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Light:
Light is a source of energy which produces sensation of vision.

Physical Optics:
The branch of physics in which we deals with the wave nature of light is called physical optics.

- In 1678, a Dutch scientist "hygens" proposed that light from a luminious source travel in space as a wave

Wavefront:
Such a surface on which all the points have same phase of vibration.

Explanation- (Page 194)

TYPES

1. Spherical Wavefront 2. Plane Wavefront

SPHERICAL WAVEFRONT

The wave front in which electromagnetic waves are propagated in spherical form is called spherical wavefront.

- Energy transmitted equally in all direction
- The direction in which energy is travelled is called a Ray.

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Plane Wavefront

A small portion of spherical wavefront is called plane wavefront, which is far away from the source.

Hygen's Principle: (Page # 195) 2 points

Interference In Light Waves

- We know for constructive interference the path difference will be

$$\Delta S = n\lambda$$

where $n = 0, 1, 2, 3 \ldots$

In this case its called maxima or bright fringe or bright band

- For destructive interference the path difference will be

$$\Delta S = (2n+1)\frac{\lambda}{2}$$

$$= \cancel{2}\left(n+\frac{1}{2}\right)\frac{\lambda}{\cancel{2}}$$

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

where $n = 0, 1, 2, 3 \ldots$

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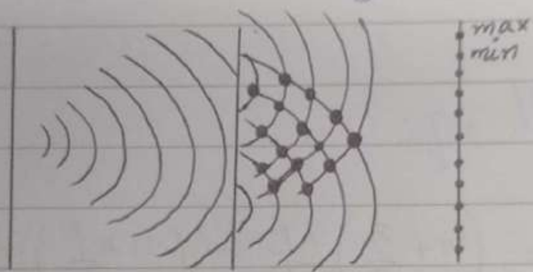
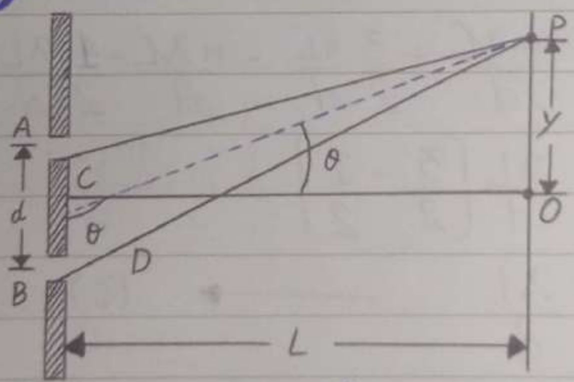
Young Double Slit Experiment

In **1801**, an English Scientist **Thomas Youngs** performed an experiment to prove the wave nature of light.

- A single slit is illuminated by a non chromatic source of light having single wavelength "λ" as shown.
- Light is thus passing through next two slits and interfere each other and form bridght and dark fringes on screen as shown



Explanation:



Consider two rays that coming from two slits and reached at a point 'P' named as "AP" and "BP"
We observe 'BP' is large ray as compared to ray 'AP'
So 'BD' is the path difference b/w these two rays. So, now consider $\triangle ABD$

BD = perpendicular
AB = base = d

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$$\sin\theta = \frac{BD}{AB}$$

$$\sin\theta = \frac{BD}{d}$$

$$BD = d\sin\theta \longrightarrow \quad (1)$$

For bright fringe:

Suppose if maxima is formed at point 'P'. So for

$$\text{Bright fringe} = n\lambda \longrightarrow \quad (2)$$

Compare 1 and 2

$$d\sin\theta = n\lambda \longrightarrow \quad (3)$$

$$n = 0, 1, 2, 3 \ldots\ldots$$

For Dark fringe:

Suppose if minima is formed at point 'P'. So for:

$$\text{Dark fringe} = \left(n + \frac{1}{2}\right)\lambda \longrightarrow \quad (4)$$

Compare 1 and 4

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

$$n = 0, 1, 2, 3 \ldots$$

(Calculations for frindge and Fringe spacing)

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In this case, its called minima or dark fringe or dark band

Explanation:- Page # 195 + 196 (MCQs + SIQs)

Calculations for fringes (Part of Young Double Slit Exp)

For this we consider triangle $\triangle COP$ in which.

