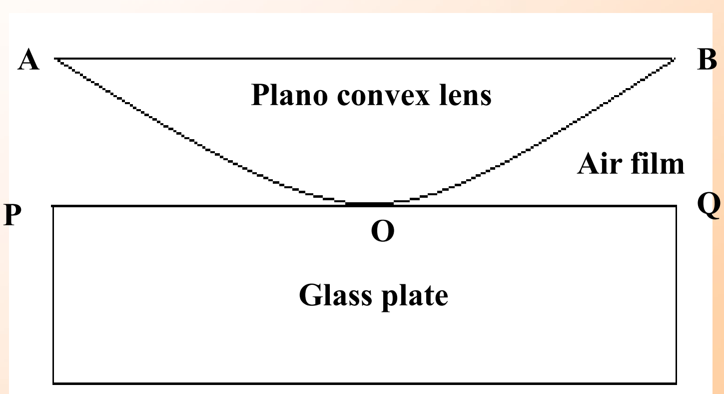
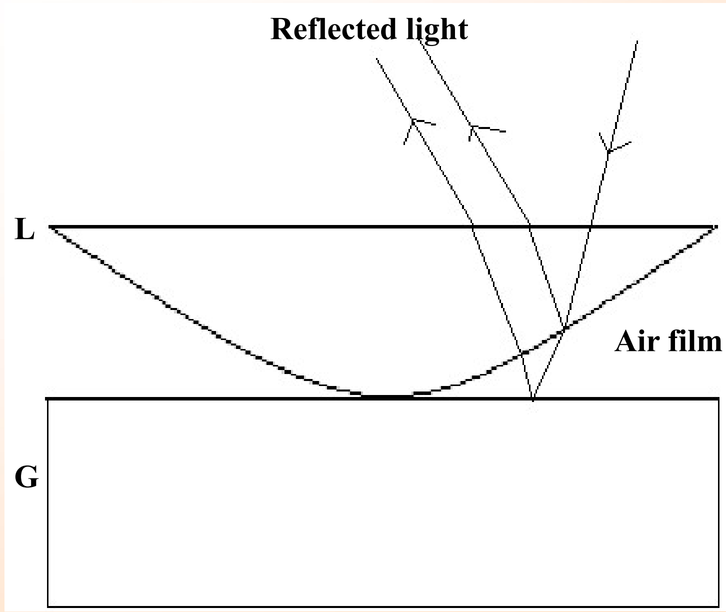
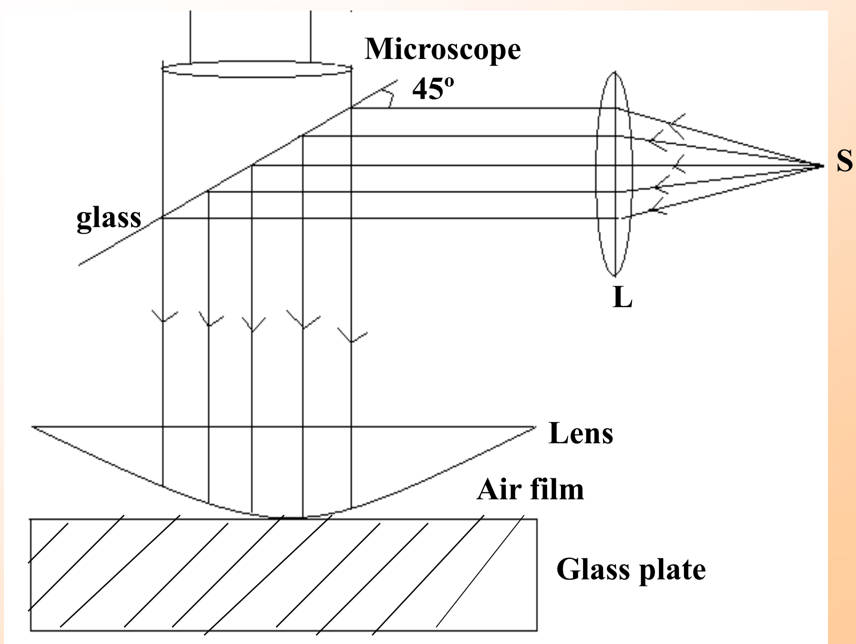
Newton's Rings



Thickness of air film is zero at point of contact O.



Circular interference fringes are formed by reflected light



Interference occurs between the light reflected from the lower surface of the lens and the upper surface of the glass plate G.

