



# PRAYAS

## JEE 2025

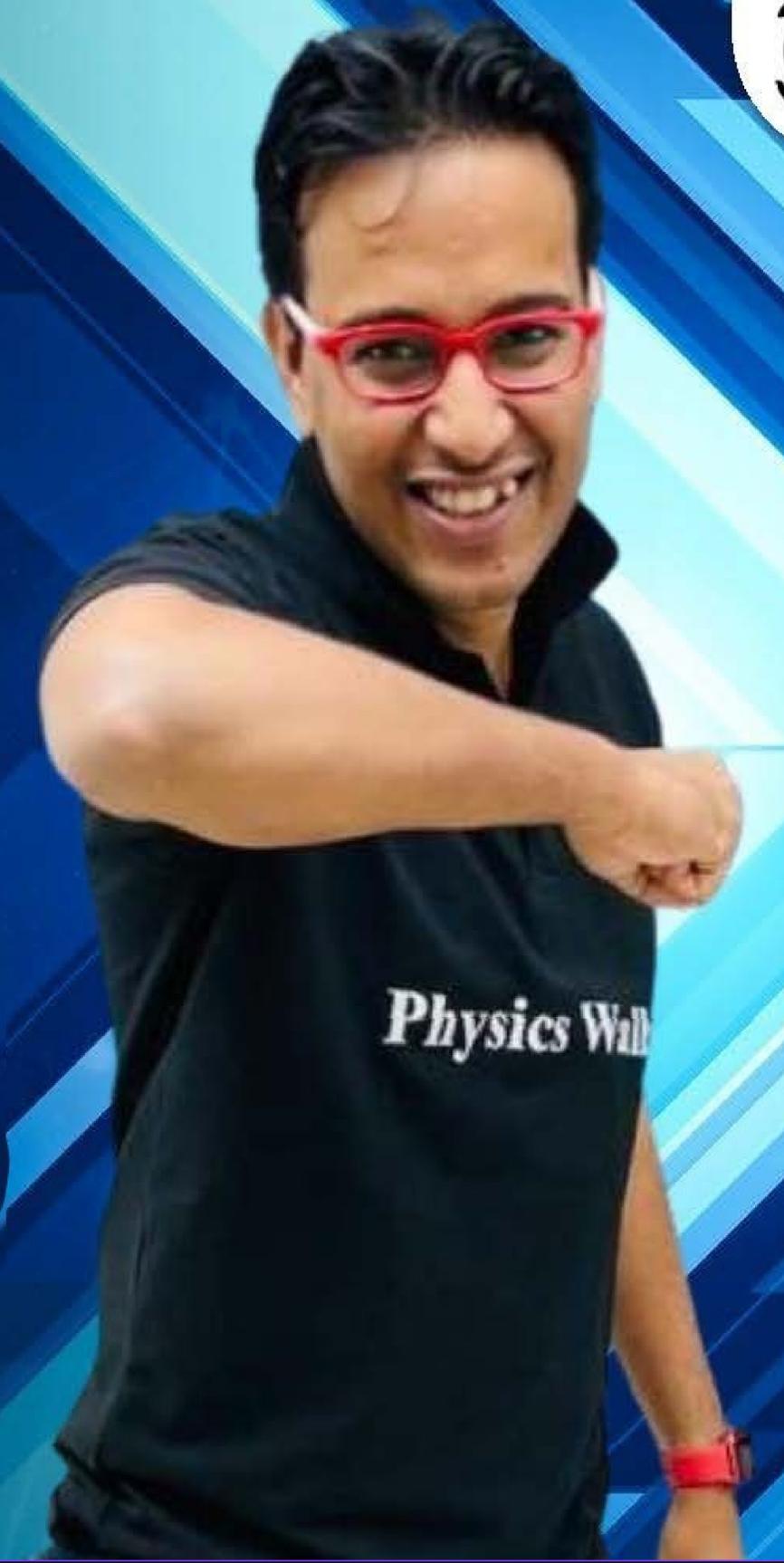
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Lecture - 04

Physics

### Wave Optics

By- Saleem Ahmed Sir





# Topics *to be covered*

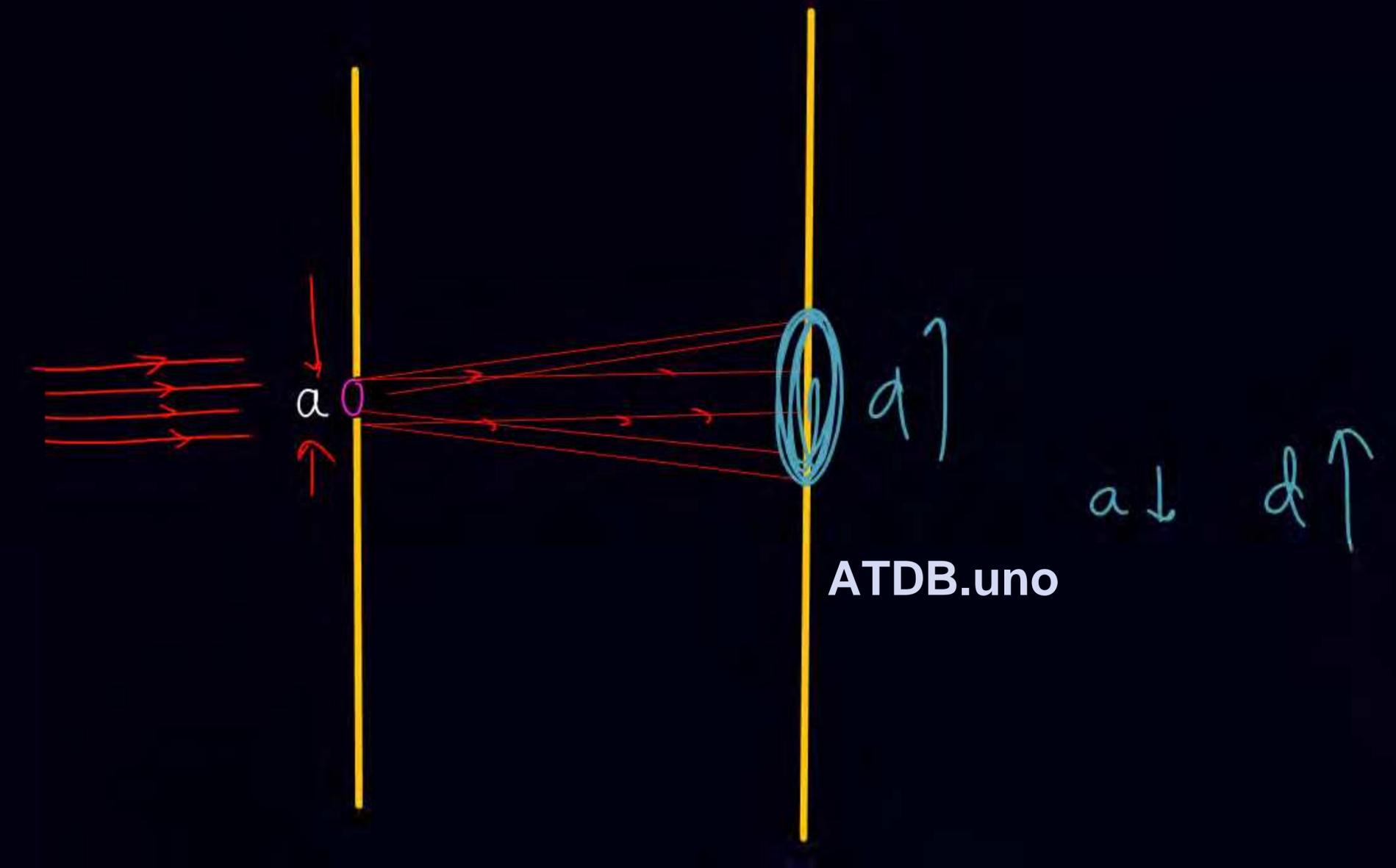
**1** Diffraction

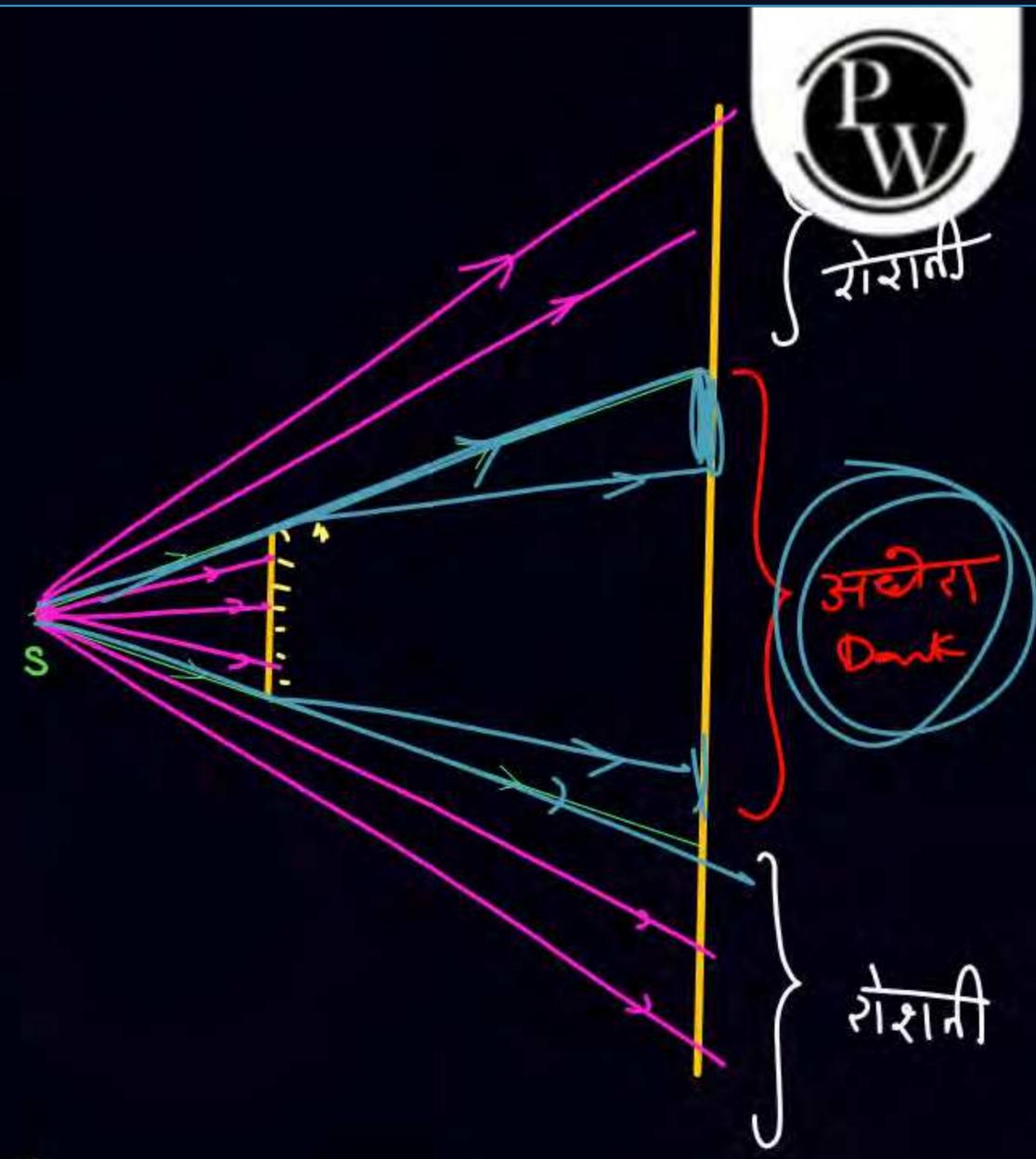
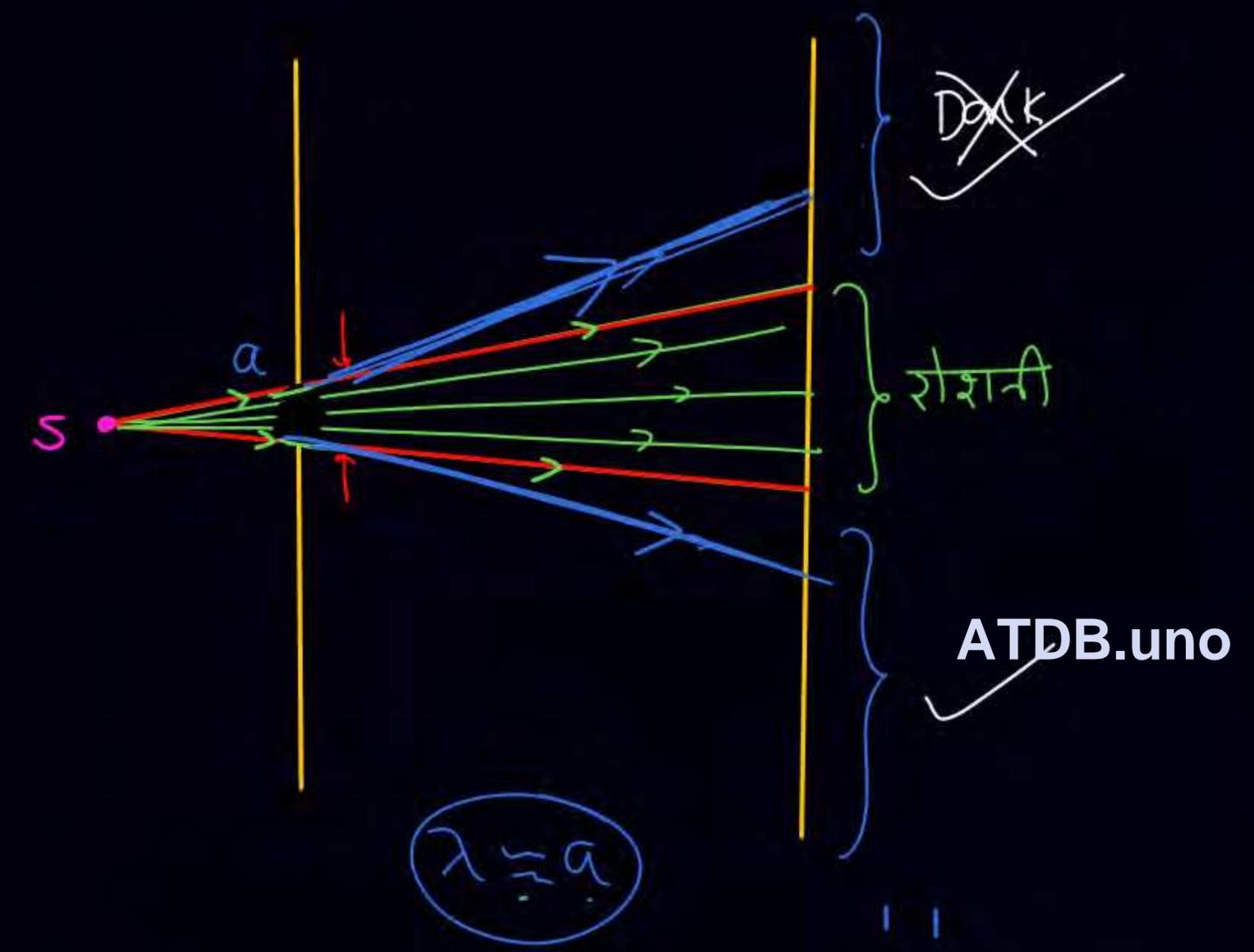
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**2**

