Assignment: Wave Interference

Jin Hyung Park

SPH4U

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Question:

How does the frequency of the light, the spacing of the light sources, and the intensity of the light impact the distance between nodal lines (or fringes)?

Variables:

- Independent Variable
  - Frequency of the light
  - The spacing of the light sources
  - The intensity of the light
- Dependent Variable
  - Distance between nodal lines (or fringes)
- Controlled Variable
  - The separation of the light sources (1529.2 nm)
  - The intensity of the light (50%)

Hypothesis:

The equation derived from Young's slit experiment which is stated on this chapter is $\frac{\lambda}{d} = \frac{\Delta x}{L}$.
From this, we can rewrite the equation as $\Delta x = \frac{L(\frac{c}{f})}{d} = \frac{Lc}{fd}$ where Δx represents the distance between two nodal lines and f denotes the frequency of light and d illustrates the separation between two slits, and L represents the distance between the two light sources. From this equation, the hypothesis is that the frequency of light and the separation between two slits have an inverse relationship with the distance between two lights while the intensity of the light has no relationship with the distance.

Materials:

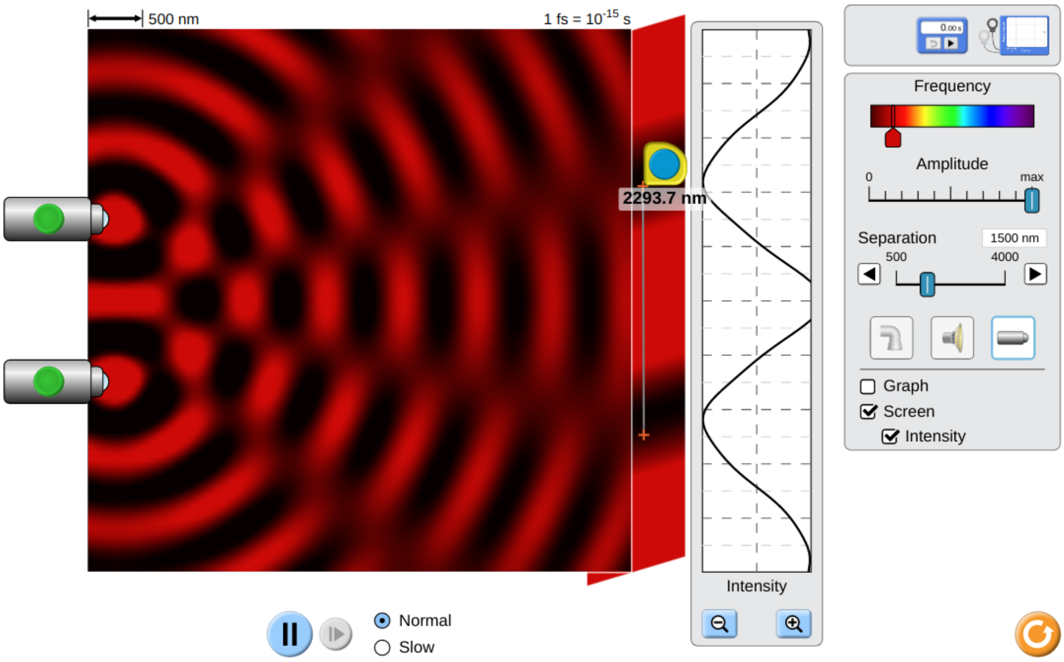
- Lights
- Measuring Tape
- Screen
- Intensity Chart

Procedure:

1. The spacing between the two black fringes seen on the screen (x) was recorded using the Measuring Tape.
2. The distance between the light sources and the screen (L) was measured using the Measuring Tape.
3. The spacing between the two light sources was recorded using the Measuring Tape.
4. The incoming light's wavelength was changed to Blue, and the steps 1, 2, and 3 were repeated for the new wavelength.
5. The entering light's amplitude or intensity was changed, and any variations in the fringe pattern were observed.
6. The light source spacing was changed (d), and any variations in the fringe pattern were observed.

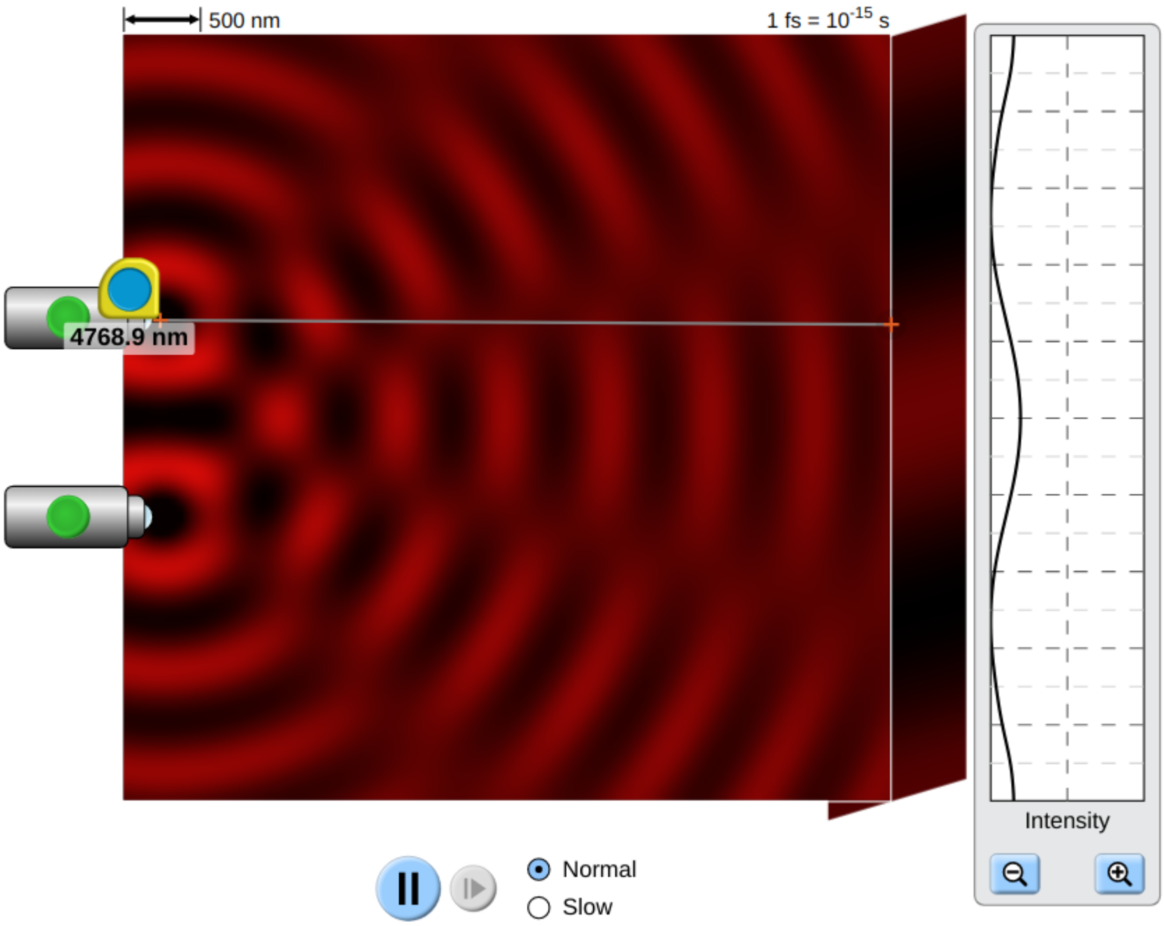
Observations:

