VISUAL PHYSICS

SHORT NOTES

CHAPTER

Refraction - Plane Surface

Available at:

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when ray of light travels from one medium to other with or without bending

Refraction :- Plane Surface

→ focal length $= \infty$

Refractive index of a medium

$$\eta = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}} = \frac{c}{v}$$

* medium$_1$ → $\eta_1 = \frac{c}{v_1}$

medium$_2$ → $\eta_2 = \frac{c}{v_2}$

* η_{12} = refractive index of medium 1 with respect to medium 2

$$\eta_{12} = \frac{\eta_1}{\eta_2} = \frac{c/v_1}{c/v_2} = \frac{v_2}{v_1}$$

$$\eta_{21} = \frac{v_1}{v_2}$$

★ Going from one medium to other medium

Speed of light → change

Wavelength → change

frequency → NOT CHANGE

So, $\eta_1 = \dfrac{c}{v_1} = \dfrac{c}{f\lambda_1} = \dfrac{f\lambda_0}{f\lambda_1}$

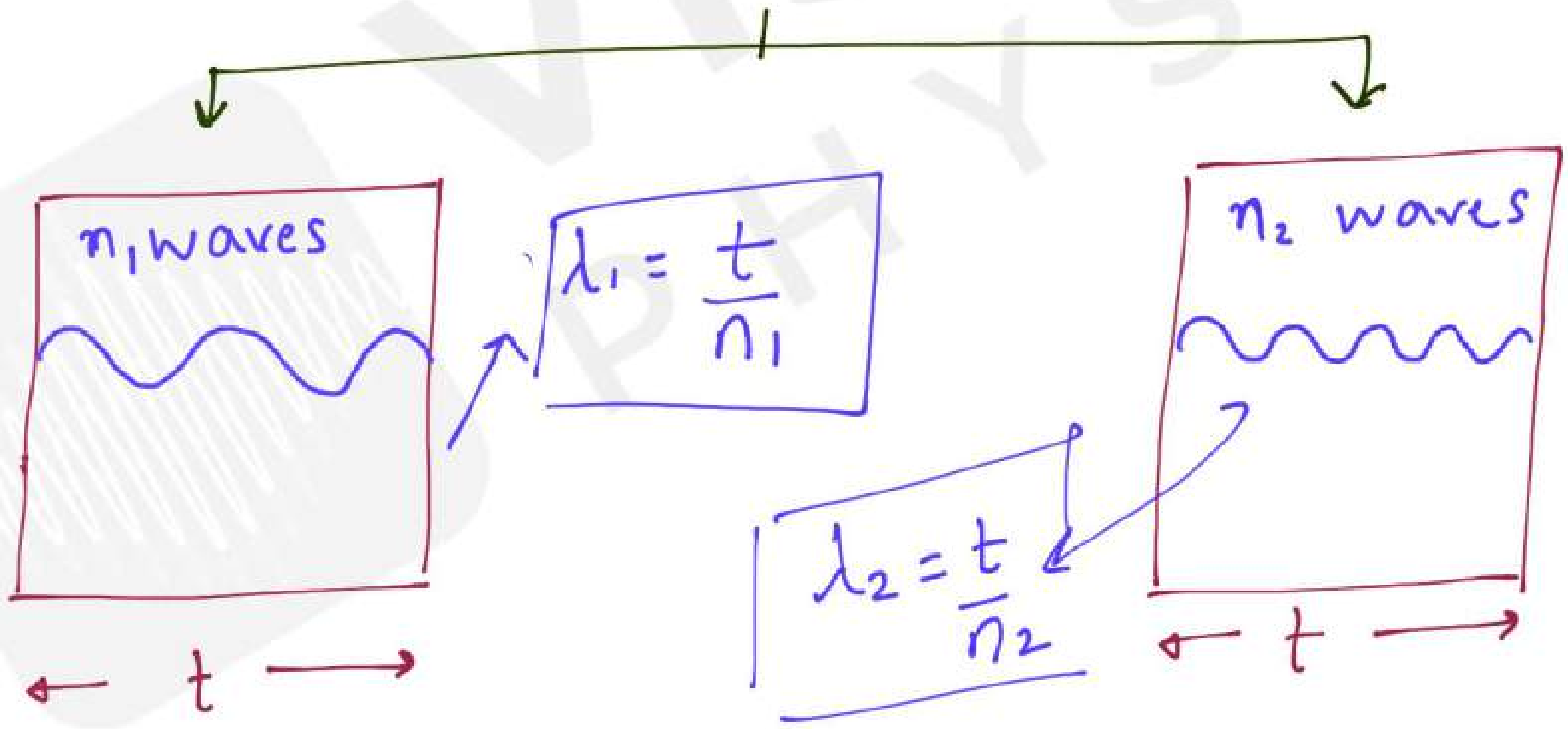
frequency

wavelength in medium$_1$

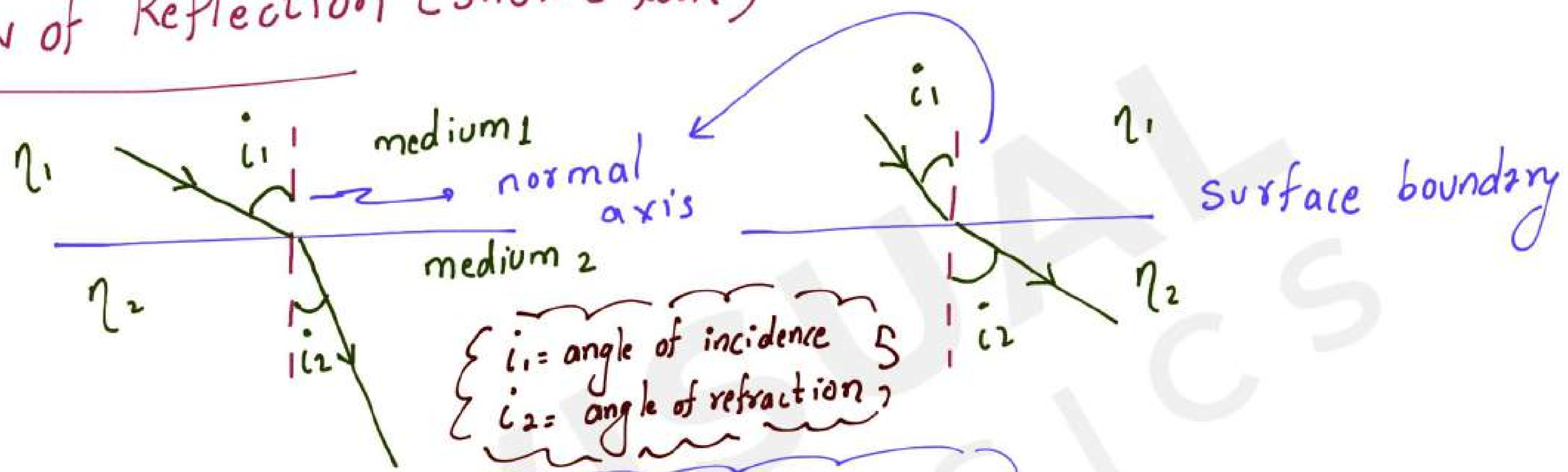
wavelength in vacuum

$\Rightarrow \boxed{\eta_1 = \dfrac{\lambda_0}{\lambda_1}}$ $\Rightarrow \boxed{\eta_{12} = \dfrac{v_2}{v_1} = \dfrac{\lambda_2}{\lambda_1}}$ ☆

Waves in different slabs:



Law of Reflection (snell's law)



{ i_1 = angle of incidence }
{ i_2 = angle of refraction }

Snell's law → $\eta \sin i = \text{Constant}$

or $\eta_1 \sin i_1 = \eta_2 \sin i_2$ → $\boxed{\dfrac{\sin i_1}{\sin i_2} = \dfrac{\eta_2}{\eta_1}}$

