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”.

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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, \( \cos r = \frac{QN}{QR} \Rightarrow \frac{QR}{\cos r} = \frac{QN}{\cos r} \)

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

\[
\frac{RT}{QN} = \frac{RT \cos r}{QN}
\]

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

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

\[
\sin i = \frac{NP}{OP} \quad \text{From the triangle NPO}
\]
\[
\sin r = \frac{NP}{IP} \quad \text{From the triangle NPI}
\]
\[ n_1 \sin i = n_2 \sin r \]

Here \( n_1 = n \) \( n_2 = 1 \)

\[ n \frac{NP}{OP} = 1 \frac{NP}{IP} \]

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

\[ P \text{ is a point which very close to } N \]
\[
n = \frac{\text{real depth}}{\text{apparent depth}}
\]

Normal shift = \(OI = OI = ON - IN = ON - \frac{ON}{n}\)

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

Normal shift = \(t \left[1 - \frac{1}{n}\right]\)
TOTAL INTERNAL REFLECTION

denser medium
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 = \( \theta \) = 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 $\Delta QNR$

$A + QNR = 180^0$

$r_1 + r_2 + QNR = 180^0$

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 = $(i_1 + i_2) - (r_1 + r_2) = i_1 + i_2 - A \quad \text{ (from 1)}$

d + A = i_1 + i_2 ---------------------(2)$
at minimum deviation

\[ i_1 = i_2 = i \]
\[ r_1 = r_2 = r \]
\[ d = D \]

\[ \therefore (1) \iff A = 2r \quad \text{or} \quad r = A/2 \]
\[ (2) \iff D + A = 2i \quad \text{or} \quad i = (A+D)/2 \]

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

\[
\frac{CO}{\sin i} = \frac{OM}{\sin \theta} \quad (1)
\]

\[
\frac{CI}{\sin r} = \frac{IM}{\sin \theta} \quad (2)
\]

Dividing equation (2) by equation (1)
\[
\frac{CI}{\sin r} \times \frac{\sin i}{CO} = \frac{IM}{\sin \theta} \times \frac{\sin \theta}{OM}
\]

\[
\frac{\sin i}{\sin r} = \frac{IM \times CO}{OM \times CI}
\]

We know that \(n_1 \sin i = n_2 \sin r\)

\[
\therefore \frac{\sin i}{\sin r} = \frac{n_2}{n_1}
\]
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 \( uvR \)

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

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

\[ \frac{\text{R.I. of object space}}{\text{object distance}} + \frac{\text{R.I. of image space}}{\text{image distance}} = \frac{\text{diff in R.I s}}{\text{radius of curvature}} \]
Lens maker’s formula
OE = incident ray
FI = refracted ray
O = point object
I` = virtual object for the surface ADC
OP = u = object distance
R₁, R₂ = 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,
\[
\frac{1}{u} + \frac{n}{v^1} = \frac{(n-1)}{R_1} \quad \cdots \quad (1)
\]

For the refraction through surface ADC,
\[
-\frac{n}{v^1} + \frac{1}{v} = \frac{(n-1)}{R_2} \quad \cdots \quad (2)
\]

Negative sign indicates that the object is virtual.
Adding (1) and (2)

\[ \frac{1}{u} + \frac{n}{v^3} - \frac{n}{v^3} + \frac{1}{v} = (n-1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right] \]

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

\[ \frac{1}{f} = (n-1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right] \quad \therefore \quad \frac{1}{f} = \frac{1}{u} + \frac{1}{v} \]
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 first lens,

\[
\frac{1}{u} + \frac{1}{v^!} = \frac{1}{f_1} \quad \cdots \quad (1)
\]

here $l^!$ is the image formed
For refraction through second lens, here $l^1$ serves as virtual object for the second lens. 

\[
\frac{1}{v^1} + \frac{1}{v} = \frac{1}{f_2} 
\] (2)

Adding equations (1) and (2)

\[
\frac{1}{u} + \frac{1}{v^1} - \frac{1}{v^1} + \frac{1}{v} = \frac{1}{f_1} + \frac{1}{f_2}
\]
Let $F$ be the effective focal length of the combination.

\[ \frac{1}{F} = \frac{1}{u} + \frac{1}{v} = \frac{1}{f_1} + \frac{1}{f_2} \]
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.
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 angle 5° 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 separated 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.