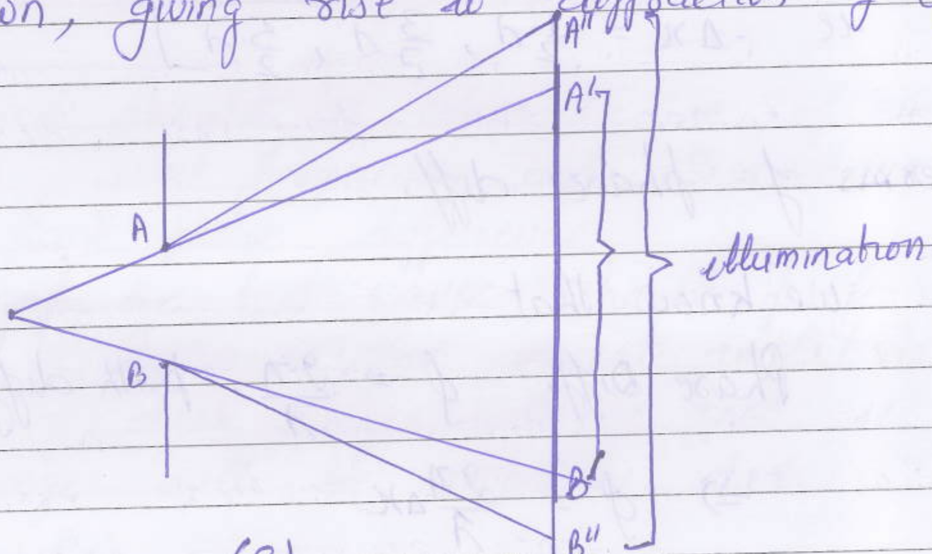
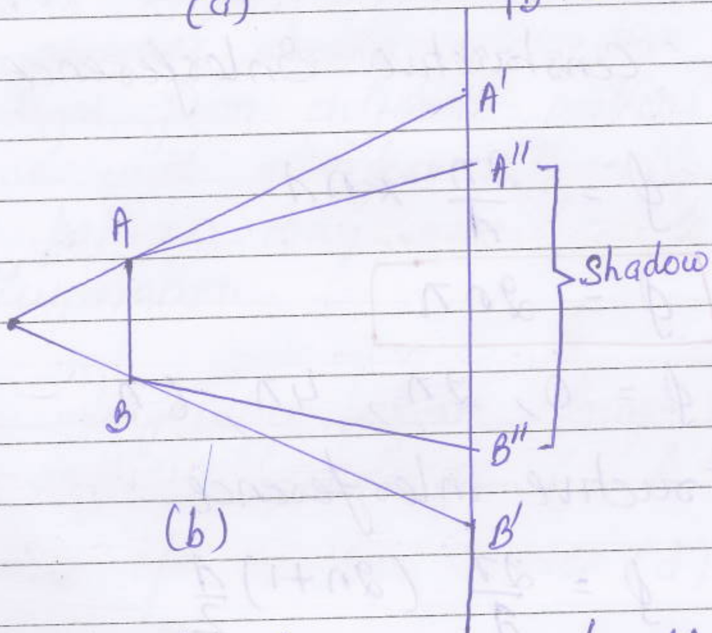
Diffraction of light ↦

Diffraction of light ↦ The phenomenon of bending of light around the corners of slit or obstacle is called diffraction.

When a slit or obstacle AB is placed in front of a light source then light bends around the corners of slit or obstacle as shown, giving rise to diffraction of light.



(a)



(b)

Since light travels in the straight line, therefore portion A'B' should be illuminated (in fig a) or should have shadow (in fig b). But due to diffraction (bending of light), it is A''B'' instead

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Diffraction of radio & sound wave is so common in our daily life but diffraction of light wave is not so common. Because for diffraction to take place, size of the slit should be of the size comparable to wavelength of wave. Since wavelength of sound waves is of the order of 6m w/c of light waves is of the order of nano meters and slits of size comparable to 6m are common w/c of size comparable to nano meters is not so common. Thus diffraction of light is not common in our daily life.

