Diffraction

Diffraction:

bending of light around the sharp edges of an object and then spread out

Types of Diffraction

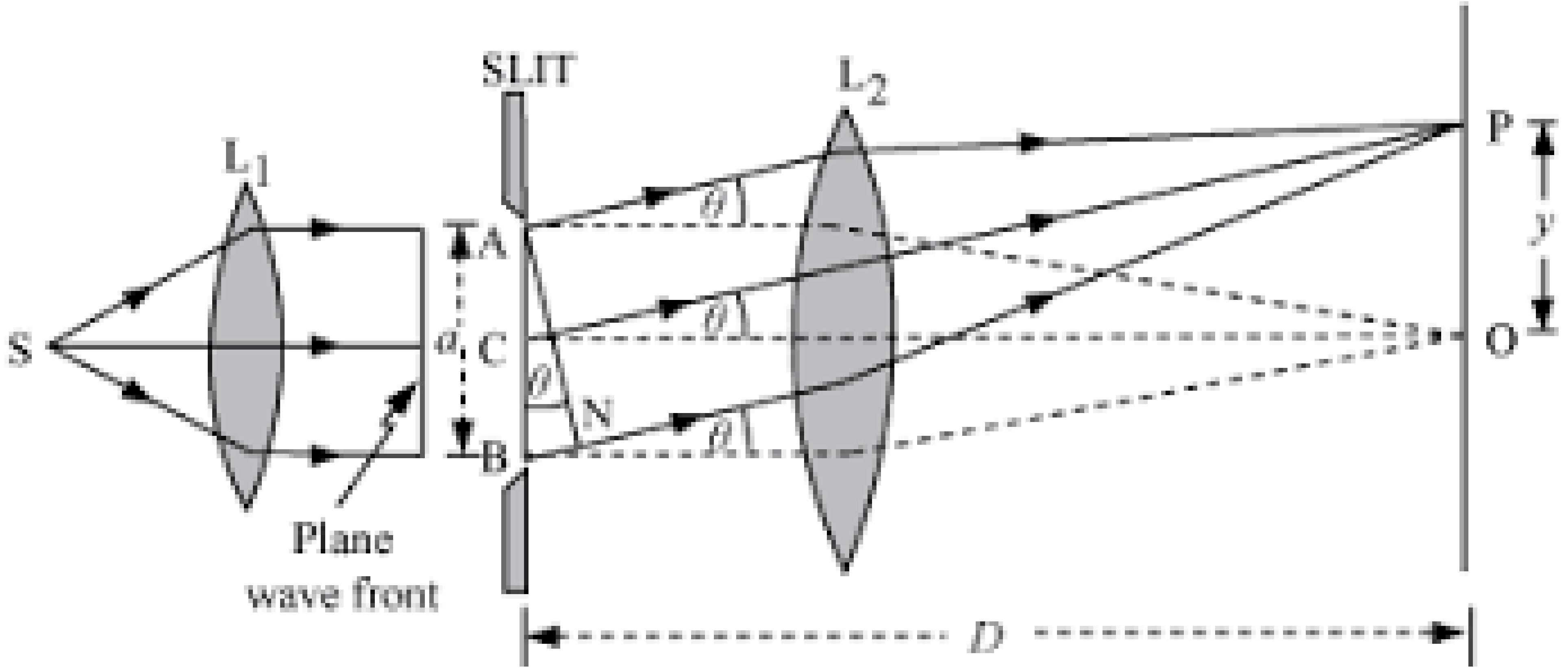
1. Fresnel Diffraction (source and screen at finite distance)
2. Fraunhofer Diffraction (source and screen at infinite distance)

Difference between Interference and Diffraction pattern

Interference pattern	Diffraction pattern
1. It is due to superposition of two wavefronts coming from coherent sources .	1. It is due to interference of secondary wavelets , which originates from the same wave front .
2. In the interference pattern the fringe width is constant.	2. In the diffraction pattern the fringe width is not constant .
3. Points of minimum intensity are perfectly dark .	3. Points of minimum intensity are not perfectly dark .
4 . All bright bands are of uniform intensity.	4 . All bright bands are not of same intensity .