Since the convex side of the lens is a spherical surface, the thickness of the air film will be constant over a circle (whose centre will be at O) and we will obtain concentric dark and bright rings.

↓

Newton's rings

It should be pointed out that in order to observe the fringes the microscope has to be focused on the Surface of the film.

Each ring will be locus of all such points where thickness is same.

Condition for bright ring will be

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

For air film , μ =1 and for near normal incidence r is very small and hence cos r = 1

Thus,

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

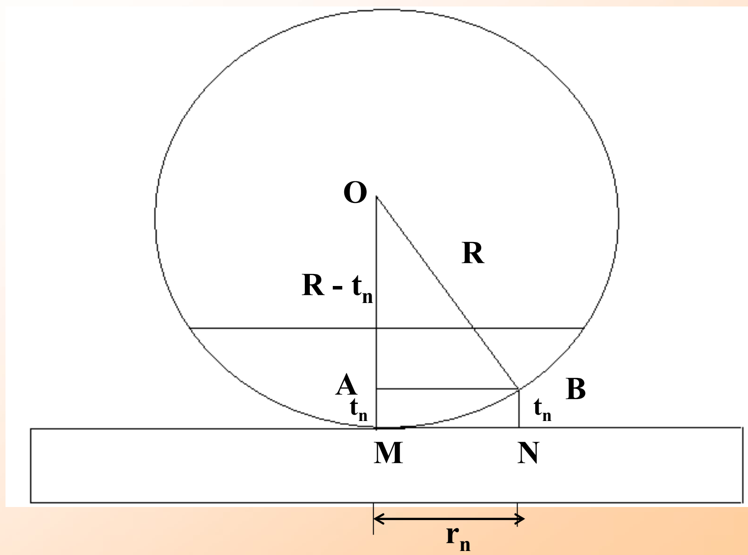
Where n = 0,1,2,3….

For dark rings,

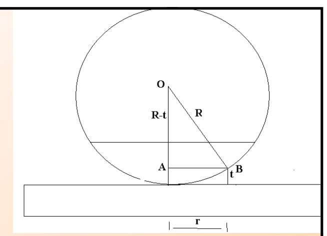
$$2\mu t\cos r = n\lambda$$

Again for air film μ = 1 and for small r we have Condition for dark rings,

$$2t = n\lambda$$



R = radius of curvature of lens
t = thickness of air film at a distance AB $=r_n$
OA = R - t



From ΔOAB

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

$$\Rightarrow r_n^2 = R^2 - (R - t)^2 = R^2 - R^2 - t^2 + 2Rt = 2Rt - t^2$$

As R>>t , $r_n^2 = 2Rt$

$$\Rightarrow t = r_n^2/2R$$

So condition for bright rings

$2t = (2n+1)\lambda/2$

$$\text{or,}\quad \frac{2r_n^2}{2R} = (2n+1)\frac{\lambda}{2}$$

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

$$\Rightarrow r_n = \sqrt{\frac{(2n+1)\lambda R}{2}}$$

$$\Rightarrow \text{Diameter}\quad D_n = 2\sqrt{\frac{(2n+1)\lambda R}{2}}$$

$n = 0,1,2,3,\ldots.$

Similarly for dark rings,

$$2t = n\lambda$$

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

$$\Rightarrow r_n = \sqrt{n\lambda R}$$

$n = 0,1,2,3,\ldots.$

Diameter of dark rings,

$$D_n = 2r_n = 2\sqrt{n\lambda R}$$

CENTER IS DARK

At n = 0, radius of dark ring = 0.

radius of bright ring $= \sqrt{\frac{\lambda R}{2}}$

Alternately dark and bright rings will be produced.

The spacing between second and third dark rings is smaller than the spacing between the first and second one.

Consider the diameter of dark rings

$$D_1 = 2\sqrt{1\lambda R} = 2\sqrt{\lambda R}$$
$$D_2 = 2\sqrt{2\lambda R} = 2\sqrt{2\lambda R}$$
$$D_3 = 2\sqrt{3\lambda R} = 2\sqrt{3\lambda R}$$
$$D_4 = 2\sqrt{4\lambda R} = 4\sqrt{\lambda R}$$

Four fringes

$$D_4 - D_1 = 2\sqrt{\lambda R}$$

$$D_9 = 2\sqrt{9\lambda R} = 6\sqrt{\lambda R}$$

$$D_{16} = 2\sqrt{16\lambda R} = 8\sqrt{\lambda R}$$

$$D_{16} - D_9 = 2\sqrt{\lambda R} \Rightarrow 8 \text{ fringes}$$

Fringe width decreases with the order of the Fringe and fringes get closer with increase in their order.

