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Diffraction -

× ① Fresnel 's Half Period zone
× ② zone plate
✓ ③ Fraunhofer 's diffraction by single slit
✓ ④ Fraunhofer 's diffraction by double slit
✓ ⑤ Theory of plane transmission grating.
✓ ⑥ width of principal maxima.
✓ ⑦ Rayleigth 's Criteria of limit of resolution
? ⑧ Resolving power of prism
✓ ⑨ Resolving power of grating.
✓ ⑩ Huygen's principle

Huygen's Principle :- According to Huygen's wave Theory of light

① Each point on a luminous source vibrates simple harmonically all the time.
② It emits wave in all direction
③ A Continuous surface, every point on which, is vibrating in same phase is called a wavefront
④ Propogation of light means propogation of wavefronts.

Difference b/w^n Interference and Diffraction-

Interference	Diffraction
① Interference is due to superposition of secondary wavelets from two different wavefronts (from two source)	① Diffraction is caused by superposition of secondary wavelets from two different elements of same wavefront.
② Two coherent sources are must	② just a single source required.
③ fringe width (β) is same i.e. maxima/min. are equally spaced	③ β is unequally spaces. generally β goes on decreasing as we move away from centre of pattern.
④ All bright fringes have same intensity.	④ All bright fringes donot have same intensity.
⑤ Minima are perfectly dark	⑤ Minima are not perfectly dark.
⑥ The contrast b/w^n maxima and minima is very good.	⑥ Not a good contrast b/w^n maxima and minima.

Diffraction

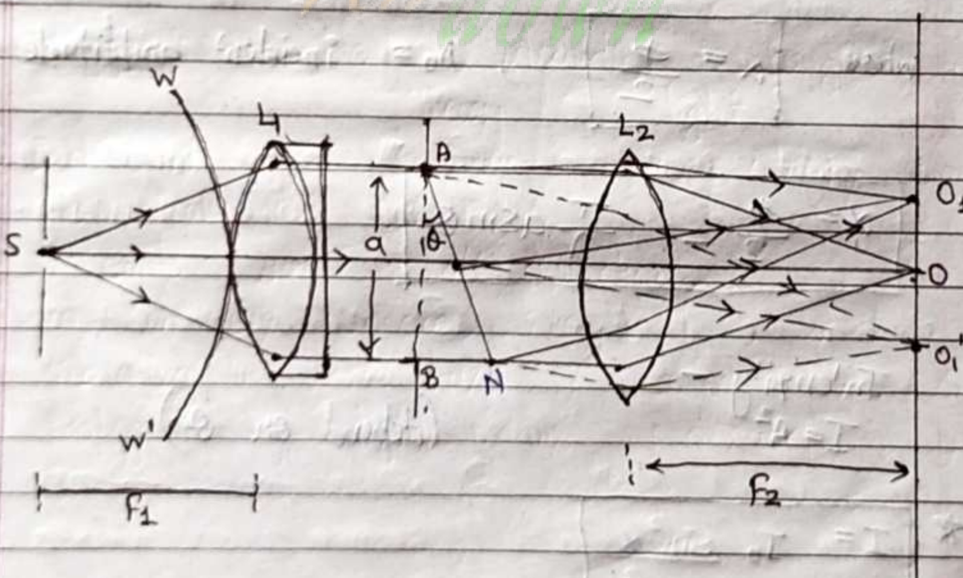
① Fraunhoffer's Diffraction

The source of light and the screen are at infinite distance from the diffraction elements.

② Fresnel's diffraction

The source of light and screen are at finite distance from the diffraction elements.

Fraunhoffer's Diffraction at a single slit (Rectangular Aperture) :-



① setup for Fraunhoffer's diffraction pattern due to single slit S.

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(2) Max^m path difference = $\boxed{BN = a\sin\theta}$

(3) path difference from A to B vary uniformly from zero to $a\sin\theta$ as we move from A to B of slit.

