Wave Optics

→ $\Delta\phi = \frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{\lambda}(\mu\Delta x)$ if med. other than air w.r.t. 1

→ $\vec{y}_{res} = \vec{y}_1 + \vec{y}_2 + \dots + \vec{y}_n$, $y_{res} = A\cos(\omega t+\phi) = R\cos(\omega t+\phi)$

→ $A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$ $\quad I \propto A^2 \propto (\text{slit width})^2$

for cohrent source

$I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$,

for incohrent source

$I = I_1 + I_2 + \dots + I_n$

→ When $\Delta\phi = 0°$ or $360°$ → constructive interference

$A_{max} = A_1 + A_2$, $I_{max} = [\sqrt{I_1} + \sqrt{I_2}]^2$

→ When $\Delta\phi = 180°$ → destructive interference

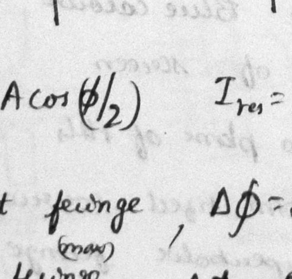
$A_{min} = A_1 - A_2$, $I_{min} = [\sqrt{I_1} - \sqrt{I_2}]^2$

$$\frac{A_{max}}{A_{min}} = \frac{A_1+A_2}{A_1-A_2} \qquad \frac{I_{max}}{I_{min}} = \frac{[\sqrt{I_1}+\sqrt{I_2}]^2}{[\sqrt{I_1}-\sqrt{I_2}]^2} \qquad \frac{A^2_{max}}{A^2_{min}} = \frac{(A_1+A_2)^2}{(A_1-A_2)^2}$$

→ $I_{avg} = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\langle\cos\phi\rangle$ but for long time $\langle\cos\phi\rangle = 0$

$I_{avg} = \frac{I_{max}+I_{min}}{2}$

→ **I. YDSE**



$\Delta x = d\sin\theta \simeq d\tan\theta = \frac{yd}{D} = \sqrt{D^2+d^2} - D$

$\Delta x = (\mu_r - 1)t$

$\Delta\phi = \frac{2\pi}{\lambda}(\Delta x)$

$R_{res\,amp} = 2A\cos(\phi/2)$ $\quad I_{res} = 4I_0\cos^2(\phi/2)$

→ Bright fringe (max), $\Delta\phi = 2n\pi$, $\Delta x = n\lambda$ $\quad I_{max} = 4I_0$

$y_n = \frac{n\lambda D}{d}$

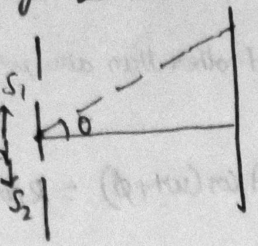
→ Dark fringe (min), $\Delta x = \frac{(2n-1)\lambda}{2}$, $\Delta\phi = (2n-1)\pi$, $I_{min} = 0$

$y_n = \frac{(2n-1)\lambda D}{2d}$

→ Band width (or) fringe width $\quad \beta = \frac{\lambda D}{d}$

if YDSE conducted in other than air medium $\quad \beta_{med} = \frac{\beta_{free}}{\mu}$

Angular fringe width (θ)



$$\theta = \frac{y}{D} = \frac{\lambda}{d} = \frac{\beta}{D}$$

$$\theta_{med} = \frac{\theta_{free}}{\mu}$$

b = size of object
l = distance of object fr
λ = wavelength of light

→ If $\frac{b^2}{l\lambda} >>> 1$ then geometrical optics is satisfied.

Validity of Ray optics $Z_f = \frac{a^2}{\lambda}$

→ If $\frac{b^2}{l\lambda} < 1$ or $\frac{b^2}{l\lambda} \simeq 1$ then wave optics is satisfied.

→ If n_1 fringes are observed with light of wavelength λ_1 & n_2 fringes are observed with light of wavelengths λ_2 (bright bands)

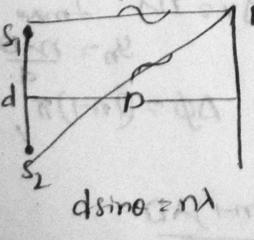
$$n_1\lambda_1 = n_2\lambda_2 \qquad n_1\beta_1 = n_2\beta_2$$

min. $\quad n_1\lambda_1 = (2n_2 - 1)\lambda_2$

→ If white light ray is used in YDSE then all colours travels equally towards the centre of screen & hence white coloured fringe is formed at centre of screen.

