International Journal of Contemporary Research In Multidisciplinary

Research Article

Ancient India's Contribution to Science

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DOI: https://doi.org/10.5281/zenodo.21308541

Abstract

In this paper, we study single slit and double slit diffraction using theory, experiment and simulation. The aim of this study is to understand the behaviour of light subjected to different conditions and also try to relate it with the concept of Maya from Indian philosophy. In the experiments, sodium light is used to observe diffraction patterns. We also study how different parameters like slit width, wavelength, intensity and distance between slits influence the pattern. The results show that light behaves like a wave in diffraction. In quantum mechanics experiments, it also behaves like a particle when observed. This idea is compared with the concept of Maya, where reality depends on observation. The study shows that there is some similarity between modern physics and ancient Indian philosophy.

Manuscript Information

- **ISSN No:** 2583-7397
- **Received:** 08-04-2026
- **Accepted:** 25-05-2026
- **Published:** 05-06-2026
- **IJCRM:**5(SP1); 2026: 124-131
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- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Madiha, Bindal P, Kumar R, Gupta S. Ancient India's contribution to science. Int J Contemp Res Multidiscip. 2026;5(SP1):124-131.

Access this Article Online

www.multiarticlesjournal.com

KEYWORDS: Single slit diffraction, Double slit diffraction, Maya, wave-particle duality.

1. INTRODUCTION

Light is a form of energy which travels in the form of waves. It shows different properties like reflection, refraction, interference and diffraction. Although the double slit experiment was not discovered in India, there were some earlier talks about the nature of light in Indian History. Phenomenon like reflection and refraction were also discussed by Indian scientists. The ancient Indian philosopher and scientist, Acharya Kanada, discussed the nature of light and its behavior in his book, the "Vaisheshika Sutra". In his book, Kanada explained the concept of reflection by stating that when a beam of light falls on a smooth and polished surface, it reflects back. Acharya Bhaskaracharya_was an ancient Indian mathematician and astronomer. In his book "Siddhanta Shiromani", he described the phenomenon of refraction of light through a glass prism. Bhaskaracharya's observations on the refraction of light were made several centuries before the same phenomenon was described in Europe by Sir Isaac Newton. Aryabhatta's book, Aryabhatia, contains a systematic treatment of the position of planets. a systematic study of the setting of the planets in space. Aryabhatta introduced sine tables using the concept of ardha-jya, or half-chord. He also demonstrated an early understanding of cosine and sine. His innovations laid the foundation for modern trigonometry. This concept of trigonometry is relevant to double slit experiment as the experiment depends on the geometric terms like angle, necessary for fringe conditions.

Diffraction happens when light passes through a small aperture and spreads out. In single slit diffraction, we get a pattern with a bright central maximum and dark and bright fringes on both sides [1]. In double slit experiment, light passes through two slits and forms an interference pattern within a diffraction envelope [2].

These experiments establish the wave nature of light firmly [3]. But in quantum mechanics, it is also seen that when we observe the behaviour of light in certain experiments, it behaves like a particle instead of a wave. This is called wave-particle duality [4].

In Indian philosophy, there is a concept called Maya, which means that the world we see is not the ultimate reality but depends on our perception. In this paper, we try to understand diffraction and also explore if it has any connection with this idea.

2. METHODOLOGY

In this study, to get an insight into behaviour of light, both experiment and simulations were carried out. The experiment was performed using sodium light of wavelength 589×10^{-9} m. Light is passed through single slit and double slit apertures and the patterns formed on the screen are studied.

For simulation, we used theoretical formulas of intensity distribution in diffraction patterns and plotted graphs by changing different experimental parameters.

Single Slit Diffraction

When light passes through a single slit, it spreads out and forms a diffraction pattern. The pattern has a bright central part and smaller bright fringes on both sides. The bright fringes are due to constructive interference of waves diffracted by the slit, and the dark areas are due to destructive interference. The central maximum is brighter than the other maxima. The intensity of the maxima rapidly decreases as one is further from the centre.

