# Example of diffraction and interference of light wave: lab report

Finance, Investment

# Abstract

The objective of this experiment is examination of diffraction and interference of visible light when it is passed across narrow double and single slits. In order to do so, the diffraction patterns of light will be investigated through collection of pertinent data relating to the distance between pattern's centres and maxima. Of particular interest in this experiment is the varying intensity of light and respective positions on the display screen as ascertained trough measurement and calculation of width and separation distances for respective patterns. The experiment concludes by highlighting the wave attributes of visible light as manifested in diffraction when passed through a sufficiently narrow slit as compared to its wavelength.


# Introduction

Light wave is classified as an electromagnetic signal and is capable of exhibiting a typical wave phenomenon when subjected to proper circumstances. Such phenomena comprise of destructive and constructive interference. The visible light's wavelength varies between 400 and 750nm and presents a scale for display of wave-like effects appearance. For example, in this experiment, a broad beam of light is passed through narrow slits as compared to light's wavelength. The effect of this depicts the wave properties of light as manifested in diffraction pattern displayed on the screen.

## Description of the Experiment

The wave nature of light can be demonstrated through diffraction and interference. Diffraction is the spreading of light at openings and edges while interference is the process by which light waves travelling in same medium combines to produce a new wave. The laser light is diffracted as they pass through the slits. Therefore, the light waves spread out and interact with other wave forms. This process results into either constructive or destructive interference. Constructive interference is seen as bright patterns on the screen while the dark fringes are as a result of destructive interference.

## Double slit

Double slit arrangement

For slit separation d, the condition for constructive interference satisfies the equation $d\sin\Theta = m\lambda$

Where d = slit separation, m = 0, 1, 2, 3 , and λ = wavelength of light

## The constructive interference occurs when the path difference is whole number wavelength

But tan Θ = sin Θ for small Θ

Therefore equation $d\sin\Theta = m\lambda$ can be written as;

$m\lambda = dYL$

Where Y is the distance from the center of the interference to the mth maximum and L is the distance between the slits and the screen

## Single slit

Single slit arrangement

The slit separation d in equation $m\lambda = dYL$ is replaced with slit width a. The equation becomes;

$m\lambda = aYL$

Where m = 1, 2, 3

## Materials

- Slit patterns
- Screen
- Laser light
- Metric ruler

## Procedure

Double-slit interference: Determination of laser wavelength

Using pattern D on the diffraction plate, double slit experiment was set up. The laser was placed right behind the plate and used to see interference pattern, which was placed at approximately 2 meters from the plate. The distance from pattern's centre and the second maximum (m= 2) was measured.

## Double-slit interference: determination of slit separation

The results from Part 1a were used to determine slit separation for pattern E. With the set-up as in Part 1a, the qualitative differences were recorded and distance between fourth intensity maximum and centre of pattern was measured. Out of this distance, the slit separation, d was calculated.

## Single slit diffraction

The diffraction plate was left in the same distance from the observation screen, pattern A was moved in front of the laser. The diffraction pattern was observed, and distance between two symmetric minima were measured and divided by two. Using equation mλ= aYL the slit width was calculated.

## Double-slit interference: Determination of slit widths

In the double-slit interference set-up, pattern D was used. In the formed interferences, a “ hole” represents a missing order of interference. From the distance between the missing order and the maximum of zeroth order, slit width was calculated. The same procedure was repeated for pattern E.

## Diffraction Grating

In front of the laser, a diffraction grating was place and diffraction patter observed. Of particular interest in this set-up was the distance between the first maximum and the slits, from which slit separation, d was calculated.

## Data and results

Double-slit interference: Determination of laser wavelength

The distance from the slit to the the screen was measured using metric ruler. This distance was found to be 100. 0cm. The distance was converted to millimetres.

L= 1000mm±0. 1mm

The distance from center of interference the pattern to the second maximum (m= 2) was measured using metric ruler. The distance was 1. 00cm.

Y= 10mm±0. 1mm

The equation mλ= dYL was used to calculate the wavelength of the laser light by replacing m, Y, d and L with 2, 10, 0. 125 and 1000 respectively.

mλ= dYL ⇒2λ=(0. 125)101000

2λ= 0. 00125 ⟹λ= 6. 25×10-4 mm

The wavelength of the laser light λ= 625nm

## The relative uncertainty in wavelength λ equals the sum of relative uncertainties in d, Y, and L

δλλ= δdd+δyY+δLL

δλ6. 25×10-4mm= 0. 01mm0. 125mm+0. 1mm10. 00mm+0. 1mm1000.

