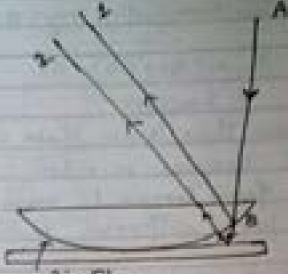
Newton's Rings

Prove that in reflected light (i) Diameter of bright rings are proportional to the square root of odd number, and (ii) Diameter of dark rings are proportional to the square root of natural numbers



Formation of Newton's Rings — When a plano-convex lens of large radius of curvature is placed with its convex surface in contact with a plane glass plate, an air-film is formed between the lower surface of the lens and the upper surface of the plate. Thickness of the film gradually increases from the point of contact outwards. If monochromatic light is allowed to fall normally on this film, a system of alternate bright & Dark concentric rings with their centre dark is formed in the air film. These are called Newton's rings. Newton's rings are formed as a result of interference between the light waves reflected from the upper & lower surfaces of the air-film. As the rings are observed in reflected light, the effective path difference between the interfering rays is

$p = 2\mu t \cos(r+\theta) - \frac{\lambda}{2}$ where θ is the angle of the film at any point But since the radius of curvature of the curved surface of the lens is very large and θ is extremely small and hence neglected

So $p = 2\mu t \cos r - \frac{\lambda}{2}$

Now $\mu = 1$ for air film and $r = 0$ for Normal Incidence

$$p = 2\mu t - \frac{\lambda}{2} = 2t - \frac{\lambda}{2}$$

At the point of contact of the lens $t = 0$ $p = \frac{\lambda}{2}$ hence central spot is dark.

for bright fringe $2t - \frac{\lambda}{2} = n\lambda$

$$2t = (2n+1)\frac{\lambda}{2} \quad \text{Maxima} \text{ —(1)}$$

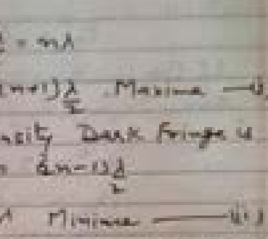
Condition for Minimum Intensity Dark fringe is

$$2t - \frac{\lambda}{2} = (2n-1)\frac{\lambda}{2}$$

$$2t = n\lambda \quad \text{Minima} \text{ —(2)}$$

Fringes are in the form of concentric circles. Since each fringe is a locus of constant film thickness these are known as the 'fringes of constant thickness'.

Let LOL' be the lens placed on the glass plate AB, the point of contact being O. Let R be the radius of curvature of the curved surface of the lens. Let r_n be the radius of Newton's ring corresponding to a point P_n where the film thickness is t. Draw ⊥ PN. Then from the property of circle, we have



$PN^2 = ON \times NE$

$\rho_n^2 = t(2R-t) = 2Rt - t^2$

Since t is small compared to R, we can neglect t^2

Hence $\rho_n^2 = 2Rt$

$$2t = \frac{\rho_n^2}{R} \quad \text{——— (ii)}$$

The condition for a bright ring is

$$2t = (2n+1)\frac{\lambda}{2} = \frac{\rho_n^2}{R}$$

$$\rho_n^2 = (2n+1)\frac{\lambda R}{2}$$

If D_n be the Diameter of the n^{th} bright ring then $D_n = 2\rho_n$; $\rho_n = \frac{D_n}{2}$

$$D_n^2 = 2(2n+1)\lambda R$$

$$D_n = \sqrt{2\lambda R}\,\sqrt{(2n+1)}$$

$$D_n \propto \sqrt{(2n+1)}$$

Thus the Diameters of bright rings are proportional to the square roots of the odd natural numbers. The Diameters of the first few rings are in the ratio $= 1 : \sqrt{3} : \sqrt{5} : \sqrt{7}$

- Diameters of Dark rings — The condition for a dark ring is $2t = n\lambda = \frac{\rho_n^2}{R}$

So $\rho_n = D_n/2$

$$\therefore \frac{D_n^2}{4R} = n\lambda$$

$$D_n = \sqrt{4n\lambda R}$$

$D_n \propto \sqrt{n}$. Thus, the Diameters of Dark rings are proportional to the square root of natural numbers.

If D_{n+p} is the Diameter of (n+p)th bright ring then $D^2_{n+p} = 2[2(n+p)+1]\lambda R$

and if D_n is the Diameter of the nth bright ring $D_n^2 = 2(2n+1)\lambda R$

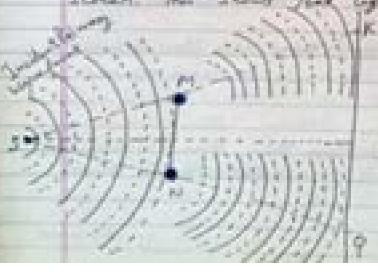
$$D^2_{n+p} - D_n^2 = 4p\lambda R \quad \text{——(iv)}$$

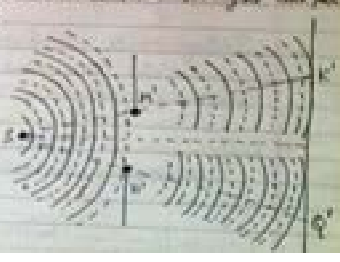
$$\therefore \lambda = \frac{D^2_{n+p} - D_n^2}{4pR}$$

On measuring the Diameters of the rings and the radius of curvature R, the wavelength λ can be calculated with the help of above expression. If λ is known then the Radius of curvature R of the lens may be determined.

—— x —— x —— x —— x ——

Diffraction :→ If an opaque obstacle or aperture whose size is comparable to the wavelength of Incident light, be placed in the region between screen & source of light a distinct shadow is obtained on the screen. This shows that light travels in a straight line path.





When the light passes through a small aperture (slit, hole) or by the side of the small obstacle then it does not follow rectilinear path strictly but bends around the corners of an obstacle is called diffraction.

Fresnel not only explained satisfactory the bending of light around the corners but also rectilinear propagation of light.

* Fresnel's class of Diffraction – The source of the light or screen on which diffraction pattern is observed both are at finite distances from the obstacle or aperture. In this case no lenses are used as incident wavefront is in its original form (spherical/cylindrical/plane).

* Fraunhofer class of Diffraction The source of the light or the screen are effectively at infinite distances from the obstacle or aperture showing diffraction. The infinitely placed sources are brought in the field of view by using converging lenses as the incident wavefront is usually plane after traversing long distances to reach the obstacle.

* Interference — Superimposition takes place between wavelets generated from two or more coherent sources.

* Diffraction — Superimposition takes place between the secondary wavelets generated from a single source.

* In Diffraction pattern fringes are never equally spaced