1. Introduction

In the 17th century, the properties of light were explained by Sir Isaac Newton and Christian Huygens. Sir Isaac Newton was explained the properties of light by introducing Corpuscular theory in 1675. It explains reflection, refraction, and dispersion properties of light. It fails to explain interference, diffraction, polarization, photo electric effect, and double refraction.

In 1679, Christian Huygens proposed the wave theory of light. According to Huygens wave theory, each point on the wave front is to be considered as a source of secondary wavelets. It explains reflection, refraction, dispersion, double refraction, diffraction, interference, and polarization properties of light. It fails to explain, photo electric effect, black body radiation etc,

2. Interference of light

The best evidence for the wave nature of light is interference phenomenon. This was experimentally demonstrated by Thomas Young in 180, through double slit experiment. Due to interference, we will observe many observations in our day today life, such as multiple colours on soap bubbles as well as on oil film when viewed under sun light. Interference concept is explained on the basis of superposition of wave's concept.

When two light waves superimpose, then the resultant amplitude or intensity in the region of superposition is different than the amplitude of individual waves.

Definition:-

The modification in the distribution of intensity in the region of superposition is known as interference.

In case of interference pattern we observe two cases

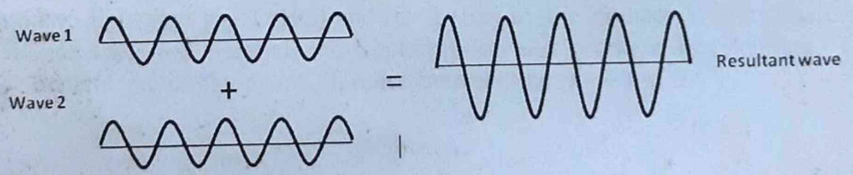
- Constructive interference
- Destructive interference

Constructive interference

- The waves are reaching at a point are in phase constructive interference occurs
- In constructive interference, the resultant amplitude is always equal to the sum of the amplitudes of two individual waves.
- *Condition*

The path difference between the two waves is equal to the integral multiple of wave length (λ) the constructive interference occurs.

$path\ diference = n\lambda$ Where n = 0, 1, 2, 3, 4 …



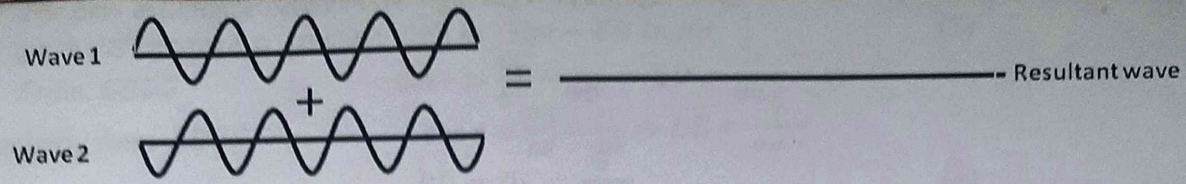
Destructive interference

- The waves are reaching at a point are in out of phase destructive interference occurs
- In Destructive interference, the resultant amplitude is always equal to the difference of the amplitudes of two individual waves.
- Condition

The path difference between the two waves is equal to the odd integral multiple of $\lambda/2$ destructive interference occurs

$$path\ diference = \frac{(2n-1)\lambda}{2} \quad \text{Where } n = 1, 2, 3, 4 \ldots \ or$$

$$path\ diference = \frac{(2n+1)\lambda}{2} \quad \text{Where } n = 0, 1, 2, 3, 4 \ldots$$



3. Types of interference:-

For the formation of interference pattern, two coherent light sources are required. To get two coherent sources form a single light source, two techniques are used. They are

1. Division of wave front
2. Division of amplitude

Division of wave front

The wave front from a single light source is divided into two parts using the phenomenon of reflection, refraction, or diffraction. Young's double slit experiment is belongs to this class of interference.

Division of amplitude

The amplitude of a single light beam is divided into two parts by parallel reflection or refraction. Newton's ring experiment, Michelson's interferometer is belongs to this class of interference.