Diffraction of light is of two types:-

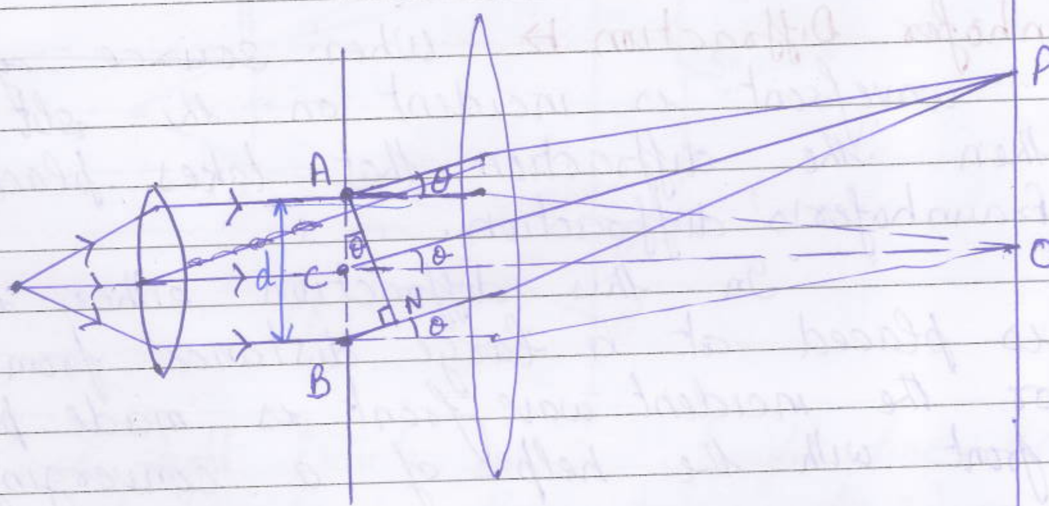
① Fresnel Diffraction :- When source of light and slit lies at a finite distance, then the diffraction that takes place is called fresnels diffraction.
Since source is placed close to slit thus the incident wavefront is either spherical or cylinderical.

2. Fraunhofer Diffraction :- When ~~source of~~ a plane wavefront is incident on the slit or obstacle then the diffraction that takes place is called fraunhofer's diffraction.
In this diffraction either the source is placed at a large distance from the slit or the incident wave front is made plane wave front with the help of a converging lens.

Diffraction at a single slit (Fraunhofer Diffraction)

Consider a plane wavefront from a monochromatic light is allowed to fall on a narrow slit AB ~~as shown~~ of width d as shown. According to Huygen's principle every point in b/w A and B acts as source of secondary disturbance. These secondary wavelets initially in same phase and reach at point O on the screen after travelling the same optical path and hence reinforce each other forming central maxima at point O.

Whereas the wavelets which get diffracted through different angles reach at various points on the screen and will have some path and hence phase difference. ~~The maximas~~ Depending on the path difference, secondary minimas or maximas are formed on screen.



Where as for the secondary wavelets diffracted through angle θ, the path difference b/w the

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wavelets from point A and B while reaching at point P will be BN (as optical path from A to P and NP to P is equal)

ie path differece, $BN = AB \sin\theta$ $\left(\because \frac{BN}{AB} = \sin\theta\right)$

$\Rightarrow$ $\boxed{BN = d\sin\theta}$

Thus for ~~diffrac~~ different differaction angles θ, path difference b/w the two wavelets from point A and B will be different. Thus various secondary maximas and minimas will be formed on the various points of screen.

