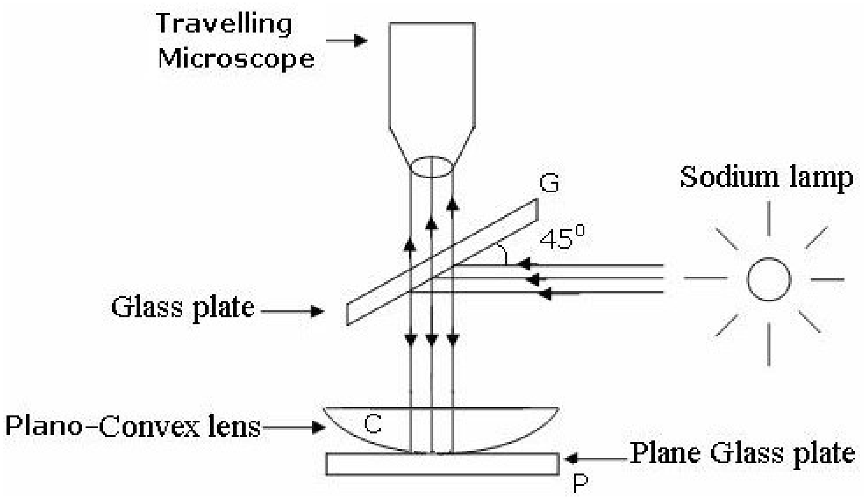
Newton's ring

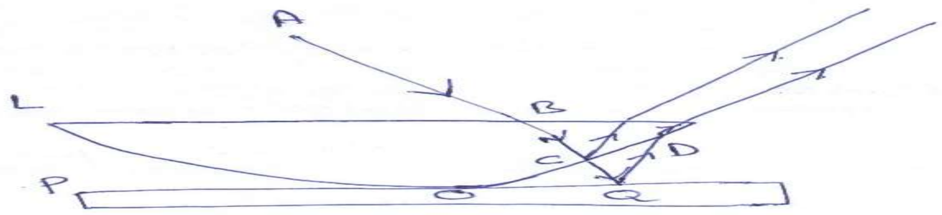
- When a plano-convex lens of large focal length is placed on a plane glass plate, a thin film of air is enclosed between the lower surface of the lens and the upper surface of the plate.
- Thickness of the air film is very small at the point of contact and gradually increases from the centre to outwards.
- Interference fringes produced with

monochromatic light are circular

- When viewed with white light, concentric circles

with different colours with dark as centre are found.





Let us suppose the radius of curvature of the lens is R and the air film of thickness t_n is at a distance $OQ = r_n$, from the point of contact O, where nth fringe will be formed.

In the case of reflected light the condition for bright fringe is

$$2\mu t_n \cos r = (2n-1)\lambda/2$$

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

$n = 0$ is dark band.

For normal incidence $r = 0 \Rightarrow \cos\theta = 1$

so $$2\mu t_n = (2n-1)\lambda/2$$

for dark fringe is

$$2\mu t_n \cos r = n\lambda$$

where $n = 0, 1, 2, \ldots$

for normal incidence $2\mu t_n = n\lambda$

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

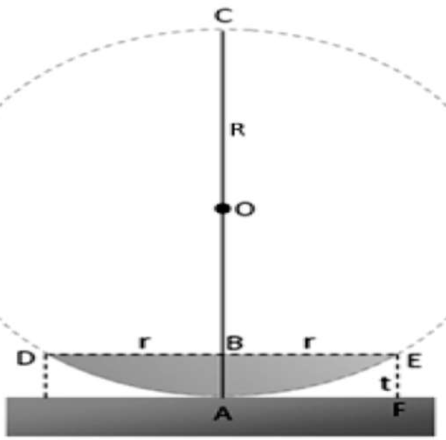


Fig. 2.

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.

$$\overline{DB} \times \overline{BE} = \overline{AB} \times \overline{BC} \tag{4}$$

$$r \times r = t(2R - t) \tag{5}$$

$$r^2 = 2Rt - t^2 \tag{6}$$

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

$$r^2 = 2Rt \tag{7}$$

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

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. <u>Condition for a dark ring (destructive interference in thin film)</u>

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

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***.

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:

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