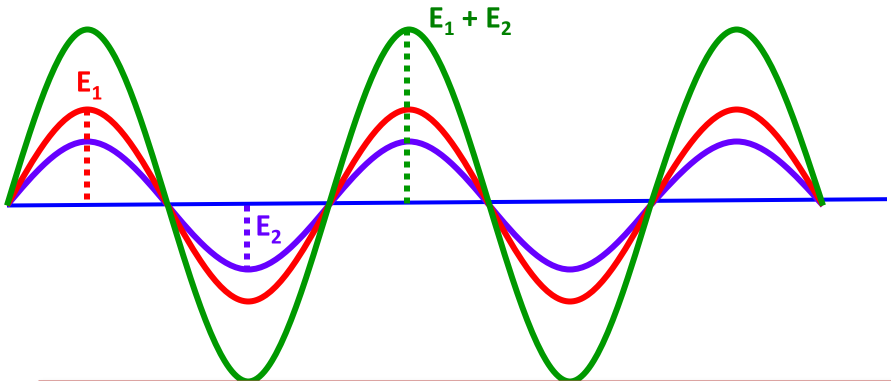
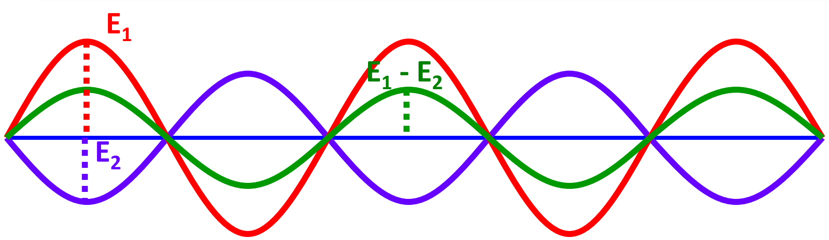
Interference

The phenomenon of modification in intensity of light due to mixing/superimposing of two or more light waves is called **Interference of Light.**

Constructive and Destructive Interference



Constructive Interference $E = E_1 + E_2$



Destructive Interference $E = E_1 - E_2$

1[st] Wave (E_1)

2[nd] Wave (E_2)

Resultant Wave

Reference Line

Phase difference $(\Phi) = (2\pi/\lambda)$ path difference

Condition for Constructive Interference :

Path difference $= n\lambda$

Phase difference $\Phi = 2n\pi$

where n = 0, 1, 2, 3, …….

Condition for Destructive Interference :

Path difference $= (2n \pm 1)\lambda / 2$

Phase difference $\Phi = (2n \pm 1)\pi$

where n = 0, 1, 2, 3, ……. for +ve

where n = 1, 2, 3, ……. for - ve

Conditions for sustained interference

1.The two sources must be coherent.

