Diffraction of Light.

It is the phenomenon of bending of light around the corners of an obstacle/aperture of the size of the wavelength of light.



Note: Diffraction is the characteristic of all types of waves.

Greater the wavelength of wave, higher will be its degree of diffraction.

Experimental study of diffraction was extended by Newton as well as Young. Most systematic study carried out by Huygens on the basis of wave theory.

The minimum distance at which the observer should be from the obstacle to observe the

diffraction of light of wavelength λ around the obstacle of size d is given by $x = \frac{d^2}{4\lambda}$.

(1) Types of diffraction: The diffraction phenomenon is divided into two types



(2) Diffraction of light at a single slit: In case of diffraction at a single slit, we get a central bright band with alternate bright (maxima) and dark (minima) bands of decreasing intensity as shown



(i) Width of central maxima $\beta_0 = \frac{2\lambda D}{d}$; and angular width $= \frac{2\lambda}{d}$

(ii) Minima occurs at a point on either side of the central maxima, such that the path difference between the waves from the two ends of the aperture is given by $\Delta = n\lambda$; where $n = 1, 2, 3 \dots$

i.e.
$$d\sin\theta = n\lambda \Rightarrow \sin\theta = \frac{n\lambda}{d}$$

(iii) The secondary maxima occurs, where the path difference between the waves from the two

ends of the aperture is given by $\Delta = (2n+1)\frac{\lambda}{2}$; where $n = 1, 2, 3 \dots$

i.e.
$$d\sin\theta = (2n+1)\frac{\lambda}{2} \Rightarrow \sin\theta = \frac{(2n+1)\lambda}{2d}$$

(3) Comparison between interference and diffraction

Interference	Diffraction
Results due to the superposition of waves from	Results due to the superposition of wavelets
two coherent sources.	from different parts of same wave front. (single coherent source)
All fringes are of same width $\beta = \frac{\lambda D}{d}$	All secondary fringes are of same width but the central maximum is of double the width
	$\beta_0 = 2\beta = 2\frac{\lambda D}{d}$
All fringes are of same intensity	Intensity decreases as the order of maximum increases.
Intensity of all minimum may be zero	Intensity of minima is not zero.
Positions of nth maxima and minima	Positions of nth secondary maxima and minima
$x_{n(\text{Bright})} = \frac{n\lambda D}{d}$, $x_{n(\text{Dark})} = (2n-1)\frac{\lambda D}{d}$	$x_{n(\text{Bright})} = (2n+1)\frac{\lambda D}{d}, x_{n(\text{Dark})} = \frac{n\lambda D}{d}$
Path difference for nth maxima $\Delta = n\lambda$	for nth secondary maxima $\Delta = (2n+1)\frac{\lambda}{2}$

(4) Diffraction and optical instruments: The objective lens of optical instrument like telescope or microscope etc. acts like a circular aperture. Due to diffraction of light at a circular aperture, a converging lens cannot form a point image of an object rather it produces a brighter disc known as Airy disc surrounded by alternate dark and bright concentric rings.

The angular half width of Airy disc $= \theta = \frac{1.22\lambda}{D}$ (where D = aperture of lens)

The lateral width of the image $= f\theta$ (where f = focal length of the lens)



Note: Diffraction of light limits the ability of optical instruments to form clear images of objects when they are close to each other.

(5) Diffraction grating: Consists of large number of equally spaced parallel slits. If light is incident normally on a transmission grating, the diffraction of principle maxima (PM) is given by $d\sin\theta = n\lambda$; where d = distance between two consecutive slits and is called grating element.