Figure 1. The separation between the two dark fringes (nodal lines) which is Δx.



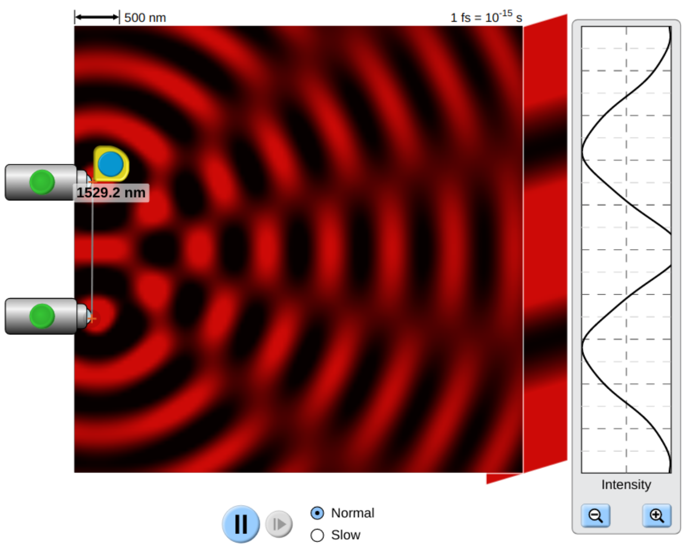
We could notice that the distance between two dark fringes was measured on the point where destructive interference happened. The distance between two dark fringes is 2293.7nm.

Figure 2. The distance from light sources to the screen, which is L.



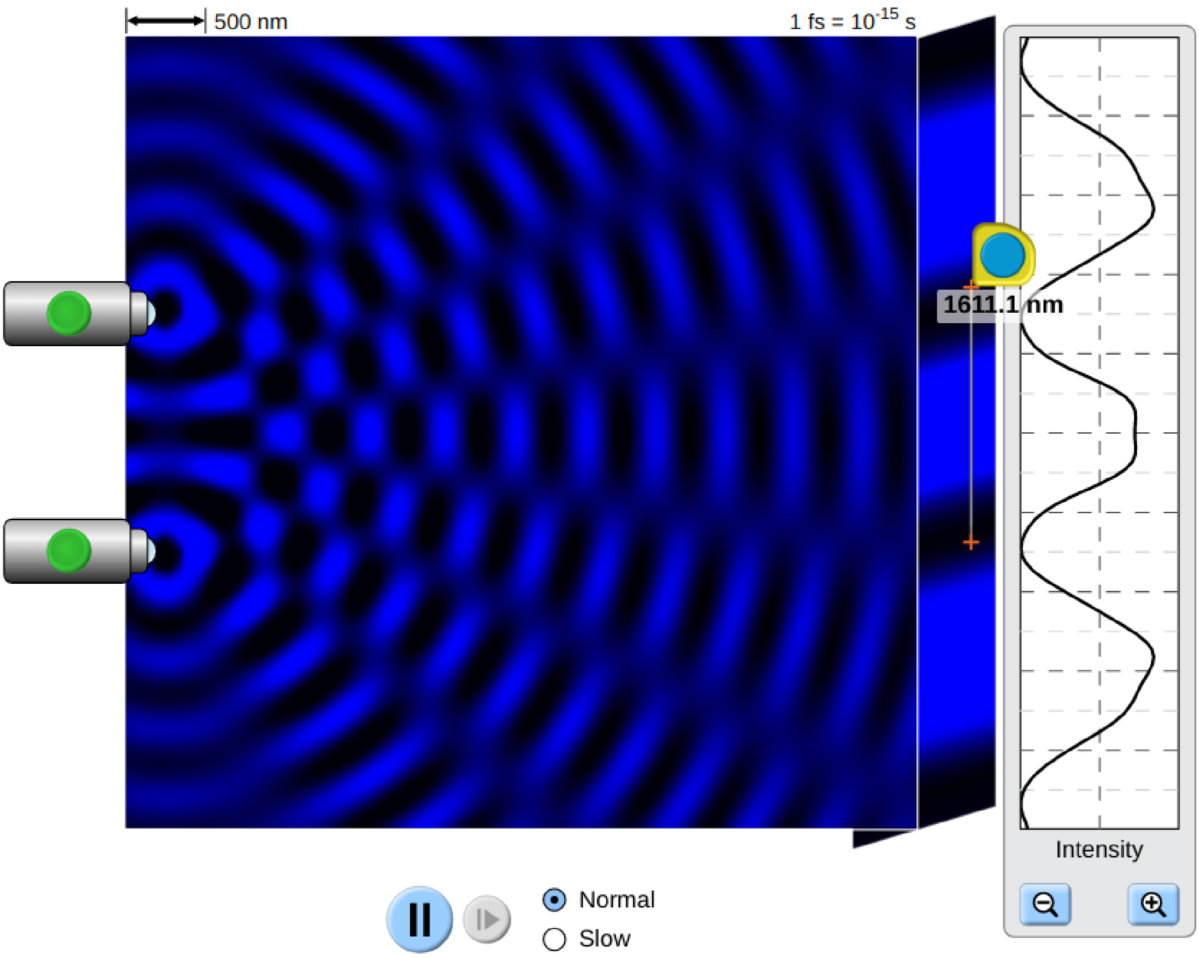
The distance from the light sources to the screen was measured by locating measuring tape in between the source of two lights to the point exactly where the light touches the screen. The distance from the light sources to the screen is 5005.5nm.