CO = base $= L$

OP = prep $= Y$

So

$$\tan\theta = \frac{Prep}{base} = \frac{Y}{L}$$

$$\tan\theta = \frac{Y}{L}$$

$$Y = L\tan\theta$$

For very small angle we observe maximas and minimas are very close to each other So the angle are very small between the fringes

So

$$\sin\theta \approx \tan\theta$$

So above equation becomes

$$Y = L\sin\theta \longrightarrow (a)$$

For maxima we know

$$d\sin\theta = n\lambda$$

$$\sin\theta = \frac{n\lambda}{d}$$

Put this in equ (a) we get

$$Y = \frac{Ln\lambda}{d}$$

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Now for minima we know.

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

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

Put this in equ (a) we get.

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

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

Fringe Spacing

Now we calculate the distance b/w the two consecutive maximas or minimas called fringe spacing so for bright fringe
The nth fringe will be

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

Every next bright fringe

$$Y_{n+1} = (n+1)\frac{\lambda L}{d}$$

Substract both equ

$$Y_{n+1} - Y_n = (n+1)\frac{\lambda L}{d} - \frac{n\lambda L}{d}$$

$$= \frac{\cancel{n\lambda L}}{\cancel{d}} + \frac{\lambda L}{d} - \frac{\cancel{n\lambda L}}{d}$$

$$\Delta Y = \frac{\lambda L}{d} \longrightarrow (b)$$

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Now for dark fringe
Consider nth dark band

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

Very next nth band

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

$$Y_{n+1} = \left(n+\frac{3}{2}\right)\frac{\lambda L}{d}$$

(MCQs)

We also observe its directly proportional to the distance b/w slit and screen "L" and inversely proportional to the separation b/w the slit "d"

Fringe spacing increase if we use red light as compared to blue light.

Now
Substract both equ

$$Y_{n+1} - Y_n = \left(n+\frac{3}{2}\right)\frac{\lambda L}{d} - \left(n+\frac{1}{2}\right)\frac{\lambda L}{d}$$

$$= \cancel{\frac{n\lambda L}{d}} + \frac{3}{2}\frac{\lambda L}{d} - \cancel{\frac{n\lambda L}{d}} - \frac{1}{2}\frac{\lambda L}{d}$$

$$= \frac{\lambda L}{d}\left[\frac{3}{2}-\frac{1}{2}\right]$$

$$\Delta Y = \frac{\lambda L}{d} \longrightarrow (c)$$

We observe both equ (b) and (c) frindge spacing are same between the fringes

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Numericals

Q.1: Given Data:

Wavelength $= \lambda = 546 nm$
$= 546 \times 10^{-9} m$

Separation between the slit $= d = 0.10 mm$
$= 0.10 \times 10^{-3} m$

Distance of screen to slit $= L = 20 cm$
$= 20 \times 10^{-2} m$

To Find:

Angle $= \theta = ?$

Fringes spacing $= \Delta y = ?$

Calculated:

$$d \sin \theta = \left(n + \frac{1}{2}\right) \lambda \qquad n = 0 \text{ (Minima)}$$

$$d \sin \theta = \left(0 + \frac{1}{2}\right) \lambda$$

$$d \sin \theta = \frac{1}{2} (546 \times 10^{-9} m)$$

$$d \sin \theta = 2.73 \times 10^{-7} m$$

$$\sin \theta = \frac{2.73 \times 10^{-7}}{0.10 \times 10^{-3}}$$

$$\theta = \sin^{-1} (2.73 \times 10^{-3})$$

$$\theta = 0.156^{\circ}$$

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

$$= \frac{546 \times 10^{-9} \times 20 \times 10^{-2}}{0.10 \times 10^{-3}}$$

$$= 1.092 \times 10^{-3} m$$

$$\Delta Y = 1.09 mm$$

9.2: Given Data:

