines (Δx), which are the dark fringes in the interference pattern, is influenced by three main factors: wavelength (λ), slit separation (d), and the distance between the double slits and the screen (L). In this lab, the first two factors along with the factor of amplitude/intensity of light will be investigated. The formula $\Delta x = \frac{\lambda L}{d}$ summarises the relationship among Δx, λ, and d. The formula does not include the variable of amplitude or intensity of light, therefore amplitude has no effect on the fringe spacing. Fringe spacing is directly proportional to the wavelength (less constructive pattern – antinodes, and less destructive pattern – nodes because wavelength is longer) and inversely proportional to the slit separation (because waves have more room to interefere). Hence, the hypothesis is that increasing the wavelength will lead to the greater separation between nodal lines; increasing the slit separation will lead to smaller separation between nodal lines; and the change of light amplitude or intensity will not change the separation between nodal lines [1].

<table>
<tr><th></th><th>Dependent variable</th><th>Independent variable</th><th>Control</th></tr>
<tr><td>Test 1</td><td rowspan="3">Separation between modal lines</td><td>Wavelength</td><td>Separation of light sources, amplitude of the light, distance between the light source and the screen</td></tr>
<tr><td>Test 2</td><td>Separation of the light sources</td><td>Wavelength, amplitude of the light, distance between the light source and the screen.</td></tr>
<tr><td>Test 3</td><td>Amplitude of the light</td><td>Wavelength, separation of the light sources, distance between the light source and the screen.</td></tr>
</table>

Material:

1. A light source such as a laser or monochromatic light bulb emitted green, red, and blue light
2. 3 black boards with two narrow and closely spaced slits.
3. A screen or detector that capture the interference pattern.
4. A monitor to detect intensity of interference pattern.

5. Measurement tape

Procedures:

Test 1: Fringes spacing with different wavelength

1. Two light sources that emitted green light was turned on and passed through a black board with two small slits with slit separation d = 1500nm. The distance between light sources and detector screen was set at L = 5000 nm. Amplitude of intensity of light was turned to maximum.
2. Allowed waves to interfere until the bright and dark fringes appeared on the screen.
3. Measurement tape was used to measure the separation between two adjacent dark fringes (Δx). Data were recorded in Table 1.
4. Step 1 to 3 were repeated but changed to blue light and red light source.

Test 2: Fringes spacing created by green light source with different amplitude of intensity

1. Two light sources that emitted green light was turned on and passed through a black board with two small slits with slit separation d = 1500nm. The distance between light sources and detector screen was set at L = 5000 nm.
2. The amplitude of intensity of green light was adjusted from maximum to 80% of maximum, and then to 50% of maximum.
3. Measurement tape was used to measure the separation between two adjacent dark fringes at different amplitude of intensity. Data were recorded in Table 2.

Test 3: Fringes spacing created by green light sources with different spacing of light sources

1. Two light sources that emitted green light was turned on and passed through a black board with two small slits with slit separation d = 1500nm, 2000nm, and 2500nm. The distance between light sources and detector screen was set at L = 5000 nm. Amplitude of intensity of light was turned to maximum.
2. Measurement tape was used to measure the separation between two adjacent dark fringes at different slit separation. Data were recorded in Table 3.

Observation:

When wavelengths were adjusted, longer the wavelength (changed from red to green to blue), I saw the number of nodes, anti-nodal line, and fringes increased. Two light sources seemed to have more interference.

When amplitudes were adjusted, the interference pattern did not change in a significant way, but the intensity of the fringes on the screen decreased.

When the spacing between two green light sources increased, interreference patterns become greater and more intense and the number of fringes increased.

