A Short Note On

“Fresnel Diffraction”

(For 2nd Semester Physics-Hons. Students)

By

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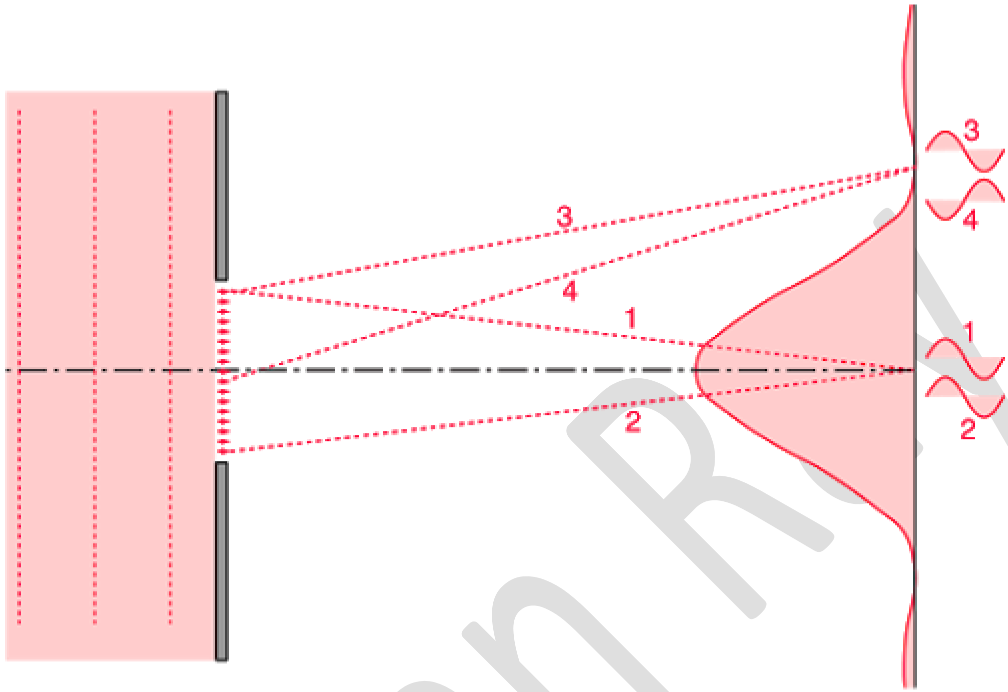
Diffraction:



Definition:

The phenomena of bending of light wave around the obstacle or aperture comparable with the wave length of light, resulting in its spreading into the geometrical shadow of the object into the space is known as diffraction.

Difference between Interference and Diffraction:

a) Interference occurs due to the superposition of the two different coherent sources but the diffraction occurs due to the superposition of the secondary wavelets from the different parts of the same wave front.

b) In case of interference the fringe widths are equal but in diffraction, fringes are of varying width.

c) In interference, all maxima have the same intensity but in diffraction maxima have the varying intensity.

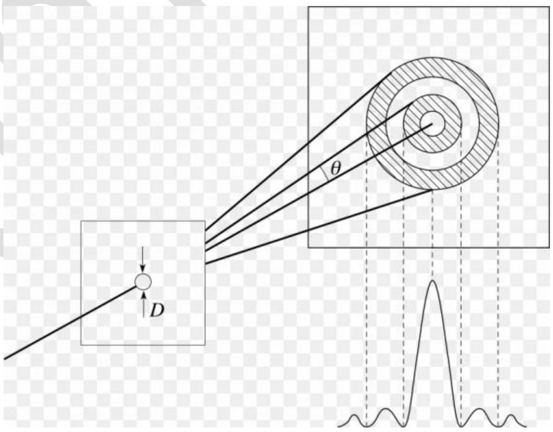
d) There is a good contrast between the maxima and minima in case of interference but in diffraction, the contrast between the maxima and minima are poor.