Figure 3. The separation between two light sources.



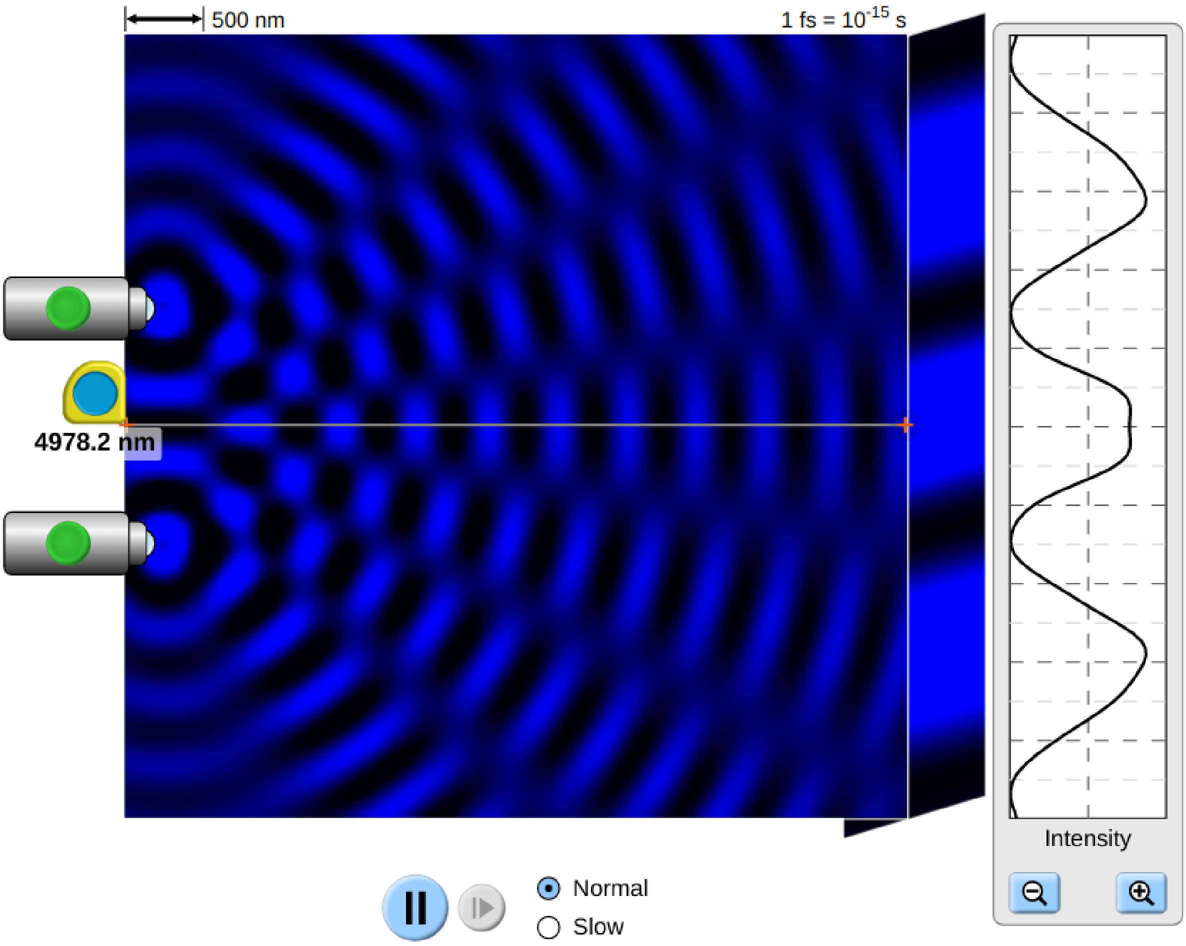
The separation between two light sources was measured at the point of the middle part of the output to measure the exact distance. The separation between two light sources is 1529.2nm.

Figure 4. The distance between the two dark fringes shown on the screen which is Δx after the wavelength of the incoming light was adjusted to Blue.



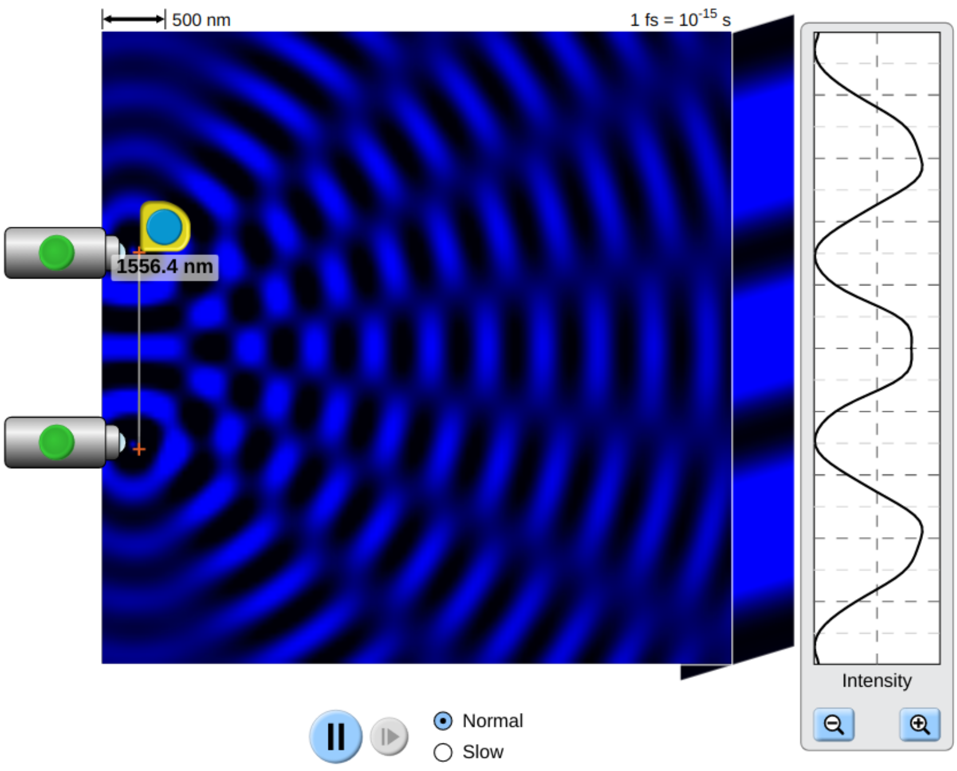
The distance between two fringes was measured on the point where the destructive interference happened. The distance between two fringes is 1611.1nm. Compared to the distance of Red, the distance between two nodal lines has decreased when there is Blue.

