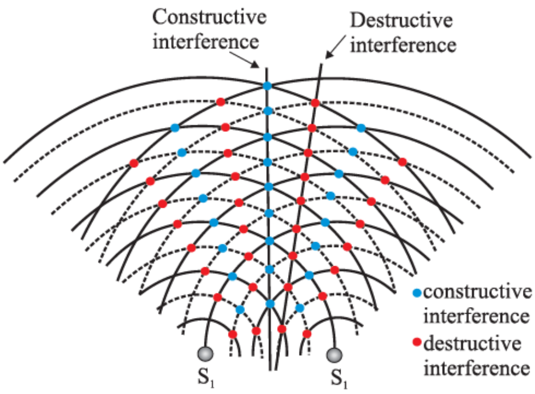
Ch. 2 Interference

Principle of Superposition of Waves:

When two or more waves travelling through a medium arrive at a point simultaneously, each wave produces its own displacement at that point, independent of each other. The resultant displacement at that point is equal to vector sum of displacement of individual waves.

If the waves arrive at a point are in phase, there displacement is added and resultant displacement is maximum while the waves arrive at a point are out of phase, there displacement is subtracted and resultant displacement is minimum.

Interference: The phenomenon of enhancement in displacement or cancellation of displacement due to the superposition of two light waves is called as interference.



Interference for water waves.

Types of Interference:

There are two types of interference:

1. Constructive Interference
2. Destructive Interference

1. Constructive Interference: The waves arrive at a point are in phase i.e. crest of one wave coincides with the crest of other wave or trough of one wave coincides with the trough of other wave, the displacement is added and resultant displacement is maximum. Such a point is called as bright point and such a interference is called as constructive interference.

For constructive interference,

Path difference =0, λ, 2 λ, 3 λ, 4 λ,……………………

= nλ where n = 0, 1, 2, 3………

Phase difference = 0, 2π, 4π, 6π……………………

= $2n\pi$ where n = 0, 1, 2, 3………

Condition: If the path difference between the two light waves interfering at a point is equal to an integral multiple of wavelength, there is a constructive interference and point is bright.

2. Destructive Interference: The waves arrive at a point are out of phase i.e. crest of one wave coincides with the trough of other wave or trough of one wave coincides with the crest of other wave, there displacement is subtracted and resultant displacement is minimum. Such a point is called as dark point and such a interference is called as destructive interference.

For destructive interference,

Path difference = $\lambda/2$, $3\lambda/2$, $5\lambda/2$, ……………………

= $(2n+1)\,\lambda/2$ where n = 0, 1, 2, 3………

= $(2n-1)\,\lambda/2$ where n = 1, 2, 3………

Phase difference = π, 3π, 5π……………………

= $(2n-1)\,\pi$ where n = 1, 2, 3………

Condition: If the path difference between the two light waves interfering at a point is equal to odd multiple of half wavelength, there is a destructive interference and point is dark.

Conditions for steady Interference of Light

- The sources must be coherent i.e. they maintain a constant phase with respect to each other.
- The sources should be monochromatic i.e. of single wavelength
- The sources should be equally bright.
- The sources should be narrow and close to each other.

1. Interference in Thin Films due to reflected light

Consider a transparent film of this *t* and refractive index μ *is* shown in figure.

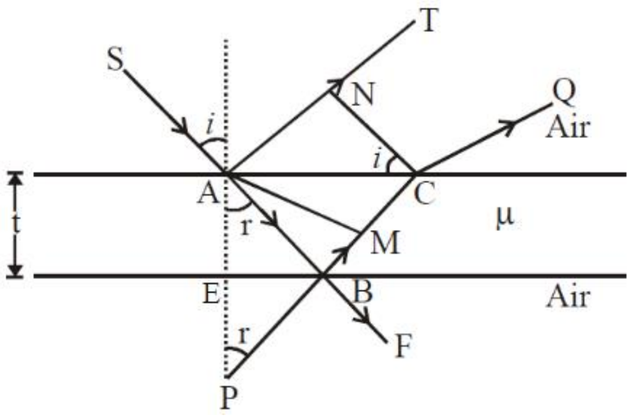


Figure 1 Interference in thin film due to reflected light

Let SA is incident ray, incident on upper surface of the film. It is partly reflected along AT and partly refracted along AB. At B part of it is reflected along BC and finally emerges out along CQ.

To calculate the path difference between two rays AT and CQ, draw CN normal AT and AM normal to BC.

Let *i*-is angle of incidence

r- is angle of refraction.

Also produce CB to meet AE produced at P. Hence ∠APC = *r*.

The optical path difference is,

$$x = \mu(AB + BC) - AN \quad ----- (1)$$

From figure,

$$Sini = \frac{AN}{AC} \text{ and } Sinr = \frac{CM}{AC}$$

$$\therefore \frac{Sini}{Sinr} = \frac{AN}{AC} \times \frac{AC}{CM} = \frac{AN}{CM}$$

We know that, R.I of medium,

$$\mu = \frac{Sini}{Sinr} = \frac{AN}{CM}$$

$$\therefore AN = \mu CM$$

Therefore, equation (1) becomes,

$$x = \mu(AB + BC) - \mu CM = \mu(AB + BC - CM)$$

But AB+BC = PC

$$\therefore x = \mu(PC - CM) = \mu PM \quad ----(2)$$

In ΔAPM, $Cosr = \frac{PM}{AP}$

$$\therefore PM = AP\ Cosr = (AE + EP)Cosr$$

$$PM = 2t.Cosr$$

Since, AE = EP = t

Therefore, equation (2) becomes

$$x = \mu PM = \mu.2t\ Cosr \quad ------(3)$$

Eq^n (3) is correct only when reflected light does not represent the correct path difference but only the apparent.