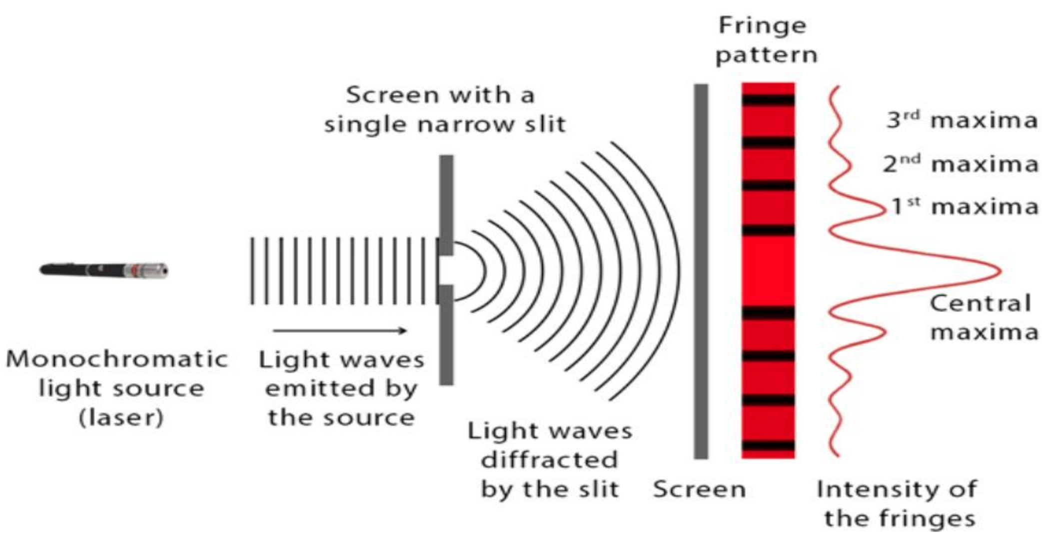


Figure 1: Single Slit diffraction [1]

To complement the theoretical analysis, single slit diffraction was numerically simulated to obtain the intensity distribution on the screen.

The program made use of the theoretical formula for intensity I, with A as the amplitude of the incident light and x is the distance of the observation point on the screen from the centre.

$$I(x) = A^2 \left(\frac{\sin(\beta)}{\beta}\right)^2 \qquad \beta = \frac{\pi \, a \sin\theta}{\lambda}$$

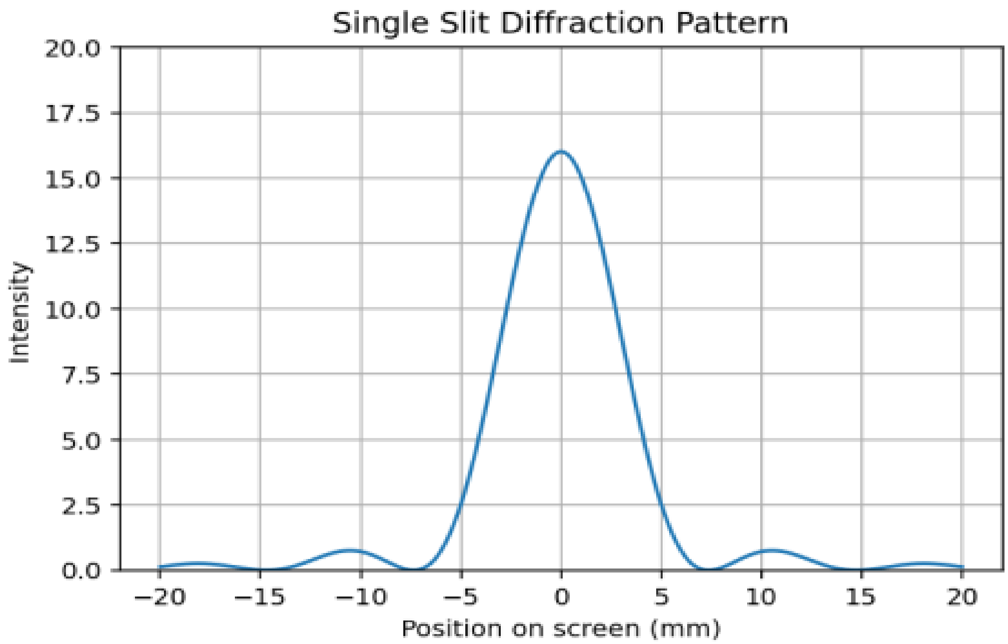
Parameters used in the code:

Parameter	Symbol	Value
Wavelength (Sodium Light)	λ	589×10^{-9} m
Slit Width	a	80×10^{-6} m
Screen Distance	D	1 m
Wave Amplitude	A	4
Angle of diffraction	θ	Variable