Wavelength determination

Radius of the nth dark ring r_n is given by

$$r_n^2 = n\lambda R$$

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

$$\Rightarrow D_n^2 = 4n\lambda R.....(1)$$

Similarly for (n+m)th dark band

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

(2) – (1)

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

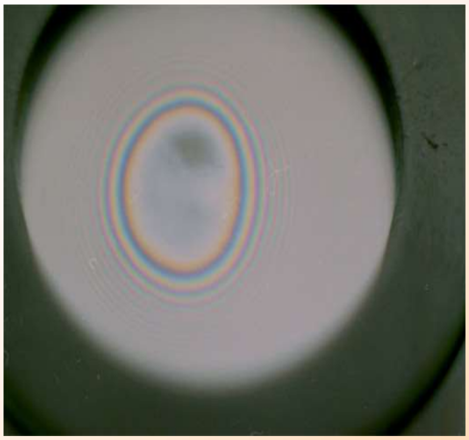
$$\Rightarrow \lambda = \frac{D_{n+m}^2 - D_n^2}{4mR}$$

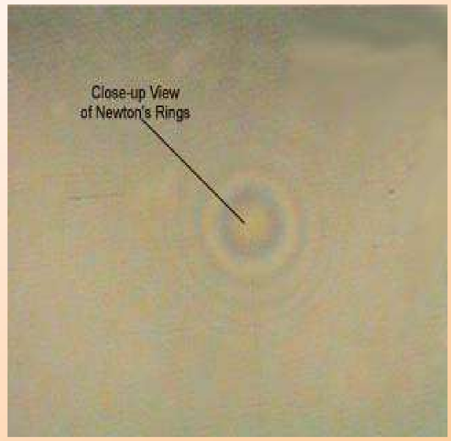
Suppose diameter of 6th and 16th ring are Determined then, m = 16-6 = 10

So

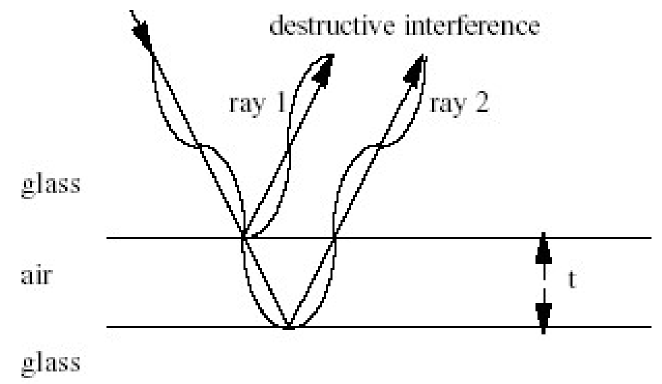
$$\lambda = \frac{D_{16}^2 - D_6^2}{4 \times 10 \times R}$$

Radius of curvature can be accurately measured with the help of a spherometer and therefore by measuring the diameter of dark or bright ring you can experimentally determine the wavelength.

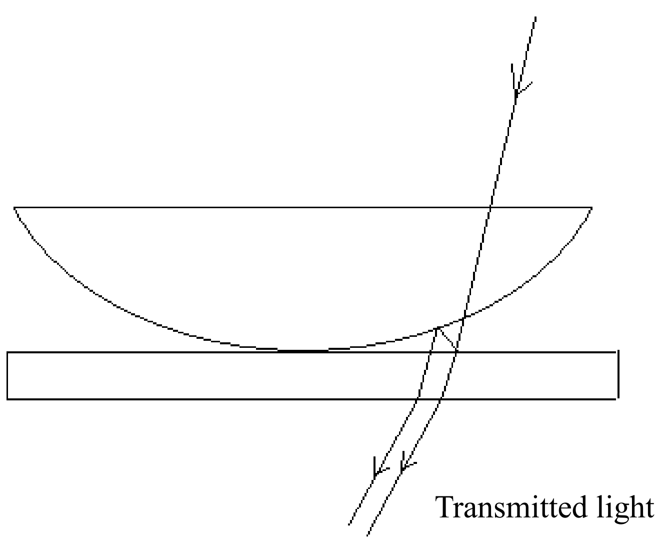




Newton’s rings with transmitted light



1 Interference in light reflected from a thin air gap separating two glass plates.



Condition for bright fringes

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

Condition for dark fringes

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

For air as thin film and near normal incidence

$\mu = 1$ **and** $\cos r = 1$

So for bright fringes, $2t = n\lambda$

For dark fringes, $2t = \frac{2n+1}{2}\lambda$

But we know that $t = \frac{r^2}{2R}$ **, r = radius of ring**

For bright rings

$$\frac{2r^2}{2R} = n\lambda \quad \Rightarrow r = \sqrt{n\lambda R}$$

For dark rings

$$\frac{2r^2}{2R} = (2n+1)\frac{\lambda}{2} \quad \Rightarrow r = \sqrt{\frac{(2n+1)\lambda R}{2}}$$

