UNIT-II :

INTERFERENCE AND DIFFRACTION

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INTERFERENCE OF LIGHT:

Interference is the phenomenon of the superimposition of one light source over the other.

Due to the superimposition of any two light sources, the resultant energy is redistributed into a position of maximum intensity and of minimum intensity.

Constructive Interference : If the crest of one wave falls on the crest of the other, constructive interference is produced.

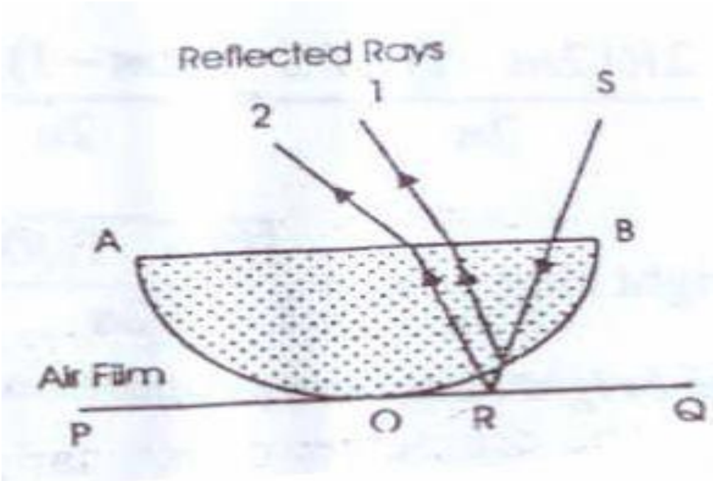
INTERFERENCE OF LIGHT:

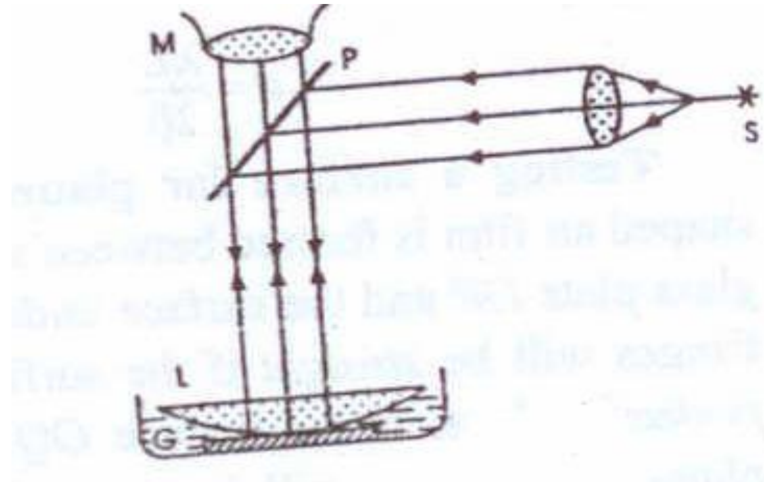
Destructive Interference : If the crest of one wave falls on the trough of the other, destructive interference is produced.

When a soap film or an oil film is viewed from a reflected light or transmitted light, it exhibits different colours.

It is due to the interference pattern produced in thin films

NEWTONS RING:





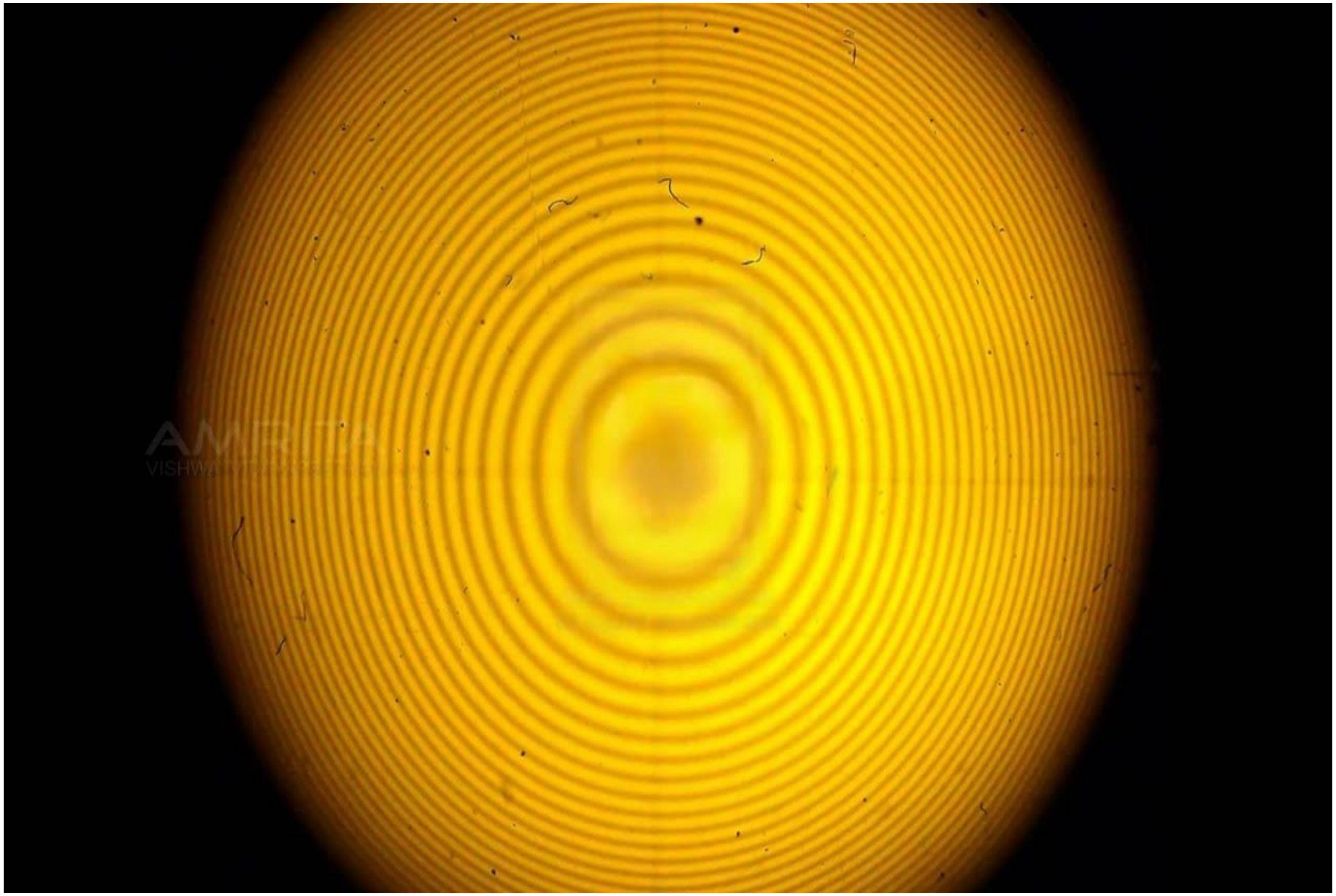
CONSTRUCTION :

