Additional Material for Interference and Diffraction

Interference of Light

Interference is the phenomenon that occurs when two waves of the same frequency combine to reinforce or cancel each other, in the same medium. The amplitude of the resulting wave is the sum of the amplitudes of the combining wave.

Interference of light waves from two sources was first demonstrated by **British physicist Thomas Young**.
Below is the diagram of the experimental set up made by Thomas Young. The light is made to pass through a slit **a** at S1. The waves emerging from the slit S1 will pass through two parallel slits **b** and **c** at S2.

The slits **b** and **c** are now coherent light sources because the waves orignating from them are from the same wavefront. So they have same frequency and amplitude.
Thomas Young observed that the light waves orignating from **b** and **c** produce alternate dark and bright pattern called fringes.

The bright fringes appear when the light waves from **b** and **c** interfere constructively. The dark fringes appear when the light waves interfere destructively.

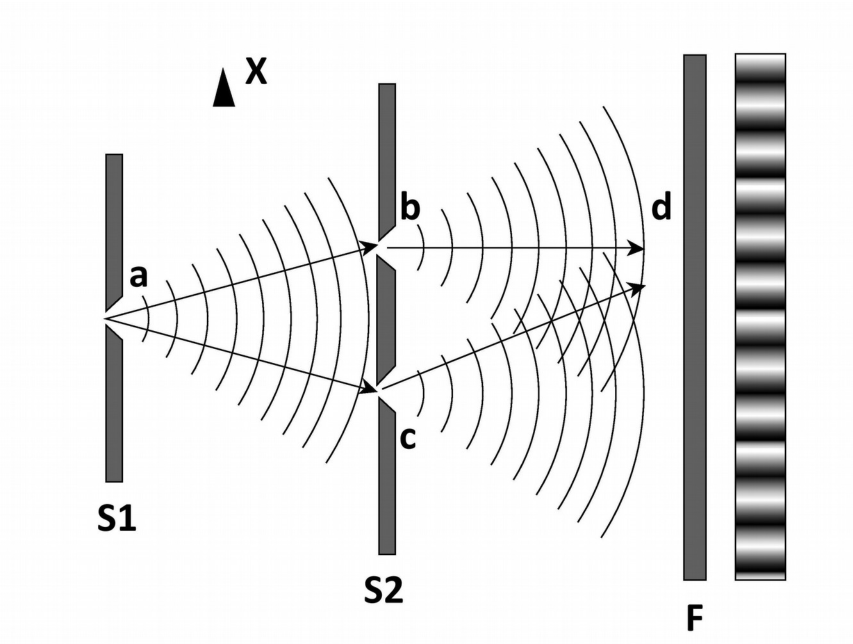

Figure-1

The distance between two consecutive bright and dark fringes can be calculated by the given formula.

$$\beta = \lambda D/d$$

Here,
β is the fringe width.
λ is the wavelength.
D is the distance between the slit and the screen.
d is the distance between the slits.

Diffraction of Light

The bending of light waves around the corners of an obstacle into the region of geometrical shadow of the obstacle is **Diffraction**.

Single Slit Diffraction

Below is the diagram of the experimental set up of a single slit diffraction.

The parallel beam of light is allowed to pass through a single slit. In this case the intensity profile for a single slit is different from that of the intensity profile of interference.

Here the central maxima is much more brighter than other secondary maximas.

The intensity of the maximas on the either side of the central maxima decreases as we move away from center.
This pattern is called diffraction pattern.

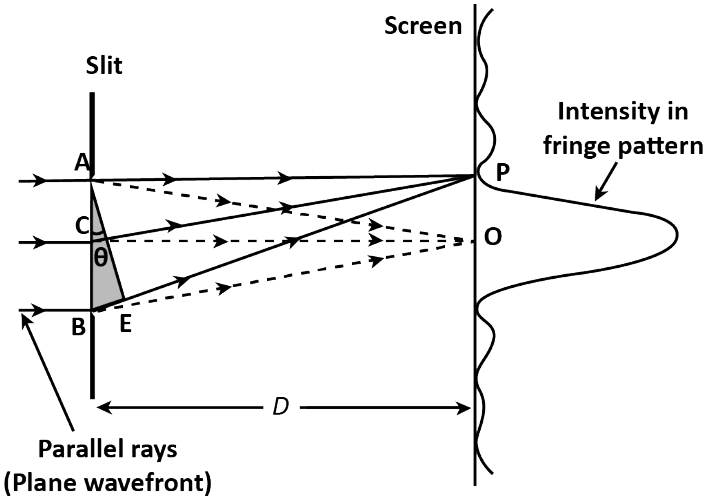

Figure-2

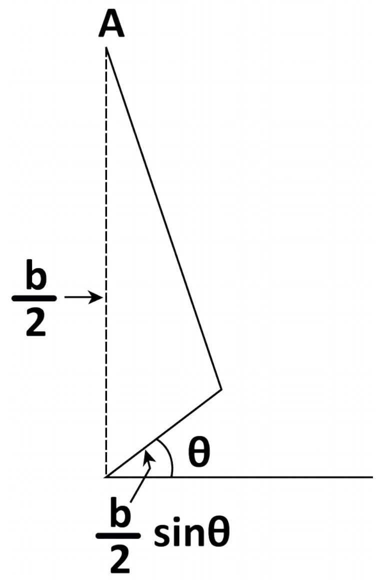

Figure-3

Let's find out how to get a dark fringe at point **P**. Refer to **Figure 2**. Consider point **P** which collects the waves originating from different points of the slit at an angle **θ.** A perpendicular is drawn from point **A** to the parallel rays. This perpendicular represents the wavefront of the parallel beam diffracted at an angle **θ.** The optical path difference from any point on this wavefront to point **P** is equal.

The optical path difference between the waves sent by the upper edge **A** of the slit and the waves sent by the centre of the slit is **b/2(sinθ)**.

Refer to **Figure 3**. Consider the angle for which
b/2(sinθ)= λ/2 .

The phase difference for the above two waves will be :

$$\delta = (2\pi/\lambda)(\lambda/2)$$
$$= \pi$$

The two waves cancel each other. The waves from any point in the upper half of the slit get cancelled by the waves from the point **b/2** distance below it. These minima positions are placed in a direction in which the path difference is an even multiple of **λ/2**. The whole slit can be divided into such pairs and hence, the intensity at **P** will be zero. This is the condition of the first minima i.e., first dark fringe.

So,

$$b/2(\sin\theta) = \lambda/2$$
$$b \sin\theta = \lambda$$

Similarly other minima are located at points corresponding to

$$\mathbf{b \sin \theta = n \lambda}$$

where n = 1,2,3.......

Besides the central maxima at **O**, there are maxima which lie in between the minima on the either side of the central maxima. These maxima positions are placed in a direction in which the path difference is an odd multiple of **$\lambda/2$**.

Therefore for secondary maxima:

$$\mathbf{b \sin \theta = (2n + 1) \lambda/2}$$

where n = 1,2,3........

The diffraction pattern is observed only when the obstacle or the opening of slit has dimensions comparable to the wavelength of the wave.

Content for this additional material is taken from Concepts of Physics by H.C. Verma and NCERT Physics textbook of Class 12.