❑ Diffraction:

When light is allowed to pass by the edge of an obstacle, a shadow will be formed. This shadow is not distinct and perfectly dark but there is illumination to some extent within the geometrical shadow of the obstacle. This shows that light can bend round an obstacle. This bending of light waves around a corner or on the edge of an obstacle causing a rapid diminution in the intensity of light is called diffraction. In other words, diffraction is the encroachment of light within the geometrical shadow, which means departure of the path of light from true rectilinear path.

❑ Types of diffraction:

The diffraction phenomena can usually be derived into two categories:

(i) Fresnel diffraction
(ii) Fraunhofer diffraction

(i) Fresnel diffraction:

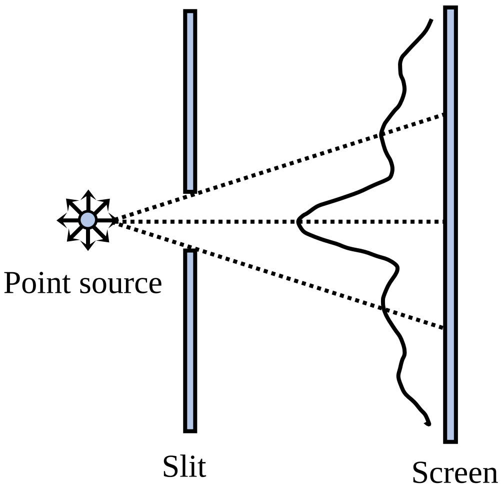

Fig. 1

In the Fresnel class of diffraction, the source of light and the screen are, in general, at a finite distance from the diffracting aperture (slit/edge) as shown in Fig. 1.

(ii) Fraunhofer diffraction:

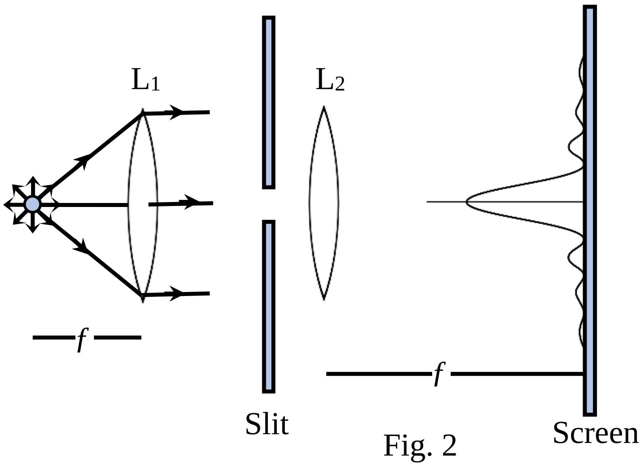

Fig. 2

In the Fraunhofer class of diffraction, the source and the screen are at infinite distances from the aperture (slit/edge). This kind of diffraction can easily be achieved by placing the source on the focal plane of a convex lens and placing the screen on the focal plane of another convex lens. The first lens makes the light beam parallel and the second lens effectively makes the screen receive a parallel beam of light as shown in Fig. 2.

❑ Distinction between Fresnel and Fraunhofer class of diffraction:

Fresnel diffraction	Fraunhofer diffraction
1) Fresnel classes of diffraction are those in which either the source or the screen or both are at finite distances from the obstacle.	1) Fraunhofer classes of diffraction are those in which the source of light and the screen are virtually at infinite distances from the aperture.
2) No lenses are required to make the rays parallel or convergent.	2) Lenses are required to make the rays parallel and convergent.
3) The incident wave front is not plane. As a result, the phase of secondary wavelets is not the same at all points in the plane of the aperture.	3) The incident wave front is plane. For this reason, the phase of secondary wavelets is the same at all points in the plane of the aperture.
4) The resultant amplitude at any point of the screen is obtained by the mutual interference of secondary wavelets from different elements of unblocked portion of the wave front.	4) Diffraction is produced by the interference between parallel ray which are brought into focus with the help of a convex lens.
5) It is difficult to treat it theoretically.	5) It is easier to treat it theoretically.

❑ The essential points of difference between interference and diffraction of light:

The followings are the main points of difference between interference and diffraction:

Interference	Diffraction
1) Interference corresponds to the situation when we consider the superposition of waves coming out from a number of point or line sources.	1) Diffraction corresponds to the situation when we consider waves coming out from an area source like circular or rectangular aperture or even a large number of rectangular apertures like the diffraction grating.
2) Interference fringe is the result of interaction of light coming from two different wave fronts originated from the same source.	2) Diffraction pattern is the result of interaction of light coming from different parts of the same wave front.
3) Points of minimum intensity are perfectly dark.	3) Points of minimum intensity are not perfectly dark.
4) All the bright bands are of uniform intensity.	4) All the bright bands are not of the same intensity.
5) Interference fringes are may be or may not be of the same width.	5) Diffraction fringes are not of the same width.

❑ Fraunhofer diffraction at a single slit and conditions for minima and maxima:

Let us consider a monochromatic source of light that passes through a slit AB of width a as shown in Fig. 1. At point P on the screen, the secondary waves interfere destructively and produce a dark fringe. Let D be the distance between the slit and the screen, and y be the distance between point P and point O, the center of the screen. AC is perpendicular to BP. Let θ be the angle of diffraction, and θ' is the angle BAC.

