Interference

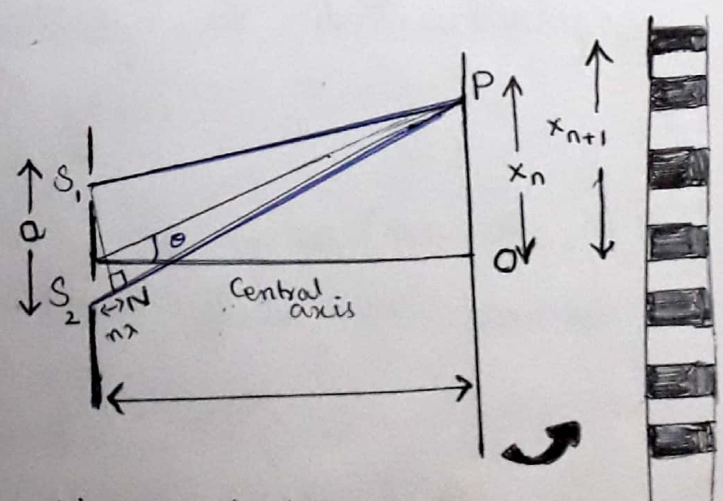
The superposition of two waves of same wavelength or frequency (monochromatic) with a const. phase difference (coherence) combine so that they energies are not uniformly distributed in space but give maxima and minima or an interferene pattern is called Interference.

Using monochromatic source of light INTERFERENCE can be acheived in two ways.

1. Division of wavefront.
   i.e Youngs double slit Expt.
2. Division of Amplitude
   i.e Newtons Rings, Thin flims.

✓ **Youngs Double slit Expt.**

Consider a monochromatic source of light which passes through two slits S_1 and S_2 at a distance d from each other.



Youngs double slit Exp.

The optical path difference (OPD) betⁿ S_2P and S_1P provi[des] the necessary Condition.

$$OPD = S_2P - S_1P$$
$$= S_2N$$

$$\sin\theta = \frac{S_2N}{d},$$

$$S_2N = d\sin\theta.$$

The Condition for ~~Cond~~ Constructive interference [in phase] is

$$d\sin\theta = n\lambda$$

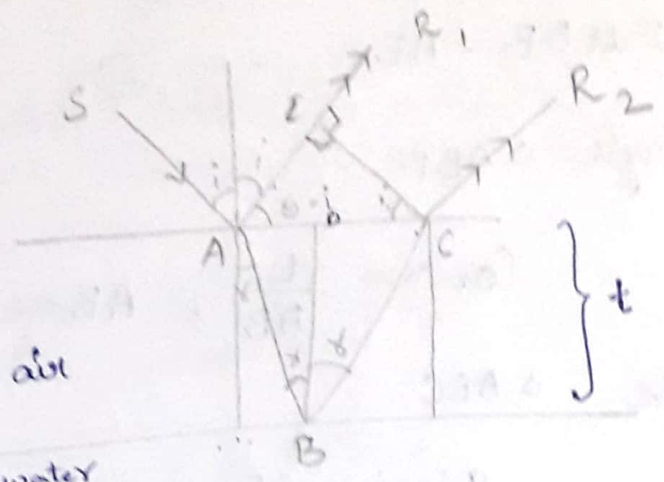
and the Condition for interference (out of phase) is

$$d\sin\theta = (n + 1/2)\lambda$$

where $n = 0, 1, 2, 3 \ldots$

An interference pattern is observed on the screen which is made of evenly distributed bright and white patched Called as interference.

DIVISION OF AMPLITUDE INTERFERENCE FROM THIN FLIMS.



Consider a thin film of thickness t and refractive index μ. The monochromatic source S is incident at an angle i. and gets parity refracted at an angle r and get reflected at the point B and Emerged from the point C as R_2

The two rays AR_1 and $ABCR_2$ interfere to give a steady interference pattern as they satisfy both Conditions ie monochromatic and Coherence.

The optical path length (OPL) is defined as $\mu \times$ Geometrical path length. OPL = $\mu \times$ GPL.

The OPD between the two waves defines where they interfere Constructively or destructively.