2. The sources must be monochromatic.

3. The interfering waves should have same amplitude or intensity

4. The distance between two sources should be small.

5. The perpendicular distance of screen from two sources should be large.

6. Sources must be narrow.

7. The two interfering waves must have the same plane of polarization.

Methods for obtaining Coherent Sources

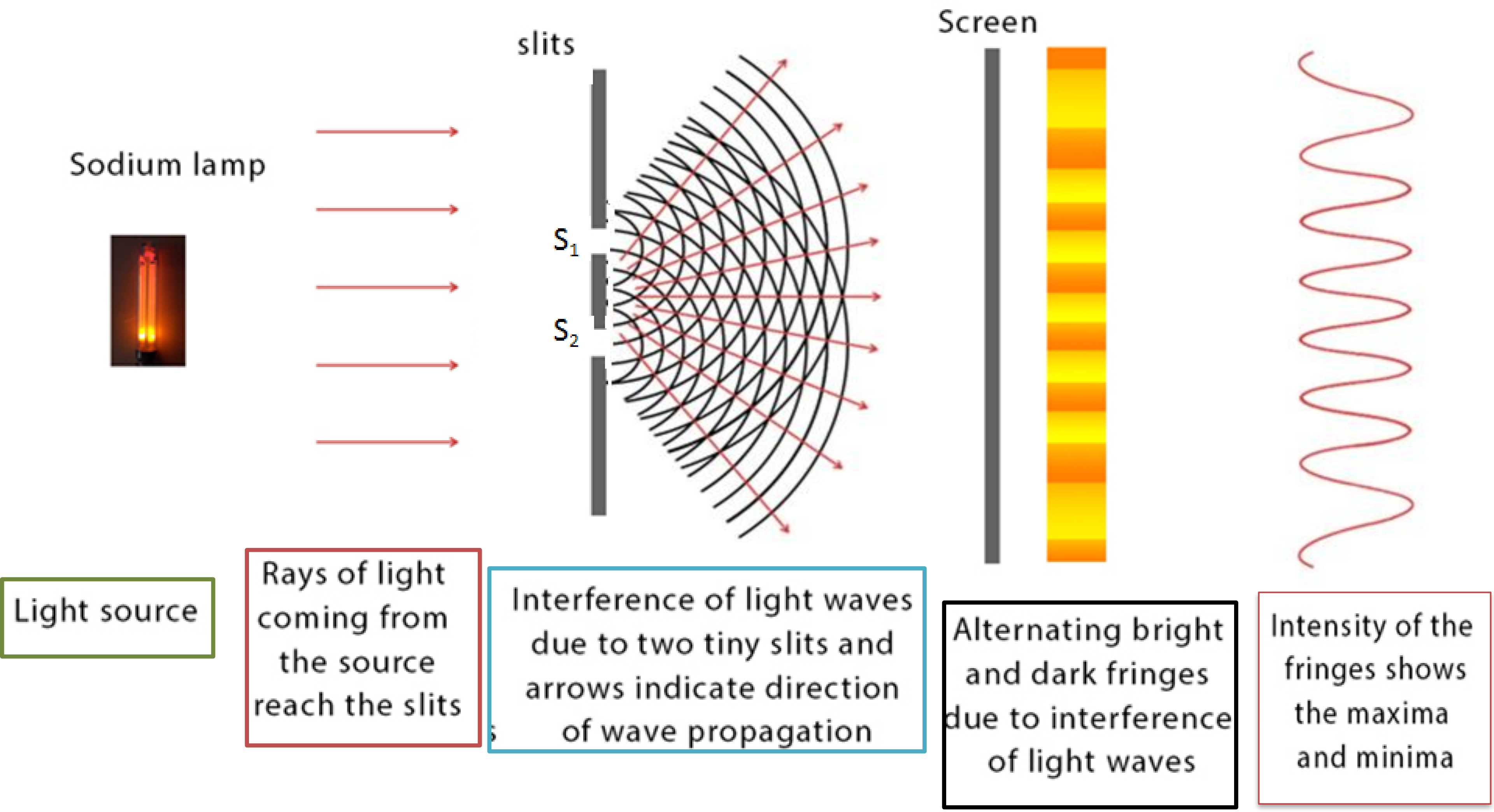
Division of Wavefront

Examples: Young’s double slit, Biprism etc

Division of Amplitude

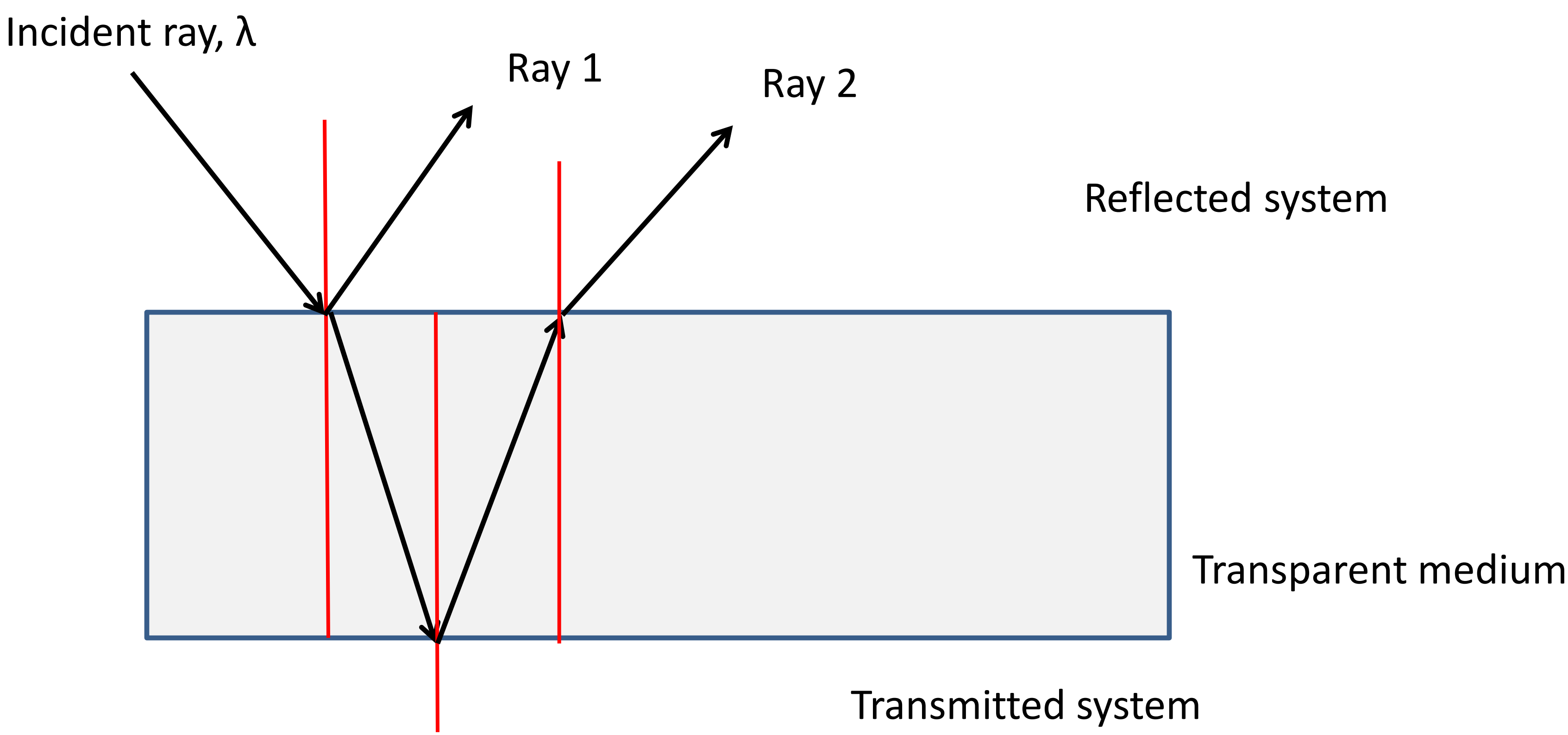
Examples: Thin film, Newton’s Ring etc

Division of Wavefront



Double-Slit Experiment

Division of Amplitude



Let's discuss about reflected rays 1 and 2

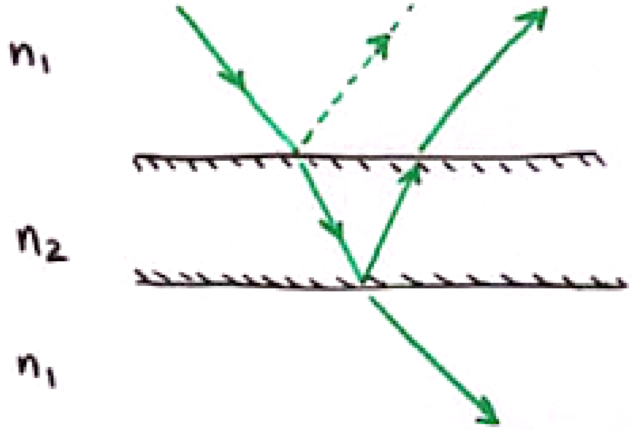
Hence they will interfere Reflected system

In this, intensity or amplitude of waves changes.

Hence it is called Interference due to Division of Amplitude

