OPTICS

PART 1

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SHORT NOTES

optics

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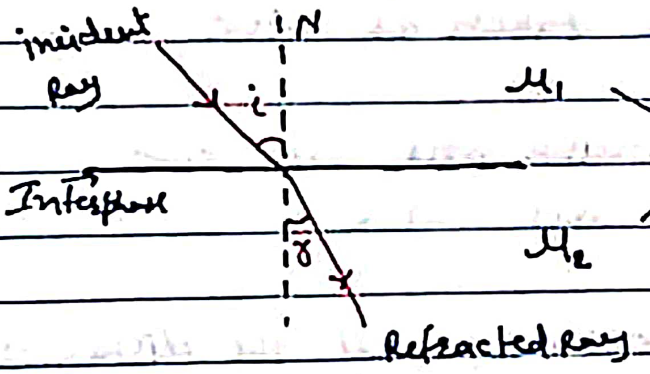
Fermat principle :- out of all possible paths that it might take to get from one point to another, light takes the path which requires the shortest time.

Laws of Reflection
1. incident ray, reflected Ray and normal lies in the same plane
2. incident angle = Reflection angle , $\angle i = \angle r$

Snell's law of Refraction

$$\boxed{\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = \mu_{21}}$$



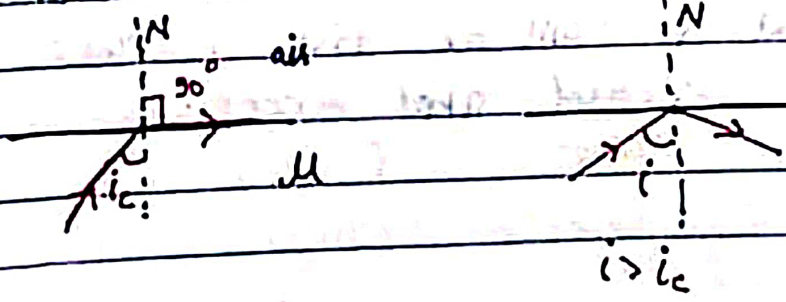
μ_1, μ_2 → Refractive index of mediums

→ in Reflection phenomenon no change in ν, v, and λ
→ in Refraction phenomenon no change in ν (frequency)

Critical angle :- value of incident angle for which Refracted angle is 90°

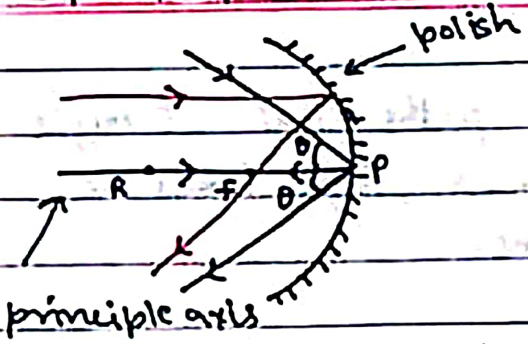
$$\boxed{i_c = \sin^{-1}\left(\frac{1}{\mu}\right)}$$

Total internal Reflection
when $i > i_c$ then refracted Ray, reflects in same medium. i.e turns back in same medium.

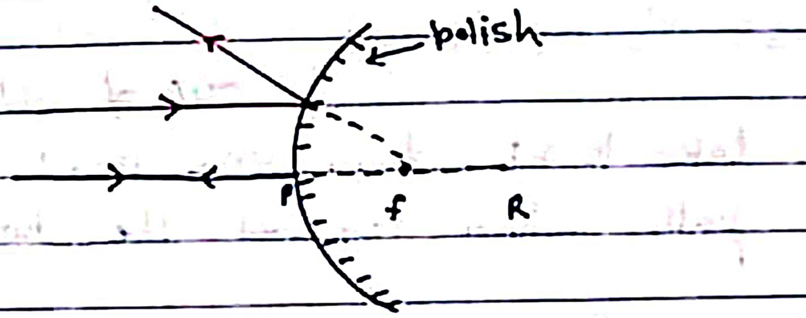


Total internal reflection occurs only when light incident from a dense media to rare media

Spherical mirrors



concave mirror (converging)



Convex mirror (diverging)

Sign Convention

1. all the distances in the direction of incident light are taken as +ive, and opposite to dir^n of incident light are taken as –ive

2. all heights above the principle axis are +ive. and below the principle axis –ive