Suppose for diffraction angle θ_1, the path diff. b/w the two wavelets from point A and B of the slit is λ,

ie $d\sin\theta_1 = 1\lambda$,

then point P on the screen will be the position of Ist secondary minima. Because, the slit can be supposed to be divided into two equal parts AC and CB, so that for every point in the upper half AC there is a point in lower half CB having path diff of $\lambda/2$ and phase difference of π. Thus these wavelets interfere destructive at point P and give rise to Ist secondary minima.

Similarly for diffraction angle θ_2 and path difference of 2λ

ie $d\sin\theta_2 = 2\lambda$,

2nd secondary minima is formed at point P.

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Again because, now the slit can be supposed to be divided into four equal parts having path difference of $\lambda/2$ with the neighbouring part. Again wavelets from four parts interfere destructively producing 2nd secondary minima.

Hly for $\boxed{d \sin\theta_n = n\lambda}$, we get n^{th} secondary minima.

Suppose for diffraction angle θ_1', the path difference b/w the two wavelets from point A and B is $\frac{3}{2}\lambda$

ie $d \sin\theta_1' = \frac{3}{2}\lambda$

Here point P' will be the position of Ist secondary maxima. Because, now the slit can be supposed to be divided into 3 equal parts having path difference of $\lambda/2$ with the neighbouring part. Thus the wavelets from the two parts having path diff. of $\lambda/2$ cancel out each other w/o wavelets from 3rd part reinforce each other producing Ist secondary ~~minima~~ maxima of comparably lower intensity.

Similary for $d \sin\theta_2' = \frac{5}{2}\lambda$

we will get second secondary minima

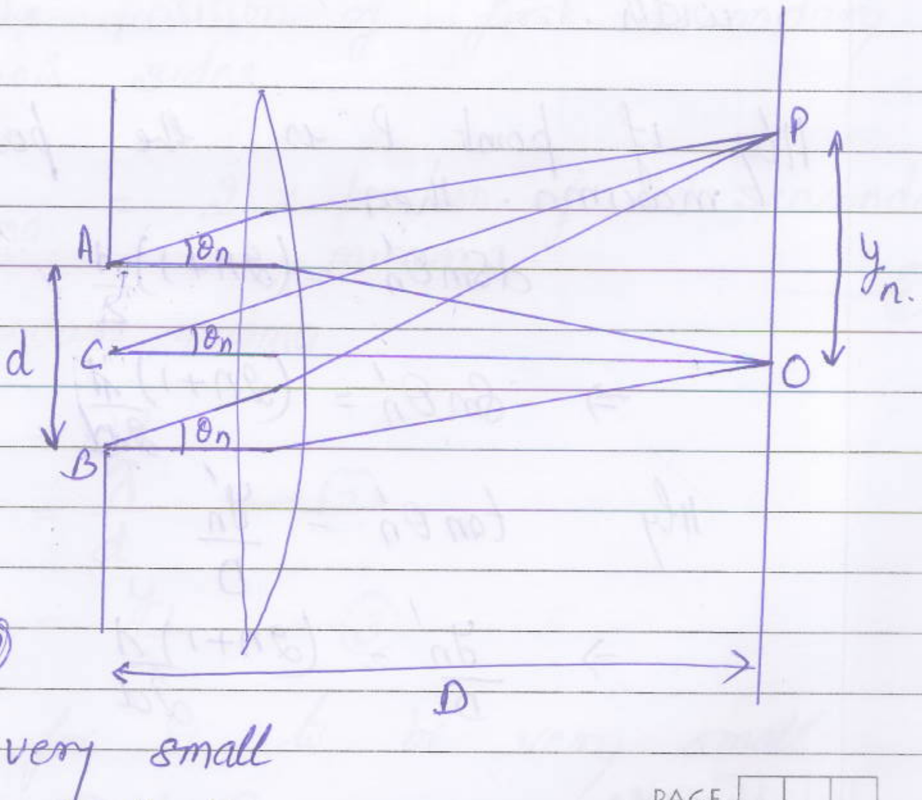
Because now the slit can be supposed to be divided into 5 equal parts. and light from four parts cancel out each other and we get light of comparitive lower intensity from the 5^{th} part of the slit.

