Session-7 – Optics – Refraction through plane surface

$\boxed{\text{Laws of Refraction}} \rightarrow \boxed{\text{Ref. index}} \rightarrow \boxed{\text{Ref. thru slab}} \rightarrow \boxed{\text{TIR}}$

Recap →

1) $n_1 \sin i = n_2 \sin r$

2) $n = c/v$

$v = c/n$

3) $\frac{n_2}{n_1} = \frac{c/v_2}{c/v_1} = \frac{v_1}{v_2}$

$n \uparrow \quad v \downarrow$

$n \rightarrow 4/3$ (water)

$\rightarrow 3/2$ (glass)

$\rightarrow 1$ (air)

$\rightarrow 2$ (diamond).

4). lateral shift, $\frac{t}{\cos r} \sin(i-r)$

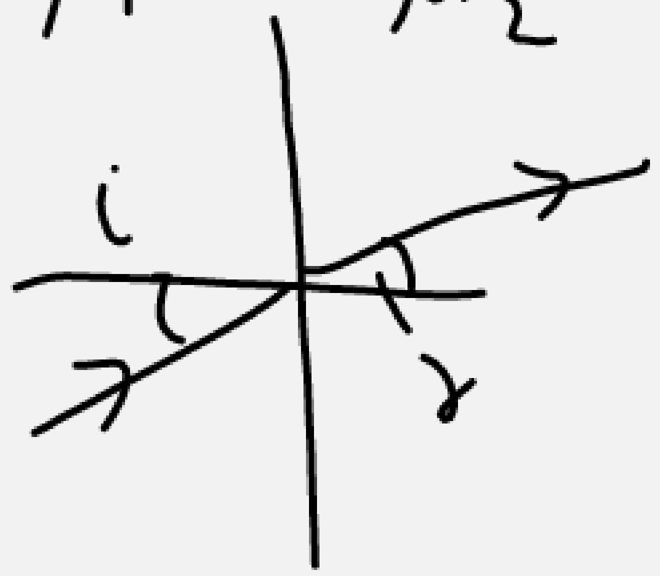
5). Normal shift → $t\left(1 - \frac{1}{\mu}\right)$.

Relative Ref. Index.

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

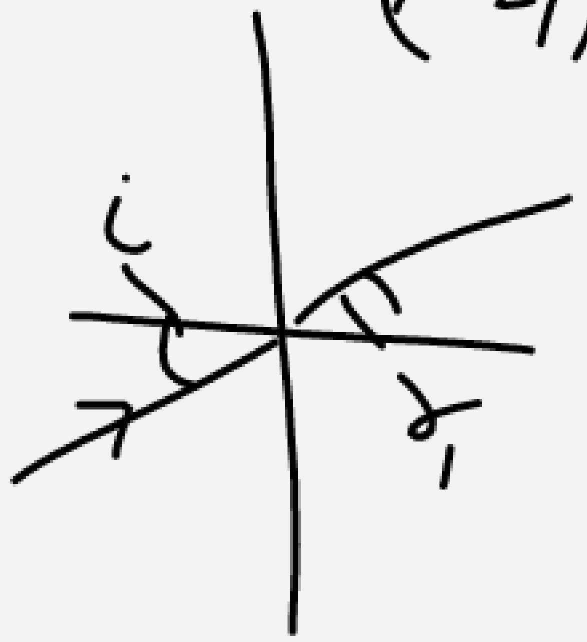
$= \left(\frac{\mu}{1}\right)$ $\qquad \boxed{\mu = \frac{\mu_2}{\mu_1}}$

