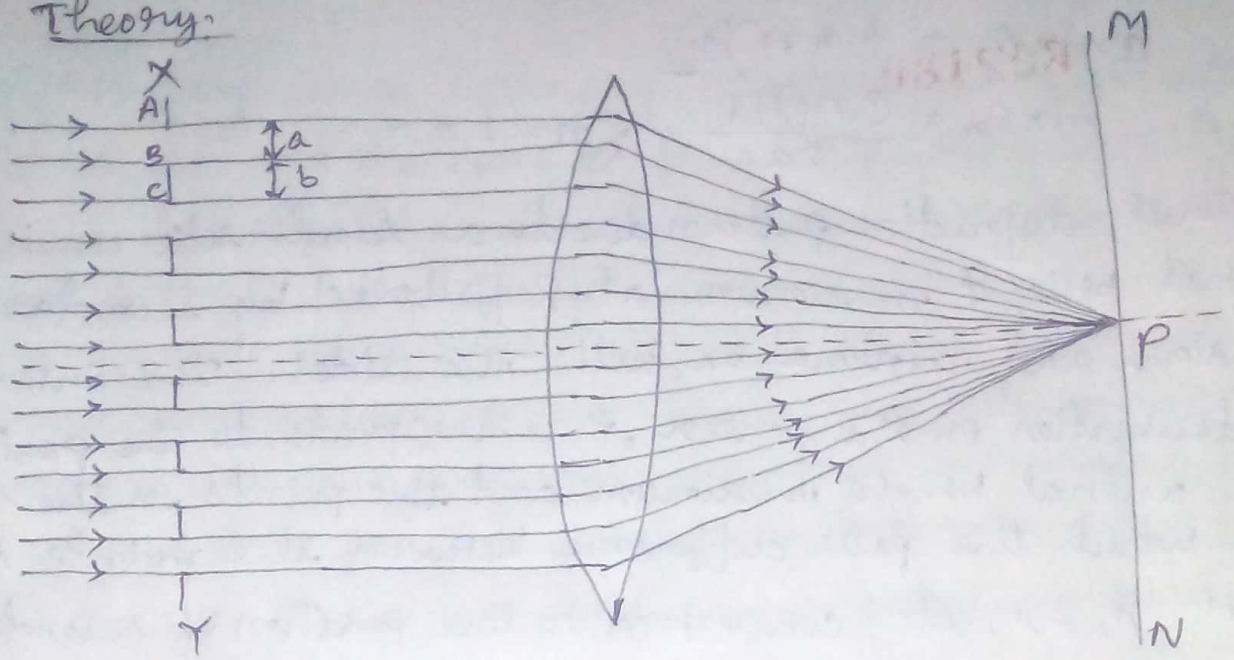
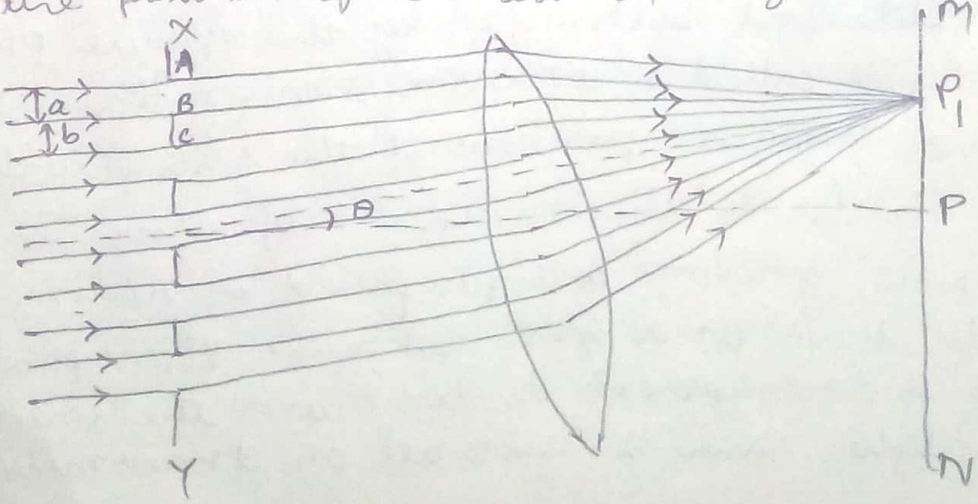
8 Plane diffraction grating: A diffraction grating is an extremely useful device and in one of its form it consists of a vary large number of narrow slits side by side. The slits are separated by opaque spaces. When a wavefront is incident on a grating surface, light is transmitted through the slits and obstructed by the opaque portions. Such a grating is called a transmission grating. The secondary waves from the positions of the slits interfere with one another, similar to the interference of waves in Young's experiment. Now, gratings are prepared by ruling equidistant parallel lines on a glass surface. The space bet^n any two lines is transparent to light and the lined portion is opaque to light. Such surfaces act as transmission gratings.

Theory:



XY is the grating surface and MN is the screen, both perpendicular to the plane of the paper. The slits are all parallel to one another and perpendicular to the plane of the paper, Here AB is a slit and BC is an opaque portion. The width of each slit is a and the opaque spacing between any two consecutive slits is b, Let a plane wavefront be incident on the grating surface. Then all the secondary waves travelling in the same direction as that of the incident light will come to focus at the point P on the screen. The screen is placed at the focal plane of the collecting lens. The point P where all the secondary waves reinforce one another corresponds to the position of the central bright maximum.



Now, consider the secondary waves travelling in a ~~dir~~ direction inclined at an angle θ with the direction of the incident light. The collecting lens also is suitably rotated such that the axis of the lens is parallel to the direction of the secondary waves. The secondary waves come to focus at the point P_1 on the screen. The intensity at P_1 will depend on the path difference between the secondary waves originating from the corresponding points A and C of two neighbouring slits.

$AB = a$; $BC = b$. The path difference between the secondary waves starting from A and C is equal to $AC \sin\theta$

But $AC = AB + BC = a + b$

$\therefore$ path difference $= AC \sin\theta$
$= (a+b)\sin\theta$

The point P_1 will be of maximum intensity if this path difference is equal to integral multiples of λ where λ is the wavelength of light. In this case, all secondary waves originating from the corresponding points of the neighbouring slits reinforce one another and the angle θ gives the direction of maximum intensity. In general

$$(a+b)\sin\theta_n = n\lambda$$

If the incident light consists of more than one wavelength the beam gets dispersed and the angles of diffraction for different wavelengths will be different. Let λ and $\lambda + d\lambda$ be

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two nearby wavelengths present in the incident light and θ and $(\theta+d\theta)$ be the angles of diffraction corresponding to these two wavelengths. Then, for first order principal maxima

$$(a+b)\sin\theta = \lambda$$
$$(a+b)\sin(\theta+d\theta) = \lambda + d\lambda$$

$(a+b)$ is called the grating element. Here 'a' is the width of the slit and 'b' is the width of the opaque portion. For a grating with 15,000 lines per inch the value of

$$(a+b) = \frac{2.54}{15000}\ \text{cm}$$