# Syllabus Description

| Course Code | Course Title | | | | | |
|---|---|---|---|---|---|---|
| 316U06C102 | Engineering Physics | | | | | |
| Teaching Scheme (hrs.) | TH | PRACT | | TUT | | Total |
| | 02 | -- | | -- | | 02 |
| Credits Assigned | 02 | -- | | -- | | 02 |
| Examination Scheme | Marks | | | | | |
| | CA | | ESE (Theory/On-Screen) | PR/OR Exam | LAB/TUT CA | Total |
| | IA | MSE | | | | |
| | 20 | 30 | 50 | -- | -- | 100 |

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# Syllabus Overview

| Module No. | Unit No. | Details | Hrs. | CO |
|---|---|---|---|---|
| 1 | **Wave Optics** | | 08 | CO1 |
| | 1.1 | Interference: Introduction, methods of interference, Derivation of interference in thin parallel films, Theoretical discussion of a wedge shaped film and Newton's Ring | | |
| | 1.2 | Diffraction: Introduction, Theoretical discussion of diffraction grating and Resolving power | | |
| 2 | **Photonics** | | 07 | CO2 |
| | 2.1 | Lasers: Interaction of radiation with matter, Basic principles and components required for lasing, Relation between Einstein's coefficient, Threshold condition of laser | | |
| | 2.2 | Fiber optics: Concept of total internal reflection, Types of optical fiber, Derivation of Numerical aperture for step index fiber, Important parameters related an optical fiber, losses in optical fibers | | |

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# Syllabus Overview

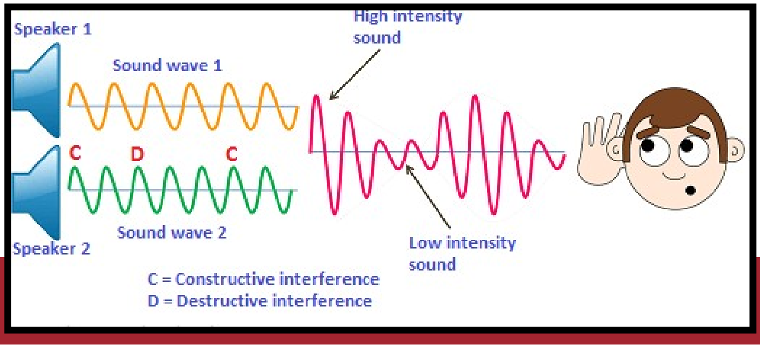
| | | | | |
|---|---|---|---|---|
| 3 | **Quantum Mechanics-I** | | 07 | CO3 |
| | 3.1 | De-Broglie hypothesis and its various forms | | |
| | 3.2 | Heisenberg's uncertainty principle, its implications and application | | |
| | 3.3 | Wavefunction and its probabilistic interpretation, Condition of Normalization | | |
| 4 | **Basics of Semiconductors and Electromagnetism** | | 08 | CO4 |
| | 4.1 | Intrinsic and Extrinsic semiconductors, Mobility, Conductivity in semiconductors | | |
| | 4.2 | Drift and Diffusion current densities | | |
| | 4.3 | Fermi- Dirac distribution function, Position of Fermi Level in Intrinsic and Extrinsic Semiconductors | | |
| | 4.4 | Del operator, Gradient, divergence, curl, Fundamental theorems and their physical interpretation | | |

# Module 1- 1.1: INTERFERENCE

- Interference : A fundamental concept in wave physics
- Occurs when two or more waves meet while traveling through the same medium.
- Instead of simply passing through each other, the waves superimpose, meaning their amplitudes add together at each point in space and time.

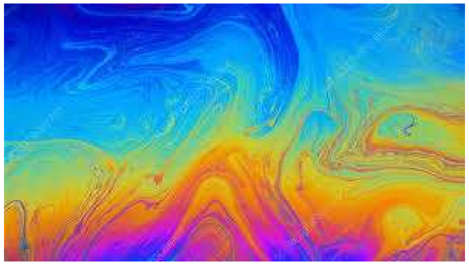
- There are two main types of interference:
- Constructive Interference – when waves combine to make a wave with larger amplitude (peaks align with peaks).
- Destructive Interference – when waves combine to reduce or cancel each other out (peaks align with troughs).

