# Light Of Wavelength 630 Nm (630 X 10-9 M) Is Used To Produce A Double Slit Diffraction Pattern Where

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## Introduction

Light of wavelength 630 nm (630 × $10^{-9}$ meters) plays a crucial role in demonstrating fundamental phenomena in wave optics, particularly in the context of interference and diffraction. One of the most significant experiments illustrating the wave nature of light involves the use of a double slit apparatus. When monochromatic light of this wavelength passes through two closely spaced slits, it produces a distinctive double slit diffraction pattern characterized by bright and dark fringes on a screen. This pattern offers insights into the wave properties of light, the principles of superposition, and the principles governing interference.

Understanding how light of 630 nm wavelength produces such a pattern involves examining the physics of diffraction, interference, and the mathematical relationships that describe fringe spacing and intensity distribution. This knowledge is foundational for various applications in optics, spectroscopy, and even modern technologies such as interferometry and holography.

In this article, we delve into the detailed mechanisms behind the formation of the double slit diffraction pattern using 630 nm wavelength light, explore the theoretical principles, and discuss practical considerations for experimental setups. We aim to provide a comprehensive understanding suitable for students, educators, and professionals interested in wave optics and its applications.

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## Principles of Double Slit Interference

### Wave Nature of Light

The double slit experiment fundamentally demonstrates that light exhibits wave-like behavior. When a coherent light source illuminates two narrow, closely spaced slits, the light waves emerging from each slit interfere with each other constructively and destructively, depending on the phase difference.

Key concepts include:

- Coherence: The light source must be monochromatic and coherent, meaning the waves maintain a constant phase difference.
- Superposition: The principle that the resultant wave at any point is the sum of the individual waves.

## Conditions for Interference

For observable interference fringes:

- The slit separation $d$ must be comparable to the wavelength.
- The distance between the slits and the screen $L$ should be sufficiently large compared to the slit width to produce distinguishable fringes.

The interference pattern results in bright fringes (constructive interference) where the phase difference is an integer multiple of $2\pi$, and dark fringes (destructive interference) where the phase difference is an odd multiple of $\pi$.

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# Mathematical Description of the Fringe Pattern

## Key Parameters

- Wavelength of light ($\lambda$): 630 nm = $630 \times 10^{-9}$ m
- Slit separation ($d$): Distance between the two slits
- Distance from slits to screen ($L$): Usually in meters
- Fringe position ($y$): Distance from the central maximum to the $n^{th}$ bright or dark fringe

## Fringe Spacing Formula

The fringe separation or fringe width ($\Delta y$) is given by:

$$
\Delta y = \frac{\lambda L}{d}
$$

\]

Where:

- $\lambda$ is the wavelength (630 nm)
- $L$ is the distance from the slits to the screen
- $d$ is the slit separation

This formula indicates that the fringe spacing is directly proportional to the wavelength and the distance $L$, and inversely proportional to the slit separation.

## Conditions for Bright and Dark Fringes

- Bright fringes (constructive interference):

$$
d \sin \theta = n \lambda \quad \text{(for } n = 0, 1, 2, \ldots \text{)}
$$

- Dark fringes (destructive interference):

$$
d \sin \theta = \left(n + \frac{1}{2}\right) \lambda
$$

For small angles where $\sin \theta \approx \tan \theta \approx y / L$:

$$
y_n = \frac{n \lambda L}{d}
$$

This relation enables calculation of fringe positions on the screen.

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# Experimental Setup and Procedure

## Components Required

1. Coherent monochromatic light source (e.g., laser with 630 nm wavelength)
2. Double slit apparatus with known slit separation $d$
3. Projection screen or detection surface
4. Optical bench for stability
5. Measuring instruments (ruler, calipers)

### Step-by-Step Procedure

1. Align the laser beam to ensure it is collimated and directed perpendicular to the double slit.
2. Adjust the slit apparatus so that the slit separation $d$ is known or measurable.
3. Place the screen at a known distance $L$ from the slits.
4. Turn on the laser and observe the interference pattern on the screen.
5. Measure the fringe width ($\Delta y$) and the positions of bright fringes.
6. Calculate the slit separation $d$ using the fringe spacing formula if unknown, or verify the pattern with known parameters.

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## Interpretation of Results

Using the measured fringe spacing and known values of $\lambda$ and $L$, one can:

- Confirm the wave nature of light through the presence of interference fringes.
- Calculate the slit separation $d$ if not known.
- Demonstrate the proportionality between fringe spacing and wavelength.
- Explore how changing parameters affects the pattern.

For example, increasing $L$ increases fringe width, making fringes more distinguishable, while decreasing $d$ increases fringe width but can reduce fringe visibility if too small.

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## Applications of Double Slit Diffraction Patterns with 630 Nm Light

### Scientific and Educational Significance

- Verification of wave theory: Demonstrates the wave nature of light convincingly.
- Optical measurements: Used to determine slit separation, wavelength, or coherence length.