00mm

δλ6. 25×10-4mm= 0. 08mm+0. 01mm+(1×10-4mm)

δλ= 0. 0901(6. 25×10-4)⇒5. 6×10-5mm

λ= 6. 25×10-4±5. 6×10-5 mm

λ= 625±56nm

## Double-slit interference: determination of slit separation

The distance from the centre of interference pattern to fourth maximum (m= 4) was measured using metric ruler. The distance was 1. 10cm

Y= 11. 00mm±0. 1mm

The equation the equation mλ= dYL was used to calculate the slit separation.

46. 25×10-4= d111000 ⟹0. 0025= d. 0. 011

Slit separation d= 0. 227mm

## The relative uncertainty in wavelength λ equals the sum of the relative uncertainties in d, Y, and L.

δλλ= δdd+δyY+δLL

5. 6×10-5mm6. 25×10-4mm= δd0. 227mm+0. 1mm11mm+0. 1mm1000.

00mm

0. 0896nm= δd0. 227mm+0. 009mm+(1×10-4mm)

δλ= 0. 0901(6. 25×10-4)⇒5. 6×10-5nm

0. 0805(0. 227mm)= δd

δd= 0. 018mm

d= 0. 227±0. 018mm

## Single slit diffraction

The distances between two symmetric minima for pattern A and pattern C were measured using a metric ruler. These distances were divided by 2. The resulting distances were 2cm and 0. 5cm for pattern A and pattern B respectively.

## Pattern A

Y= 20. 00mm±0. 1mm

## Pattern C

Y= 5. 00mm±0. 1mm

The Equation λ= amYL was used to calculate slit width for pattern A and pattern C.

## Pattern A

6. 25×10-4mm= a20. 00mm1000mm ⟹a= 0. 03125mm

## Pattern C

6. 25×10-4mm= a5. 0mm1000mm ∴a= 0. 125mm

## Uncertainty in wavelength λ equals the sum of relative uncertainties of d, Y and L.

Pattern A

δλλ= δdd+δyY+δLL

δa0. 03125mm= 5. 6×10-5mm6. 25×10-4mm+0. 1mm100. 00mm+0.

1mm20. 00mm

= 8. 96×10-10nm+1×10-4mm+0. 005mm

δa0. 03125mm= 0. 051mm

δa= 1. 59×10-4mm ∴a= 0. 03125±1. 59×10-4mm

## Pattern C

δa0. 125mm= δλλ+δLL+δyy

δa0. 0125mm= 5. 6×10-5mm6. 25×10-4mm+0. 1mm1000. 00mm+0.

1mm500. 00mm

δa= 0. 0025mm ∴a= 0. 125±0. 0025mm

## The calculated values for slit widths were compared to given values of slit widths by finding the percentage errors.

Pattern A

Calculated slit width a= 0. 03125mm

Calculated value a= 0. 04mm

% Error =

21. 875%

## Pattern C

Calculated slit width a= 0. 0125mm

Given slit width a= 0. 016m

% Error =

21. 875%

## Double-slit interference: Determination of slit widths

The distances from the center of the 0th order to the fist minimum (m= 1) for pattern D and Pattern E were measured using metric ruler. The distances were 1. 5cm and 1. 8cm for pattern D and Pattern E respectively.

## Pattern D

Y= 15. 00mm±0. 1mm

## Pattern E

Y= 18. 00mm±0. 1mm

The equationλ= amYL was used to calculate the slit width

## Pattern D

λ= aYL ⟹6. 25×10-4= a151000⟹a= 0. 04167mm

## Pattern E

λ= aYL ⟹6. 25×10-4= a181000⟹a= 0. 0347mm

## Uncertainty in wavelength λ equals the sum of relative uncertainties of d, Y and L.

Pattern D

δλλ= δdd+δyy+δLL

δa0. 04167mm= 5. 6×10-5mm6. 25×10-4mm+0. 1mm1000. 00mm+0. 1mm15. 00mm

δa0. 04167mm= 8. 96×10-10mm+1×10-4mm+0. 00667mm δa0. 04167mm= 0. 00876mm

δa= 2. 82×10-4mm ∴a= 0. 04167±2. 82×10-4mm

## Pattern E

δa0. 0347mm= 8. 96×10-10mm+1×10-4mm+0. 1mm18mm

δa= 1. 96×10-4 ∴a= 0. 0347±1. 96×10-4mm

The calculated values of slit widths were compared with the given slit width of a= 0. 04mm

## Pattern D

Calculated slit width d = 0. 04167mm

Given slit width d = 0. 04 mm

% Error =

4. 175%

## Pattern E

Calculated slit width Y= 0. 0347

Measured slit width Y = 0. 04 mm

% Error =

0. 53%

Diffraction Grating

The distances from the center of interference to the first maxima (m= 1) was found to be 9. 00cm while the distance from the grating to the screen was 20. 00cm

Y= 90. 00mm±0. 1mm

L= 200. 00mm±0. 1mm

The equationmλ= dYL was used to find the slit separation

16. 25×10-4= d90200 ∴d= 0. 0014mm

## Uncertainty in wavelength λ equals the sum of relative uncertainties of d, Y and L.

Pattern D

δλλ= δdd+δyy+δLL

5. 6×10-5mm6. 25×10-4mm= δd0. 0014mm+0. 1mm90mm+0.