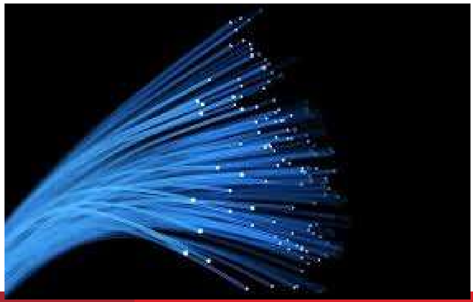
- This principle is most commonly observed with light, sound, and water waves, but it also plays a vital role in engineering disciplines such as electronics, communications, structural design, and optical technology.




# Applications of Interference

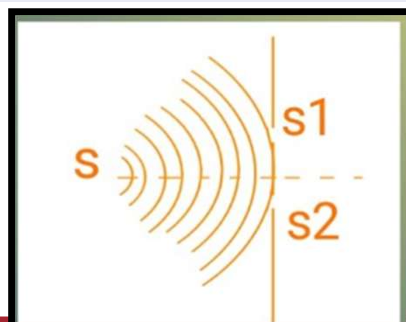
- Noise-Cancelling Headphones
  Uses **destructive interference** to cancel ambient noise.
- Anti-reflective Coatings on Glasses or Screens
  Thin-film interference is used to reduce unwanted reflections on glasses, camera lenses, and mobile screens.
- Soap Bubbles and Oil Slick Colors
  The colorful patterns are due to interference of light waves reflecting off the different layers of the thin film (e.g., the soap or oil layer).
- Radio and Wi-Fi Signals
  Signal strength fluctuations often occur due to **interference** between direct and reflected paths of waves.
- Optical Sensors and Fiber Optics
  Interference patterns in fiber optics help detect strain, temperature, pressure in smart structural monitoring systems

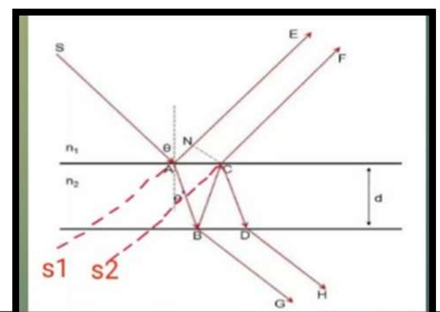





# Methods of producing interference

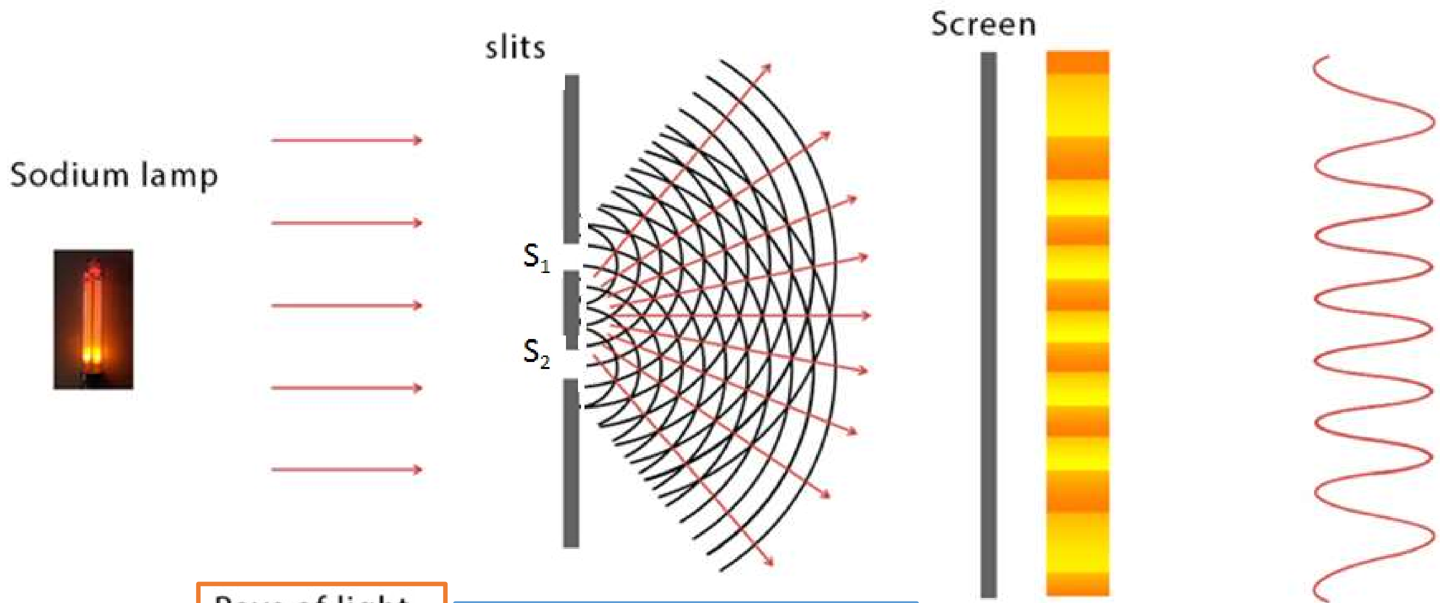
| Aspect | Division of Wavefront | Division of Amplitude |
|---|---|---|
| Principle | Splits wavefront into parts | Splits beam by reflection/transmission |
| Coherent Sources | Created geometrically | Naturally coherent (from same source) |
| Applications | Basic optical experiments | Precision instruments & sensors |
| Examples | Young’s slits, Biprism, Lloyd’s Mirror | Newton’s Rings, Michelson Interferometer |