It has been established on the basis of electromagnetic theory that, when light is reflected from the surface of an optically denser medium a phase change π, equivalent to a path difference λ/2 occurs.

∴ Corrected path difference

$$x = 2\mu tCosr - \frac{\lambda}{2} \quad ----- (4)$$

(1) If the path difference $x = n\lambda$ *, where n = 0, 1, 2, 3 …………etc.* constructive interference takes place and the film appears bright.

$$2\mu tCosr - \frac{\lambda}{2} = n\lambda$$

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

$$2\mu tCosr = (2n + 1)\frac{\lambda}{2} \quad ------- (5)$$

Where n = 0, 1, 2, 3--------

(2) If the path difference *x = (2n+1)λ/2 , where n = 0, 1, 2, 3 …………etc.* destructive interference takes place and the film appears dark.

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

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

Here n is an integer only, therefore (n+1) is taken as n.

$$\therefore 2\mu t Cosr = n\lambda \quad ------(6)$$

Where n = 0, 1, 2, 3--------

2. Interference in Thin Films due to transmitted light

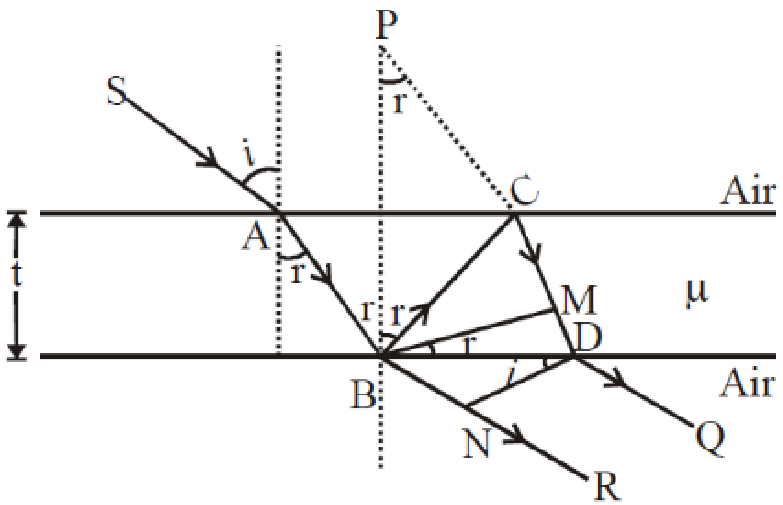


Figure 2 Interference in thin film due to transmitted light

Consider a transparent film of thickness t and refractive index μ is as shown in figure.

Let SA is incident ray, incident on upper surface of the film. At point A, it is partly refracted along AB. At B part of it is reflected along BC and partly refracted along BR. The ray BC after reflection at C, emerges along DQ.

At B and C reflection takes place at the rarer medium. Hence no phase change occurs. Draw BM normal to CD and DN normal to BR.

The optical path difference between the ray DQ and BR is given by,

The optical path difference is,

$$x = \mu(BC + CD) - BN \quad -----(1)$$

From figure,

$$Sini = \frac{BN}{BD} \text{ and } Sinr = \frac{MD}{BD}$$

$$\therefore \frac{Sini}{Sinr} = \frac{BN}{BD} \times \frac{BD}{MD} = \frac{BN}{MD}$$

We know that, R.I of medium,

$$\mu = \frac{Sini}{Sinr} = \frac{BN}{MD}$$

$$\therefore BN = \mu MD$$

Therefore, equation (1) becomes,

$$x = \mu(BC + CD) - \mu MD \quad = \mu(BC + CD - MD)$$

From figure, ∠BPC = r and CP = BC = CD

∴ BC + CD = PD

$$\therefore x = \mu(PD - MD) = \mu PM \quad ----(2)$$

In ΔBPM, $Cosr = \frac{PM}{BP}$

$$\therefore PM = BP\ Cosr$$

But BP = 2t

$$PM = 2t.Cosr$$

Therefore, equation (2) becomes

$$x = \mu PM = \mu.2t\ Cosr \quad ------(3)$$

Eq^n (3) is path difference between two light rays which are transmitted through thin film.

(1) If the path difference $x = n\lambda$ *, where n = 0, 1, 2, 3 …………etc.* constructive interference takes place and the film appears bright.

$$\therefore 2\mu tCosr = n\lambda \quad ------(4)$$

Where n = 0, 1, 2, 3--------

(2) If the path difference $x = (2n+1)\lambda/2$*, where n = 0, 1, 2, 3 …………etc.* *des*tructive interference takes place and the film appears dark.

$$2\mu t Cosr = (2n+1)\frac{\lambda}{2} \quad --------(5)$$

Where n = 0, 1, 2, 3--------

3. Fringes produced by a Wedge-Shaped Thin Film

Consider two plane surfaces OA and OB inclined at an angle θ and enclosing a wedge-shaped air film. The thickness of the air film increases from O to A. When the air film is viewed with reflected monochromatic light, a system of equidistant interference fringes are observed which are parallel to the line of intersection of two surfaces. The interfering rays do not enter the eye parallel to each other but they appear to diverge from a point near the film.