A plano-convex lens of large radius of curvature is placed with its convex surface in contact with a plane glass plate.

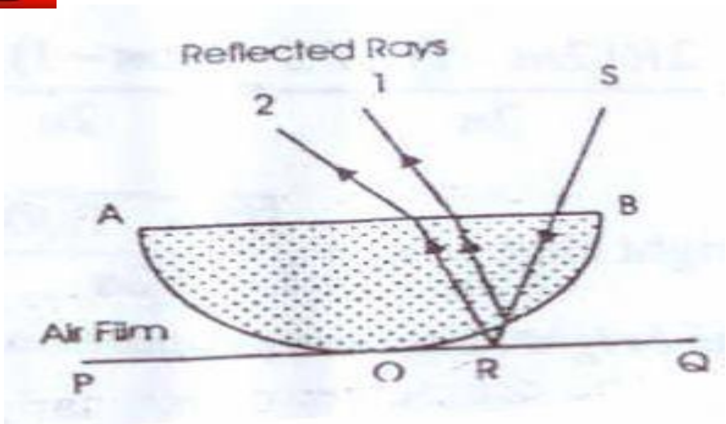
Then, an air film is formed between the lower surface of the lens AOB and the upper surface of the plate POQ

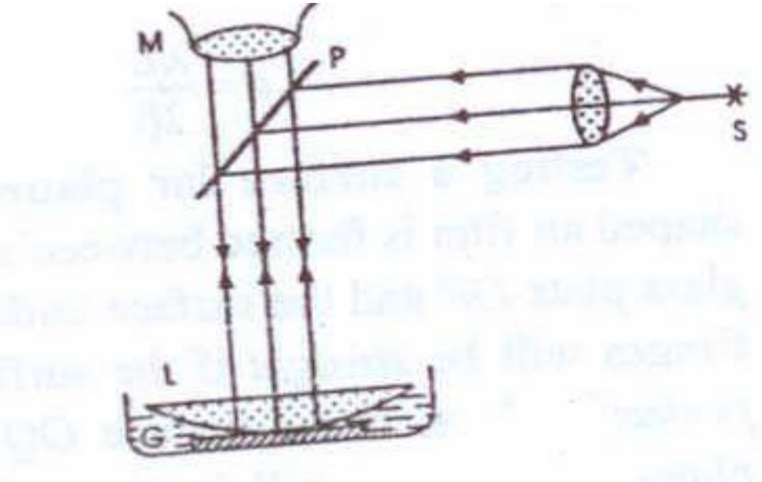
The thickness of the air film is zero at the point of contact O and gradually increases from the point of contact outwards.

NEWTONS RING:



NEWTONS RING:

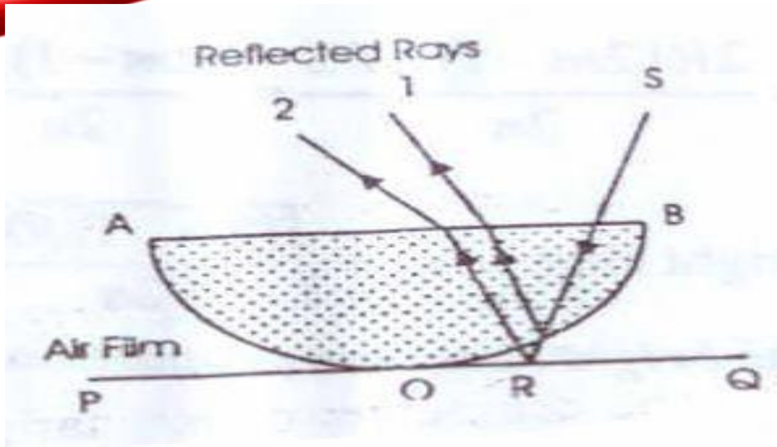




If monochromatic light is allowed to fall normally on this film, a system of alternate bright and dark concentric rings is formed in the air film.