# Division of Wave front

## Double-Slit Experiment




Light source

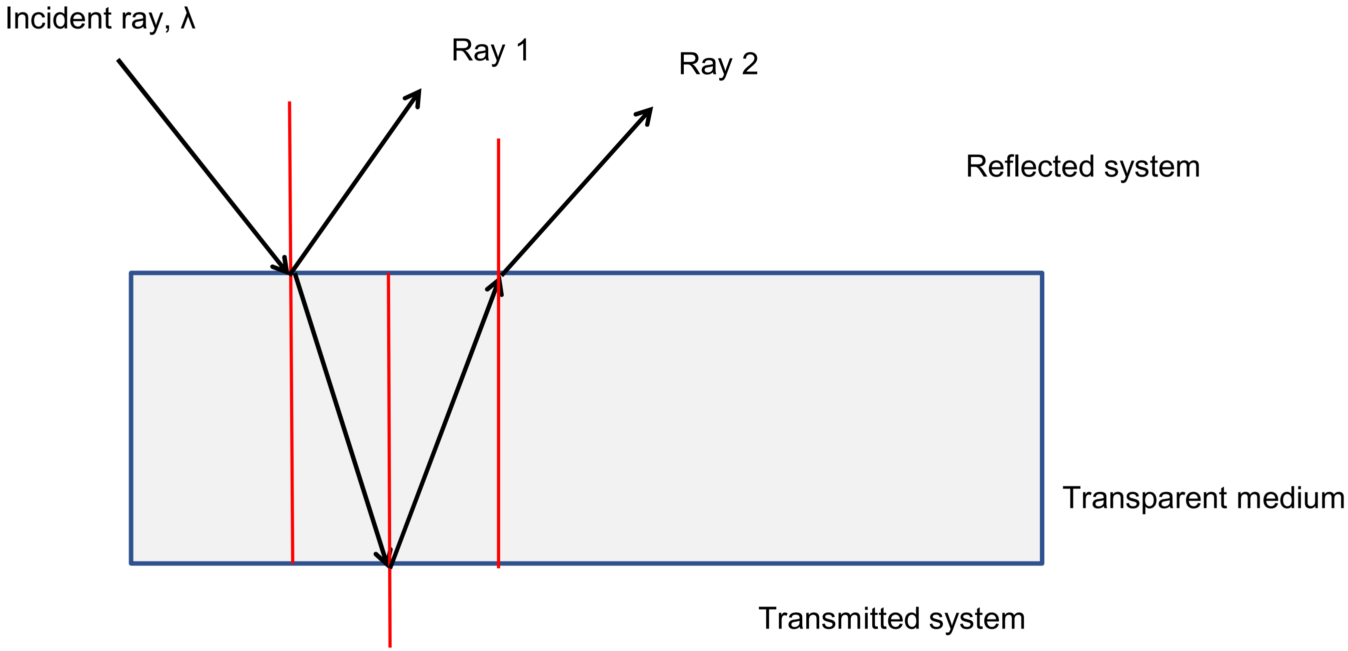
Rays of light coming from the source reach the slits