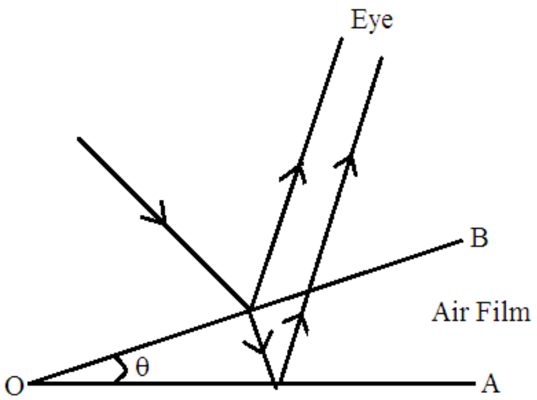


Fig. (a)

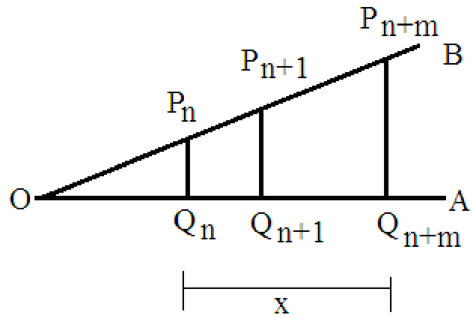


Fig. (b)

Suppose n^{th} bright fringe occurs at P_n as shown in Fig. b.

The thickness of the air film at is $P_n = P_nQ_n$.

Applying the relation for bright fringes,

The optical path difference for reflected light is,

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

Where n = 0, 1, 2, 3--------

As angle of incidence is small, Cosr = 1.

For air, $\mu = 1$ and $t = P_nQ_n$

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

$$\therefore 2P_nQ_n = (2n+1)\frac{\lambda}{2} ------(1)$$

The next bright fringe (n+1) will occur at P_{n+1}, such that

$$2P_{n+1}Q_{n+1} = (2(n+1)+1)\frac{\lambda}{2} = (2n+3)\frac{\lambda}{2} ----(2)$$

Subtracting eq^n (1) from eq^n (2)

$$2P_{n+1}Q_{n+1} - 2P_nQ_n = (2n+3)\frac{\lambda}{2} - (2n+1)\frac{\lambda}{2}$$

$$= (2n+3-2n-1)\frac{\lambda}{2} = (2)\frac{\lambda}{2}$$

$$2(P_{n+1}Q_{n+1} - P_nQ_n) = \lambda$$

$$\therefore (P_{n+1}Q_{n+1} - P_nQ_n) = \frac{\lambda}{2} ----- (3)$$

The next bright fringe will occur at the point where the thickness of the air film increases by λ/2.

Suppose the $(n+m)^{th}$ bright fringe is at P_{n+m}. Then, there will be m bright fringes between P_n and P_{n+m} such that

$$(P_{n+m}Q_{n+m} - P_nQ_n) = \frac{m\lambda}{2} --- (4)$$

If the distance $Q_nQ_{n+m} = x$

∴ Angle of inclination is,

$$\theta = \frac{(P_{n+m}Q_{n+m} - P_nQ_n)}{Q_nQ_{n+m}}$$

$$\therefore \theta = \frac{\frac{m\lambda}{2}}{x} = \frac{m\lambda}{2x}$$

$$\therefore x = \frac{m\lambda}{2\theta}$$

Therefore, the angle of inclination between OA and OB can be known. Here, x is the distance corresponding m fringes.

The fringe width is,

$$\beta = \frac{x}{m} = \frac{\lambda}{2\theta}$$

4. Newton's Ring:

When a plano-convex lens of long focal length is placed on a plane glass plate, a thin film of air is enclosed between the lower surface of the lens and upper surface of the plate. The thickness of the air film is very small at the point of contact and gradually increases from the centre outwards. The fringes produced with monochromatic light are circular. The fringes are concentric circles, uniform in thickness with the point of contact as the centre.

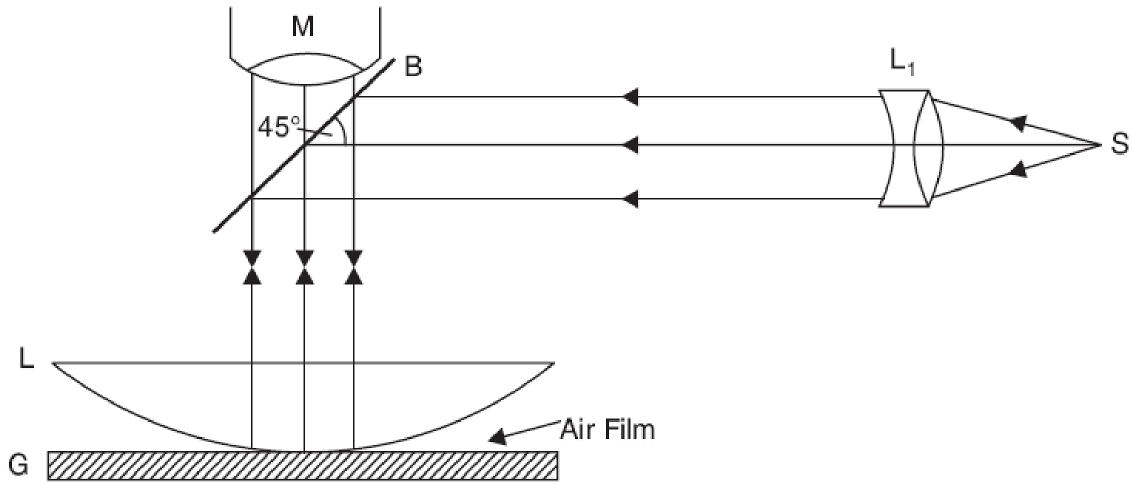


Fig. 1 Experimental set up for viewing Newton's rings

The experimental set of Newton's ring as shown in Fig.1. Let S is a source of monochromatic light at the focus of the lens L_1. A horizontal beam of light falls on the glass plate B at 45°. The glass plate B reflects a part of the incident light towards the air film enclosed by the lens L and the plane glass plate G. The reflected beam from the air film is viewed with a microscope. Interference takes place and dark and bright circular fringes are produced. This is due to the interference between the light reflected from the lower surface of the lens and upper surface of the glass plate G.