$\eta_1 > \eta_2$

→ $i_2 > i_1$

$\eta_2 > \eta_1$

$i_1 > i_2$

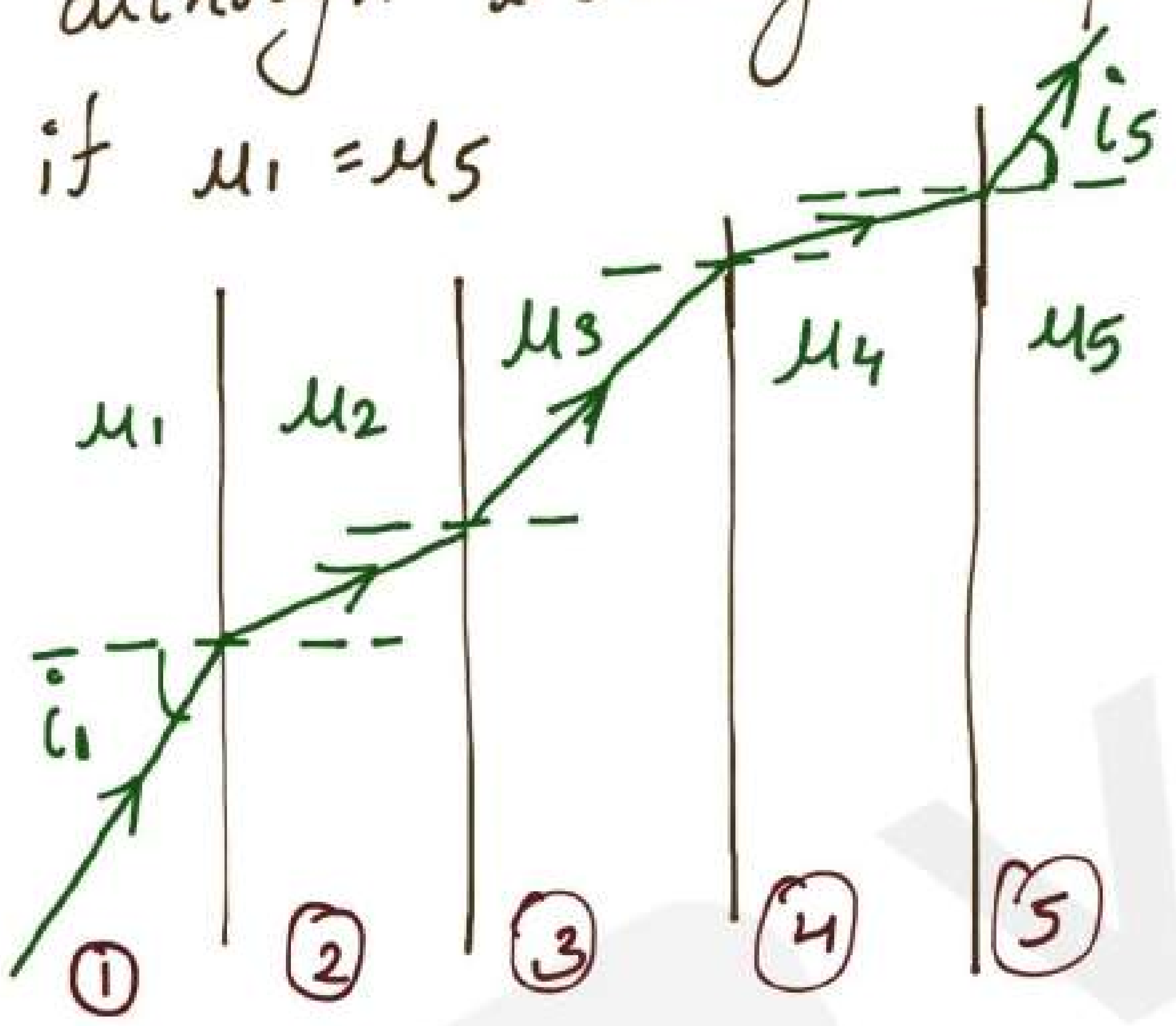
* $\eta_1 > \eta_2$

η_1 → Denser medium

η_2 → rarer medium

& vice-versa

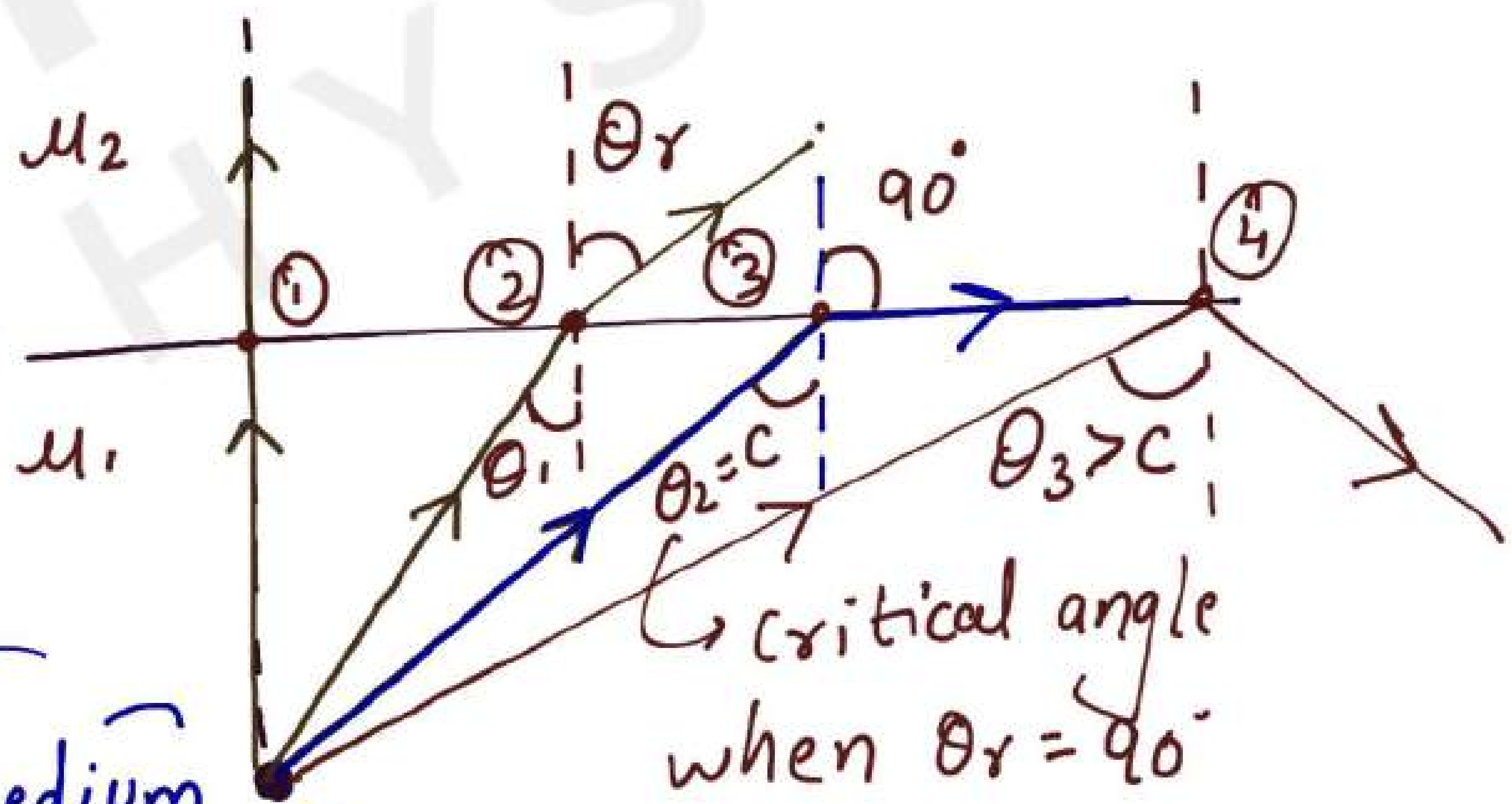
* If the boundaries of the media are parallel, the emergent ray although laterally displaced is parallel to the incident ray if $\mu_1 = \mu_5$



$$\boxed{\mu_1 \sin i_1 = \mu_5 \sin i_5}$$

Critical angle & TIR :