4. Conditions for interference

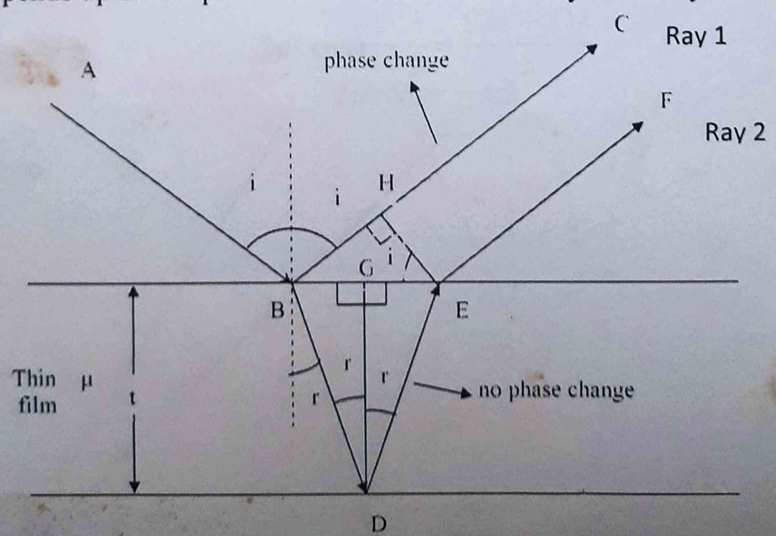
1) Two light sources of emitting light waves should be coherent.
2) Two sources must emit continuous light waves of same wavelengths or frequency.
3) The separation between the two sources should be small.
4) The distance between the two sources and the screen should be large.
5) To view interference fringes, the background should be dark.
6) The amplitude of light waves should be equal or nearly equal.
7) The sources should be narrow.
8) The sources should be monochromatic.

5. Interference in thin films by reflection

Principle:-

The formation of colours in thin films can explained as due to the phenomenon of interference. In this example, the formation of interference pattern is by the division of amplitude.

Consider a thin film of uniform thickness 't' and refractive index 'μ'. Let a monochromatic light ray AB is incident is on the upper surface of the film at point 'A' with an angle 'i'. The incidence light ray AB is divided into two light rays ray 1 (BC) and ray 2 (EF) by the division of amplitude principle. These two light rays BC and EF are parallel and superimpose and produce interference. The intensity of interference fringe depends up on the path difference between the ray 1 and ray 2.



The path difference between the light rays (1) and (2) is

$$path\ difference = \mu(BD + DE)\ in\ film - BH\ in\ air \qquad (1)$$

From ΔBDG $\qquad \cos r = \frac{DG}{BD} = \frac{t}{BD} \Rightarrow BD = \frac{t}{\cos r}$

Similarly from ΔDEG $\qquad \cos r = \frac{DG}{DE} = \frac{t}{DE} \Rightarrow DE = \frac{t}{\cos r}$

$$\therefore BD = DE = \frac{t}{\cos r} \qquad (2)$$

From $\qquad \Delta BEH \qquad \sin i = \frac{BH}{BE} = \frac{BH}{BG+GE}$

$\therefore BH = (BG + GE).\sin i$

From ΔBDG and ΔDEG $\qquad BG = GE = t\tan r$

$BH = (2t\tan r).\sin i$

From Snell's law at point B

$$\sin i = \mu \sin r$$

$$\therefore BH = 2\mu t \tan r . \sin r \qquad (3)$$

Substituting the equations (2) and (3) in equation (1), we get

$$Path\ difference = \frac{2\mu t}{\cos r} - 2\mu t \tan r . \sin r$$

$$= \frac{2\mu t}{\cos r} - 2\mu t.\frac{\sin^2 r}{\cos r}$$

$$= \frac{2\mu t}{\cos r}(1 - \sin^2 r)$$

$$= \frac{2\mu t}{\cos r}\cos^2 r$$

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

At point B the light ray (1) is reflected at the surface of thin film (denser medium). So the light ray (1) undergoes a phase change π or an additional path difference λ/2.

