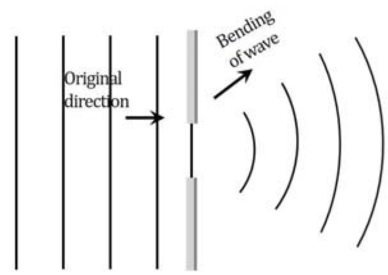
DIFFRACTION

Diffraction

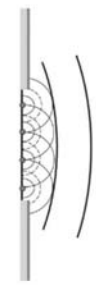
The bending of a wave or its deviation from its original path when it encounters a small obstacle is referred to as diffraction.



Why bending occurs ?

To understand why light bends, we must see light as a wave. Using Huygens' principle, we can explain the bending of light like this:

When a flat wavefront hits a narrow opening with a sharp edge, each point on the wavefront acts like a tiny source of light waves. These tiny sources emit spherical waves, as illustrated. The overall shape formed by these waves represents the new wavefront.



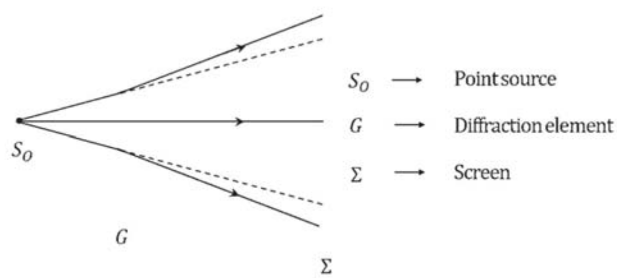
Interference occurs between these tiny sources, which clarifies why light bends when it encounters a narrow opening with a sharp edge.

Condition for diffraction:

Wavelength of light (λ) ≈ size of obstacle

Diffraction Experiment

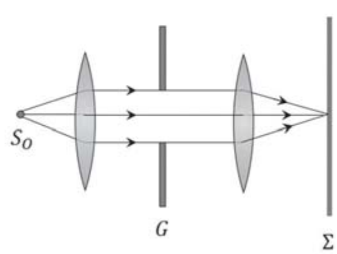
Diffraction through a small single slit



When light passes through a pinhole or a narrow slit, we notice a bright spot in the center of the screen. The size of this spot is larger than the size of the pinhole or slit. Additionally, we see dark and bright rings encircling the central bright spot.

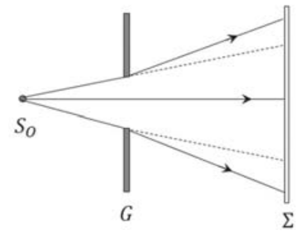
Fraunhofer Diffraction

Source and screen are very far away from diffraction element. High intense interference pattern is observed on screen due to parallel ray incidence and convergence of pattern.



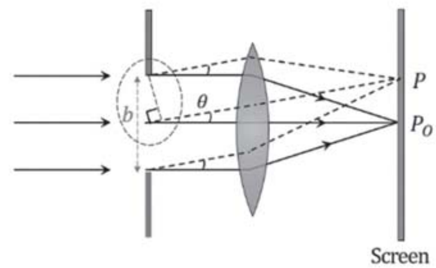
Fresnel Diffraction

Source and screen are at finite distance from diffraction element. Diffraction was first demonstrated by this experiment.



Fraunhofer Diffration - Single Slit

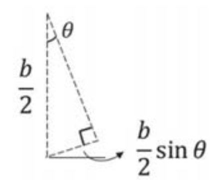
Consider the interference at point P due to multiple small sources as shown in figure.



Path difference between the rays can be found from triangle ABC. A C B

Path difference,

$$\Delta x = \frac{b}{2}\sin\theta$$



Here,

Slit width: b

At any general point P,

$I =$ Resultant intensity of all secondary wavelets

$I_0 =$ Resultant intensity at the center point P_0

$$\text{Path difference, } \Delta x = \frac{b}{2}\sin\theta$$

$$\text{Condition for } 1^{st} \text{ minima: } \Delta x = \frac{\lambda}{2}$$

$$\Rightarrow \Delta x = \frac{b}{2}\sin\theta = \frac{\lambda}{2}$$

$$\Rightarrow b\sin\theta = \lambda$$

If θ is small:

$$\theta = \frac{\lambda}{b}$$

For n^{th} minima,

$$b\sin\theta = n\lambda$$

If $n = 0$

$$\Rightarrow b\sin\theta = 0$$

$$\Rightarrow \theta = 0$$

⇒ Path difference between the rays is zero

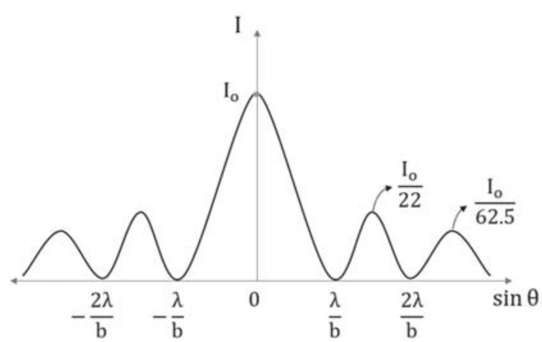
⇒ The constructive interference will occur at P_O. Thus, P_O is the central maxima.

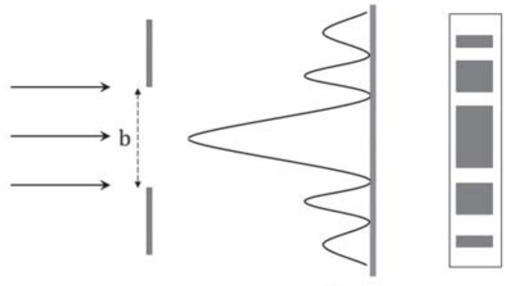
Intensity at any general point ?

Resultant intensity of interference pattern at an angle θ is,

$$I = \frac{I_0 \sin^2\beta}{\beta^2} \quad \text{Where, } \beta = \frac{\pi}{\lambda}(b\sin\theta)$$

Variation of intensity with sinθ is shown in the figure .



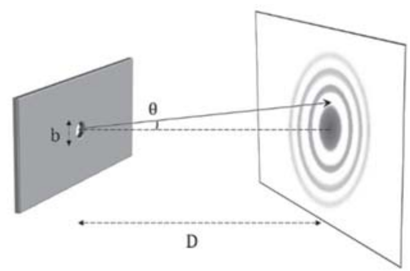


In YDSE, all the maxima have the same intensity whereas in case of Fraunhofer diffraction, the intensity of maxima decreases as we move away from the central maxima.
In YDSE, I_0 is the intensity of light coming from one slit but in case of Fraunhofer diffraction, I_0 is the intensity of light at the central maxima.

Fraunhofer Diffration - Circular Aperture

We get circular bright and dark spots on the screen for circular aperture as shown in the figure.
For first dark ring,

$\sin\theta = \frac{1.22\lambda}{b}$



Where,
b = diameter of aperture
D = distance of screen from hole
λ = wavelength of light
θ = diffraction limit

Radius of central bright diffraction disc:

$$R = \frac{1.22\lambda D}{b}$$