Interference of Light - Wave Optics

Thin Film

Thin film is a transparent film having thickness slightly above the average wavelength of light.

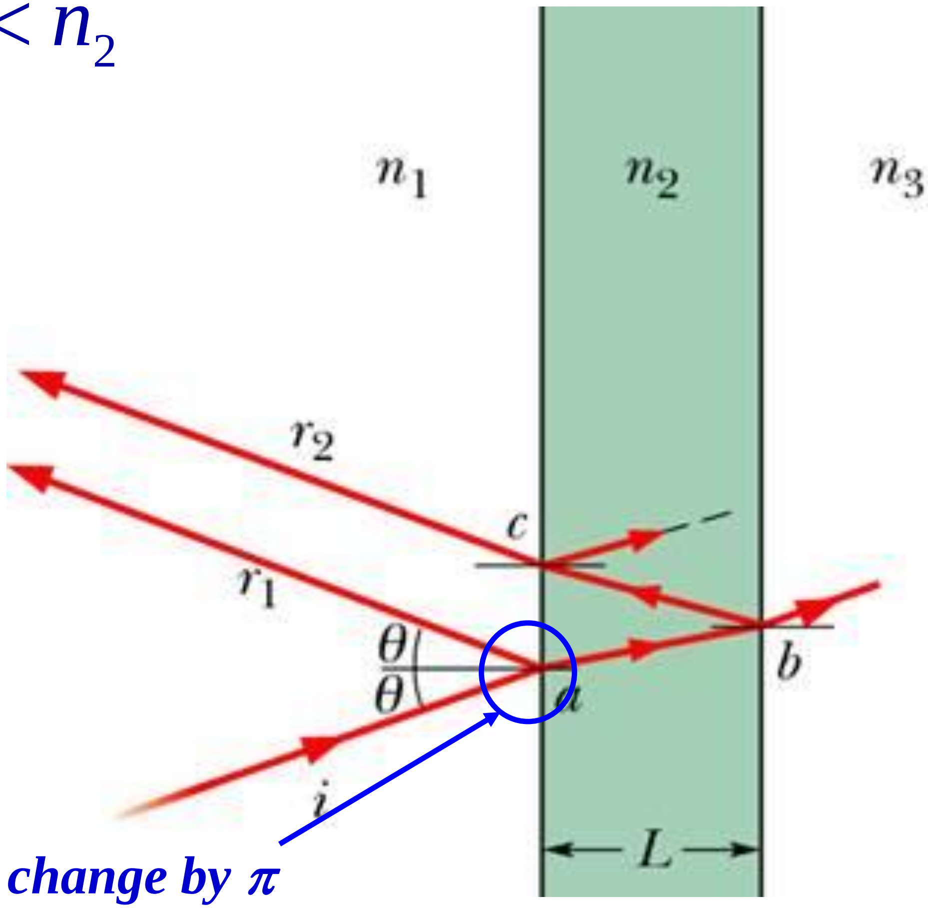
Wavelength of visible light - roughly 5500 A° (0.55 μm)

A film having a thickness in ‘mm’ is also considered as a thick film.

Examples –

- Oil films on the roads in rainy days
- Soap bubbles
- Antireflection coatings on camera lenses
- Anti-transmission coatings on invisible glasses
- Interference filters etc.