**3**

**4**





## THE DIFFRACTION OF LIGHT

When a wave is obstructed by an obstacle, the rays bend round the corner. This phenomenon is known as *diffraction*. We can explain the effect using Huygens' principle. When a wavefront is partially obstructed, only the wavelets from the exposed parts superpose and the resulting wavefront has a different shape. This allows for the bending round the edges. In case of light waves, beautiful fringe patterns comprising maximum and minimum intensity are formed due to diffraction.

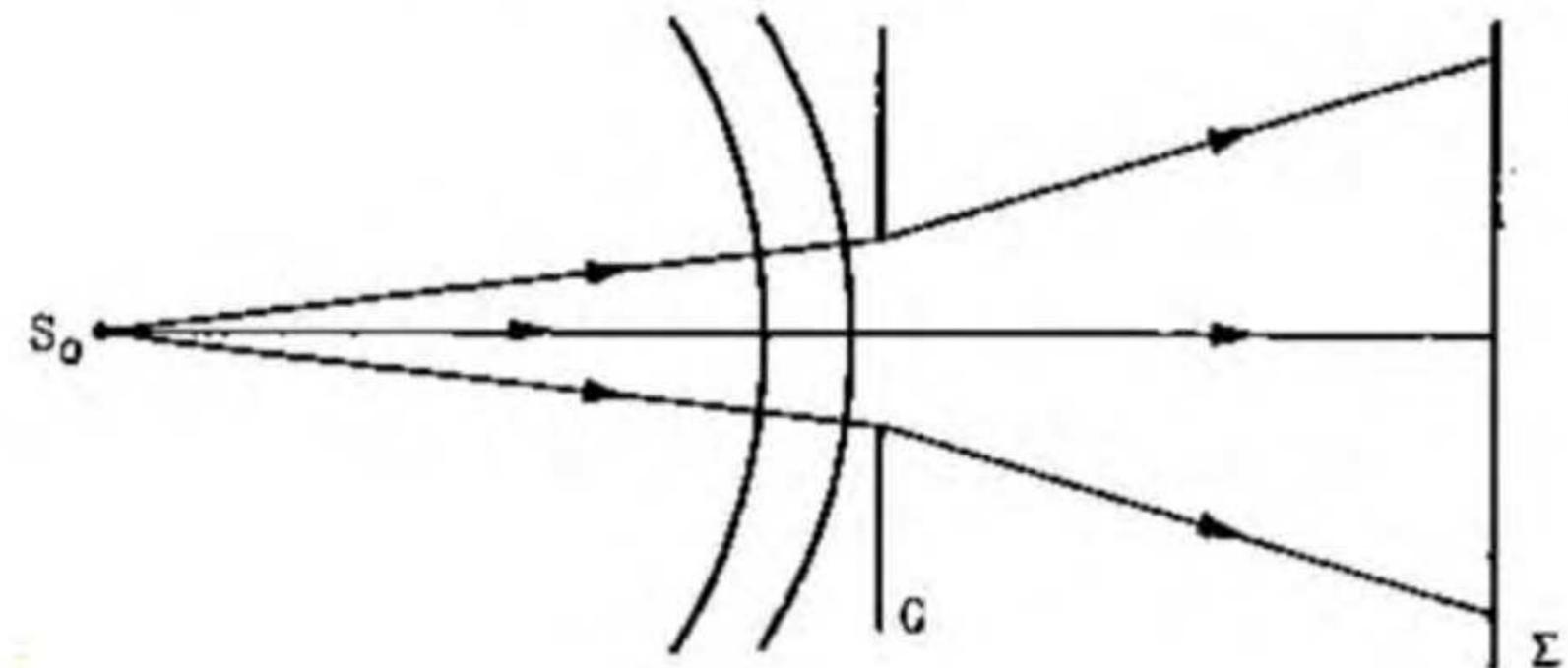


Figure 17.11

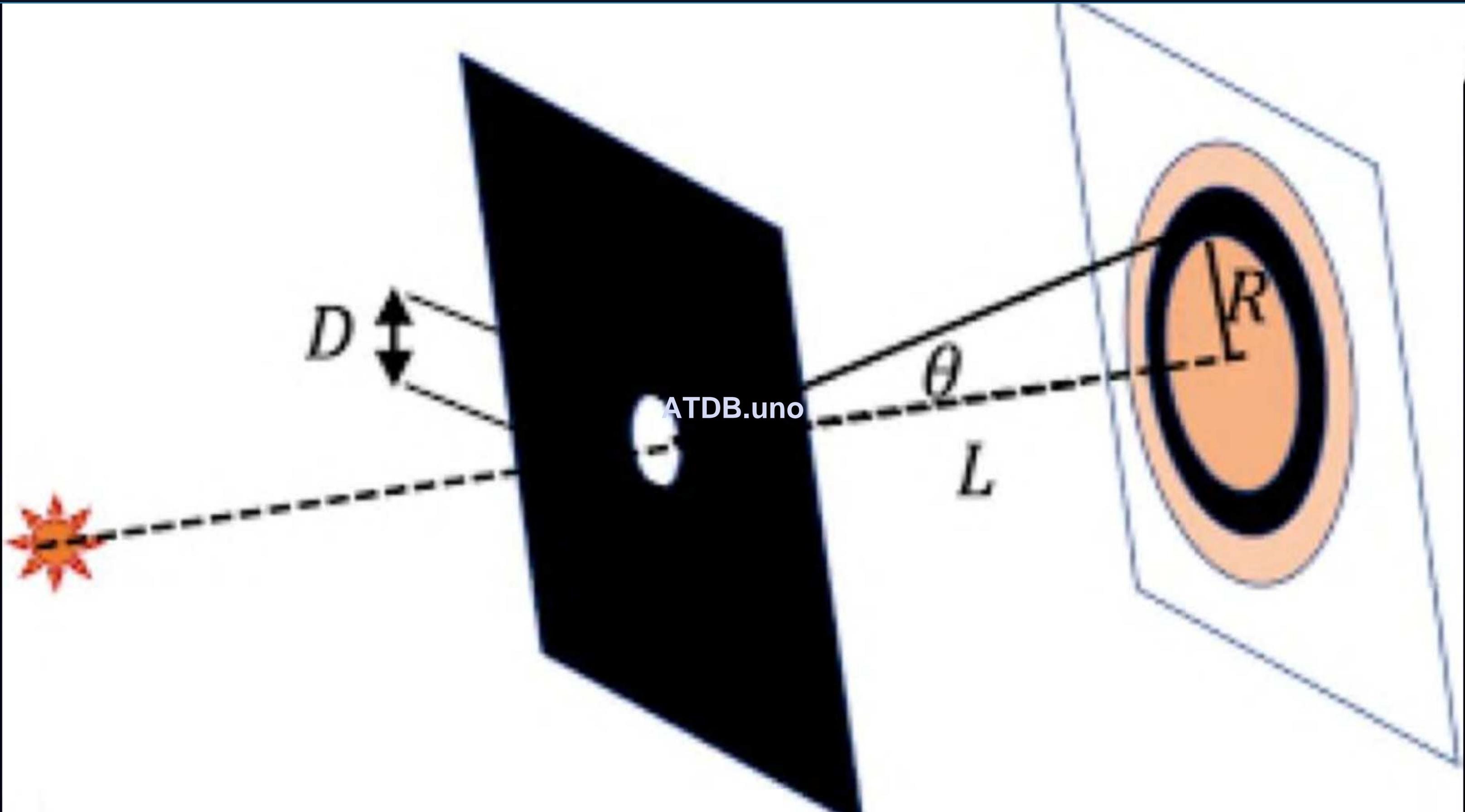




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# FRAUNHOFER DIFFRACTION BY A CIRCULAR APERTURE

The mathematical analysis shows that the first dark ring is formed by the light diffracted from the hole

at an angle  $\theta$  with the axis  $\sin \theta = \frac{1.22\lambda}{b}$ .

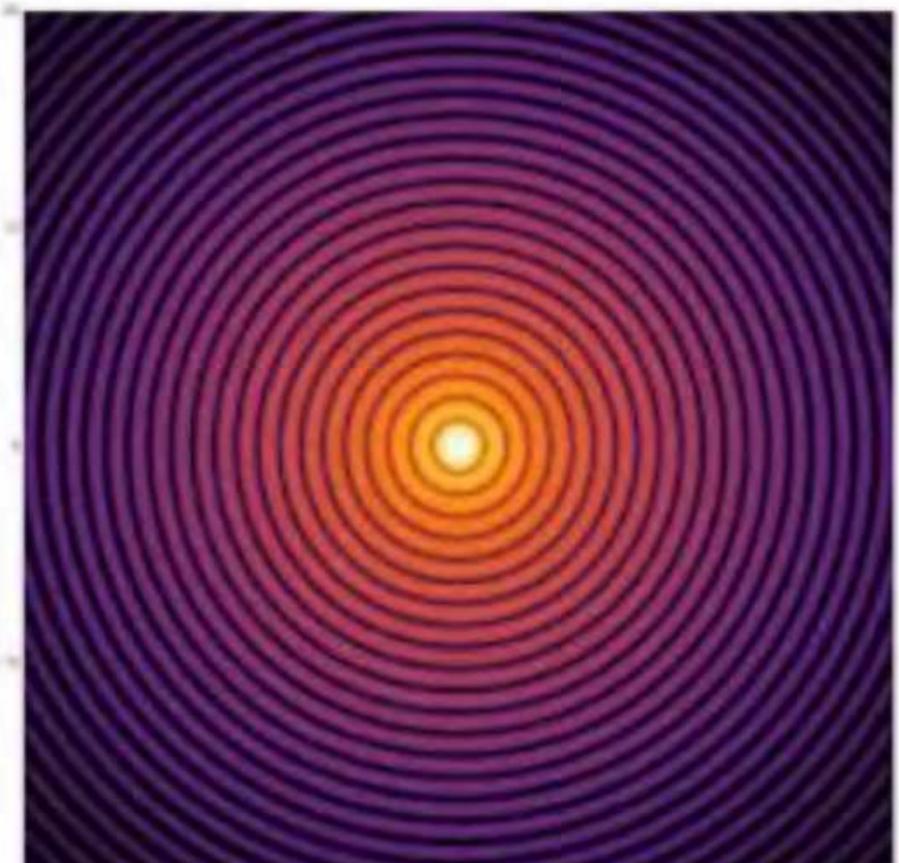
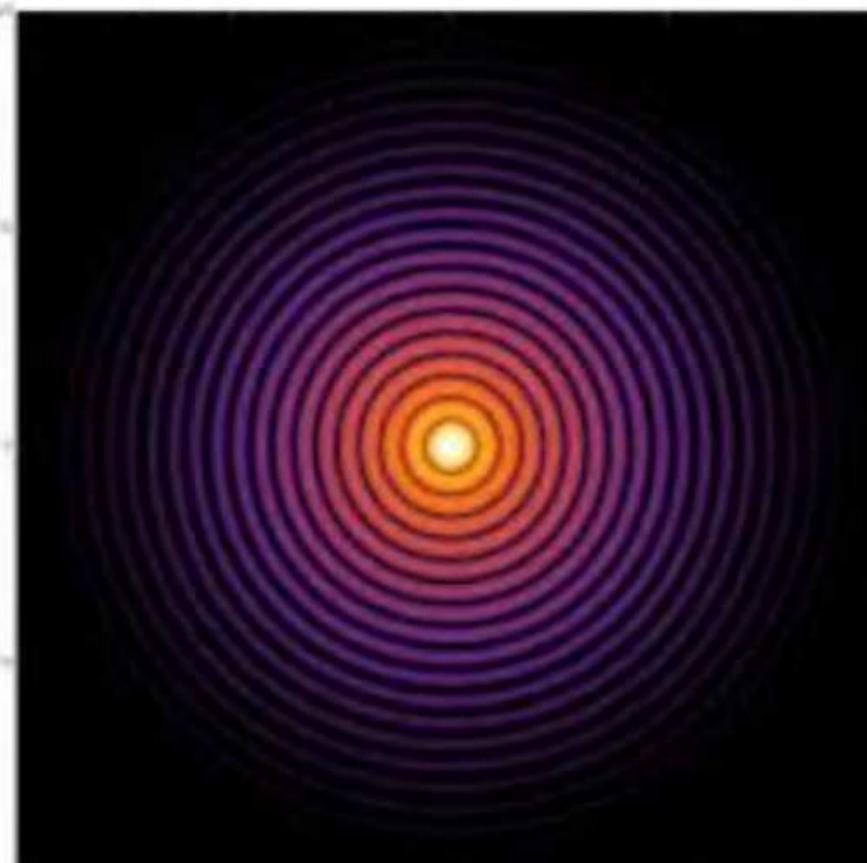