Total path difference $= 2\mu t \cos r - \frac{\lambda}{2}$

Constructive interference (or Bright fridge)

General condition; $pathdifference = n\lambda$

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

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

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

Destructive interference (or Dark fridge)

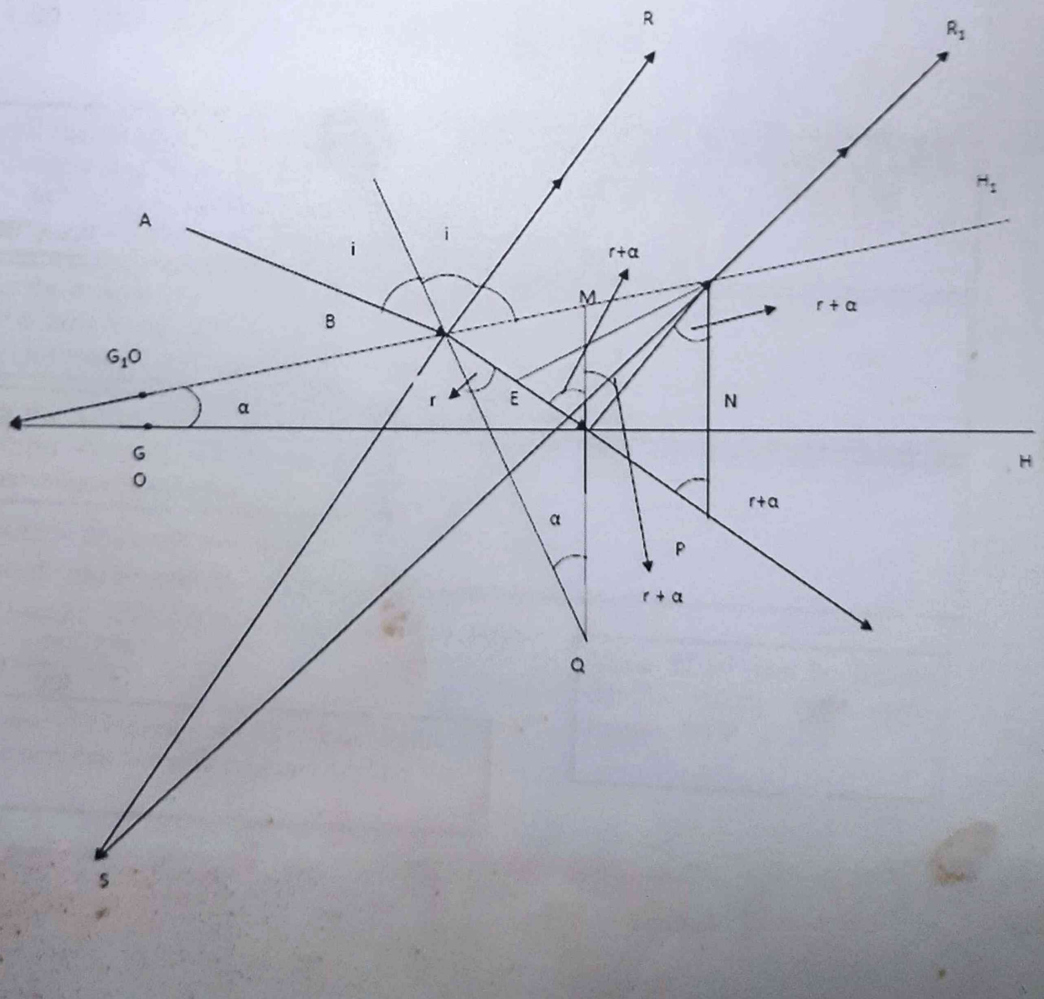
General condition: $pathdifference = (2n+1)\frac{\lambda}{2}$

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

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

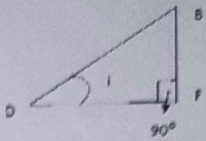
Wedge-shaped film (Thin film of Non-Uniform thickness):

Consider two plane glass surfaces **GH** and **G_1H_1**. both are inclined at angle at an angle **(α)**, so that air film of increasing thickness is formed between both of two surfaces. Let **(μ)** be the refractive index of the material film. Interference in wedge shape film can be studied only when this film is illuminated by source of monochromatic light. Suppose a beam of monochromatic light AB incident at an angle **(i)** at a point (B) on the upper surface **G_1H_1** .Then a part of this light will be reflected in the direction **BR** and a part of this light be refracted in a direction **BC**, this refracted ray will be incident at an angle **(r+ α)** at a point **(C)**. Then a part of this refracted will be reflected at the denser surface in the direction **CD** and comes out in the form of ray **DR_1**. Our aim is to be study interference between two reflected ray **BR** and **DR_1**. From the fig. it is observed that ray **BR** and **DR_1** are not parallel so that they appear to diverge from a point **(S)** means interference take place at **S** which is virtual. So that intensity at a point **S** is maximum or minimum depend upon the path difference between the two reflected ray **BR** and **DR_1** that is



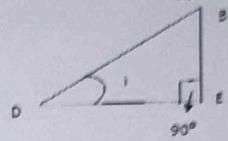
$(BC + CD)\mu - BF(\mu = 1)$ - - - - - - - - - - - - (1) First of all find out value of **BF**.