$$n_1 < n_2, n_3 < n_2$$



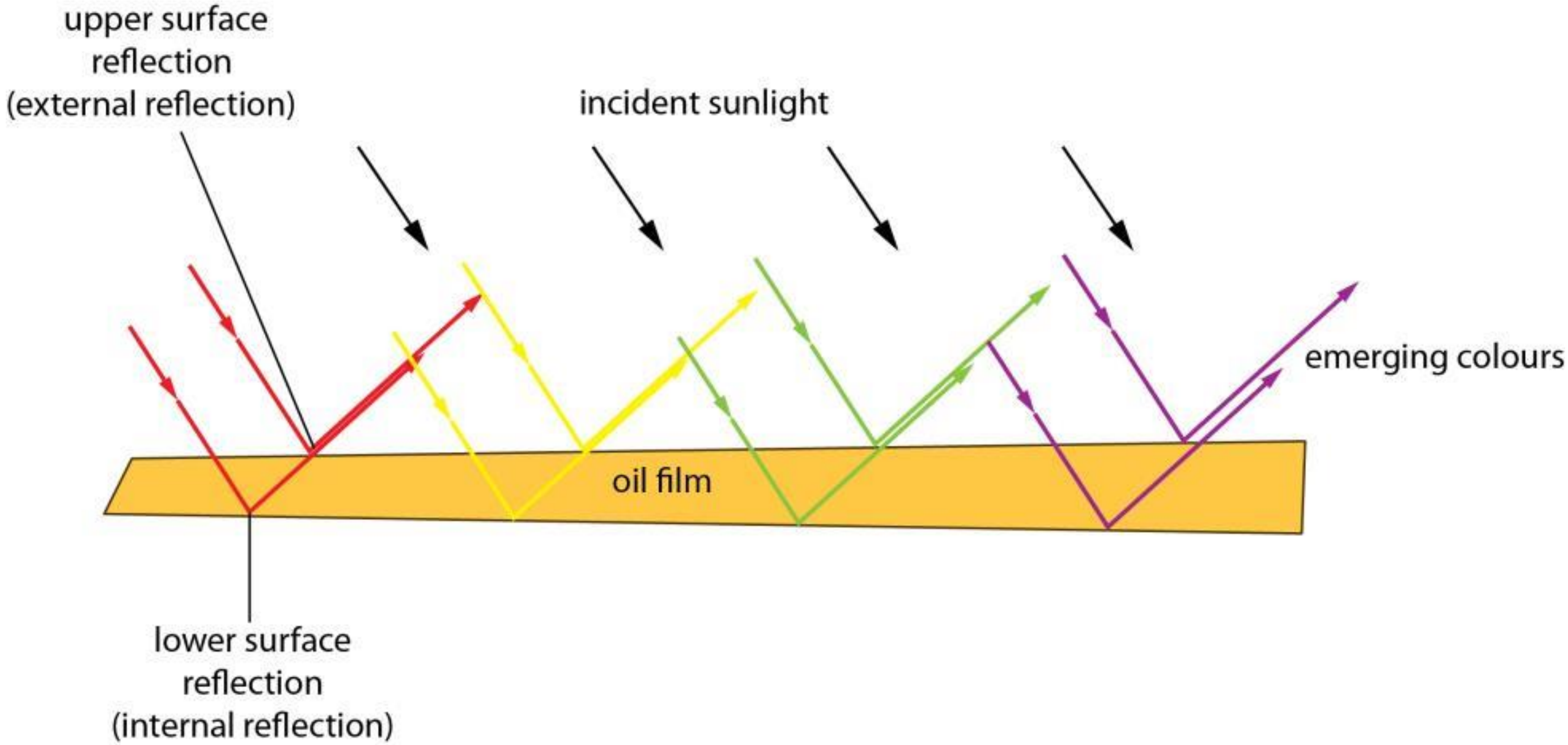
Phase change by π

Thin films

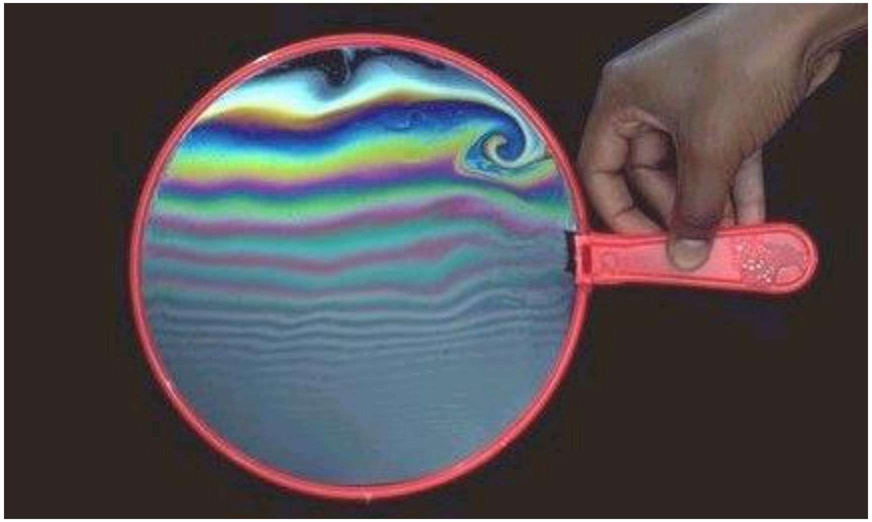
e.g. soap bubbles, oil films

Reflections from the upper and lower surfaces of a film interfere.