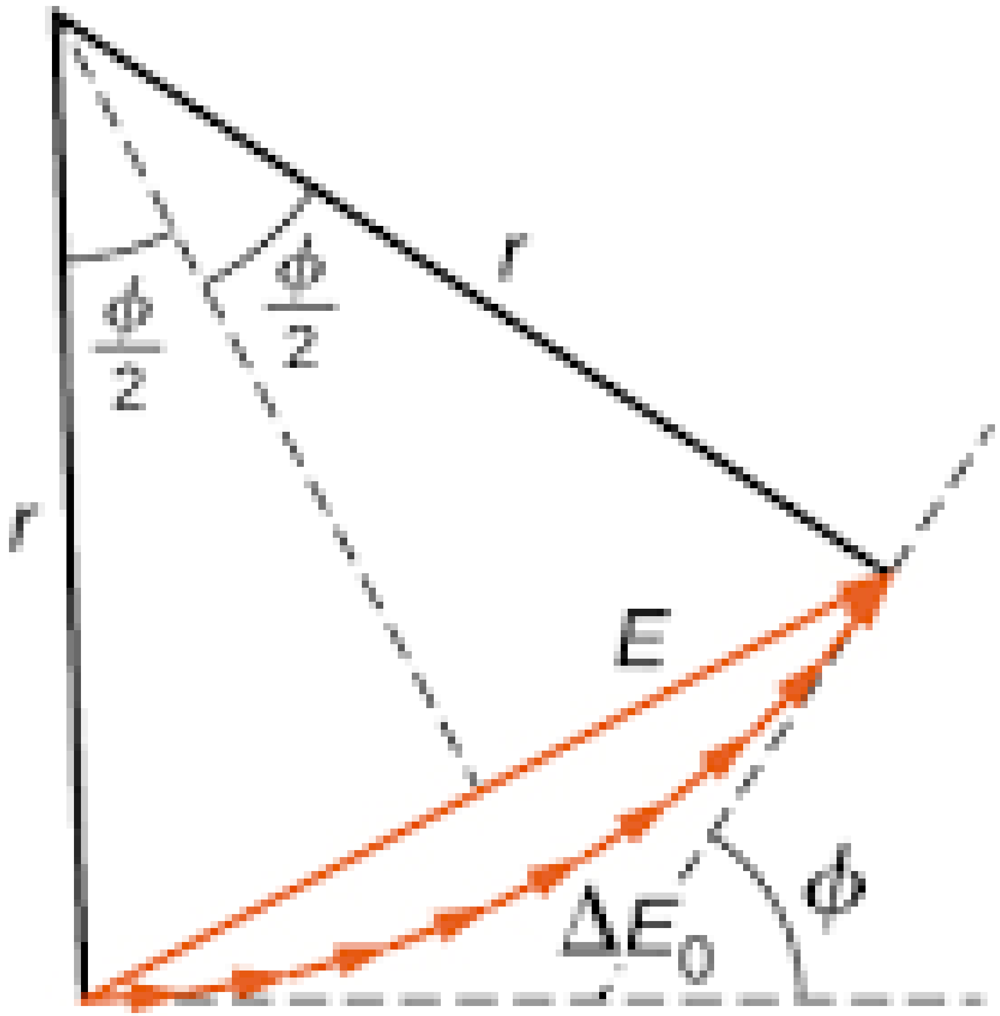
Fresnel Diffraction	Fraunhofer Diffraction
Source and screen at finite distance from slit	Source and screen at infinite distance from slit
Incident wavefront is spherical or cylindrical	Incident wavefront is plane
Diffracted wavefront is spherical or cylindrical	Diffracted wavefront is plane
Path difference between rays before entering the slit which depends on distance between source and slit	No path difference
Lenses are not required	Lenses are required
Mathematical treatment is complicated	It is easy
It has less applications for designing optical instruments	Many applications