Separation $= d = 0.5 mm = 0.5 \times 10^{-3} m$

Distance $= L = 200\ cm$

$= 200 \times 10^{-2} m$

First bright fringe $= m = 1$

Distance $= Y = 2.40 mm$

$= 2.40 \times 10^{-3} m$

To Find: Wavelength $= \lambda = ?$

Calculated:

$$Y = \frac{\lambda L}{d}$$

$$\lambda = \frac{Yd}{L}$$

$$\lambda = \frac{2.40 \times 10^{-3} \times 0.5 \times 10^{-3}}{200 \times 10^{-2}}$$

$$\lambda = 6 \times 10^{-7} m$$

$$\lambda = 600 \times 10^{-9} m$$

$$\lambda = 600 nm$$

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9.3: Given Data:

Second Order maxima $= n = m = 2$

$\theta = 0.25°$

$\lambda = 650\,nm$

$= 650 \times 10^{-9}\,m$

To Find: Slit Separation $= d = ?$

Calculated:

$$d \sin\theta = n\lambda$$

$$d = \frac{n\lambda}{\sin\theta}$$

$$d = \frac{2 \times 650 \times 10^{-9}}{\sin(0.25)}$$

$$d = 0.30 \times 10^{-3}\,m$$

$$d = 0.30\,mm$$

9.4: Given Data:

$\lambda = 588\,nm$

$= 588 \times 10^{-9}\,m$

Distance by $M_1 = L = 0.233\,mm$

$= 0.233 \times 10^{-3}\,m$

To Find:

Number of fringes $= m = ?$

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Calculated:

$$L = m\frac{\lambda}{2}$$

$$m = \frac{2L}{\lambda}$$

$$m = \frac{2\times 0.233\times 10^{-3}}{588\times 10^{-9}}$$

$$m = 7.92\times 10^{-2}$$

$$m = 729$$

Formulas

$d\sin\theta = n\lambda$

$L = \frac{m\lambda}{2}$

$2d\sin\theta = n\lambda$

$d = \frac{L}{N}$

9.5: Given Data:

Second Order $= n = 2$

$\theta = 38°$

$N = 5400\ \text{lines}/\text{cm}$

$N = 540000\ \text{lines}/\text{m}$

$N = 5400\ \text{lines}/\text{cm}$

$N = 5400\ \frac{\text{lines}}{10^{-2}\text{m}}$

$N = 540000\ \frac{\text{lines}}{\text{m}}$

To Find: $\lambda = ?$

Calculated:

$$d\sin\theta = n\lambda$$

$\therefore d = \frac{1}{N}$

So

$$\frac{1}{N}\sin\theta = n\lambda$$

$$\frac{\sin\theta}{N\times n} = \lambda$$

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$$\frac{\sin 38}{540000 \times 2} = \lambda$$

$5.69 \times 10^{-7} m = \lambda$

$570 \times 10^{-9} m = \lambda$

$\lambda = 570 nm$

9.6: Given Data:

Number of lines $= N = 2500 \frac{lines}{cm}$

$= 250000/m$

$\theta = 15°$

$n = 2$

To Find: $\lambda = ?$

Calculated:

$d \sin\theta = n\lambda$

$\frac{1}{N} \sin\theta = n\lambda$

$$\frac{\sin\theta}{N \times n} = \lambda$$

$$\frac{\sin 15}{250000 \times 2} = \lambda$$

$\lambda = 5.176 \times 10^{-7} m$

$\lambda = 517.6 \times 10^{-9} m$

$\lambda = 518 nm$

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9.7: Given Data:

$\lambda = 589 nm = 589 \times 10^{-9} m$

$N = 3000 \text{ lines}/cm$

$N = 300000/m$

$\theta = 90°$

To Find: Highest Order $= n = ?$

Calculated:

$d \sin\theta = n\lambda$

$n = \frac{d \sin\theta}{\lambda}$ $\therefore d = \frac{1}{N}$

$n = \frac{\sin\theta}{N\lambda}$ $N = \frac{\sin\theta}{n\lambda}$

$n = \frac{\sin 90}{300000 \times 589 \times 10^{-9}}$

$n = 5.66$

$n = 5^{th}$ order