NOTE:- You have to start measuring all the distances from pole of mirror or (lens).

mirror formula

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

f = focal length
u = object distance
V = image distance

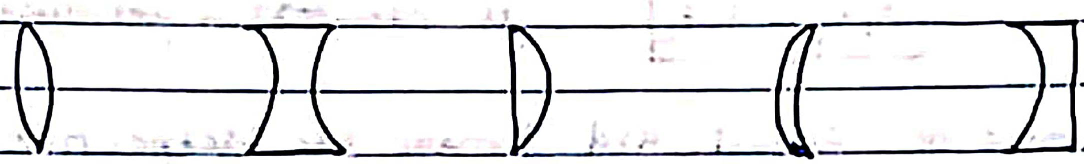
magnification

$$m = \frac{h'}{h} = -\frac{V}{u}$$

NOTE1:- Focal length of plane mirror is "∞"

NOTE2 – When magnification will be –ive then nature of image will be Real and inverted and when magnification will be +ive nature of image will be virtual and erect.

Lens : Combination of two refracting surfaces



Biconvex — Biconcave — planoconvex — Convexo Concave — plano concave

Lens formula

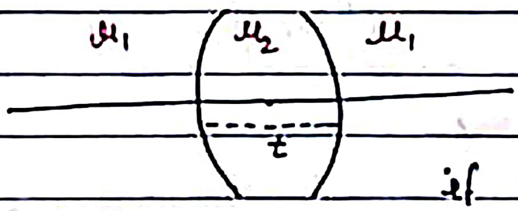
$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

→ images from convex lens are same as for concave mirror and that of concave lens are same as for convex mirror

Refraction at a spherical surface -

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

⇒ Refraction through thick lens and its focal length



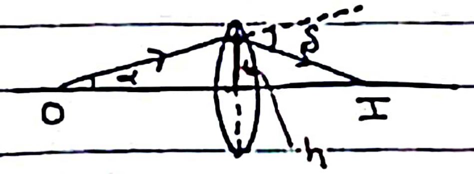
$$\frac{1}{f} = (\mu_2 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(\mu_2 - 1)t}{\mu_2 R_1 R_2}\right]$$

if $t = 0$ then for thin lens :-

$$\frac{1}{f_0} = (\mu_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

lens maker formula →

Deviation produced by a thin lens



$$\delta = \frac{h}{f}$$

* Combination of two thin lens separated by a distance d

$$f = \frac{f_1 f_2}{f_1 + f_2 - d}$$

position of equivalent lens from first lens

$$\alpha_1 = \frac{fd}{f_2}$$

from 2nd lens

$$\alpha_2 = -\frac{fd}{f_1}$$

Newton's formula and Other Relation

$$\boxed{x_1 x_2 = f_1 f_2}$$ is Newton's formula

here distance of object and image are respectively x_1 and x_2 taken from focal points.

Relation betw^n focal lengths $\quad -\frac{f_1}{f_2} = \frac{\mu_1}{\mu_2}$

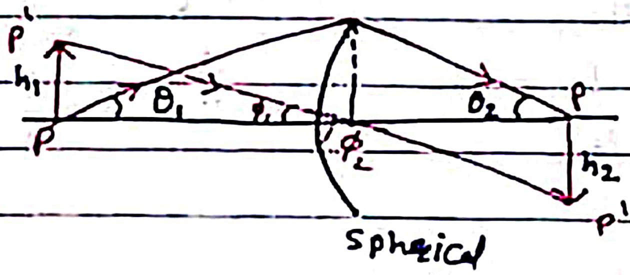
Transverse magnification/lateral

$$\boxed{m_t = h'/h = \frac{\mu_1}{\mu_2}\frac{v}{u}}$$

Axial or Longitudanal magnification $\quad \boxed{m_a = \frac{\mu_1}{\mu_2}\left(\frac{v^2}{u^2}\right)}$

Angular magnification $\quad \boxed{m_\theta = \frac{\sin\theta_2}{\sin\theta_1} = \frac{\mu_1 h_1}{\mu_2 h_2}}$