Figure 5. The distance between the light sources to the screen after the wavelength of the incoming light was adjusted to Blue, which is L.



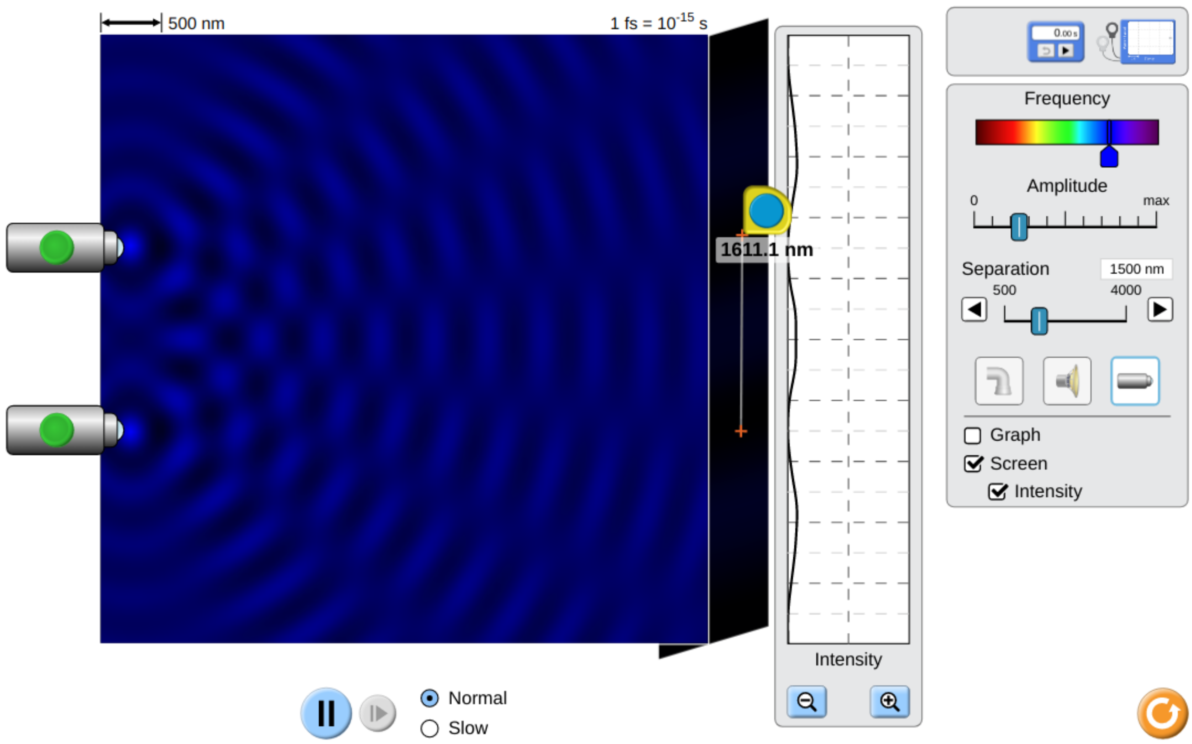
The distance between two light sources to the screen is measured where the measuring tape was located in between two light sources to the point where the screen touched. The distance between two light sources is 4978.2 nm.

Figure 6. The separation between the two light sources after the wavelength of the incoming light was adjusted to Blue.



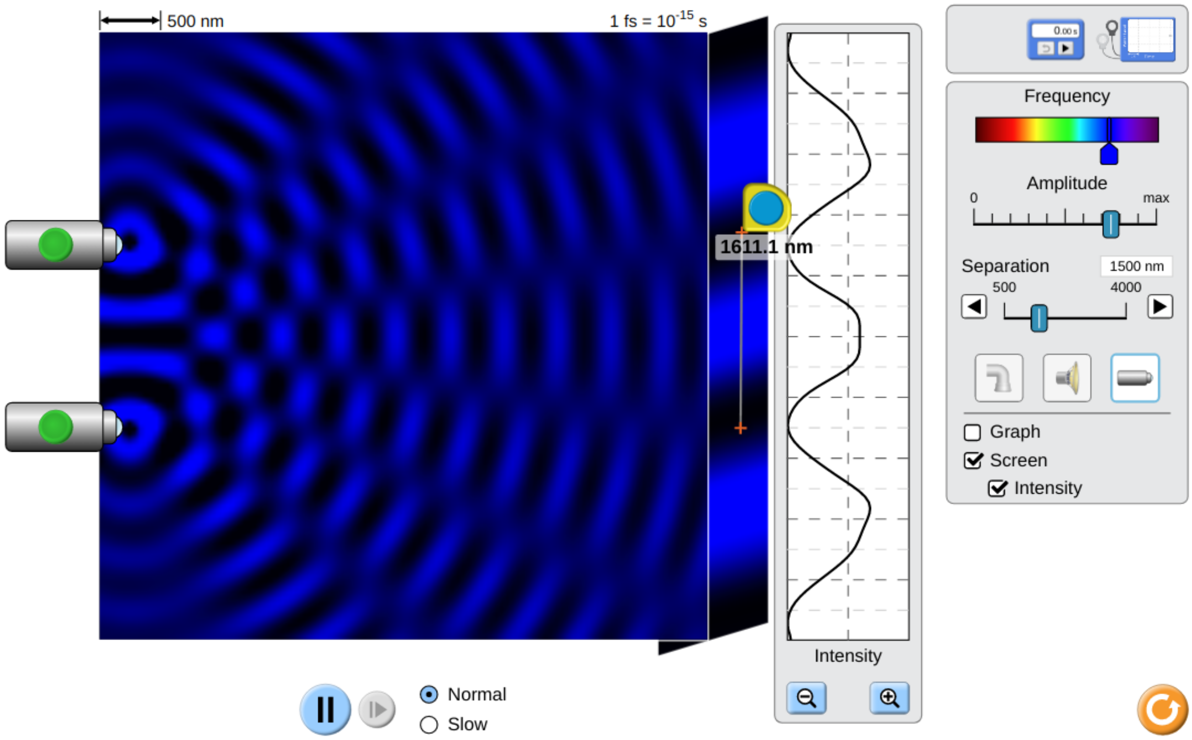
The separation between the two light sources was measured where the measuring tape was the middle of the light outputs. The separation between the two light sources is 1556.4 nm.