Fraunhofer Diffraction at Single Slit



$$\Delta = a \sin\theta$$
$$\Phi = (2\pi/\lambda)\, a \sin\theta$$

Phasor diagram



$$E_\theta{}^2 = Em^2\left(\frac{\sin\alpha}{\alpha}\right)^2$$

$$I_\theta = Im\left(\frac{\sin\alpha}{\alpha}\right)^2$$

Where, $\alpha = \frac{\pi}{\lambda} a \sin\theta$

- **Principal Maxima:**

$$I_\theta = I_m, \quad \text{if } \alpha = 0$$

- **Condition for minima:**

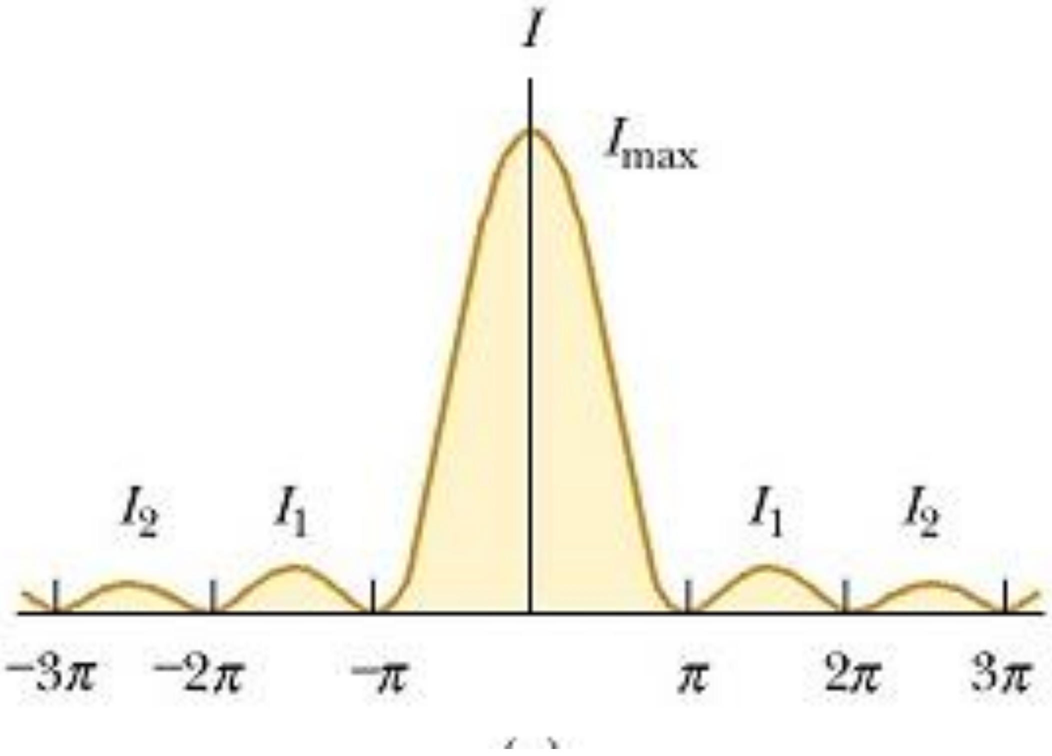
$$a \sin\theta = n\lambda, \text{ if } \alpha = \pm\, n\pi$$

- **Condition for secondary maxima:**

$$I_\theta = \text{Im} \left(\frac{\sin \alpha}{\alpha}\right)^2, \quad \text{if } \alpha = \pm \left(n + \frac{1}{2}\right)\pi$$

