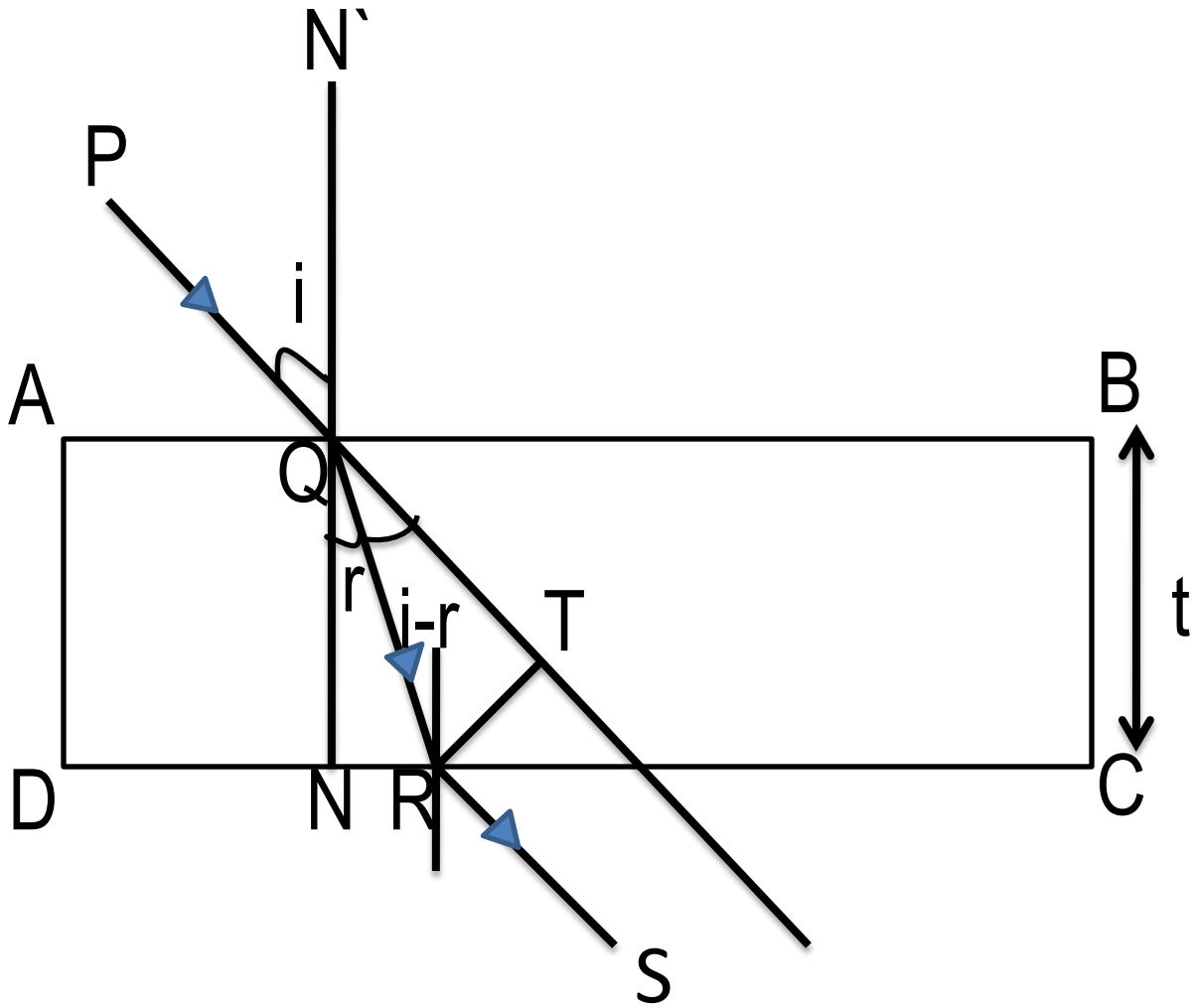
# LATERAL SHIFT

When a ray of light is incident obliquely on a parallel sided glass slab the emergent ray shifts laterally . The perpendicular distance between the direction of the incident ray and emergent ray is called "lateral shift".