We know $\mu = \dfrac{\sin i}{\sin r}$, calculate value of $\sin i$ and $\sin r$



Take right angle triangle DFB $\quad \sin i = \dfrac{BF}{BD}$

Similarly find out value of $\sin r$ taking Right angle triangle **DEB** (by draw perpendicular from the point from the point **D** on the ray **BC**) $\quad \sin r = \dfrac{BE}{BD}$



Putting value of we get value of μ

$$\mu = \frac{\sin i}{\sin r} = \frac{\frac{BF}{BD}}{\frac{BE}{BD}} = \frac{BF}{BD} x \frac{BD}{BE} = \frac{BF}{BE} \quad or\ BF = \mu BE$$

Putting value of **BF** in equation (1) we get

$(BC + CD)\mu - \mu BE = \mu(BC + CD - BE)$ - - - - - - - - - - - (2)

From the fig (1.2) value of **BC** can be written as $BC = BE + EC$ putting value BC in equation (2) we get

$\mu(BC + CD - BE) = \mu(BE + EC + CD - BE) = \mu(EC + CD)$ - - - -(3)

First of all find out angle of incidence of refracted ray at a point **C** on the surface **GH** by taking the right angle triangle **OMC** In fig (1.2.) that $\quad \angle MCD = 90^0 \quad \angle MOC = \alpha$
$\angle OMC = 90^0 - C$ .consider the triangle **BQM** in that
$\angle B = 90^0 \ \& \angle M = 90^0 - \alpha \ then\ \angle Q = 180^0 - (90^0 + 90^0 - \alpha) = \alpha$

Consider the triangle BQC in that
$\angle B = 90^0 \ \& \ \angle Q = \alpha \ then\ \angle C = r + \alpha$
Consider the triangle **DNC** in that

Consider the triangle **DNC** in that
$\angle N = 90^0 \ \& \ \angle C = 90^0 - r + \alpha \ then\ \angle D = r + \alpha$
Consider the triangle **DPC** in that
$\angle C = 180^0 - 2(r + \alpha) \& \ \angle D = r + \alpha \ then\ \angle P = r + \alpha$

Consider the triangle **DNC** and **PNC** in both of them $\angle D = \angle P, \quad \angle N = \angle N$and
$NC = common\ base\ in\ both\ them$

When two angle and one side is common then such type of triangle (AAS) is congruent triangle thus in these triangle

$DN = NP \ \& \ CD = CP \ and\ NC = common$

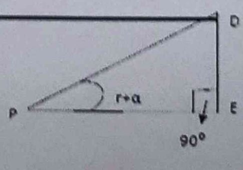
Thus value of can be written in equation (3) we get

$\mu(EC + CD) = \mu(EC + CP) = \mu(EP)$ - - - - - - - - - - - (4)

$\cos(r + \alpha) = \dfrac{PE}{PD} = \dfrac{PE}{2t}$

Value of EP can be finding out by taking right angle triangle **DEP**

Putting value of EP in equation (4) we get Path-difference between two reflected rays will be



$2\mu t \cos(r + \alpha)$ - - - - - - - - - - - - - - - (5)

But according to principle of reversibility when wave reflected from the surface of optically denser medium then it suffer a phase change of π if phase change π occurs then path-difference $\frac{\lambda}{2}$ introduce in it. Thus total path-difference between two reflected rays will be: $2\mu t\cos(r+\alpha)+\frac{\lambda}{2}$ -------------------- (6)

So intensity ay a point S will be maxinium only when path difference between the two reflected rays will be equal to nλ. Thus

$$2\mu t\cos(r+\alpha)+\frac{\lambda}{2}=n\lambda \quad where\ n=1,2,3,4,5 --------$$