Newton's Ring by reflected light:

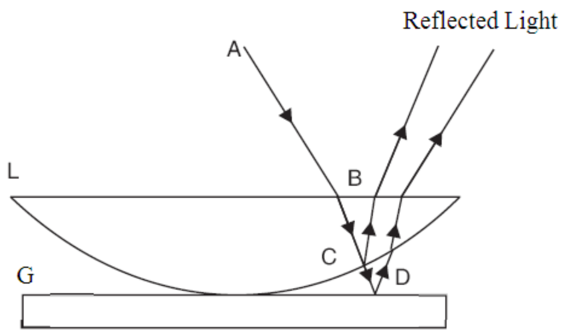


Fig. (a)

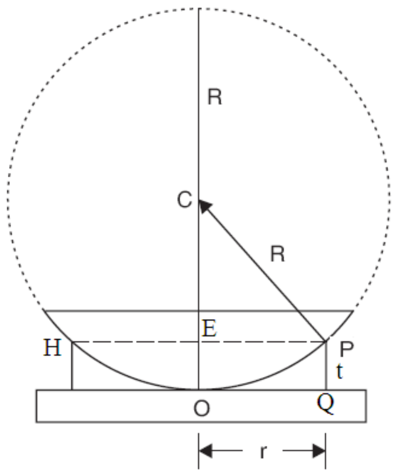


Fig. (b)

Suppose the radius of the curvature of the lens is R and air film of thickness t is at a distance OQ = r, from the point of contact O.

Here, the interference is due to reflected light.

Therefore, the path difference for bright ring is

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

Where n = 0, 1, 2, 3, …………

As, *r* is small, cosr = 1 and for air μ = 1.

∴ Above eq^{n} becomes,

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

The path difference for dark ring is

$$2\mu t Cosr = n\lambda$$

Where n = 0, 1, 2, 3, …………

$$\therefore 2t = n\lambda --------(2)$$

From Fig. (b),

$$EP \times HE = OE \times (2R\text{-}OE)$$

$$But\ EP = HE = r\ ,\ and\ OE = PQ = t$$

$$\therefore \quad r^2 = t\,(2R - t)$$

$$But\ 2R - t \approx 2R$$

$$\therefore \quad r^2 = t\,.2R$$

$$t = r^2/2R$$

Substituting value of t in eq^n (1) and (2),

For bright ring,

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

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

$$\therefore r = \sqrt{(2n+1)\frac{\lambda R}{2}} \quad ------ (3)$$

For dark ring,

$$2.\frac{r^2}{2R} = n\lambda$$

$$\therefore r^2 = n\lambda R$$

$$\therefore r = \sqrt{n\lambda R} \quad ---------- (4)$$

When n=0, the radius of the dark ring is zero and radius of bright ring is $\sqrt{\frac{\lambda R}{2}}$. Therefore, the centre is dark. Alternately dark and bright rings are produced.

Determination of wavelength of sodium light using Newton's Rings:

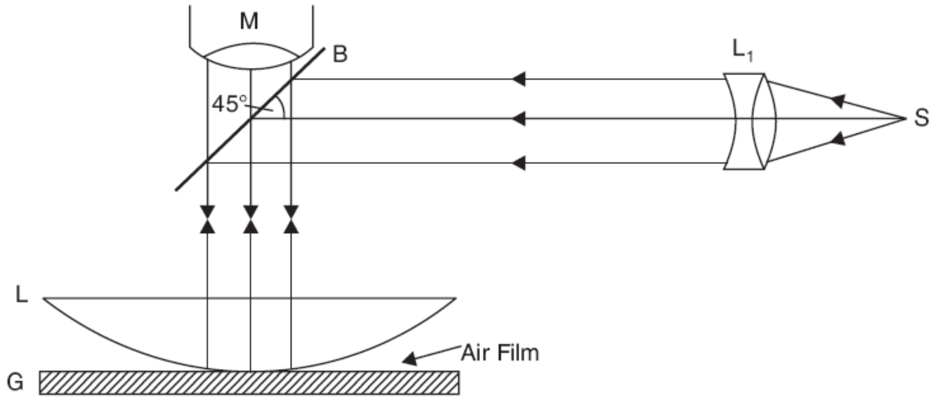


Fig. 1 Experimental set up for viewing Newton's rings

The experimental arrangement of Newton's ring is as shown in Fig.1. Let S is a source of sodium light. A parallel beam of light from the lens L1 is reflected by glass plate B inclined at an angle of 45° to the horizontal. L is a plano-convex lens of large focal length. Newton's rings are viewed through B by travelling microscope M focussed on the air film. Circular bright and dark rings are seen with the centre dark. With help of a travelling microscope, measure the diameter of the nth dark ring.