$\mu_2 < \mu_1$



$$\frac{\sin C}{\sin 90^\circ} = \frac{\mu_2}{\mu_1}$$

$$\sin C = \frac{\mu_2}{\mu_1} = \frac{\text{RI of rarer medium}}{\text{RI of denser medium}}$$

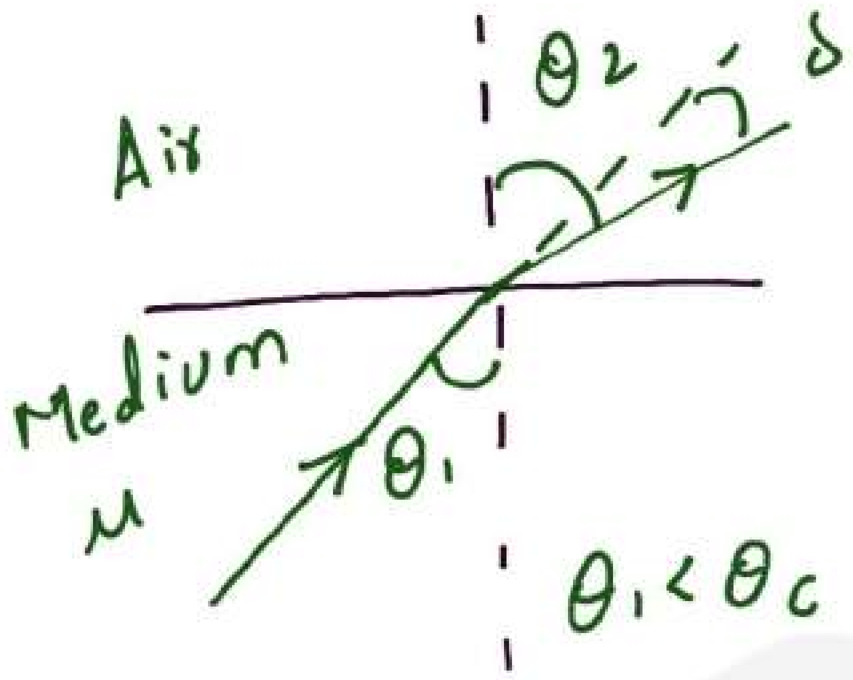
Deviation of ray due to Refraction

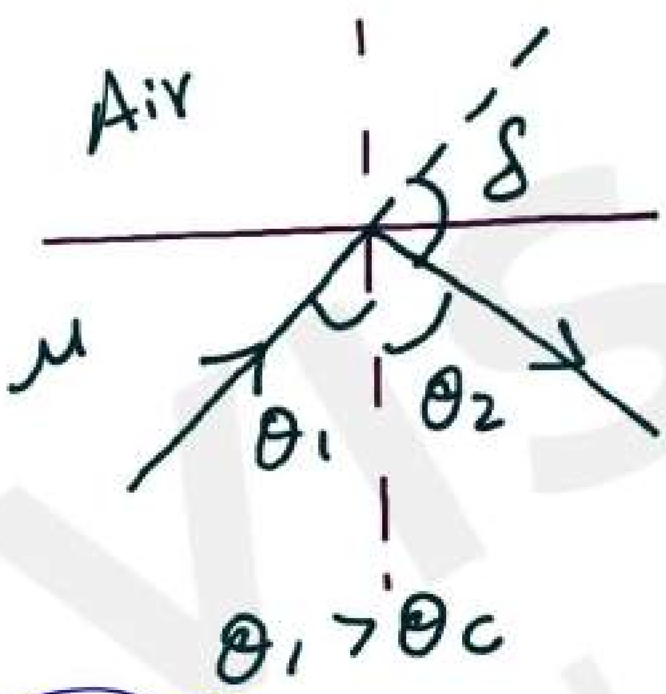
$\delta = \theta_2 - \theta_1$

$\sin\theta_2 = \mu \sin\theta_1$

$\theta_2 = \sin^{-1}(\mu \sin\theta_1)$

$\delta = \sin^{-1}(\mu \sin\theta_1) - \theta_1$



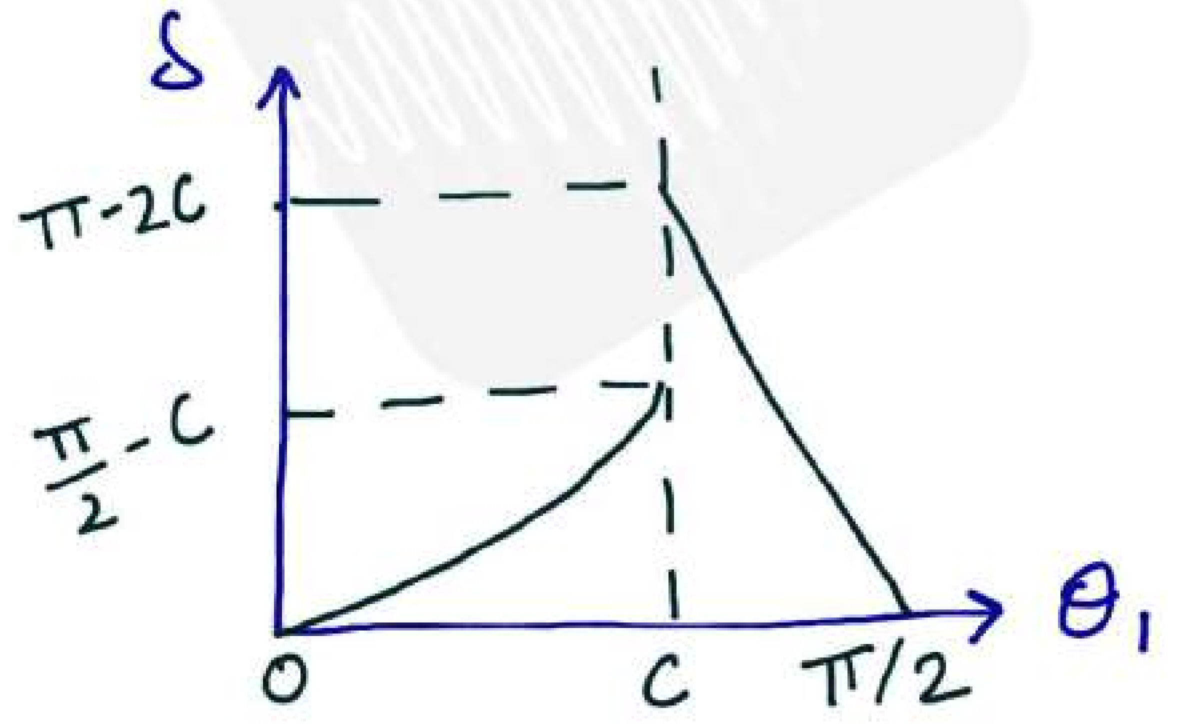


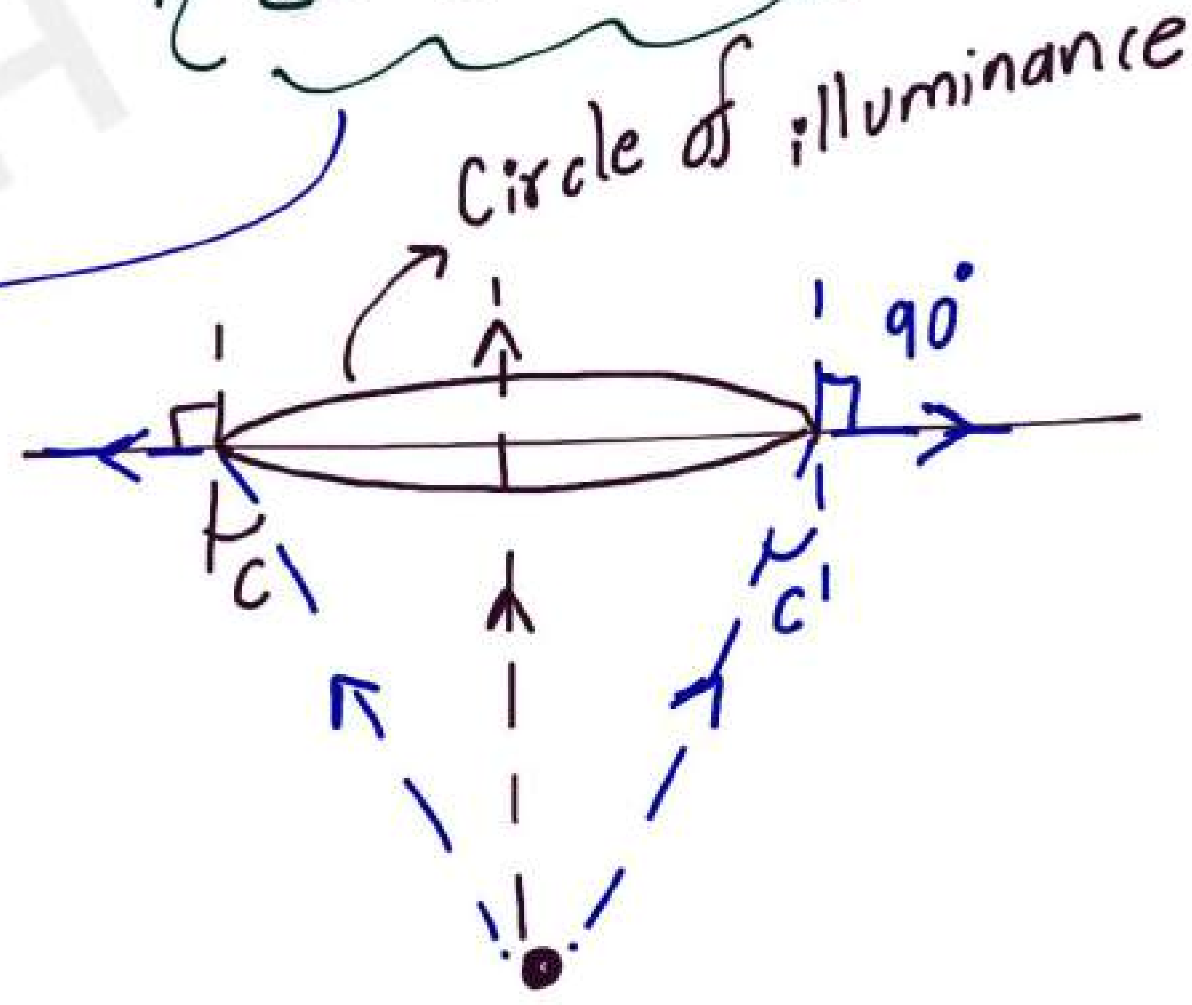
$$\delta_{max} = \frac{\pi}{2} - c$$ for $\theta_1 \leq C$

