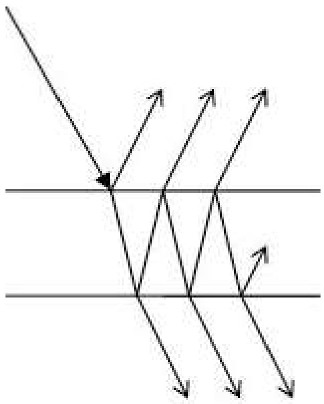
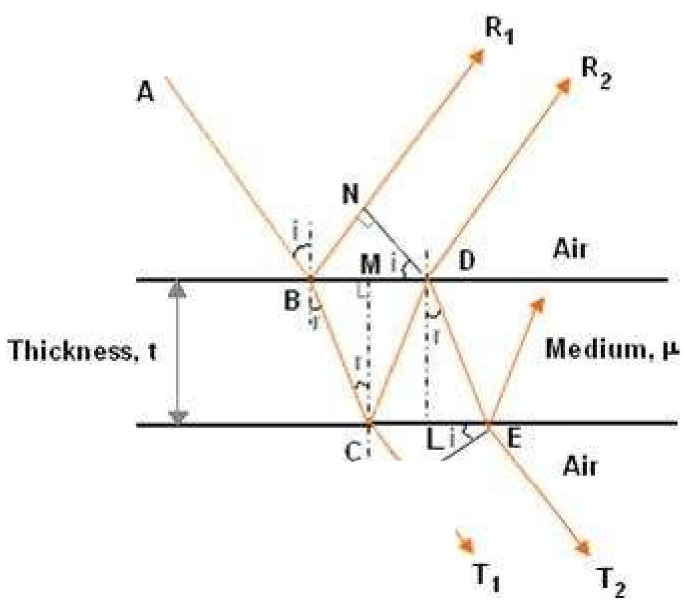
Thin Film Interference

A film of thickness from 0.5 to 10 μm is a transparent medium of glass, mica, air enclosed between glass, soap film, etc. When the light is made incident on this thin film partial reflection and partial refraction occur from the top surface of the film. The refracted beam travels in the medium and again suffers partial reflection and partial refraction at the bottom surface of the film. In this way several reflected and refracted rays are produces by a single incident ray. As they moves are superimposed on each other and produces interference pattern.



Interference in Parallel Film (Reflected Rays)

Consider a thin film of uniform thickness ‘t’ and refractive index μ bounded between air. Let us consider monochromatic ray AB is made incident on the film, at B part of ray is reflected (R_1) and a part is refracted along BC.At C The beam BC again suffer partial reflection and partial refraction, the reflected beam CD moves again suffer partial reflection and partial refraction at D. The refracted beam R_2 moves in air. These two reflected rays R_1 and R_2 interfere to produce interference pattern.



The optical path difference between the two reflected rays

$$\Delta = \mu(BC + CD) - BN$$

In ΔBDN, *sin i = BN / BD* and *BC = CD* as ΔBMC ≡ ΔMCD, therefore

$$\Delta = 2\mu BC - BDsini$$

In ΔBMC, *cos r = t /BC,* therefore

$$\Delta = \frac{2\mu t}{cosr} - BDs$$

$$\Delta = \frac{2\mu t}{cosr} - 2BMsini$$

In ΔBMC, tan *r = BM / t* , therefore

$$\Delta = \frac{2\mu t}{cosr} - 2t(tanr)sini$$

According to snell's law $\mu = \frac{sin\mathbf{i}}{sin\mathbf{r}}$

$$\Delta = \frac{2\mu t}{cosr} - 2\mu t(tan\mathbf{r})sin\mathbf{r}$$

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

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

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

$\Delta = 2\mu tcos\mathbf{r}$..........................(2.11)

Correction on account of phase change at reflection: when a beam is reflected from a denser medium (ray R_1 at B), a path change of λ /2 occur for the ray.

