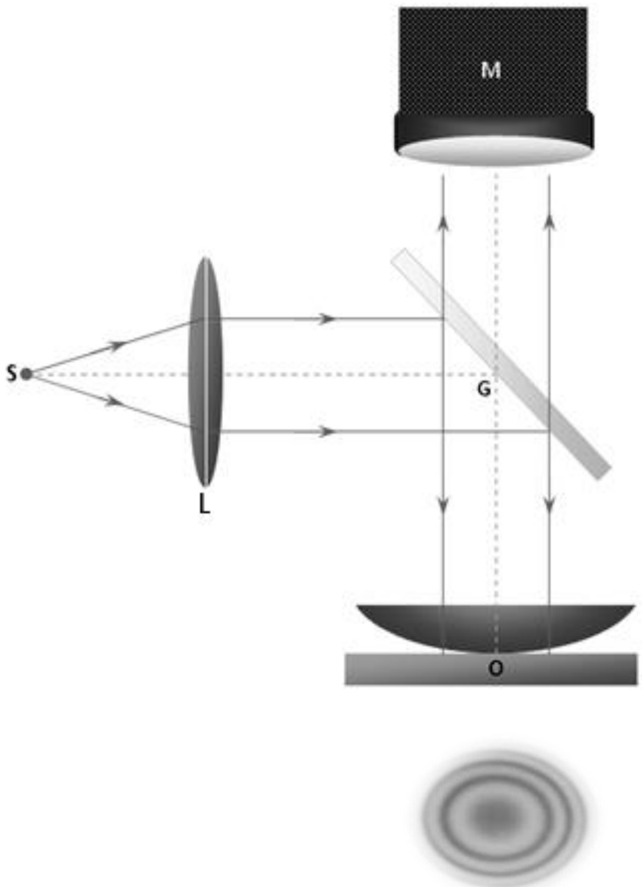
NEWTON'S RING

When a plano-convex lens with its convex surface is placed on a plane glass plate, an air film of gradually increasing thickness is formed between the lens and the glass plate. The thickness of the air film is almost zero at the point of contact O and gradually increases as one proceeds towards the periphery of the lens. If monochromatic light is allowed to fall normally on the lens, and the film is viewed in reflected light, alternate bright and dark concentric rings are seen around the point of contact. These rings were first discovered by Sir Isaac Newton, hence named as **Newton's Rings**. If it is viewed with the white light then coloured fringes are obtained. The experimental arrangement of the Newton's Ring apparatus is shown in *figure 1*.



S	Monochromatic Source
L	Convex Lens
M	Microscope
G	Glass Plate inclined at an angle of 45˚
O	Centre of Plano-convex lens

Fig. 1: Experimental arrangement of the Newton's Ring apparatus

A parallel beam of monochromatic light is reflected towards the lens *L*. Consider a beam of monochromatic light strikes normally on the upper surface of the air film. The beam gets partly reflected and partly refracted. The refracted beam in the air film is also reflected partly at the lower surface of the film. The two reflected rays, i.e. produced at the upper and lower surface of the film, are coherent and interfere constructively or destructively. When the light reflected upwards is observed through microscope *M* which is focused on the glass plate, a pattern of dark and bright concentric rings are observed from the point of contact *O*. These concentric rings are known as *Newton's Rings*.

The path difference between the two successive reflected rays are obtained using wedge shaped interference case as:

$$\Delta = 2\mu t\cos(r+\theta) \pm \lambda/2 \quad (1)$$

For air film, $\mu = 1$ and at normal incidence, $i = r = 0$. Since, θ is very small then $\cos\theta = 1$. Hence, eq. (1) reduces to

$$\Delta = 2t \pm \lambda/2 \quad (2)$$

At the point of contact of the lens and the glass plate (O), the thickness of the film is effectively zero i.e. $t = 0$

$$\Delta = \pm\lambda/2 \quad (3)$$

This is the condition for minimum intensity. Hence, the centre of Newton rings generally appears dark.

DIAMETER OF NEWTON'S RING

Diameter of Bright Rings:

Consider a ring of radius *r* due to thickness *t* of air film as shown in the *figure 2.*

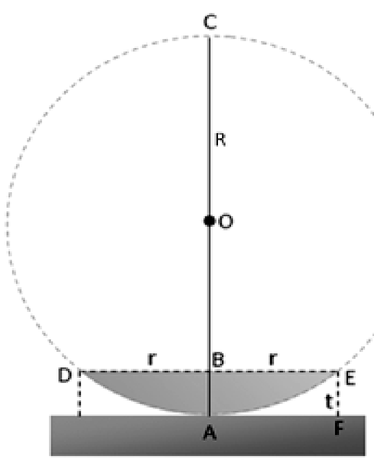


Fig. 2.