(4) Phase difference b/w^n first and last wave — (i.e from A to B)

$$\boxed{\phi = \left(\frac{2\pi}{\lambda}\right)(a\sin\theta)}$$

(5) Resultant Amplitude at point O_1 —

$$\boxed{A = A_0 \frac{\sin\alpha}{\alpha}}$$ (depend on α)

where $\boxed{\alpha = \frac{\phi}{2}}$, A_0 = incident amplitude on AB

(6) $$\boxed{\alpha = \frac{\phi}{2} = \frac{\pi}{\lambda} a\sin\theta}$$

(7) Intensity —
$I = A^2$ (depend on θ)

* $$\boxed{I = I_0 \frac{\sin^2\alpha}{\alpha^2}}$$

Pen down

(8) Principal or central maxima :-

At central maxima - $\alpha = 0, \phi = 0, \theta = 0$
i.e in direction of incident light.

$$\boxed{\begin{aligned} A_{max} &= A_0 \\ I_{max} &= A_0^2 \end{aligned}}$$

$$\boxed{\text{as } \frac{\sin\alpha}{\alpha} \to 1 \quad \Rightarrow \alpha \to 0}$$

(9) Position of secondary minima :-

for minima,

$\sin\alpha = 0$

$\alpha = \pm\pi, \pm 2\pi, \pm 3\pi, \ldots \pm n\pi$

$\boxed{\alpha = n\pi}$, $n = \pm 1, \pm 2, \ldots$

$$n\pi = \frac{\pi}{\lambda} a\sin\theta$$

** $\boxed{a\sin\theta = n\lambda}$

(10) Position of secondary maxima :-

$\boxed{a\sin\theta = \pm\left(n + \frac{1}{2}\right)\lambda}$. $n = 1, 2, 3, \ldots$

$\boxed{\alpha = \left(n \pm \frac{1}{2}\right)\pi}$, $n = \pm 1, \pm 2, \pm 3 \ldots$

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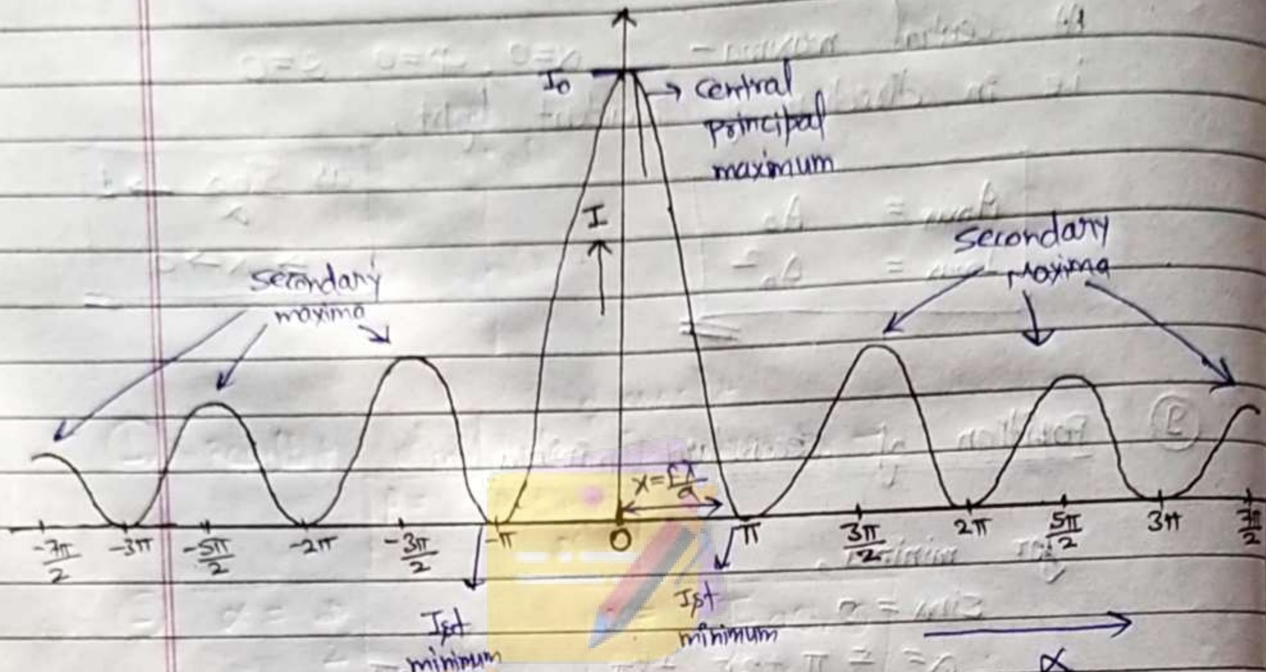
(11) Intensity Distribution Curve :-



Intensity in secondary maxima is very small as compared to principal maximum and also goes on decreasing towards higher order of secondary maxima.