Langrange's law or Helmholtz's Relation



$$\boxed{\mu_1 h_1 \tan\theta_1 = \mu_2 h_2 \tan\theta_2}$$

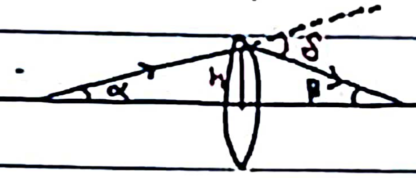
Focal length when lens is immersed in a liquid

$$\frac{1}{f_{liq}} = \left(\frac{n_{glass}}{n_{liq}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\boxed{{}_l n_g = n_g / n_l}$$

$$\boxed{f_{liq} = \frac{({}_a n_g - 1)}{({}_l n_g - 1)} \times f_{air}}$$

Deviation produced by a thin lens



$$\delta = h/f$$

Apparent depth

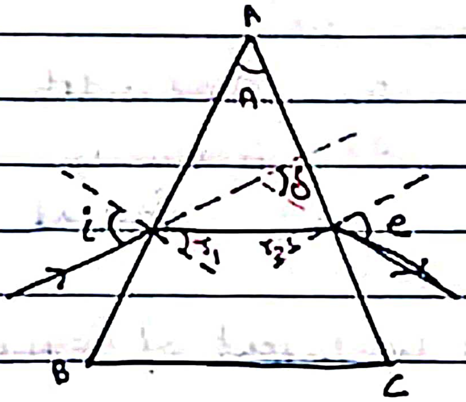
$$d' = d/n_{relative}$$

Ex:. Coin in a Beaker of water

$d \rightarrow$ distance of object from the interface = real depth

$d' \rightarrow$ distance of Image from the interface = apparent depth

- Refraction through prism –



$$\delta = i + e - A$$

if inside Ray parallel to Base

$r_1 = r_2 = r$ (say) and $\delta \rightarrow D_m$

$$r = \frac{A}{2}$$

$$n_{21} = \frac{\sin[(A+D_m)/2]}{\sin A/2}$$

$$i = \frac{A + D_m}{2}$$

$$D_m = (n_{21} - 1)A$$

n_{21} is refractive index, A is angle of prism

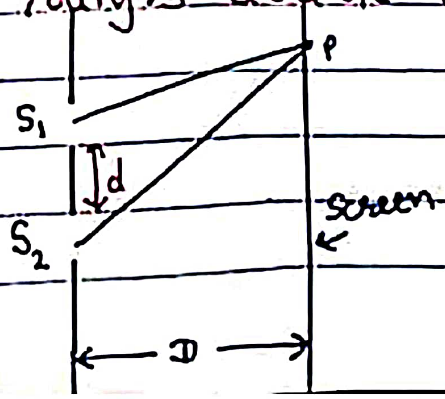
D_m is deviation angle

Interference

Resultant intensity ~~$I = (\sqrt{I_1} + \sqrt{I_2})$~~

$$I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(\times\Delta - \phi)$$

Young's double slit experiment



Constructive	Destructive
$\Delta = n\lambda$	$\Delta = (n + 1/2)\lambda$
$\phi = 2n\pi$	$\phi = (2n+1)\pi$
$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$	$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$
$I_{max} = 4I_0$,	$I_{min} = 0$ [if $I_1 = I_2 = I$

here Δ is path difference and ϕ is phase difference.

position of n^{th} fringe in

Constructive

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

distructive

$$x_n = (n+\tfrac{1}{2})\frac{\lambda D}{d}$$

fringe width $\beta = \frac{\lambda D}{d}$ same for both

* Coherence length L, Coherence time 'Δt'

$$L = c\,\Delta t = \frac{c}{\Delta \nu} = \frac{\lambda^2}{\Delta\lambda}$$

$\Delta\lambda$ = Band width
$\Delta\nu$ = frequency spread

$$Q = \frac{\nu}{2\Delta\nu}$$ accuracy coefficient of source

Coherent Sources:- when phase difference of waves obtained from two sources at any point does not change with time then sources are called Coherent source.

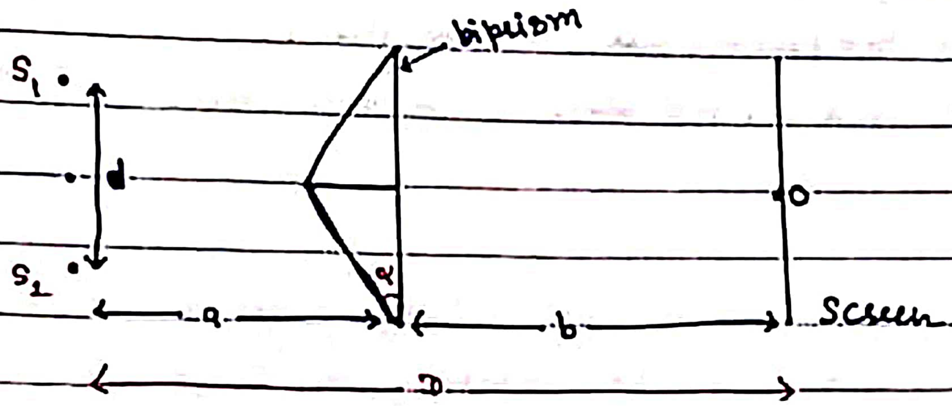
there are 2 methods to obtain Coherent Source