Program:

```
import numpy as np
import matplotlib.pyplot as plt

#Parameters
wavelength = 589e-9 # wavelength of light (m)
a = 80e-6 # slit width (m)
D = 1.0 # distance to screen (m)
A = 4.0 # amplitude of the wave

x = np.linspace(-0.02, 0.02, 4000) # position on screen (m)

# beta = (pi * a * sin(theta)) / lambda

beta = (np.pi * a * x) / (wavelength * D)

#Intensity
intensity = (A**2) * (np.sinc(beta / np.pi))**2

#Plot of single slit diffraction
plt.figure()
plt.plot(x * 1000, intensity)

plt.xlabel("Position on screen (mm)")
plt.ylabel("Intensity")
plt.title("Single Slit Diffraction Pattern")

plt.ylim(0, 20)
plt.grid(True)

plt.show()
```

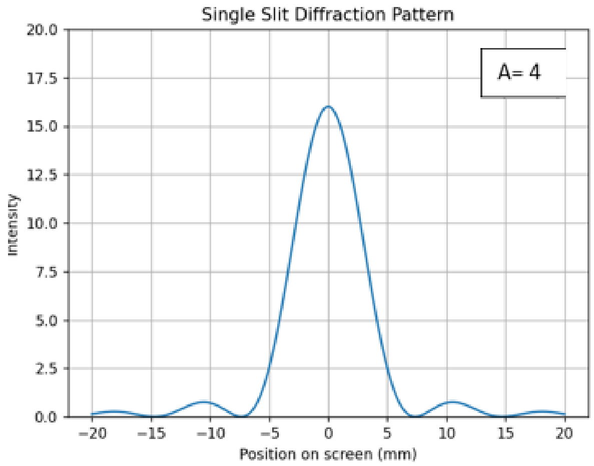
Output:

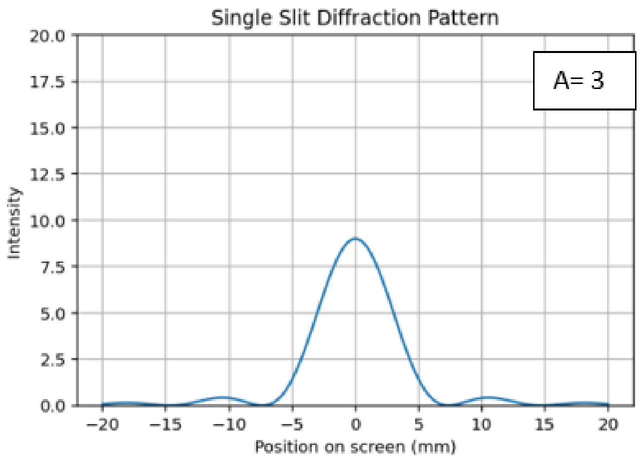


Study of variation of single slit diffraction

1. **Varying Intensity of incident light**

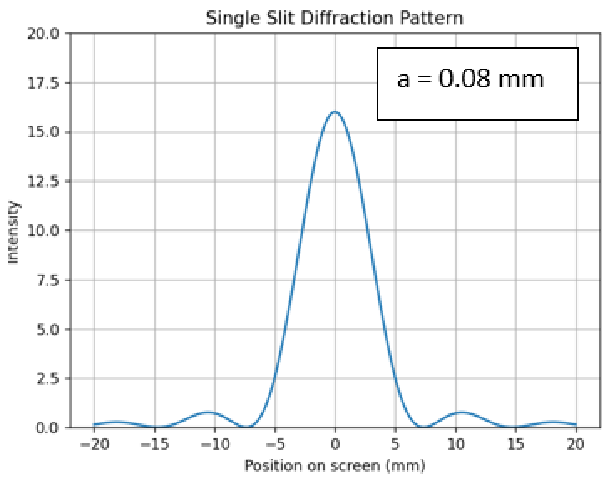
($wavelength, slit\ width\ and\ screen\ distance\ fixed$)