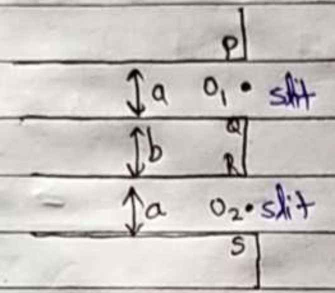
(12) Effect of increasing λ or a :-

(a) ~~areas~~, Condition for Ist minima is -
$a \sin\theta = n\lambda$, $n=1$ for Ist minima

(i) on $\uparrow \lambda$, θ also $\uparrow$ses so first minima will obtain at greater θ. hence width of principal maxima increases

(ii) on $\uparrow a$, $\theta \downarrow$ses $\Rightarrow$ width of principal maxima decreases.

Fraunhoffer's Diffraction at Double slit :-



① Resultant Amplitude of one slit is given by –

$$\boxed{A = \frac{A_0 \sin\alpha}{\alpha}}$$

② $\boxed{\alpha = \frac{\phi}{2}}$, $\boxed{\alpha = \frac{\pi}{\lambda} a \sin\theta}$

③ Path difference = $(a+b)\sin\theta$

④ phase difference = (say δ)

$$\boxed{\delta = \frac{2\pi}{\lambda}((a+b)\sin\theta)}$$

⑤ Resultant Amplitude of these two waves is given by (say T) =

$$\boxed{T^2 = 4A^2 \cos^2\frac{\delta}{2}}$$

putting value of A and δ –

(6) $$\boxed{T = 2A_0 \frac{\sin\alpha}{\alpha} \cdot \cos\left[\frac{\pi}{\lambda}(a+b)\sin\theta\right]}$$

Hence Resultant Amplitude T depends on

(a) diffraction factor $= \frac{A_0 \sin\alpha}{\alpha}$

(b) Interference factor $= \cos\left(\frac{\pi}{\lambda}(a+b)\sin\theta\right)$

(7) (a) Diffraction factor :- $\frac{A_0 \sin\alpha}{\alpha}$

same as single slit.

i.e

(i) $\alpha \to 0$, $\frac{\sin\alpha}{\alpha} \to 1$. called principal or central maxima.

(ii) $\alpha = \pm n\pi \Rightarrow$ Amplitude = minimum.

(iii) $\alpha = \pm\left(n+\frac{1}{2}\right)\pi \Rightarrow$ Amplitude is maximum

(b) Interference factor :- $\cos\left(\frac{\pi}{\lambda}(a+b)\sin\theta\right) = \cos\beta = \cos\frac{\delta}{2}$

This factor arises due to superposition of secondary wavelets from corresponding points of two slits.

(i) Expression for Intensity

$$\boxed{I = T^2 = 4A_0^2 \left(\frac{\sin^2\alpha}{\alpha^2}\right)\cos^2\beta}$$