for $\theta_1 > C$

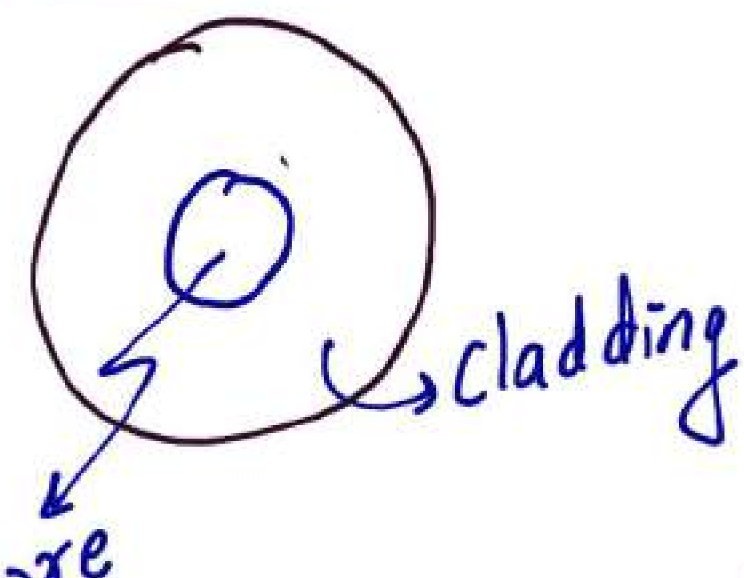
$$\delta = \theta - 2\theta_1$$

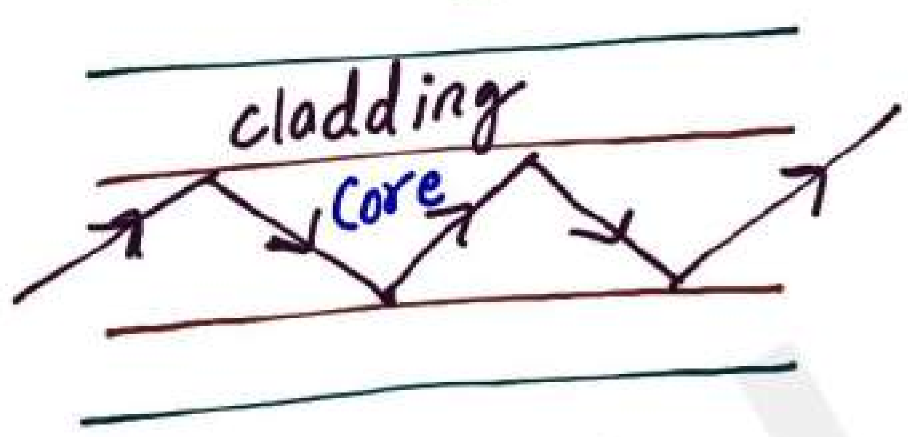
$$\delta_{max} = \pi - 2C$$



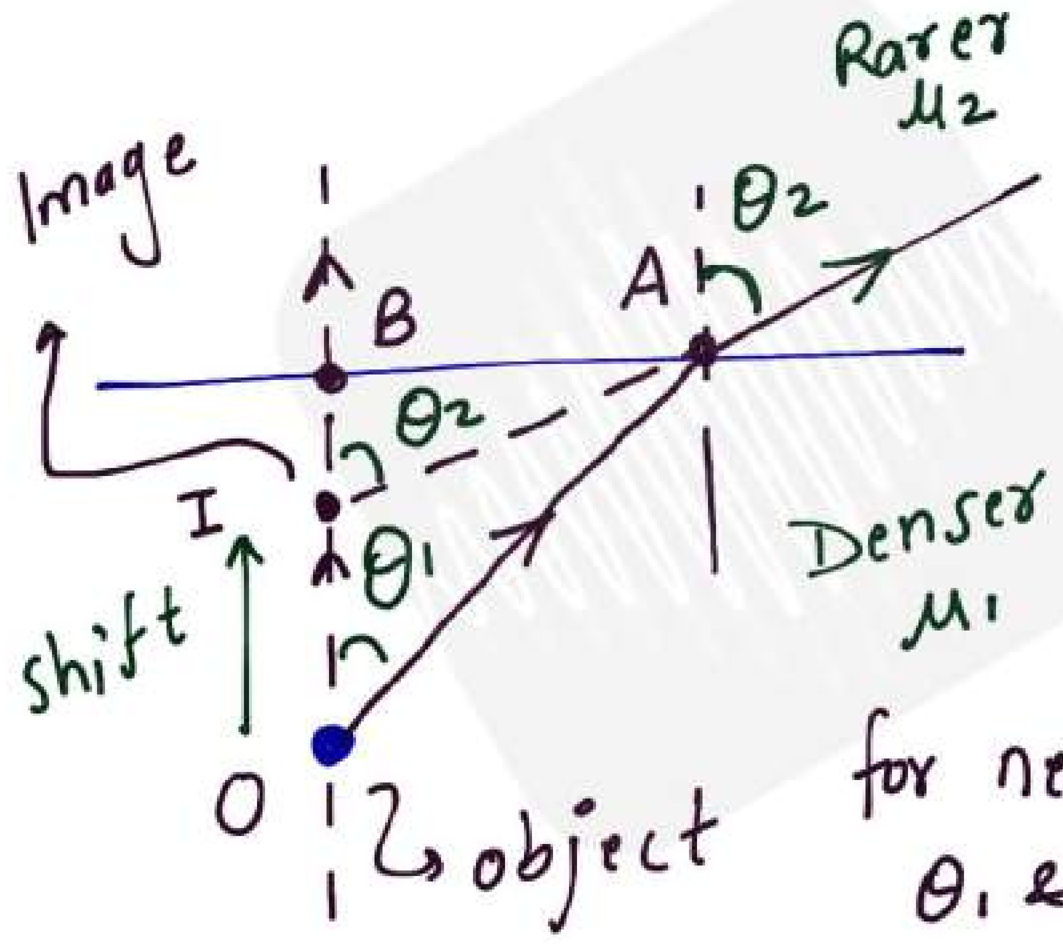


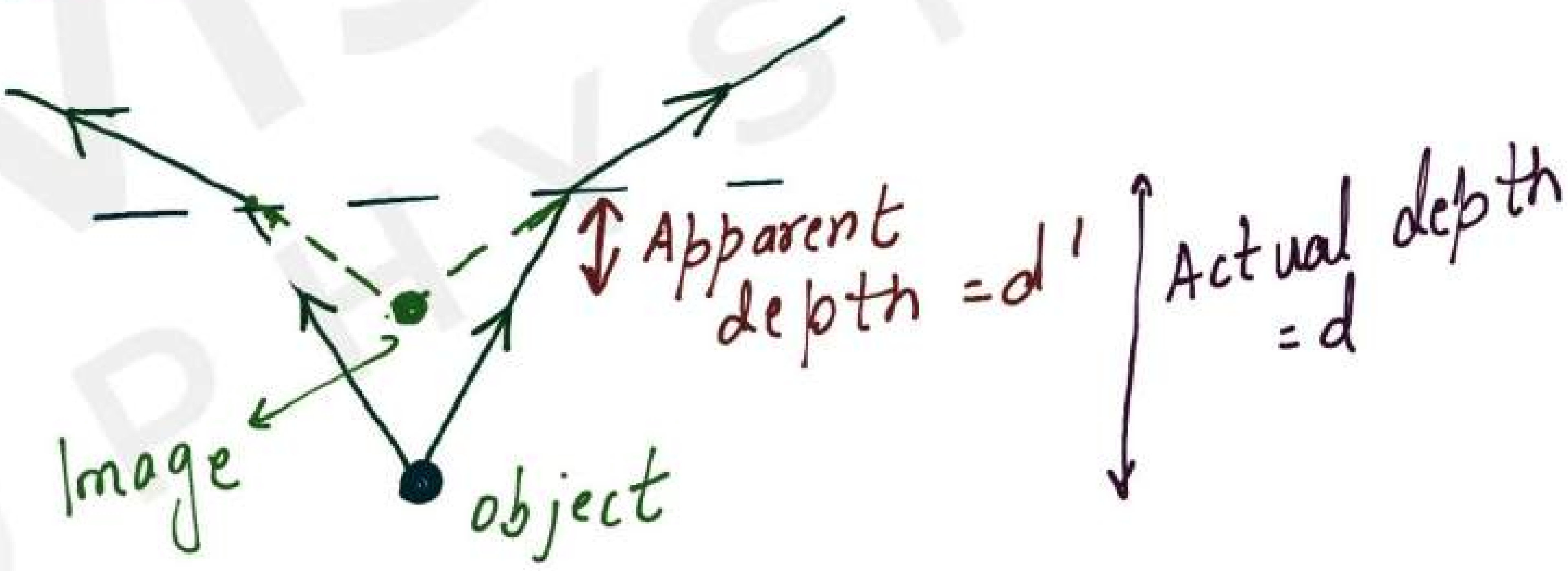
optical fiber: TIR used for long range information travel





Apparent shift due to refraction :





for nearly normal incident θ_1 & θ_2 will be very small

$$\tan\theta_1 \simeq \sin\theta_1 = \frac{AB}{\text{object distance from refracting surface}}$$

$$\tan\theta_2 \simeq \sin\theta_2 = \frac{AB}{\text{image distance from refracting surface}}$$