According to the geometrical theorem (i.e. property of the circle), the product of intercepts of the intersecting chord is equal to the product of sections of the diameter.

$$\overline{DB} \times \overline{BE} = \overline{AB} \times \overline{BC} \quad (4)$$

$$r \times r = t(2R - t) \quad (5)$$

$$r^2 = 2Rt - t^2 \quad (6)$$

Since *t* is very small hence t^2 will also be negligible, thus,

$$r^2 = 2Rt \quad (7)$$

$$t = \frac{r^2}{2R} \tag{8}$$

a. Condition for a bright ring (constructive interference in thin film)

$$2\mu t = (2n-1)\frac{\lambda}{2} \qquad \text{where } n=1, 2, 3\ldots.. \tag{9}$$

Putting eq. (8) in eq. (9) we get

$$2\mu\left(\frac{r^2}{2R}\right) = (2n-1)\frac{\lambda}{2} \tag{10}$$

Radius of the n^{th} bright ring becomes

$$r_n^2 = (2n-1)\frac{\lambda R}{2\mu} \tag{11}$$

Thus diameter of the n^{th} bright ring is

$$\left(\frac{D_n}{2}\right)^2 = (2n-1)\frac{\lambda R}{2\mu} \tag{12}$$

$$D_n^2 = 2(2n-1)\frac{\lambda R}{\mu} \tag{13}$$

$$D_n = \sqrt{2(2n-1)\frac{\lambda R}{\mu}} \tag{14}$$

If the medium considered is air then $\mu = 1$ and eq. (14) simplifies to

$$D_n = \sqrt{2(2n-1)\lambda R} \tag{15}$$

$$D_n \propto \sqrt{(2n-1)} \qquad \text{where } n=1, 2, 3\ldots.. \tag{16}$$

Thus, ***diameter of the bright rings is proportional to the square root of odd natural numbers***.

b. Condition for a dark ring (destructive interference in thin film)

$$2\mu t = n\lambda \qquad \text{where } n = 0,1, 2, 3\ldots.. \tag{17}$$

Putting eq. (8) in eq. (17) we get

$$2\mu\frac{r^2}{2R} = n\lambda \tag{18}$$

Radius of the n^{th} dark ring becomes

$$r_n^2 = \frac{n\lambda R}{\mu} \tag{19}$$

Thus, diameter of the n^{th} dark ring is

$$\left(\frac{D_n}{2}\right)^2 = \frac{n\lambda R}{\mu} \tag{20}$$

$$D_n^2 = \frac{4n\lambda R}{\mu} \tag{21}$$

$$D_n = \sqrt{\frac{4n\lambda R}{\mu}} \qquad \text{where } n = 0, 1, 2, 3\ldots.. \tag{22}$$

If the medium considered is air then $\mu = 1$ and eq. (22) simplifies to

$$D_n = \sqrt{4n\lambda R} \tag{23}$$

$$D_n \propto \sqrt{4n\lambda R} \qquad \text{where } n = 0, 1, 2, 3\ldots.. \tag{24}$$

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

APPLICATIONS OF NEWTON'S RING

1. Determination of Wavelength of Monochromatic Light (λ)

The diameter of the nth dark ring is given by:

$$D_n^2 = 4n\lambda R \tag{25}$$

Similarly, the diameter of the (n + p)th dark ring is given by:

$$D_n^2 = 4(n+p)\lambda R \tag{26}$$

Subtracting eq. (25) from eq. (26), we get

$$\lambda = \frac{D_{n+p}^2 - D_n^2}{4pR} \tag{27}$$

where, p is an integer.

2. Determination of Refractive Index of the Liquid (μ)

The diameter of the nth dark ring in air film is given by:

$$\left(D_n^2\right)_{air} = 4n\lambda R \tag{28}$$

Similarly, the diameter of nth dark ring in liquid film is given by:

$$\left(D_n^2\right)_{liquid} = \frac{4n\lambda R}{\mu} \tag{29}$$

Therefore, the Refractive Index of the Liquid is obtained as:

$$\mu = \frac{\left(D_n^2\right)_{air}}{\left(D_n^2\right)_{liquid}} \tag{30}$$