ABCD=Principle section of a glass slab

PQ=incident ray

QR=refracted ray

RS=emergent ray

NN`=normal

RT=lateral shift

BC=t=thickness of the slab

i=angle of incidence

r=angle of refraction

Consider triangle NQR, $\cos r = \frac{QN}{QR} \Rightarrow QR = \frac{QN}{\cos r}$

From the triangle QRT, $\sin(i-r) = \frac{RT}{QR} \Rightarrow \frac{RT}{QN}$

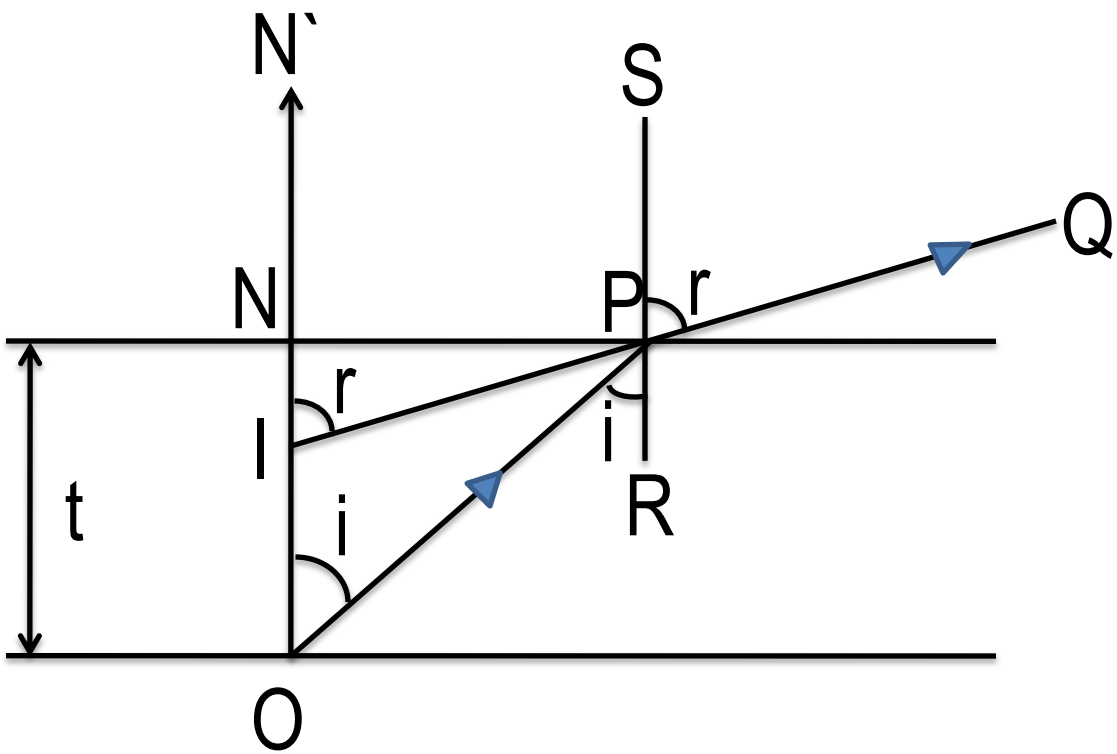
$$\frac{RT}{\frac{QN}{\cos r}} = \frac{RT \cos r}{QN}$$

$$\therefore RT = \frac{QN \sin(i-r)}{\cos r}$$

$$\text{LATERAL SHIFT} = t\frac{\sin(i-r)}{\cos r}$$

# NORMAL SHIFT

The apparent shift in the position of an object placed in one medium and **viewed along the normal**, from the other medium.