Suppose the diameter of nth dark ring is D_n,

We know that, the radius of nth dark ring is

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

But $D_n = 2r_n$ and $r_n = D_n/2$

$$\therefore \frac{D_n}{2} = \sqrt{n\lambda R}$$

Squaring on both side,

$${D_n}^2 = 4n\lambda R - - - - (1)$$

Measure the diameter of the (n+m)th dark ring, let it be D_{n+m},

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

Subtracting equation (1) from equation (2)

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

$$= 4m\lambda R$$

$$\therefore \lambda = \frac{{D_{n+m}}^2 - {D_n}^2}{4mR} - - - - - - (3)$$

By using equation (3) wavelength of sodium light is calculated.

5. Michelson Interferometer:

The Phenomenon of interference has been used to test the plane-ness of surfaces and also to reduce reflecting power of the lens and the prism surfaces. Instruments based on the principle of interference of light is known as interferometer. Michelson designed an interferometer to determine the wavelength of light, thickness of thin strips and for the standardization of the metre.

Michelson interferometer is as shown in figure 1.

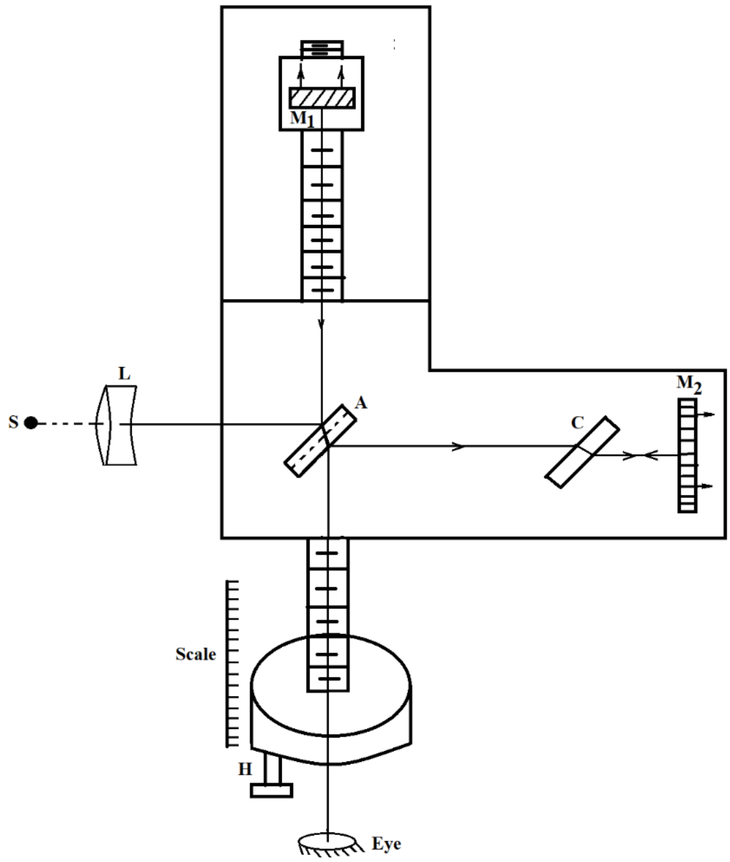


Fig. 1 Michelson Interferometer

It consists of two highly polished mirror M_1 and M_2 and two glass plates A and C parallel to each other. The rear side of glass plate A is half silvered so that light coming from the source is equally reflected and transmitted by it. The light from a monochromatic source S after passing through the lens L falls on the plate A. Lens L makes the beam parallel. The plate A is inclined at an angle of 45°. One-half of the energy of the incident beam is reflected by the plate A towards the mirror M_1 and another half is transmitted towards the mirror M_2. These two beams travel among two mutually perpendicular paths and are reflected back by the mirror M_1 and M_2. These two beams return to plate A. The beam reflected back by M_1 is transmitted through glass plate A and beam reflected back M_2 by is reflected by glass plate A towards the eye. The Beam going towards the mirror M_1 and a reflected back has to pass twice through the glass plate A. Therefore, to compensate for the path the plate C is used between mirror M_2 and A. The light beam going towards the mirror M_2 and reflected back towards A also passes twice through the compensating plate C. Therefore, the paths of the two rays in glass are same. The mirror M_1 is fixed on the carriage and can be moved with help of handle H. The distance through which mirror is moved can be read on the scale. The planes of the mirrors M_1 and M_2 can be made perfectly perpendicular with help of fine screws. The compensating plate is the necessity for white light fringes but can be dispensed with while using monochromatic light.

If the mirrors M_1 and M_2 are perfectly perpendicular, the observer's eye will see the images of the mirror M_1 and M_2 through A. There will be an air film between two images and distance can be varied with handle H. The fringes will be perfectly circular. If the path travelled by the two rays is exactly same, the field of view will be completely dark. If the two images of M_1 and M_2 are inclined the enclosed air film will be wedge-shaped and straight-line fringes will be observed. When the mirror M_1 is moved away or towards the glass plate A with help of handle H, the fringes cross the centre of the field of view of observer's eye. If M_1 is moved through a distance $\lambda/2$, one fringe will cross the field of view and will move to the position previously occupied by the next fringe.

Types of fringes:

i) Circular fringes:

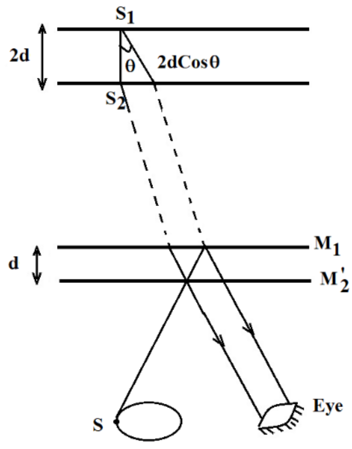


Fig. 2

Circular fringes are produced with monochromatic light in a Michelson interferometer. The mirror M_1 and virtual mirror M'_2 which is the image of M_2 must be parallel as shown in figure 2.