→ $\lambda_R > \lambda_B$. Red colour fringe is formed far away from centre of screen. Blue colour fringe is visible nearer to centre of screen.

→ Screen placed ||el to plane of slits

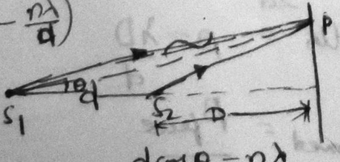


$d\sin\theta = n\lambda$

If point sized sources are used hyperbolic fringe is formed

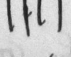
If cylindrical size

$y_{max} = D\sqrt{2\left(1 - \frac{n\lambda}{d}\right)}$



$d\cos\theta = n\lambda$

pointsize - concentric



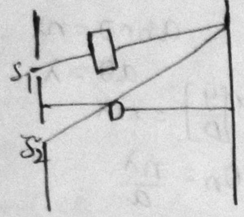
cylindrical

→ Visibility (V) $= \dfrac{I_{max} - I_{min}}{I_{max} + I_{min}} = \dfrac{2\sqrt{I_1}\sqrt{I_2}}{I_1 + I_2}$ $0 \le V \le 1$

$I_{max} = I_{min}$, $\Rightarrow V = 0$ we can't observe dark & bright fringes clearly.

$I_{min} = 0$, $\Rightarrow V = 1$ we can observe dark & bright fringe clearly.

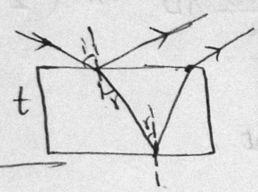
→ Lateral displacement of fringes:



$y = \dfrac{(\mu-1)tD}{d} = \dfrac{(\mu-1)t\beta}{\lambda}$, $\beta = \dfrac{(\mu-1)tD}{d}$

no of fringes shifted $n = \dfrac{(\mu-1)t}{\lambda}$

Interference in thin films:



$2\mu t\cos r = \cancel{[n+1/2]\lambda} = [2n-1/2]\lambda$ $n = 1,2,3,\ldots$
max max

$2\mu t\cos r = n\lambda \Rightarrow n = 0,1,2,\ldots$
min

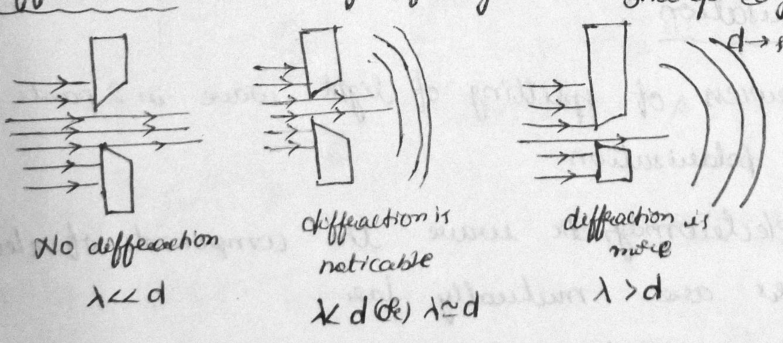
→ Finding no of maxima in YDSE

$d\sin\theta = n\lambda \Rightarrow \sin\theta = \dfrac{n\lambda}{d}$

$-1 \le \dfrac{n\lambda}{d} \le 1 \Rightarrow \dfrac{-d}{\lambda} \le n \le \dfrac{d}{\lambda}$ - minima is formed b/w 2 maxima.