Thin Film

- When a film of oil spread over surface of water is illuminated by white light , beautiful colours are seen.
- This is due to interference between the light waves reflected from the film and the light waves transmitted through the film.
- Thin film may be a thin sheet of transparent material such as glass, mica or an oil film enclosed between two transparent sheets or a soap bubble.



Important Note

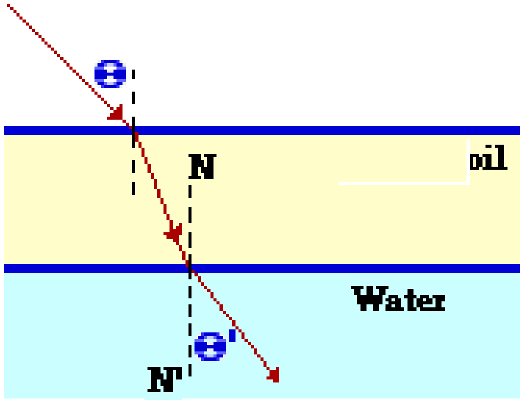
1. Thin film:

In optics, a transparent medium having thickness (0.1 λ) to (10 λ) is called thin film.

Example: layer of oil on glass or water surface

2. Optical Path:

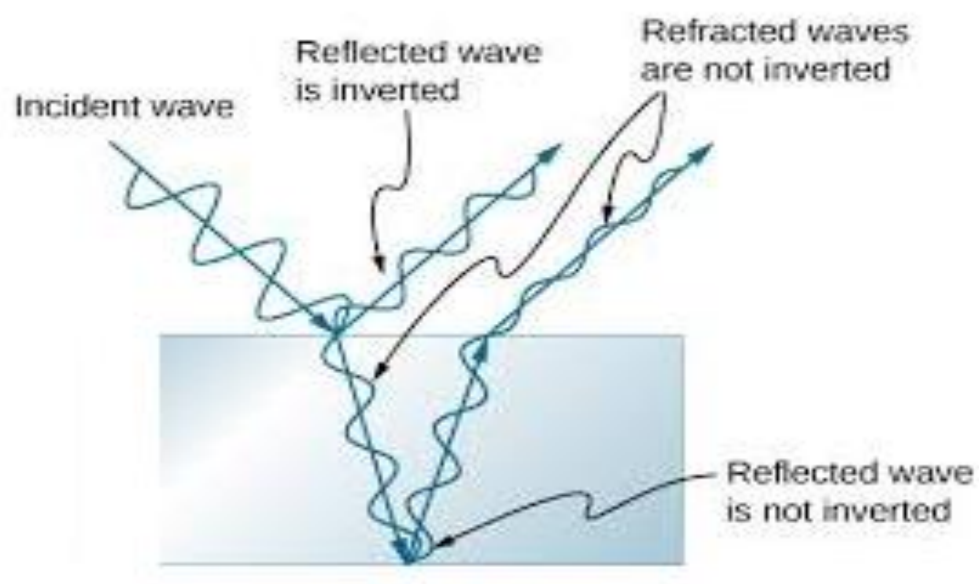
If light travels a distance of ‘t’ in an medium of refractive index ‘μ’, then its equivalent path in air or vacuum is ‘μt’.



3. Reflection of Transverse waves :

No phase or path changes due to reflection from rarer medium.