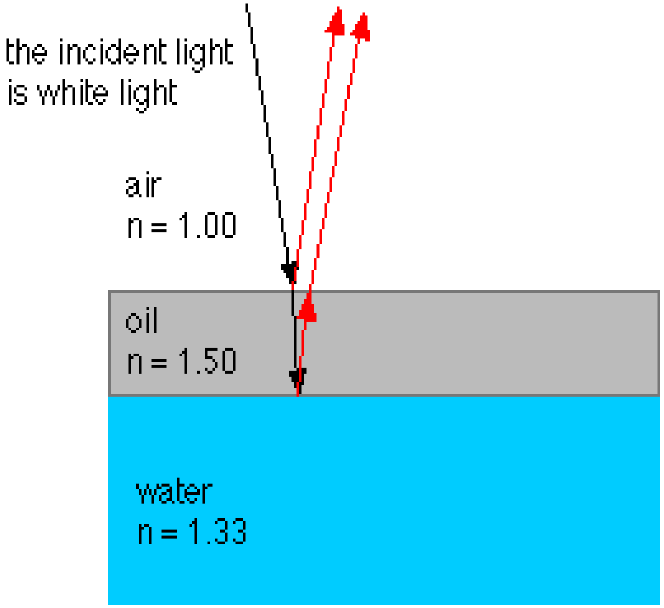
The **phase relationship** depends on both wavelength (colour) and film thickness.



Thin Film Interference:



The patterns of colors that one sees in oil slicks on water or in bubbles is produced by interference of the light bouncing off the two sides of the film.

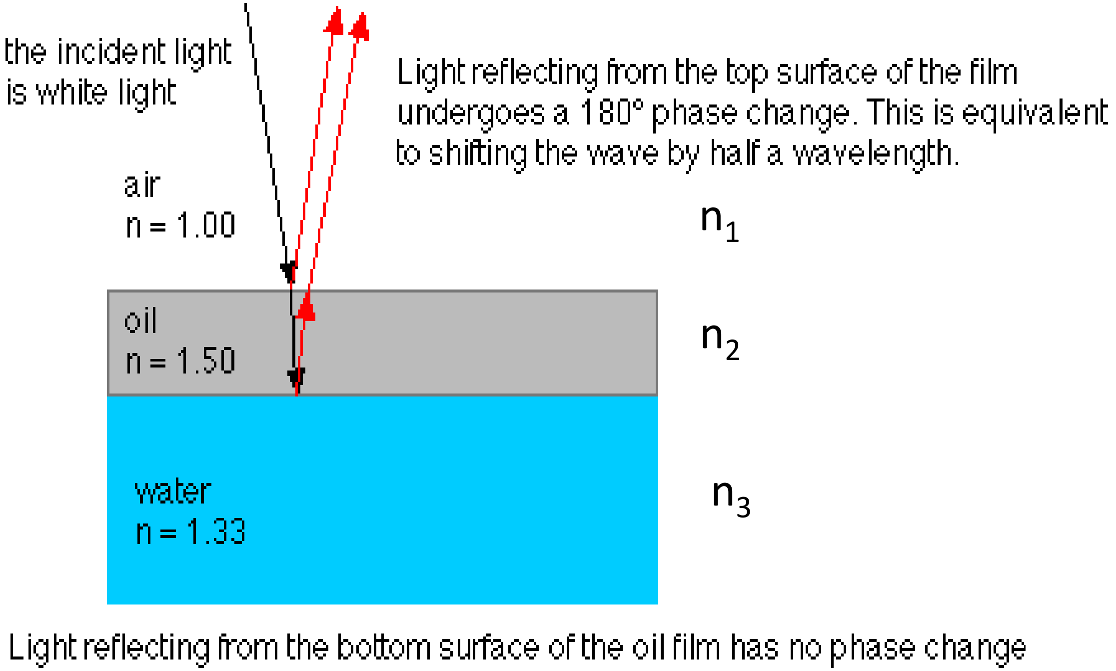


Light reflecting from the bottom surface of the oil film has no phase chang

To understand this we need to discuss the phase changes that occur when a wave moves from one médium to the another where the speed is different.

Thin Films

First reflected light ray comes from first interface, second from second. These rays interfere with each other.