$||^{ly}$ for $\boxed{d\sin\theta_n' = (2n+1)\frac{\lambda}{2}}$ we will get n^{th} secondary maxima.

Intensity of secondary maximas goes on decreasing because for Ist secondary maxima we get light from $\frac{1}{3}$rd of slit and for 2nd secondary maxima from $\frac{1}{5}$th and for 3rd secondary ~~mini~~ maxima from $\frac{1}{7}$th part of the slit and so on.

Intensity of secondary maximas relating to the intensity of central maxima are in the ratio of $1 : \frac{1}{21} : \frac{1}{61} : \frac{1}{121}$ - - -

Width of secondary maximas, minimas and central maxima ↦



Suppose P is position of n^{th} secondary ~~ma~~ minima.

Thus $d\sin\theta_n = n\lambda$

$\Rightarrow \sin\theta_n = \frac{n\lambda}{d}$ —①

Also in ΔCOP

$\tan\theta_n = \frac{y_n}{D}$ —②

for θ to be very small

$\sin\theta_n \cong \tan\theta_n$

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$$\Rightarrow \frac{y_n}{D} = \frac{n\lambda}{d} \qquad \{\text{using } ① \text{ and } ②\}$$

$$\Rightarrow y_n = \frac{nD\lambda}{d}.$$

Since secondary maximas lie b/w two successive minimas. Thus width the secondary maxima is

$$\beta = y_n - y_{n-1}$$

$$= n\frac{D\lambda}{d} - (n-1)\frac{D\lambda}{d}.$$

$$= \frac{D\lambda}{d}(n-n+1)$$

$$\Rightarrow \boxed{\beta = \frac{D\lambda}{d}}$$

Since β is independent of n, therefore all the secondary maximas are of same width.

Illy if point P is the position of n^{th} secondary maxima. then

$$d\sin\theta_n' = (2n+1)\frac{\lambda}{2}$$

$$\Rightarrow \sin\theta_n' = (2n+1)\frac{\lambda}{2d}$$

Illy $\tan\theta_n' = \frac{y_n'}{D}$

$$\Rightarrow \frac{y_n'}{D} = (2n+1)\frac{\lambda}{2d} \qquad \{\because \sin\theta \simeq \tan\theta$$

$$\Rightarrow y_n' = (2n+1)\frac{\lambda D}{2d}$$

Thus width of secondary minimas is

$$\beta' = y_n' - y_{n-1}'$$

$$= (2n+1)\frac{D\lambda}{2d} - [2(n-1)+1]\frac{D\lambda}{2d}$$

$$= \frac{D\lambda}{2d}[2n+1-2n+2-1]$$

$$\boxed{\beta' = \frac{D\lambda}{d}}$$

ie $\beta = \beta'$

~~Also~~ Thus all secondary maximas and minimas are of same width.

Width of central maxima :→ The central maxima extends upto to the position of first secondary minima of both sides.

Thus width of central maxima = 2 × position of Ist senconda minima. —— (1)

for Ist secondary minima

$$d\sin\theta_1 = 1\lambda$$

$$\sin\theta_1 = \frac{\lambda}{d} \quad \text{—— (2)}$$

also $\tan\theta_1 = \frac{y_1}{D}$ —— (3)

but for θ to be very small

$$\sin\theta_1 \simeq \tan\theta_1$$

$$\Rightarrow \frac{\lambda}{d} = \frac{y_1}{D}.$$

$$\Rightarrow y_1 = \frac{\lambda D}{d}.$$

$\therefore$ Width of Central maxima $= 2y_1$ using (1)