Figure 7. When the amplitude of the incoming light was adjusted to decrease.



In comparison to normal intensity, the screen chart and screen altered as the intensity dropped. The color intensity of the nodal lines and black fringes was poor, but the distance between the nodal lines remained constant.

Figure 8. When the amplitude of the incoming light was adjusted to increase.



In comparison to normal intensity, the screen chart and screen altered as the intensity rose. The color intensity of the nodal lines and black fringes was intense, yet the spacing between the nodal lines remained constant. As the intensity grew, so did the amplitude of the antinodes.

Figure 9: When the distance d, between the light sources was reduced.

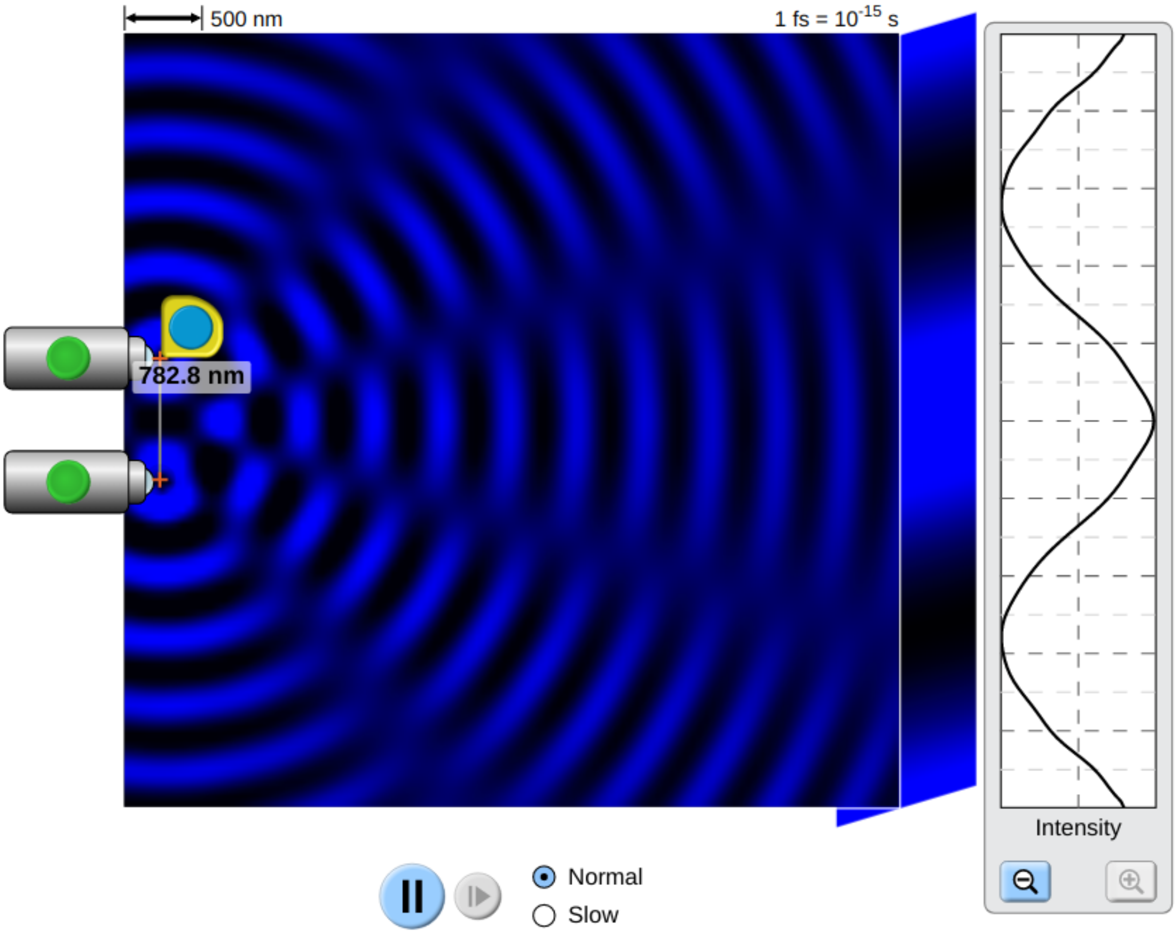
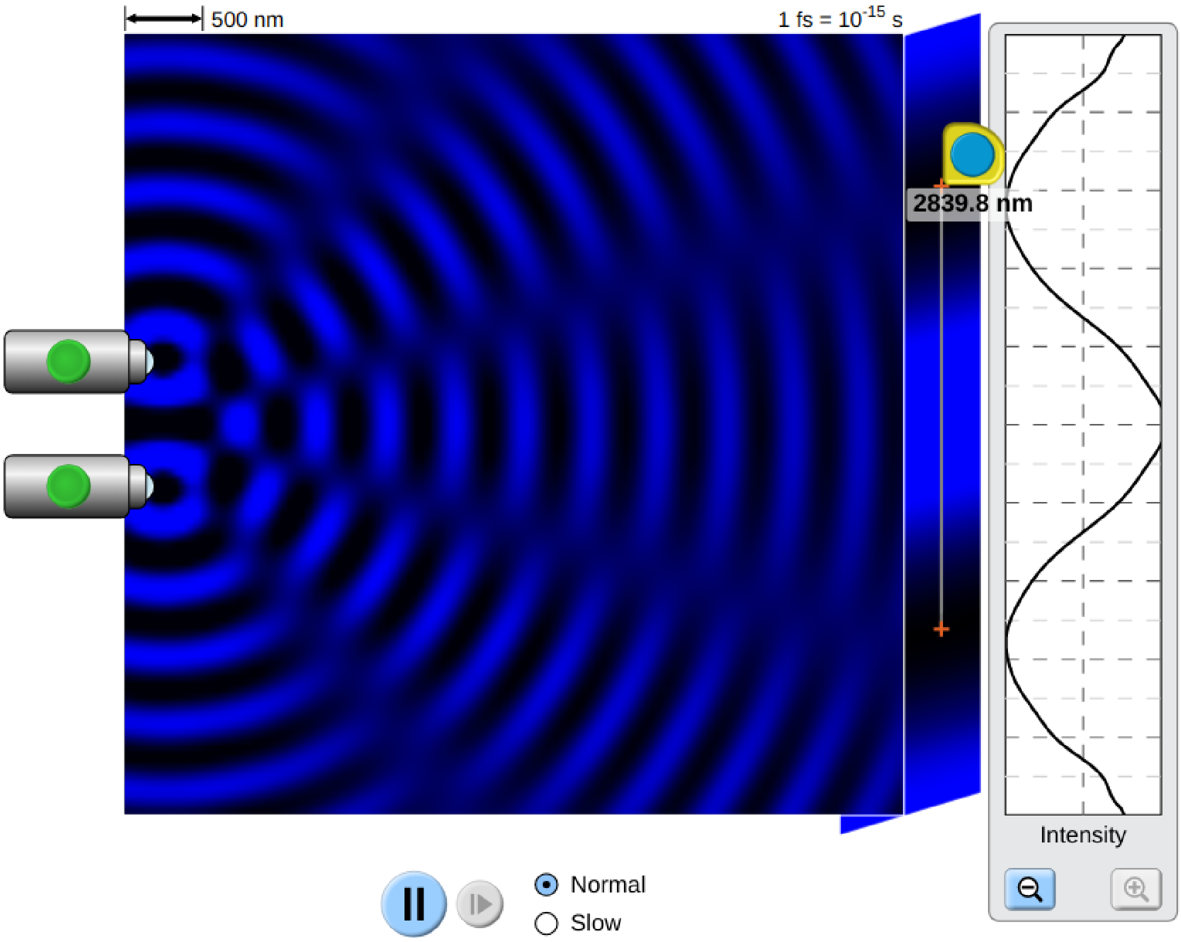