How the interfere will depend on the relative indices of refraction. In the example above the first ray suffers a 180 degree phase change (1/2 a wavelength) upon reflection. The second ray does not change phase in reflection, but has to travel a longer distance to come back up. The distance is twice the thickness of the layer of oil.

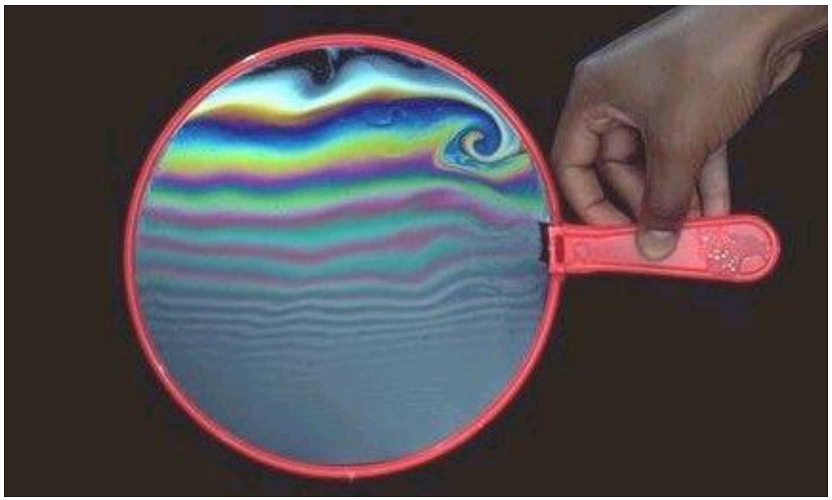
For constructive interference the distance 2L must therefore be a half-integer multiple of the wavelength, i.e. 0.5 λ, 1.5 λ,…,(0.5+2n)λ.

$$\boxed{\text{In phase: } 2L = \frac{\text{odd number}}{2} \times \frac{\lambda}{n_2}}$$

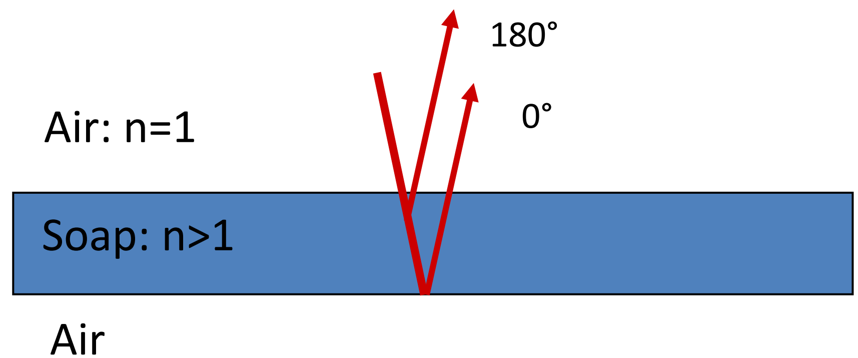
$$\boxed{\text{Anti-phase: } 2L = \text{integer} \times \frac{\lambda}{n_2}}$$

Thin Films: Soap Bubbles

If the film is very thin, then the interference is totally dominated by the 180° phase shift in the reflection.