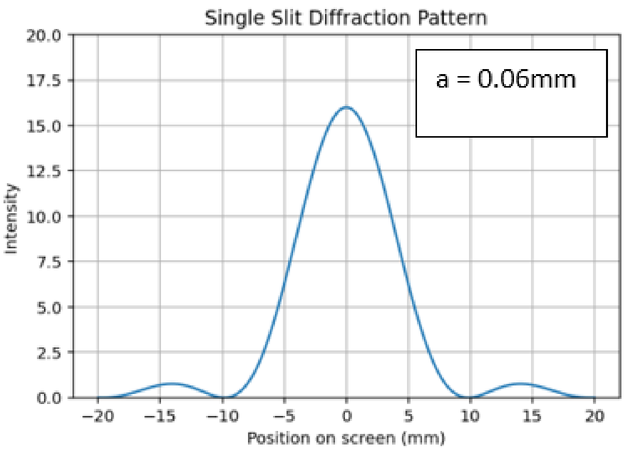




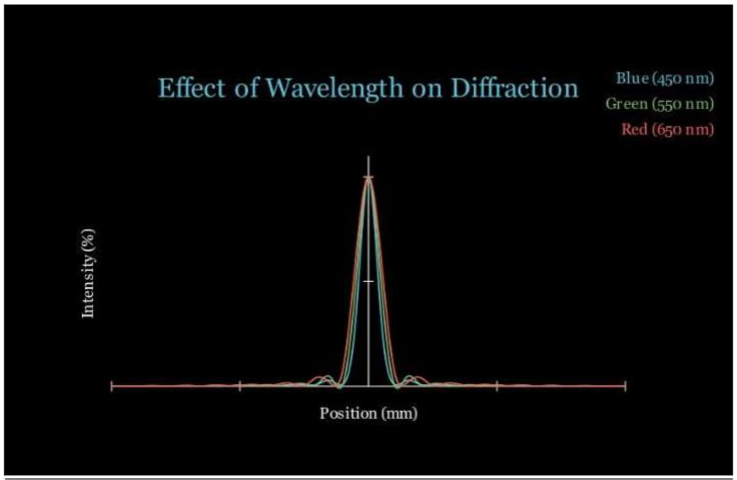
2. **Varying slit width**

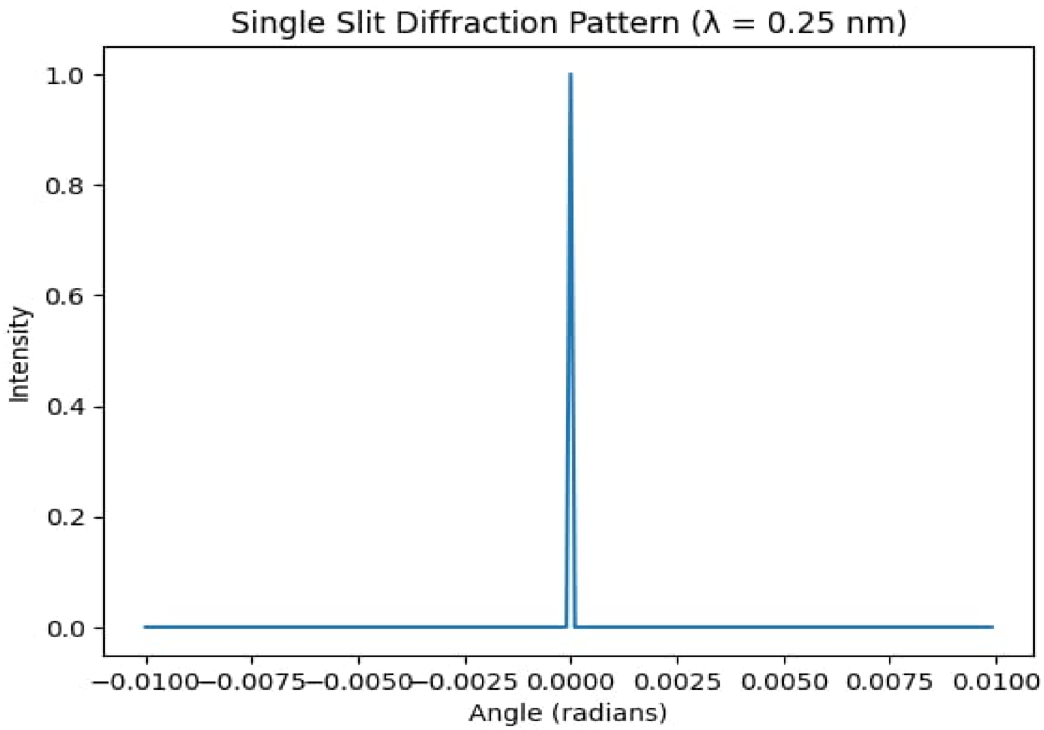
($wavelength, amplitude\ and\ screen\ distance\ fixed$)





Narrowing the slit (a) causes the light to spread more, making the central maximum wider and the overall diffraction pattern more spread out which also changes the position of the maxima and the minima.