So intensity ay a point S will be mini-mum only when path difference between the two reflected rays will be equal to $(2n+1)\frac{\lambda}{2}$ Thus

$$2\mu t\cos(r+\alpha)+\frac{\lambda}{2}=(2n+1)\frac{\lambda}{2} \quad where\ n=1,2,3,4,5 -----$$

6. **Newton's rings**

Principle:-

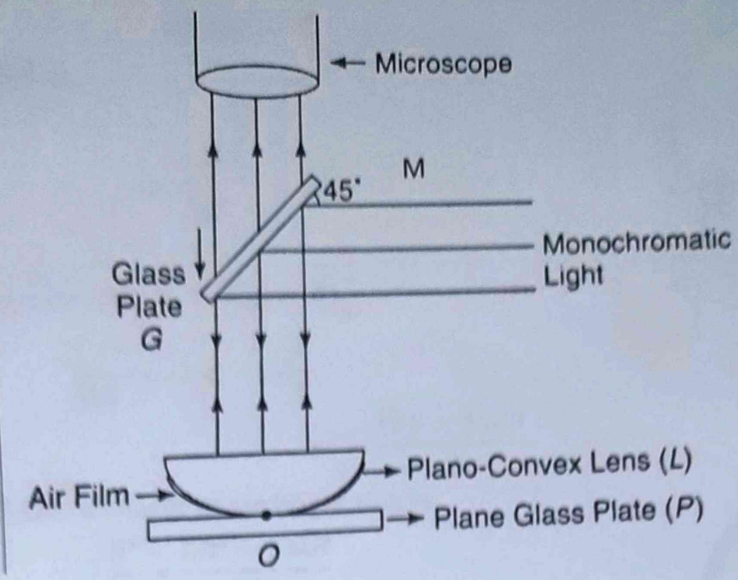
The formation of Newton's rings can explained as due to the phenomenon of interference. In this example. the formation of interference pattern is obtained by the division of amplitude.

Experimental arrangement

Experimental arrangement

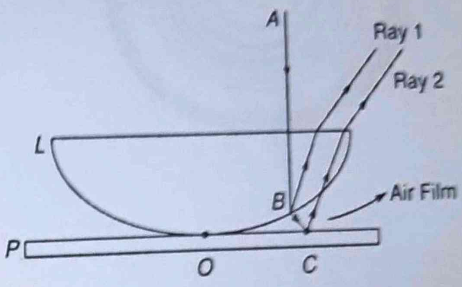
- ✓ The experimental arrangement of Newton's rings is shown in figure.
- ✓ The Plano -convex lens (L) of large radius of curvature is placed with its convex surface on the glass plate (P). The Plano convex lens touches the glass plate at O.
- ✓ A monochromatic light is allowed to fall normally on the lens with the help of glass plate M kept at 45^0 to the incident monochromatic light.
- ✓ A part of light is reflected by the curved surface of the lens 'L' and a part of light is transmitted is partly reflected back by the upper surface of the plane glass plate P.

These rings are seen through microscope.



O

Explanation of Newton's rings



Newton's rings are formed due to the interference between the light rays reflected from the lower surface of the lens and the upper surface of the glass plate (or top and bottom surfaces of the air film).

Let a vertical light ray AB be partially reflected from the curved surface of Plano convex lens with out phase change and partially transmitted light ray BC is again reflected at C on the glass plate with additional phase change of π or path difference $\lambda/2$.

The path difference between the two rays is

$$2\mu t\cos r+\frac{\lambda}{2}$$

For air film $\mu=1$ and for normal incidence $r=0$, so

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

At the point of contact $t=0$, path difference is $\frac{\lambda}{2}$ i.e., the reflected and incidence light are out of phase and destructive interference occur. So the center fringe is always dark.

<u>Constructive interference (or Bright fridge)</u>

General condition: $pathdifference = n\lambda$

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

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

Where $n=0,1,2,\dots\dots\dots$

<u>Destructive interference (or Dark fridge)</u>

General condition: $pathdifference = (2n+1)\frac{\lambda}{2}$

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

$$2t=n\,\lambda$$

Where $n=0,1,2,\dots\dots\dots$

<u>**Theory of Newton's rings**</u>

To find the diameters of a dark and bright fringes construct a circle with the radius of curvature R of a lens L. Let us choose a point P at a distance 'r' from the center of lens and t be the thickness of air film at point p.