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The radius of the diffraction disc is given by  $R = \frac{1.22\lambda D}{b}$ ,



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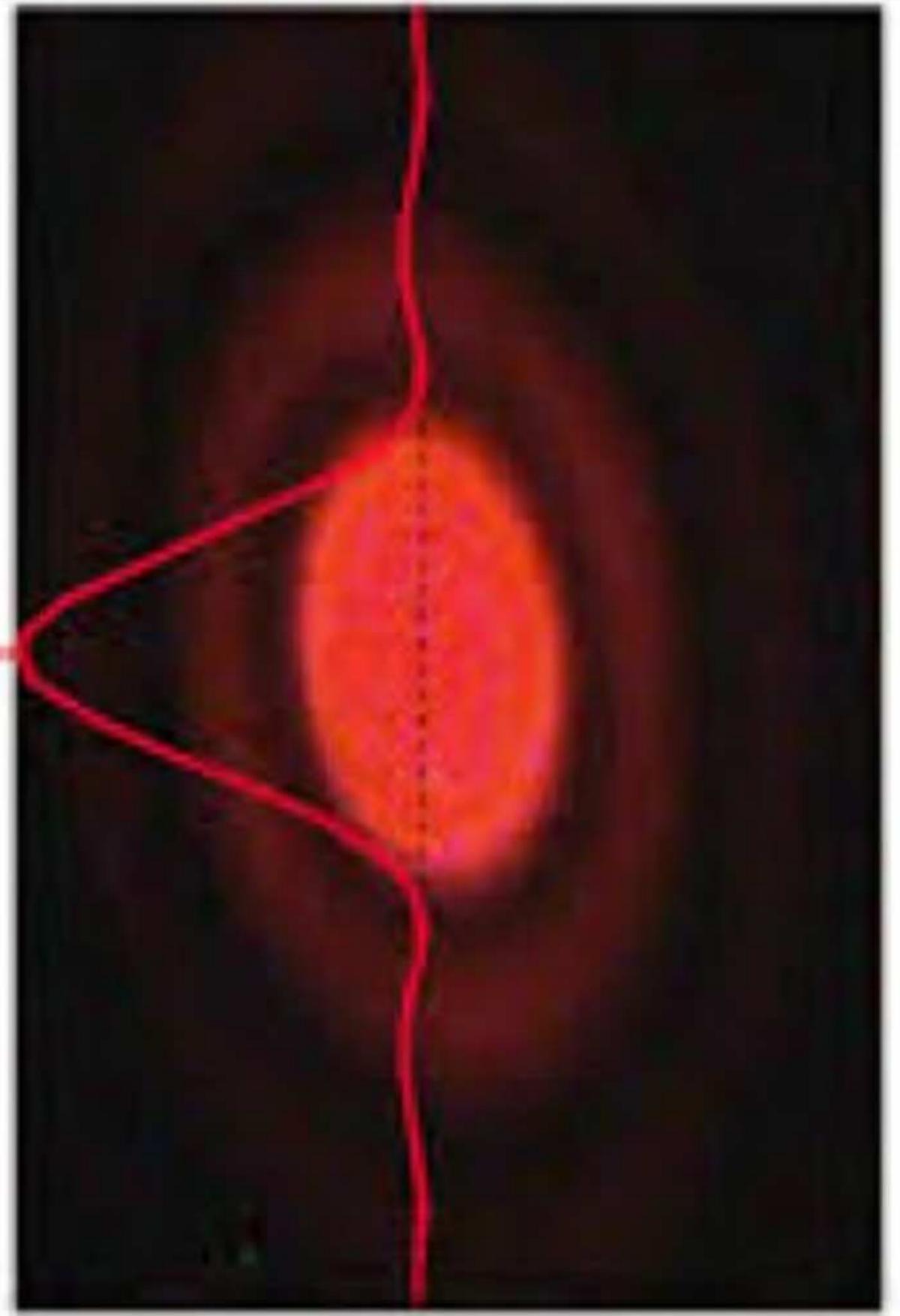
# DIFFRACTION

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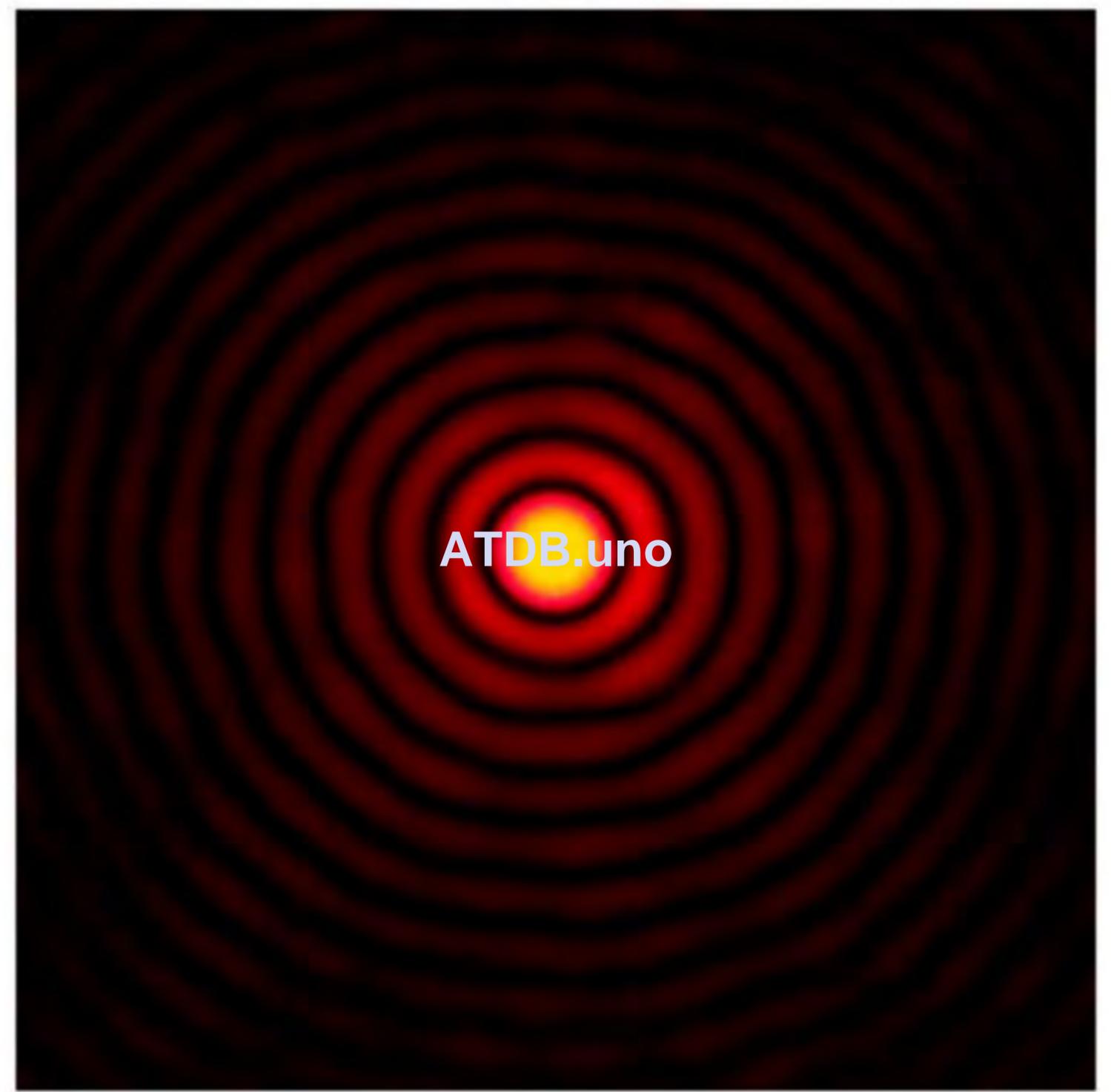
Laser



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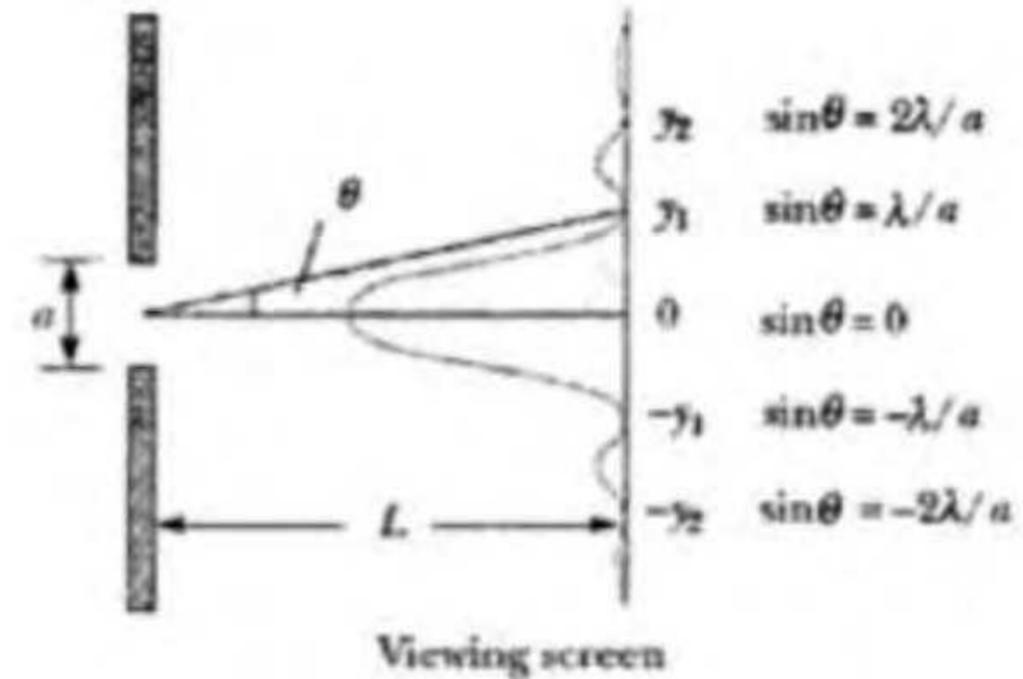


# DIFFRACTION BY CIRCULAR APERTURE 'AIRY DISK'



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## Properties of dark & bright fringes:



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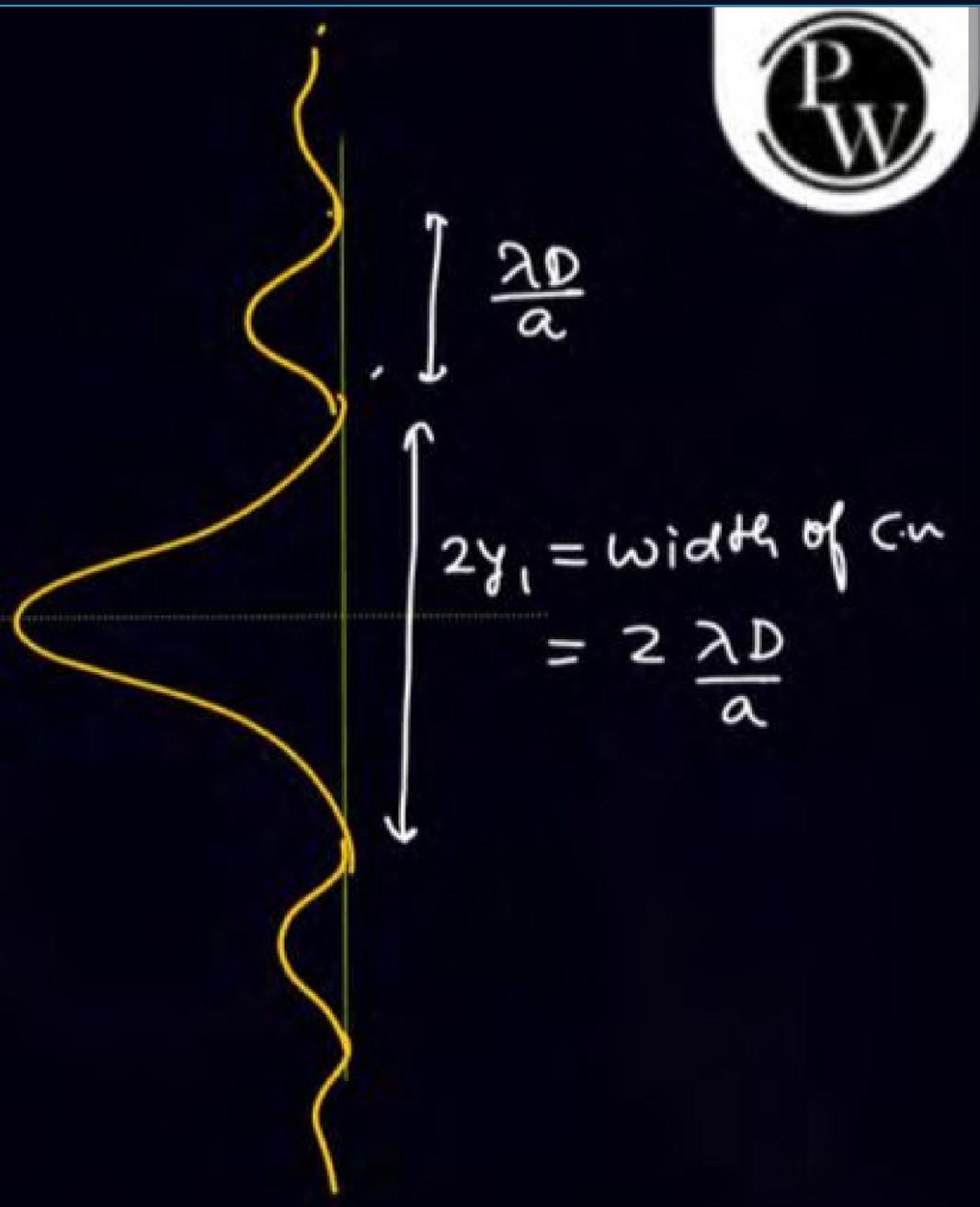
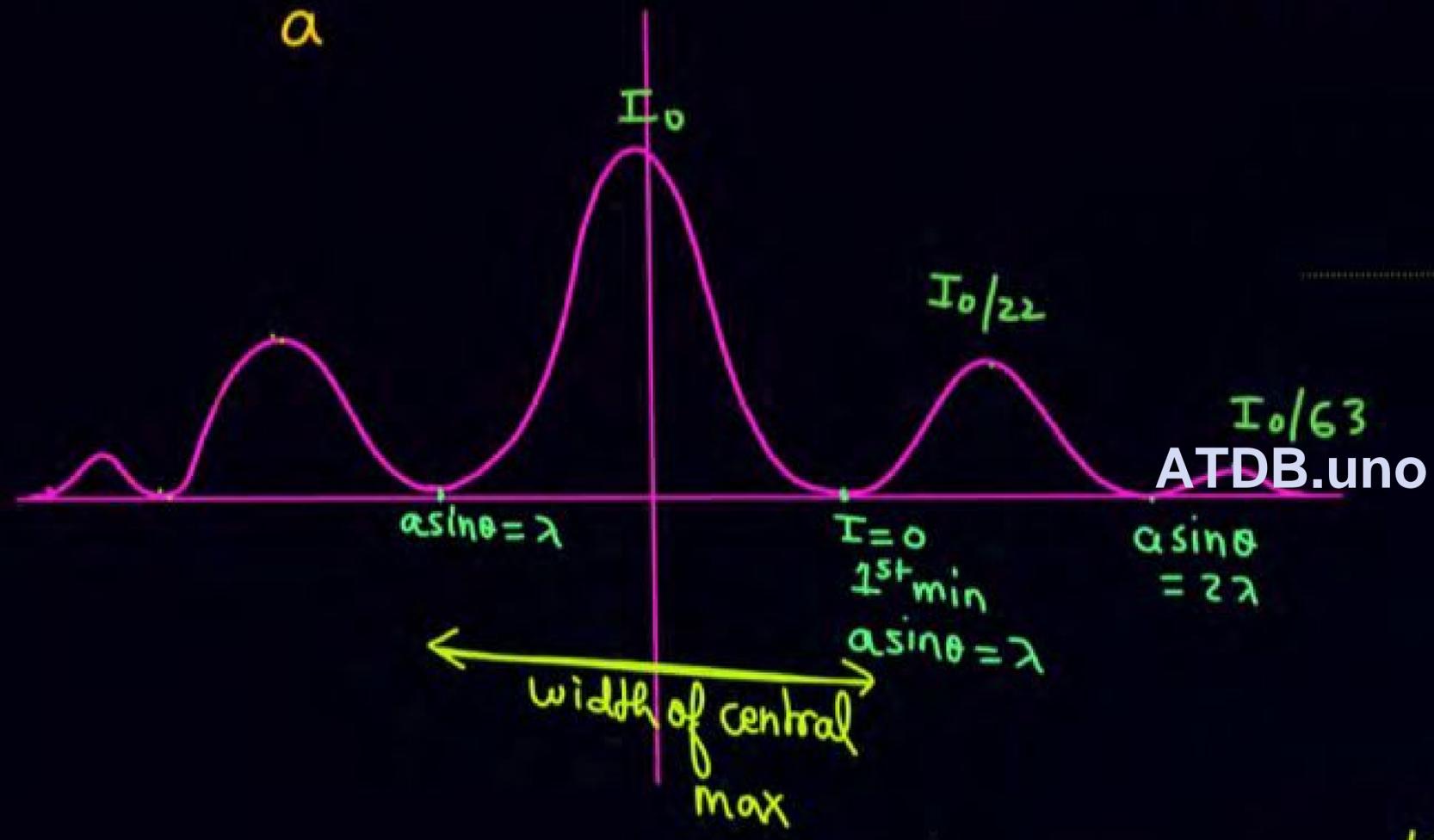
- It results from superposition of secondary wavelets originating from various parts of single coherent source.
- Diffraction fringes are never of equal width.
- Intensity of all the bright fringes is not the same.
- Dark fringes are not perfectly dark.



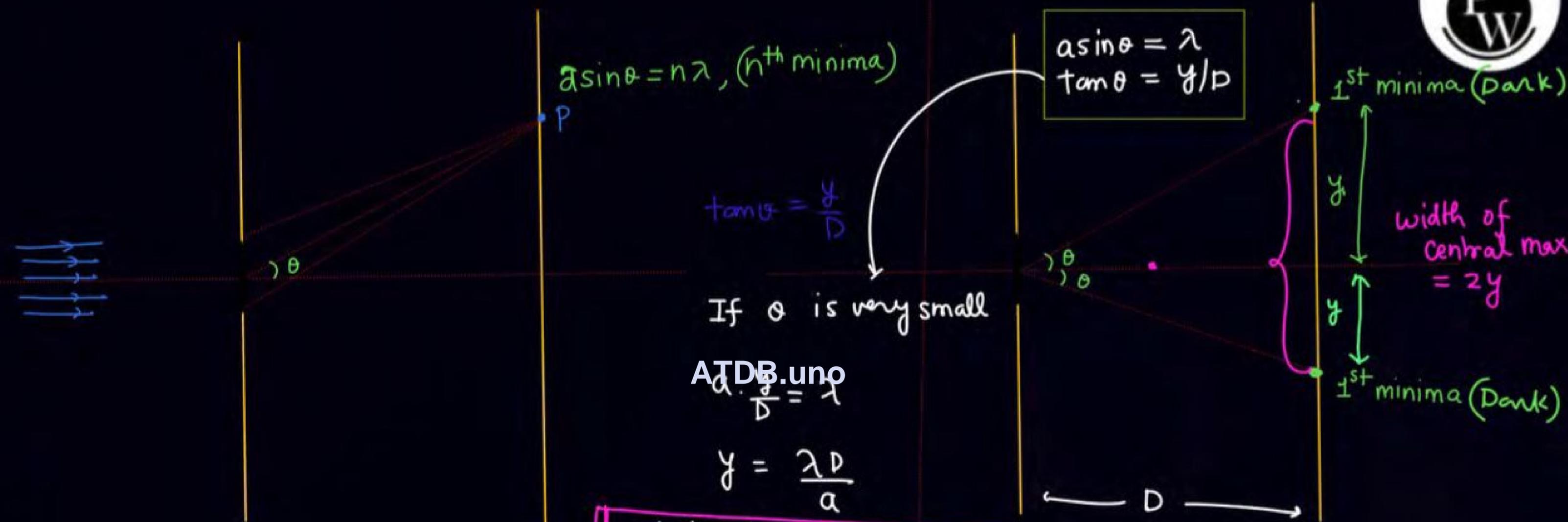
→  $I = I_{max} \left( \frac{\sin \alpha}{\alpha} \right)^2$



a



$$w = \frac{2 \lambda D}{a}$$



$a \sin \theta = n \lambda$ , ( $n^{\text{th}}$  minima)

$a \sin \theta = \lambda$   
 $\tan \theta = y/D$

$\tan \theta = \frac{y}{D}$

If  $\theta$  is very small

$a \cdot \frac{y}{D} = \lambda$

$y = \frac{\lambda D}{a}$

width of central  
 Max =  $2y = \frac{2\lambda D}{a}$

1<sup>st</sup> minima (Dark)

1<sup>st</sup> minima (Dark)

width of central max =  $2y$



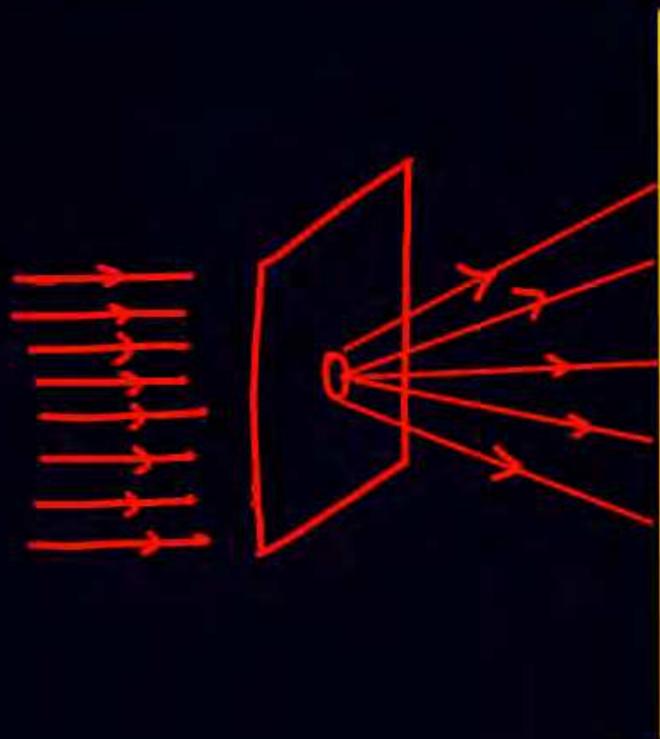
Diffraction → Bending of light rays from sharp edges of an opaque obstacle or aperture and its spreading in the shadow region is defined as diffraction of light or deviation of light from its rectilinear propagation.

- \* Size of an obstacle or aperture should be nearly equal to the wavelength of light

$$\lambda \approx a$$

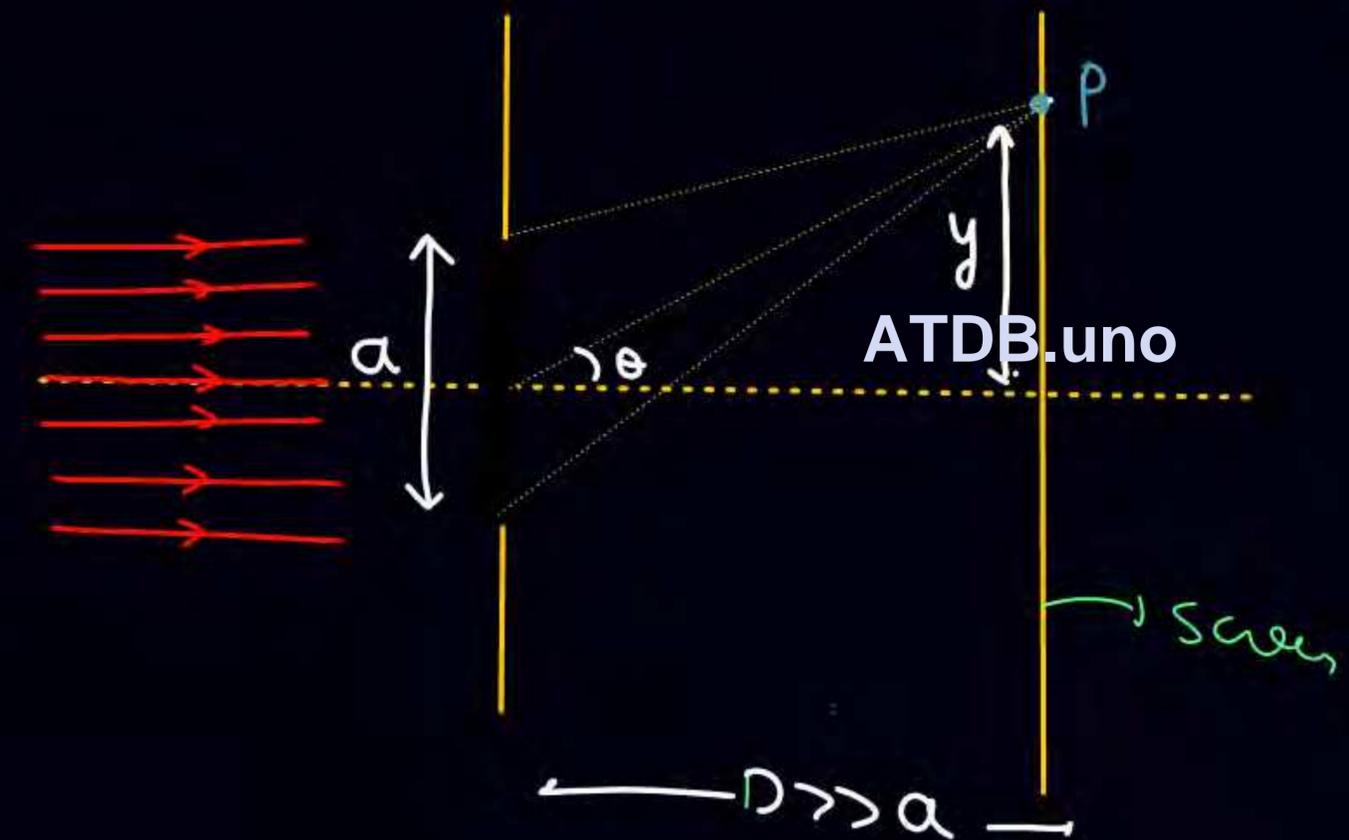
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- \* If  $\lambda \ll a \Rightarrow$  Then rectilinear motion of light is observed.



