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B.Sc(H)-II
PAPER-III

PHYSICS
OPTICS

By. Dr. M.K. THAKUR
A.P.S.M. College
Barauni

LECTURE SERIES-6

NEWTON'S RINGS

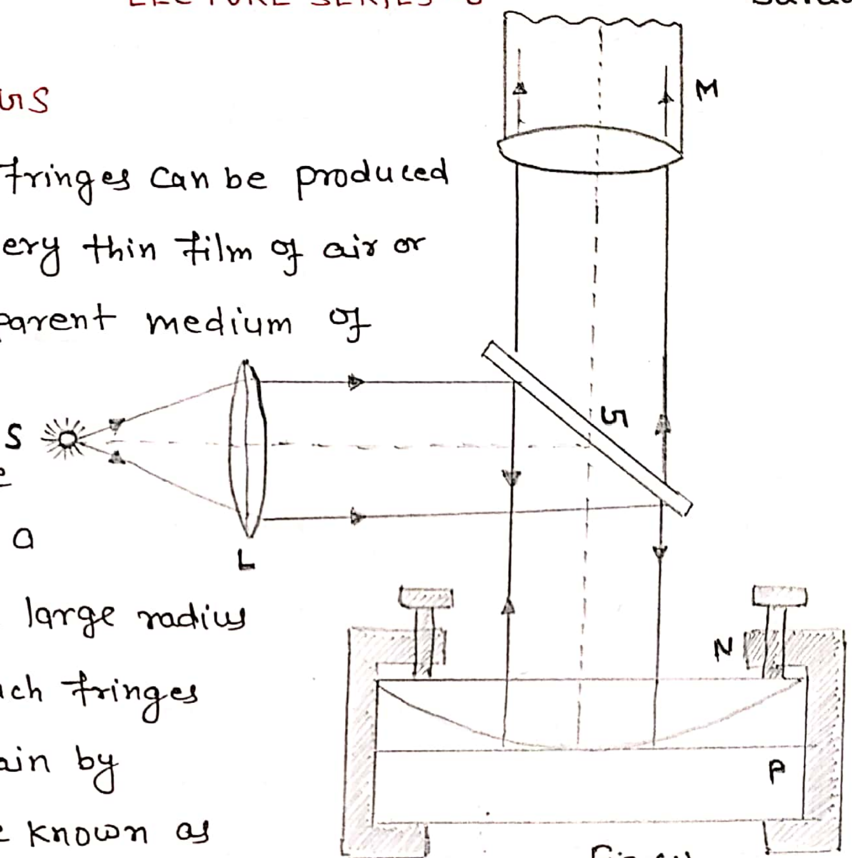

Fig.(1)

Circular fringes can be produced by enclosing very thin film of air or any other transparent medium of varying thickness between a plane glass plate and a convex lens of a large radius of curvature. Such fringes were first obtain by Newton and are known as Newton's rings.

EXPERIMETAL ARRANGEMENT

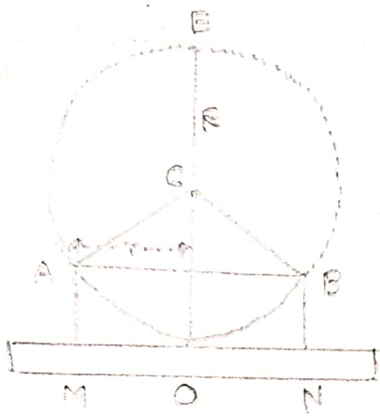

Fig.(2)

To produce Newton's rings monochromatic light from extended source S is rendered parallel by a convex lens L. It falls on a glass plate G inclined at an angle of 45° to the incident beam and is reflected normally on to a convex lens N of large radius of curvature placed on a plane glass plate P in a holder, as shown in fig. (1)

Light rays reflected upward from the top and bottom surface of the air film formed between the lens and the glass plate P, supperimpose each other with a path-difference depending upon the air thickness. Due to interference of these rays, dark and bright circular fringes are seen with monochromatic light.

THEORY Let AOB be the vertical section of the lens surface through its centre of curvature C having a radius of curvature equal to R. The lens is in contact at O with the plane glass plate MON, in such a manner that the point B and A are equidistance from O.

Complete the circle AOBE and draw the diameter ODCE. Draw also BN and AM perpendiculars to the plane MN

Let $AM = BN = t$

The thickness of the air film will be zero at the point of contact O. The point at which the thickness of the air film is the same will be along circles with O as centre. The thickness of the air film at the point M is AM and point having the same thickness as AM will lie along the circle with O as centre and radius OM. The fringes obtained are circular.

The path-difference between two ray, one reflected from A and the other M as shown in fig.(2) is $2\mu t \cos r$.

Now, since μ for air is unity and incidence is normal, hence, the angle of refraction r is zero.

$\therefore$ Path-difference $= 2t$

As one of the rays MKK' (Fig.3) suffers reflection at a denser medium i.e at M or N, further phase change of π or path difference $\lambda/2$ takes place. Hence

Total path difference $= 2t + \frac{\lambda}{2}$

The points A and B equidistant from O will therefore, lie on a bright ring of diameter according as the path-difference.