$$\Rightarrow \frac{\sin\theta_1}{\sin\theta_2} = \frac{\tan\theta_1}{\tan\theta_2} = \frac{\text{Image distance from refracting surface}}{\text{object distance from refracting surface}}$$

$$\mu_1 \sin\theta_1 = \mu_2 \sin\theta_2 \quad \frac{\sin\theta_1}{\sin\theta_2} = \frac{\mu_2}{\mu_1} = \frac{\tan\theta_1}{\tan\theta_2}$$

$$\frac{\frac{AB}{OB}}{\frac{BA}{BI}} = \frac{\mu_2}{\mu_1} \Rightarrow \frac{BI}{OB} = \frac{\text{Apparent depth}}{\text{Real depth}} = \frac{\mu_2}{\mu_1}$$

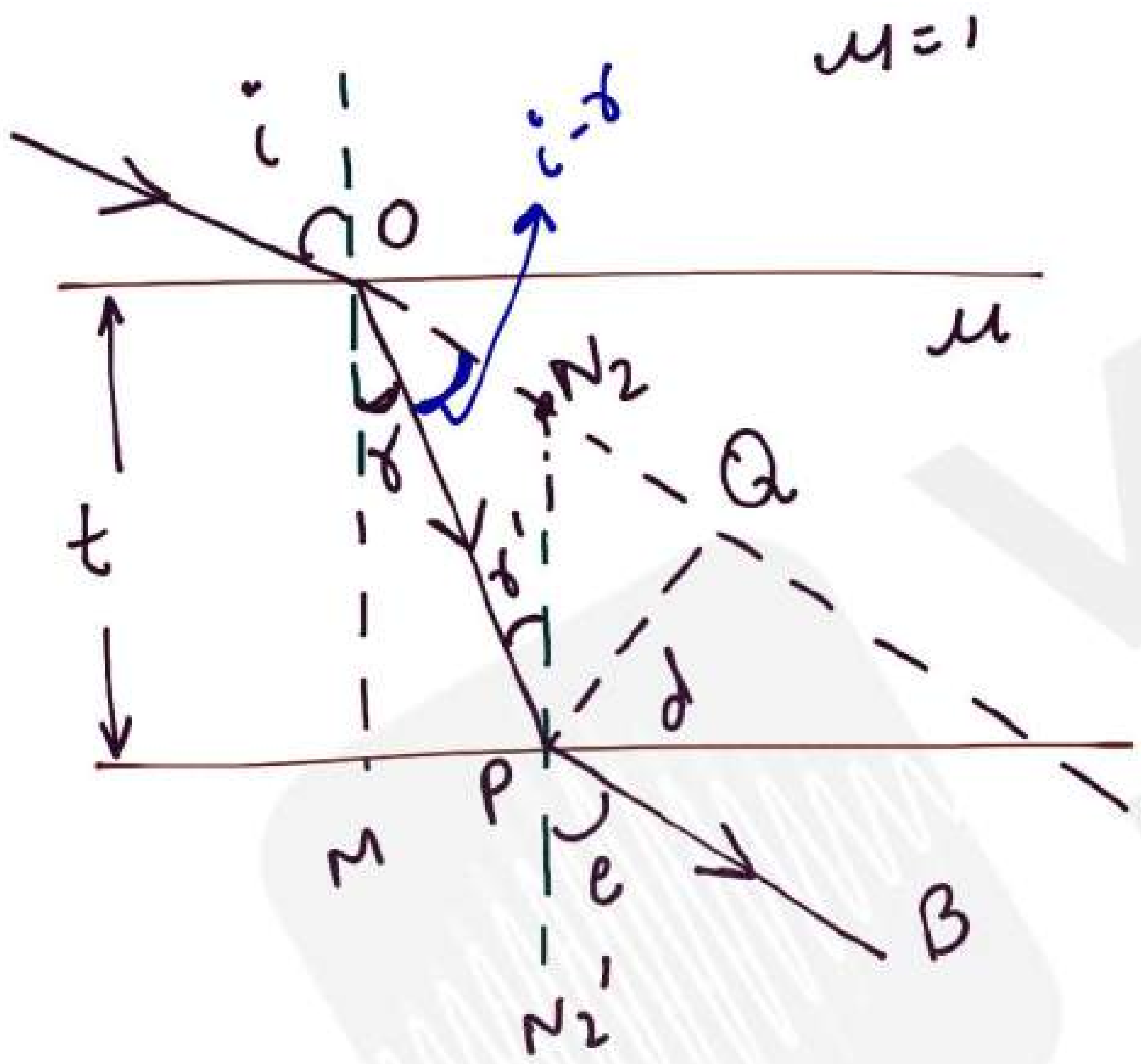
$$\text{Apparent depth} = \frac{\text{Real depth}}{\mu_1/\mu_2} = \frac{\text{Real depth}}{\mu_{rel}}$$