II. Diffraction - bending of light at sharp edges.

d → slit width

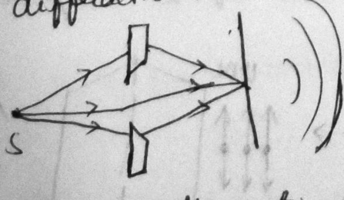


No diffraction $\lambda << d$

diffraction is noticable $\lambda < d$ (or) $\lambda \simeq d$

diffraction is more $\lambda > d$

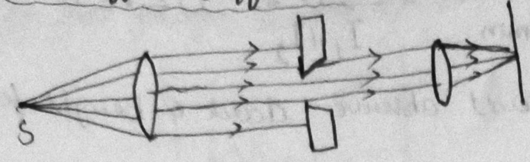
→ Fresnel diffraction:



$\dfrac{b^2}{l\lambda} \simeq 1$ source & screen are very close

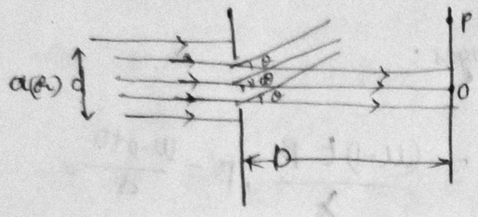
Mathematical approach is difficult.

Fraun-Hoffer diffraction:



$$\frac{b^2}{d\lambda} < 1$$

Single slit diffraction:



$$\Delta x = a\sin\theta = a\tan\theta = a\left[\frac{y}{D}\right]$$

$$a\sin\theta = n\lambda$$

$$a\theta = \lambda$$

$$a\sin\theta = a\tan\theta = a\left[\frac{y}{D}\right] = n\lambda$$

for n^{th} order minima $y_n = \frac{n\lambda D}{a}$ $\quad \theta_n = \frac{n\lambda}{a}$

for n^{th} order maxima $a\sin\theta = \left[\frac{2n+1}{2}\right]\lambda$

$$y_n = \frac{(2n+1)}{2a}\lambda D \quad \theta_n = \left(\frac{2n+1}{2}\right)\frac{\lambda}{a}$$

$$\text{Resolving power} = \frac{1}{\text{Resolving limit}}$$

Human eye $\theta = 1'$ => limit

Telescope $\theta = \frac{1.22\lambda}{d}$ "

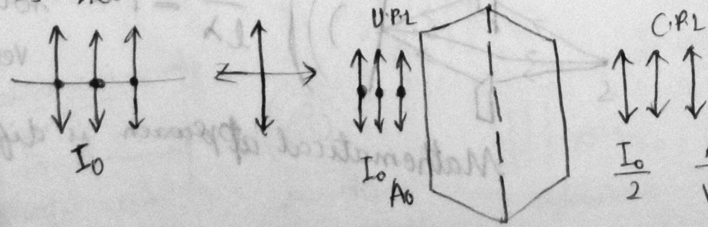
Microscope $\theta = \frac{0.61\lambda}{\mu\sin\alpha}$ "

III. Polarisation:

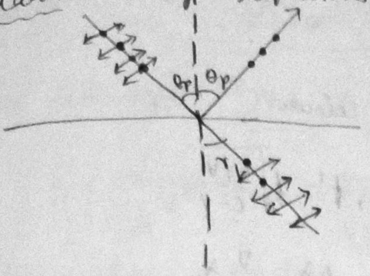
→ The process of splitting of light wave in 2 parts is known as polarisation.

→ In electromagnetic wave the components of electrical vectors are mutually ⊥ar

→ Unpolarised light (UPL) consists of 2 components 1 is ⊥ar & other is ‖el.