They are called Newton's rings.

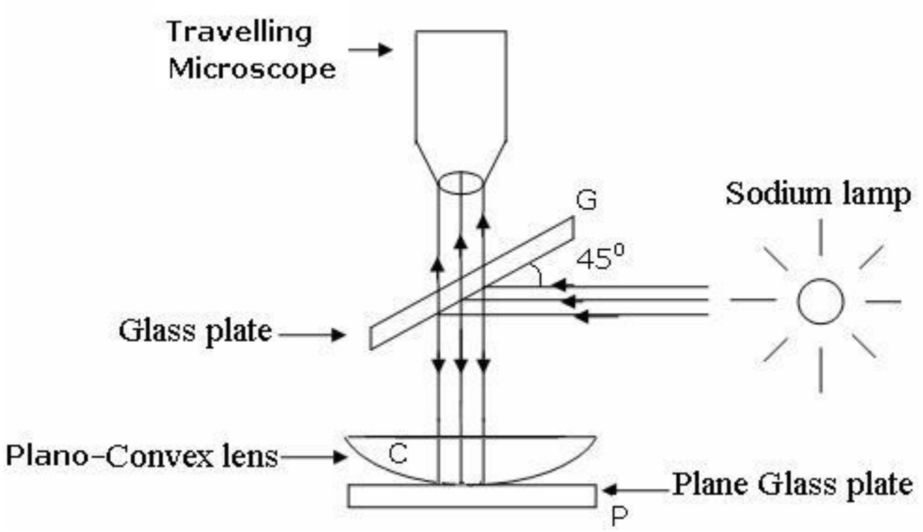
NEWTONS RING:



The thickness of air-film remains constant along a circle with its centre at O. Hence, the fringes are in the form of concentric circles.

Newton's rings are formed as a result of interference between the light waves reflected from the upper and lower surface of the air film. 1 and 2 are the interfering rays corresponding to an incident ray SR.

EXPERIMENTAL ARRANGEMENT:



Experimental arrangement for producing Newton’s rings by reflected light.

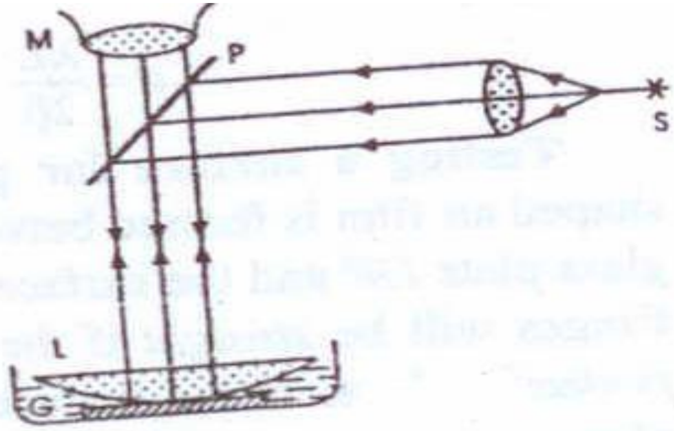
S is source of monochromatic light.

The light from S rendered parallel rays by a convex lens.

These horizontal parallel rays fall on a glass plate G at 45, and are partly reflected from it.

This reflected beam falls normally on the lens C placed on the glass plate P

EXPERIMENTAL ARRANGEMENT:



Interference occurs between the rays reflected from the upper and lower surfaces of the film.

The interference rings are viewed with a microscope M focused on the air film.

CONDITION FOR BRIGHT AND DARK RINGS:

- The optical path difference between the rays is

$$\Delta = 2\mu t \cos r - \frac{\lambda}{2}$$

since μ=1 $\cos r = 1$ $\Delta = 2t - \frac{\lambda}{2}$

- Intensity maxima Δ=m λ $2t - \frac{\lambda}{2} = m\lambda$

- Bright fringe is obtained $2t = (2m+1)\frac{\lambda}{2}$
- Intensity minima

$$\Delta = (2m+1)\frac{\lambda}{2}$$

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

$$2t = m\lambda$$

Dark fringe is obtained

RADII OF DARK FRINGES:

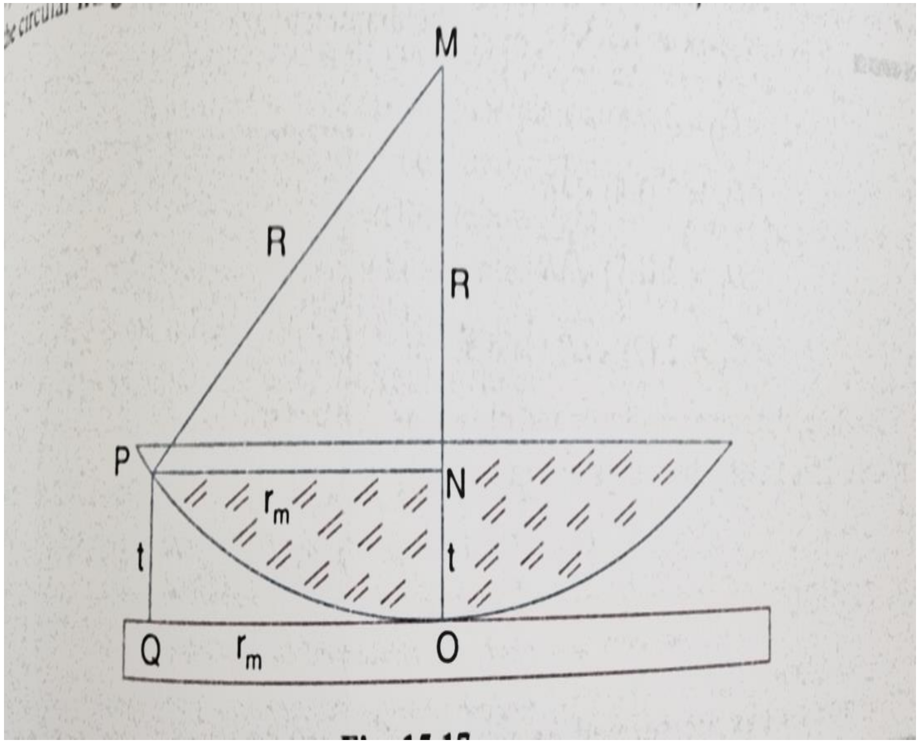
- R be the radius of curvature of lens
- Q is the position of dark fringe
- Thickness of air film at Q= PQ=t
- Radius of circular fringe at Q be
- OQ $=r_m$
- By Paythagorus theorem
- $PM^2=PN^2+MN^2$

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

$$r_m^2 = 2Rt - t2$$

Since R>>t 2Rt>>t^2

$$r_m^2 = 2Rt$$



RADII OF DARK FRINGES:

- **Condition for darkness at Q is:**

2t=mλ

$$r_m^2 = m\lambda R$$

$$r_m = \sqrt{m\lambda R}$$

Radii of dark fringes ,m=1,2,3,…

$$r_1 = \sqrt{1\lambda R} \qquad or \quad r_1 \propto \sqrt{1}$$

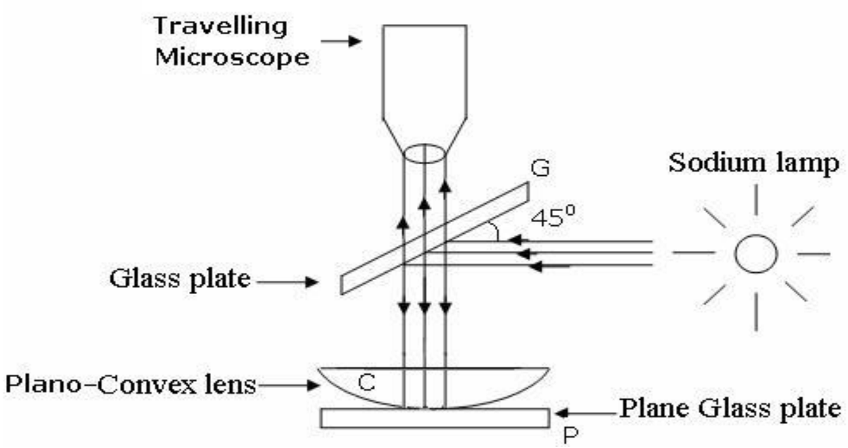
$$r_2 = \sqrt{2\lambda R} \qquad or \quad r_2 \propto \sqrt{2}$$

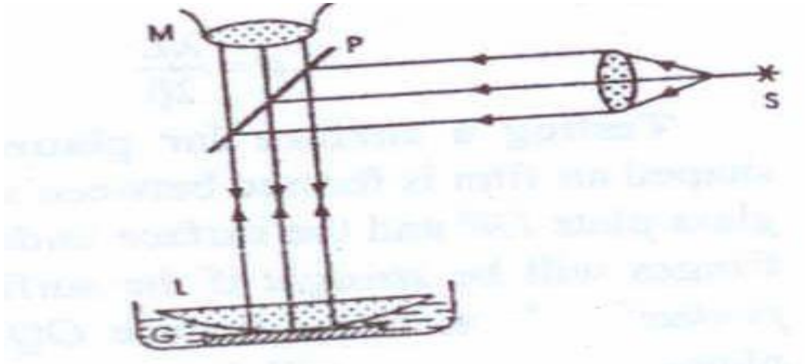
$$r_m \propto \sqrt{\lambda}$$

Ring diameter:
Diameter of mth dark ring

$$D_m = 2r_m \qquad D_m = 2\sqrt{m\lambda R}$$

DETERMINATION OF WAVELENGTH OF SODIUM LIGHT BY NEWTON'S RING :





- **Experimental arrangement: Fig. shows an experimental arrangement for**
- producing Newton's rings by reflected light. S is source of monochromatic light.
- The light from S rendered parallel rays by a convex lens L1.
- These horizontal parallel rays fall on a glass plate G at 45, and are partly reflected from it.