Figure 10: When the distance d, between the light sources was reduced.



When the spacing between the light sources was reduced, the gap between the nodal lines grew larger than before. There was also a reduction in the number of nodal lines present.

Figure 11: When the distance d, between the light sources was increased.

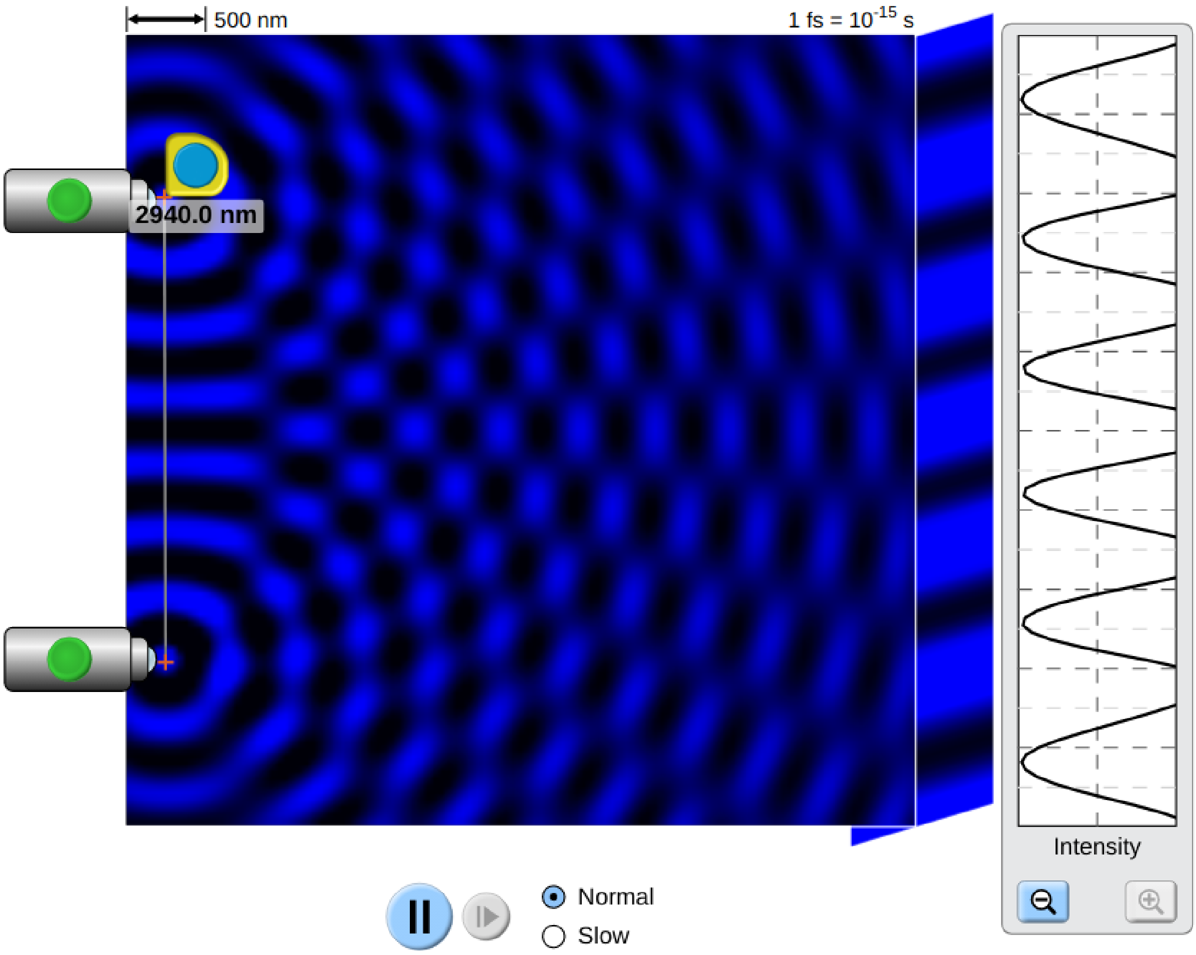
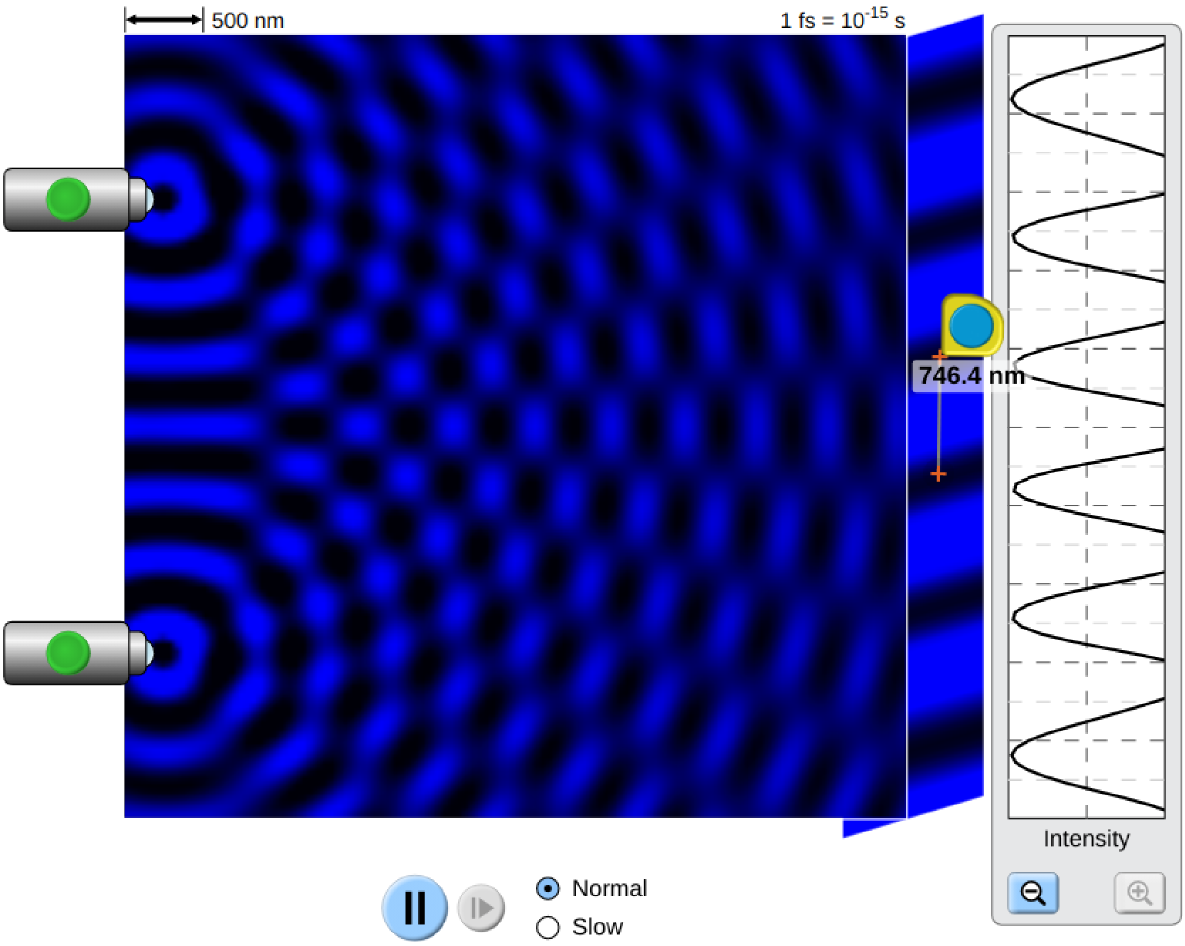


Figure 12: When the distance d, between the light sources was increased.



The distance between the nodal lines was seen to decrease as the spacing between the light sources grew. As can be seen on the screen, the number of nodal lines present has also grown.

<u>Results:</u>

Table 1 shows the variables that influenced the separation of the nodal lines.

Dependent	**Frequency**	**Separation**	**Intensity**
Variables	(Separation of light sources: 1529.2nm) (Intensity of the light 50%)	(Frequency of the light: Blue) (Intensity of the light: 50%)	(Frequency of the light: Blue) (Separation of light sources: 1529.2nm)
Distance between two nodal lines	Red: 2293.7nm Blue: 1611.1nm	782.8nm: 3285.49nm 2940.0nm: 874.773nm	25%: 1611.1nm 75%: 1611.1nm
Amplitude between antinodes	Red: 0.35 Blue: 0.5	782.8nm: 0.6 2940.0nm: 0.45	25%: 0.1 75%: 0.8

Discussion:

1. Background

   When two diffracting lights interfere with one another, patterns are produced, according to Young's experiment and Huygen's interpretation. Those patterns are caused by light diffraction, in which the light travels like semicircular ripples in water, resulting in a pattern of maxima and minima. The double slit interference pattern must be brought forward as a plausible explanation based on the observations and outcomes in this lab.