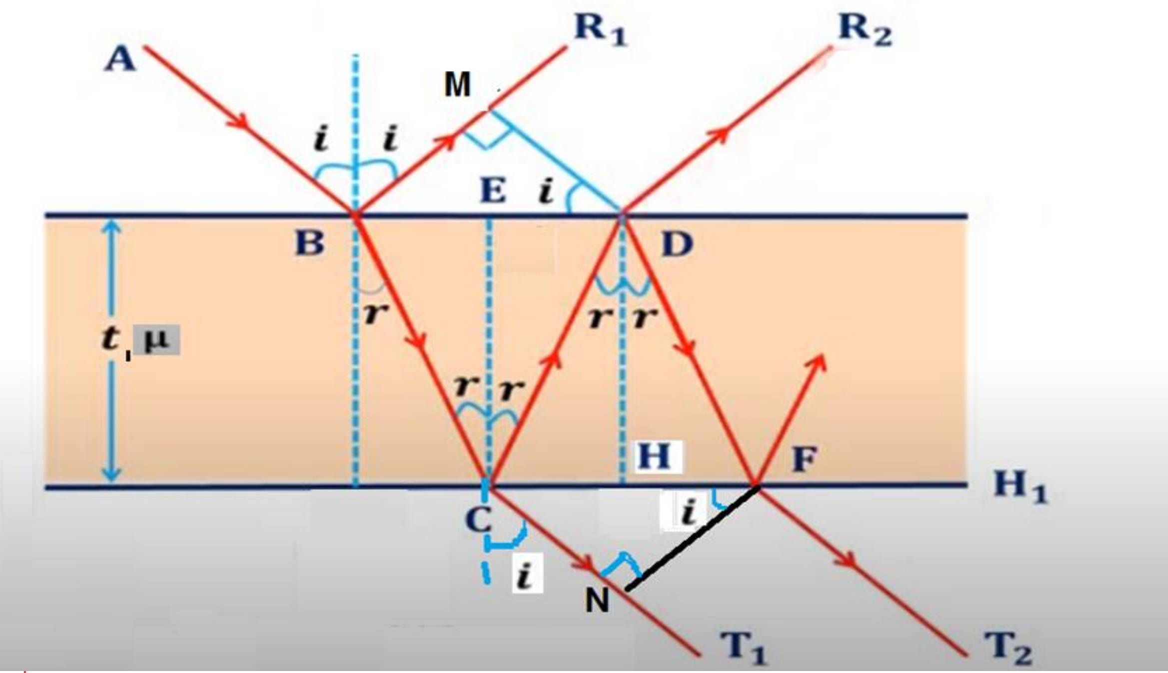
Phase changes by π radian (which is equivalent to path change of λ/2) takes place, when reflection takes place from surface of denser medium.



Interference in thin film of uniform thickness (Reflected System)

Refer Class notes for details

Interference in thin film of uniform thickness (Transmitted System)



Path difference $= 2\mu t \cos r$

net path difference $= 2\mu t \cos r$

Conditions for maxima and minima in transmitted light

The two rays BT_1 and DT_2 will reinforce each other if

$$2\mu t \cos r = n\lambda \quad \text{(condition of maxima)}$$

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

Again the two rays will destroy each other if

$$2\mu t \cos r = (2n+1)\frac{\lambda}{2} \quad \text{(condition of minima)}$$

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

Reflected Light

Bright Fringe

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

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

Dark Fringe

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

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

Transmitted Light

Bright Fringe

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

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

Dark Fringe

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

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

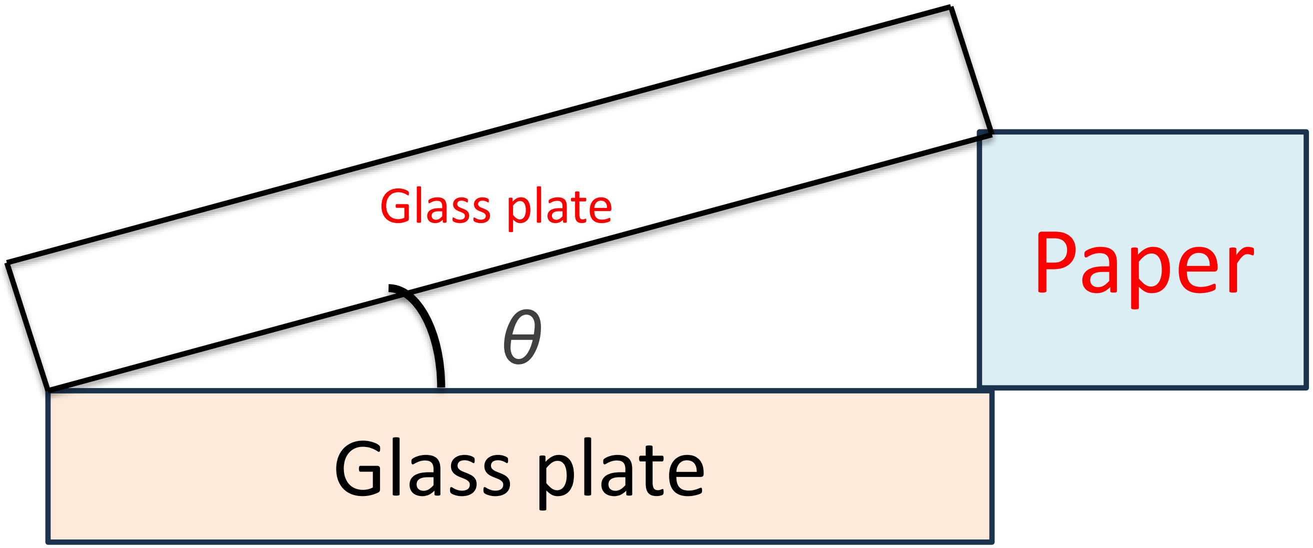
The condition of bright in reflected system is same as condition for dark in transmitted or vice- versa.