$$\mu_{rel} = \frac{\mu_i \text{ (RI of medium of incidence)}}{\mu_r \text{ (RI of medium of refraction)}}$$

$$\text{shift} = S = \text{Real depth} - \text{Apparent depth}$$

$$\left\{ S = \text{Real depth}\left(1 - \frac{1}{\mu_{rel}}\right) \right\}$$

Lateral displacement of emergent beam through Glass slab :



if e is angle of emergence from snell's law:

$\mu_a \sin i = \mu \sin r$ &

$\mu \sin r' = \mu_a \sin e$

$r' = r$ & $\mu_a = 1$

$\sin i = \sin e$ or $(e = i)$

$d = PQ = OP \sin(i-r) = \frac{OM}{\cos r} \sin(i-r)$

$$\left\{ d = \frac{t \sin(i-r)}{\cos r} \right\}$$

for i is very small, r is very small

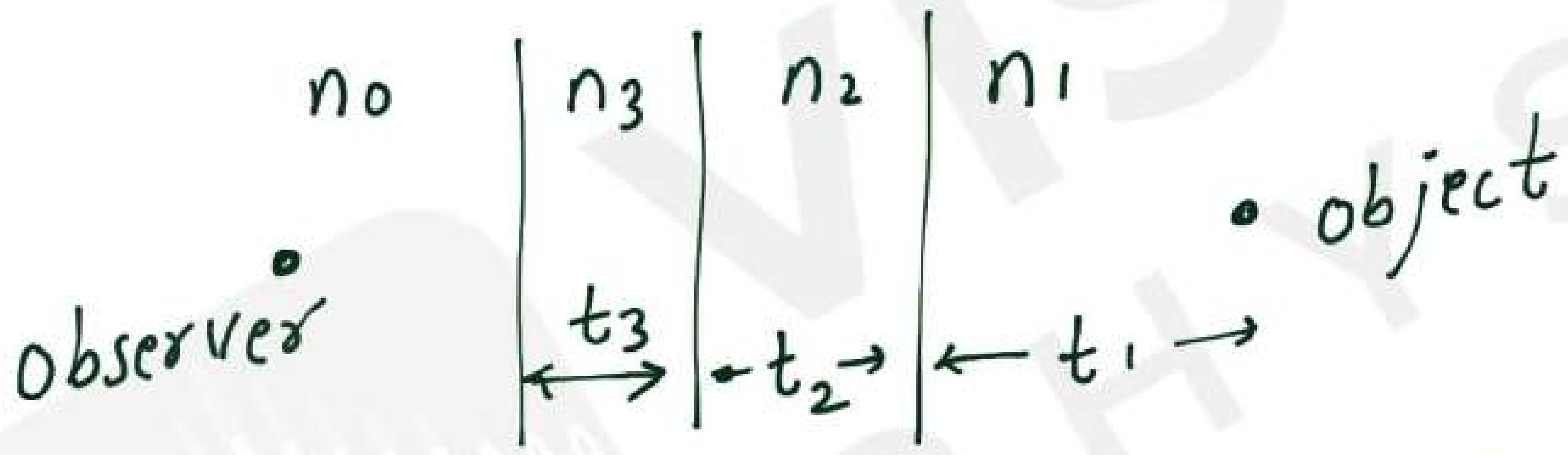
$\sin i \to i$, $\sin r \to r$ & $\cos r \to 1$

$\dfrac{\sin i}{\sin r} = \mu$ takes the form $\dfrac{i}{r} = \mu$

$\Rightarrow d = \dfrac{t(i-r)}{i} = ti\left(1 - \dfrac{r}{i}\right)$

$$d = ti\left(1 - \frac{1}{\mu}\right)$$

for multiple slabs:

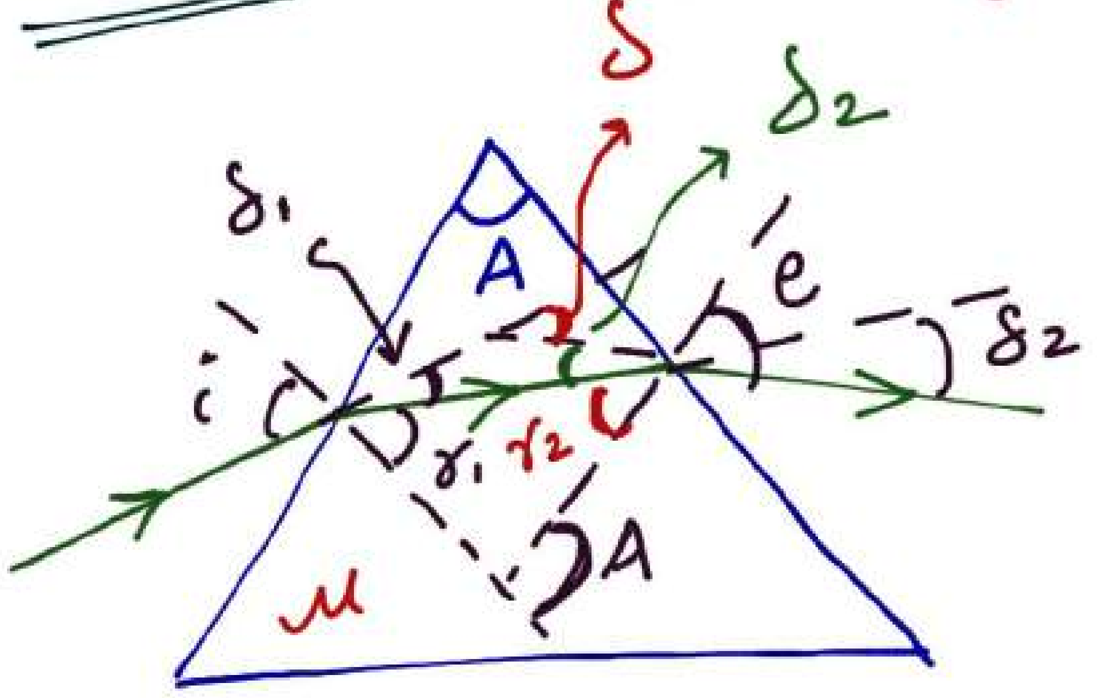


$\Rightarrow$ Apparent shift $= t_1\left[1 - \dfrac{1}{n_{1\,rel}}\right] + t_2\left[1 - \dfrac{1}{n_{2\,rel}}\right] + \dots + t_n\left[1 - \dfrac{1}{n_{n\,rel}}\right]$

$\Rightarrow n_{1\,rel} = n_1/n_0$, $n_{2\,rel} = n_2/n_0$ etc.