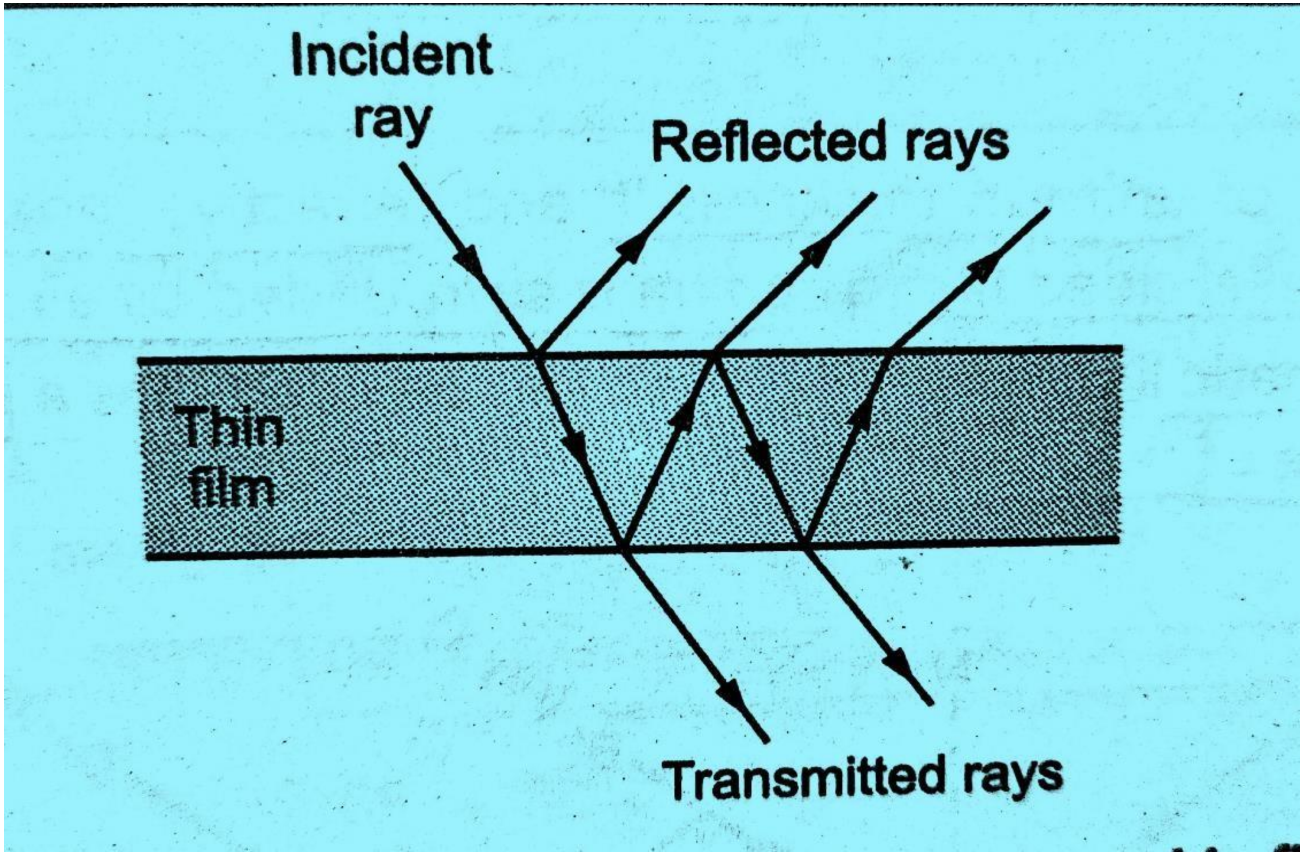


At the top the film is thinnest (due to gravity it lumps at the bottom), so one sees thefilm dark at the top.



This film is illuminated with white light, therefore we see fringes of different colors corresponding to the various constructive interferences of the individual components of the white light, which change as we go down. The thickness increases steeply as we go down, which makes the width of the fringes become narrower and narrower.

