INTERFERENCE

When light waves coming from two sources are mixed up while crossing each other's path, then there is a modification in the intensity of light in the region of crossing. This modification in intensity is called interference.

The maximum intensity is called constructive interference and minimum intensity is called destructive interference.

Interference of light is a wave phenomenon, which can be explained on the basis of superposition principle.

According to the superposition principle, the resultant amplitude of two waves arriving at a point simultaneously is given by the vector sum of individual amplitudes.

Conditions of steady interference

(1) Sources should be coherent

(2) —〃—— 〃 —— monochromatic

(3) —〃—— 〃 —— narrow

(4) Distance between two sources should be small.

(5) Distance of screen should be large

(6) state of polarisation should be same.

② Types of Interference

(1) Division of wavefront: ex: Young's exp. Biprism, Lloyd's mirror etc.

(2) Division of amplitude: Incident beam is split into two parts by partial reflection and refraction.
ex: Thin transparent film, Newton's ring etc.

Important results:

(1) When a ray of light travels a distance x' in medium of R.I. μ then its effective path $= \mu x'$

(2) phase difference $\delta = \left(\frac{2\pi}{\lambda}\right)(\text{opd})$

(3) An additional o.p.d of $(\lambda/2)$ or phase difference of (π) takes place, due to reflection at surface of denser medium.

for air $c = \frac{x}{t}$

for medium, $v = \frac{x'}{t}$

$\therefore \mu = \frac{c}{v} = \frac{x/t}{x'/t} = \frac{x}{x'}$

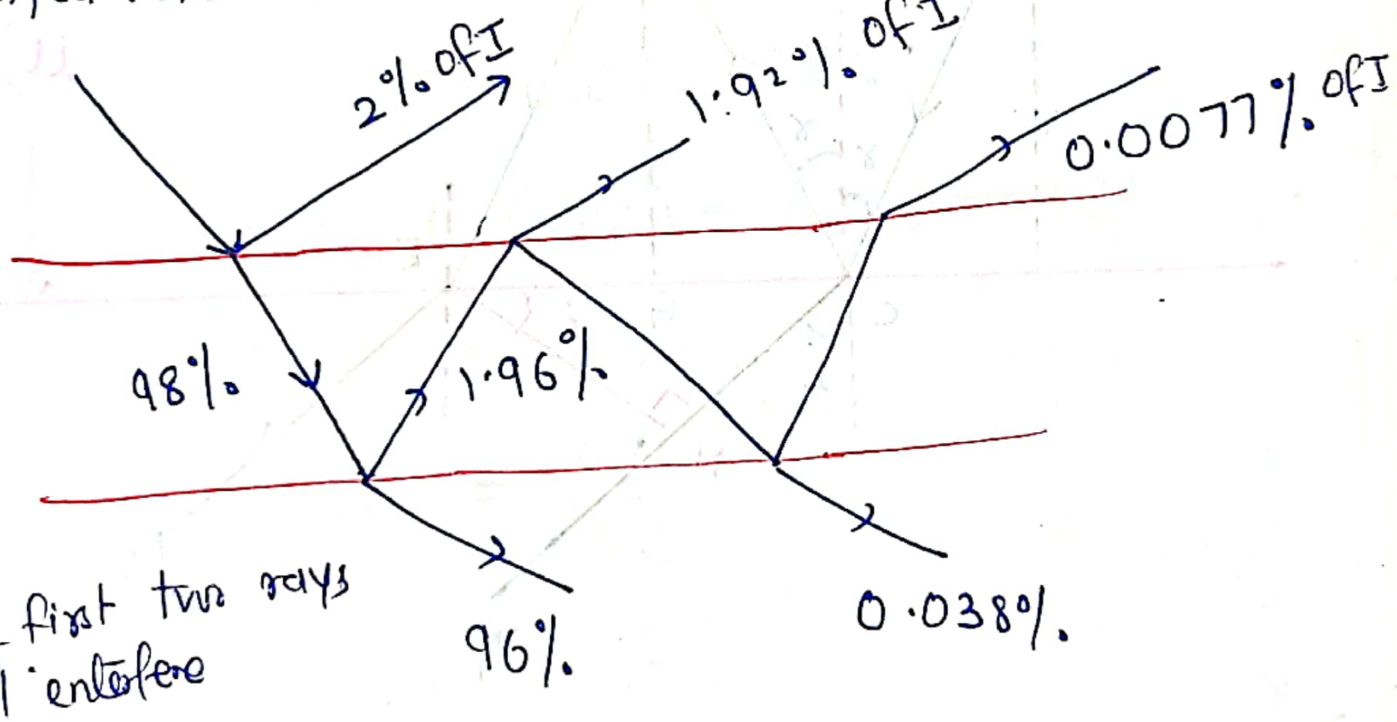
$$\boxed{x = \mu x'}$$

Thin transparent film of uniform thickness ③

(1) thin → relative term (10 μm to 50 μm)