Types of diffraction:

There are mainly two types of diffraction –
a) Fresnel Diffraction
b) Fraunhofer Diffraction

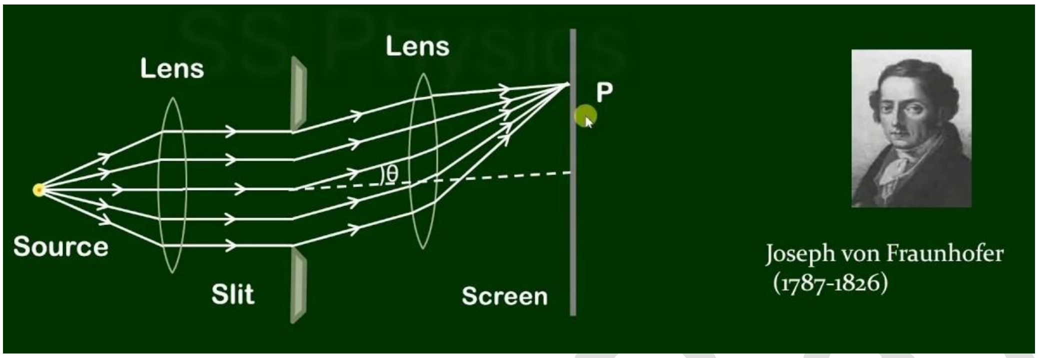
Fresnel Diffraction:

Fresnel diffraction can be observed if the source of light and the screen at which diffraction pattern is formed are kept at finite distance from the diffracting obstacle. In this situation the wave fronts falling on the obstacle are not plane. Similarly the wave fronts leaving the obstacle are not plane.



Fraunhofer Diffraction:

Fraunhofer diffraction can be observed if the source of light and screen at which diffraction pattern is formed are placed at infinite distance from the diffracting obstacle. This can be done by using two converging lenses. One lens is placed between the source of light and the obstacle while the other lens is placed between the obstacle and screen. The lens between the source and obstacle makes the rays parallel to each other while the lens between the obstacle and screen, focus the parallel rays at point on the screen.



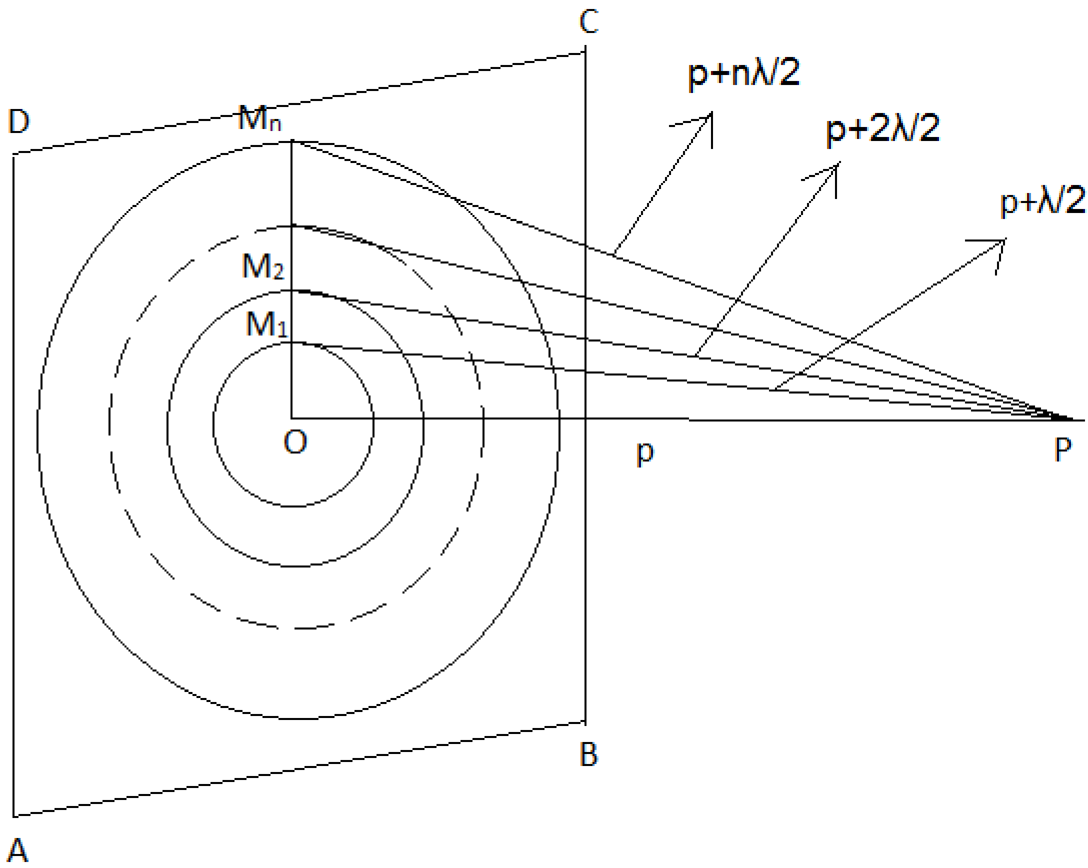
Rectilinear propagation of light; Fresnel half period zone:

We shall follow Fresnel's method – the technique of half period zone – for finding the effect of plane wave front at some external point in front of it and use the technique to explain rectilinear propagation of light.