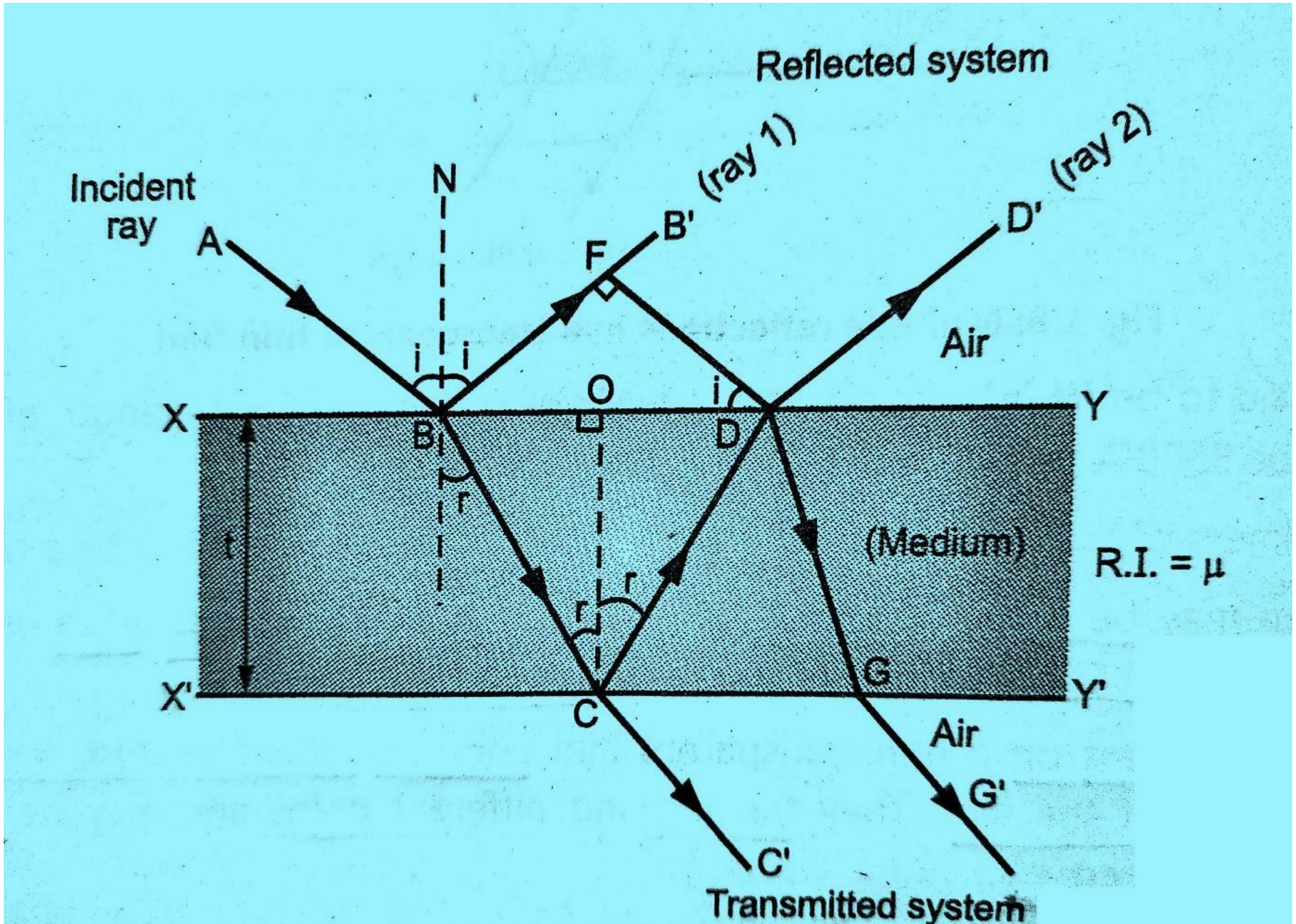
Thin Film



According to Stokes Law –

- When a ray of light gets **Reflected** from a **Denser Medium** into a **Rarer Medium** it undergoes a **Phase Change of π** or a **Path Change of λ/2**
- A **distance t** traversed by light in a medium of **Refractive Index μ** has an equivalent **Optical Path μt**.

Interference Due to Thin Film of Uniform Thickness



Reflection of Light from a Parallel Thin Film

- **The Geometric Path Difference between the ray 1 and ray 2 is**

$$(BC + CD) - BF$$

- **The Optical Path Difference between the ray 1 and ray 2 is**

$$PD = \Delta = \mu(BC + CD) - BF$$

- **The Optical Path Difference express in terms of t, μ and i (or r)**

$$PD = \Delta = 2\mu t \cos r \pm \lambda/2$$

Interference patterns of the Reflected Side of Thin Film

- **Total Path Difference**
  = Path Difference due to Thin Film + Path Difference due to Reflection

$$PD = \Delta = 2\mu t \cos r \pm \lambda/2$$

- **Condition for Constructive Interference:**
- **If the total Path Difference equal to an integral multiple of λ then ray 1 and ray 2 meet in a phase and undergo constructive interference**

$$\Delta = n\lambda$$

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

$$2\mu t \cos r = (2n \pm 1)\lambda/2 \quad \text{where } n = 0, 1, 2, 3 \ldots$$

- **Condition for Destructive Interference:**
- **If the total Path Difference equal to an odd integral multiple of λ/2 then ray 1 and ray 2 meet in a opposite phase and undergo destructive interference**

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

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

$$2\mu t \cos r = n\lambda \quad \text{where } n = 0, 1, 2 \ldots$$

Interference patterns of the Transmitted Side of Thin Film

- Total Path Difference
  = Path Difference due to Thin Film + Path Difference due to Reflection

$$PD = \Delta = 2\mu t \cos r \pm 0$$

- Condition for Constructive Interference:

$$\Delta = n\lambda$$

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

- The total Path Difference should be equal to an integral multiple of λ.

- Condition for Destructive Interference:

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

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

- The total Path Difference should be equal to an odd integral multiple of λ/2.

Thank you