Interference of light waves due to two tiny slits and arrows indicate direction of wave propagation

Alternating bright and dark fringes due to interference of light waves

Intensity of the fringes shows the maxima and minima

# Division of Amplitude




Reflected rays 1 and 2 will interfere

In this, intensity or amplitude of waves changes.

**Hence it is called Interference due to Division of Amplitude**

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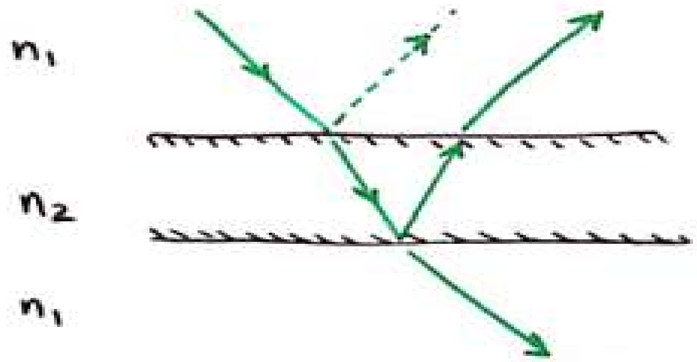
# Thin and Thick Films

| Feature | Thin Film | Thick Film |
| --- | --- | --- |
| Thickness Range | Nanometers to a few microns | Tens to hundreds of microns or more |
| Interference Effects | Prominent, visible (colors, patterns) | Negligible or minimal |
| Common Use | Optical, electronic, coatings | Mechanical, insulation, circuits |
| Examples | Soap bubbles, AR coatings, oil films | Resistors, PCBs, varnishes |

# 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.




1. Parallel Rays interference with each other?

2. How many rays will interfere ?

3. What about thickness?

# Important Note

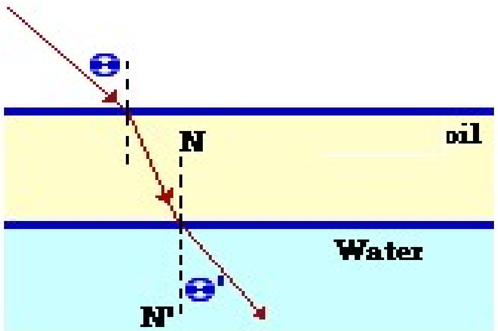
## 1. Thin film:

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:

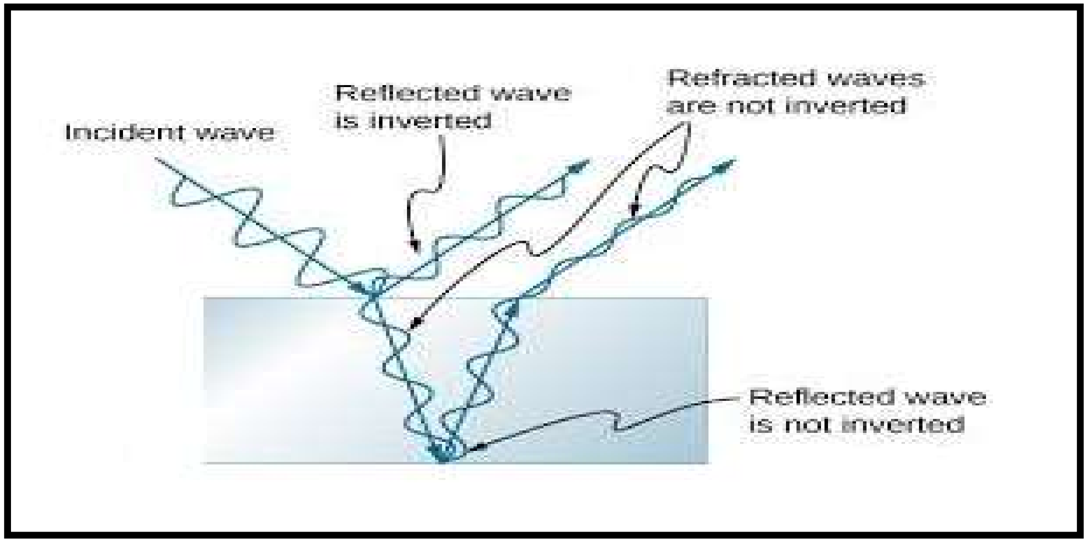
If light travels a distance of ‘t’ in an medium of refractive index ‘μ’, then its equivalent path in air or vacuum is ‘μt’.