Half period zone:

According to Huygen, each point of wave front sense out secondary wavelets. Fresnel assume that these wavelets interfere among themselves to produce resultant intensity at any point. To find the resultant intensity, he divided the wave fronts into a number of zones, called Fresnel's half period zone.

Construction of half period zones:



Let a plane wave front ABCD of wave length λ move from left to right and P be the external point where the intensity is sought. From P, draw a perpendicular PO to the wave front. The point O is called pole of the wave front relative to P.

Let PO = p and P as centre and radii p+λ/2, p+2λ/2, p+3λ/2, ……etc draw a series of spheres, the section of which by wave front are concentric circle with O at centre. The area of the first inner most circle is the 1st half period zone, the annular area between the first and second circle is the 2nd half period zone and so on. The n-th half period zone is thus the annular area between the (n-1)-th and n-th circle.

Why it is called half period zone?

Since when we consider two rays, one from the top and the other from the bottom of the zone which reach the screen, there is a path difference of $\lambda/2$ between them which is equivalent to half period. That is why, it is called a half period zone.

Area of a zone:

The area of the n-th half period zone is $= \Pi(OM_n^2 - OM_{n-1}^2)$

$$= \Pi[\{(p+n\lambda/2)^2 - p^2\} - \{(p+(n-1)\lambda/2)^2 - p^2\}]$$

$$= \Pi[\{pn\lambda+n^2\lambda^2/4\} - \{p(n-1)\lambda+(n-1)^2\lambda^2/4\}]$$

$$= \Pi[p\lambda+\lambda^2/4\{n^2-(n-1)^2\}]$$

$$= \Pi[p\lambda+\lambda^2/4(2n-1)]$$

$$= \Pi p\lambda \qquad \text{[when n is very large, n = (n-1)]}$$

Thus approximately the area of the n-th zone is independent of the order n of the zone. This means that the area of each zone is nearly equal to same.

Average distance of the n-th zone from P:

The average distance of the n-th zone from P is

$= ½ [(p+n\lambda/2)+\{p+(n-1)\lambda/2\}]$

$=p+(2n-1)\lambda/4$

Amplitude due to a zone at P:

The factors on which amplitude at P due to a zone depends are –

(i) Area of the zone

(ii) The average distance of the zone

(iii) The obliquely factor

The amplitude A_n due to n-th zone is given by,

$A_n \infty \Pi[\{p\lambda+\lambda^2/4(2n-1)\}/\{ p+(2n-1)\lambda/4\}] (1+\cos(\theta_n))$

$\quad \infty \Pi\lambda(1+\cos(\theta_n))$

As n increases, so thus θ_n but $\cos(\theta_n)$ decreases. This means that the amplitude at P due to a zone will gradually decreases as the order n of the zone increases.

Resultant amplitude due to a whole wave front:

If A_1 , A_2 , ………………. , A_n be the amplitudes at P due to 1^{st} , 2^{nd} , ……….. , etc. zone respectively. They are in decreasing order of magnitude. Again the waves of two successive zones reach P in opposite phase.

Therefore, resultant amplitude at P due to whole wave front is

$A = A_1-A_2+A_3-A_4+A_5$------------------$+(-1)^{n-1}A_n$

$\quad = A_1/2+(A_1/2-A_2+A_3/2)+(A_3/2-A_4+A_5/2)+$---------------------

The last term being $A_n/2$ if n is odd, or $(A_{n-1}/2 – A_n)$ if n is even. Each of the bracket gives essentially zero since A_2 is slightly smaller than A_1 but slightly greater than A_3 and so on. Now n is extremely large and because of obliquely factor $A_{n-1}= A_n=0$.

$$\text{Therefore } A=(1/2)\, A_1$$

So the amplitude due to the entire wave front at a point in front of it just half that of the 1^{st} half period zone. The contributions of the other half period zones are cancelled by mutual interference.