Newton's rings

B.Sc. II (paper-1)

Unit-I

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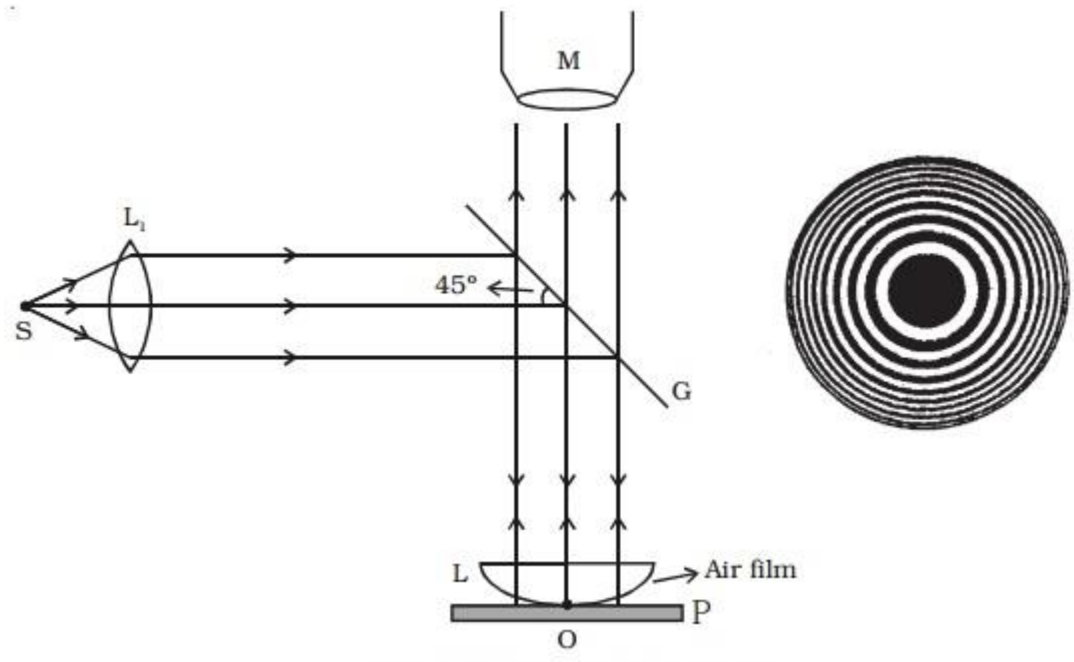
Newton’s rings

An important application of interference in thin films is the formation of Newton’s rings. When a plano convex lens of long focal length is placed over an optically plane glass plate, a thin air film with varying thickness is enclosed between them. The thickness of the air film is zero at the point of contact and gradually increases outwards from the point of contact. When the air film is illuminated by monochromatic light normally, alternate bright and dark concentric circular rings are formed with dark spot at the centre. These rings are known as Newton’s rings. When viewed with white light, the fringes are coloured .

Experiment

In Fig shows an experimental arrangement for producing and observing Newton’s rings. A monochromatic source of light S is kept at the focus of a condensing lens L_1. The parallel beam of light emerging from L_1 falls on the glass plate G kept at 45^o. The glass plate reflects a part of the incident light vertically downwards, normally on the thin air film, enclosed by the plano convex lens L and plane glass plate P. The reflected beam from the air film is viewed with a microscope. Alternate bright and dark circular rings with dark spot as centre is seen.



THEORY

The formation of Newton’s rings can be explained on the basis of interference between waves which are partially reflected from the top and bottom surfaces of the air film. If *t* is the thickness of the air film at a point on the film, the refracted wavelet from the lens has to travel a distance *t* into the film and after reflection from the top surface of the glass plate, has to travel the same distance back to reach the point again.

Thus, it travels a total path *2t*. One of the two reflections takes place at the surface of the denser medium and hence it introduces an additional phase change of π or an equivalent path difference *λ/2* between two wavelets.

