YBN University, Ranchi

Geomtrical optics

Optics ⇒ The branch of Physic which deals with the study of phenomeon realted to light.

Ex ⇒ Light, reflection, Dispersion, diffraction

Type of optics

(i) Physical optics
(ii) Geomtrical optics

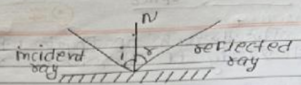
(i) Physical optics ⇒ It deals with the phenomeon based on the nature of light weather wave ~~or~~ particle or nature.

Ex ⇒ Interference, diffraction etc

(ii) Geomtrical optics ⇒ It is realted to study of optical instrument without taking into account of nature of light.

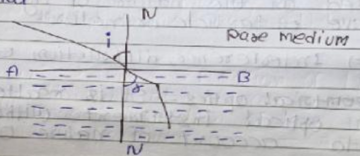
Ex ⇒ It becoming only reflection and refraction.

Reflection of Light ⇒ Reflection of Light is the phenomeon of bouncing back of light in the same medium on the surface of any object. In reflection path of light ray change without any change in medium.

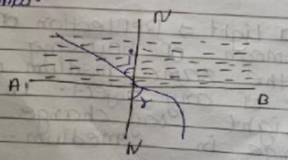


Reflection of Light ⇒ When Light passes from one to another medium then it deviate from its original path. So, this phenomen is called reflection of light.

When Light passes from rare medium to denser medium then it bends towards the normal.



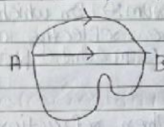
When Light passes from denser medium to rare medium then it go away the normal.



Fermat's Principle

In 1658, Pierre De Fermat a French mathmatician started that " a ray of Light is passing from one point to another point through a set of media by any member of reflection or refractions choose a path along which the time taken is minimum or least"

It is also know as last time.



Based on this principle the law of rectelinear propogation, the law of reflection can be derived. However in some cases it have been Found by time taken but light is not minimum but maximum or else. It is neither maximum not minium but it is stationary constant. There Fore modify form of fermant's principle of list time is know as Fermat's principle of stationary time or fermat's principle of extermium which may be state as Forever.

* Fermat's principle of stationary time or Fermat principle of exteriem path

A ray of Light passing from one point to another point through a set of medium by any member of reflection or refraction choose a path for which the time taken is either minimum or maximum or stationary time.

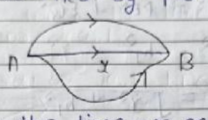
Notes:- (i) Minium:→ In which case a ray of Light plane reflecting or refracting plane through from one point to second point.

(ii) Maximum: → When refraction of Light passing through a concave & convex lense Image formation of lens time taken is maximum.

(iii) Stationary: → When reflection through eliplitical reflector.

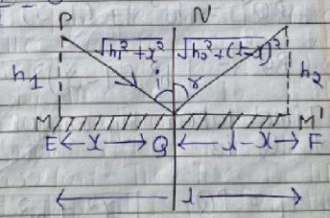
Derivation of law of reflection from fermat's principle:-

Fermat's Principle states that light travel b/w two points along the path that requires the least time as compared to the other near by paths.



To minimize the time we set the derivative of the time with respect to 'x' is equal to zero.

i.e, $\frac{dt}{dx} = 0$



Consider a plane reflecting surface MM' 4 ray of light starting from point 'P' reflects off the surface MM' at point Q before arriving at point R.

Let $PE = h_1$, $RF = h_2$
Let $EF = l$ & $EQ = x$

then $QF = (l - x)$

From right angled ΔPEQ we have

$$PQ^2 = PE^2 + EQ^2$$

$$PQ^2 = h_1^2 + x^2$$

$$PQ = \sqrt{x^2 + h_1^2} \quad \text{--- (i)}$$

From right angle ΔRFQ we have

$$RQ^2 = RF^2 + FQ^2$$

$$RQ^2 = h_2^2 + (l - x)^2$$

$$RQ = \sqrt{h^2 (l - x)^2} \quad \text{--- (ii)}$$

Time taken by ray of light from P to Q is

$$t_1 = \frac{PQ}{c} \sqrt{\frac{x^2 + h_1^2}{c}} \quad \text{--- (iii)}$$

Time taken by ray of light from Q to R is given by

$$t_2 = \frac{QR}{c}$$

$$t_2 = \frac{h_1^2 + (l-x)}{c} \quad -(iv)$$

Total time taken by ray of light ~~to~~ in travelling from point P to R after reflection at point Q from reflecting surface MM' is given by

$$t = t_1 + t_2$$

$$t = \sqrt{\frac{h_1^2 + x^2}{c}} + \sqrt{\frac{h_2^2 + (l-x)^2}{c}}$$

To minimize the time use set the derivates of time w.r.t 'x' equal to zero.

$$\frac{dt}{dx} = \frac{\cancel{2}x}{\cancel{2}c\sqrt{h_1^2+x^2}} + \frac{\cancel{2}(l-x)(-1)}{\cancel{2}c\sqrt{h_2^2+x^2}} = 0$$

$$\frac{dt}{dx} = \frac{x}{c\sqrt{h_1^2+x^2}} - \left(\frac{(l-x)}{c(h_2^2+(l-x)^2}\right) = 0$$

$$\frac{dt}{dx} = \frac{1}{c}\frac{x}{\sqrt{h_1^2+x^2}} - \frac{(l-x)}{\sqrt{h_2^2+(l-x)^2}} = 0$$

$$\frac{x}{h_1^2+x^2} - \frac{(l-x)}{\sqrt{h_2^2+(l-x)^2}} = 0$$

$$\frac{x}{\sqrt{h_1^2+x^2}} = \frac{l-x}{\sqrt{h_2^2+(l-x)}}$$

$\sin i = P/H$

$= \frac{x}{\sqrt{h_1^2+x^2}}$

$$\boxed{\sin i = \sin r}$$

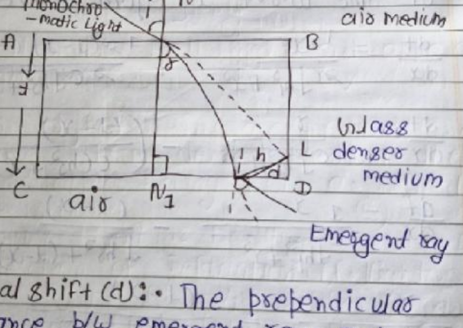
$\boxed{i = r}$ Proved.

$\sin r = P/H$

$= \frac{l-x}{\sqrt{(h_2)^2+(l-x)^2}}$

* Refraction of light through thin glass plate

When monochromatic light is incident on thin glass plate then refraction takes place as shown in figure



Lateral shift (d) :- The prependicular distance b/w emergent ray and incident ray is called Lateral shift.

Expression For lateral shift

In Δ PNL

$\sin(i+r) = PL/PN$

$\sin(i-r) = d/PN$

$\therefore d = PN \sin(i-r)$ — (i)

In Δ PNN'

$\cos x = \dfrac{NN'}{PN}$

$\cos r = \dfrac{t}{PN}$

$\Rightarrow PN \cos r = t$

$\Rightarrow PN = \dfrac{t}{\cos r}$

$\therefore PN = t \sec r$

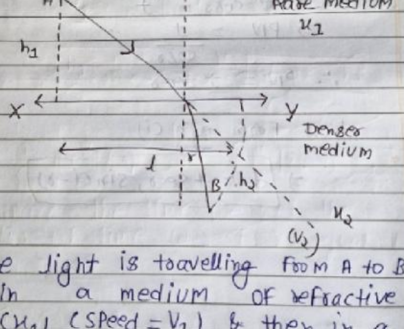
Now From eqn (i)

$\Rightarrow \boxed{d = t\sec r, \sin(i-r)}$

Derivation of law of refraction from fermat's principle :-

"Fermat's principle states that light travel b/w two points along the path that require the least time as compared to the other nearly paths"

To minmize the time we set the derivative of the time with respect to 'x' is equal to zero i.e, $\frac{dt}{dx} = 0$



In Figure light is travelling from A to B First in a medium of refractive Index (μ_1) (Speed = V_1) & then in a medium of refractive index (μ_2) (Speed = V_2) through point p.

Time taken by ray of light is travelling to 'A' to 'P' is given ~~by~~ $t_1 = \frac{AP}{v_1}$

$$\therefore t_1 = \frac{AP}{v_1}$$

$$t_1 = \frac{\sqrt{(AE)^2 + (EP)^2}}{v_1}$$

$$= \frac{\sqrt{(h_1)^2 + (x)^2}}{v_1} \quad \text{— (i)}$$

Time taken by ray of light travelling from P to B is given

$$t_2 = \frac{PB}{v_2}$$

$$= \frac{\sqrt{(PF)^2 + (BF)^2}}{v_2}$$

$$= \frac{\sqrt{(l-x)^2 + (h_2)^2}}{v_2} \quad \text{— (ii)}$$

Total time taken by ray of light is travelling from A to B after refraction at point 'P' is given by

$$t = t_1 + t_2$$

$$t = \frac{\sqrt{(h_1)^2 + (x)^2}}{v_1} + \frac{\sqrt{(l-x)^2 + (h_2)^2}}{v_2} \quad \text{— (iii)}$$

$$\mu_1 = \frac{c}{v_1} \Rightarrow v_1 = \frac{c}{\mu_1} \quad \text{— (iv)}$$

$$\left[\text{Refractive index} = \frac{\text{Velocity of Light in air}}{\text{Velocity of Light in medium}} \right]$$

Similarly, $\mu_2 = \frac{c}{v_2} \Rightarrow v_2 = \frac{c}{\mu_2}$ — (v)

Using eq (4) & (5) in eq^n (3)

$$t = \frac{\sqrt{(h_1)^2 + (x)^2}}{c/\mu_1} + \frac{\sqrt{(l-x)^2 + (h_2)^2}}{c/\mu_2}$$

$$t = \frac{\mu_1\sqrt{h_1^2 + x^2}}{c} + \frac{\mu_2\sqrt{(l-x)^2 + h_2^2}}{c}$$

$$t = \frac{1}{c}\left(\mu_1\sqrt{h_1^2 + x^2} + \mu_2\sqrt{(l-x)^2 + h_2^2}\right)$$

To minimize the time we set the derivation of time w.r.t x equal to zero.

$$\frac{dt}{dx} = \frac{1}{c}\left(\mu_1 \frac{1}{2} \cdot \frac{2x}{\sqrt{h_1^2 + x^2}} + \mu_2 \cdot \frac{1}{2} \frac{2(l-x)(-1)}{\sqrt{(l-x)^2 + h_2^2}}\right) = 0$$

$$= 1/c \left[\mu_1 \frac{x}{\sqrt{h_1^2 + x^2}} - \mu_2 \frac{(l-x)}{\sqrt{(l-x)^2 + h_2^2}} \right] = 0$$

$$\Rightarrow \mu_2 \frac{x}{\sqrt{h_1^2 + x^2}} - \frac{\mu_2 (l-x)}{\sqrt{(l-x)^2 + h_2^2}} = 0$$

$$= \mu_2 \frac{x}{\sqrt{h_1^2 + x^2}} - \frac{\mu_2 (l-x)}{\sqrt{(l-x)^2 + h_2^2}} = 0$$

$$= \mu_2 \frac{x}{\sqrt{h_1^2 + x^2}} - \frac{\mu_2 (l-x)}{\sqrt{(l-x)^2 + h_2^2}} = 0$$

$\sin i = \frac{P}{h} = \frac{x}{\sqrt{(h_1)^2 + (x)^2}}$ $\sin r = \frac{P}{h} = \frac{l-x}{\sqrt{(l-x)^2 + (h_2)^2}}$

$\Rightarrow \boxed{\mu_1 \sin i = \mu_2 \sin r}$ which is snell's law of rotation.

Hence proved.

* Refractive index ⇒ The ratio of velocity of light in vaccum to the velocity of light in medium is called refractive index of that medium.

i.e, $\mu = \frac{c}{v}$

Where, c = Speed of light (3×10^8 m/s)
v = Velocity of light in a medium

Refractive index is unit less and dimensionless quantity. It's value is different in different medium.

e.g., μ air = 1
Water = 4/3
Glass = 3/2
Diamond = 2.42

Note:- Refractive index of dense medium is greater than that of rare medium.

Realtive refractive index ($_1\mu_2$):-

When light passes from one medium to another medium the refractive index of medium ② with respect to medium ① is written as:

$$_1\mu_2 = \frac{\mu_2}{\mu_1}$$

Eg → $_w\mu_g = \frac{\mu_g}{\mu_w} = \frac{3/2}{4/3} = \frac{3}{2} \times \frac{3}{4} = \frac{9}{8}$

$_g\mu_w = \frac{\mu_w}{\mu_g} = \frac{4/3}{3/2} = \frac{4}{3} \times \frac{2}{3} = \frac{8}{9}$

critical angle ⇒ when light incident from dense medium of the refracting surface in such way that angle of refraction becomes 90° then corresponding angle of incident is called critical angle. It depend upon refractive index of the medium.

V.V.I * Expression for critical angle
Let us consider a light incident from denser medium on the refracting surface and refraction takes place as shown in Figure

According to Snell's law

$$_1\mu_2 = \frac{\sin i}{\sin r}$$

$$_2\mu_1 = \frac{\sin r}{\sin i}$$

where $r = 90°$, then $i = C$

$$\mu = \frac{\sin 90°}{\sin C}$$

where $r = 90°$, then $i = C$

$$\mu = \frac{\sin 90°}{\sin C}$$

$$\mu = \frac{1}{\sin C}$$

∴ critical angle is inversely proportional to the refractive index.

$$\mu \sin C = 1$$

$$\sin C = \frac{1}{\mu}$$

$$\therefore \boxed{C = \sin^{-1}\frac{1}{\mu}}$$

* Total internal reflection

When light incident from denser medium on the ~~st~~ refracting surface at greater angle of critical angle then whole light is reflected back in the same medium so this phenomenon is called Total internal reflection of light.

→ Condition ~~of~~ for TIR :-

(i) The light must travel from denser to rare medium.

(ii) Angle of incidence must be greater than critical angle.

→ Application of TIR of light

i) Air bubble inside the water is more shining.

ii) Diamond is more shining due to TIR of light.

* lateral shift (d)

The prependicular distance between emergent ray and incident ray is called lateral shift.

Expression for lateral shift

In Δ PNL

$$\sin(i-r) = \frac{PL}{PN}$$

$$\sin(i-r) = \frac{d}{PN}$$

$$\therefore d = PN \sin(i-r) \quad \text{— (i)}$$

In Δ PNN'

$$\cos r = \frac{NN'}{PN}$$

$$\cos r = \frac{t}{PN}$$

$$\Rightarrow PN \cos r = t$$

$$\Rightarrow PN = \frac{t}{\cos r}$$

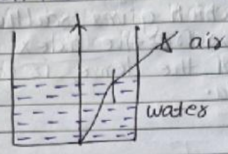
$$\therefore PN = t \sec r$$

Now from eqn (i)

$$\Rightarrow d = t \sec r, \sin(i-r)$$

Realtion b/w real depth and apparent depth:

When object is in denser medium and looking from air medium (rare) then it appear lifted from its original poisition.



$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

Realtion b/w Real height and apparent height

When object is in rare medium and looking from denser medium then object appear away from a normal poisition.

Applications of Refraction of Light

i) Sun appear ovale at the time of sunrise and sunset.

ii) Star appear twinkle.

iii) Straight rod deep in water and looking from air then appear bended.

Q.1 What do you mean by lense maker formula? Derive this formula for thin convex lense?

Solⁿ ⇒ lense maker formula

That formula which gives realtionship b/w focal length, refractive index and radii of curvature of the lense, is called lense making formula.

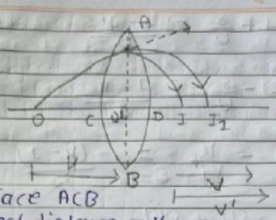
i.e,

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Where f = Focal length of the lense
μ = Refractive index of lense
R_1 & R_2 = radii of curvature

Expression for lense making formula:-

Let us consider a thin convex lense having refractive index 'μ' and radii of curvature of r_1 and r_2. Again we suppose 'O' is a point object where real image ~~at~~ is formed at I by the surface 'ACB'. In this case we assume that surface ADB is disappear.



For surface ACB
Object distance $= u$
Image distance $= v_1$

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

$$\frac{\mu_1}{v_1} - \frac{1}{u} = \frac{\mu - 1}{r_1} \quad \text{— (i)}$$

But actually surface ADB is appeared final image is formed at I. In this case acts as a virtual object

For surface ADB
$\mu_1 = \gamma$
$\mu_2 = 1$
Image distance $= v$
Object distance $= v_1$

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

$$\Rightarrow \frac{1}{v} - \frac{\gamma}{u} = \frac{1-\mu}{R}$$

$$\Rightarrow \frac{1}{v} - \frac{\gamma}{u} = \frac{1-\mu}{r_2}$$

$$\frac{1}{v} - \frac{\mu}{v_1} = -\frac{(\mu-1)}{r_2} \quad \text{— (ii)}$$

equating (i) + (ii)

$$\frac{1}{v} - \frac{1}{u} = \frac{\mu-1}{r_1} - \frac{(\mu-1)}{r_2}$$

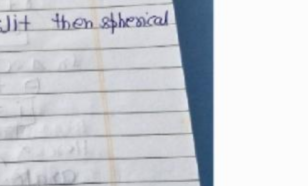
$$\Rightarrow \frac{1}{F} = (\mu-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Wave Front ⇒ The locus of the medium particle around thus show which vibrate in the same phase is called wave front.

Its shape & size depend upon the nature of shows.

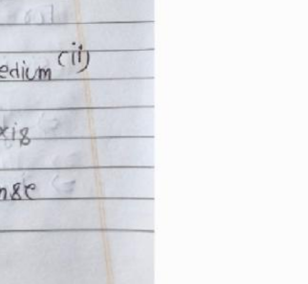
Types of wave Front

i) Spherical wave Front ⇒ When source of light is point then spherical wave front is formed.



(ii) Cylindrical wave Front (WF)

When source of light is as slit then spherical wave form.



(iii) Plane wave Front ⇒ When spherical wave cover large distance then it is called plane wave front.

Refraction by spherical surface:

i) For convex surface

Here $OP \simeq OP'$ object of distance (u) (-)
$PC \simeq P'C$ Radius of curvature (R)
$PI \simeq P'I$ = Image of distance (v)

In Δ QCI

$r + \alpha = \beta$

$\boxed{r = \beta - \alpha}$ — (i)

In Δ OQC

$\theta + \beta = i$

$\boxed{i = \theta + \beta}$

Here α, β, θ i & r are very small angle.

Now, from snell's law

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

∵ for small angle i and r

$\sin i \simeq$ & $\sin r \simeq r$

For small angle i and r,

$\sin i = r$ & $\sin r = r$

$$\Rightarrow \frac{i}{r} = \frac{\mu_2}{\mu_1}$$

$$\Rightarrow i\mu_1 = r\mu_2$$

Now Putting the value of i and r from eq^n (i) & (ii)

$(\theta + \beta)\mu_1 = (\beta - \alpha)\mu_2$

$\Rightarrow \mu_1\theta + \mu_1\beta = \mu_2\beta - \mu_2\alpha$

$\Rightarrow \mu_1\theta + \mu_2\alpha = (\mu_2\beta - \mu_1\beta)$

$\Rightarrow \mu_1\theta + \mu_2\alpha = \beta(\mu_2 - \mu_1)$ — (iii)

Now, $\Delta\, OQP'$

$\tan\theta = \frac{QP'}{OP'} = \frac{QP'}{QP}$

$\because \theta$ is very small angle

$\therefore \tan\theta \simeq \theta$

$\theta = \frac{QP'}{OP}$

Now, In $\Delta\, QCP'$

$\tan\beta = \frac{QP'}{CP'} = \frac{QP'}{CP}$

$\because \beta$ is very small angle

$\tan\beta \simeq \beta$

$\therefore \beta = \frac{QP'}{CP}$

Now, In $\Delta\, QIP'$

$\tan\alpha = \frac{QP'}{IP'} = \frac{QP'}{IP}$

$\because \alpha$ is very small angle

$\therefore \tan\alpha = \alpha$

$\alpha = \frac{QP'}{IP}$

Now Putting the value of α, β in eq^n (iii)

$\mu_1\theta + \mu_2\alpha\,(\mu_2 - \mu_1)\beta$

$\mu_1 \frac{QP'}{OP} + \mu_2 \frac{QP'}{IP} = (\mu_2 - \mu_1)\frac{QP'}{CP}$

$\Rightarrow QP'\left[\frac{\mu_1}{OP} + \frac{\mu_2}{IP}\right] = (\mu_2 - \mu_1)\frac{QP'}{CP}$

$\Rightarrow QP'\left[\frac{r_1}{OP} + \frac{r_2}{IP}\right] = [\mu_2 - \mu_1]\frac{QP'}{CP}$

$\Rightarrow \frac{\mu_1}{OP} + \frac{\mu_2}{IP} = \frac{(\mu_2 - \mu_1)}{CP}$

$\Rightarrow \frac{\mu_1}{-u} + \frac{\mu_2}{v} = \left(\frac{\mu_2 - \mu_1}{R}\right)$

The unit of veregence measurement is diaptor $1D = \frac{1}{F}$ (in metre)

Vergence formula

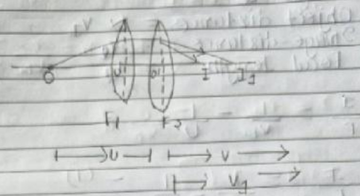
$$V = \frac{1}{q} \text{ (in metre)}$$

$$= \frac{100}{q} \text{ (in cm)}$$

The Focal point is the point at which light rays that passes through a lense or reflected off a curved mirror converge as appear to diverge. It is also know as focus or principle Focus.

Equivalent lense:-

If image of an object formed by several lenses at a particular point in certain magnification. If image of that object formed by single lense at the point that magnification then this single lense is called equivalent lense focal length of this lense is called equvialent Focal length.



Let us consider O' is a point object whose image is formed at I' by the lense L_1 in case we suppose that L_2 lense is disappear.

For lense 'L_1'
Object distance = U
Image distance = V_1
focal length = F_1

$$\frac{1}{F} = \frac{1}{V} - \frac{1}{U}$$

$$\Rightarrow \frac{1}{F_1} = \frac{1}{V_1} - \frac{1}{U} \quad \text{— (1)}$$

But actually L_2 lense is appear. So final image is formed at I by the lense L_1 in case we suppose that L_2 lense is disappear.

For Lense 'L2'

Object distance = ~~u~~ v_1

Image distance = v_2

Focal length = F_2

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

$$\Rightarrow \frac{1}{F_2} = \frac{1}{v_2} - \frac{1}{u_1} \quad -(i)$$

~~But actually L_2 lense is appeard. So~~

adding eq^n (i) & (ii)

$$\frac{1}{F_1} = \frac{1}{v_1} - \frac{1}{u} \quad -(iii)$$

If F be the Focal length of equivalent lense

$$\frac{1}{F} = \frac{1}{v} - \frac{1}{u} \quad -(iv)$$

From eq^n (iii) & (ii)

$$\boxed{\frac{1}{F} = \frac{1}{F_1} + \frac{1}{F_2}}$$ Hence proved

---

• Optical Path ⇒ The distance travelled by light in vaccum in a time 't' which it has travelled a distance 'd' in a given medium is called as optical path.

Or

When a ray of light travel a distance 'd' in a medium of refractive index 'μ'. The product 'μd' is called the optical path.

Optical Path ∝ time of travel

Optical Path ← $\boxed{x = \mu d}$ → distance

μ → refractive Index

Consider there is a medium PQ = Geometrical Path. The time taken by light to cover distance from 'P to Q' = t whose refractive Index is 'μ'.

In vaccum

$P' \xrightarrow{\quad x \quad} Q'$

⟶ t ⟵

$P'Q'$ = Optical Path

The speed of light in a medium = $\frac{\text{distance travelled}}{\text{time}}$

$$v_c = c = \frac{x}{t}$$

$$v_m = \frac{d}{t}, \quad v_c = \frac{x}{t}$$

$t = d/v_m$, $t = \frac{x}{c}$

$\frac{x}{c} = \frac{d}{v_m}$ { but $\mu = \frac{c}{v_m}$ }

$x = \frac{cd}{v_m} = \frac{c}{v_m} d$

$\Rightarrow \boxed{x = \mu d}$

Geometrical Path ⇒ The Geometrical Path is the distance a light ray travel b/w two points as measured along a segment of optical Path.

Sign convention

Left ⟶ Right

- Incident light will be considered as travelling from left to right.
- An arrow ahead a ray indicate the direction in which light is travelling.
- All distance (object distance), image distance, focus length are the major from optical system.

- Distance major from left of optical axis is consider as negative.
- Distance major above the principal axis is consider as postive.
- Distance major below the principal axis is consider as negative.
- Angle of incident, refraction and reflection of measure from the normal to the ray.
- Angle measured as anticlockwise direction of considerd as postive and measure as clock wise direction or negative.

Lateral magnification :- (Spherical surface)

Lateral magnification or linear magnification or transverse magnification (m) is defined as the ratio of size of image to the size of object.

$$m = \frac{\text{size of image}}{\text{size of object}}$$

let a spherical reflecting surface MPN separating two medium refractive index μ_1 and μ_2 From ΔABC & $A'B'C$

$$\frac{A'B'}{AB} = \frac{A'C}{AC} \quad \text{— (i)}$$

$A'B' = -y_2$

$AB = y_1$

$A'C = PA' - PC$
$= v - R$

$AC = AP + PC$
$= -u + R$

$$\frac{-y_2}{y_1} = \frac{v-R}{-u+R}$$

Multiplying with negative

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

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

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

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

$$\mu_1\left(\frac{R-u}{uR}\right) = \mu_2\left(\frac{R-v}{vR}\right)$$

$$\Rightarrow \frac{\mu_2}{\mu_2} \times \frac{vR}{uR} = \frac{R-v}{R-u}$$

$$\Rightarrow \frac{\mu_2}{\mu_2} \times \frac{v}{u} = \frac{R-v}{R-u} \quad \text{— (iii)}$$

From eq^n (iii) & (ii)

$$\Rightarrow \frac{\mu_1}{\mu_2} \times \frac{v}{u} = \frac{y_2}{y_1}$$

$$\Rightarrow \frac{y_2}{y_1} = \frac{\mu_1}{\mu_2} \times \frac{v}{u}$$

$$\boxed{\therefore \; M = \frac{\mu_1}{\mu_2}\left(\frac{v}{u}\right)}$$

Axial magnification (longitudinal) (Spherical surface)

In general objects are not linear but distributed or extended therefore in addition to Lateral magnification or longitudinal magnification also occur.

$$L = \frac{dv}{du} = \frac{\text{Length of image along axis}}{\text{Length of object along axis}}$$

It is defined as the ratio of length of image along axis to length of object along axis"

from refraction formula

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

differentation both sides

$$\mu_1\left(\frac{-1}{v_2}\right) - \mu_2\left(\frac{-1}{v_2}\right)\left(\frac{dv}{du}\right) = 0$$

$$\Rightarrow \frac{\mu_1}{u_2} + \frac{\mu_2}{v_2}\left(\frac{dv}{du}\right) = 0$$

$$\Rightarrow \frac{\mu_2}{v_2}\left(\frac{dv}{du}\right) = \frac{\mu_1}{u^2}$$

$$\Rightarrow \frac{dv}{du} = \frac{\mu_1^2}{\mu_2^2} \cdot \frac{v^2}{u^2} \times \frac{\mu_2}{\mu_1}$$

$$\Rightarrow \frac{dv}{du} = \frac{m^2 \mu^2}{\mu_1}$$

$$\boxed{L = \frac{m^2 \mu^2}{\mu'}}$$

Cardinal points or Planes: → In 1841, Gauss

Show that any number of ~~exact lenses~~ co-axial lenses could be treated as a single unit without the necessity of treating the single surface of lenses separately. The lense formula can be apply to the system provided the distances are measured from to hypothetical parallel planes. These planes are know as cardinal planes and the point off intersection of these planes with the axis are called the principal point or Gauss point.