Inferences

1. **Change in Intensity**

When intensity is decreased, the brightness of fringes decreases but their position does not change.

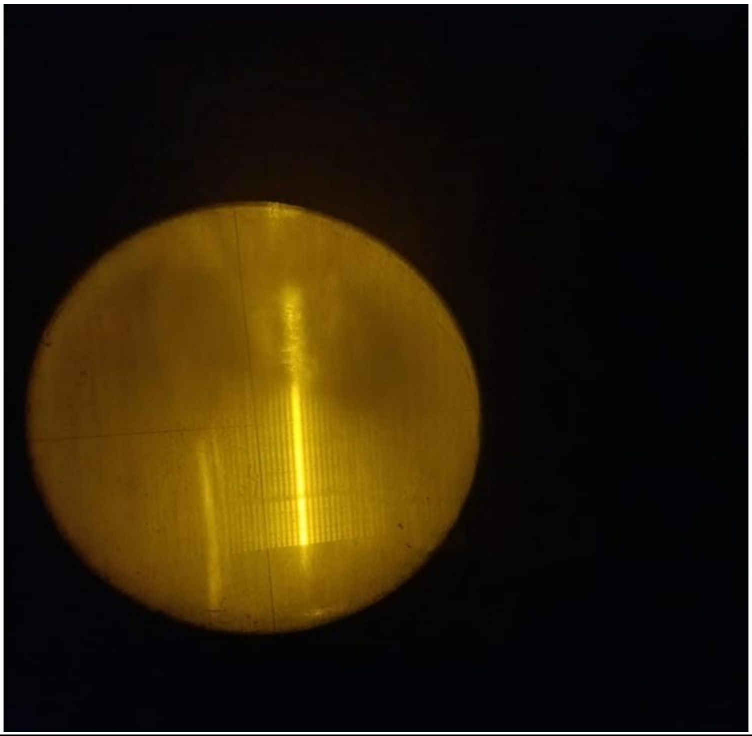
2. **Change in Slit Width**

When slit width is small, the pattern spreads more and central maximum becomes wider. When slit width is large, the pattern becomes narrow.

3. **Change in wavelength**

An increase in wavelength causes an increase in width of fringes and vice versa as expected.

An experimental study was also performed for single slit diffraction using sodium light as a slit source. The diffraction pattern obtained matches with theoretical result and is shown below



The experimental results are similar to theoretical and simulation results.

Double Slit Diffraction

Double-slit diffraction occurs when coherent, monochromatic light passes through two narrow, closely spaced slits, spreading out (diffracting) and overlapping to create an interference pattern of alternating bright and dark fringes on a screen.

Young's double-slit experiment provided strong evidence for the wave nature of light. It also showed that light can behave like a particle, as evidenced by the discrete nature of the interference pattern.

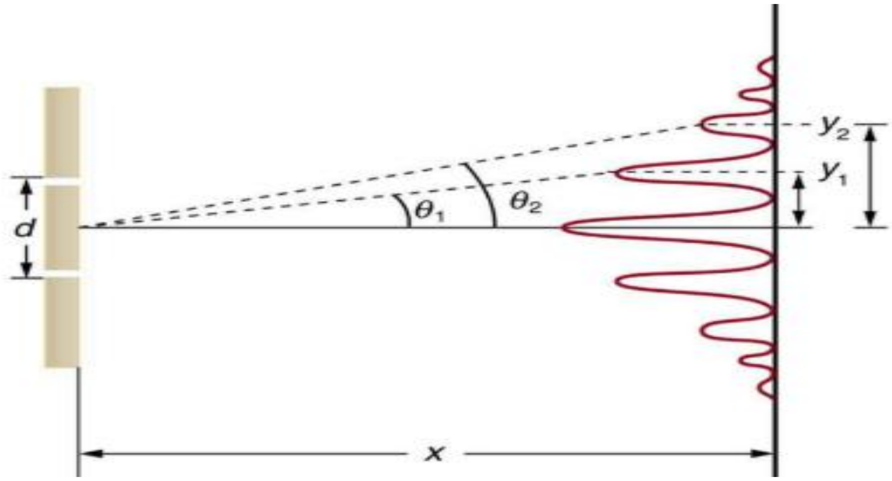


Figure 2: Double Slit Diffraction [2]