$$\Rightarrow \boxed{\text{width of central maxima} = \frac{2\lambda D}{d}.}$$

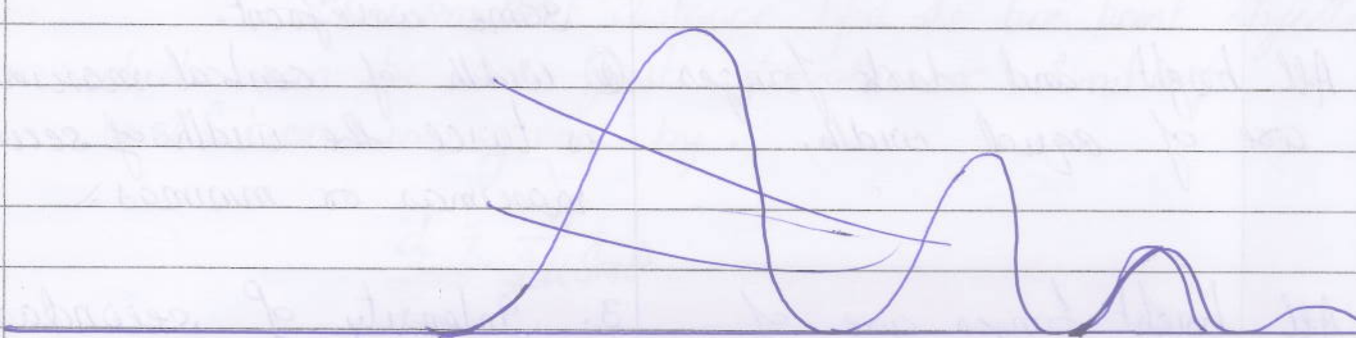
or width of central maxima $= 2\beta$ or $2\beta'$

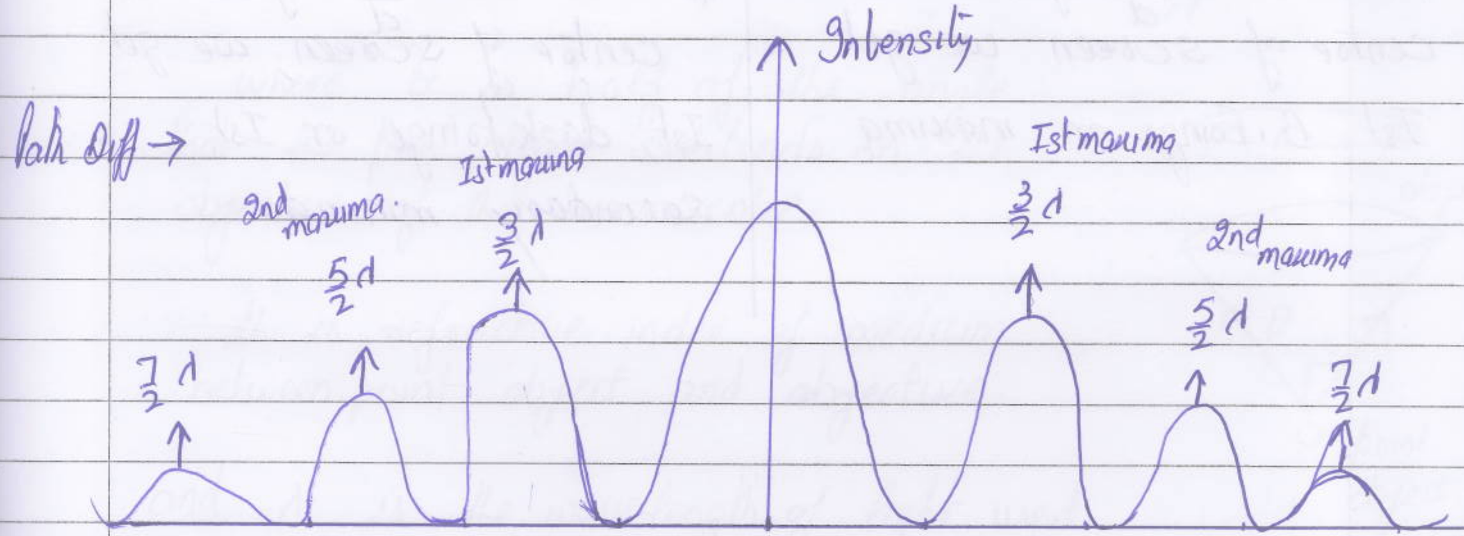
Thus width of central maxima is 2 time the width of ~~β~~ secondary maximas or minimas w/a intensity of central maxima is 21 times the intensity I^{st} secondary maxima and 61 times the intensity of 2^{nd} secondary maxima.