The source is an extended one and S_1 and S_2 are the virtual images of the source due to M_1 and M'_2. If the distance $M_1M'_2$ is d, the distance between S_1 and S_2 in the $2d$. The path difference between two beams will be $2dCos\theta$.

Therefore, the rays for which $2dCos\theta = n\lambda$ will reinforce to produce maxima. These circular fringes which are due to interference with a phase difference determined by the inclination θ are known as fringes of equal inclination or Haidinger's fringes. When M_1 and M'_2 coincides, the path difference is zero and the field of view is perfectly dark as shown in figure 3(b). When M'_2 is nearer the eye than M_1 the fringes are well separated as shown in figure 3(a). When M'_2 is farther from eye than $M_{1,}$ the fringes are closed as shown in figure 3(c).


(a) (b) (c)

Fig. 3

ii) Localized Fringes:

When the mirror M_1 add virtual mirror M'_2 are inclined, the air film is enclosed is wedge-shaped and straight-line fringes are observed. The shape of the fringes observed for various values of the path difference as shown in figure 4.

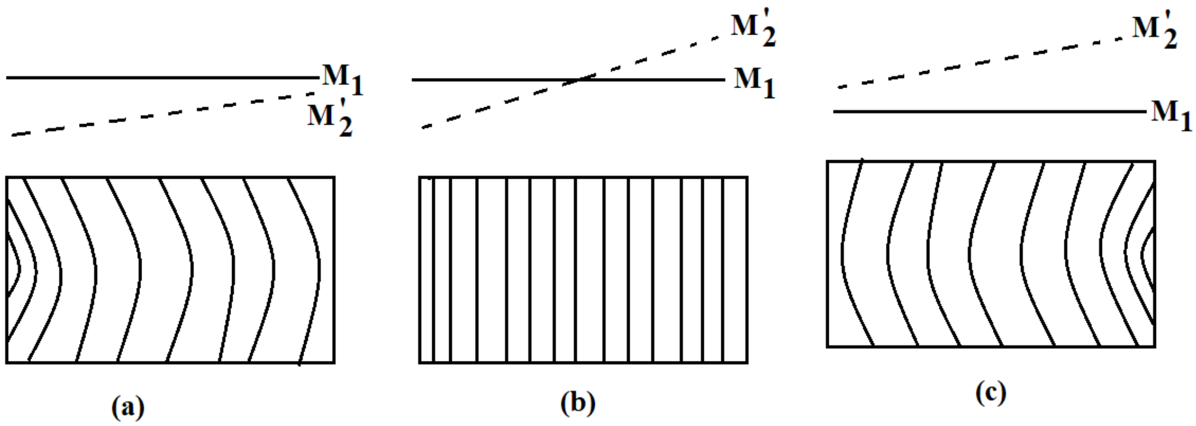


Fig. 4

The fringes are perfectly straight line when M_1 actually intersect M'_2 as shown in figure 4 (b). In another positions, the shape of fringes is curved and are always convex towards the thin edge of the wedge as shown in figure 4 (a) and (c). This type of changes are not observed for large path differences.

iii) White light fringes:

With white light, the fringes are observed only when the path difference is small. The different colours overlap on each other and only the first few coloured fringes are visible. the central fringe is dark and other fringes are coloured. After about 10 fringes a number of colours overlap at a point. White light fringes are useful for the determination of the zero-path difference, especially in the standardization of metre.

Determination of wavelength of monochromatic light:

The mirrors M_1 and M_2 are adjusted so that circular fringes are visible in the field of view. If M_1 and M_2 are equidistant from the glass plate A, the field of view will be perfectly dark. The mirror M_2 is kept fixed and mirror M_1 is moved with help of handle of micrometre screw and the number of fringes that cross the field of view is counted.

Suppose for the monochromatic light of wavelength λ, the distance through which mirror is moved is = d

then number of fringes that cross the centre of field view n then $d = \frac{n\lambda}{2}$

because for one fringe shift, the mirror moves through a distance equal to half the wavelength. Hence λ can be determined.

Determination of the difference in wavelength between two neighbouring spectral lines:

There ae two spectral lines D_1 and D_2 of sodium light. They are very near to each other and difference in their wavelength is small. Suppose λ_1 is wavelength of line D_1 and λ_2 is wavelength of line D_2. Also $\lambda_1 \neq \lambda_2$. Each spectral lines will give rise to its fringes in Michelson interferometer. By adjusting the position of the mirror M_1 of the Michelson interferometer, the position is found when the fringes are very bright. In this position, the bright fringe due to D_1 coincides with the bright fringe due to D_2. When the mirror M_1 is moved, the two sets of fringes get out of step because their wavelengths are different. When mirror M_1 is moved through a certain distance, the bright fringe due to one set will coincide with dark fringe due to other set and no fringes will be seen. Again, by moving mirror M_1, position is reached when a bright fringe of one set falls on the bright fringe of other and fringes are again distinct. This is possible when n^{th} order of longer wavelength coincides with $(n+1)^{th}$ order of shorter wavelength.