Therefore, the colours which are present in the reflected system are absent in the transmitted system.

Formation of Colours in thin films :

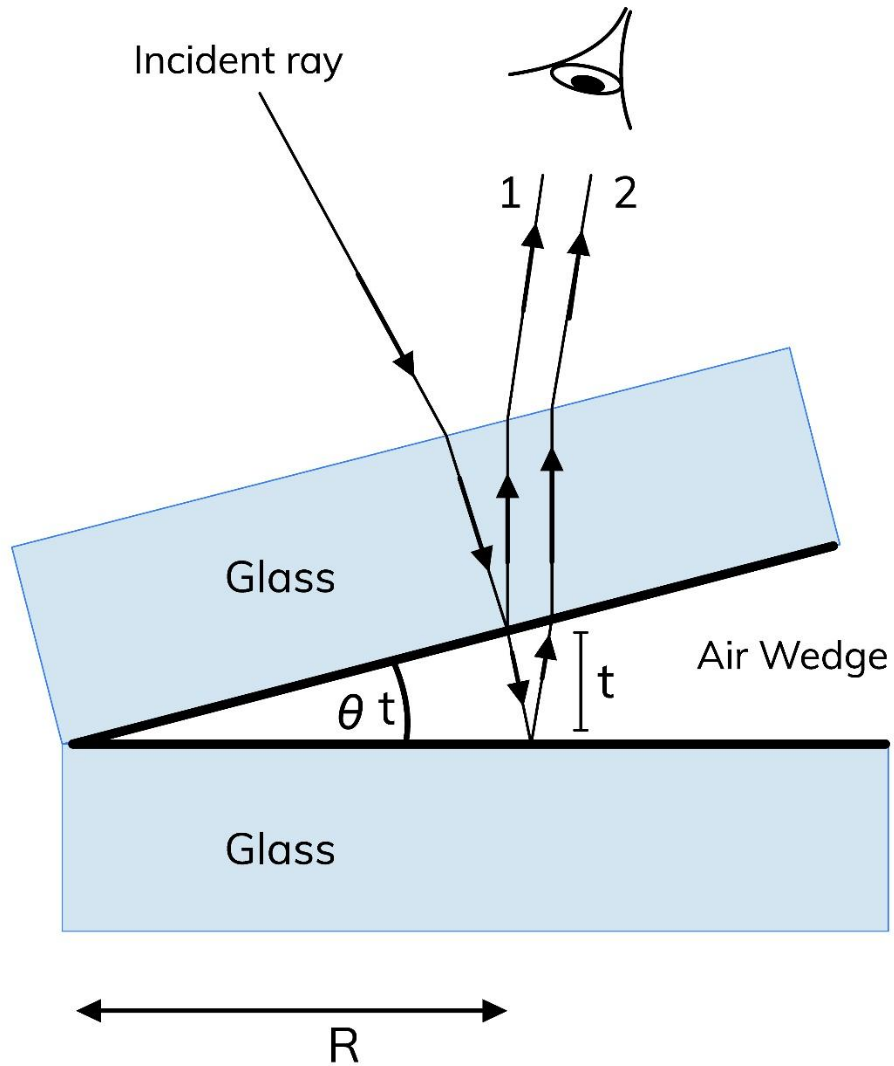
- We often see bright bands of colours on the surface of a soap bubble or on a thin layer of oil floating on water.
- Normally the colours are seen in the reflected system.
- The optical path difference in the reflected system is given by ($2\mu t\cos r \pm \frac{\lambda}{2}$)
- Therefore, if a film is illuminated by white light, different colours (with different wavelength) will have different optical path in the film in the given time.
- Some colours interfere constructively and due to this formation of colours take place.
- The optical path difference also depends on thickness (t) and angle of refraction (r).
- Therefore, when 't' and/or 'r' changes, optical path difference changes. This also leads to the formation of colours.

wedge shaped film



If two glass plates are placed face to face with one end separated by a piece of paper or thin metal foil an air film of non-uniform thickness is formed between them.

It is called **wedge shaped film.**


Incident ray
1
2
Glass
Air Wedge
t
θ t
Glass
R

The optical path difference is given by

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

for maxima / bright, $\delta = n\lambda \longrightarrow (2)$

from (1) and (2)

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

$$\boxed{2\mu t \cos(r+\theta) = (2n \mp 1)\frac{\lambda}{2}} \longrightarrow (3)$$

The optical path difference is given by

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

for minima / dark, $\delta = (2n \pm 1)\frac{\lambda}{2} \longrightarrow (4)$

from (1) & (4)

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

$$\boxed{2\mu t \cos(r+\theta) = n\lambda} \longrightarrow (5)$$

(3) is equation of bright/max and (5) is equation for dark/min.