Result:

Table 1: Fringes spacing with **different wavelength**
(Amplitude:" Maximum; L = 5000 nm; d = 1500nm)

Light source color	Wavelength (nm)	Separation between two dark fringes (nm)
Blue	380 – 500	1500
Green	500 – 570	1671.5
Red	approximately 700	2154.5

Figure 1: Fringe spacing v.s. different wavelength

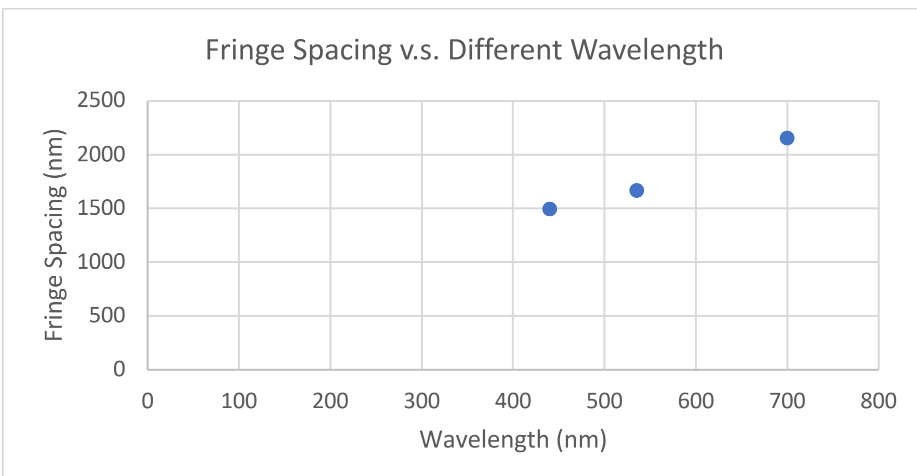


Table 2: Fringes spacing created by green light source with **different amplitudes**
(λ = 500 – 570nm; L = 5000 nm; d = 1500nm)

Amplitude	Separation between two dark fringes (nm)
Maximum	1671.5
80%of maximum	1668.5
50% of maximum	1670.5

Figure 2: Fringe spacing v.s. different light amplitude

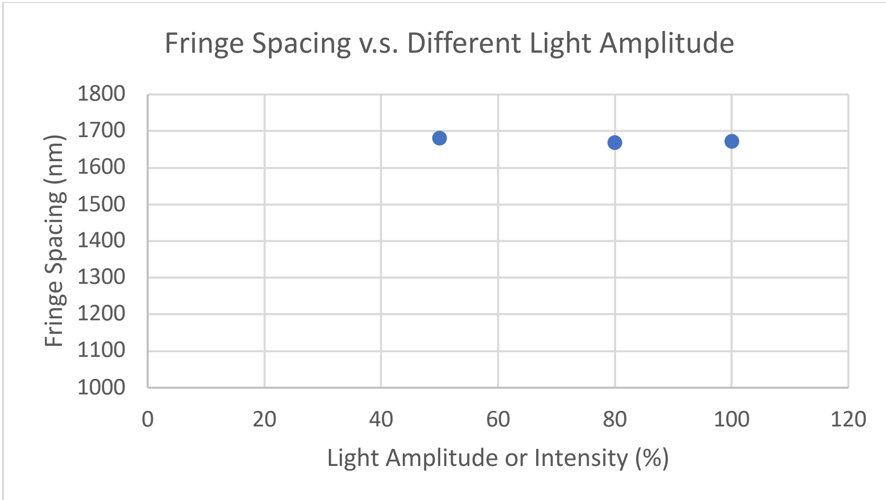
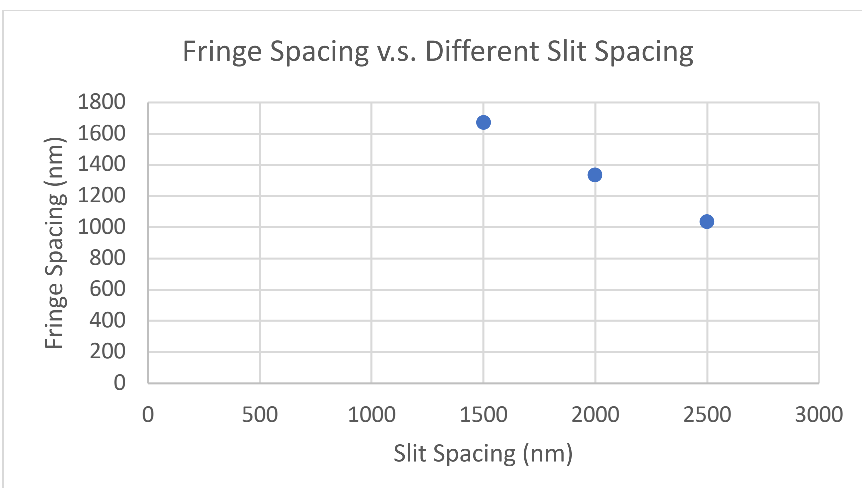


Table 3: Fringes spacing created by green light source with **different spacing** of light sources (Amplitude:" Maximum, $\lambda = 500 - 570$nm; L = 5000 nm)

Spacing of the light sources (nm)	Separation between two dark fringes (nm)
1500	1671.5
2000	1335.5
2500	**1037.5**

Figure 3: Fringes spacing v.s. different slit spacing of two light sources



Sample Calculation:

If a green light source with $\lambda = 520nm$ passes through two closely spaced slits, given d = 2500nm and L = 5000nm:

$\Delta x = \frac{\lambda L}{d} = \frac{(520nm)(5000nm)}{(2500nm)} = 1040$nm which is close to the experimental value, 1037.5nm.

Discussion:

Double slit experiment is a breakthrough to demonstrate wave-particle duality of light. It serves to investigate the nature of light at the quantum level and challenges our understanding of classical physics. The experiment aims to show that light particles exhibit both wave-like and particle-like behaviors. By passing particles or waves through two closely spaced slits, the experiment reveals an interference pattern on a screen of detector. This pattern arises due to the constructive and destructive interreference of the waves. When waves of light emits from slits, nodes occur as two light sources interfere destructively, resulting in regions of darkness of minimal intensity in the interreference pattern, called dark fringes. Antinodes, on the other hand, occur as two light sources interfere constructively, resulting in regions of brightness or maximum intensity in the pattern.

In this lab, the distance between two adjacent dark fringes, Δx, was investigated in terms of different 1) light wavelength, thus frequency, 2) light amplitude of intensity, and 3) spacing of light sources. The default set-up of this lab was allowing a green light with maximum intensity to pass through a dark board with two small pin holes 1500 nm apart, and the distance between the dark board and the screen of detector where the interference pattern was observed was 5000 nm. Three tests were performed. In test 1, Δx was measured with three different kinds of light: blue, green, and red. The result (see Table 1 and Figure 1) revealed that Δx become greater when the wavelength of light become smaller or when the frequency of light become bigger (because wavelength is inversely proportional to frequency). In test 2, Δx was measured when the green light intensity was adjusted from maximum, to 80% of maximum and 50% of maximum. The result (see Table 2 and Figure 2) showed that the separation between two dark fringes did not change significantly. So amplitude of intensity of light does not play a role on light interference in double slit experiment. In test 3, green light was used and Δx was measured at 1500 nm, 2000 nm, and 2500 nm of light sources spacing. The result (see Table 3 and Figure 2) showed greater the spacing between light sources, smaller the separation between adjacent dark fringes.

This lab was successfully done, the relationship between separation of dark fringes and wavelength, frequency, light intensity, and spacing between light sources were clearly identified. Even some measurements might be slightly inaccurate due to human error, the overall pattern and outcome was not affected or altered by that at all. If further work is recommended, adjusting 1) the distance between light sources and the detector (L), 2) temperature, 3) or even interference pattern with three or more light sources could be done. The result must be really interesting.

Conclusion:

In this virtual lab, double slit experiment demonstrated the wave-particle duality of light. Three different tests successfully shown how fringe spacing was affected by wavelength, light intensity, and the separation of light sources. Fringe spacing, Δx, increases with greater wavelength or smaller separation of light sources. And light intensity play no role on fringe spacing.

Citation:

1. *Physics tutorial: Young's experiment*. The Physics Classroom. (n.d.). https://www.physicsclassroom.com/class/light/Lesson-3/Young-s-Experiment