Let n_1 and n_2 be the changes in order at centre of field, when the mirror M_1 is displaced through a distance *d* between two consecutive positions of maximum distinctness of the fringes.

$$\therefore 2d = n_1\lambda_1 = n_2\lambda_2$$

If λ_1 is greater than λ_2, $n_2 = n_1+1$

$$\therefore 2d = n_1\lambda_1 = (n_1+1)\lambda_2 \quad ------(1)$$

$$\therefore n_1\lambda_1 = n_1\lambda_2 + \lambda_2$$

$$n_1(\lambda_1 - \lambda_2) = \lambda_2$$

$$n_1 = \frac{\lambda_2}{(\lambda_1 - \lambda_2)}$$

Substituting value of n_1 in equation (1)

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

$$\lambda_1 - \lambda_2 = \frac{\lambda_1 \lambda_2}{2d} \quad ------ (2)$$

Taking λ as mean of λ_1 and λ_2

$$\therefore \Delta\lambda = \lambda_1 - \lambda_2 = \frac{\lambda^2}{2d} \quad ------ (3)$$

By using equation (3) the difference in wavelength $\lambda_1 - \lambda_2$ can be calculated.

Also, wave number is defined as reciprocal of wavelength.

$$\therefore \overline{\nu_1} = \frac{1}{\lambda_1} \text{ and } \overline{\nu_2} = \frac{1}{\lambda_2}$$

From equation (2),

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

$$\frac{\lambda_1 - \lambda_2}{\lambda_1 \lambda_2} = \frac{1}{2d}$$

$$\frac{1}{\lambda_2} - \frac{1}{\lambda_1} = \frac{1}{2d}$$

$$\overline{\nu_2} - \overline{\nu_1} = \frac{1}{2d}$$

This equation represents the difference in the wave numbers of the two spectral lines.

Numerical:

1. A parallel beam of light (λ=5890 $\times 10^{-8}$ cm) is incident on a thin glass plate (μ=1.5) such that the angle of refraction into the plate is 60°. Calculate the smallest thickness of the glass plate which will appear dark by reflection.

Solution: Given

$\lambda = 5890 \times 10^{-8}$ cm

$\mu = 1.5$

r = 60°

t = ?

We know that,

The path difference of light wave reflected from thin glass plate which will appear dark is

$$2\mu t\ cosr = n\lambda$$

$$2 \times 1.5 \times t \times cos60 = 1 \times 5890 \times 10^{-8}$$

$$3t \times 0.5 = 5890 \times 10^{-8}$$

$$t = \frac{5890 \times 10^{-8}}{1.5} = 3926 \times 10^{-8} = 3.926 \times 10^{-5} cm$$

2. A glass wedge of angle 0.01 radian is illuminated by monochromatic light of 6000Å falling normally on it. At what distance from the edge of wedge, will 10^{th} fringe be observed by reflected light.

Solution: Given

$\lambda = 6000$ Å $= 6000 \times 10^{-8}$ cm $= 6 \times 10^{-5}$ cm

$\theta = 0.01$ radian

n = 10

x = ?

The distance of wedge from edge is,

$$x = \frac{n\lambda}{2\theta}$$

$$x = \frac{10 \times 6 \times 10^{-5}}{2 \times 0.01} = 3 \times 10^{-4} \times 10^{3}$$

$$x = 3 \times 10^{-1} cm = 0.3\ cm$$

3. A plano-convex lens of radius 300cm is placed on an optically flat glass plate and is illuminated by monochromatic light. The diameter of the 8^{th} bright ring in the reflected system is 0.72cm. calculate the wavelength of light used.

Solution: Given

R= 300 cm

D=2r= 0.72 cm, r = 0.36 cm

n = 8

λ = ?

The radius of n^{th} bright ring of reflected light is,

$$r = \sqrt{(2n-1)\frac{\lambda R}{2}}$$

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

$$\therefore \lambda = \frac{2r^2}{(2n-1)R} = \frac{2 \times (0.36)^2}{(2 \times 8 - 1) \times 300}$$

$$\therefore \lambda = \frac{2 \times 0.1296}{4500} = \frac{0.2592}{4500}$$

$$\lambda = 0.0000576 = 5.76 \times 10^{-5} cm = 5760 Å$$

4. In a Newton's rings experiment the diameter of 15^{th} ring was found to be 0.590 cm and that of the 5^{th} ring was 0.336 cm. If the radius of the plano-convex lens is 100 cm., calculate the wavelength of light used.
   Solution: Given

   D_{15} = 0.590 cm

   D_5 = 0.336 cm

   R = 100 cm

   λ = ?

The wavelength of Newton's ring is

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

Where m =15-5 = 10

$$\lambda = \frac{{D_{15}}^2 - {D_5}^2}{4mR} = \frac{(0.590)^2 - (0.336)^2}{4 \times 10 \times 100}$$

$$\lambda = \frac{0.3481 - 0.1109}{4 \times 10^3} = \frac{0.2372}{4 \times 10^3}$$

$$\lambda = 0.0593 \times 10^{-3} = 5.93 \times 10^{-5} cm = 5930 Å$$

5. In moving one mirror in a Michelson interferometer through a distance of 0.1474 mm, 500 fringes cross the centre of field of view. What is the wavelength of light?
   Solution: Given

$d = 0.1474$ mm $= 0.1474 \times 10^{-1}$cm

$n = 500$

By Michelson interferometer, distance of fringes

$2d = n\lambda$

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

$$\lambda = \frac{2 \times 0.1474 \times 10^{-1}}{500} = \frac{0.2948 \times 10^{-3}}{5}$$

$$\lambda = 0.05896 \times 10^{-3} = 5896 \times 10^{-8} cm$$

$$\lambda = 5896 Å$$

6. Calculate the distance through the mirror of the Michelson interferometer has to be displaced between two consecutive positions of maximum distinctness of D_1 and D_2 lines of sodium. Wavelength of D2 line = 5890 Å and of D_1 lines = 5896 Å.