for maximum Intensity -

(a) $\cos\left[\frac{\pi}{\lambda}(a+b)\sin\theta\right] = \pm 1$

(b) $(a+b)\sin\theta_n = \pm n\lambda$

(c) $\theta = \pm \frac{n\lambda}{a+b}$, $n = 0, 1, 2, 3 - -$

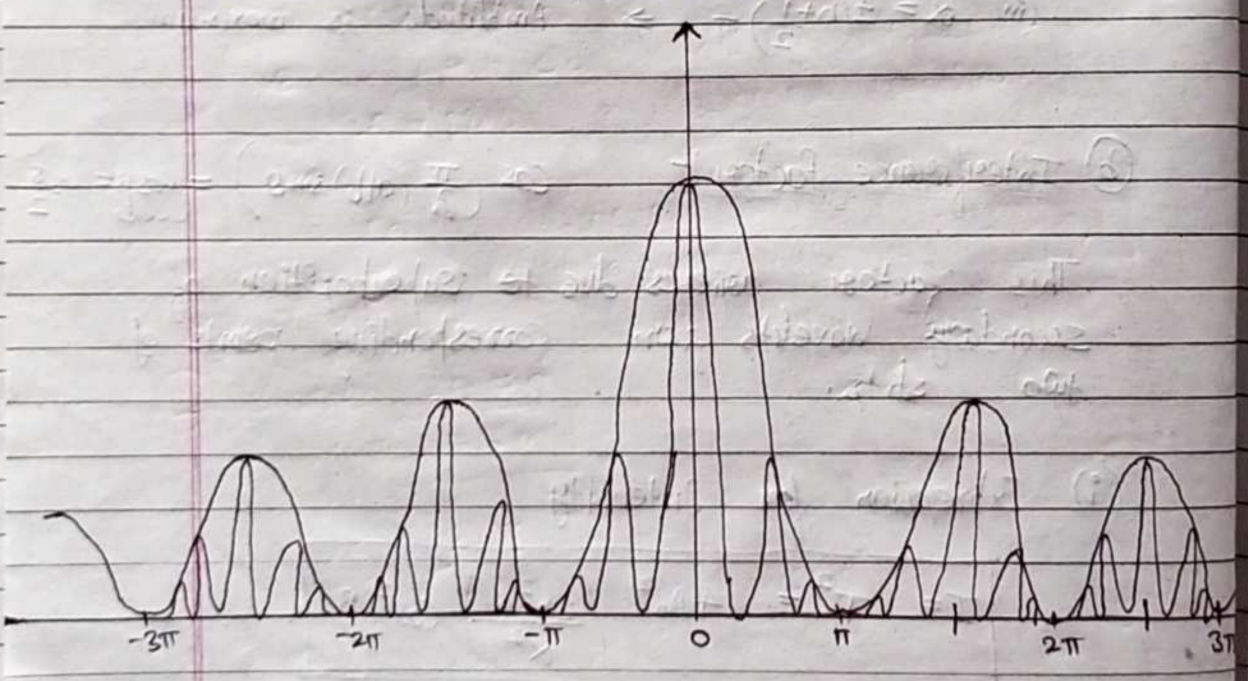
for minimum intensity -

(a) $\cos\left(\frac{\pi}{\lambda}(a+b)\sin\theta\right) = 0$

(b) $(a+b)\sin\theta_n = \pm (2n+1)\frac{\lambda}{2}$

(c) $\theta = \frac{(2n+1)\lambda}{2(a+b)}$, $n = 0, 1, 2, 3 . - -$

(8) Combined Contribution Curve



(9) $\underline{\text{I}^{st}}$ minima direction for double slit -

$$\boxed{\theta_{\text{double slit}} \approx \sin\theta = \frac{3\lambda}{2(a+b)}}$$

(10) $\theta_{1\,\text{single slit}} = \dfrac{\lambda}{a}$

$\theta_{1\,\text{double slit}} = \dfrac{3\lambda}{2(a+b)}$

for $a=b$

$$\boxed{\theta_{1\,\text{single slit}} = \frac{\lambda}{a} < \frac{3\lambda}{4a} = \theta_{1\,\text{double slit}}}$$

(11) Missing Interference maxima :-

for maximum interference

$$\boxed{\sin\theta_n = \frac{n\lambda}{a+b}} = \frac{n\lambda}{2a} \quad (\text{for } a=b)$$

for minimum ~~interference~~ diffraction -

$$\boxed{\sin\theta_m = \frac{m\lambda}{a}}$$

when both condition hold simultaneous ~~then~~ -

$$\boxed{n = 2m}$$

hence, second, fourth, sixth, --- order interference maxima will be missing.

(12) Effect of increasing number of slits :-

If number of slits is increased, interference maxima become more intense and sharp.

If number increased more & more, interference maxima becomes sharp lines seperated by secondary maxima of neglisible intensity.

Differance b/w single slit and Double slit Diffraction pattern :-

single slit	Double slit
Diffraction pattern ① Consits of a centre bright and minima of gradually decreasing intensity.	① Diffraction pattern consist of equally spaced interference maxima and minima with the central maxima.
② Intensity – $I = I_0 \left(\frac{\sin\alpha}{\alpha}\right)^2$	② Intensity – $I = 4I_0 \left(\frac{\sin\alpha}{\alpha}\right)^2$
③ $\alpha = \frac{\pi e \sin\theta}{\lambda}$	③ $\beta = \frac{\pi(e+d)\sin\theta}{\lambda}$
④ central maxima – $I = I_0$	④ central maxima $I = 4I_0$
⑤ on ↑ slit width e, max & min will come closer to central maxima.	⑤ on ↑ e, central peak will become sharper but fringe spacing remain constant.