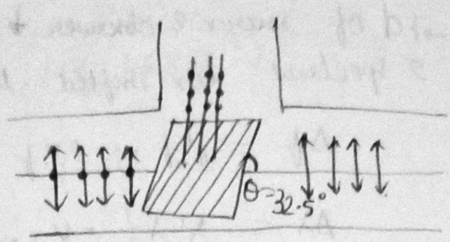


→ Polarisation by reflection

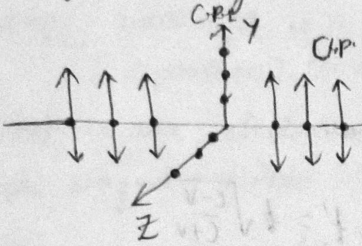


$$\tan\theta_p = {}_1\mu_2$$

by refraction



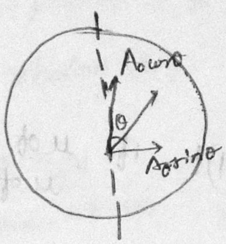
by scattering



degree of polarisation depends on the angle of scattering

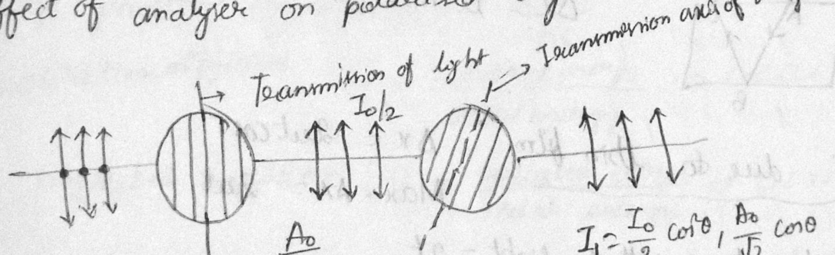
→ Effect of polariser on polarised light:

only I polariser



$$I = \frac{I_0}{2} \quad A = \frac{A_0}{\sqrt{2}}$$

→ Effect of analyser on polarised light



$\frac{A_0}{\sqrt{2}}$

$$I_1 = \frac{I_0}{2}\cos\theta, \quad \frac{A_0}{\sqrt{2}}\cos\theta$$

$$I_2 = \frac{I_0}{2}\cos^2\theta_1 \cos\theta_2 \quad A = \frac{A_0}{\sqrt{2}}\cos\theta_1 \cos\theta_2$$

$$I = \frac{I_0}{2}\cos^{2(n-1)}\theta$$

Brewster's law

Doppler effect

1. d change ν, λ also changes.
2. Doppler effect in sound is asymmetric. In light is symmetric
3. Only blue & red shifts are possible

→ Blue shift

→ 1. d of source & observer ↓ ν ↑ λ ↓

2. Spectral line shifted to blue & violet colour

$$\Delta f = f' - f = +\frac{v}{c} f \Rightarrow f' = f\left[1 + v/c\right] \quad , \quad f' = f\sqrt{\frac{c+v}{c-v}}$$

$$\Delta\lambda = \lambda' - \lambda = -\frac{v}{c}\lambda \Rightarrow \lambda' = \lambda\left[1 - \frac{v}{c}\right] \quad , \quad \Delta\lambda = \frac{v}{c}\lambda$$

→ Red shift

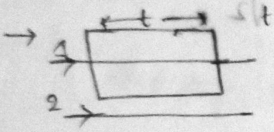
1. d of source & observer ↑ ν ↓ & λ ↑

2. Spectral line shifted to red colour

① $\Delta f = f' - f = -\frac{v}{c} f \Rightarrow f' = f\left[1 - \frac{v}{c}\right] \quad , \quad f' = f\sqrt{\frac{c-v}{c+v}}$

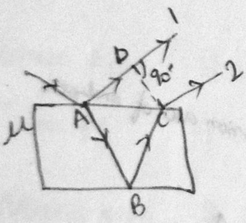
② $\Delta\lambda = \lambda' - \lambda = +\frac{v}{c}\lambda \Rightarrow \lambda' = \lambda\left[1 + \frac{v}{c}\right]$

→ Interference

→  t = thickness

$\Delta x = (\mu - 1)t$

$\Delta x = \left(\frac{\mu_2}{\mu_1} - 1\right)t$ if μ of slab $= \mu_2$, μ of med. $= \mu_1$

→ 

$\Delta x = \mu(ABC) - AD$ $\quad \boxed{t = n\lambda}$

⇒ YDSE due to thin film

$\Delta x = 2\mu t \cos r$

Max. $\Delta x = 2\mu t$

(I) Due to transmitted light $= 2t$

i) Bright fringe $\quad 2\mu t \cos r = n\lambda, n = 1, 2, 3, \ldots$

ii) dark fringe $\quad 2\mu t \cos r = (2n-1)\lambda/2, n = 1, 2, 3, \ldots$

(II) Due to reflection

i) Bright fringe $\quad 2\mu t \cos r + \lambda/2 = n\lambda, n = 1, 2, 3, \ldots$

$2\mu t \cos r = (2n-1)\lambda/2, n = 1, 2, 3, \ldots$

ii) dark fringe $\quad 2\mu t \cos r + \lambda/2 = (2n+1)\lambda/2, n = 0, 1, 2, \ldots$

$2\mu t \cos r = n\lambda, n = 1, 2, 3, \ldots$

→ for scattering size of obstacle should be smaller than wavelength, and here