# 3. Reflection of Transverse waves :

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

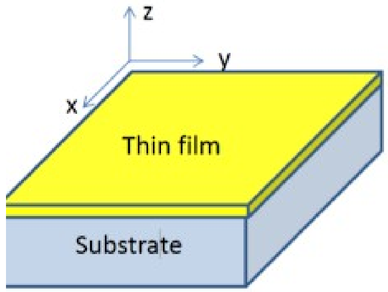
Phase changes by $\pi$ radian (which is equivalent to path change of $\lambda/2$) takes place, when reflection takes place from surface of denser medium.

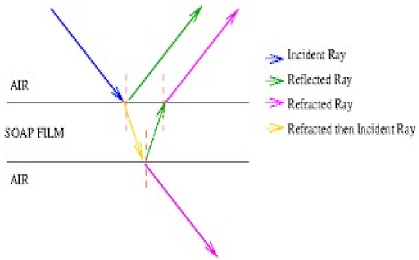


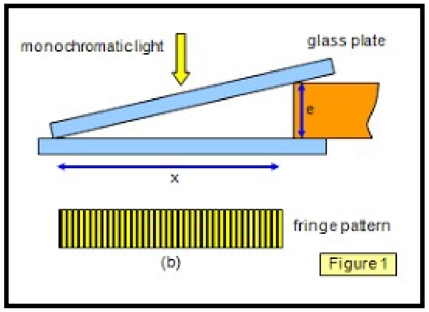
# Parallel thin films and Wedge shaped films

**Thin parallel film:**
A thin film with a uniform thickness across its surface.
**Applications:**
Used in various applications, including anti-reflection coatings, High reflection coatings, optical filters, and mirrors.
**Thickness Measurement:**
The thickness can be determined by analyzing the interference patterns produced by the film.

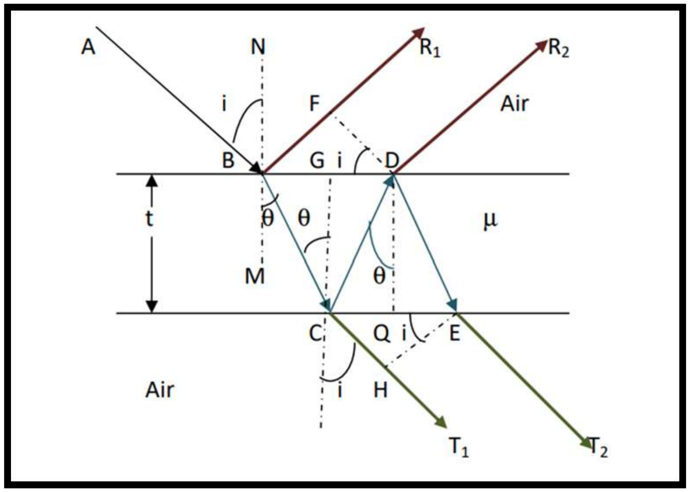
**Wedge-Shaped Thin Films:**
A thin film with a thickness that varies linearly across its surface, forming a wedge shape.
**Applications:**
Used in applications like wedge prisms, optical components, and in the study of thin film properties.
**Thickness Measurement:**
The angle of the wedge and the fringe spacing can be used to determine the film's thickness at different points.



# Interference due to thin parallel film




- Both the reflected beams and transmitted beams interference fringes will be formed.
- Since the reflected beams are parallel, the interfering beams superpose at infinity.
- Hence the fringes are formed at infinity. The same thing holds for transmitted beam.
- To observe the fringes a convex lens is required to focus the parallel beams at its focal plane.