## Technological and Practical Uses

- Spectroscopy: Using diffraction patterns to analyze light properties.
- Interferometry: Precise measurement of distances and refractive indices.
- Holography and imaging: Exploiting interference for three-dimensional images.
- Laser calibration: Fine-tuning optical devices with known wavelength sources.

## Advanced Research

- Studying quantum phenomena, such as wave-particle duality.
- Developing high-precision sensors and measurement devices.

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# Factors Affecting the Pattern and Accuracy

- Coherence length: Longer coherence length produces clearer fringes.
- Slit quality: Uniformity and sharpness of slits influence fringe sharpness.
- Wavelength stability: Laser sources with stable wavelength produce consistent patterns.
- Environmental conditions: Vibrations, air currents, and temperature fluctuations can distort fringes.

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# Conclusion

Light of wavelength 630 nm ($630 \times 10^{-9}$ meters) provides an excellent medium for demonstrating the fundamental principles of wave optics through the double slit diffraction pattern. The formation of bright and dark fringes on a screen encapsulates core concepts such as interference, superposition, and the wave nature of light. By understanding the mathematical relationships and experimental techniques involved, students and researchers can explore the intricate behaviors of light and harness these phenomena in various scientific and technological applications.

The ability to produce and analyze such interference patterns not only confirms the wave nature of light but also serves as a foundation for advanced optical technologies that rely on interference, diffraction, and coherence. Whether in educational demonstrations or cutting-edge research, the use of 630 nm wavelength light in double slit experiments remains a cornerstone in the study of wave optics.

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Keywords: light wavelength 630 nm, double slit diffraction pattern, interference fringes, wave optics, fringe spacing, coherence, optical experiments, diffraction, interference pattern, monochromatic light

# Frequently Asked Questions

## What is the significance of using a wavelength of 630 nm in double slit diffraction experiments?

A wavelength of 630 nm (red light) is commonly used because it provides clear diffraction patterns with easily measurable fringe spacing, making it ideal for demonstrating wave interference in double slit experiments.

## How does changing the wavelength to 630 nm affect the fringe width in a double slit diffraction pattern?

The fringe width is directly proportional to the wavelength; thus, using 630 nm results in wider fringes compared to shorter wavelengths, facilitating easier observation and measurement of the diffraction pattern.

## Why is the wavelength of 630 nm preferred over other wavelengths for producing a double slit diffraction pattern?

630 nm is preferred because it balances visibility and resolution, producing sufficiently spaced fringes that are observable with standard optical equipment, unlike very short wavelengths which produce very narrow fringes.

## In the context of double slit diffraction, what is the relationship between wavelength and the position of bright fringes?

The position of bright fringes (fringe separation) is directly proportional to the wavelength; increasing the wavelength shifts fringes farther apart, making the pattern more spread out.

## What factors influence the clarity of the diffraction pattern when using light of wavelength

## 630 nm in a double slit experiment?

Factors include the slit width and separation, coherence and monochromaticity of the light source, and experimental setup stability; using 630 nm light ensures good fringe visibility when these factors are optimized.

# Additional Resources

Light Of Wavelength 630 Nm (630 x $10^{-9}$ M) Is Used To Produce A Double Slit Diffraction Pattern Where

Understanding the behavior of light as it interacts with obstacles and apertures has been a cornerstone of wave optics. When a monochromatic light of wavelength 630 nm (or 630 x $10^{-9}$ meters) is used in a double slit experiment, it reveals the fascinating phenomena of diffraction and interference, creating a distinctive pattern that exemplifies the wave nature of light. This article offers a comprehensive guide to how light of this particular wavelength produces a double slit diffraction pattern, exploring the underlying principles, calculations, experimental setup, and significance in optical physics.

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The Fundamentals of Light and Wavelength

Before delving into the specifics of the double slit pattern, it’s critical to understand what the wavelength signifies. The wavelength ($\lambda$) of light is the distance over which the wave's shape repeats, typically measured in nanometers (nm) or meters (m). For visible light, wavelengths range approximately from 380 nm (violet) to 750 nm (red).

Wavelength 630 nm falls within the red region of the visible spectrum. It’s chosen for experiments because it is easily produced via lasers or monochromatic sources and exhibits clear diffraction and interference patterns. The wavelength directly influences the position and size of the fringes in the double slit experiment, with longer wavelengths producing wider fringes.

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Why Use Light of 630 nm for Double Slit Experiments?

Using light of 630 nm offers certain advantages:

- Visibility of Patterns: The fringes are sufficiently spaced to be clearly observed with standard optical equipment.
- Availability of Sources: Red lasers and LEDs emitting at this wavelength are common and stable.
- Educational Value: Its position in the visible spectrum makes it ideal for demonstrating wave phenomena to students and researchers.

The wavelength's influence on the diffraction pattern can be summarized as follows:

- Fringe Spacing: The distance between adjacent bright fringes increases with wavelength.
- Pattern Resolution: Longer wavelengths produce broader fringes, which are easier to measure.
- Interference Effects: The coherence length of the light source impacts the clarity of the pattern.