Therefore the true path difference is $\Delta = 2\mu tcos\mathbf{r} + \frac{\lambda}{2}$..........(2.12)

Condition of Maxima (Bright Fringe)

Maxima occur when path difference

$$\Delta = n\lambda$$

$$2\mu tcos\mathbf{r} + \frac{\lambda}{2} = n\lambda$$

$\boldsymbol{2\mu tcosr = \pm\frac{(2n-1)\lambda}{2}}$ ....(2.13)

Condition for Minima (Dark Fringe)

Minima occur when path difference

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

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

$$\boldsymbol{2\mu t cos r = \pm n\lambda}$$ ....(2.14)

Interference in Parallel Film (Transmitted Rays)

The optical path difference between transmitted rays T_1 and T_2 will be

This path difference is calculated in the same way as above to get

$$\Delta = 2\mu t cos\mathbf{r}$$ ....(2.15)

Condition of Maxima (Bright Fringe)

Maxima occur when path difference,

$$\Delta = n\lambda$$

$$2\mu t cos\mathbf{r} = n\lambda$$ ....(2.16)

Condition for Minima (Dark Fringe)

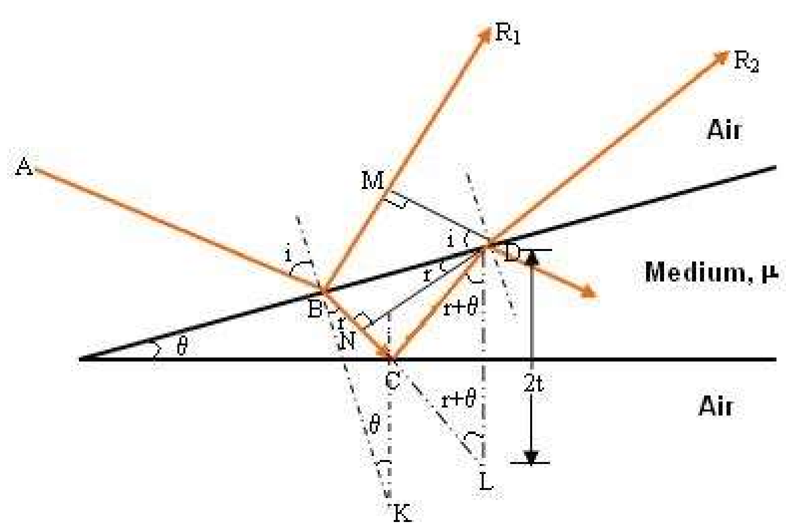
Minima occur when path difference,

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

$$2\mu t cos\mathbf{r} = \frac{(2n-1)\lambda}{2}$$ ....(2.17)

Interference in Wedge Shaped Film (Reflected Rays)

The wedge shaped film has a thin film of varying thickness, having thickness zero at one end and increases at the other. The angle of wedge is θ.



The optical path difference between the two reflected rays R_1 and R_2 will be

$$\Delta = \mu(BC + CD) - BM$$

From the geometry

$$\Delta = \mu(BN + NC + CD) - BM$$

As in ΔBMD;

$$sin\mathbf{i} = \frac{BM}{BD}$$

And in ΔBND

$$sin\mathbf{r} = \frac{BN}{BD}$$

According Snell's Law,

$$\mu = \frac{sin\mathbf{i}}{sin\mathbf{r}} = \frac{BM/BD}{BN/BD} = \frac{BM}{BN}$$

Or $BM = \mu BN$

Thus $\Delta = \mu(NC + CD)$

$$\Delta = \mu(NC + CL)$$

$$\Delta = \mu NL$$

As in ΔNDL

$$cos(r + \theta) = \frac{NC}{2t}$$

$$\Delta = 2\mu t cos(r + \theta)$$

Correction on account of phase change at reflection: when a beam is reflected from a denser medium (ray R_1 at B), a path change of λ /2 occur for the ray.

Therefore the true path difference is

$$\Delta = 2\mu t cos(r + \theta) + \frac{\lambda}{2}$$

Condition of Maxima (Bright Fringe)

Maxima occur when path difference,

$$\Delta = \pm n\lambda$$

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

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

Condition for Minima (Dark Fringe)

Minima occur when path difference

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

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

$$\boldsymbol{2\mu t cos(r+\theta) = \pm n\lambda}$$