Prism:

$\delta \rightarrow$ Angle of deviation
$\hookrightarrow$ Angle between emergent & incident ray



$\delta_1 = i - r_1$, $\delta_2 = e - r_2$

$\Rightarrow \delta = \delta_1 + \delta_2$

$\delta = (i - r_1) + (e - r_2)$

$\Rightarrow \delta = i + e - \underbrace{(r_1 + r_2)}_{A}$ → Angle of prism

$$\Rightarrow \boxed{\delta = i + e - A}$$

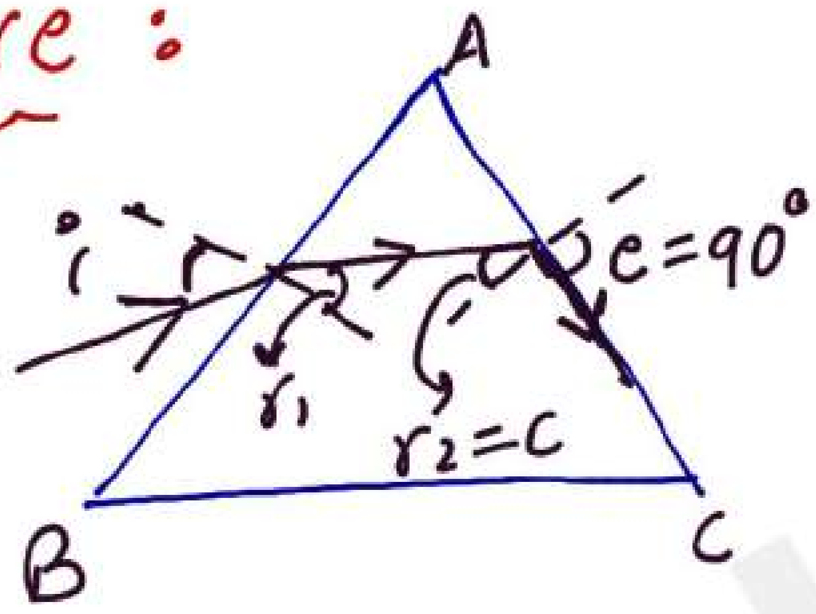
$\{$ if $A > 2\theta_c \}$ → θ_c: critical angle

$\hookrightarrow$ the ray will not emerge out of a prism (whatever may be the angle of incidence)

$$\left\{ \mu > \frac{1}{\sin(A/2)} \right\}$$

for Grazing emergence :

$e = 90^\circ$



$A = r_1 + r_2 = r_1 + C$

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

$$\Rightarrow \sin i = n \sin(A - C)$$

$$= n\left[\sin A \cos C - \cos A \sin C\right]$$

$$= n\left[\sin A \sqrt{1 - \sin^2 C} - \cos A \sin C\right]$$

$$= n\left[\sin A \sqrt{1 - \frac{1}{n^2}} - \cos A \times \frac{1}{n}\right]$$

$$\Rightarrow \sin i = n\left[\frac{\sin A}{n}\sqrt{n^2 - 1} - \frac{\cos A}{n}\right]$$

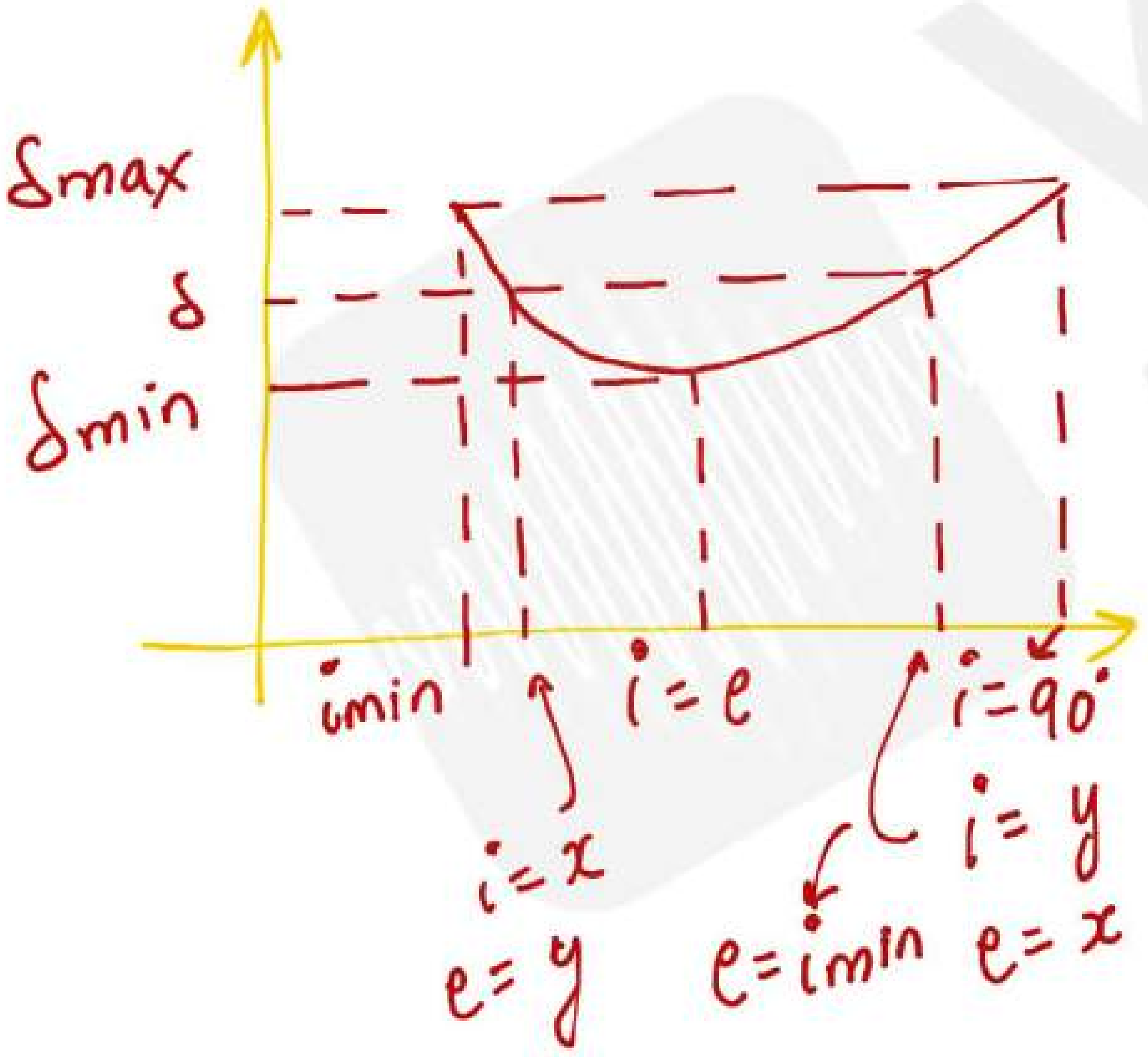
$$\Rightarrow \sin i = \sin A \sqrt{n^2 - 1} - \cos A$$