Solution: Given

$\lambda_1 = 5896$ Å $= 5896 \times 10^{-8}$ cm

$\lambda_2 = 5890$ Å $= 5890 \times 10^{-8}$ cm

The difference in wavelength of two spectral lines,

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

$$\therefore 2d = \frac{\lambda_1 \lambda_2}{(\lambda_1 - \lambda_2)} = \frac{5896 \times 10^{-8} \times 5890 \times 10^{-8}}{(5896 \times 10^{-8} - 5890 \times 10^{-8})}$$

$$\therefore 2d = \frac{5896 \times 5890 \times 10^{-16}}{(6 \times 10^{-8})}$$

$$\therefore d = \frac{5896 \times 5890 \times 10^{-8}}{12} = 491.33 \times 5890 \times 10^{-8}$$

$$\therefore d = 4.913 \times 5.89 \times 10^{-3} = 28.94 \times 10^{-3}$$

$$\therefore d = 0.02894\ cm$$

Multiple Choice question:

1. When light is reflected from the surface of an optically denser medium then phase change is-

a) π b)π/2 c)2π d) 0

2. When light is reflected from the surface of an optically rarer medium then phase change is-

a) π   b)π/2   **c) 0**   d) 3π/2

3. When light is reflected from surface of thin film, then the path difference for bright film is—

a) $2\mu t cosr = n\lambda$ b) $2\mu t cosr = n\lambda/2$

c) $2\mu t cosr = (2n+1)\lambda/2$ d) $2\mu t cosr = n\lambda/4$

4. When light is transmitted through the surface of thin film, then the path difference for bright film is—

a) $2\mu t cosr = n\lambda$ b) $2\mu t cosr = n\lambda/2$

c) $2\mu t cosr = (2n+1)\lambda/2$ d) $2\mu t cosr = n\lambda/4$

5. When light is reflected from surface of thin film, then the path difference for dark film is—

a) **$2\mu t cosr = n\lambda$**   b) $2\mu t cosr = n\lambda/2$

c) $2\mu t cosr = (2n+1)\lambda/2$ d) $2\mu t cosr = n\lambda/4$

6. When light is transmitted through the surface of thin film, then the path difference for dark film is—

a) $2\mu t cosr = n\lambda$ b) $2\mu t cosr = n\lambda/2$

c) $2\mu t cosr = (2n+1)\lambda/2$ d) $2\mu t cosr = n\lambda/4$

7. In Newton's ring experiment, the fringes produced are

a) Straight line   b) wedge-shaped   **c) circular**   d) localized

8. In Newton's ring experiment, the radius of dark ring is-----------------------

a) $\boldsymbol{\sqrt{n\lambda R}}$ b) $\sqrt{2n\lambda R}$ c) $\sqrt{\frac{(2n-1)\lambda R}{2}}$ d) $\sqrt{n\lambda R/2}$

9. In Newton's ring experiment, the radius of bright ring is-----------------------

a) $\sqrt{n\lambda R}$ b) $\sqrt{2n\lambda R}$ **c)** $\boldsymbol{\sqrt{\frac{(2n-1)\lambda R}{2}}}$ d) $\sqrt{n\lambda R/2}$

10. In Newton's ring experiment the _______________ lens is used,

(a) Convex   (b) concave   **(c) plano-convex**   (d) plano-concave

11. In Newton's ring experiment, the center of circular fringes is----------------

a) dark   b) bright   c) dark as well as bright   d) more bright

12. For n=0, the radius of dark ring is -----

a) One   b) $\sqrt{\lambda R/2}$ **c) zero**   d) $\sqrt{3\lambda R/2}$

13. For n=0, the radius of bright ring is -----

a) One **b) $\sqrt{\boldsymbol{\lambda R/2}}$** c) zero d) $\sqrt{3\lambda R/2}$

14. In Newton's rings experiment the diameter of the 15th ring was found to be 0.4 cm and that of 5th ring was 0.1cm. If the radius of plano-convex lens is 100cm, then the wavelength of light used is ----

a) 3750A° b) 4000 A° c) 4500A° d)5890A°

15. Michelson designed an interferometer to determine-----------------

a) the wavelength of light b) thickness of thin strip

c) standardization of meter **d) All of these**

16. In Michelson interferometer experiment, if the mirrors M_1 and M_2 are perfectly perpendicular, then the fringes will be,

a) perfectly circular b) Wedge shaped c) Straight line d) inclined

17. In Michelson interferometer experiment, white light fringes are used for-------------

a) Determination of zero path difference b) Standardisation of meter

c) **both a and b** d) wavelength of light

18. In moving one mirror in a Michelson interferometer through a distance of 0.15mm, 500 fringes cross the centre of the field of view, then the wavelength of light used is,

a) 4000 A° **b) 6000A°** c) 4500A° d) 3500A°

19. A phase difference π between two interfering beams is equivalent to the path difference

a) λ **b) λ/2** c)2 λ d) 3λ/2

20. Two plane surfaces inclined at an angle then ------ type of fringes are observed.

a) circular b) **Wedge shaped** c) white light d) none of the above