OP=incident ray

PQ=refracted ray produced backwards meet ON at I

NN`=normal

OI=normal shift

RPO=i=angle of incidence=NPO

QPS=r=angle of refraction=NIP

t=thickness of the optical medium

$$\sin i = \frac{NP}{OP}$$ From the triangle NPO

$$\sin r = \frac{NP}{IP}$$ From the triangle NPI

$n_1 \sin i = n_2 \sin r$

Here $n_1 = n \quad n_2 = 1$

$$n\frac{NP}{OP} = 1\frac{NP}{IP}$$

$$n = \frac{NP}{IP} \times \frac{OP}{NP} = \frac{OP}{IP} = \frac{ON}{IN}$$

$\because$ P is a point which very close to N

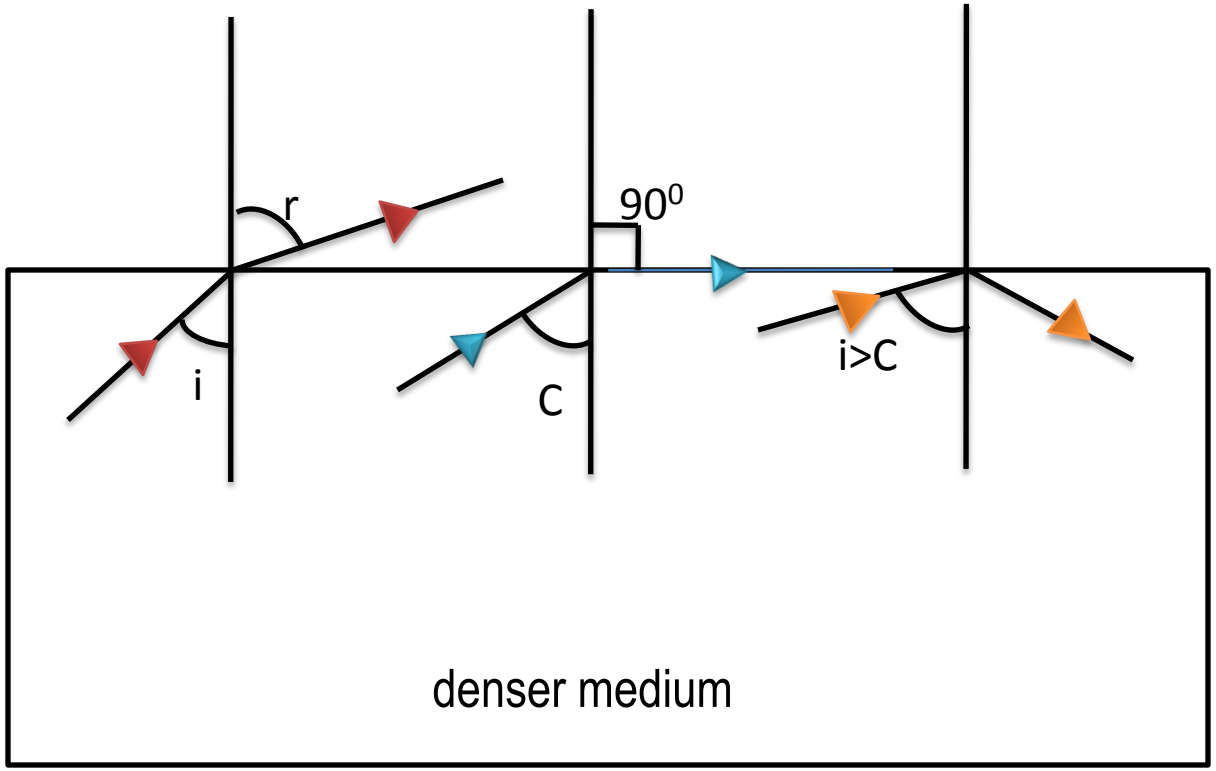
$$n = \frac{\text{real depth}}{\text{apparent depth}}$$