Absent orders :-

the direction of interference maxima -

$$(e+d)\sin\theta = n\lambda$$

the direction of ~~interference~~ Diffraction minima -

$$e\sin\theta = m\lambda$$

when for a θ, interference maxima overlaps with diffraction minima gives absent orders.

i.e

$$\frac{e+d}{e} = \frac{n}{m}$$

① when $e = d$

$$\boxed{n = 2m}$$

$m = 1, 2, 3, \ldots$

$n = 2, 4, 6, \ldots$

i.e. 2, 4, 6 etc order of interference will be missing in diffraction pattern.

Thus

central diffraction maxima will have 3 interference maxima i.e $\boxed{m = -1, 0, 1}$

② when $2e = d$

$$\boxed{n = 3m}$$

$m = 1, 2, 3 \ldots$

$n = 3, 6, 9 \ldots$ (missing)

Thus central diff. maxima will have 5 interfe maxima i.e $\boxed{n = -2, -1, 0, 1, 2}$

Width of Central Maxima:-

Let distance b/w secondary minimum from centre of principal Maximum $= x$

width of central Maxima $= 2x$

Let distance b/w slit and screen $= D$

$$\boxed{\tan\theta = \sin\theta = \frac{x}{D}} \qquad x << D$$

for first minimum

$$x = \pm \frac{\lambda D}{e}$$

f is focal length of lens, $D = f$ (lens is very close to slit)

$$\boxed{x = \pm \frac{\lambda f}{e}}$$

☆☆ $\boxed{\text{width of central Maxima} = \frac{2\lambda f}{e}}$

(1) width $\propto \lambda$

☆ (2) width $\propto \frac{1}{\text{slit width } (e)}$

(a) If e ↑ses, width ↓ses for $\lambda =$ constant hence max & min lie very close to each other

(b) If e ↓ses (narrow slit), width ↑ses for $\lambda =$ constant, hence diffraction maxima and minima are quite distinct.

Fraunhoffer Diffraction at N-slits
OR
Theory of plane diffraction grating :-

N slits,
$a =$ slit width
$b =$ seperation b/w^n two adjacent slits.
$\lambda =$ monochromatic light 's wavelength.

① Resultant amplitude from one slit -

$$\boxed{A = A_0 \frac{\sin\alpha}{\alpha}}$$

② $$\boxed{\alpha = \frac{\pi}{\lambda} a \sin\theta}$$

③ phase difference b/w^n 2 adjacent waves -

$$\boxed{\delta = \frac{2\pi}{\lambda}(a+b)\sin\theta}$$

④ For N- slits, using vector Addition

Resultant Amplitude (T) :-

$$\boxed{T = A \frac{\sin N\phi}{\sin\phi}}$$

⑤ Resultant Intensity :-

$$\boxed{I = \frac{A^2 \sin^2 N\phi}{\sin^2\phi}}$$

⑥ Principal Maxima :-

T will max^m when $\sin\phi \to 0$, $\frac{\sin N\phi}{\sin\phi} = N$ (max)

$\sin\phi = 0$

$\boxed{\phi = n\pi}$, $n = 0, \pm1, \pm2, \ldots$

★★ $\boxed{(a+b)\sin\theta = n\lambda}$

ⓐ At principal maxima, $\frac{\sin N\phi}{\sin\phi} = N$

$\boxed{T = AN}$

$\boxed{I = A^2N^2}$

and N is large $\Rightarrow$ $I \propto N^2$ $\Rightarrow$ The maxima are very intense

⑦ secondary Minima :-

$\sin N\phi = 0$

$\boxed{N\phi = m\pi}$ (where $m \neq nN$)

★★ $\boxed{N(a+b)\sin\theta = m\lambda}$

ⓐ also depend on N, there is large number of minima on both side of principal maxima.

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⑧ Secondary Maxima :-

There can be $(N-2)$ secondary maxima in b/w^n two successive principal maxima.