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

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

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

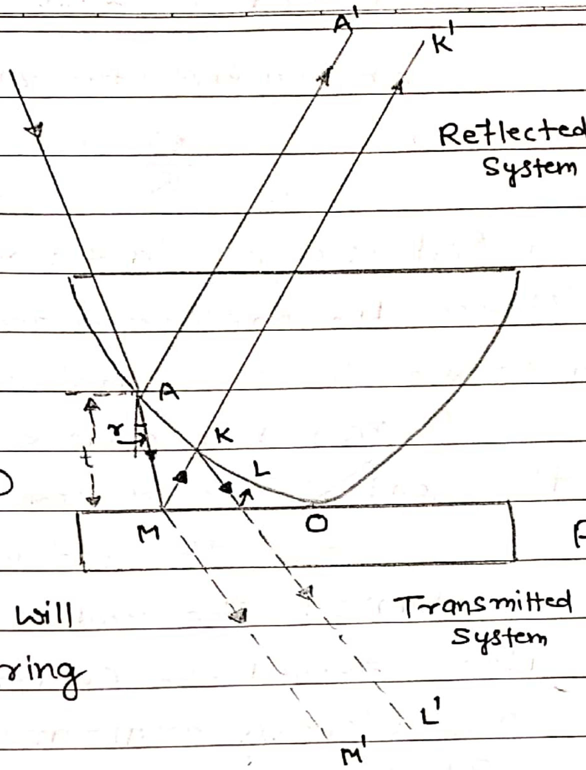

Fig.(3)

Similarly the points A and B will lie at the centre of a dark ring when the path-difference

$$2t = n\lambda \text{ — (2) where } n = 1, 2, 3 \ldots \text{ etc}$$

Radius of dark and bright rings.

From the geometry of the circle (in fig.2)

$$AD \times DB = OD \times DE = OD(2R - OD)$$

$$= 2Rt - OD^2 = 2Rt \quad \text{—— (3)}$$

Since OD, the thickness of the air film is very small, OD^2 can be neglected, as compared to $2Rt$. If r is the radius of the ring, then $AD = DB = r$

$$\therefore \quad r^2 = 2Rt \quad \text{or} \quad 2t = \frac{r^2}{R} \quad \text{—— (4)}$$

For a bright ring, we have $2t = (2n-1)\frac{\lambda}{2}$ where $n = 1, 2, 3 \ldots$
Substituting the value of $2t$ in eqn (4), we have

$$\frac{r^2}{R} = (2n-1)\frac{\lambda}{2} \quad \text{—— (5)}$$

or Radius of nth bright ring $r = \sqrt{\frac{(2n-1)\lambda R}{2}}$ —— (6)

Hence the radius or diameter of bright rings are proportional to square root of odd integral numbers.

For a dark rings we have $2t = n\lambda$ where $n = 0, 1, 2, 3, \ldots$ etc

Substituting the value of $2t$ in eqn ⑥, we have

$$\frac{r^2}{R} = n\lambda \quad \text{—— ⑦}$$

or Radius of nth dark ring $r = \sqrt{n\lambda R}$ —— ⑧

Hence the radius or diameter of dark rings are proportional to square root of natural integral numbers.

For $n=0$, $r=0$, a dark ring. Hence in reflected system the central ring of zero order is dark.

For $n=1$, the radius of the dark ring $= \sqrt{\lambda R}$ and

For $n=1$, The radius of the bright ring $= \sqrt{\frac{\lambda R}{2}}$

Hence, around the central dark ring there are alternate bright and dark rings.

If d is the diameter of the nth dark ring, then

$$d = 2r = 2\sqrt{2nR\lambda}$$

For the central dark ring $n=0$

$$\therefore d = 2\sqrt{nR\lambda} = 0$$

The difference between the diameters of 4th and 1st dark rings

$$d_4 - d_1 = 2\sqrt{4\lambda R} - 2\sqrt{\lambda R} = 2\sqrt{\lambda R} \quad \text{—— ⑨}$$

WAVE LENGTH (λ)

Suppose that the convex surface of the lens is in perfect contact with the glass plate and the thickness of air film is zero at the contact point. It is possible that the two surface may have some imperfection or some dust particles may be present and thus the thickness of air-film may not be zero. Hence we are not sure of the order of the central fringe which may be bright or dark.

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To avoid this, the diameters of two bright fringes say nth and mth are measured with the help of a low power travelling microscope, then for A and B to lie on the nth bright ring, we have from eqn (5)

$$\frac{d_n^2}{4R} = (2n-1)\frac{\lambda}{2} \quad \text{——} \quad (10)$$

and for A and B on lie on the mth bright ring

$$\frac{d_m^2}{4R} = (2m-1)\frac{\lambda}{2} \quad \text{——} \quad (11)$$

Subtracting (11) from (10), we get

$$\frac{d_n^2 - d_m^2}{4R} = (n-m)\lambda$$

or
$$\boxed{\lambda = \frac{d_n^2 - d_m^2}{4R(n-m)}} \quad \text{——} \quad (12)$$

This is the wave length of monochromatic or sodium light

Teacher's Signature: