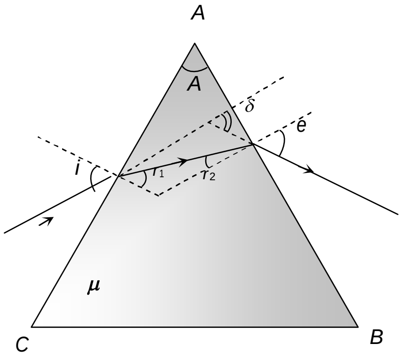
Prism

Prism is a transparent medium bounded by refracting surfaces, such that the incident surface (on which light ray is incidenting) and emergent surface (from which light rays emerges) are plane and non parallel.

(1) **Refraction through a prism**



i – Angle of incidence,
e – Angle of emergence,
A – Angle of prism or refracting angle of prism,
r_1 and r_2 – Angle of refraction,
δ – Angle of deviation

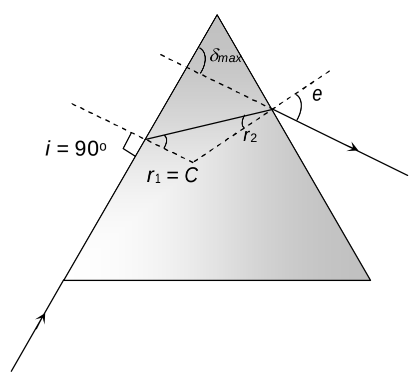
$A = r_1 + r_2$ and $i + e = A + \delta$

For surface AC $\mu = \dfrac{\sin i}{\sin r_1}$; For surface AB $\dfrac{1}{\mu} = \dfrac{\sin r_2}{\sin e}$

(2) Deviation through a prism : For thin prism $\delta = (\mu - 1)A$. Also deviation is different for different colour light *e.g.* $\mu_R < \mu_V$ so $\delta_R < \delta_V$.

$\mu_{\text{Flint}} > \mu_{\text{Crown}}$ so $\delta_F > \delta_C$

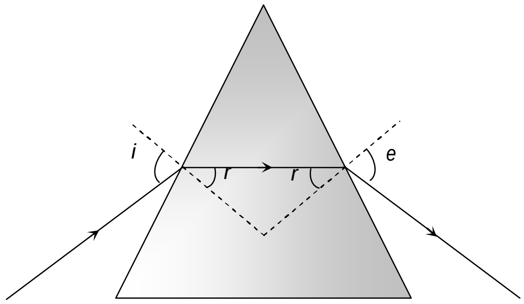
(i) Maximum deviation : Condition of maximum deviation is $\angle i = 90^o \Rightarrow r_1 = C,\ r_2 = A - C$ and from Snell's law on emergent surface

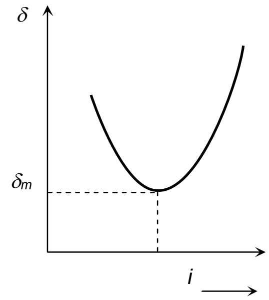


$$e = \sin^{-1}\left[\frac{\sin(A-C)}{\sin C}\right]$$

$$\delta_{\max} = \frac{\pi}{2} + \sin^{-1}\left[\frac{\sin(A-C)}{\sin C}\right] - A$$

(ii) Minimum deviation : It is observed if $\angle i = \angle e$ and $\angle r_1 = \angle r_2 = r$, deviation produced is minimum.





(a) Refracted ray inside the prism is parallel to the base of the prism for equilateral and isosceles prisms.

(b) $r = \frac{A}{2}$ and $i = \frac{A + \delta_m}{2}$

(c) $\mu = \frac{\sin i}{\sin A/2}$ or $\mu = \frac{\sin \frac{A+\delta_m}{2}}{\sin A/2}$ (Prism formula).

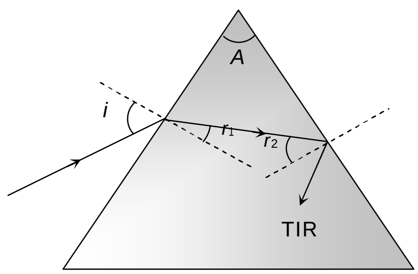
(3) **Condition of no emergence** : For no emergence of light, TIR must takes place at the second surface

For TIR at second surface $r_2 > C$

So $A > r_1 + C$ (From $A = r_1 + r_2$)

As maximum value of $r_1 = C$

So, $A \geq 2C$. for any angle of incidence.