In Case of thin films.

$$OPD = \mu(AB + BC) - AE \quad \text{—} \; ①$$

We drop a normal from CE on AR.

where

$$CE \perp AR.$$

$AB = BC$

$$OPD = 2\mu AB - AE. \quad \text{— (2)}$$

In a traingle ΔABD

$$\cos r = \frac{t}{AB} \; ; \quad AB = \frac{t}{\cos r} \quad \text{— (3)}$$

In a traingle . ΔAEC.

$$\sin i = \frac{AE}{AC} , \quad AE = AC \sin i \quad \text{— (4)}$$

$AD = DC$

$AC = 2AD$.

$$\tan r = \frac{AD}{DB}.$$

In a traingle ΔADB.

$$\tan r = \frac{AD}{t} \quad \text{— (5)}$$

from Eq 4

$$AE = AC . \sin i$$

$(AC = 2AD)$

$$AE = \sin i \,(2AD)$$

from Eq 5 $\quad AD = (t \cdot \tan r)$.

$$AE = \sin i \,(2t \cdot \tan r)$$

$$OPD = 2\mu AB - AE$$

$$= 2\mu \left[\frac{t}{\cos r} \right] - \sin i \,(2t \cdot \tan r)$$

$\tan\theta = \frac{\sin\theta}{\cos\theta}$

$$AE = \frac{2\mu t}{\cos r} - \sin i \cdot 2t \cdot \frac{\sin r}{\cos r}.$$

$$OPD_{AE} = \frac{2\mu t}{\cos\gamma} - \frac{\sin\gamma \cdot (2t)\sin\gamma}{\cos\gamma}$$

$$OPD_{A \cdot E} = \frac{2\mu t}{\cos\gamma}\left[1 - \sin^2\gamma\right]$$

$$OPD_{AE} = \frac{2\mu t}{\cancel{\cos\gamma}}\left[\cos^{\cancel{2}}\gamma\right]$$

$$OPD_{AE} = 2\mu t \cos\gamma$$

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

where

$n = 0, 1, 2, 3 \ldots\ldots$

(1) $t < \lambda$ $\quad$ 1st term $2\mu t/\cos\gamma$ is neglegible

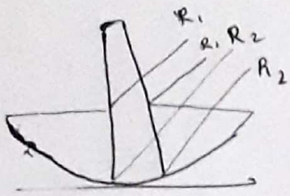
OPD is always $\lambda/2$

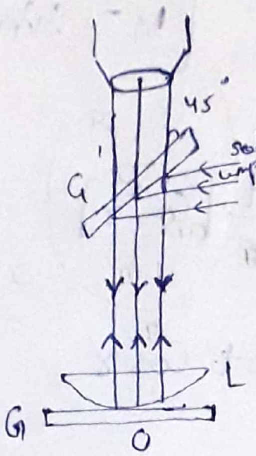
and all points will be dark.

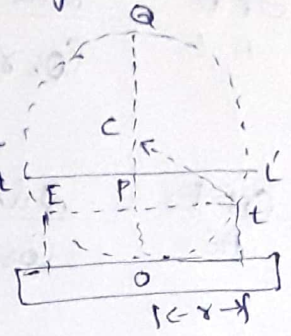
NEWTONS RINGS.

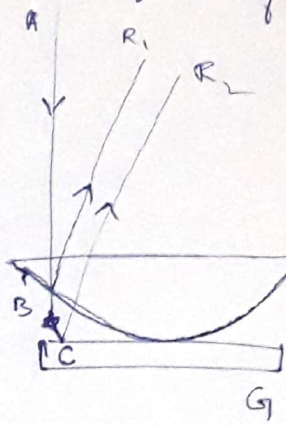
When a plano convex lens is placed on a plane glass plate with its convex surface downwards and air flims of increasing thickness is formed. If the monochromatic light around the point is allowed to fall normally and the lens is viewed in reflecting light. alternate dark and bright concentric rings around the point of contact are seen.

Newtons rings are formed due to interference between wave reflected from the top and bottom surface of the air flims between the plates.









$$Am \times MB = CM \times MD$$

$$CM = MD = r_n$$

$$2\mu t/\cos r = (n + 1/2)\lambda$$

(Bright)

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

(dark)

for normal incidence $r = 0$

$\cos r = 1$

$\mu = 1$ (air)

Bright $\rightarrow$ $2t = (n + 1/2)\lambda$ — ①

dark $\rightarrow$ $2t = n\lambda$ — ②

The central spot is dark for reflected light (for transmitted light, it is bright).

~~and~~ ~~at~~ the rings are perfectly circular and with equal thickness.

$$AO \times OB = OC \times OD$$

AO = OB = radius of ring (r_n)

$$r_n^2 = OC \times OD.$$

$$= (2R - t) \times t.$$

$$r_n^2 = 2Rt - t^2$$

$$r_n^2 = 2Rt.$$

(t^2 much less $2Rt$)

$$r_n = \sqrt{2Rt}, \quad D_n = 2\sqrt{2Rt}$$

we know that, $2t = n\lambda$

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

$$D_n^2 = 4Rn\lambda$$

Similarly $D_m^2 = 4Rm\lambda$

Subracting both Equations.

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

$$D_m^2 - D_n^2 = 4Rm\lambda - 4Rn\lambda$$

$$D_m^2 - D_n^2 = 4R\lambda(m-n)$$

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

This is the method used to find the wavelength of a monochromatic light source in lab.