Let a parallel sided thin film of refractive index μ and thickness, 't' be considered within an air medium. It is assumed surfaces of the film have a high reflection coefficient

AB ⟶ A beam of light of amplitude 'a' incident on the upper surface of the film.

$BR_1$ ⟶ Light reflected from the upper surface of the film.

BC ⟶ Light transmitted into the film through the upper surface.

CD ⟶ Light reflected from the lower surface of the film.

$CT_1$ ⟶ Light transmitted outside the film through the lower surface

$DR_2$ ⟶ Light transmitted outside the film through the upper surface

Condition for Maxima: $\boxed{2\mu t\cos\theta = (2n+1)\frac{\lambda}{2}}$

Condition of Minima: $\boxed{2\mu t\cos\theta = n\lambda}$

BCD in medium of RI $\mu \Rightarrow \mu(BC+CD)$

BM in air $\Longrightarrow$ BM

$\therefore$ o.p.d $= \mu(BC+CD) - BM \longrightarrow (1)$

$\because BC = CD \longrightarrow 2(BC)$

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

$\cos r = \frac{CG}{BC} = \frac{t}{BC}$

$\therefore BC = (t)/(\cos r) \longrightarrow (3)$

$\sin i = \frac{BM}{BD} = \frac{BM}{BG+GD} = \frac{BM}{2(BG)}$

$\because BG = GD$

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

$\tan r = \frac{BG}{CG} = \frac{BG}{t} \Rightarrow BG = t\tan r \longrightarrow (5)$

$(5) \rightarrow (4)$

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

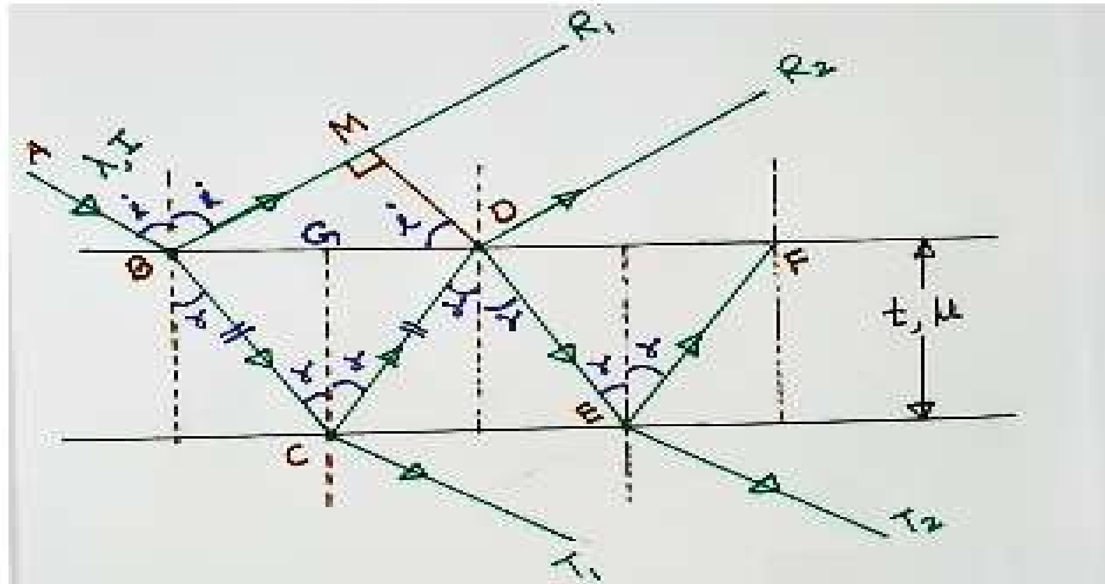
$(3),(6) \rightarrow (2)$

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

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

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

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




Reflection at B $\Rightarrow$ at surface of denser (path changes by $\lambda/2$)

Reflection at C $\Rightarrow$ at surface of rarer (no path changes)