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

Intensity distribution of diffraction pattern due to single slit



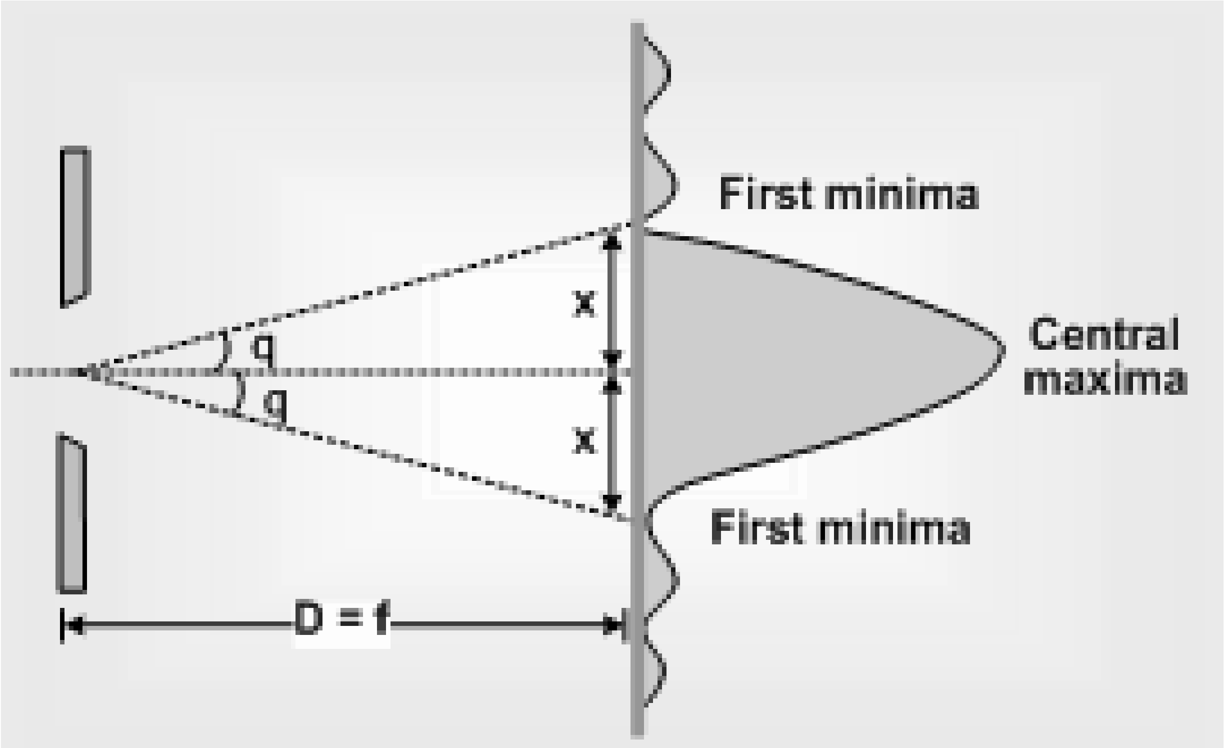
Dependence of spectrum on slit width

- **if, a = λ**
- **if a >> λ**
- **if a << λ**

Hence,

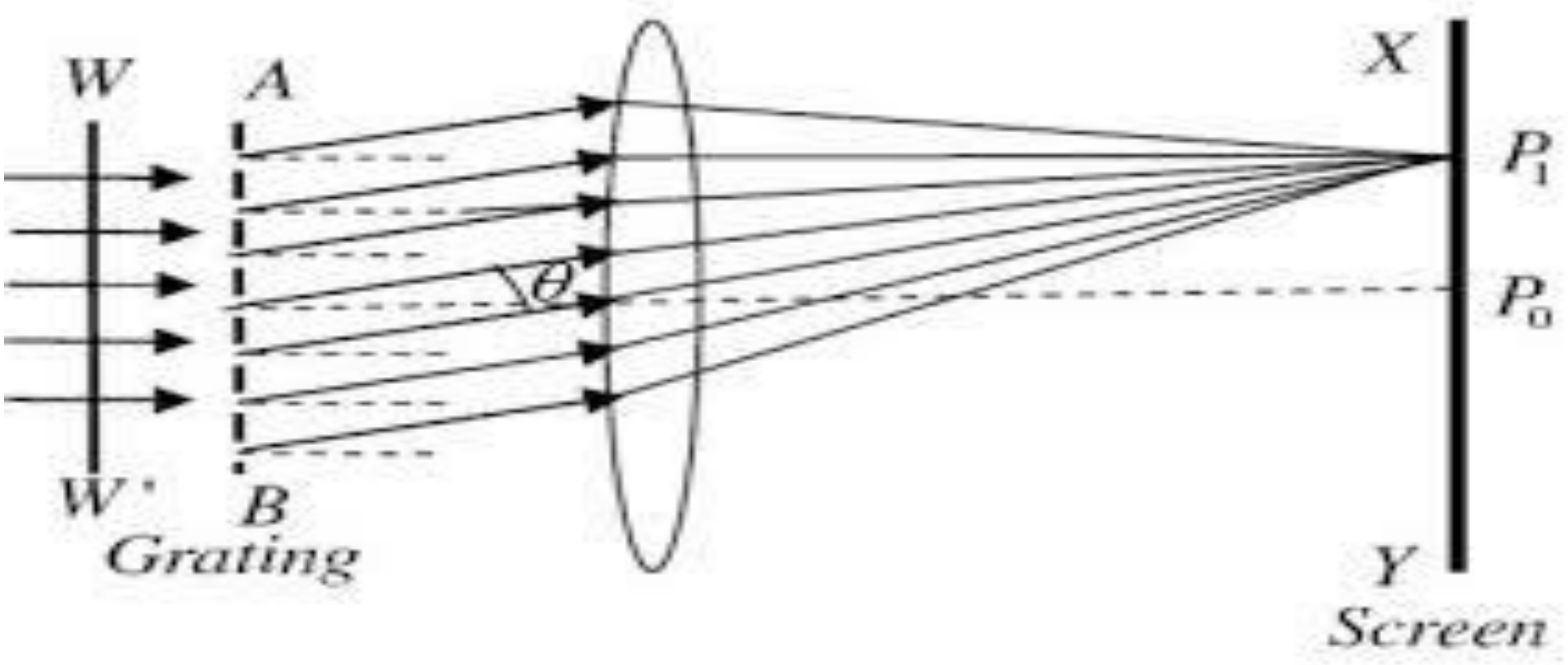
$$a \approx \lambda$$

Width of Central or Principal Maximum



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

Diffraction Grating



Grating element

(a+b) = $\frac{1}{N}$, N is number of lines per unit length

$$I_\theta = Im\left(\frac{sin\alpha}{\alpha}\right)^2\left(\frac{sinN\beta}{\beta}\right)^2$$

- **Principal Maxima:**

  $(a+b)\sin\theta = m\lambda$, where $m = 0, \pm 1, \pm 2, \ldots\ldots$

- **Condition for minima:**

  $(a+b)\sin\theta = \frac{n}{N}\lambda$, where $n = 1, 2, 3, \ldots\ldots (N-1), \ldots\ldots$

  $n \neq 0, N, 2N, \ldots\ldots$

- **Secondary maxima:** (N-2)