1mm200mm

8. 96×10-10mm= δd0. 0014mm+0. 0011mm+5×10-4mm

δd= 2. 25×10-6mm

## The dispersing power of the diffraction grating was found by getting the reciprocal of slit separation d.

= 1d= 10. 0014mm= 714. 29 slits/mm

## Analysis and Conclusion

In case of the single slit experiment the distance from the 0th order to the first minima for pattern D and pattern E were 15. 00mm and 18. 00mm respectively. The slit width is calculated using the equation λ= amYL by replacing λ, m, Y, and L with 6. 25 X 10-4, 1, 1000 and20 for pattern A.

6. 25×10-4mm= a20. 00mm1000mm ⟹a= 0. 03125mm

For pattern C; λ, m, Y, and L are replaced with 6. 25 X 10-4, 1, 1000 and 5.

6. 25×10-4mm= a5. 0mm1000mm ∴a= 0. 125mm

The uncertainty in the calculation of slit width is calculated using the equation δλλ= δdd+δyY+δLL where δλλ = relative uncertainty in λ, δdd =

relative uncertainty in d, δyY = relative uncertainty in Y and δLL = relative uncertainty in L

# Pattern A

δλλ= δdd+δyY+δLL

δa0. 03125mm= 5. 6×10-5mm6. 25×10-4mm+0. 1mm100. 00mm+0. 1mm20. 00mm

= 8. 96×10-10nm+1×10-4mm+0. 005mm

δa0. 03125mm= 0. 051mm

δa= 1. 59×10-4mm ∴a= 0. 03125±1. 59×10-4mm

# Pattern C

δa0. 125mm= δλλ+δLL+δyy

δa0. 0125mm= 5. 6×10-5mm6. 25×10-4mm+0. 1mm1000. 00mm+0. 1mm500. 00mm

δa= 0. 0025mm ∴a= 0. 125±0. 0025mm

# The comparison between the calculated and given slit widths is done by finding the percentage errors.

Pattern A

Calculated slit width a= 0. 03125mm

Calculated value a= 0. 04mm

% Error =

21. 875%

## Pattern C

Calculated slit width a= 0. 0125mm

Given slit width a= 0. 016m

% Error =

21. 875%

Smaller slit width produced widely spread patterns. Y increased with decrease in d as predicted by equationλ= amY L. The error in pattern A and pattern C were equal. The consistency of error is an indication that there was systematic error in the experiment. Possible causes include wrong use of measuring instrument or use of imperfect instrument.

It was noticed that distance between the bright and dark fringes was smaller for pattern E than patter D. In other words Pattern D had widely spaced dark and bright fringes

Part I produced brighter fringes than part I. a. The double slit used in part I produced greater interference of light resulting into fringes with higher intensity greater intensity. Pattern A had fringes that were widely spaced than pattern C. Meaning that the distances between the centers of the interference pattern to the maxima or minima was wider in Pattern A than Pattern C.

The missing orders or holes were caused by destructive interference of light. During destructive interference the amplitudes of two light waves cancel out. Consequently, a dark fringe is formed. This appears as a ‘ hole’ between the bright fringes.

The observed diffraction patterns were more intense or bright. The diffraction grating had many slits that caused greater interference of light.

Consequently, bright fringes of high intensity were produced. Moreover, the regions separating the dark and bright patterns were clearer for diffraction grating than single and double slit interferences.

## Summarised results

The uncertainties for single slit experiment were higher than the uncertainty in double slit experiments. This was brought by the fact that double slit produced clearer fringes of high intensity than single slit. Consequently, there were minimal errors in the measurement of the distance from the center of interference pattern to minima or maxima because of distinct and clear separation between dark and bright fringes.

When the slits are made smaller, the diffraction pattern spread out in accordance with the equation$Y= \lambda Ld$. The smaller slit separation and width causes pronounced diffraction of light. Consequently, the pattern becomes wider. For large slits the patterns are squeezed together.

Two waves of light from two slits separated by distance d create a dark spot on the screen because of destructive interference. The destructive interference occurs when the crest of one wave is superposed to the trough of the other wave. The missing orders or holes were caused by destructive interference of light. During destructive interference the amplitudes of two light waves cancel out. Consequently, a dark fringe is formed.