DETERMINATION OF WAVELENGTH OF SODIUM LIGHT BY NEWTON'S RING:

- This reflected beam falls normally on the lens L placed on the glass plate PQ. Interference occurs between the rays
- reflected from the upper and lower surfaces of the film.
- The interference rings are viewed with a microscope M focused on the air film.

PROCEDURE:

- With the help of the traveling microscope the diameters of a number of dark rings are measured.
- The position of the microscope is adjusted to get the centre of Newton's rings at the point of intersection of the cross-wires.
- The microscope is moved until one cross wire is tangential to the 16th dark ring.
- The microscope reading is taken.
- Then microscope is moved such that the cross-wire is successively tangential to 12th, 8^{th} and 4th dark rings respectively.
- The readings are noted in each case.
- Readings corresponding to the same rings are taken on the other side of the centre.

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

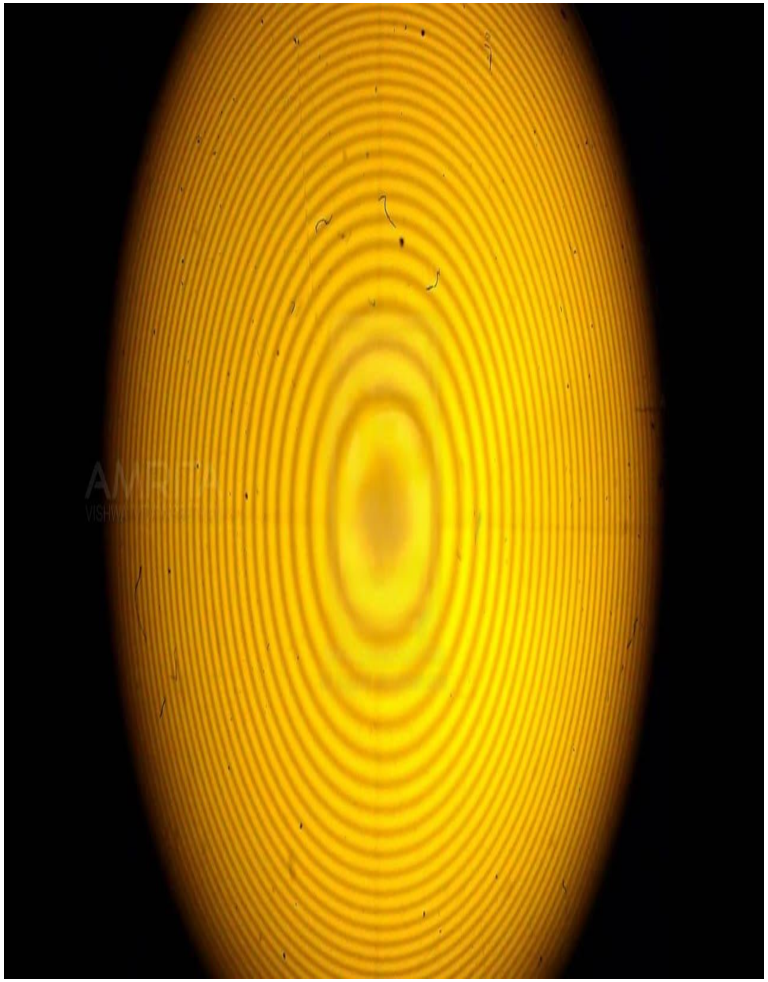
- For the (m+p)th ring

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

$$D_{m+p}^2 - D_m^2 = 4p\lambda R$$

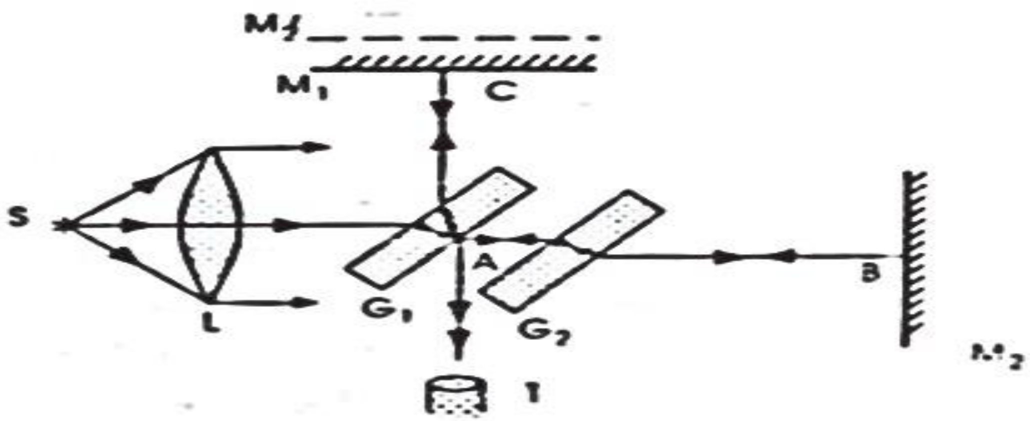
$$\lambda = \frac{D_{m+p}^2 - D_m^2}{4pR}$$