$\therefore$ max / min depends on

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

μ → constant

t → constant

r → constant

θ → constant

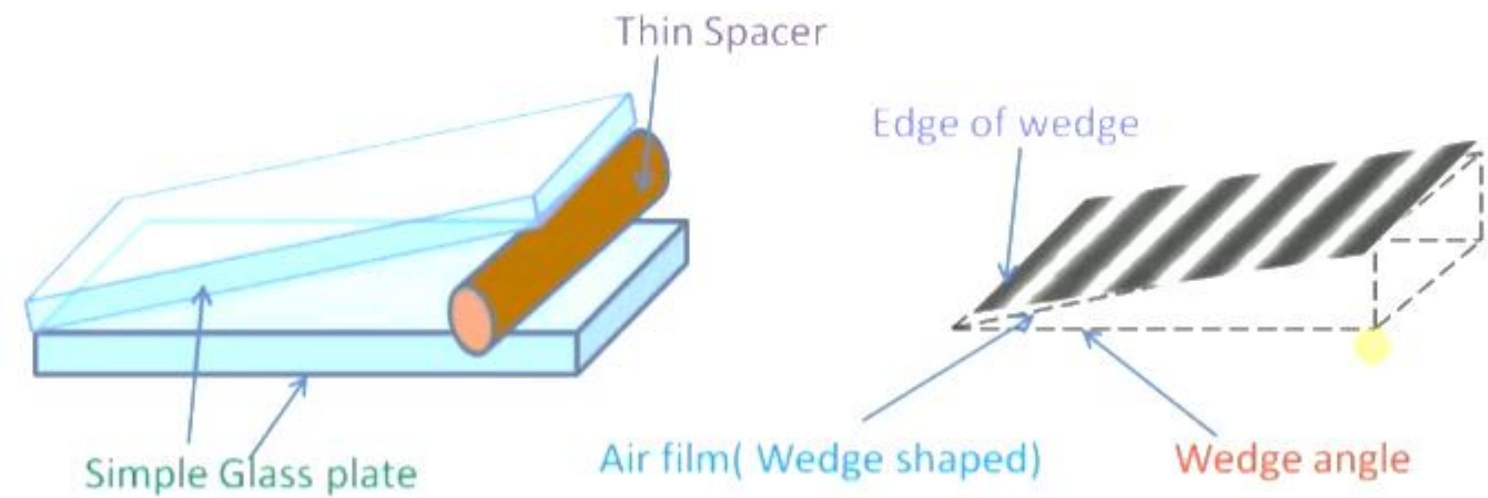
$\therefore$ for a particular order of max/min, t should remain constant

or

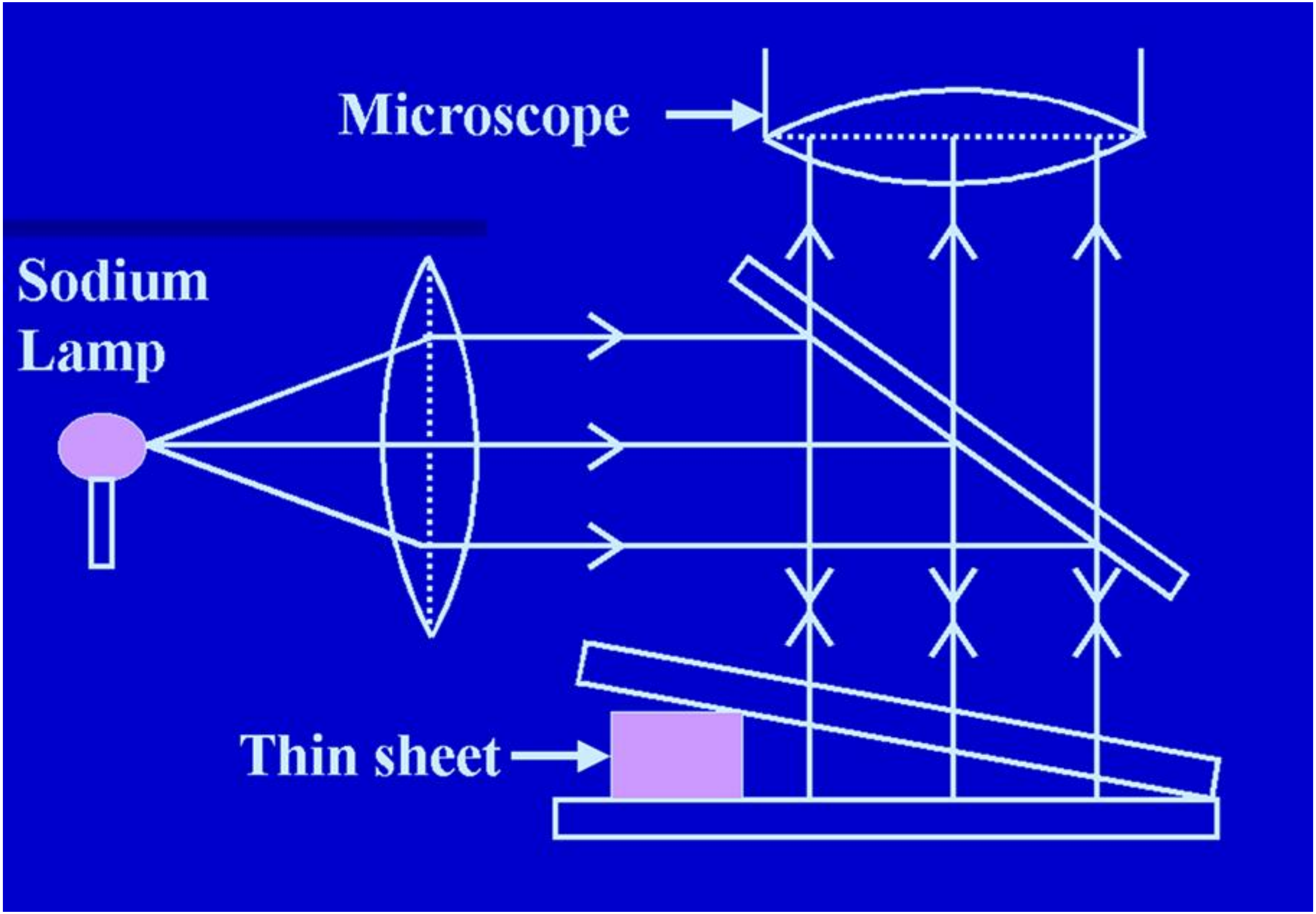
max/min will be locus of all points where t is constant.