position of secondary maxima ⇒

$$\boxed{\frac{d}{d\phi}\left(\frac{A\sin N\phi}{\sin N\phi}\right) = 0}$$

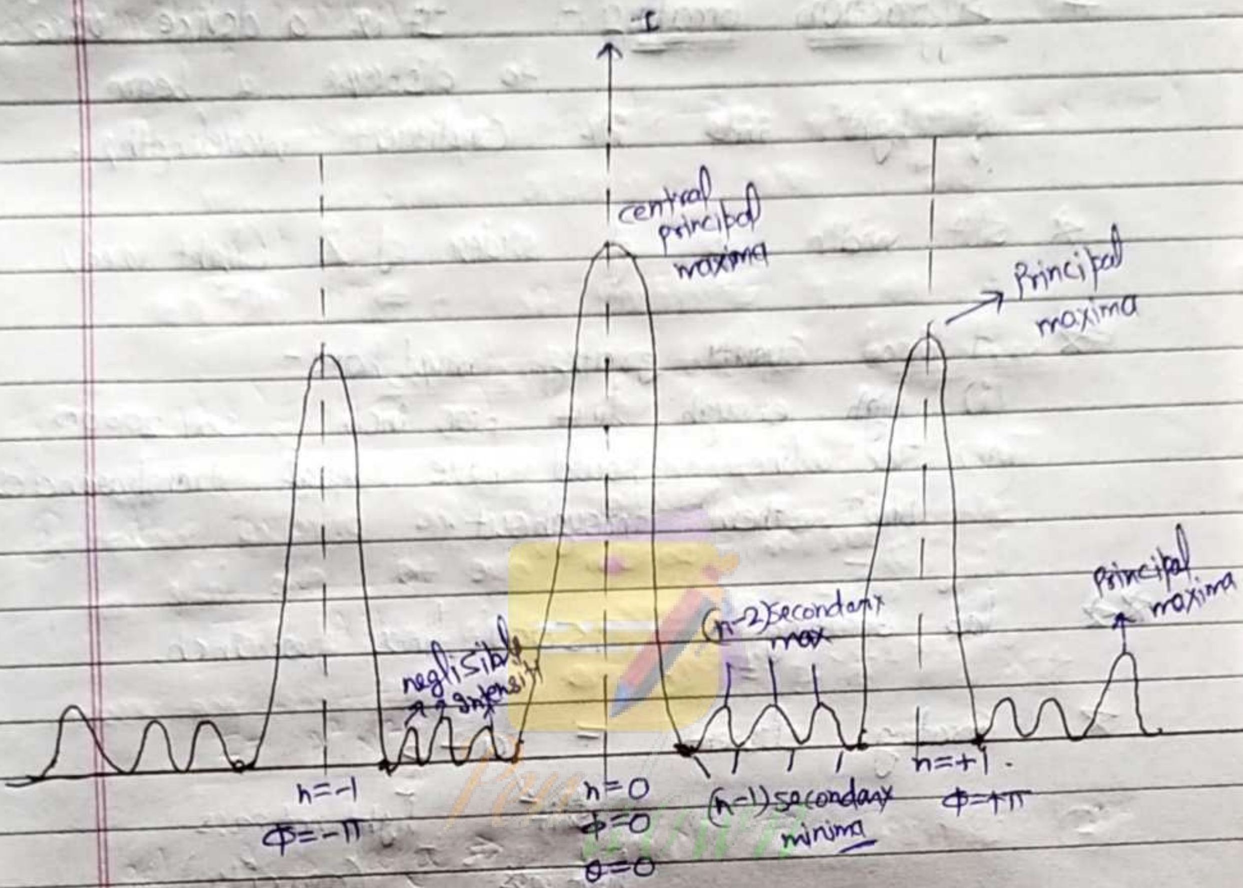
solving -

★★ $\boxed{N \tan\phi = \tan N\phi}$

⑨ Intensity Distribution Curve :-

Due to diffraction at N slits,

secondary maxima = $N-2$
secondary minima = $N-1$



(10) let $N = 15000$ in an inch

$\Rightarrow$ principal maxima becomes narrower and ~~steep~~ sharper but
secondary maxima becomes of negligible intensity and invisible in diffraction pattern.

This is the basic of diffraction grating.

Diffraction Grating :- It is a device used to dispose a beam of light into its complituent wavelengths.

☆ slit width is of order of λ (light used)

☆ A Good quality grating must have -
(i) High enough lines per inch, say 20000
(ii) The lines should have equal transparencies b/w them throughout.

☆☆ lab Grating = 15000 lines per inch.

☆ Grating element = $a + b$

a → Slit, light pass (Trasparency)

b → light not pass (opacity)

Highest order of Principal Maximum :-

$$(a+b)\sin\theta = n\lambda$$

max value of $\theta = 90^\circ$

$$(a+b) = n\lambda$$

$$\boxed{n_{max} = \frac{a+b}{\lambda}}$$

① If $(a+b)$ lie b/w λ and (2λ)
i.e $(a+b) < 2\lambda$
only first order is seen.

② If $(a+b) < 3\lambda$
only first two orders are visible