∴ The condition for brightness is, Path difference,

Path difference, $\delta = 2t + \frac{\lambda}{2} = n\lambda$

$$\therefore \quad 2t = (2n-1)\frac{\lambda}{2}$$

where n = 1, 2, 3 ... and λ is the wavelength of light used.

The condition for darkness is,

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

$$\therefore \quad 2t = n\lambda$$

where n = 0, 1, 2, 3 ....

The thickness of the air film at the point of contact of lens L with glass plate P is zero. Hence, there is no path difference between the interfering waves. So, it should appear bright. But the wave reflected from the denser glass plate has suffered a phase change of π while the wave reflected at the spherical surface of the lens has not suffered any phase change. Hence the point O appears dark. Around the point of contact alternate bright and dark rings are formed.

EXPRESSION FOR THE RADIUS OF THE NTH DARK RING

Let us consider the vertical section SOP of the plano convex lens through its centre of curvature C, as shown in Fig. Let R be the radius of curvature of the plano convex lens and O be the point of contact of the lens with the plane surface. Let *t* be the thickness of the air film at S and P. Draw ST and PQ perpendiculars to the plane surface of the glass plate. Then ST = AO = PQ = t

Let r_n be the radius of the nth dark ring which passes through the points S and P.

Then SA = AP = r_n

If ON is the vertical diameter of the circle, then by the law of segments

SA. AP = OA. AN

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

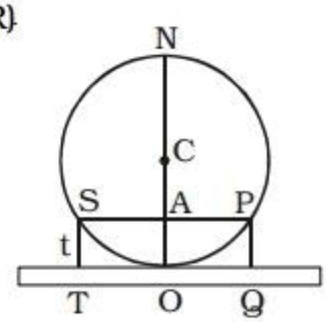
$r_n^2 = 2Rt$ (neglecting t^2 comparing with 2R)

$2t = \frac{r_n^{\,2}}{R}$

According to the condition for darkness

$2t = n\lambda$

$\therefore \quad \frac{r_n^{\,2}}{R} = n\lambda$



$$r_n^2 = nR\,\lambda$$

$$\mathbf{r_n = \sqrt{nR\,\lambda}}$$

Since R and λ are constants, we find that the radius of the dark ring is directly proportional to square root of its order. i.e. $r_1 \propto \sqrt{1}$, $r_2 \propto \sqrt{2}$, $r_3 \propto \sqrt{3}$, and so on. It is clear that the rings get closer as n increases.

APPLICATIONS OF NEWTONS RINGS

Using the method of Newton's rings, the wavelength of a given monochromatic source of light can be determined. The radius of nth dark ring and $(n+m)^{th}$ dark ring are given by

$$r_n^2 = nR\lambda \quad \text{and} \quad r^2_{n+m} = (n+m)\ R\lambda$$

$$r_{n+m}^2 - r_n^2 = mR\lambda$$

$$\therefore \quad \lambda = \frac{r_{n+m}^2 - r_n^2}{mR}$$

Knowing r_{n+m}, r_n and R, the wavelength can be calculated.

(ii) Using Newton's rings, the refractive index of a liquid can calculated. Let λ_a and λ_m represent the wavelength of light in air and in medium (liquid). If r_n is the radius of the n^{th} dark ring in air and if r'_n is the radius of the n^{th} dark ring in liquid, then

$$r_n^2 = nR\,\lambda_a$$

$$r'^2_n = nR\,\lambda_m = \frac{nR\lambda_a}{\mu} \qquad [\because \mu = \frac{\lambda_a}{\lambda_m}]$$

$$\therefore \quad \mu = \frac{r_n^2}{r'^2_n}$$

References Books

1. A textbook of opics by **Brij Lal And Subramaniam.**
2. Optics by **Ajay Ghatak.**
3. Physical optics and lasers by **J.P Agrawal.**