$$\lambda = \frac{Slope}{4R}$$

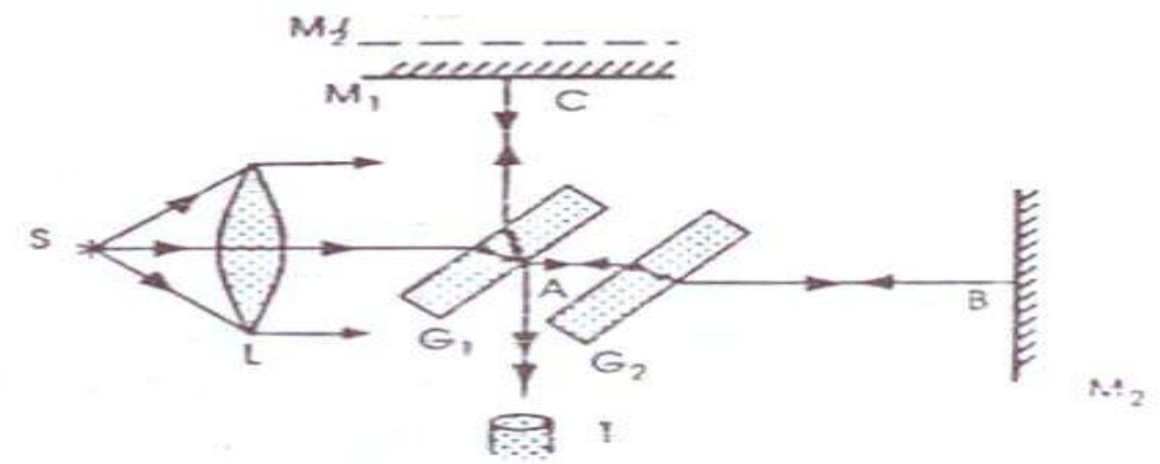


MICHELSON'S INTERFERROMETER:

- **Principle:** Here, the two interfering beams are formed by division of amplitude.
- The amplitude of the light beam from an extended source is divided into two parts of equal intensity by partial reflection and refraction.
- These beams are sent in two perpendicular directions.
- The two beams are finally brought together after reflection from plane mirrors to produce interference fringes.

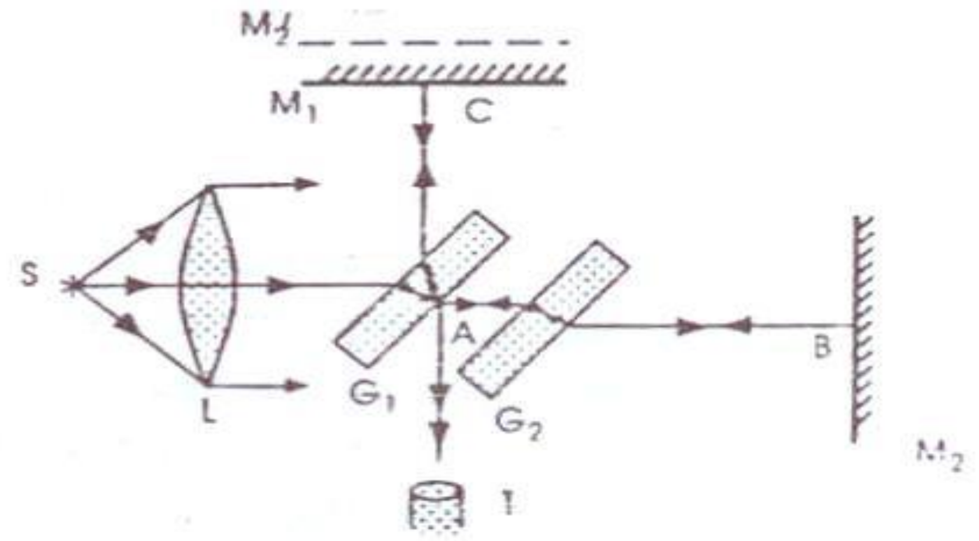


APPARATUS



- : **M1 and M2 are front silvered plane mirrors (The two mirrors are** mounted vertically on two arms at right angles to each other.
- The planes of the mirrors can be slightly tilted with the fine screws at their backs.
- The mirror M2 is fixed. The mirror M1 can be moved parallel to itself by means of very sensitive micrometer screw.
- G1 and G2 are two plane parallel glass plates of equal thickness.

APPARATUS



- The plate G1 is semi silvered on the back side. G_1 is a beam splitter; i.e., a beam incident on G1 is partially reflected and partially transmitted.
- G1 is inclined at an angle of 45^0 to the incident beam.
- G2 is called the compensating plate.
- S is a light source.