$$\boxed{i = \sin^{-1}\left[\sqrt{n^2 - 1}\,\sin A - \cos A\right]}$$

for max Deviation

$$\delta_{max} = 90^\circ + e - A$$

$$e = \sin^{-1}[\mu \sin(A - \theta_c)]$$



for minimum Deviation

$$i = e, \quad \delta_{min} = 2i - A$$

$$\mu = \frac{\sin[(\delta_{min} + A)/2]}{\sin(A/2)}$$

Thin prism

↳ A ⇝ very small

as $A = r_1 + r_2$

↳ small as well so as i_1 & i_2

$$\sin i_1 = \mu \sin r_1$$

$$i_1 = \mu r_1 \quad [\text{as } i_1, i_2, r_1 \,\&\, r_2 \text{ are small}]$$

$$\& \ \sin i_2 = \mu \sin r_2$$

$$i_2 = \mu r_2$$

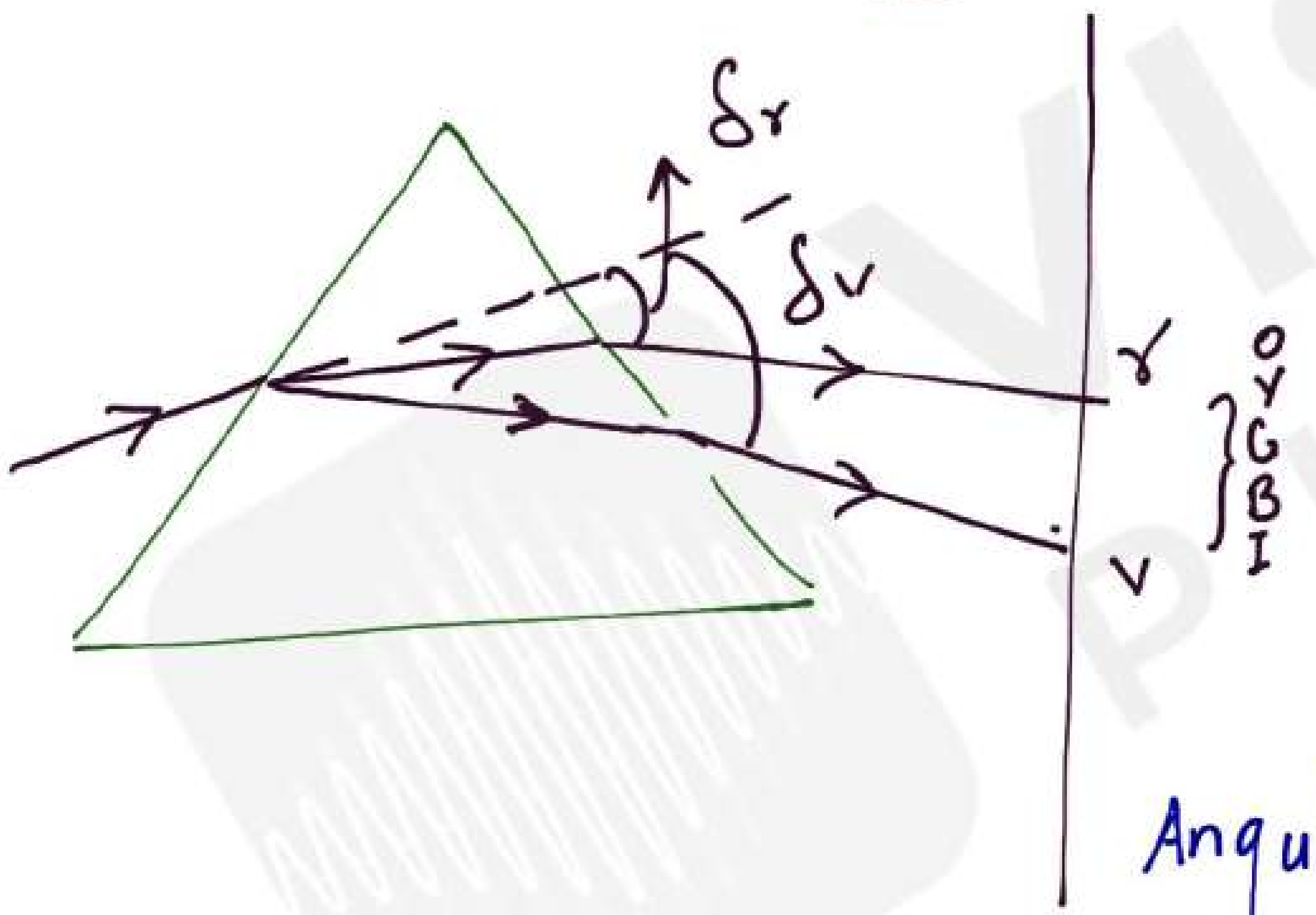
$$\delta = (i_1 - r_1) + (i_2 - r_2)$$

$$\delta = (r_1 + r_2)(\mu - 1) \Rightarrow \boxed{\delta = A(\mu - 1)}$$

Dispersion of light

→ when ray of light passes through prism it splits up into rays of constituent colours or wavelength

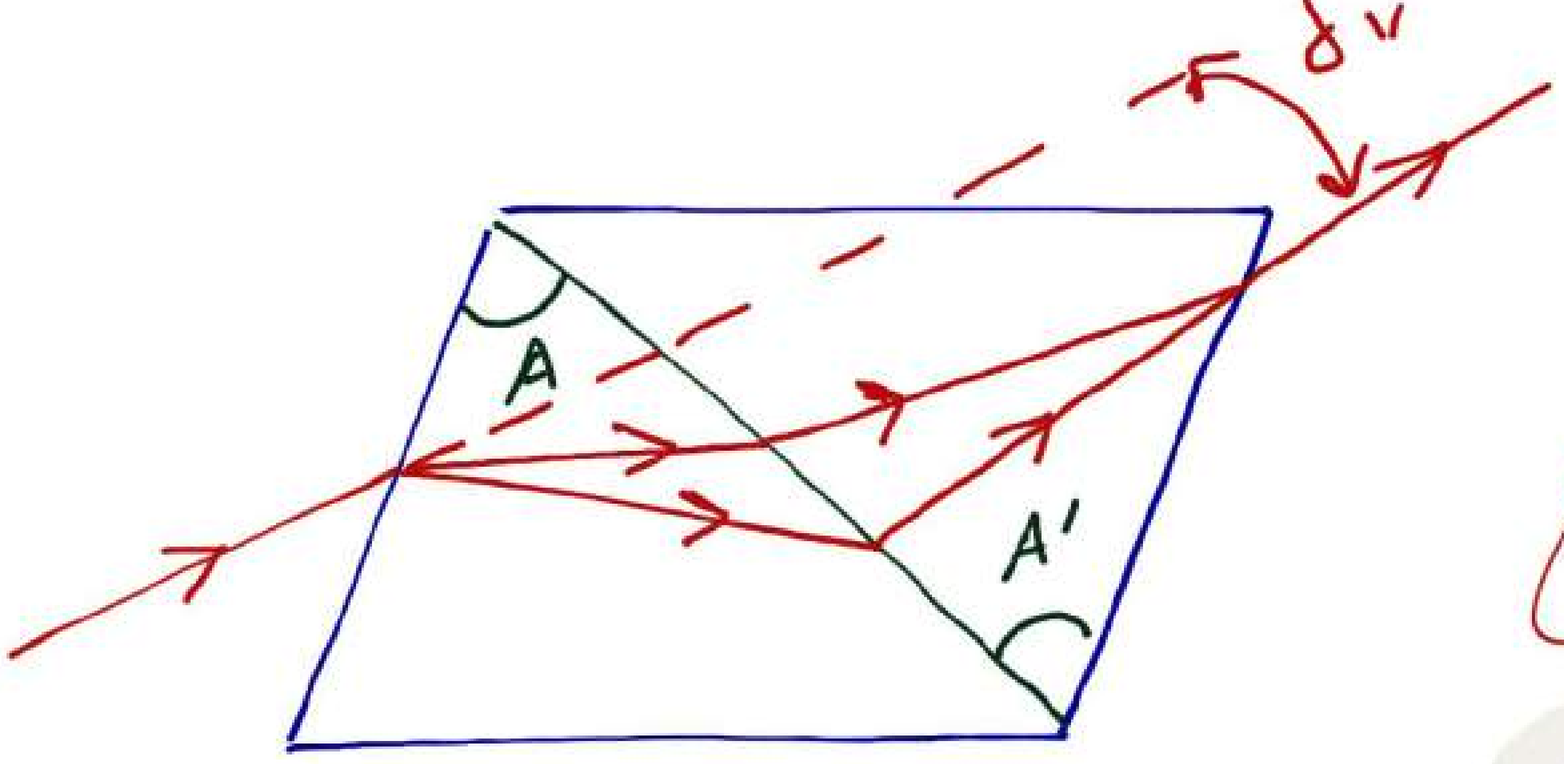
↳ this happens because refractive index varies with wave length



$\Rightarrow \boxed{\mu_{blue} > \mu_{red}}$

Angular dispersion : $\theta = \delta_v - \delta_r$

Dispersive power : $\boxed{\omega = \dfrac{\delta_v - \delta_r}{\delta}}$



for two prism:

$$(\mu_v - \mu_r)A + (\mu_v - \mu_r)A' = 0$$

$$\left\{ A' = \frac{(\mu_v - \mu_r)A}{\mu_v - \mu_r} \right\}$$

$$\omega\delta + \omega'\delta' = 0$$

$$\left\{ \delta = \delta' \left[1 - \frac{\omega}{\omega'} \right] \right\}$$

ω & ω' → dispersive powers of two prism

δ & δ' → mean deviations