Maximum Order

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

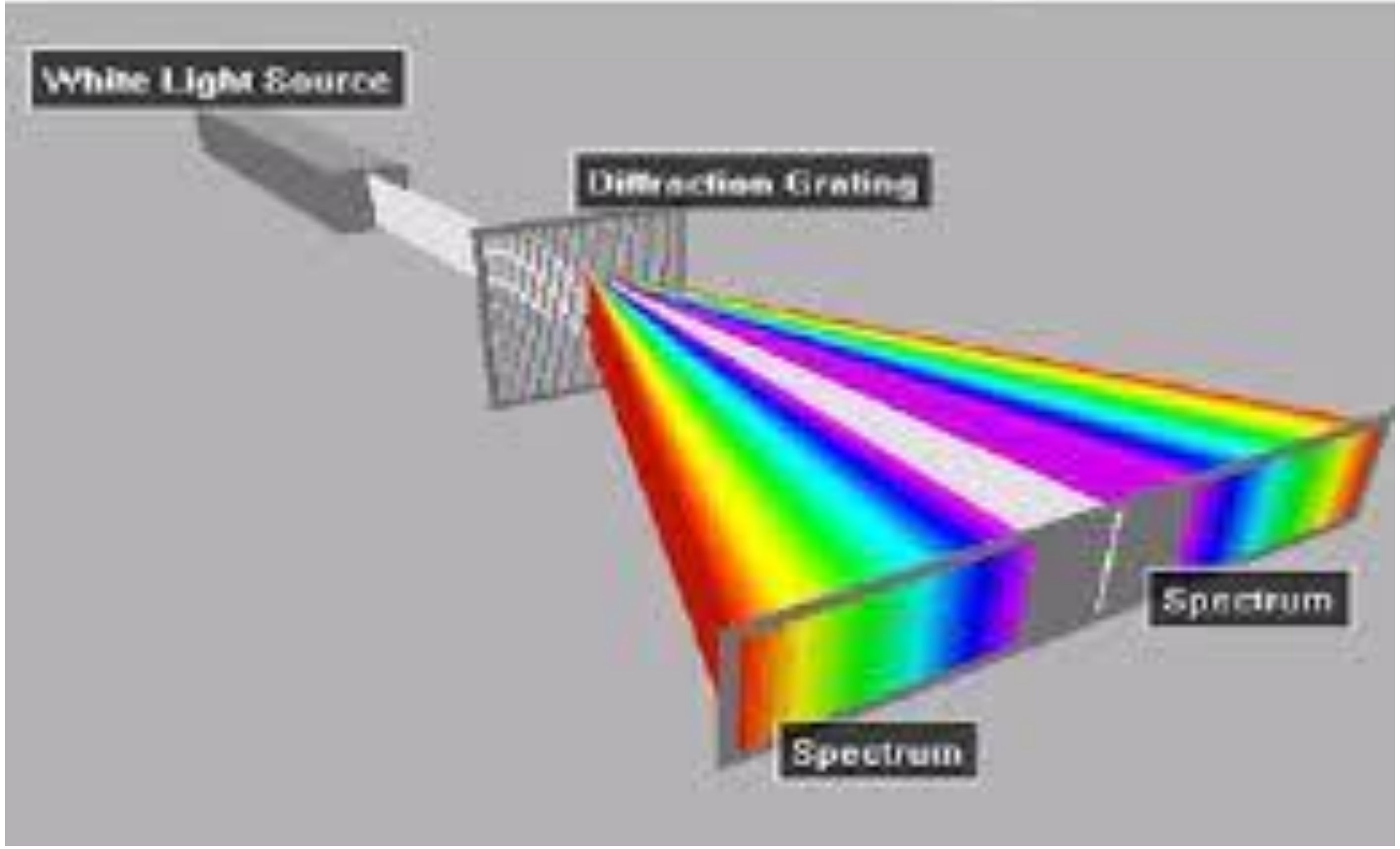
$m_{max} = (a+b)/ \lambda$

When, $\sin \theta = 1$

Absent Spectra

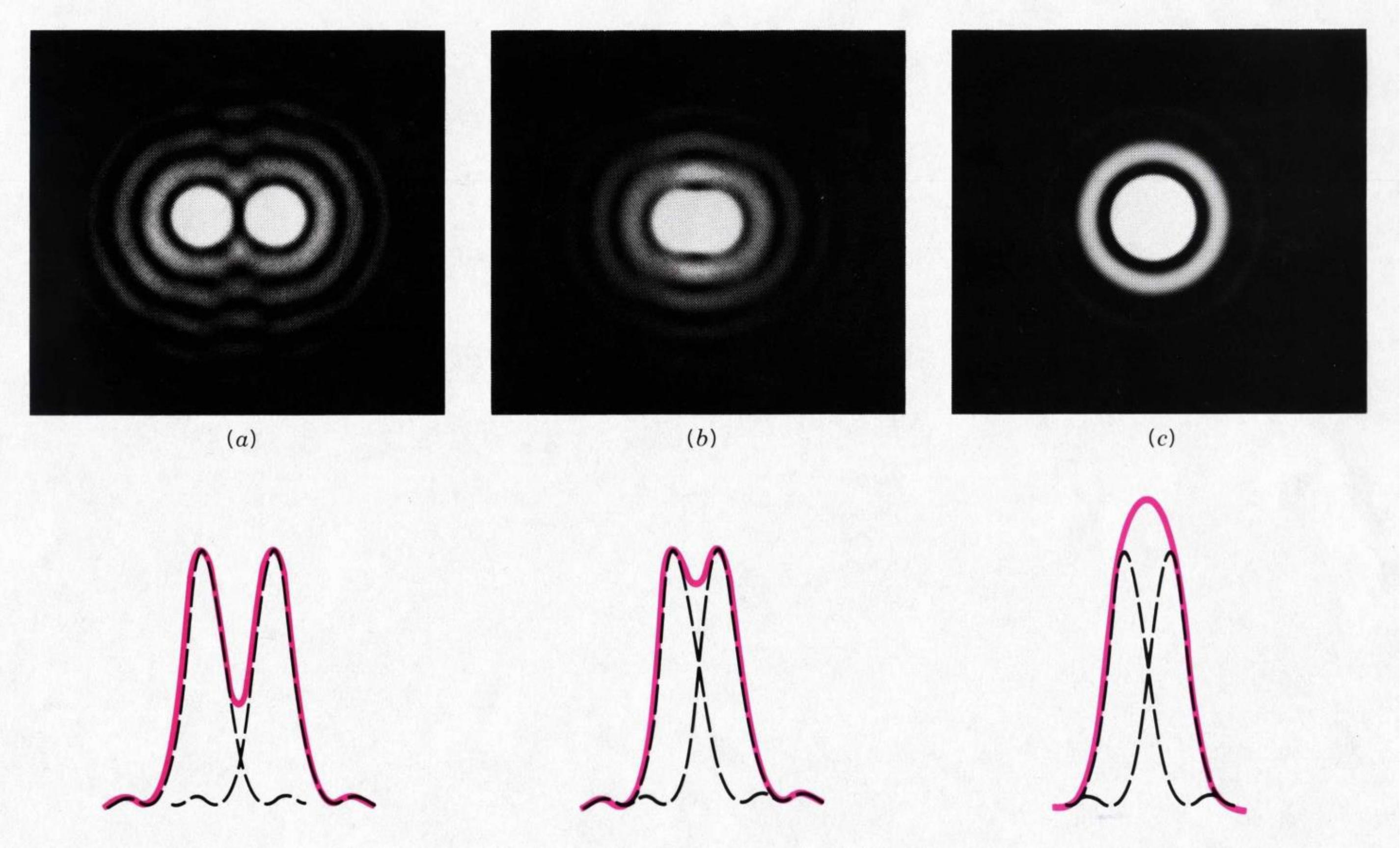
$$m = \left(\frac{a+b}{a}\right) n$$

Diffraction Grating



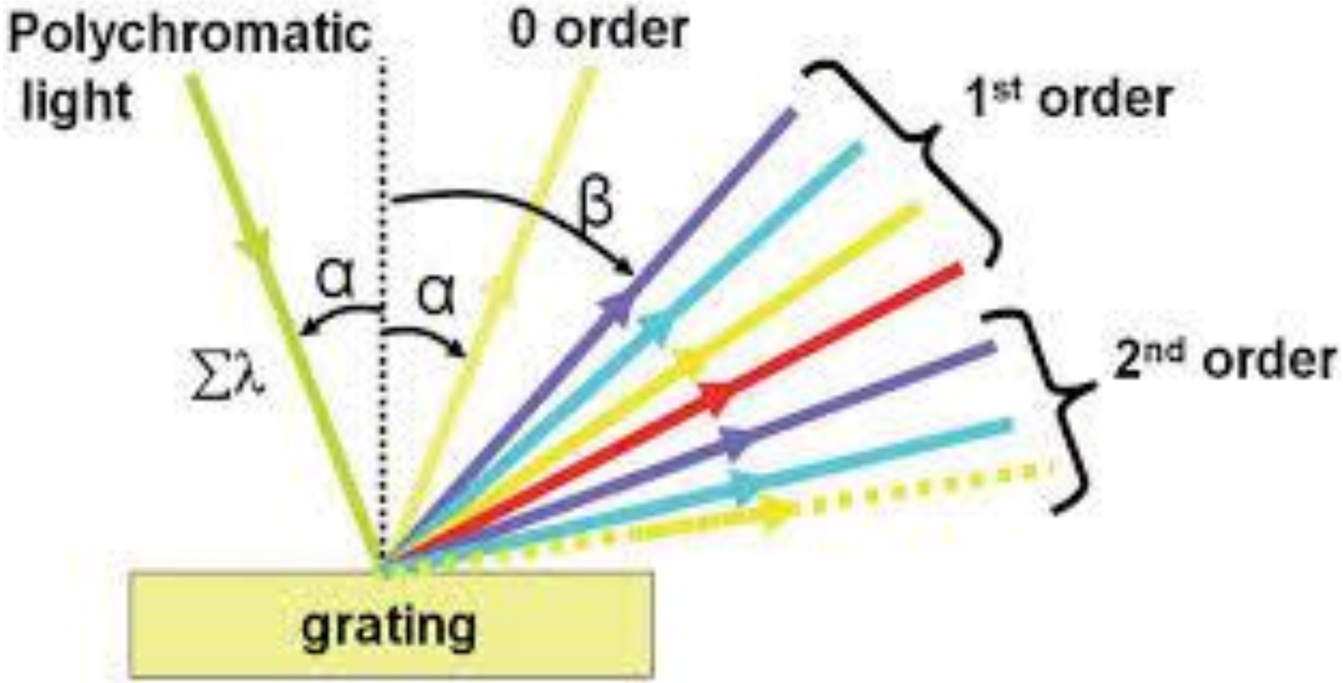
Resolving Power

Resolving power: to resolve lines whose wavelengths are close together



Resolving power of grating

$$\mathbf{R.\ P.}\ \frac{\lambda}{d\lambda} = \boldsymbol{m\ N}$$


Polychromatic light
0 order
1st order
2nd order
β
α
α
Σλ
grating

Closely space tracks on CD or DVD : diffraction grating