# Fraunhofer Diffraction

## Diffraction through single slit

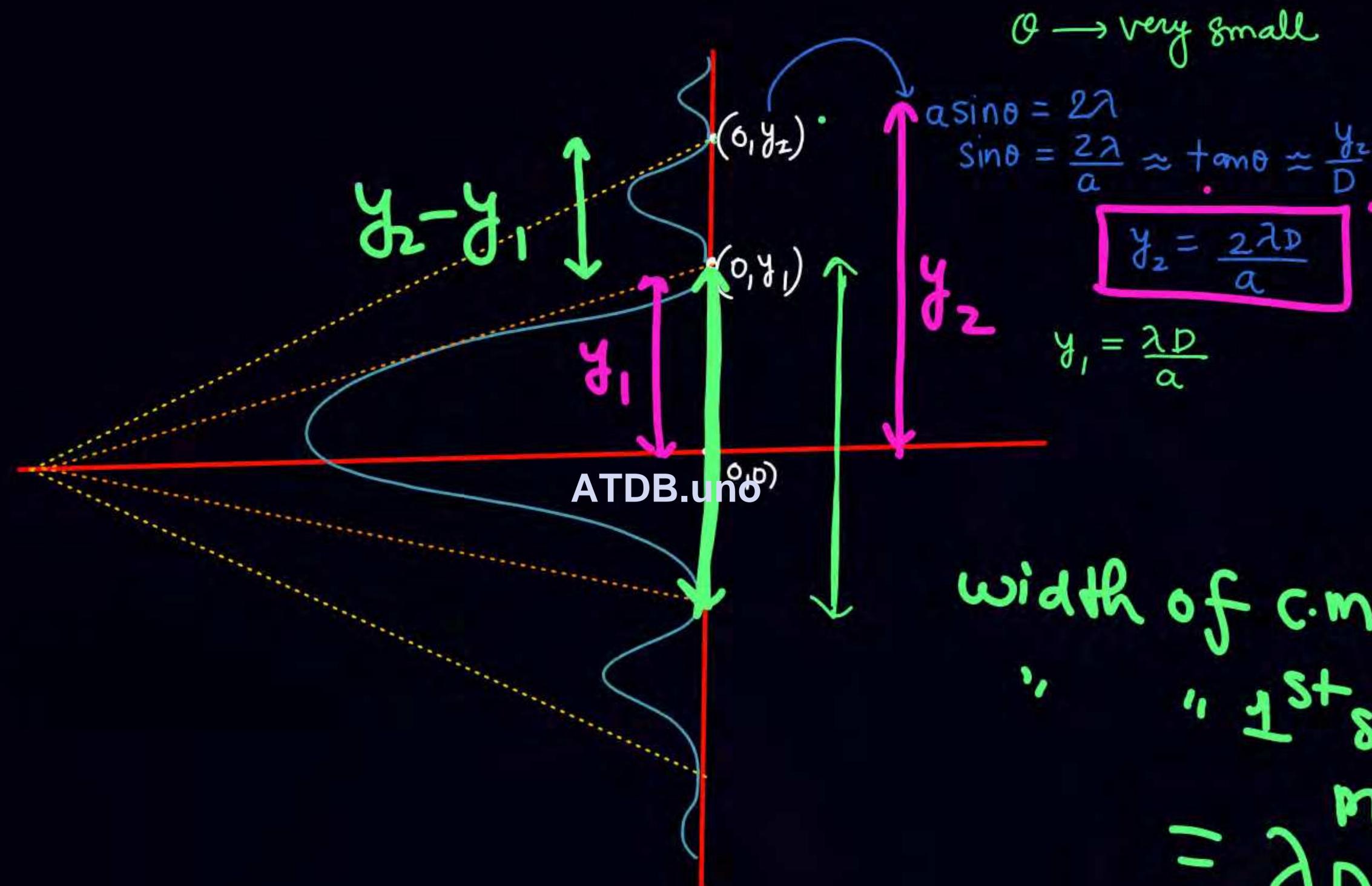


$$a \sin \theta = n \lambda \quad (n^{\text{th}} \text{ minima})$$

$$\tan \theta = \frac{y}{D}$$

$$\begin{cases} a \sin \theta = \lambda & (1^{\text{st}} \text{ minima}) \\ a \sin \theta = 2\lambda & (2^{\text{nd}} \text{ minima}) \\ a \sin \theta = \frac{3\lambda}{2} & (1^{\text{st}} \text{ secondary max.}) \end{cases}$$





width of c.m =  $2y_1$   
 " " 1<sup>st</sup> second  
 =  $\frac{\lambda D}{a}$  max

(SKC)

काम का सब



$$a \sin \theta = n \lambda \text{ (for } n^{\text{th}} \text{ minima)}$$

$$\text{width of central maxima} = \frac{2 \lambda D}{a}$$

$$\text{Angular spread} = 2\theta = \frac{2 \lambda}{a}$$

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For any stylebaji Use  $\Rightarrow \tan \theta = y/D$

$$a \sin \theta = n \lambda$$

$\downarrow$   
( $n^{\text{th}}$  minima)

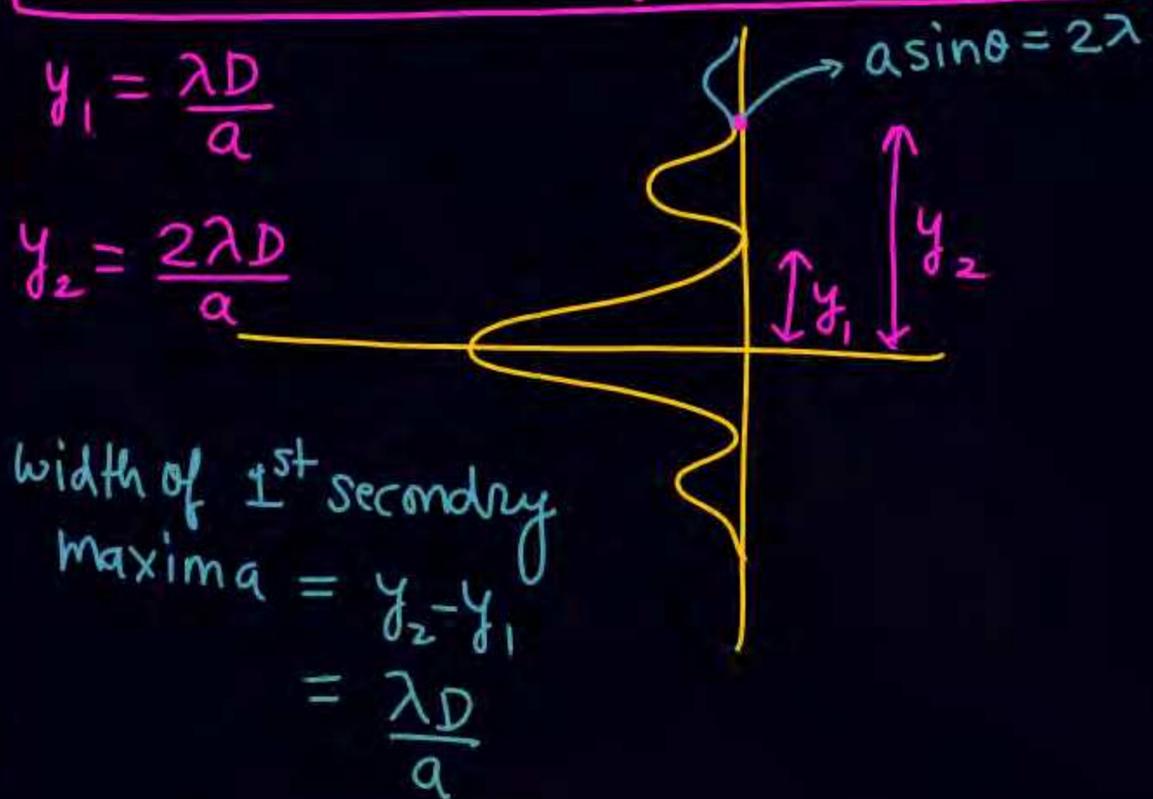
If  $\theta$  is very small

$$\text{width of central max} = \frac{2 \lambda D}{a}$$

$$\text{width of } 1^{\text{st}} \text{ secondary max} \equiv \lambda D/a$$

$$y_1 = \frac{\lambda D}{a}$$

$$y_2 = \frac{2 \lambda D}{a}$$



$$\begin{aligned} \text{width of } 1^{\text{st}} \text{ secondary} \\ \text{maxima} &= y_2 - y_1 \\ &= \frac{\lambda D}{a} \end{aligned}$$



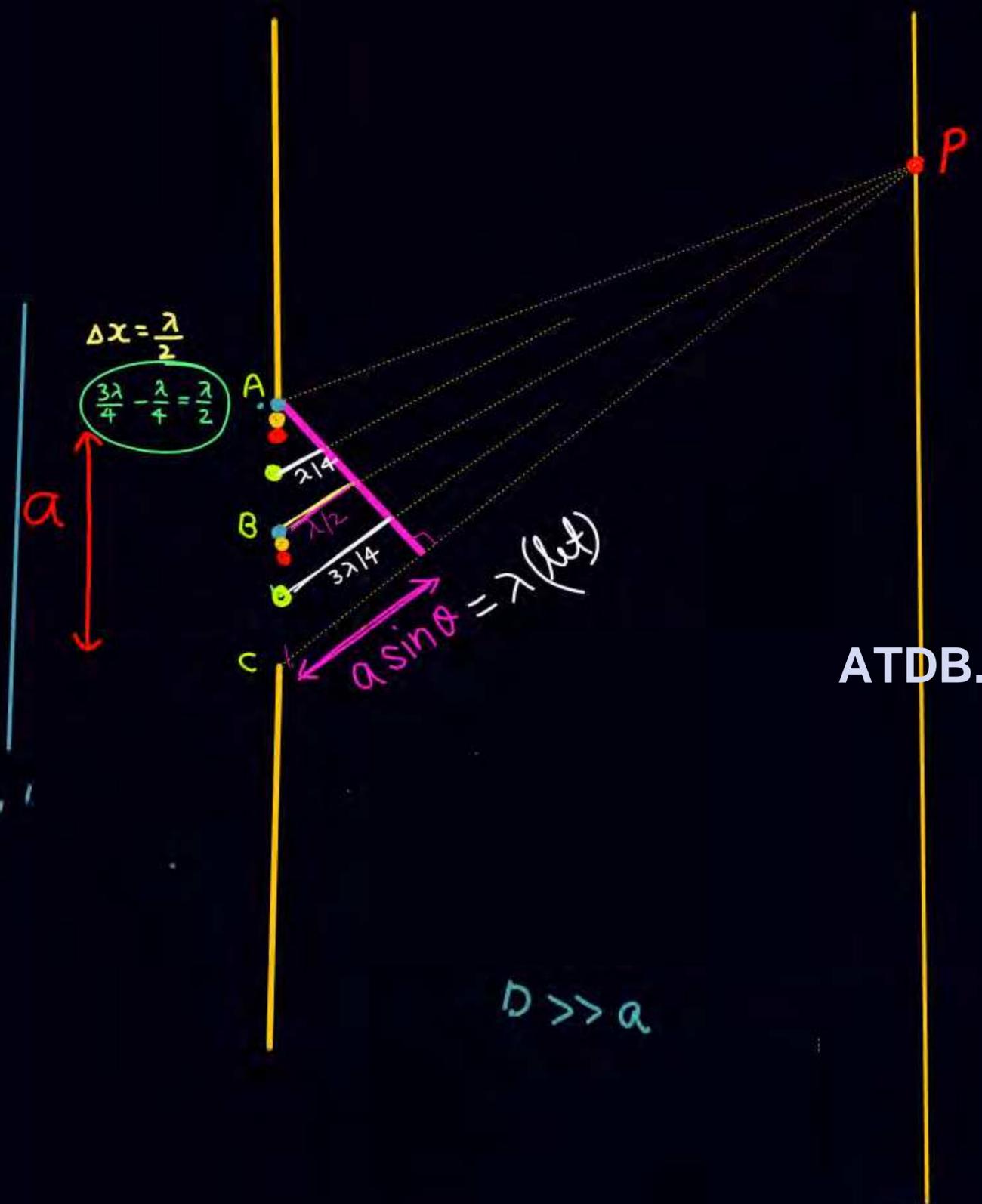
$$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda} = \frac{\lambda}{2} \cdot \frac{1}{\lambda}$$