In optics, if λ → wavelength of visible light then $\left(\frac{\lambda}{10}\right)$ to (10λ) thickness is called thin film. (1000λ is → thick film)

(2) When multiple reflections takes place, then only first two reflected rays are comparable intensities



∴ only first two rays will enterfere

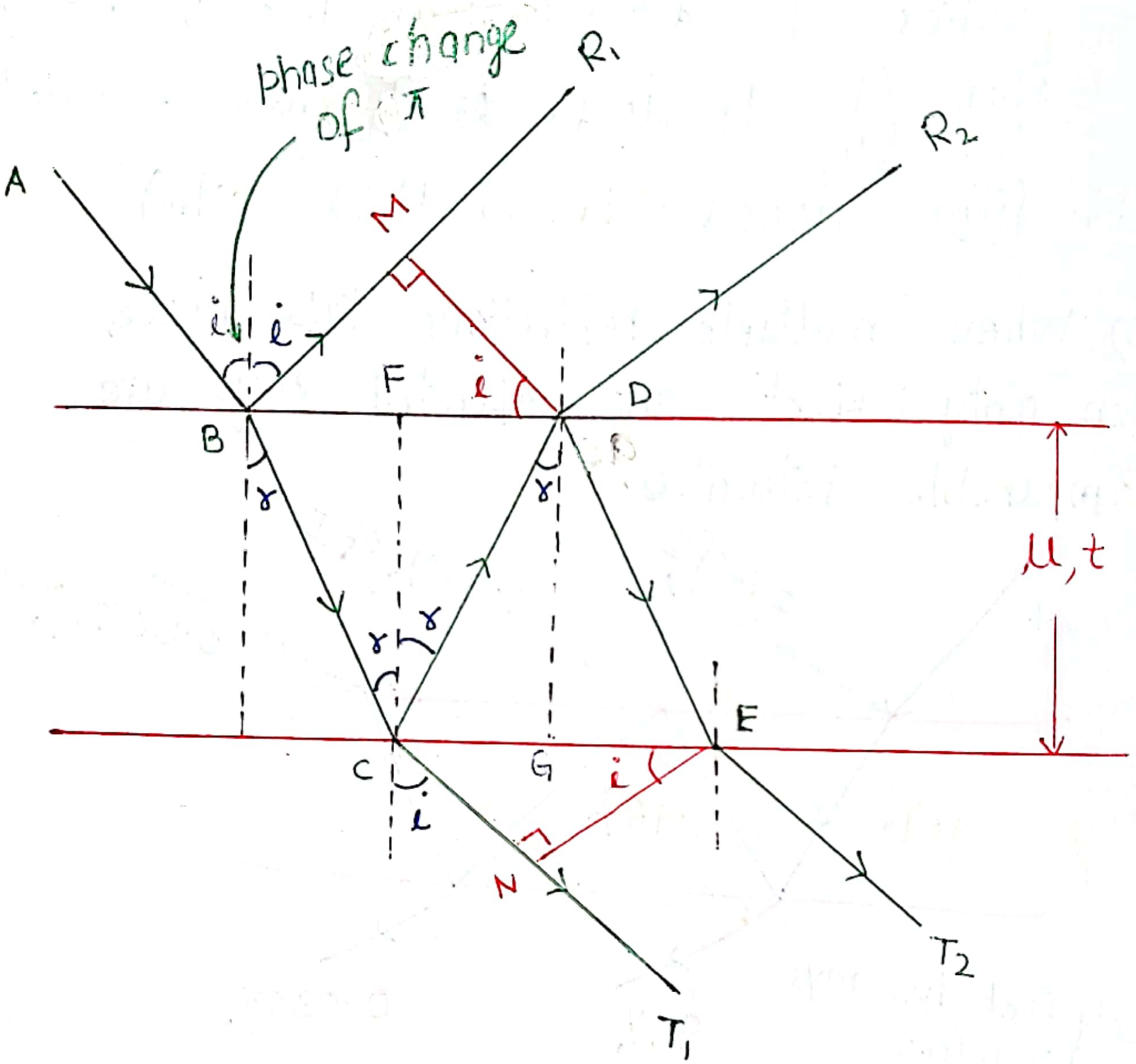
$\lambda \Rightarrow 5500\,\text{Å}$

$\frac{\lambda}{10} \Rightarrow 0.55 \times 10^{-6}$ m, $10\lambda \Rightarrow 5.5$ μm

Scanned with CamScanner

④

Interference in thin film :- (A) Reflected System



(1) Consider a ray of light AB, incident on a thin transparent medium of R.I μ and thickness t.