1. by division of wavefront
   Ex → fresnel's biprism, Young's double slit, fresnel's lens
2. by division of Amplitude
   thin film, Newton's Rings, Michleson's morley

→ point source or narrow source needed

→ Extended Source needed

Fresnel's biprism :- (Arrangement)



⇒ finding wavelength of monocromatic light by Fresnel's biprism

$$\lambda = \frac{\beta d}{D} = \frac{2\beta \alpha a(\mu-1)}{(a+b)}$$

$$d = 2a\alpha(\mu-1)$$

⇒ determination of thickness of thin sheet of transparent material :- put that sheet betwn the path of one of the source (S_1 or S_2) in biprism arrangement. then path difference

$$\Delta = \frac{xd}{D} = t(\mu-1)$$

[x is distance from centre of Screen to observation point on Screen)

So now on putting sheet central fringe shifts towards n^{th} bright fringe then

$$t = \frac{n\lambda}{\mu-1}$$

if central fringe shifts towards dark fringe →

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

t is thickness of that sheet.

Interference in thin films :-

$$r = \frac{\mu-1}{\mu+1}$$

Due to transmitted Rays		Due to Reflected Rays	
Constructive	distructive	Constructive	distructive
$2\mu t\cos r = n\lambda$	$2\mu t\cos r = (n+\frac{1}{2})\lambda$	$2\mu t\cos r = (n+\frac{1}{2})\lambda$	$2\mu t\cos r = n\lambda$

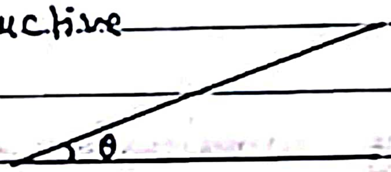
→ Infinitely thin film acts as non Reflecting Surface
for reflected Rays — distructive
for transmitted Rays — Constructive

$\boxed{r^2+t^2=1}$ important Relation

✳ Interference due to a thin wedge-shaped film

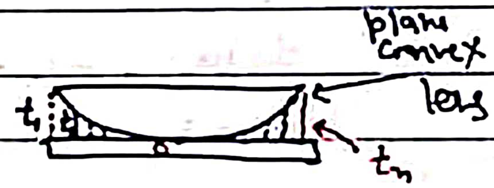
$$2\mu t\cos\theta = \left(n+\tfrac{1}{2}\right)\lambda$$ for Constructive

$$2\mu t\cos\theta = n\lambda$$ for distructive



fringe width $\beta = \frac{\lambda}{2\mu\sin\theta}$

Newton's Rings



Due to transmitted Rays		Due to Reflected Rays	
Constructive	Distructive	Constructive	Distructive
$2\mu t_n = n\lambda$	$2\mu t_n = (n+\frac{1}{2})\lambda$	$2\mu t_n = (n+\frac{1}{2})\lambda$	$2\mu t_n = n\lambda$
$r_n = \sqrt{\frac{n\lambda R}{\mu}}$	$r_n = \sqrt{(n+\frac{1}{2})\frac{\lambda R}{\mu}}$	$r_n = \sqrt{(n+\frac{1}{2})\frac{\lambda R}{\mu}}$	$r_n = \sqrt{\frac{n\lambda R}{\mu}}$
Central fringe bright		Central fringe dark	

$$t = \frac{r^2}{2R}$$

r → Radius of Ring

R → Radius of Curvature of plane Convex lens

t → thickness of film

r_n = n^{th} ring's Radius (fringe)

Determination of wavelength

$$\lambda = \frac{D_{n+p}^2 - D_n^2}{4pR}\,\mu$$

Determination of Refractive index

$$\mu = \frac{D_{n+p}^2 - D_n^2}{D'^2_{n+p} - D'^2_n}$$ for air / for liquid