$$\text{Normal shift} = OI = OI = ON - IN = ON - \frac{ON}{n}$$

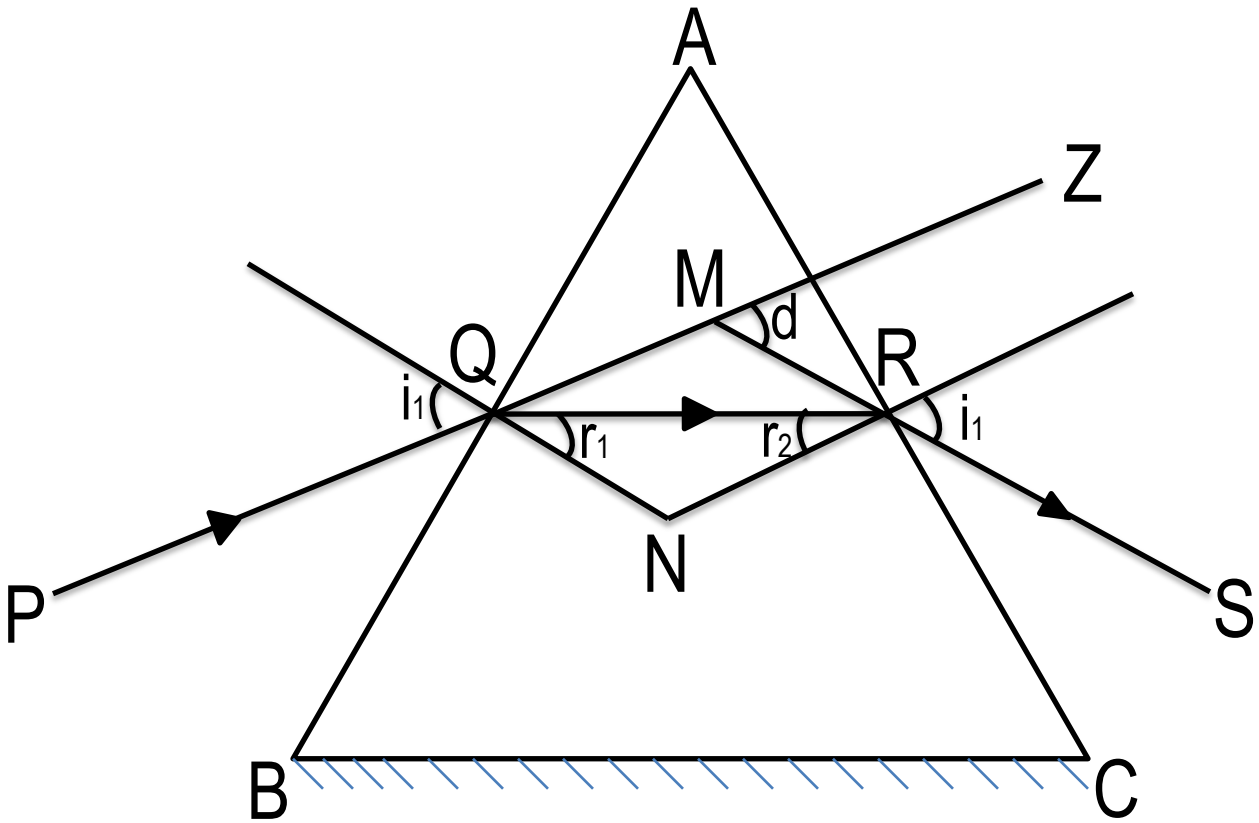
$$NS = ON\left[1 - \frac{1}{n}\right] = t\left[1 - \frac{1}{n}\right]$$

$$\text{Normal shift} = t\left[1 - \frac{1}{n}\right]$$

# TOTAL INTERNAL REFLECTION



# REFRACTION THROUGH A PRISM



ABC = principal section of the prism

BC = Base

A = Angle of the prism

PQ = Incident ray

QR = Refracted ray

RS = Emergent ray

ZMS = d = Angle of deviation

$i_1$ = Angle of incidence

$r_1$ = Angle of refraction

$r_2$ = Angle of incidence at the face AC

$i_2$ = Angle of emergence

Consider the Quadrilateral AQNR

In the ΔQNR

$A + QNR = 180^0$

$r_1 + r_2 + QNR = 180^0$

equating the above two equations, we have

$A + QNR = r_1 + r_2 + QNR$

$\therefore A = r_1 + r_2$ ----------(1)

$d = (i_1 - r_1) + (i_2 - r_2)$ (exterior angle is equal to sum of interior opposite angles)

$d = (i_1 + i_2) - (r_1 + r_2) = i_1 + i_2 - A$ (from 1)

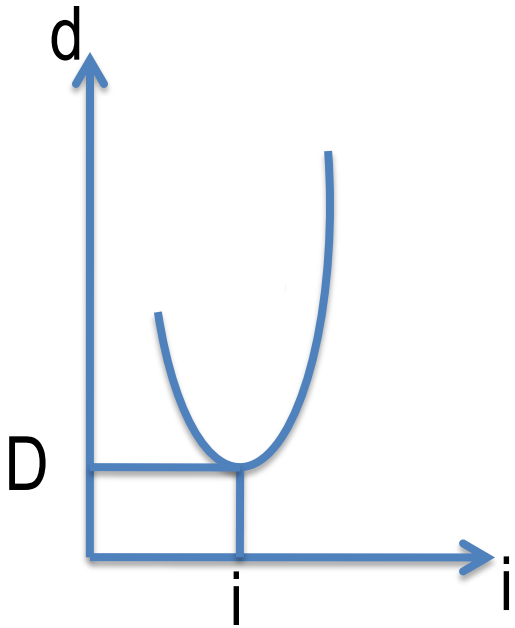
$d + A = i_1 + i_2$ ----------(2)

at minimum deviation

$i_1 = i_2 = i$

$r_1 = r_2 = r$

$d = D$




$\therefore$ (1) $\Longrightarrow$ $A = 2r$ or $r = A/2$

(2) $\Longrightarrow$ $D + A = 2i$ or $i = (A+D)/2$

$$n = \frac{\sin i}{\sin r} = \frac{\sin \frac{A+D}{2}}{\sin \frac{A}{2}}$$

# REFRACTION THROUGH CURVED SURFACES

**Curved surface:** it is a part of a sphere.

**Principal axis:** the horizontal line passing through the centre of the curved surface.

**Pole(P):** centre of the curved surface.

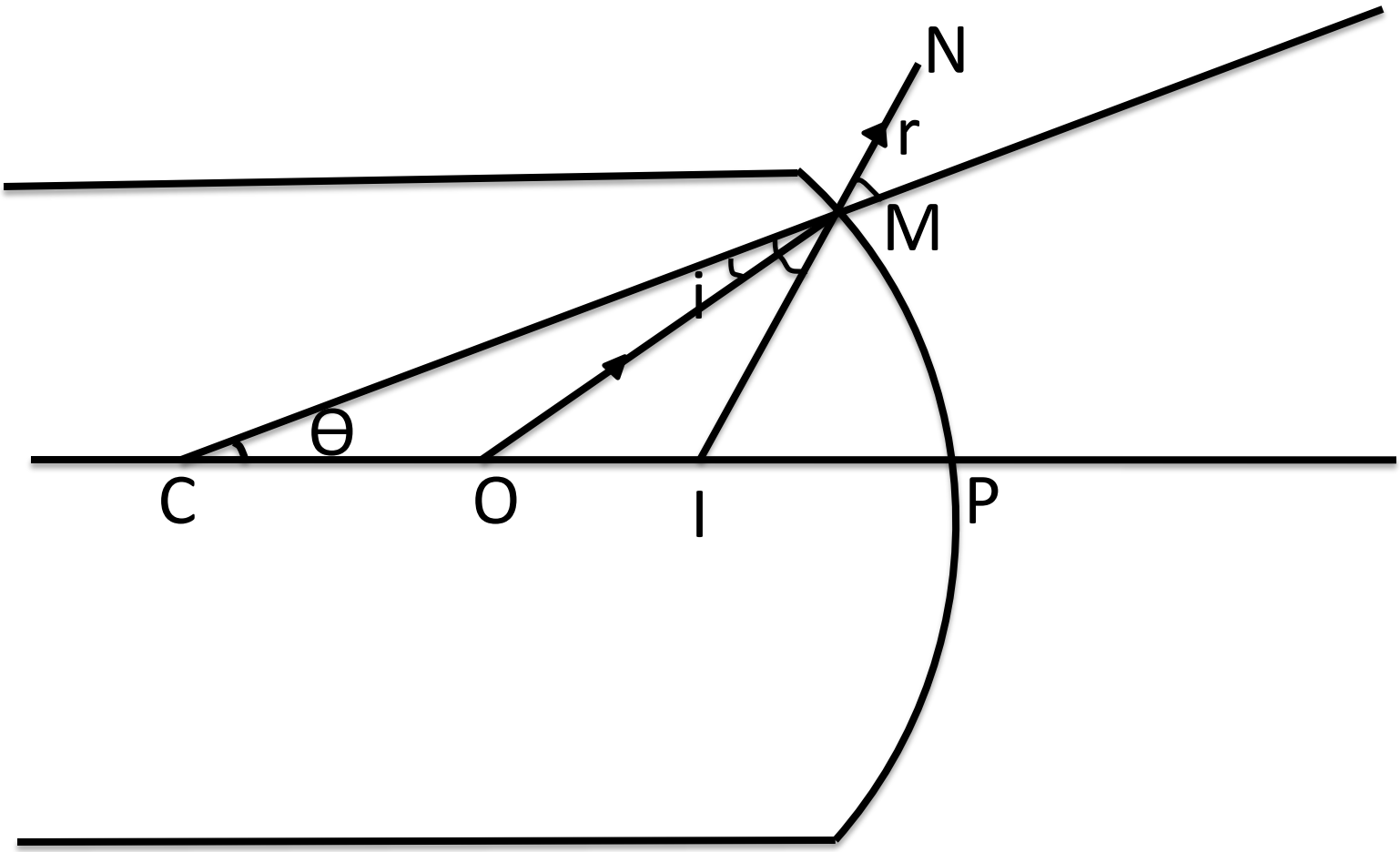
**Centre of curvature(c):**it is a point on the principal axis which is the centre of the sphere in which curved surface is a part.

**Principal focus(F):**it is a point on the principal axis where parallel rays from infinity converge or appear to diverge from that point

**Focal length (f):** It is the distance between the principal focus and the pole.

**Radius of curvature(R):** It is the distance between centre of curvature and the pole

# Relation between n,u,v&R



OM= incident ray

MN=refracted ray

MI = refracted ray produced backwards

CP = radius of curvature (R)

OP = object distance (u)

IP = image distance (v)

I =angle of incidence

r = angle of refraction

Applying sine rule to the triangles CMO & CMI

$$\frac{CO}{\sin i} = \frac{OM}{sin\theta} ---------- (1)$$

$$\frac{CI}{\sin r} = \frac{IM}{sin\theta} ---------- (2)$$

Dividing equation (2) by equation (1)

$$\frac{CI}{\sin r} \times \frac{\sin i}{CO} = \frac{IM}{sin\theta} \times \frac{sin\theta}{OM}$$

$$\frac{sini}{sinr} = \frac{IM \times CO}{OM \times CI}$$

We know that $n_1$ sini = $n_2$ sinr

$$\therefore \quad \frac{sini}{sinr} = \frac{n_2}{n_1}$$

M is a point which is very close to P, therefore

$IM \approx IP = -v$ (because image is virtual)

$OM \approx OP = u$

$CO = CP - OP = R - u$

$CI = CP - IP = R + v$

$$\frac{n_2}{n_1} = \frac{-v(R-u)}{u(R+v)} = \frac{-vR+vu}{uR+uv}$$

$$n_2uR + n_2uv = -n_1vR + n_1uv$$

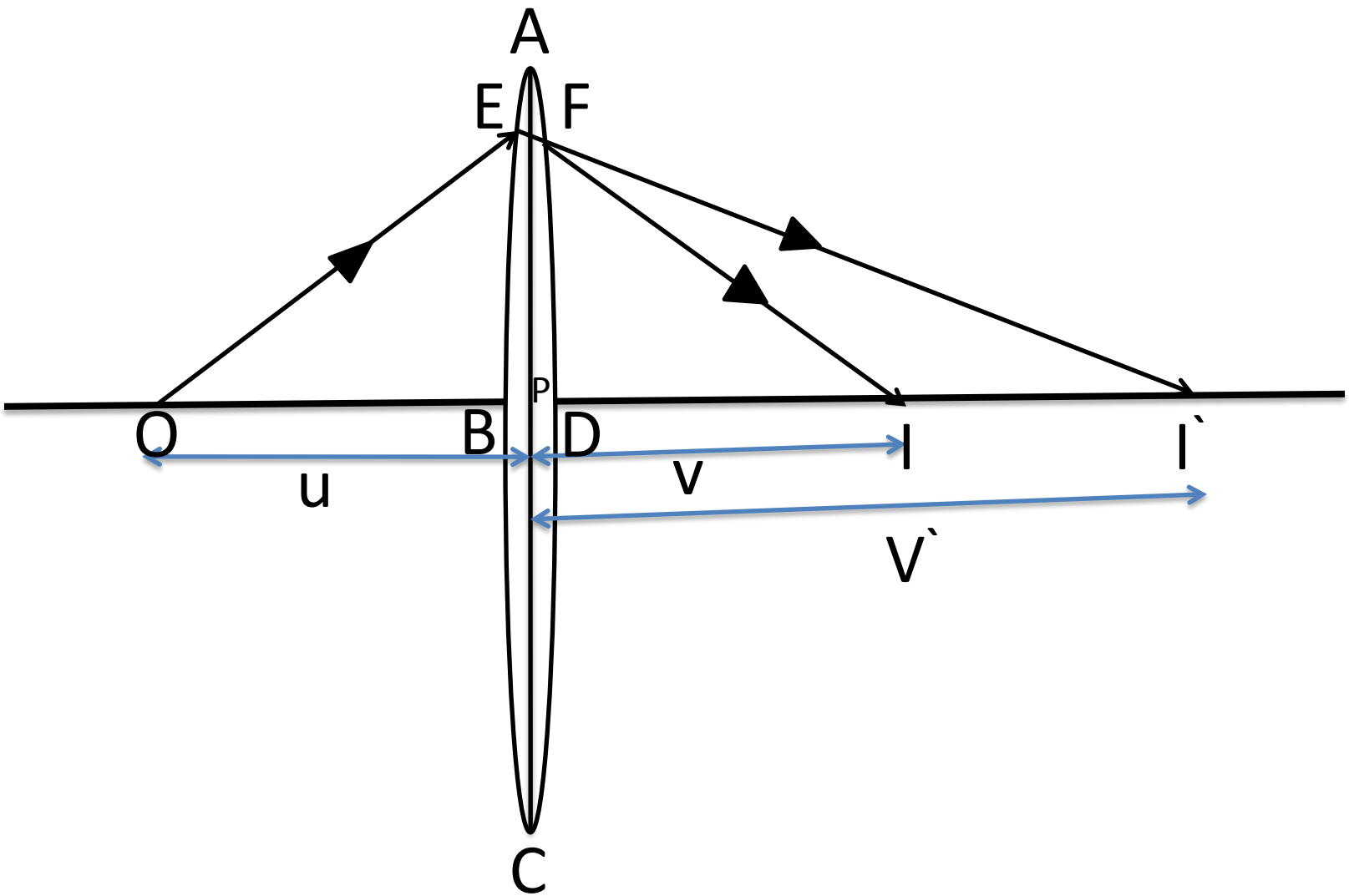
Dividing the above equation through out by **uvR**

$$\frac{n_2}{v} + \frac{n_2}{R} = \frac{-n_1}{u} + \frac{n_1}{R}$$

$$\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_1}{R} - \frac{n_2}{R} \quad = \frac{1}{R}(n_1 \sim n_2)$$

$$\frac{R.I\ of\ object\ space}{object\ distance} + \frac{R.I\ of\ image\ space}{image\ distance} = \frac{diff\ in\ R.I\ s}{radius\ of\ curvature}$$

# Lens maker's formula



OE = incident ray

FI = refracted ray

O = point object

I` = virtual object for the surface ADC

OP = u =object distance

$R_1$ ,$R_2$ =radii of curvatures of the surfaces ABC and ADC

PI =v=image distance

P I` =v` =image distance for the first surface

For the refraction through surface ABC,

$$\frac{1}{u} + \frac{n}{v'} = \frac{(n-1)}{R_1} \ldots\ldots\ldots\ldots\ldots (1)$$

For the refraction through surface ADC,

$$-\frac{n}{v^1} + \frac{1}{v} = \frac{(n-1)}{R_2} \ldots\ldots\ldots\ldots\ldots (2)$$

Negative sign indicates that the object is virtual

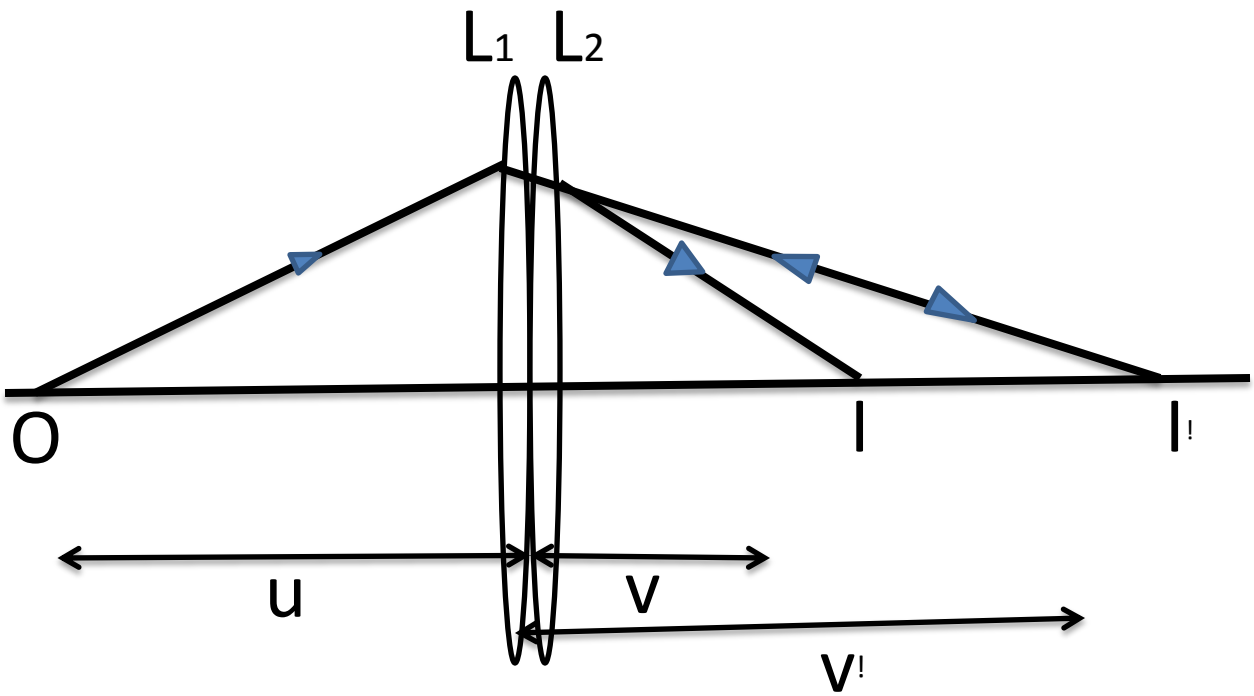
Adding (1) and (2)

$$\frac{1}{u}+\frac{n}{v'}-\frac{n}{v'}+\frac{1}{v}=(n-1)[\frac{1}{R_1}+\frac{1}{R_2}]$$

$$\frac{1}{u}+\frac{1}{v}=(n-1)[\frac{1}{R_1}+\frac{1}{R_2}]$$

$$\frac{1}{f}=(n-1)[\frac{1}{R_1}+\frac{1}{R_2}] \quad \because \frac{1}{f}=\frac{1}{u}+\frac{1}{v}$$

# Two thin lenses in contact



Let us consider two thin lenses in contact

let $f_1$ and $f_2$ be their focal lengths

let u=object distance

v=image distance

$v^!$=virtual image distance

**For refraction through through first lens,**

$$\frac{1}{u}+\frac{1}{v^!}=\frac{1}{f_1}\ldots\ldots\ldots\ldots\ldots(1)$$

here $I^!$ is the image formed

For refraction through second lens,

here $I^{!}$ serves as virtual object for the second lens.

$$-\frac{1}{v'}+\frac{1}{v}=\frac{1}{f_2} \ldots\ldots\ldots\ldots\ldots (2)$$

Adding equations (1) and (2)

$$\frac{1}{u}+\frac{1}{v'}-\frac{1}{v'}+\frac{1}{v}=\frac{1}{f_1}+\frac{1}{f_2}$$

$$\frac{1}{F} = \frac{1}{u} + \frac{1}{v} = \frac{1}{f_1} + \frac{1}{f_2}$$

let F be the effective focal length of the combination.

$$\therefore \quad \frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

# Questions carrying ONE mark each

1. Define critical angle.
2. Mention an application of total internal reflection.
3. What is dispersion of light?
4. Write the expression for the deviation produced by a thin prism.
5. Define dispersive power of the material of a prism.
6. What is angular dispersion?
7. Write the condition for dispersion without deviation.

8. Define power of a lens.

9. What is magnification?

10. Write the relation between power and focal length of a lens.

11. Write the expression for the equivalent focal length of two thin lenses separated by a distance.

12. What is a thin prism?

13. What is the lateral shift produced by a parallel sided glass slab for grazing incidence of light?

14. A thin convex lens of focal length 0.1m & a thin concave lens of focal length 0.1m are placed co-axially in contact. What is the net power of the combination?

# Question carrying two marks

1.Mention the conditions for total internal reflection to occur.

2.Arrive at the relation between critical angle and refractive index.

3.What is an optical fibre? on what principle does it work?

4.Write the ray diagram showing the experimental arrangement for pure spectrum.

5.What is a pure spectrum? give an example.

6.What is an impure spectrum? give an example.

7.Calculate the refractive index of a pair of media given critical angle as 40˚.

8.Calculate the angle of deviation produced by a thin prism of refracting angle5˚ and refractive index 1.5.

9.An object is kept at a distance of 0.12m from a convex lens forms an image at a distance of 0.18m.calculate the magnification produced.

10.Two thin convex lenses of focal lengths 0.15m & 0.2m are seperated by a distance of 0.6m. Find the effective focal length of the combination.

## Question carrying FIVE mark each

1. What is lateral shift? Derive an expression for lateral shift produced by a parallel sided glass slab for oblique incidence.

2. What is normal shift? Derive the expression for normal shift produced when an object in a denser medium is viewed normally through air.

3.Derive the expression for refractive index in terms of the angle of the prism and angle of minimum deviation.

4.Derive the relation connecting n,u,v & R for refraction at a spherical surface concave towards a point object in a denser medium.

5.Derive lens maker's formula.

6.Derive the expression for the effective focal length of two thin lenses in contact.