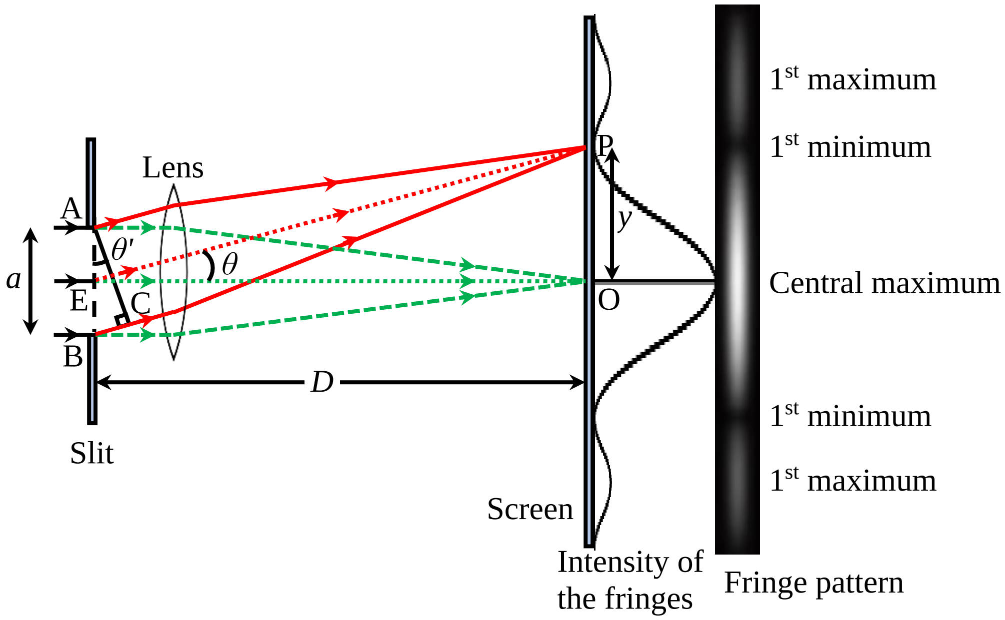

Fig. 1. Fraunhofer diffraction of a plane wave at single slit

We assume that the screen is at a considerable distance from the slit, i.e., $D >> a$. Hence,

$$\theta = \theta'$$

and $\quad \sin\theta \approx \tan\theta \approx \theta = \frac{y}{D}$

The path difference between the two rays AP and BP is given by,

$$\text{BP} - \text{AP} = \text{BC}$$

In the right-angled triangle BCA,

$$\sin\theta' = \sin\theta = \frac{\text{BC}}{\text{BA}}$$

or, $\quad \text{BC} = \text{BA}\sin\theta = a\sin\theta$

$$\therefore \text{BC} = a\sin\theta$$

Therefore, the path difference between two rays AP and EP $= \frac{a}{2}\sin\theta$

a) Condition for diffraction minima:

For the first minimum of intensity (at point P), the path difference between two rays AP and EP is $\lambda/2$, which is the condition for destructive interference.

i.e., $\quad \frac{a}{2}\sin\theta = \frac{\lambda}{2}$

$$\therefore \; a\sin\theta = \lambda$$

Therefore, in general, the secondary minima can be obtained for the following condition:

$a \sin \theta_n = n\lambda$ where, $n = \pm 1, \pm 2, \pm 3, \ldots$, etc.

or, $a \frac{y_n}{D} = n\lambda$ [since, $\sin \theta_n = \frac{y_n}{D}$]

$\therefore y_n = \frac{n\,\lambda\,D}{a}$ ……………. (1)

This equation gives the distance of the n^{th} dark fringe from the center.

The width of secondary minima (dark fringe) is given by,

$$\beta = y_{n+1} - y_n = \frac{(n+1)\,\lambda\,D}{a} - \frac{n\,\lambda\,D}{a}$$

$$\therefore \beta = \frac{\lambda D}{a}$$

a) Condition for diffraction maxima:

The secondary maxima can be obtained for the following condition:

$a \sin \theta_n = (2n+1)\frac{\lambda}{2}$ where, $n = \pm 1, \pm 2, \pm 3, \ldots$, etc.

or, $a \frac{y_n}{D} = (2n+1)\frac{\lambda}{2}$

$\therefore y_n = (2n+1)\frac{\lambda\,D}{2a}$

The width of secondary maxima (bright fringe) is given by,

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

or, $\beta = (2n+1)\frac{\lambda\,D}{2a} - [(2(n-1)+1]\frac{\lambda\,D}{2a}$

or, $\beta = \frac{n\lambda D}{a} + \frac{\lambda D}{2a} - \frac{n\lambda D}{a} + \frac{\lambda\,D}{2a}$

$$\therefore \beta = \frac{\lambda D}{a}$$

The width of the central maximum:

Substituting $n = 1$ in Eq. (1), we get

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

where y is the distance of the secondary minimum (1^{st} minima) from the point O. Thus, the width of the central maximum

$$\beta_c = 2y$$

$$\therefore \beta_c = \frac{2\,\lambda\,D}{a}$$