$$\Delta\phi = \frac{1}{2} 2\pi$$

$$\Delta\phi = \pi$$

$$\Delta x = \frac{\lambda}{2}$$

$$\frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$$

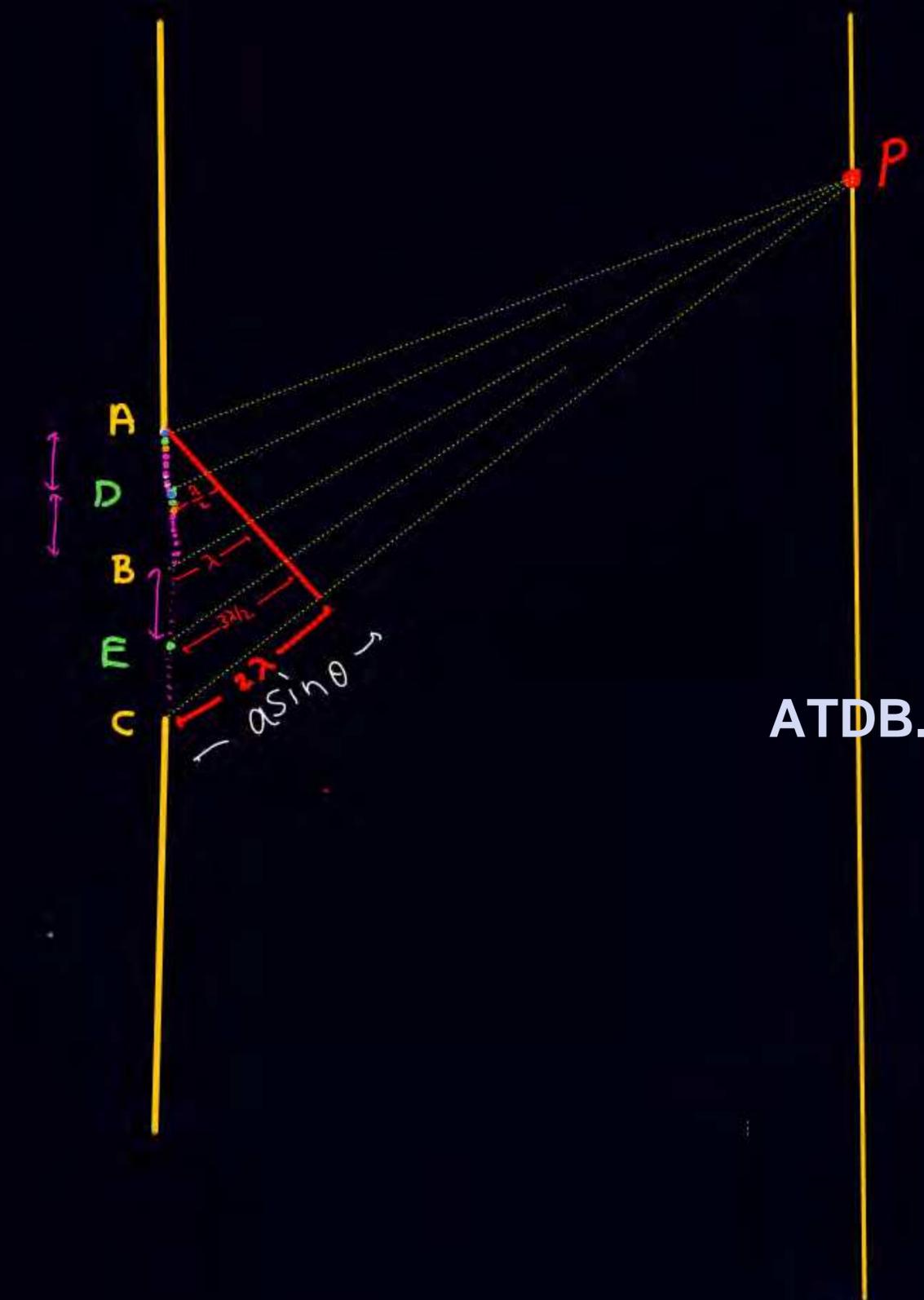


$$a \sin \theta = \lambda \text{ (Let) } (\underline{1}^{\text{st}} \text{ Minima})$$

$$a \sin \theta = 2\lambda = (2^{\text{nd}} \text{ Minima})$$

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$$D \gg a$$



$a \sin \theta = \lambda$  (Let)  
(1<sup>st</sup> Minima)

$a \sin \theta = 2\lambda$  = (2<sup>nd</sup> minima)

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$a \sin \theta = \lambda$  1<sup>st</sup> minima  
 $a \sin \theta = 2\lambda$  2<sup>nd</sup> minima

$a \sin \theta = \frac{3\lambda}{2}$  (1<sup>st</sup> secondary maxima)

$a \sin \theta = \frac{5\lambda}{2}$  (2<sup>nd</sup> " maxima)

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## QUESTION



A single slit of width  $a$  is illuminated by a monochromatic light of wavelength 600 nm. The value of  $a$  for which first minimum appears at  $\theta = 30^\circ$  on the screen will be:

[15 April 2023 - Shift 1]

$$a \sin \theta = n \lambda, \quad (n=1)$$

$$a \sin 30 = 1 \times 600 \times 10^{-9}$$

$$a = 1200 \times 10^{-9}$$

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1 ✓ 1.2  $\mu\text{m}$

2 3  $\mu\text{m}$

3 1.8  $\mu\text{m}$

4 0.6  $\mu\text{m}$

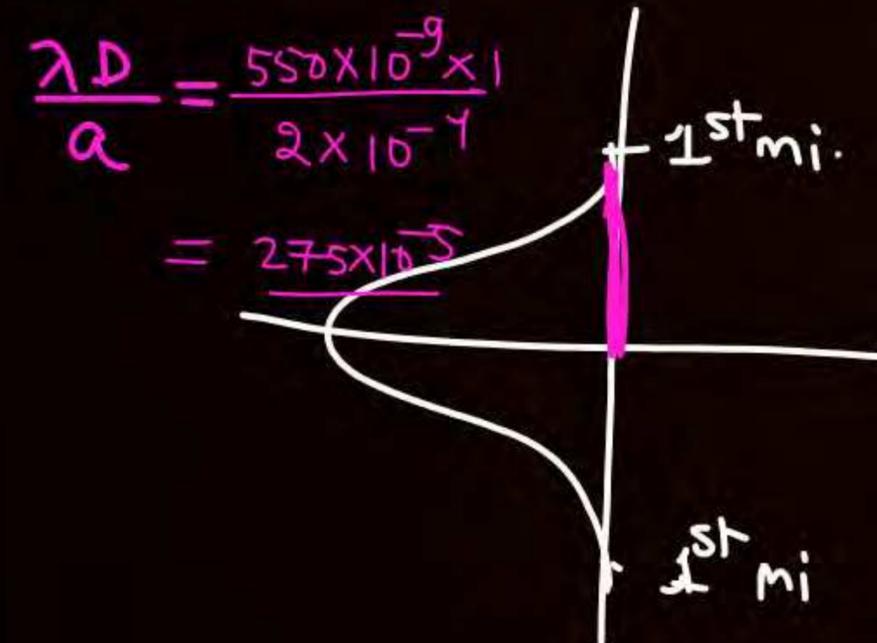
Ans : (1)

## QUESTION



In a single slit experiment, a parallel beam of green light of wavelength 550 nm passes through a slit of width 0.20 mm. The transmitted light is collected on a screen 100 cm away. The distance of first order minima from the central maximum will be  $x \times 10^{-5}$  m. The value of  $x$  is:

[05 Apr. 2024 - Shift 2]



$$a \sin \theta = 1 \times \lambda$$

$$\tan \theta = \frac{y}{D}$$

$$2 \times 10^{-4} \sin \theta = 550 \times 10^{-9}$$

$$\sin \theta = \frac{550}{2} \times 10^{-5} \approx \frac{y}{D}$$

$$y = 275 \times 10^{-5}$$



Ans. (275)

## QUESTION

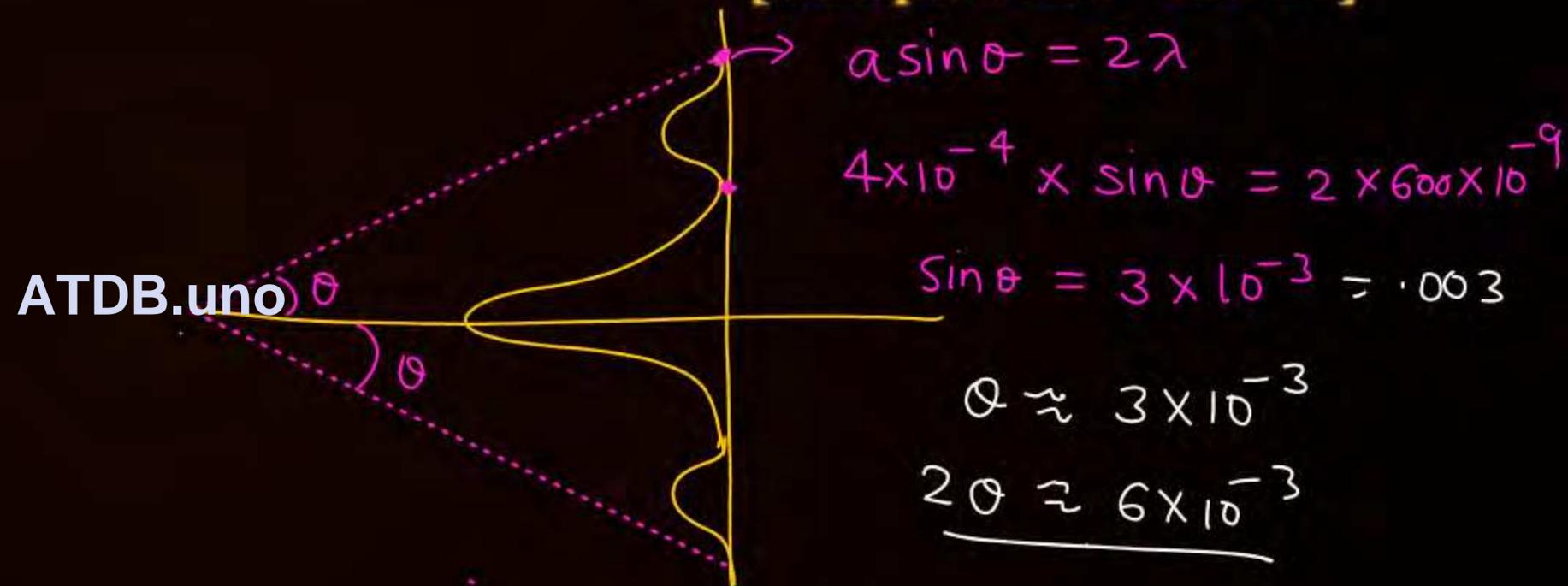


A parallel beam of monochromatic light of wavelength 600 nm passes through single slit of 0.4 mm width. Angular divergence corresponding to second order minima would be 6  $\times 10^{-3}$  rad. [08 Apr. 2024 - Shift 1]

$$a = 4 \times 10^{-4}$$

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

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$$a \sin \theta = 2\lambda$$

$$4 \times 10^{-4} \times \sin \theta = 2 \times 600 \times 10^{-9}$$

$$\sin \theta = 3 \times 10^{-3} = .003$$

$$\theta \approx 3 \times 10^{-3}$$

$$\underline{2\theta \approx 6 \times 10^{-3}}$$

Ans. (6)

## QUESTION



In a single slit diffraction pattern, a light of wavelength  $6000 \text{ \AA}$  is used. The distance between the first and third minima in the diffraction pattern is found to be 3 mm when the screen is placed 50 cm away from slits. The width of the slit is 2  $\times 10^{-4} \text{ m}$ .

[29 Jan. 2024 - Shift 2]

$$\tan \theta = \frac{y}{D}$$

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

$$\frac{2\lambda D}{a} = 3 \times 10^{-3}$$

$$\frac{2 \times 6 \times 10^{-7} \times \frac{1}{2}}{3 \times 10^{-3}} = a$$

$$2 \times 10^{-4} = a$$

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Ans. (2)

## QUESTION



Two slits are 1 mm apart and the screen is located 1 m away from the slits. A light of wavelength 500 nm is used. The width of each slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern is 2  $\times 10^{-4}$  m

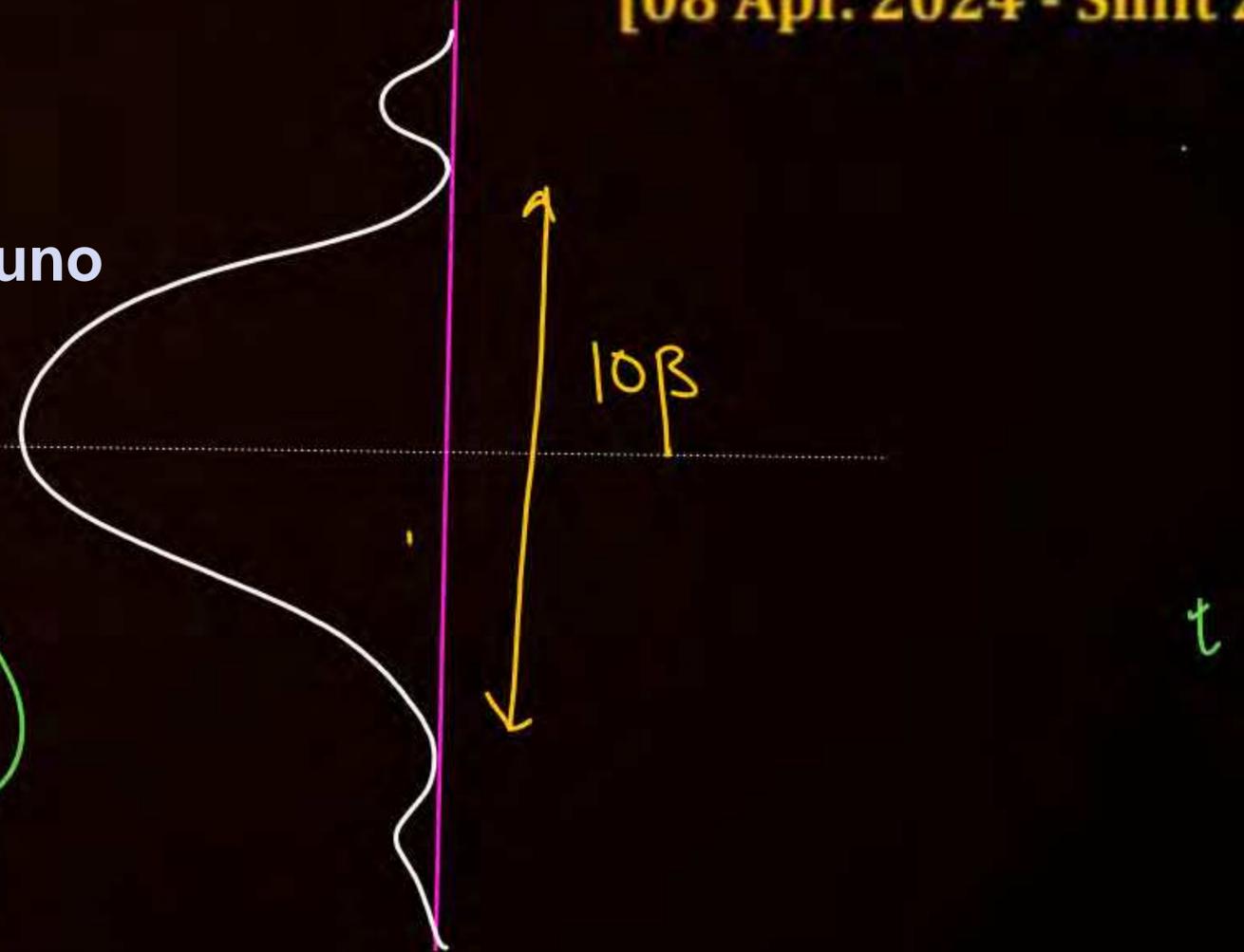
[08 Apr. 2024 - Shift 2]

$$\frac{2\lambda D}{a} = 10 \beta \quad \text{YDSE}$$

$$\frac{2 \times \cancel{\lambda} \cdot D}{a} = 10 \frac{\cancel{\lambda} \cdot D}{d}$$

$$\frac{2}{a} = \frac{10}{10^{-3}} \Rightarrow a = 2 \times 10^{-4}$$

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Ans. (2)

