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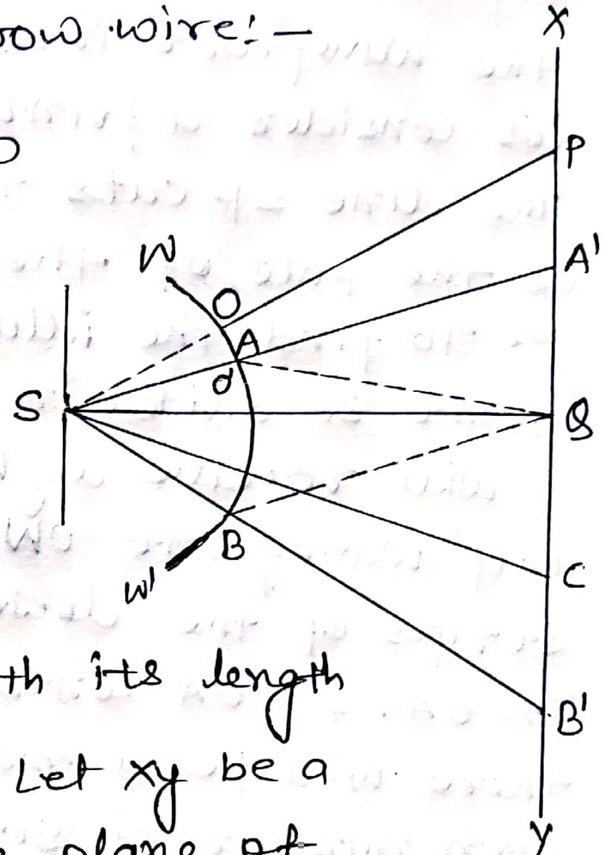
B.Sc (part-II) Hons

Nature of Fresnel's diffraction pattern due to a narrow wire.

Diffraction at a narrow wire:-



Let S be a narrow slit normal to the plane of paper and illuminated with mochromatic light of wavelengh λ. Let AB a narrow wire of diameter d, placed with its length parallel to the slit. Let XY be a screen normal to the plane of paper.

Let SA and SB produced meet the screen XY in A' and B'. Then A'B' is the region of the geometrical shadow of the wire. According to rectilinear propagation of light, there should be uniform illumination above A' and below B', and complete darkness within A'B'. But actually, unequally-spaced bands with poor contrast and running parallel to the length of the slit are observed in the region above A' and below B'. Besides this, equally-spaced bands, running parallel to the length of the slit are observed in the geometrical shadow A'B'.

Explanation:— Let WW' be the section of the wavefront incident on the wire AB. Let us consider a point P in the region above A'. The line SP cuts the wavefront at O, which is the pole of the wavefront with respect to P. To find the illumination at P, let the wavefront be divided in to half-period strips. Then P will receive light from the entire upper half wavefront OW and from those half-period strips of the lower half which are contained in OA. If OA contain an odd number of strips there will be a maximum at P. If OA contains even number of strips, there will be a minimum at P. Thus above A' we obtain unequally spaced bands with poor contrast similar to those of a straight edge. These are diffraction bands. Similarly bands are obtained in the region below B'.

Let us now consider a point Q in the geometrical shadow A'B'. The pole corresponding to it is O'. Therefore Q receives light from the unobstructed portions of the two halves of the wavefront i.e. from AW and BW'. The resultant amplitude at Q due to AW is equal to half the amplitude due to the half period strips adjacent to A and is in phase ~~to a~~ with it. Similarly, the amplitude due to BW' is equal to half the amplitude due to a strip adjacent to B and is in phase with it. Since half period strips adjacent to A and B lie on the Same wavefront, the waves start from them in the Same phase. Thus the effect of AW and BW' at Q is the Same as of two coherent sources at A and B. Hence the point Q will be bright or dark according as the path difference BQ−AQ is a whole number of wavelength. Hence, as in case of interference from two source, equally spaced bright and dark 'interference fringes' are obtained in the region A'B'. The fringe-width is give by

$$\bar{X} = \frac{D}{d}\lambda$$

where D is the distance between the wire and the screen, and 'd' is the diameter of the wire.

Determination of the thickness of the wire:- It is obvious from the last equation that knowing the fringe-width of the interference fringes in the geometrical shadow and the distance D, the thickness d of the wire can be determined. The experiment is performed on an optical bench. The slit and the wire are mounted parallel to each other on the first two uprights and the fringes are measured by a micrometer eyepiece.

If the thickness of the wire is gradually increased, the interferences gradually become narrower while the diffraction fringes remain unaffected. If the wire is quite thick, the interference fringes completly vanish, and intensity falls off rapidly from the edges A' and B' towards the centre.