THIN FILM INTERFERENCE-NORMAL AND OBLIQUE INCIDENCE

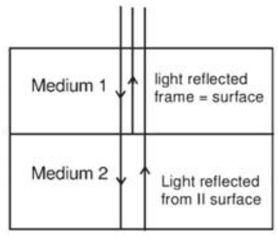
Thin film interference-Normal Incidence

When light moves from one clear substance to another, part of it bounces back at the border and part continues through. In the illustration, you can see that light bounces off both surfaces. If we have a single-colored light coming in, the two reflected waves are also single-colored light waves through amplitude sharing. These waves interfere because they overlap along the same straight line.

The phase difference between two waves arises due to

1. Optical path difference (due to distance travelled)
2. Reflection from a denser medium

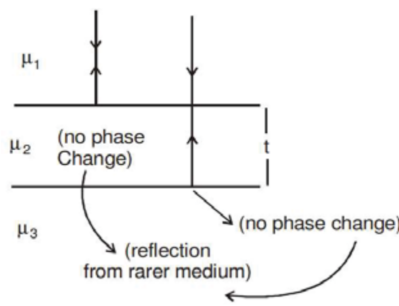
(the second factor is irrelavant for reflection at rarer medium.)



Three situation may arise :

1. Neither wave experience a phase change upon reflection

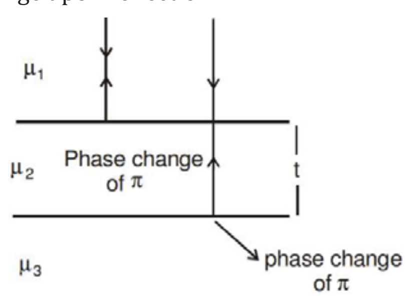
$$(\mu_1 > \mu_2 > \mu_3)$$



$$\Delta x = \frac{2\mu_2 t}{\mu_1}$$

2. Both the wave suffer a phase change upon reflection

$\mu_3 > \mu_2 > \mu_1$



$$\Delta x = \frac{2\mu_2}{\mu_1} t$$

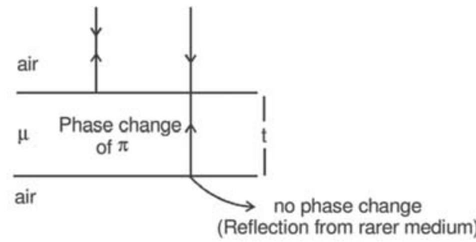
In both situations mentioned earlier, the change in phase caused by reflection doesn't matter; there's no change in phase caused by reflection. In both cases, the phase change depends only on the difference in paths traveled. This is the condition needed for interference to occur.

$$\frac{2n_2t}{n_1} = n\lambda$$

Condition for destructive interference

$$\frac{2n_2t}{n_1} = (n + \tfrac{1}{2})\lambda$$

3. One of the reflected waves experience a phase change of π radian upon reflection & the other wave does not



$$\Delta x = 2\mu t - \frac{\lambda}{2}$$

Due to phase change of π (path change of $\frac{\lambda}{2}$) the conditions are reversed.

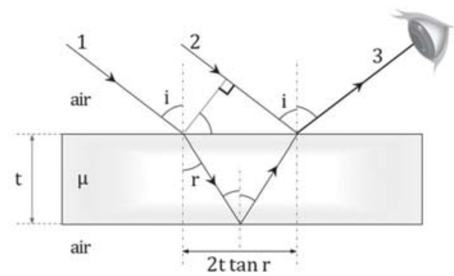
$2ut = n\lambda$ (for destructive interference)

$2ut = (n + \frac{1}{2})\lambda$ (for constructive interference)

Thin film interference-Oblique Incidence

The interference occurs between two specific rays:

1. The part of ray 2 that bounces back from the upper surface of the thin film.
2. The part of ray 1 that passes through the upper surface, bends, and then bounces back from the lower surface of the thin film.



Ray 3 is the ray which we get after interference is taken place between those two mentioned rays.

From the figure, it can be said that, $AB = BC = t \sec r$. Therefore, ray 1 has travelled extra $2t \sec r$ in the medium of R.I. μ.

The optical path length $2t \sec r$ in μ is equivalent to the optical path length $2\mu t \sec r$ in air.

Now, ray 1 and ray 2 has travelled same path upto AP. After that, ray 1 has travelled $2\mu t \sec r$ more optical path in air.

The extra optical path travelled by ray 2 is given by,

$PC = AC \sin i = 2t\tan r \sin i$

We know, when light wave is travelled from rarer medium (air) to denser (R.I.), the reflected wave suffer a phase difference π.

As phase difference π corresponds to path difference $\frac{\lambda}{2}$, the effective extra path travelled by ray 2 is,

$$PC + \frac{\lambda}{2} = AC\sin i + \frac{\lambda}{2} = (2t\tan r)\sin i + \frac{\lambda}{2}$$

Applying Snell's law, we get,

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

Hence, the extra optical path travelled by ray 2 becomes,

$$PC + \frac{\lambda}{2} = 2 + \tan r \cdot \mu\sin r + \frac{\lambda}{2} = 2\mu t \sin^2 r \sec r + \frac{\lambda}{2}$$

Therefore, effective optical path difference between ray 1 and ray 2 is,

$$\Delta x_{\text{effective}} = 2ut \sec r - 2ut \operatorname{Sin}^2 r \operatorname{Sec} r - \frac{\lambda}{2}$$

$$2u + \sec r(1 - \sin^2 r) - \frac{\lambda}{2}$$

$$\Delta x_{\text{effective}} = 2\mu t\cos r - \frac{\lambda}{2}$$