In this case the locus of all points where thickness is constant in in the form of straight lines.

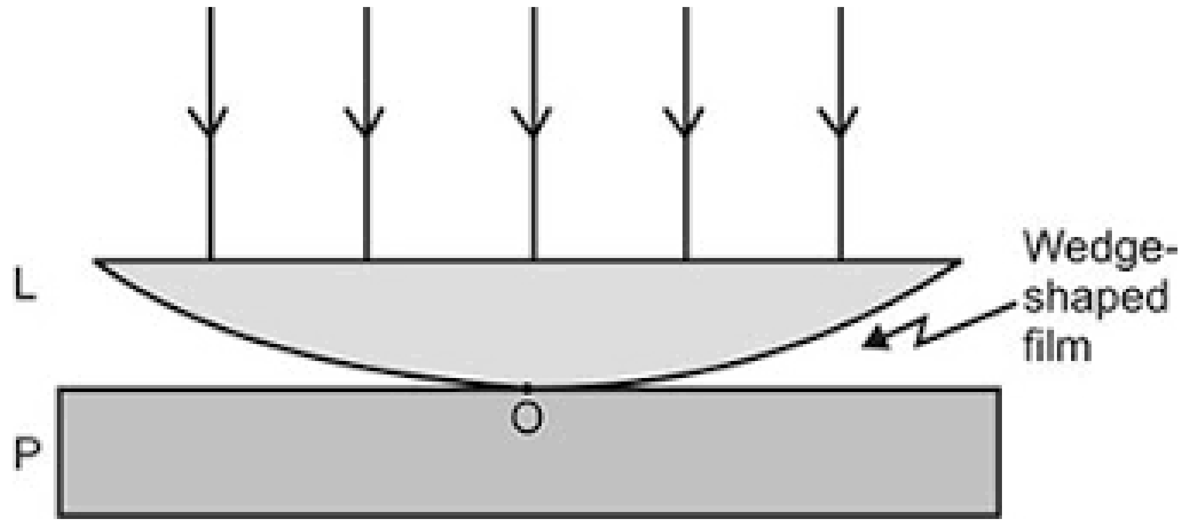
Hence we get interference fringes as straight, parallel, and equally spaced lines



Refer Class notes for details


Microscope
Sodium
Lamp
Thin sheet

Newton's Rings



When a plano-convex lens of large radius of curvature is placed on a plane glass plate, an air film of gradually increasing thickness is formed between the lens and the glass plate.

If monochromatic light is allowed to fall normally on the lens, and the film is viewed in reflected light, alternate bright and dark concentric rings are seen around the point of contact. These rings are called Newton's Rings.

