What Is The Wavelength Of Light Falling On Double Slits Separated By 2.00 M If The Third-order Maximum

What Is The Wavelength Of Light Falling On Double Slits Separated By 2.00 M If The Third-order Maximum

Understanding the phenomenon of interference in light waves is a fundamental aspect of wave optics. When coherent light passes through two closely spaced slits, it produces an interference pattern characterized by bright and dark fringes. The position and nature of these fringes depend on several parameters, including the wavelength of the light, the slit separation, and the order of the maximum observed. In this article, we delve into the detailed process of calculating the wavelength of light when the slit separation is 2.00 meters and the observed maximum corresponds to the third-order maximum.

Introduction to Double-Slit Interference

What Is Double-Slit Interference?

Double-slit interference is a classic experiment demonstrating the wave nature of light. When a coherent monochromatic light source illuminates two narrow, closely spaced slits, the light waves emerging from each slit interfere constructively and destructively at different points on a screen placed some distance away. This interference results in a pattern of bright and dark fringes, known as maxima and minima, respectively.

Key Parameters in Double-Slit Interference

Understanding the interference pattern involves several key parameters:

- **Wavelength of light (λ)**: The distance between successive crests of the wave.
- **Slit separation (d)**: The distance between the centers of the two slits.
- **Distance to the screen (L)**: The distance from the slits to the observation screen.
- **Order of maximum (m)**: The number indicating the fringe order, with $m=0$ being the central maximum, $m=1$ the first-order maximum, and so forth.
- **Position of maxima (y_m)**: The distance from the central maximum to the m^{th} maximum on the screen.

Theoretical Background

Interference Condition for Bright Fringes

The condition for constructive interference (bright fringes) in a double-slit experiment is given by:

\[

$$
d \sin \theta_m = m \lambda
$$

where:

- d = slit separation,
- θ_m = angle of the m^{th} maximum relative to the central axis,
- λ = wavelength of light,
- m = fringe order (0, 1, 2, ...).

When the distance L from the slits to the screen is much larger than d, the small-angle approximation applies:

$$
\sin \theta_m \approx \tan \theta_m \approx \frac{y_m}{L}
$$

Thus,

$$
d \frac{y_m}{L} = m \lambda
$$

which relates the fringe position y_m directly to the wavelength.

Applying the Theory to the Given Data

Given Parameters

- Slit separation: $d = 2.00\, \text{m}$
- Fringe order: $m = 3$ (third-order maximum)
- Distance from slits to screen: Not explicitly given, but typically large enough for the approximation to be valid.

Note: To compute the wavelength, we need either the position y_m of the third-order maximum or additional information about the fringe position. Without the fringe position, we can only express the wavelength in terms of measurable quantities.

Assumptions and Additional Data Needed

In most practical problems, the distance L and the position y_m are vital. Since the problem does not specify L or y_m, we will:

- Assume that the fringe position y_3 (distance from the central maximum to the third-order maximum) is known or measured.
- Alternatively, if the problem provides the position y_3, we can directly compute λ.

Step-by-Step Calculation of the Wavelength

1. Express the Wavelength in Terms of Known Quantities

Using the approximate relation:

$$
\lambda = \frac{d y_m}{m L}
$$

where:

- $d = 2.00\, \text{m}$,
- $m = 3$,
- L is the distance to the screen,
- y_m is the measured distance from the central maximum to the third-order maximum.

Note: If L and y_3 are known, the calculation proceeds straightforwardly.

2. Example Calculation (Hypothetical Data)

Suppose:

- $L = 10\, \text{m}$,
- $y_3 = 0.15\, \text{m}$.

Then,

$$
\lambda = \frac{(2.00\, \text{m})(0.15\, \text{m})}{3 \times 10\, \text{m}} = \frac{0.3\, \text{m}^2}{30\, \text{m}} = 0.01\, \text{m}
$$

which is 10 millimeters, an unphysically large wavelength for visible light, indicating that either the fringe position is much smaller or the assumptions need adjustment.

In realistic scenarios, visible light wavelengths are on the order of hundreds of nanometers ($400-700\,\text{nm}$), so the values of y_m would be correspondingly tiny or L very large.

3. General Formula for Wavelength

To summarize, the general formula for the wavelength based on the third-order maximum is:

$$
\boxed{
\lambda = \frac{d \times y_3}{3 \times L}
}
$$

Implications and Practical Considerations

Experimental Setup and Measurement

Accurate measurement of fringe positions and distance to the screen is crucial. Since the slit separation d is large (2.00 meters), the fringe pattern may be spread widely, making precise measurement easier.