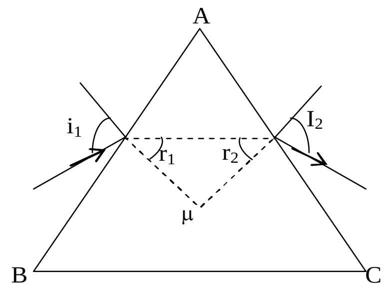


If light ray incident normally on first surface *i.e.* $\angle i = 0°$ it means $\angle r_1 = 0°$. So in this case condition of no emergence from second surface is $A > C$.

$$\Rightarrow \sin A > \sin C \Rightarrow \sin A > \frac{1}{\mu} \Rightarrow \mu > \operatorname{cosec} A$$

(4) **Deviation produced by a very thin prism**

Consider a small angled prism. When the ray of light incident on the face AB of the prism.



We have, $\mu = \frac{\sin i_1}{\sin r_1}$

If angle of i_1 and r_1 is very small

$\therefore \sin i_1 \approx i_1, \sin r_1 \approx r_1$

$(\mu_v - 1)A + (\mu^1_v - 1)A^1 = 0$

Now, for refraction at the face AC of the prism

Since angle r_2 and i_2 are very small $\frac{1}{\mu} = \frac{r_2}{I_2}$

$\frac{1}{\mu} = \frac{\sin r_2}{\sin i_2} \Rightarrow i_2 = \mu r_2$

The deviation produced by prism is given by

$\delta = I_1 + I_2 - r_1 - r_2$

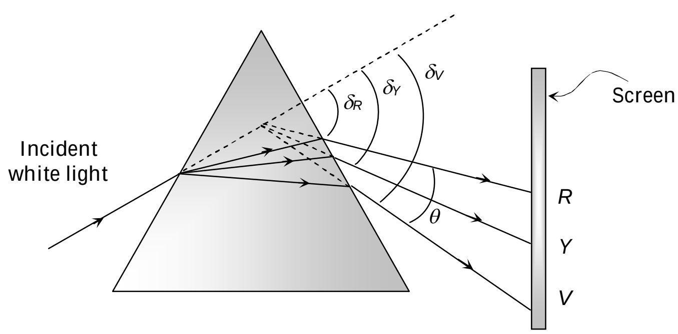
$= \mu r_1 + r_2\mu - (r_1 + r_2) = (r_1 + r_2)(\mu - 1)$

$\delta = (\mu - 1)A \qquad [r_1 + r_2 = A]$

Dispersion Through a Prism

The splitting of white light into it's constituent colours is called dispersion of light.

(1) **Angular dispersion (θ)** : Angular separation between extreme colours *i.e.* $\theta = \delta_V - \delta_R = (\mu_V - \mu_R)A$. It depends upon μ and A.



(2) **Dispersive power (ω)** :

$$\omega = \frac{\theta}{\delta_y} = \frac{\mu_V - \mu_R}{\mu_y - 1} \quad \text{where} \left\{\mu_y = \frac{\mu_V + \mu_R}{2}\right\}$$

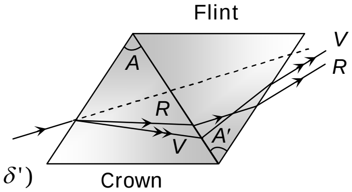
$\Rightarrow$ It depends only upon the material of the prism *i.e.* μ and it doesn't depends upon angle of prism A

(3) **Combination of prisms** : Two prisms (made of crown and flint material) are combined to get either dispersion only or deviation only.

(i) Dispersion without deviation (chromatic combination)

$$\frac{A'}{A} = -\frac{(\mu_y - 1)}{(\mu'_y - 1)}$$

$$\theta_{\text{net}} = \theta\left(1 - \frac{\omega'}{\omega}\right) = (\omega\delta - \omega'\delta')$$



(ii) Deviation without dispersion (Achromatic combination)

$$\frac{A'}{A} = -\frac{(\mu_V - \mu_R)}{(\mu'_V - \mu'_R)}$$

$$\delta_{\text{net}} = \delta\left(1 - \frac{\omega}{\omega'}\right)$$