Application of diffraction grating

- **Separation of the spectral lines associated with atomic transitions : analysis of gas spectra**
- **Analysis of spectra from stars: cosmology**
- **To identify its components**

Hydrogen spectrum

A slit of width 'a' is illuminated by white light. For what value of 'a' will the first minimum for red light fall at an angle of 30^0? Wavelength of red light is 6500 A^0.

$a \sin\theta = n\lambda$

$a = 1.3 \times 10^{-4}$ cm

Find the half angular width of the central maximum in the Fraunhofer diffraction pattern of a slit of width 12×10^{-5} cm, when illuminated by light of wavelength 6000 A^0.

$\theta = 30^0$

In a plane transmission grating, the angle of diffraction for the second order principal maximum for thee wavelength 5 X 10^{-5} cm is 30^0.

(a+b) sinθ = nλ

N = 1/(a+b)

N = 5000 lines/cm

What is the highest order spectrum that is visible with light of wavelength 6000 A^0 by means of a grating having 5000 lines per cm?

$n_{max} = (a+b)/\lambda$

$n = 3$

Monochromatic light of wavelength 6.56 X 10^{-5} cm falls normally on a grating 2 cm wide. The first order spectrum is produced at an angle of $18^0 14'$ from the normal. What is the total number of lines on the grating?

N = 4770 lines / cm

Total number of lines = 4770 X 2 = 9540