   The light waves overlap in the double slit interference pattern, creating a succession of peaks and minima, resulting in path difference, also known as destructive and constructive sequences. A minimal or destructive sequence is formed at locations where the crest and trough of the light waves collide, forming nodal lines in the pattern.

   The equation $\frac{\lambda}{d} = \frac{\Delta x}{L}$,
   where $\lambda \equiv wavelength\ of\ light,\ d \equiv separation\ between\ two\ light\ sources,$
   $\Delta x \equiv distance\ between\ two\ adjacent\ nodal\ lines$,
   and $L \equiv distance\ from\ center\ of\ sources\ to\ the\ screen$ is derived. We can rewrite the equation as $\Delta x = \frac{Lc}{fd}$, $\lambda = \frac{f}{c}$. In the lab, Lc remains unconstant where the distance from the center of resources to the screen and the speed of the light was unchanged. Thus, only frequency and separation between two light sources affects the distance between two nodal lines.

2. Patterns and Trends
   - Frequency vs. distance between two nodal lines

     The frequency or wavelength of the light source was the first independent variable. The two types of lights that were utilized were red and blue. The spacing of the nodal lines was seen to be impacted by the change in frequency. From the equation, $\Delta x = \frac{Lc}{fd}$ and the separation of the nodal lines were in an inverse proportional relationship. This meant that as frequency increased from red to blue, the separation decreased.

     - Wavelength of red light

$$\lambda_{red} = \frac{\Delta x \bullet d}{L} = \frac{(2293.7)(1529.2)}{4768.9} = \frac{3507526.04}{4768.9} = 735.50nm$$

       - Percentage Error

         $\%\ Error = |\frac{735.50-700}{700}| \times 100\% \rightarrow Typical\ wavelength\ of\ red\ light$

         $\%\ Error = 5.071\%$

     - Wavelength of blue light

       $$\lambda_{blue} = \frac{\Delta x \bullet d}{L} = \frac{\Delta x \bullet d}{L} = \frac{(1611.1)(1529.2)}{4768.9} = \frac{2463847.04}{4768.9} = 516.64nm$$

       - Percentage Error

         $\%\ Error = \left|\frac{516.64-500}{490}\right| \times 100\% \rightarrow Typical\ wavelength\ of\ blue\ light$

$$\% \ Error = 3.395\%$$

- **Intensity with distance between two nodal lines**
  The intensity of the blue light was the second independent variable. To examine the difference in the distance between the nodal lines, the intensity was increased from 25% to 75%. Rather than the distance of nodal lines affected, the amplitude of the fringe was impacted. This result is obvious according to the equation, $\frac{\lambda}{d} = \frac{\Delta x}{L}$ since there is no relationship between the intensity of the light and the variable Δx in the equation stated above.

- **Separation between the light sources and the distance between nodal lines**
  To begin with, the first trial was on the case where two light sources were 782.8 nm apart. However, the second trial was on the case where two light sources were 2940.0 nm apart. We notice the fact that the distance between the nodal lines was impacted by the separation between the light sources. From the equation, we can appreciate the fact that the separation between two light sources and the distance between the nodal lines has an inverse proportional relationship. Thus, when the separation goes close to far, the distance decreases. We can compare the observed values of Δx to the theoretical values of Δx as follows.
  - Distance between the nodal line when the light sources were 782.8 nm apart
    $$\Delta x_{theoretical} = \frac{L \bullet \lambda_{blue}}{d} = \frac{(4978)(516.64)}{(782.8)} \simeq 3285.429nm$$
    - Percentage Error
      $$\% \ Error = |\frac{2940-3285.429}{3285.429}| \times 100\% \simeq 10.513 \ (From \ Figure \ 10)$$
      $$\% \ Error \simeq 10.513\%$$

  - Separation of the nodal line when the light sources were 2940.0 nm apart
    $$\Delta x_{theoretical} = \frac{L \bullet \lambda_{blue}}{d} = \frac{(4978)(516.64)}{(2940.0)} \simeq 874.773nm$$
    - Percentage Error

$$\% \ Error = |\frac{746.4-874.773}{746.4}| \times 100\% = 17.198 \ (From \ Figure \ 12)$$
$$\% \ Error \simeq 17.198\%$$

- Error Analysis
  The poor definition of the tools and crudeness of the virtual lab might be the source of the discrepancies or percentage mistakes on the wavelengths of red and blue light. The experimenter's eyes were used to determine where the measuring tape should be placed. The exact spot to measure various distances for the experiment was difficult to identify because the lab was nearly finished. Instrumental measurement inaccuracy, often known as intuition and sight, made it virtually difficult to position the tape's tip in the correct location. Furthermore, because the figures and

values were set using a touchpad rather than numerical values, the controls and independent variables had a very low definition. As a result, there were significant percentage inaccuracies in light wavelengths. Such measurement errors would not arise if the Phet simulation featured a function that allowed the experimenter to plot the tape measure on the exact position.

Conclusion:

"How is the distance between nodal lines (or fringes) impacted by the frequency of the light, the spacing of the light sources, and the intensity of the light?" was the lab question. The variables that impact the distance between the nodal lines or fringes were discovered in this lab experiment, which was a success. The equation, $\frac{\lambda}{d} = \frac{\Delta x}{L}$, which was based on Young's experiment and Huygens explanation, may be used to explain the phenomenon. The spacing between the nodal lines was determined by the light source's frequency and the distance between the two light sources. The spacing of the two light sources is in an inverse proportional connection when the equation is rearranged ($\Delta x = \frac{Lc}{fd}$). The distance between the nodal lines decreased as the frequency rose, and vice versa. Furthermore, when the distance between the two light sources rose, so did the distance between the nodal lines!

References:

Lea, R. (2018, July 5). The Double Slit Experiment Demystified. Disproving the Quantum Consciousness connection. Retrieved June 19, 2021, from https://medium.com/predict/the-double-slit-experiment-demystified-disproving-the-quantum-consciousness-connection-ee8384a50e2f.

Double Slits with a Single Atom. (n.d.). Retrieved June 19, 2021, from https://physicsworld.com/a/double-slits-with-single-atoms/