$\therefore$ additional path changes by $(\lambda/2)$

$\therefore$ effective opd

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

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$\therefore$ effective opd

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

(1) Condition for max / bright

$$\delta = n\lambda$$

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

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

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

(2) Condition for min / dark

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

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

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

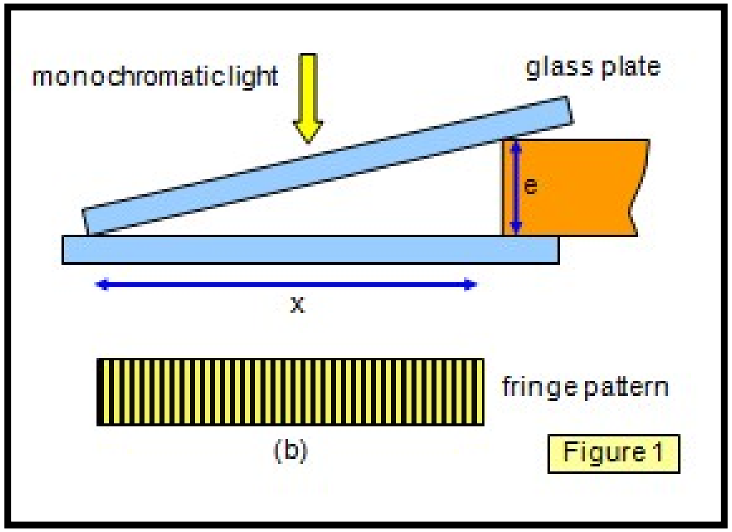
$$\boxed{2\mu t \cos r = n\lambda} \longrightarrow (10)$$

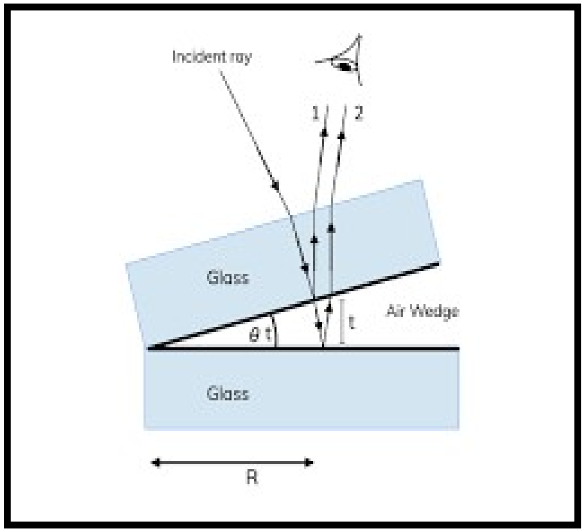
# Formation of Colours in thin films

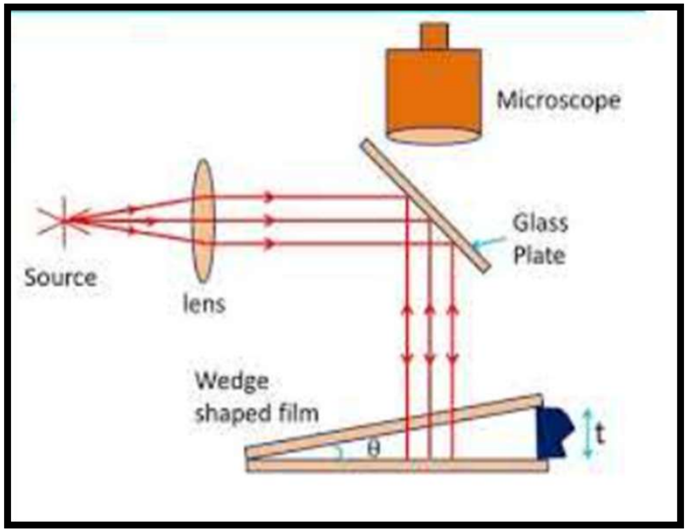


- We often see bright bands of colours on the surface of a soap bubble or on a thin layer of oil floating on water.
- Normally the colours are seen in the reflected system.
- The optical path difference in the reflected system is given by ($2\mu t\cos r \pm \frac{\lambda}{2}$)
- Therefore, if a film 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.