The program made use of the theoretical formula

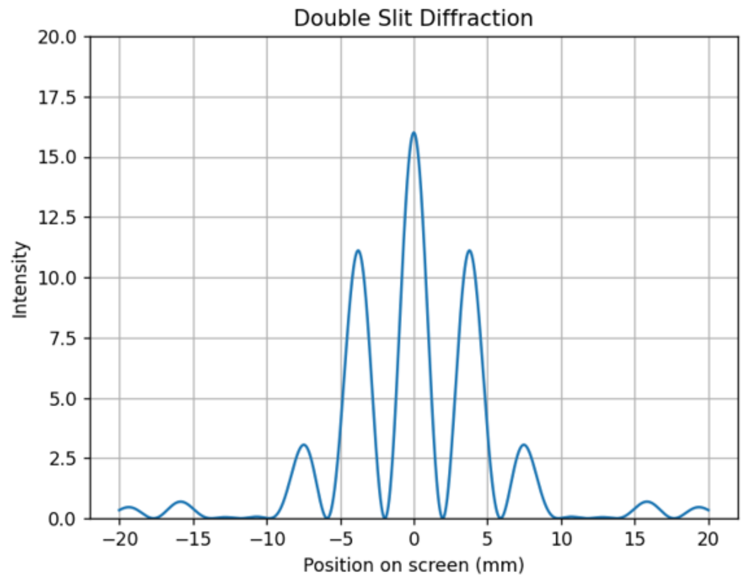
$$I(x) = 4A^2 \left(\frac{\sin\beta}{\beta}\right)^2 \cos^2(\alpha) \qquad \beta = \frac{\pi \text{ a } \sin\theta}{\lambda} \qquad \alpha = \frac{\pi \text{ d } \sin\theta}{\lambda}$$

Parameter	Symbol	Value
Wavelength (Sodium Light)	λ	589 x 10^{-9} m
Slit Width	a	50 x 10^{-6} m
Screen Distance	D	1 m
Wave Amplitude	A	4
Distance b/w slits	d	150 x 10^{-6}m