The optical path difference is given by

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

for air film, $\mu = 1$

for normal incidence, $r = 0$

for lens of large R, $\theta \simeq 0$

$$\therefore \boxed{\delta = 2t \pm \frac{\lambda}{2}} \longrightarrow (2)$$

for bright / maxima

$$\delta = n\lambda \longrightarrow ③$$

from ② & ③

$$2t \pm \frac{\lambda}{2} = n\lambda$$

$$\boxed{2t = (2n \mp 1)\frac{\lambda}{2}} \longrightarrow ④$$

for dark/ minima

$$\delta = (2n \pm 1)\frac{\lambda}{2} \longrightarrow ⑤$$

from ② and ⑤

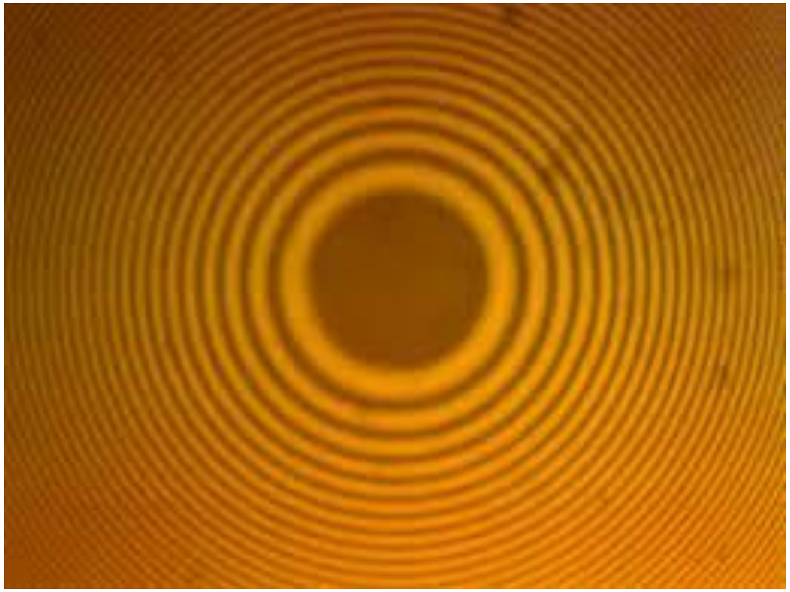
$$2t \pm \frac{\lambda}{2} = (2n \pm 1)\frac{\lambda}{2}$$

$$\boxed{2t = n\lambda} \longrightarrow ⑥$$

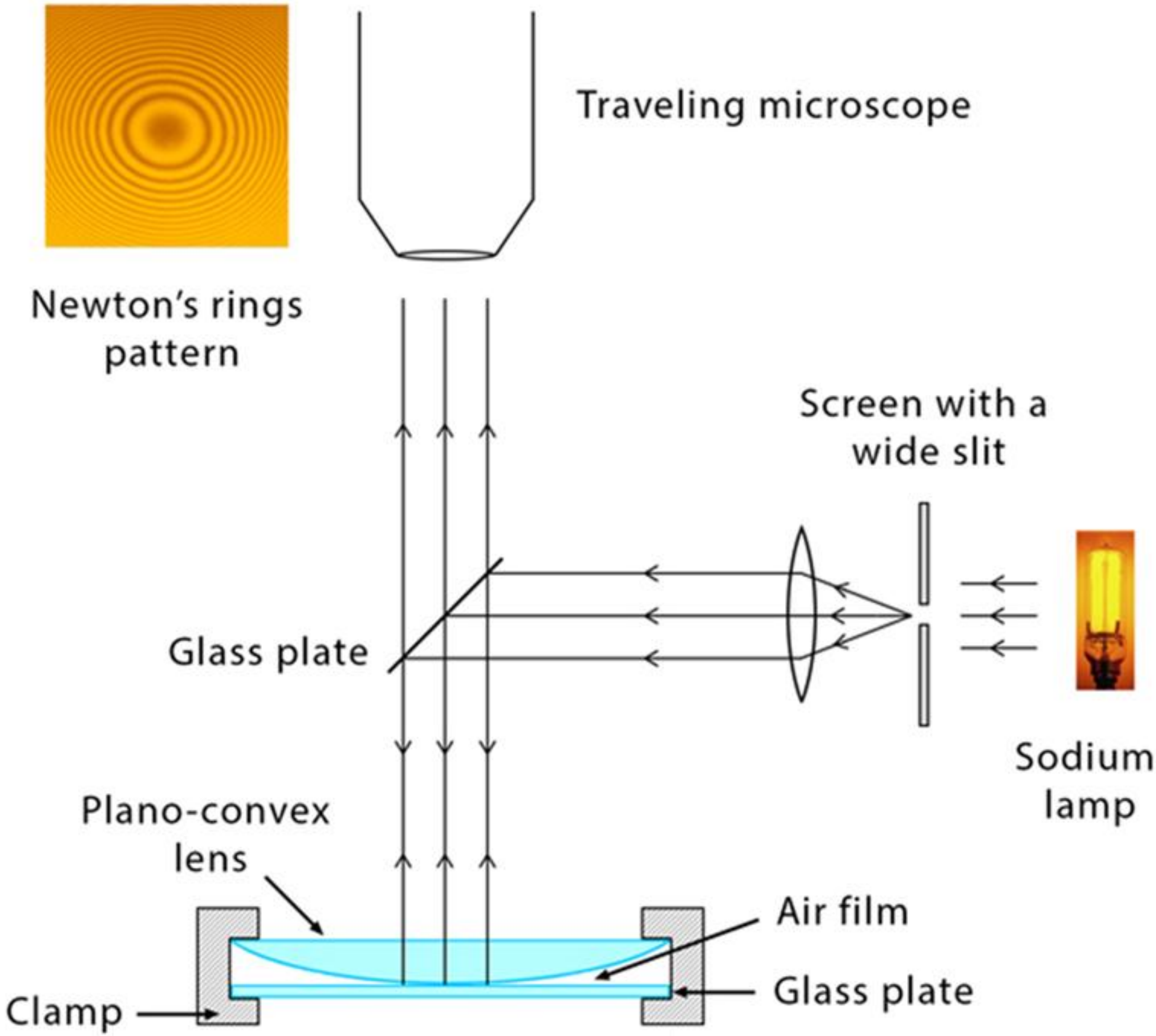
∴ for a particular order of max/min
t should remain constant
or
max/min will be locus of all points
where t is constant.

In this case the locus of all points where thickness is constant in in the form of circle.

Hence we get dark and bright concentric circles.



Refer Class notes for details


Traveling microscope
Newton's rings pattern
Screen with a wide slit
Glass plate
Sodium lamp
Plano-convex lens
Air film
Glass plate
Clamp