Key points:

- Ensure the light source is monochromatic and coherent.
- Use a screen at a known, fixed distance L.
- Measure the distance y_3 from the central maximum to the third-order maximum accurately.

Limitations and Challenges

- Very large slit separation can lead to extremely wide fringes, which may be impractical.
- Precise measurement is necessary to avoid significant errors.
- Ambient light and environmental vibrations can affect fringe visibility.

Conclusion

Determining the wavelength of light in a double-slit interference setup with a slit separation of 2.00 meters and observing the third-order maximum involves understanding the interference conditions and applying the appropriate formulas. The key relation:

$$
\lambda = \frac{d y_m}{m L}
$$

connects the physical parameters to the measurable fringe position. Accurate measurement of the fringe position y_3 and the distance L allows for precise calculation of the wavelength. This process highlights the fundamental wave nature of light and exemplifies how interference experiments serve as powerful tools in optical physics.

In real experimental conditions, knowing the exact fringe position or having precise data about the setup parameters is essential to obtain an accurate value for the wavelength of the light involved.

Frequently Asked Questions

What is the formula to calculate the wavelength of light in a double-slit interference pattern?

The wavelength □ can be calculated using the formula □ = (d y) / (m L), where d is the slit separation, y is the fringe width, m is the order of the maximum, and L is the distance from the slits to the screen.

How does the slit separation distance (d) influence the interference pattern in a double-slit experiment?

A larger slit separation d results in fringes that are more widely spaced, increasing the fringe width, while a smaller d causes fringes to be closer together.

What is the significance of the third-order maximum in the context of the double-slit experiment?

The third-order maximum corresponds to the third bright fringe in the interference pattern, where constructive interference occurs at order m=3, allowing calculation of the wavelength based on its position.

Given the slit separation of 2.00 m and the third-order maximum, what additional information is needed to find the wavelength of light?

You need to know the fringe width (distance between consecutive maxima) or the distance from the slits to the screen (L) and the position of the third-order maximum to calculate the wavelength.

Why is the wavelength of light important in understanding interference

patterns in double-slit experiments?

The wavelength determines the spacing of the interference fringes; knowing it helps analyze wave behavior and validate the wave nature of light.

How can the wavelength of light be experimentally determined in a double-slit setup with known parameters?

By measuring the fringe width (y), slit separation (d), and the distance to the screen (L), then applying the formula □ = (d y) / (m L) for the given order m.

What assumptions are made when calculating the wavelength of light from a double-slit interference pattern?

Assumptions include monochromatic light, coherent sources, small angles for fringes, and that the slit separation and distance to the screen are accurately known and measured.

Can the wavelength of visible light be accurately determined using a double-slit experiment with a slit separation of 2.00 m?

While possible in principle, a slit separation of 2.00 m is unusually large for typical double-slit experiments, which may limit accuracy; more practical setups use smaller slit separations to measure visible light wavelengths precisely.

Additional Resources

What Is The Wavelength Of Light Falling On Double Slits Separated By 2.00 M If The Third-Order Maximum is a fascinating question that delves into the core principles of wave optics and interference phenomena. Understanding this problem requires a solid grasp of the double-slit experiment, the relationship between slit separation, wavelength, and fringe formation. In this guide, we will explore the fundamental concepts, derive the relevant formulas, and walk through the step-by-step process to determine the wavelength of light under the given conditions. Whether you're a student preparing for an exam or an enthusiast keen on wave phenomena, this comprehensive breakdown aims to clarify the concepts and equip you with the tools to solve similar problems confidently.

Understanding the Double-Slit Experiment

Before diving into the calculations, it’s essential to understand what happens when light passes through two closely spaced slits and how interference fringes are formed on a screen.

The Basic Setup

- Source of Light: Monochromatic light of a specific wavelength, □.
- Double Slits: Two narrow apertures separated by a distance, denoted as 'd' (in this case, 2.00 meters).
- Screen: Positioned at a distance 'L' from the slits where the interference pattern is observed.

Interference Pattern

When light waves pass through the two slits, they interfere with each other, creating bright and dark fringes on the screen. The bright fringes, or maxima, occur at points where the waves constructively interfere.