If we put n = 0 then r = 0 for the bright ring

So for Newton's rings for transmitted rays the central ring will be bright.

CENTRAL RING IS BRIGHT.

WAVELENGTH DETERMINATION

We know radius of the nth dark ring r_n is

$$r_n^2 = n\lambda R$$

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

$$\Rightarrow D_n^2 = 4n\lambda R \quad \text{.......(1)}$$

Similarly,

$$D^2_{n+m} = 4(n+m)\lambda R \quad \textbf{........(2)}$$

(2) – (1)

$$D^2_{n+m} - D^2_n = 4(n+m)\lambda R - 4n\lambda R$$

$$= 4m\lambda R \quad \textbf{........(3)}$$

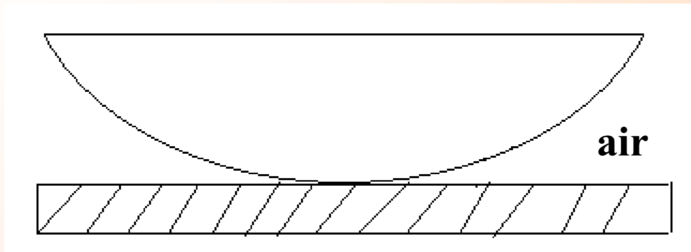
$$\lambda = \frac{D^2_{n+m} - D^2_n}{4mR}$$

Suppose diameter of the 8th and 18th ring are Determined then,

m = 18-8 =10 and

$$\lambda = \frac{D^2_{18} - D^2_8}{4 \times 10 \times R}$$

Refractive index determination

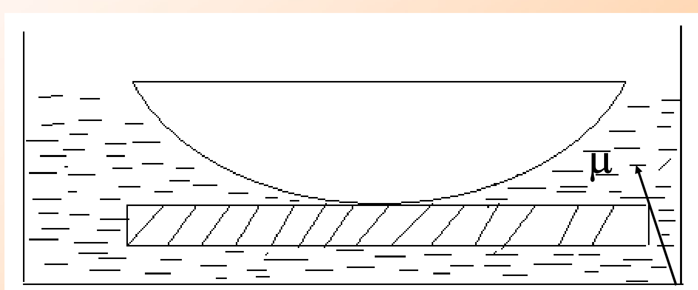


Diameter of the dark rings

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

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

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



Liquid of refractive index μ

(for near normal incidence and $\mu_g<\mu$

Condition for dark ring formation

$$2\mu t_n = n\lambda \qquad \text{but} \quad t_n = \frac{r'^2_n}{2R}$$

$$\Rightarrow 2\mu \frac{r'^2_n}{2R} = n\lambda \Rightarrow r'^2_n = \frac{n\lambda R}{\mu}$$

$$\Rightarrow \left(\frac{D'_n}{2}\right)^2 = \frac{n\lambda R}{\mu} \Rightarrow D'^2_n = \frac{4n\lambda R}{\mu} \quad \text{.....(4)}$$

Similarly we can get

$$D'^2_{n+m} = \frac{4(n+m)\lambda R}{\mu} \quad \text{.......(5)}$$

So, (5) – (4)

$$D'^2_{n+m} - D'^2_n = \frac{4m\lambda R}{\mu} \quad \text{.......(6)}$$

$$\Rightarrow \mu = \frac{4m\lambda R}{D'^2_{n+m} - D'^2_n}$$

This is the value of μ if λ is known.

μ Can also be determine if λ is unknown

We have from equation (3) and (6)

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

$$= 4m\lambda R \quad \text{........(3)}$$

$$D'^2_{n+m} - D'^2_n = \frac{4m\lambda R}{\mu} \quad \text{.......(6)}$$

Divide (3)/(6)

$$\mu = \frac{D_{n+m}^2 - D_n^2}{D'^2_{n+m} - D'^2_n}$$