Note:-→ Angular width of Central maxima $= 2\theta_1 = \frac{2\lambda}{d}$.

" " " Secondary maximas or minimas $= \frac{\lambda}{d}$.

Intensity Distribution curve ⟼ The graph b/w intensities of maxima / minimas and diffraction angle is cal intensity distribution curve.





$\theta \to$	$-\frac{3\lambda}{d}$	$-2\lambda/d$	$-\lambda/d$	0	λ/d	$2\lambda/d$	$3\lambda/d$
$y \to$	$\frac{3D\lambda}{d}$	$\frac{2D\lambda}{d}$	$\frac{D\lambda}{d}$	0	$\frac{D\lambda}{d}$	$\frac{2D\lambda}{d}$	$\frac{3D\lambda}{d}$
Path diff.	3λ	2λ	1λ		1λ	2λ	3λ
	3rd minima.	2nd minima	Ist minima		Ist minima	2nd minima	3rd minima

⟵ Central Maxima ⟶

Difference b/w interference and diffraction :-

Interference	Diffraction
① Interference is due to superposition of secondary wavelets from two diff. coherent sources	Diffraction is due to superposition of secondary wave from the different parts of same wavefront.
2. All bright and dark fringes are of equal width.	② width of central maxim is twice the width of sec maximas or minimas.
3. All bright fringes are of same intensity.	3. Intensity of seconda maximas goes on decr with order.
4. At distance $\frac{D\lambda}{d}$ from the centre of screen we get Ist B. Fringe or maxima	④ At distance $\frac{D\lambda}{d}$ from the centre of screen, we g Ist dark fringe or Ist secondary minima.

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classmate

Resolving power of microscope and telescope ↦

Resolving power of the microscope ↦ It is d/a the resiproca of the smallest distance b/w two point objects at which they can be seen just separate through a microscope.

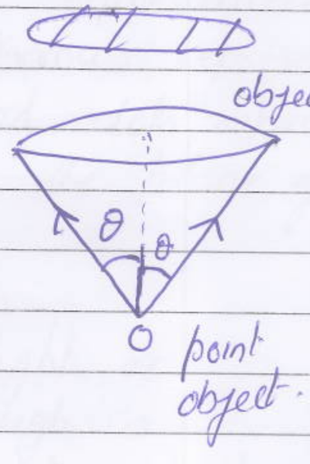
The smallest distance b/w the two point objects which can be seen just separate or limit of resolution is given by,

$$d = \frac{\lambda}{2\mu \sin\theta}$$

Thus resolving power of microscope $= \frac{1}{d}$

$$= \frac{2\mu \sin\theta}{\lambda}$$

where θ is half of the angle that the point object subtends on the objective of the microscope.



μ is refractive index of medium between point object and objective.

and λ is the wavelength of light used.

Thus to increase resolving power of the microscope, oil of high value of refractive index is placed between objective of the microscope and point object.

Also resolving power of microscope will be high when light of smaller wave length (ie blue light) is used to illuminate the object.

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Resolving power of the telescope ⇒ It is d/a the smallest angular separation b/w the two distant objects which can be seen just separate through a telescope

The smallest angular separation or limit of resolution is given as

$$d\theta = \frac{1.22\lambda}{D}$$

Thus Resolving power of telescope $= \frac{1}{d\theta}$

$$= \frac{D}{1.22\lambda}$$

where D is ~~apper~~ aperture or diameter of the objective of telescope