Key Concepts and Formulas

The Condition for Maxima

The position of bright fringes (maxima) on the screen is governed by the interference condition:

$$d \sin \theta = m \lambda$$

where:

- d = distance between the slits (2.00 m)
- θ = angle of the fringe relative to the central maximum
- m = order of the maximum (m = 0, 1, 2, 3, ...)
- λ = wavelength of the light

Fringe Position on the Screen

For small angles (which is typical in double-slit experiments at large distances), $\sin \theta$ can be approximated as:

$$ \sin \theta \approx \tan \theta = \frac{y_m}{L} $$

where:

- y_m = the lateral distance from the central maximum to the m-th maximum on the screen
- L = distance from the slits to the screen

Thus, the position of the m-th maximum is:

$$ y_m = \frac{m \lambda L}{d} $$

Problem Breakdown

Given:

- Slit separation, $d = 2.00\, \text{m}$
- Order of maximum, $m = 3$
- Need to find: wavelength λ

Assuming the problem provides or allows us to determine the position y_3 of the third-order maximum, the general approach involves:

1. Identifying the position of the third maximum on the screen.
2. Applying the formula $y_m = \frac{m \lambda L}{d}$ to find λ.

If the problem provides the position y_3 directly, the calculation is straightforward. If not, additional information such as the distance L or y_3 is needed.

Step-by-Step Solution Approach

Step 1: Gather All Known Data
- Slit separation: $d = 2.00\, \text{m}$
- Order of maximum: $m = 3$
- Distance to screen: L (assumed to be given or measured)
- Position of third maximum: y_3 (measured or provided)

Step 2: Write Down the Relevant Formula
Using the fringe position formula:

$$y_3 = \frac{3 \lambda L}{d}$$

Rearranged to solve for λ:

$$\lambda = \frac{y_3 d}{3 L}$$

Step 3: Plug in Known Values
Insert the known values for y_3, d, and L.

Note: If the value of y_3 or L is not explicitly provided, the problem either expects you to recognize that or to analyze based on typical experimental setups.

Step 4: Calculate Wavelength λ

Suppose, for example, the third maximum occurs at a position $y_3 = 0.30\, \text{m}$, and the screen is placed at $L = 10\, \text{m}$.

Then,

$$\lambda = \frac{0.30\, \text{m} \times 2.00\, \text{m}}{3 \times 10\, \text{m}} = \frac{0.60}{30} = 0.020\, \text{m}$$

or 20 mm, which is unrealistically large for visible light, indicating either the assumptions are off or the problem's data differ.

This example illustrates the importance of accurate, specific data points.

Additional Considerations and Practical Insights

Why Is the Slit Separation So Large?

In realistic experiments, the slit separation d is typically on the order of micrometers (μm), not meters. The problem statement's large value (2.00 m) might be a typo or a hypothetical scenario designed to challenge your understanding.

Adjusting for Realistic Parameters

If the problem intends for you to determine the wavelength of visible light, standard values are:

- Wavelength λ: approximately 400–700 nm (nanometers)
- Slit separation d: often in micrometers

In such cases, if the problem provides the position y_m or the fringe spacing Δy, you can rearrange formulas accordingly.

Summary of the Procedure

1. Identify the order of maximum (m = 3 in this case).
2. Obtain the position y_m of the m-th maximum on the screen.
3. Use the relation $y_m = \frac{m \lambda L}{d}$ to solve for λ.
4. Plug in the known values and compute.

Final Remarks and Tips

- Always check the units and convert them consistently.
- Remember the small-angle approximation holds when θ is small; for large angles, use $\sin \theta$ directly.
- The separation d significantly influences fringe spacing; larger d results in closer fringes.
- If any data is missing, infer or estimate based on typical experimental setups, or clarify assumptions.

Conclusion

Determining the wavelength of light falling on double slits separated by 2.00 meters when observing the third-order maximum involves understanding the interference pattern and applying the fundamental formulas of wave optics. While the problem appears straightforward, the key lies in correctly identifying all parameters, understanding the physical setup, and carefully executing the calculations. By mastering these concepts, you'll be well-equipped to analyze similar interference problems and deepen your understanding of wave phenomena in optics.

What Is The Wavelength Of Light Falling On Double Slits Separated By 2 00 M If The Third Order Maximum

What Is The Wavelength Of Light Falling On Double Slits Separated By 2 00 M If The Third Order Maximum

Related Articles

- Write Verilog Code For A 16:1 Multiplexer That Uses Continuous Assignment And The Conditional Dataflow
- 1. Obtain Root Locus Plot For The Following Open Loop System: S +3 G(s) = (s+5)(s + 2)(s - 1) For Which
- When Examining The Umbilical Cord Immediately After Birth, Which Blood Vessels Are Present In A Normal

Back to Home