## QUESTION



$$f \equiv D$$

A parallel beam of monochromatic light of wavelength  $5000 \text{ \AA}$  is incident normally on a single narrow slit of width  $0.001 \text{ mm}$ . The light is focused by convex lens on screen, placed on its focal plane. The first minima will be formed for the angle of diffraction of \_\_\_\_\_ (degree).

[27 Jan 2024 - Shift 2]

$$a \sin \theta = \lambda$$

$$1 \times 10^{-6} \sin \theta = 5000 \times 10^{-10}$$

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$$\sin \theta = 5 \times 10^{-1} = \frac{5}{10} = \frac{1}{2}$$

$$\theta = 30^\circ$$



Ans. (30)

## QUESTION



A monochromatic light of wavelength  $6000 \text{ \AA}$  is incident on the single slit of width  $0.01 \text{ mm}$ . If the diffraction pattern is formed at the focus of the convex lens of focal length  $20 \text{ cm}$ , the linear width of the central maximum is: **[01 Feb. 2024 - Shift 1]**

$$D = 20 \times 10^{-2}$$

1 60 mm

2 24 mm

3 120 mm

4 12 mm

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$$\frac{2\lambda D}{a} = \frac{2 \times 6000 \times 10^{-10} \times 20 \times 10^{-2}}{1 \times 10^{-5}}$$

$$= 240 \times 10^{-4}$$

Ans. (2)



## QUESTION

The diffraction pattern of a light of wavelength 400 nm diffracting from a slit of width 0.2 mm is focused on the focal plane of a convex lens of focal length 100 cm. The width of the 1<sup>st</sup> secondary maxima will be:

[30 Jan. 2024 - Shift 1]

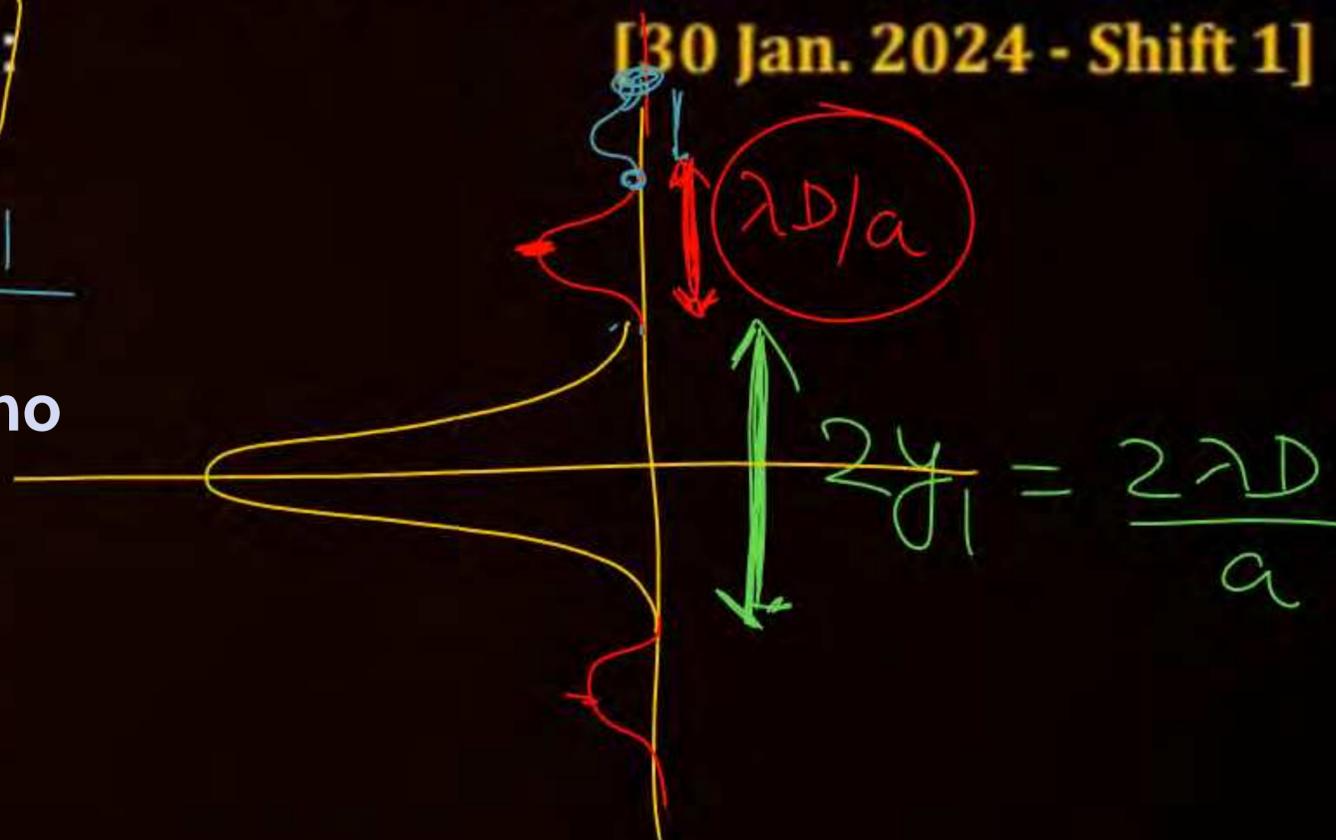
- 1 2 mm
- 2 2 cm
- 3 0.02 mm
- 4 ~~0.2 mm~~

$$\frac{\lambda D}{a} = \frac{400 \times 10^{-9} \times 1}{2 \times 10^{-4}}$$

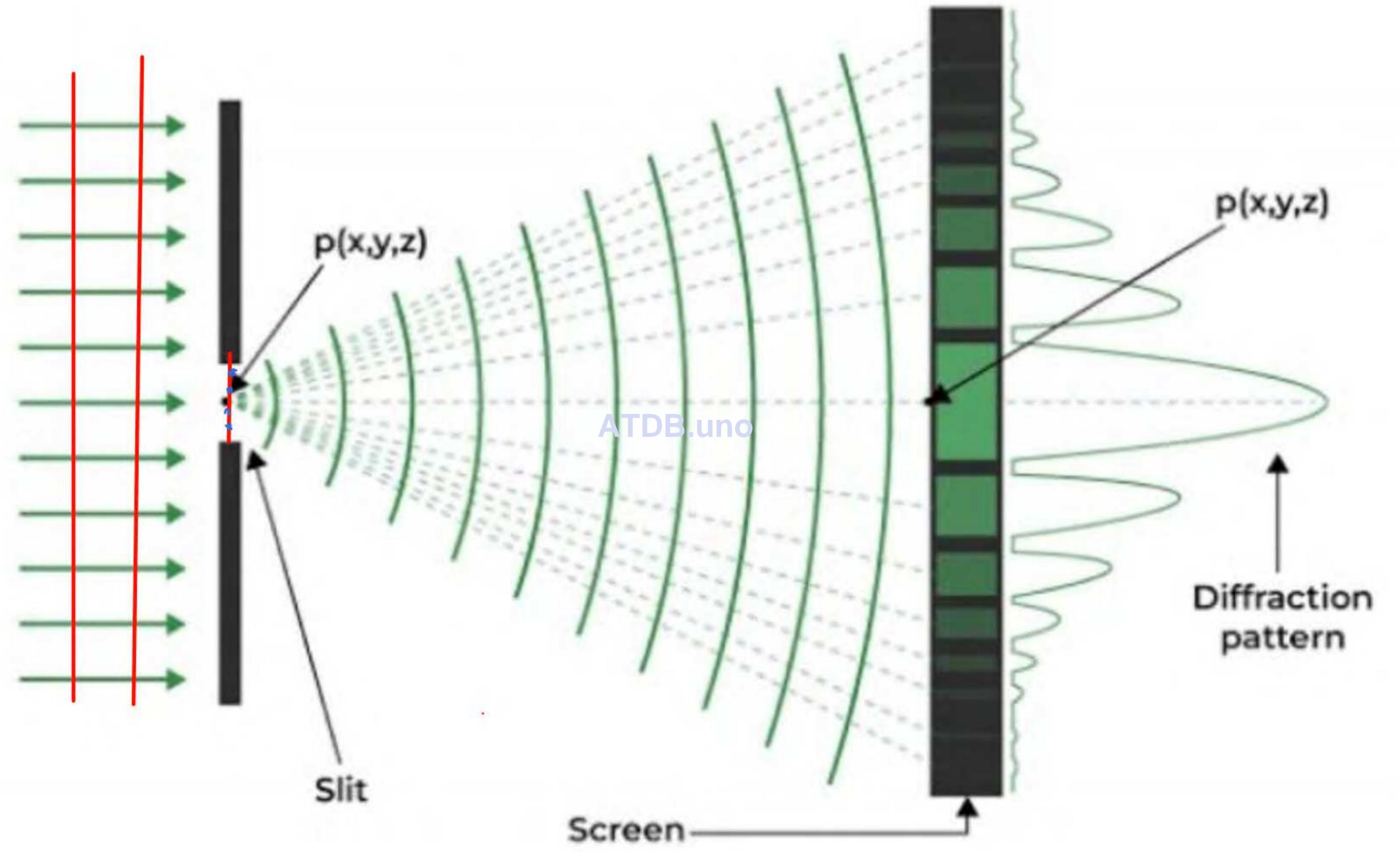
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$$= 2 \times 10^{-3}$$

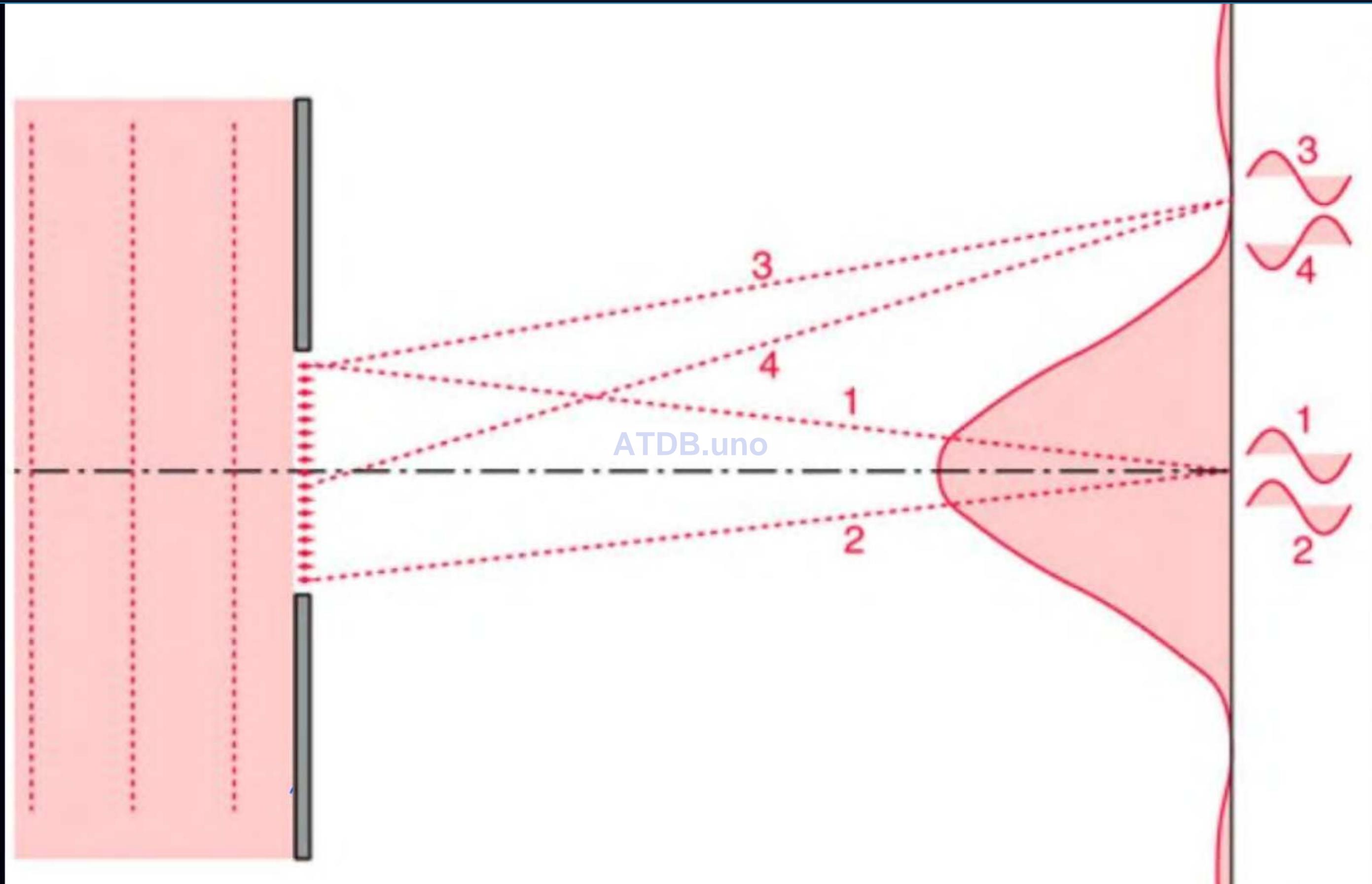
$$= 2 \text{ mm}$$



Ans. (1)