(2) The ray AB is reflected along BR, and refracted along BC, multiple reflections and refractions takes place.

(3) The reflected rays BR_1 and DR_2 interfere with each other.

Draw $\perp^{ar}$ from D on BR_1 at M.

After M, there is no path difference

$\therefore$ opd = path BCD in film - path BM in air

$$\text{opd} = \mu(BC+CD) - BM \longrightarrow ①$$

(4) from fig, $BC = CD$

$$\therefore BC + CD = 2BC$$

$$\therefore \text{opd} = \mu(2BC) - BM \longrightarrow ②$$

(5) Consider ΔBCF

$$\cos r = \frac{CF}{BC}$$

$$\therefore BC = \frac{CF}{\cos r}$$

$$(\because CF = t)$$

$$\therefore BC = \left(\frac{t}{\cos r}\right) \longrightarrow ③$$

(6) Consider ΔBDM

$$\sin i = \frac{BM}{BD} = \frac{BM}{BF+FD}$$

(6) but $BF = FD$

$$\therefore \sin i = \frac{BM}{2BF}$$

$$\therefore BM = 2BF \sin i \longrightarrow (4)$$

(7) Also,

$$\tan r = \frac{BF}{CF}$$

$$\tan r = \frac{BF}{t} \quad (\because CF = t)$$

$$\therefore BF = (t) \tan r \longrightarrow (5)$$

(5) → (4)

$$BM = (2)(t)(\tan r)(\sin i) \longrightarrow (6)$$

Sub. (3) & (6) in (2)

$$opd = \mu\left(\frac{2t}{\cos r}\right) - 2t(\tan r)(\sin i)$$

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

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

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

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

$$\text{opd} = \left(\frac{2\mu t}{\cancel{\cos r}}\right) \cdot \left(\cos^{\cancel{2}} r\right)$$

$$\text{opd} = 2\mu t \cos r \longrightarrow (7)$$

8) Now, due to reflection at surface of denser medium an additional phase difference of π or path difference of $(\lambda/2)$ takes place.

$$\therefore \text{ Effective opd } \delta = \text{opd} \pm \frac{\lambda}{2}$$

Taking +ve sign

$$\boxed{\delta = 2\mu t \cos r + \frac{\lambda}{2}} \longrightarrow (8)$$

⑧ Condition for Maxima and minima

(1) for constructive interference or maxima

opd $\delta = n\lambda$

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

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

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

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

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

(2) for destructive interference or minima

opd $\delta = (2n \pm 1)\frac{\lambda}{2}$

Taking +ve sign

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

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

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

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

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

(B) Transmitted System :-

(1) opd = path CDE in film − path CN in air

$$opd = \mu(CD + DE) - CN \longrightarrow (1)$$

$$\because \quad CD = DE$$

$$\therefore \quad CD + DE = 2\,CD$$

$$opd = \mu(2\,CD) - CN \longrightarrow (2)$$

(2) Consider Δ CDG,

$$\cos r = \frac{DG}{CD}$$

$$\cos r = \frac{t}{CD} \qquad (\because DG = t)$$

$$\therefore \quad CD = \frac{t}{\cos r} \longrightarrow (3)$$

$$opd = \frac{2\mu t}{\cos r} - CN \longrightarrow (4)$$

(3) Consider Δ CEN

$$\sin i = \frac{CN}{CE} = \frac{CN}{CG + GE}$$

$$\sin i = \frac{CN}{2CG}$$

$$(\because CG = GE)$$

$$CN = 2CG \sin i \longrightarrow (5)$$

⑩ using similar steps, we can show, that

$$\text{opd} = 2\mu t \cos r \longrightarrow (6)$$

④ Now, in this case no additional opd takes place.

$$\therefore \text{ effective opd } \delta = 2\mu t \cos r \longrightarrow (7)$$

Conditions for maxima and minima

(1) for maxima, $\delta = n\lambda$

$$\therefore \boxed{2\mu t \cos r = n\lambda} \longrightarrow (8)$$

(2) for minima, $\delta = (2n-1)\dfrac{\lambda}{2}$

$$\therefore \boxed{2\mu t \cos r = (2n-1)\cdot\frac{\lambda}{2}} \longrightarrow (9)$$