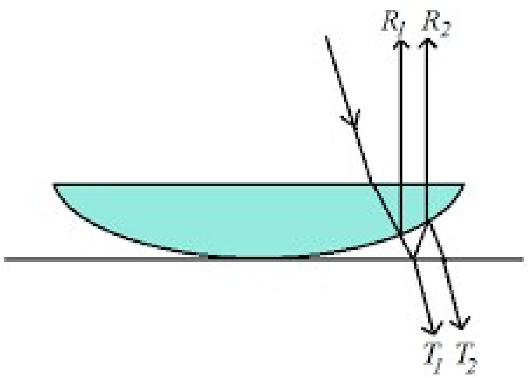
# Interference due to thin films of non uniform thickness (Wedge shaped film)

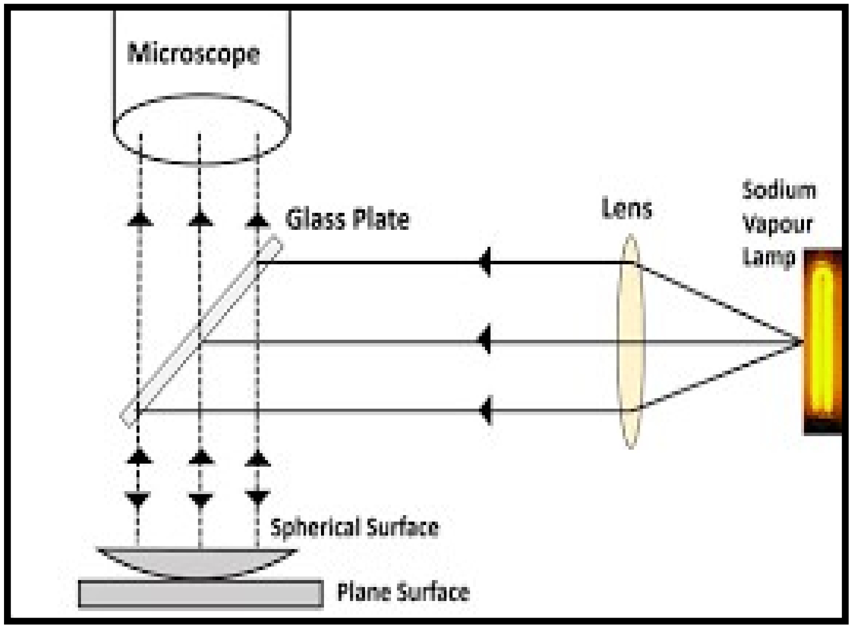


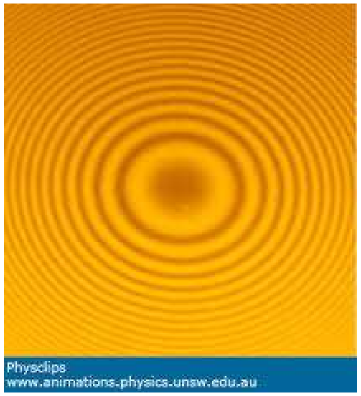



# Interference due to thin films of non uniform thickness (Newton's ring)




$$D_n^2 = 4nR\lambda$$

$$D_{n+p}^2 = 4(n+p)R\lambda.$$

Diameter for the dark ring

1) A parallel beam of light of wavelength 6000 Å is incident on a plain transparent film of R.I 1.5 If the angle of refraction is 28°. Find thickness of the film if it appears bright in the reflected light. Take $n = 1$.

2) A soap film of R.I. 1.33 and thickness $1.5 \times 10^{-5}$ cm is illuminated by light incident at $30^0$. Light reflected from it shows a dark band in the $2^{nd}$ order. Calculate wavelength of corresponding dark band.

3) A parallel beam of light falls normally on an oil film of R.I. 1.25. Complete destructive interference is observed for wavelengths 5000 Å and 6000 Å and for no wavelength in- between Find the thickness of the oil.

4) White light falls normally on a soap film ($\mu = 1.33$) of thickness 3800 Å. Which wavelength/s within the visible spectrum (4000 – 7000 Å) will be intensified in the reflected light?

5) A parallel beam light falls normally on an oil film of R.I. 1.2 having uniform thickness which is spread on water (R.I. 1.33). Brightness is obtained for wavelengths 5000 Å and 7500 Å and for no wavelength in-between. Find thickness of the oil film.