Newton's Ring:

When a plano convex lens of large focal length is placed on a plane glass plate, then a thin film of air is formed between the lower surface of the lens and the upper surface of glass plate. When a monochromatic light is allowed to fall normally on the film, then circular fringes are observed. It is special case of Interference in an air film of variable thickness. In reflected light then centre of circular fringes are dark followed by alternatively bright and dark circular rings are ~~called~~ vice-versa. in transmitted light. These rings were first investigated by Newton, so are called Newton's Ring.

The experimental arrangement as shown in fig. S is an extended monochromatic source i.e. a sodium lamp is placed at the focus of convex lens L. The horizontal parallel rays after the lens fall on a glass plate G, inclined at 45°.

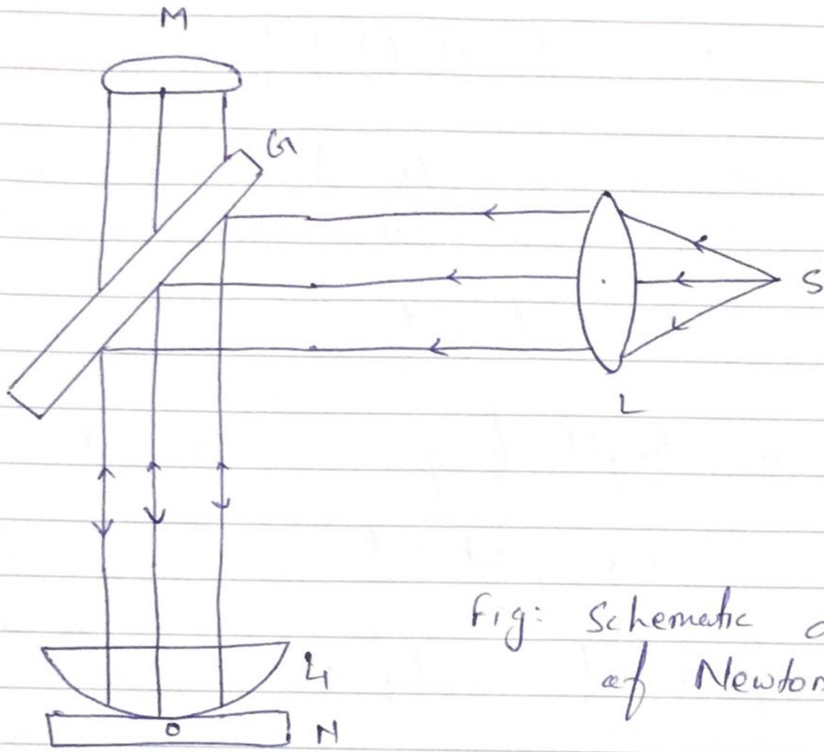

Fig: Schematic diagram of Newton's Ring.

The rays are partly reflected from the inclined glass plate and fall normally on plano-convex lens. lens of large focal length L_1 placed over a glass (plane glass) plate N.

The air film is formed between the plano convex lens L_1 and glass plate N around the point of contact, O. The interference takes place between the rays reflected from the upper and lowers surfaces of the film and are viewed with a microscope to focused on the air film.

The film formed between the curved surface of the plano-convex lens and plane glass plate is of wedge shape.

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Therefore the path difference b/w the interfering rays in reflected light will be,

$$\Delta = 2\mu t \cos(r+\theta) + \frac{\lambda}{2}$$

for normal incidence $(r=0)$ and for very small angle of wedge $(\theta \equiv 0)$, the path difference

$$\Delta = 2\mu t + \frac{\lambda}{2}$$

for a bright fringe $\qquad \Delta = n\lambda$

$$n\lambda = 2\mu t + \frac{\lambda}{2}$$

$$\boxed{(2n-1)\frac{\lambda}{2} = 2\mu t} \quad \text{--- (1)}$$

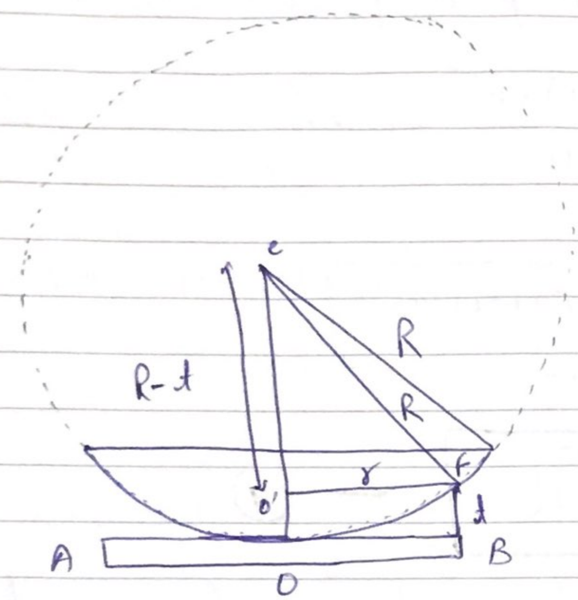
and for dark fringe $\qquad \Delta = (2n+1)\frac{\lambda}{2}$

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

$$\boxed{n\lambda = 2\mu t} \quad \text{--- (2)}$$

at the point of contact, $t=0$, the effective path difference is $\lambda/2$, which is the condition of minimum intensity. Hence the centre is dark in Newton's Ring.