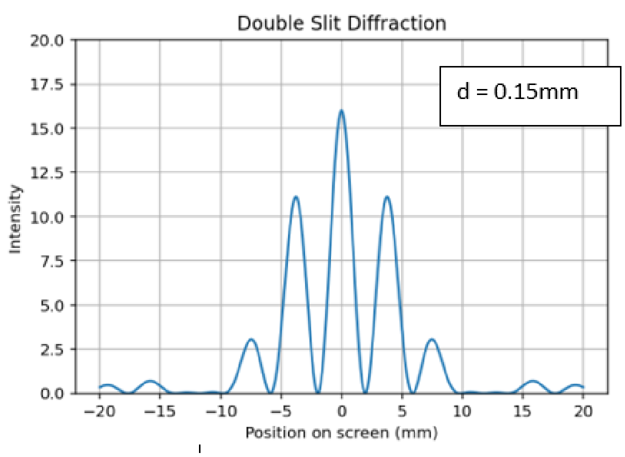
Program: -

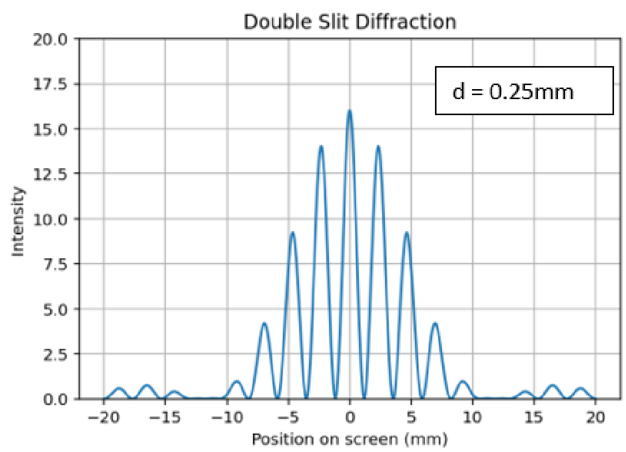
```
import numpy as np
import matplotlib.pyplot as plt

#Parameters
wavelength = 589e-9 # sodium lamp (m)
a = 50e-6 # slit width (m)
d = 150e-6 # slit separation (m)
D = 1.0 # distance to screen (m)
A = 2.0 # amplitude from one slit

#Position on screen
x = np.linspace(-0.02, 0.02, 4000)

beta = (np.pi * a * x) / (wavelength * D)
alpha = (np.pi * d * x) / (wavelength * D)

#Intensity
I = 4 * A**2 * (np.sinc(beta / np.pi))**2 * (np.cos(alpha))**2

#Plot of double slit diffraction
plt.plot(x * 1000, I)
plt.ylim(0,20)
plt.xlabel("Position on screen (mm)")
plt.ylabel("Intensity")
plt.title("Double Slit Diffraction")
plt.grid(True)
plt.show()
```

Output:

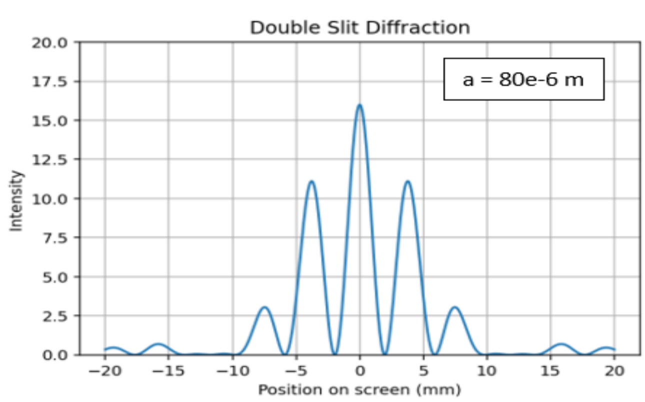


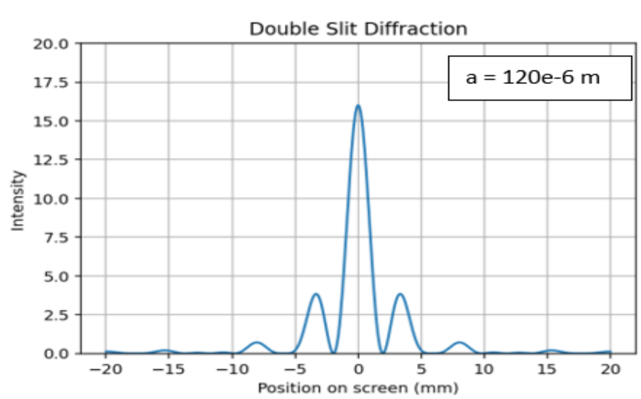
Variation of parameters in Double slit experiment
1. Varying distance between slits
$(wavelength, amplitude\ , slit\ width\ and\ screen\ distance\ fixed)$





2. Varying Slit width
$(wavelength, amplitude\ , slit\ distance\ and\ screen\ distance\ fixed)$





Inferences

1. **Change in distance between slits**

When the distance between slits increases, the fringes come closer, and more fringes are seen under the same diffraction envelope.

2. **Change in Slit Width**

When slit width increases, the number of fringes decreases in the diffraction envelope and the pattern becomes narrower.

4. RESULT

From the experiment and simulation, we observed that light forms diffraction and interference patterns as theoretically discussed. The variation of parameters were discussed which shows Light's wave nature.In quantum mechanics, it is seen that light behaves like a wave when not observed and like a particle when observed.

5. CONCLUSION

The results show that light behaves like a wave in diffraction experiments. But in quantum mechanics, observation changes the behaviour. This idea is similar to the concept of Maya in Indian philosophy. According to this, the reality we see depends on observation and is not absolute. We can compare:
Wave state -> unobserved ->many possibilities
Particle state -> observed -> one result
In philosophy:
Brahman -> real and unchanging
Maya -> changing and dependent on perception
It is seen that both physics and philosophy suggest that reality depends on observation.
This shows that ancient ideas and modern science can be connected in some way.

Acknowledgement

The authors are thankful to Kalindi College, University of Delhi, for providing the necessary academic environment and resources to conduct this study.

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