WORKING:

- Light from the sources is rendered parallel by a lens L and falls on the glass plate G1 at an angle of 45°.
- At the back surface of G1, it is partly reflected along AC and
- partly transmitted along AB.
- The reflected beam moves towards mirror M1 and falls
- normally on it.
- It is reflected back along the same path and emerges out along AT.
- The transmitted ray AB falls normally on the mirror M2. It is reflected along the same path.
- After reflection at the back surface of G1, it moves along AT. The two emergent beams have been derived from a single incident beam and are, therefore, coherent.
- The two beams produce interference under suitable conditions.

FUNCTION OF G1:

- The reflected ray AC passes through G1, thrice But the transmitted ray AB passes through G1, only once.
- That is why a second plate G2 of the same thickness and inclination as G1 is introduced.
- Thus the function of the plate G1 is only to equalize the optical paths traversed by both the beams.

CIRCULAR FRINGES:

- Circular fringes are produced with monochromatic light when mirrors M_1 and M_2 are exactly perpendicular to beach other.
- Looking though T M_1 see directly with virtual image M'_2 of mirror M2 formed by reflection in G_1
- If two arms are equal in Length,M'_2 will coincides with mirror M_1

CIRCULAR FRINGES:

- If M'_2 and M1 do not coincides, Then the path difference between the two coherent beams is 2d cos θ .
- The condition for a bright ring is
- $2d\cos\theta+\lambda/2 = m\lambda$ where m is an integer.
- $2d\cos\theta$ is path difference between two beams

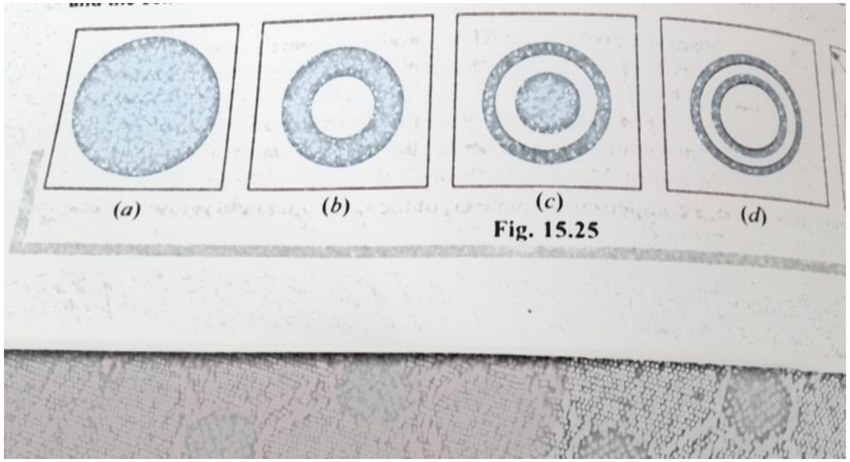


Fig. 15.25

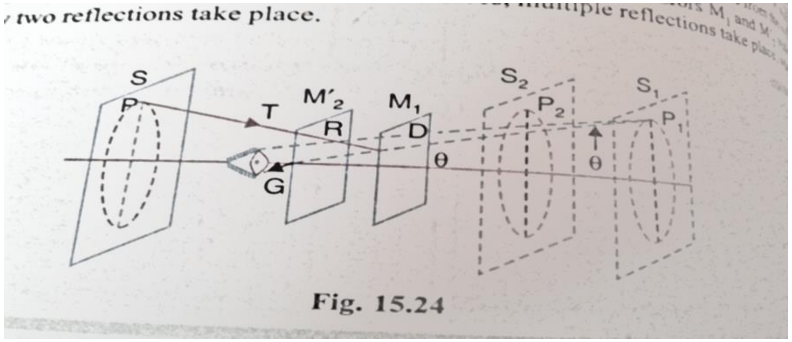
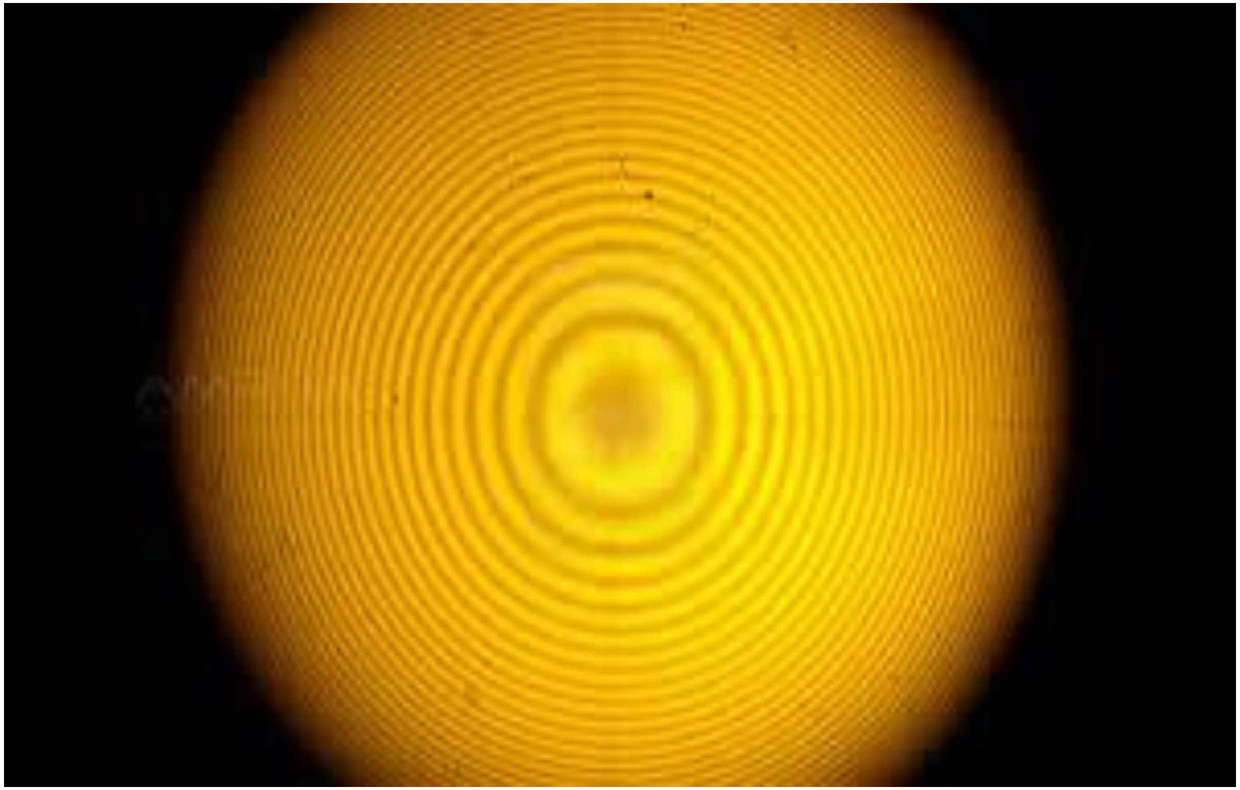