Diameter of the Rings:



Suppose R is the radius of curvature of the plano-convex while t the thickness of the film passing through point f having radius r.

Consider $\Delta O'Cf$;

$$R^2 = (R-t)^2 + r^2$$

$2Rt = t^2 + r^2$, Since t is very small, neglect t^2;

$$2Rt = r^2$$

$$\boxed{t = \frac{r^2}{2R}} \quad \text{—— (3)}$$

Diameter of the bright fringe: Substituting the value of t, from equation ~~(2)~~, (3) to in equation (1), we get

$$2\mu\left(\frac{r_n^2}{2R}\right) = (2n-1)\frac{\lambda}{2}$$

$$r_n^2 = \frac{(2n-1)\lambda R}{2\mu}$$

If D_n is the corresponding diameter, then

$$\left(\frac{D_n}{2}\right)^2 = \frac{(2n-1)\lambda R}{2\mu} \Rightarrow D_n^2 = \frac{2(2n-1)\lambda R}{\mu}$$

for air, $\mu = 1$,

$$\boxed{D_n^2 = 2(2n-1)\lambda R}$$

$$\boxed{D_n = \sqrt{2(2n-1)\lambda R}} \quad \text{--- (4)}$$

From above equation, it is clear that diameter of the bright ring is proportional to the square root of the odd natural numbers.

Diameter of dark rings: Substitute the value of eq^n (3), in equation (2), we get

$$2\mu \frac{r_n^2}{2R} = n\lambda$$

$$r_n^2 = \frac{n\lambda R}{\mu},$$ If D_n is the diameter,

then $$\left(\frac{D_n}{2}\right)^2 = \frac{n\lambda R}{\mu}$$

$$\boxed{D_n = 2\sqrt{n\lambda R}}$$ if $\mu = 1$

$$\boxed{D_n = \sqrt{4n\lambda R} = 2\sqrt{n\lambda R}} \quad \text{——} (5)$$

The diameter of dark rings is proportional to the square root of the natural numbers.

Spacing between fringes: If D_n and D_{n+1} are the diameter of n^{th} and $(n+1)^{th}$ dark rings then;

$$D_{n+1} - D_n = \sqrt{4(n+1)\lambda R} - \sqrt{4n\lambda R}$$

$$\sqrt{4\lambda R}\left[\sqrt{n+1} - \sqrt{n}\right]$$

let $\sqrt{4\lambda R} = K$

then $D_{n+1} - D_n = K\left[\sqrt{n+1} - \sqrt{n}\right]$

where $n = 1, 2, 3, \ldots$

if $n = 1$, then

$$D_2 - D_1 = K\left[\sqrt{2} - 1\right]$$

if $n=2$, $D_3 - D_2 = K\left[\sqrt{3} - \sqrt{2}\right]$

if $n=3$, $D_4 - D_3 = K\left[\sqrt{4} - \sqrt{3}\right]$

Hence it is clear, from above values that the spacing between the consecutive rings decreases with increasing order of rings.

Wavelength of monochromatic source:

By measuring the diameters of dark Newton's ring by travelling microscope, the wavelength of monochromatic light used, for Newton's Ring may be determined.

Let D_n and D_{n+p} be the diameter of n^{th} and $(n+p)^{th}$ rings respectively, then

$$D_n^2 = 4n\lambda R$$

$$D_{n+p}^2 = 4(n+p)\lambda R$$

Thus $$D_{n+p}^2 - D_n^2 = 4(n+p)\lambda R - 4n\lambda R$$

$$D_{n+p}^2 - D_n^2 = 4p\lambda R$$

$$\boxed{\lambda = \frac{D_{n+p}^2 - D_n^2}{4pR}}$$

It is the same for bright rings too.

Determinatation of refractive index of liquid.

Let D_n and D_{n+p} be the diameters of n^{th} and $(n+p)^{th}$ dark ring in air, then

$$\left(\frac{D_{n+p}^2 - D_n^2}{4pR}\right)_{air} = \lambda \Rightarrow \frac{(D_{n+p}^2 - D_n^2)_{air}}{4pR} = \lambda$$

If D_n' and D_{n+p}' be the diameter of n^{th} and and $n+p^{th}$ dark rings in liquid medium then,

$$\frac{(D_{n+p}'^2 - D_n'^2)_{liq}}{4pR} = \frac{\lambda}{\mu} \quad \text{——} \quad (2)$$