**Diffraction part 1**

**Introduction**

We know from our day-to-day experience that we can hear persons talking in an adjoining room whose door are open. This is due to the ability of sound waves to bend around the comers of obstacles in their way. You **are** also familiar with the ability of water waves to propagate around obstacles. Does light, which is an electromagnetic wave, also bend around comers of obstacles in its path? In the previous block you have learnt manifestation of wave nature of light in the form of interference: Light from two coherent sources interferes to form fringed pattern, but what may puzzle you is the fact that light casts shadows of objects, i.e. appears to travel in straight lines rather than bending around comers. This apparent contradiction was explained by Fresnel who showed that **the** ease with which a wave bends around comers is strongly influenced by the size of the obstacle (aperture) relative to its wavelength. Music and speech I wavelengths lie in the range 1.7 cm to 17m. A door is about 1 m aperture so that long wavelength waves bend more readily around the door way. On the other hand, wavelength of light is about 6000 to 8000 Å and the obstacles used in ordinary experiments are about a few centimetres in size, i.e. 104-105 times bigger. For this reason, light appears to travel along straight lines and casts shadows of objects instead of bending around their comers. However, it does not mean that light shows no bending; it does so under suitable conditions where size of obstacles is comparable with the wavelength of light. You can get a feel for this by closely examining shadows cast by objects. You will observe at the edges of shadows are not sharp. The deviation of waves from their original direction due to an obstruction in their path is called diffraction.

 ➢ Diffraction is the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening. If the opening is much larger than the light's wavelength, the bending will be almost unnoticeable

**➢ Difference between Diffraction and Interference**

It is important to know the key differences between them by examining the region of minimum intensity, this region is incredibly dark in interference and it is less dark in the case of diffraction. Like these few differences, there are a few more factors that differentiate diffraction over interference. It is important to know the distinctions between one and the other. Some of the major key differences between diffraction and interference are listed below:

**Difference between Diffraction and Interference**

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| --- | --- |
| Interference  | Diffraction  |
| Interference may be defined as waves emerging from two different sources, producing different wave fronts.  | Diffraction on the other hand can be termed as secondary waves that emerge from the different parts of the same wave.  |
| In interference the intensity of all the positions on maxima are of similar intensity in interference.  | In diffraction, there is a variance of the intensity of positions.  |
| The width of the fringes in interference is equal in interference.  | The width of the fringes is not equal in interference.  |
| It is absolutely dark in the region of minimum intensity, in the case of interference.  | In the case of diffraction, there is a variance in the intensity of interference.  |
| If the number of sources is few such as two sources, then they are referred to as interference sources.  | If the number of sources are many, that is more than two then it is referred to as  |

**What do you mean by Fresnel diffraction?**

Fresnel diffraction or near-field diffraction is a process of diffraction that occurs when a wave passes through an aperture and diffracts in the near field, causing any diffraction pattern observed to differ in size and shape, depending on the distance between the aperture and the projection. It occurs due to the short distance in which the diffracted waves propagate which results in a Fresnel number greater than 1 (*F* > 1). When the distance is increased, outgoing diffracted waves become planar and Fraunhofer diffraction occurs.

Fresnel diffraction occurs when either the distance from the source to the obstruction or distance from the obstruction to screen is comparable to the size of the obstruction. These comparable distances and sizes lead to unique diffractive behaviour.

Diffraction at a straight edge, a narrow slit, a thin wire, a small circular hole or a disc is examples of Fresnel diffraction. An application of this type of diffraction is met with in the construction of a zone plate.

**What do you mean by Fraunhofer diffraction?**

In optics, the Fraunhofer diffraction equation is used to model the diffraction of waves when the diffraction pattern is viewed at a long distance from the diffracting object, and also when it is viewed at the focal plane of an imaging lens.

It is observed at distances beyond the near- field distance of Fresnel diffraction, which affects both size and shape of the observed aperture image and occurs only when the Fresnel number, wherein the parallel rays approximation can be applied.

**Discuss Fraunhofer diffraction at single slit?**

Let us first consider a parallel beam of light incident normally on a slit AB of width 'a' which is of order of the wavelength of light as shown below in the figure

A real image of diffraction pattern is formed on the screen with the help of converging lens placed in the path of the diffracted beam

• All the rays that start from slit AB in the same phase reinforce each other and produce brightness at point O on the axis of slit as they arrive there in the same phase

• The intensity of diffracted beam will be different in different directions and there are some directories where there is no light

• Thus diffraction pattern on screen consists of a central bright band and alternate dark and bright bands of decreasing intensity on both sides

• Now consider a plane wave front PQ incident on the narrow slit AB. According to Huygens principle each point on unblocked portion of wave front PQ sends out secondary wavelets in all directions

• Their combined effect at any distant point can be found y summing the numerous waves arriving there from the principle of superposition

• Let C be the centre of the slit AB. The secondary waves, from points equidistant from centre C of the clit lying on portion CA and CB of wave front travel the same distance in reaching O and hence the path difference between them is zero

• These waves reinforce each other and give rise to the central maximum at point O

**Condition for minima**

• We now consider the intensity at point P1above O on the screen where another set of rays diffracted at a angle θ have been bought to focus by the lens and contributions from different elements of the slits do not arise in phase at P1

• If we drop a perpendicular from point A to the diffracted ray from B, then AE as shown in figure constitutes the diffracted wave front and BE is the path difference between the rays from the two edges A and B of the slit.

• Let us imagine this path difference to be equal to one wavelength.

• The wavelets from different parts of the slit do not reach point P1 in the phase because they cover unequal distance in reaching P1.Thus they would interfere and cancel out each other effect. For this to occur

BE=λ Since BE=ABsinθ asinθ=λ or sinθ=λ/a or θ=λ/a ---(1) As angle of diffraction is usually very small so that sinθ=θ

Such a point on screen as given by the equation (1) would be point of secondary minimum

• It is because we have assume the slit to be divided into two parts, then wavelets from the corresponding points of the two halves of the slit will have path difference of BE= λ and wavelets from two halves will reach point P1 on the screen in a opposite phase to produce minima

• Again consider the point P2 in the figure 1 and if for this point path difference BE=2λ, then we can imagine slit to be divided into four equal parts

• The wavelets from the corresponding points of the two adjacent parts of the slit will have a path difference of λ/2 and will mutually interfere to cancel out each other

• Thus a second minimum occurs at P2 in direction of θ given by θ=2θ/a

• Similarly nth minimum at point Pn occurs in direction of θ given by θn=nθ/a ---(2)

**Positions of maxima**

• If there is any point on the screen for which path difference BN=a sinθ=3θ/2 Then point will be position of first secondary maxima

• Here we imagine unblocked wave front to be divided into three equal parts where the wavelets from the first two parts reach point P in opposite phase thereby cancelling the effects of each other

• The secondary waves from third part remain un-cancelled and produce first maximum at the given point

• We will get second secondary maximum for BN=5θ/2 and nth secondary maxima for BN=(2n+1)θ/2 =a sinθn ---(3) where n=1,2,3,4..

• Intensity of these secondary maxima is much less then central maxima and falls off rapidly as move outwards

• Figure below shows the variation of the intensity distribution with their distance from the centre of the central maxima