There are six points which are characterised optical system.

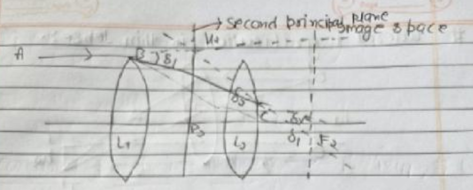
(i) ~~to for~~ Two focal point

(ii) Two principle point

(iii) Two nodale point

i) Principle points and principal planes: →

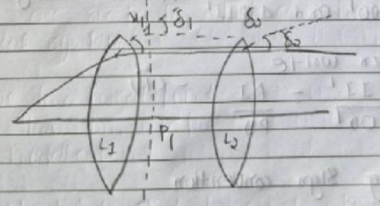
Principle point of an optical system is defined as the point from where assume refraction to occur without refrance as to where the



H_2P_2 is second principal plane and F_2 is second principal point.

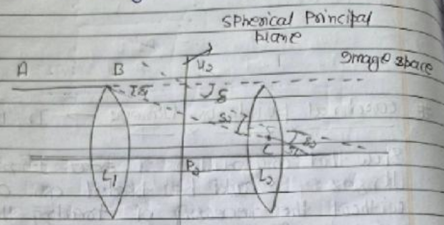
* First principle point or First principal Focus :-

A beam of light passing the point F_1 on the axis of the object side and after refraction to the principal axis then the point F_1 is called second principle Focus.



Plane H_1P_1 is called First principal plane and point P_1 is First principal point.

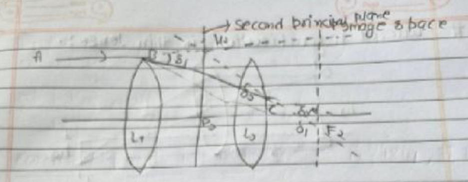
refraction actually occurs.



H_2P_2 is second principal plane and P_2 is second Principal point.

iii) Focal Point and Focal Planes : →

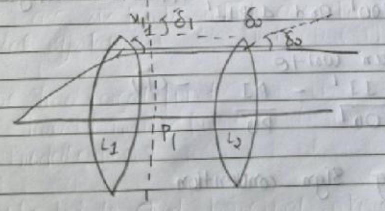
If a Parallel beam of light traveling from left to right in incident on optical system then the beam comes together at a point F_2 on the other side of the optical system (Image space) the point ~~F_2. F_2 on the other side of the~~ F_2 is called the second point and the plane passing through it is called second Focal Plane.



H_2P_2 is second principal plane and F_2 is second principal point.

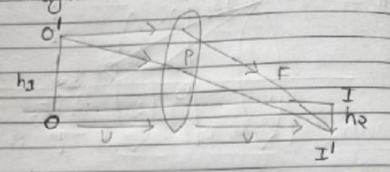
✳ First principle point or First principal Focus:·

A beam of light passing the point F_1 on the axis of the object side and after refraction to the principal axis then the point F_1 is called second principle Focus.



Plane H_1P_1 is called first principal plane and point P_1 is First principal point.

Lateral magnification in thin lense:·



Where h_1 is height of object at OO', h_2 is the height of inverted real image at II' and OP in the ray of passing through pole P.

The lateral or transverse magnification is defined as

$$M = \frac{II'}{OO'} \quad -(i)$$

From two similar opposite traingle $\Delta POO'$ and $\Delta PII'$

We can write

$$\frac{II'}{OO'} = \frac{PI}{PO} \quad -(ii)$$

Applying sign convention

$$\frac{-h_2}{h_1} = \frac{v}{-u}$$

Therefore equation (i) becomes

$$m = \frac{+h_2}{h_1} = \frac{v}{-u}$$

$$\boxed{m = \frac{h_2}{h_1} = \frac{v}{u}}$$