Fig. 15.24



APPLICATIONS OF MICHELSON'S INTERFERROMETER:

- **1) Determination of wavelength of monochromatic light:**
- M_1 and M_2 are exactly perpendicular, Circular fringes are obtained
- If M_1 moved forward or backward Circular fringes appear or disappear at the center
- Now mirror is moved through known distance d and number of fringes disappear at center is counted
- If d_1 initial thickness of air film between M1 and image of M2 corresponding to bright fringe of order m_1
- d_2 is final thickness of air film corresponding to bright fringe of order m_n in same position.

APPLICATIONS OF MICHELSON'S INTERFERROMETER:

- Then

$$2d_1 = m_1\lambda$$

$$2d_2 = m_n\lambda$$

$$2(d_2 - d_1) = (m_n - m_1)\lambda$$

$$2d = N\lambda \text{ where } (d_2 - d_1) = d \text{ and } (m_n - m_1) = N$$

$$\lambda = \frac{2d}{N}$$

2) DETERMINATION OF DIFFERENCE IN THE TWO WAVELENGTH OF TWO WAVES OR RESOLUTION OF TWO SPECTRAL LINES.

- If source has two wavelengths λ_1 and λ_2 differ slightly
- Two sets of fringes are produced corresponding to wavelength.
- Position of M_1 is adjusted for very bright fringes, then bright fringe due to λ_1 coincides with bright due to λ_2
- Again when M_1 is moved such that bright fringe due to one coincides with dark fringe due to other and no fringes will be seen.
- Again M_1 is moved such that bright of one coincides with bright of other and fringes appears again
- This is possible when m^{th} order of longer wavelength coincides with the $(m+1)^{th}$ order of shorter.

2) DETERMINATION OF DIFFERENCE IN THE TWO WAVELENGTH OF TWO WAVES OR RESOLUTION OF TWO SPECTRAL LINES.

$$2d = m_1\lambda_1 = m_2\lambda_2$$

$if\ \lambda_1 > \lambda_2$

$m_2 = m_1 + 1$

$$2d = m_1\lambda_1 = (m_1 + 1)\lambda_2$$

$$2d = \frac{\lambda_1\lambda_2}{\lambda_1 - \lambda_2}$$

$$\lambda_1 - \lambda_2 = \frac{\lambda_1\lambda_2}{2d}$$

$$\Delta\lambda = \frac{\lambda^2}{2d}$$

3) THICKNESS OF THIN TRANSPARENT SHEET

- Let transparent sheet of thickness *t* and RI μ inserted in path of interfering beam of Michelson's interferometer
- Optical path increases becomes μμt instead of *t*.
- The increase in optical path is $(\mu t - t)$ or $(\mu - 1)\, t$
- Since beam travels medium twice
- Extra path difference between two interfering beam is $2(\mu - 1)\, t$ t=
- If m is number of fringes by which fringe system is displaced
- $2(\mu - 1)\, t$ = m λ
- $t = \frac{m\lambda}{2(\mu-1)}$

4) DETERMINATION OF REFRACTIVE INDEXI OF GASES:

- If a tube containing a gas introduced in path of beam going towards M1
- Path difference equal to $2(\mu - 1)\, l$ introduced in interfering beams
- μ is RI of gas and l is length of tube
- If m fringes cross the center of field of view ,
- $2(\mu - 1)l = m\lambda$
- $\mu = \frac{m\lambda}{2l} + 1$