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The Double Slit Setup: Components and Arrangement

To produce a double slit diffraction pattern with 630 nm light, a typical experimental setup includes:

- Monochromatic Light Source: Usually a laser diode or LED emitting at 630 nm.
- Double Slit Plate: Two narrow, closely spaced slits fabricated with precise slit width (a) and slit separation (d).
- Optical Bench and Mounts: To align the light source and the slits accurately.
- Screen or CCD Detector: Positioned at a distance (L) from the slits to observe the interference pattern.
- Measuring Instruments: Rulers or calipers to measure fringe positions and distances.

Key parameters to consider:

- Slit width (a): Typically in the range of micrometers; influences the diffraction envelope.
- Slit separation (d): Also in micrometers; determines fringe spacing.
- Distance to screen (L): Usually meters; affects the overall size of the pattern.

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The Physics Behind the Double Slit Pattern

The double slit experiment elegantly demonstrates the wave nature of light. When monochromatic light passes through two narrow slits, each slit acts as a secondary source of coherent waves. These waves interfere constructively and destructively at different points on the screen, creating bright and dark fringes.

Interference condition:

- Bright fringes (constructive interference) occur when:

$d \sin \theta = m\lambda$, where m is an integer (0, ±1, ±2, ...).

- Dark fringes (destructive interference) occur when:

$d \sin \theta = (m + \frac{1}{2})\lambda$.

Diffraction effect:

- Each slit causes diffraction, producing a broad envelope of intensity due to the slit width.
- The overall pattern results from the diffraction envelope modulating the interference fringes.

Approximate fringe position:

For small angles, $\sin \theta \approx \tan \theta \approx y / L$, where:

- $y$ is the fringe displacement from the central maximum,
- $L$ is the distance from the slits to the screen.

Thus, the fringe position can be approximated by:

$y \approx (m \lambda L) / d$

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Calculations Specific to 630 nm Light

Suppose you are conducting an experiment with the following parameters:

- Wavelength, $\lambda = 630$ nm $= 630 \times 10^{-9}$ m.
- Slit separation, $d = 0.2$ mm $= 2 \times 10^{-4}$ m.
- Distance from slits to screen, $L = 2$ m.
- Observation of the first-order fringe ($m=1$).

Fringe separation (distance between adjacent bright fringes):

Using the formula:

$\Delta y = (\lambda L) / d$

Plugging in the values:

$\Delta y = (630 \times 10^{-9} \text{ m} \times 2 \text{ m}) / (2 \times 10^{-4} \text{ m}) = (1.26 \times 10^{-6} \text{ m}) / (2 \times 10^{-4} \text{ m}) = 6.3 \text{ mm}$

This means that the bright fringes are separated by approximately 6.3 mm on the screen, making them easily distinguishable.

Position of the first-order maximum:

$y_1 = (\lambda L) / d = 6.3$ mm

Implication:

By adjusting the slit separation or the distance L, you can control the fringes' spacing, demonstrating the wave nature of light and the influence of wavelength.

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Factors Affecting the Pattern and Their Control

While the basic calculations are straightforward, several factors can influence the quality and clarity of the diffraction pattern:

- Coherence of Light:

- Use a monochromatic, coherent source like a laser.
- Coherence length must be longer than the path difference to maintain interference.

- Slit Dimensions:

- Narrower slits increase diffraction but reduce intensity.
- Precise fabrication ensures uniform slit widths and separation.

- Alignment:

- The slit plane must be perpendicular to the incident beam.
- The screen should be aligned to ensure symmetrical fringe formation.

- Environmental Conditions:

- Minimize vibrations and air currents.
- Use a dark room to enhance contrast.

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Significance and Applications in Physics and Technology

Producing a double slit diffraction pattern with 630 nm light is not merely a classroom demonstration but a foundational experiment with broad implications:

- Wave-Particle Duality: Reinforces the wave aspect of light, challenging classical particle theories.
- Optical Instrument Calibration: Fringe spacing can be used to calibrate distances and slit parameters.
- Spectroscopy and Measurement: Precise measurements of wavelength and slit dimensions.
- Quantum Mechanics: Similar principles extend to electrons and other particles, illustrating wave-particle duality at a quantum level.
- Optical Devices: Understanding diffraction and interference informs the

design of gratings, filters, and lasers.

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Conclusion

Using light of wavelength 630 nm to produce a double slit diffraction pattern offers a vivid illustration of wave interference principles. The pattern's characteristics, such as fringe spacing and intensity, are directly influenced by the wavelength, slit separation, slit width, and distance to the screen. By carefully controlling these parameters, researchers and students can observe and analyze the wave nature of light, deepen their understanding of optical physics, and explore applications across scientific and technological fields. This classic experiment remains a powerful testament to the wave-particle duality and continues to inspire advancements in optics and quantum science.

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