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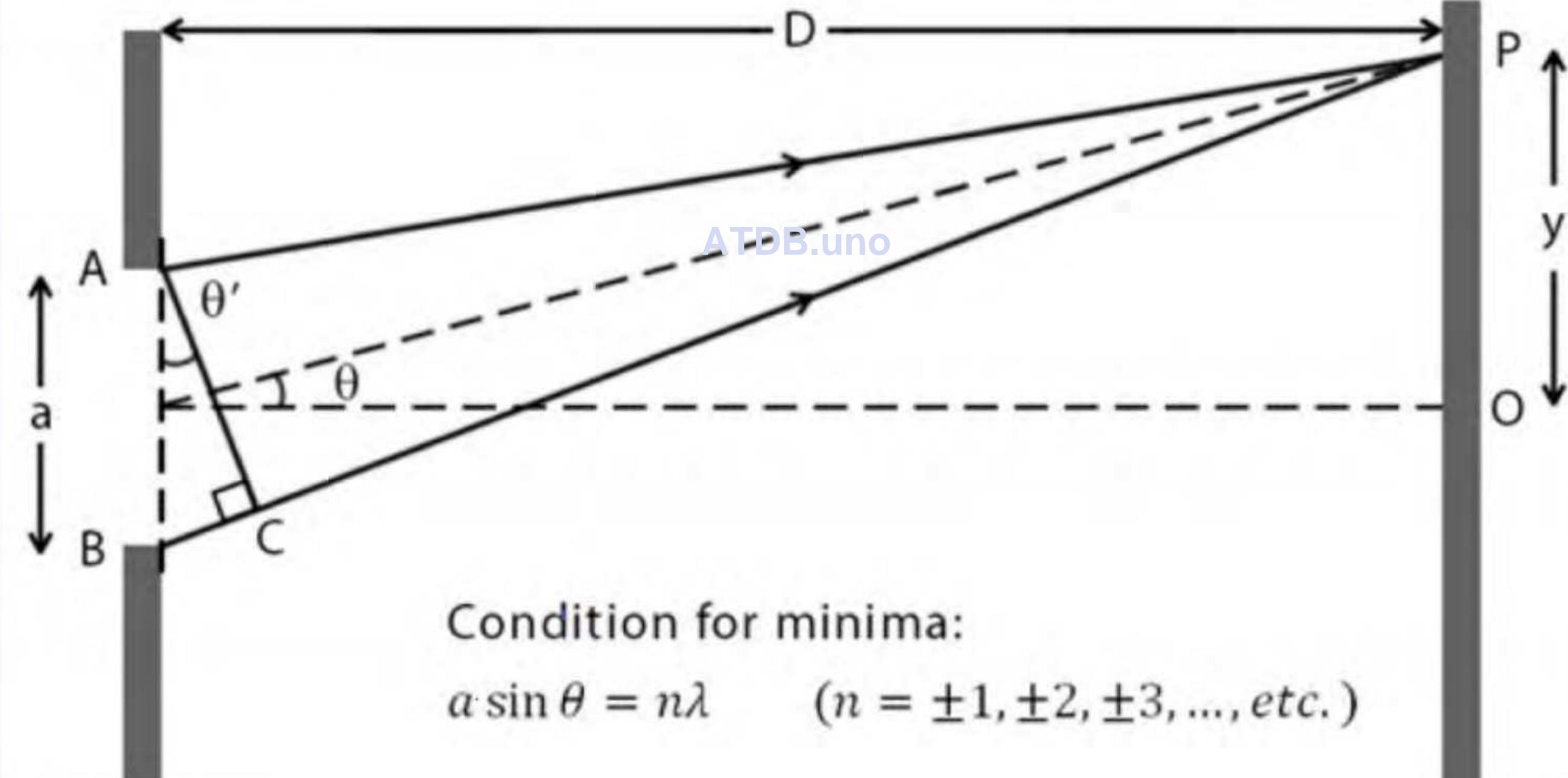
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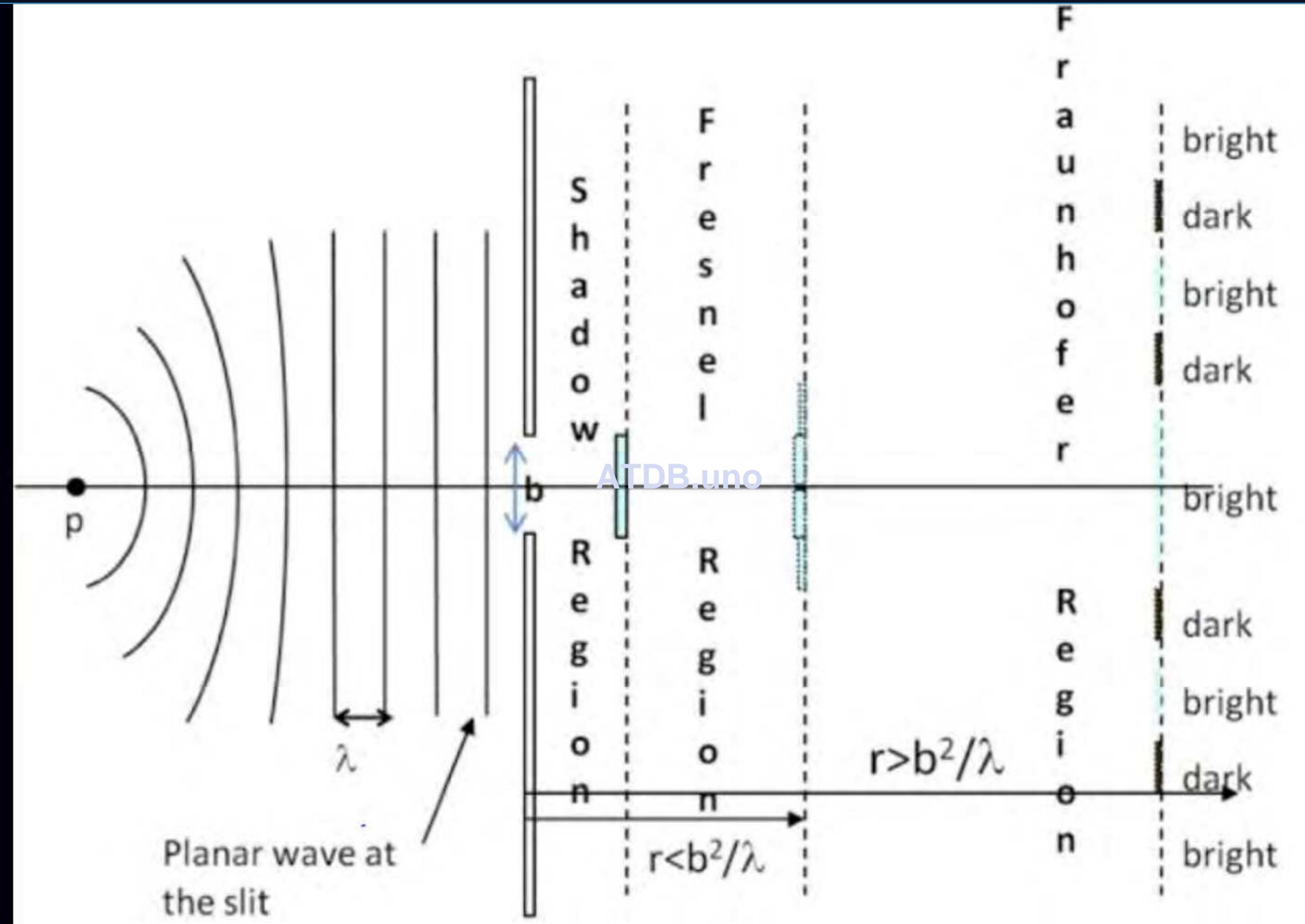
# Single-Slit Diffraction Equations



Screen with a narrow slit

Screen







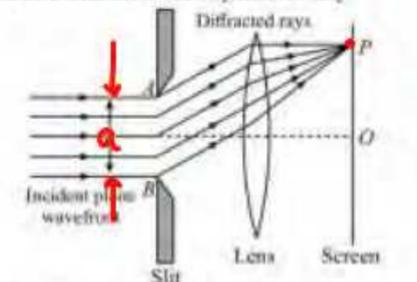
**Fraunhofer Diffraction:** Fraunhofer diffraction deals with light rays that are plane on arrival and an effective viewing distance of infinity. It follows that Fraunhofer diffraction is an important special case of Fresnel diffraction. In Young's double slit experiment, we assume the screen to be relatively distant, that we have Fraunhofer conditions.

**Difference Between Interference and Diffraction of Light**

S. No.	Interference	Diffraction
1.	Two coherent sources are necessary.	Multiple coherent sources are required.
2.	All fringes have same width.	Fringes have unequal width.
3.	Width of central bright fringes is equal to other fringes.	Width of bright central fringe is just double of other fringes.
4.	All bright fringes have equal intensity.	As order of bright fringes increases, intensity goes down.
5.	<b>For bright fringe:</b> $d \sin \theta = n \lambda$	<b>For bright fringe:</b> $a \sin \theta = (2n - 1) \lambda / 2$
6.	<b>For dark fringe:</b> $d \sin \theta = (2r - 1) \lambda / 2$	<b>For dark fringe:</b> $a \sin \theta = n \lambda$

**FRAUNHOFER DIFFRACTION FOR SINGLE SLIT**

In this diffraction pattern central maxima is bright on the both side of it, maxima and minima occurs symmetrically



- 1. For Diffraction Maxima**  
 $a \sin \theta = (2n - 1) \lambda / 2$
- 2. For Diffraction Minima**  
 $a \sin \theta = n \lambda$
- The maxima or minima is observed due to the superposition of waves emerging from infinite secondary points sources between points A and B of slit.
- 4. Fringe width of central maximum**  
The distance between two secondary minima formed on two sides of central maximum is known as the width of central maximum

$W = \frac{2\lambda D}{a}$   
 $f = \text{focal length}$   
 $a = \text{width of slit}$   
Angular

**DIFFERENCE BETWEEN INTERFERENCE AND DIFFRACTION**

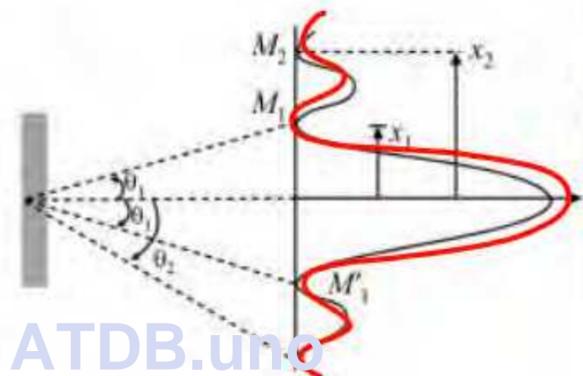
1. The distance between two consecutive minima and maxima is equal to the width of the slit.
2. Wavefronts are spherical.
3. No secondary maxima is observed.
4. No secondary minima is observed.

**COMPARISON OF INTERFERENCE AND DIFFRACTION**

1. General condition for maxima is  $d \sin \theta = n \lambda$  and for minima is  $d \sin \theta = (2n - 1) \lambda / 2$ .
2. (a) Order of diffraction is  $n$  and (b) Visibility of diffraction pattern is  $\frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}}$ .
3. General condition for maxima is  $a \sin \theta = (2n - 1) \lambda / 2$  and for minima is  $a \sin \theta = n \lambda$ .

**DIFFRACTION OF LIGHT**

When a beam of light is projected on a screen, it is observed that the light spreads out and forms a pattern of bright and dark fringes.



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$$W = \frac{2\lambda f}{a}$$

f = focal distance of convex lens

a = width of slit

$$\text{Angular width} = \Delta\theta = \frac{2\lambda}{a}$$

**DIFFERENCE BETWEEN FRESNEL AND FRAUNHOFER DIFFRACTION**

	Fresnel	Fraunhofer
1.	The source is at finite distance on one side of obstacle and screen also at finite distance from obstacle and on the other side.	Source & screen are effectively at infinite distance from obstacle.
2.	Wave front is either spherical or cylindrical.	Plane wave front.



# THANK YOU

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