Ex. $\mu_1 \quad \mu_2$



$\mu_1 \sin i = \mu_2 \sin r$

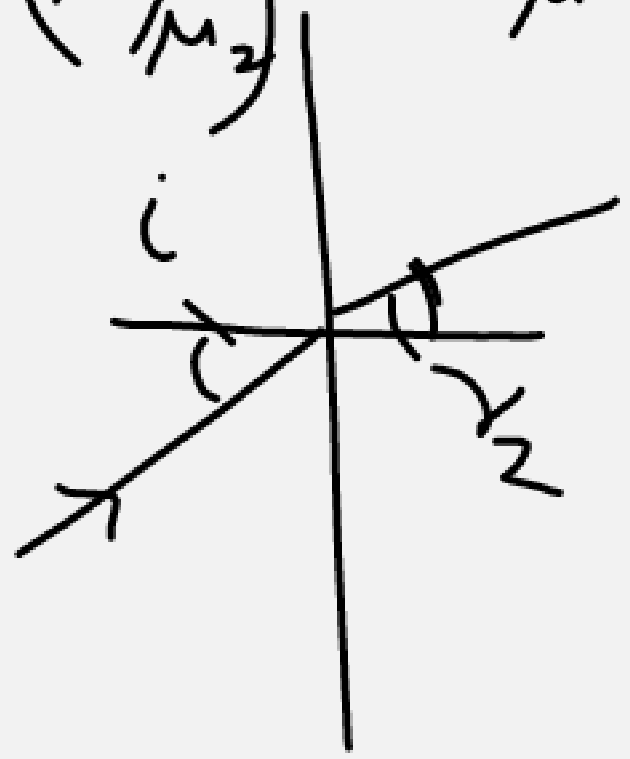
$\mu = 1 \qquad \mu = (\mu_2/\mu_1)$



$r_1 \overset{?}{=} r$

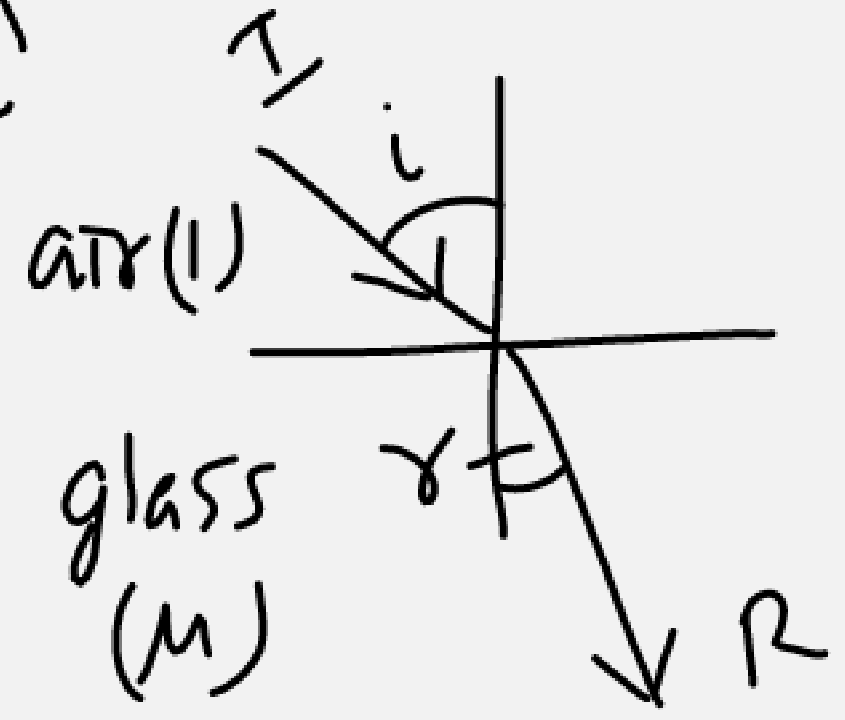
$1 \sin i = \left(\frac{\mu_2}{\mu_1}\right) \sin r_1$

$\mu = (\mu_1/\mu_2) \qquad \mu = 1$



$r_2 \overset{?}{=} r$

Ex 1



Find ratio of wavelength of I & R

$$\boxed{v = f\lambda}$$

v: changing

f: (source dep.) constant

λ: (changes)

$$\frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1} = \frac{\mu}{1}$$

Ex 2.

$\mu_{diamond} = 2$

find vel. of light in diamond.

$$v_{diamond} = c/\mu_{diamond}$$

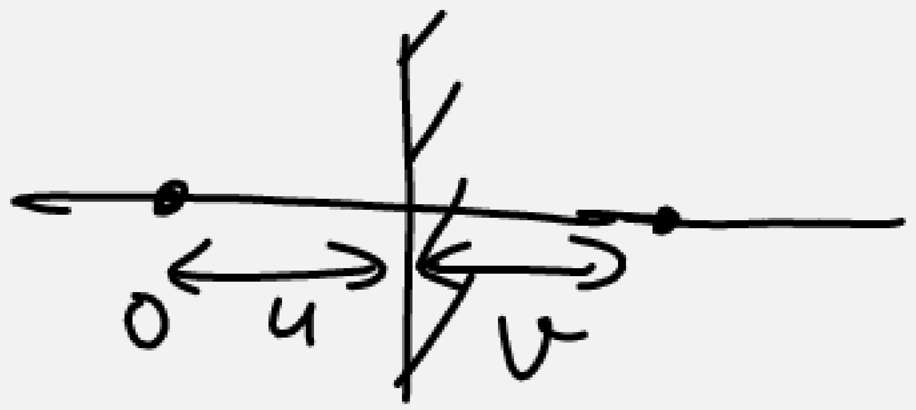
$$= \frac{3\times10^8}{2}$$

$$= 1.5\times10^8 \, m/s.$$

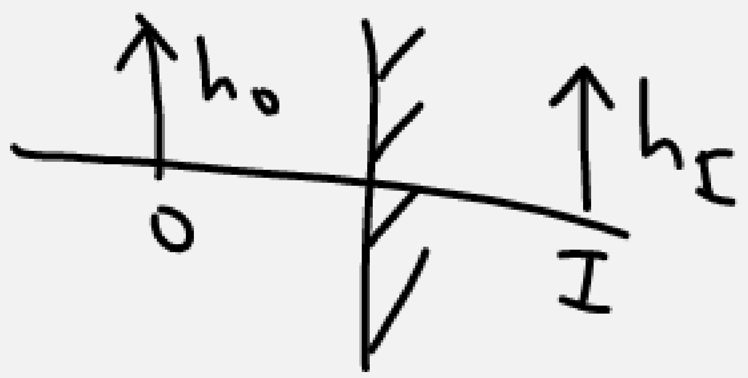
Magnification

$$m = -\frac{v}{u} = \frac{h_I}{h_o}$$

(for mirrors)



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

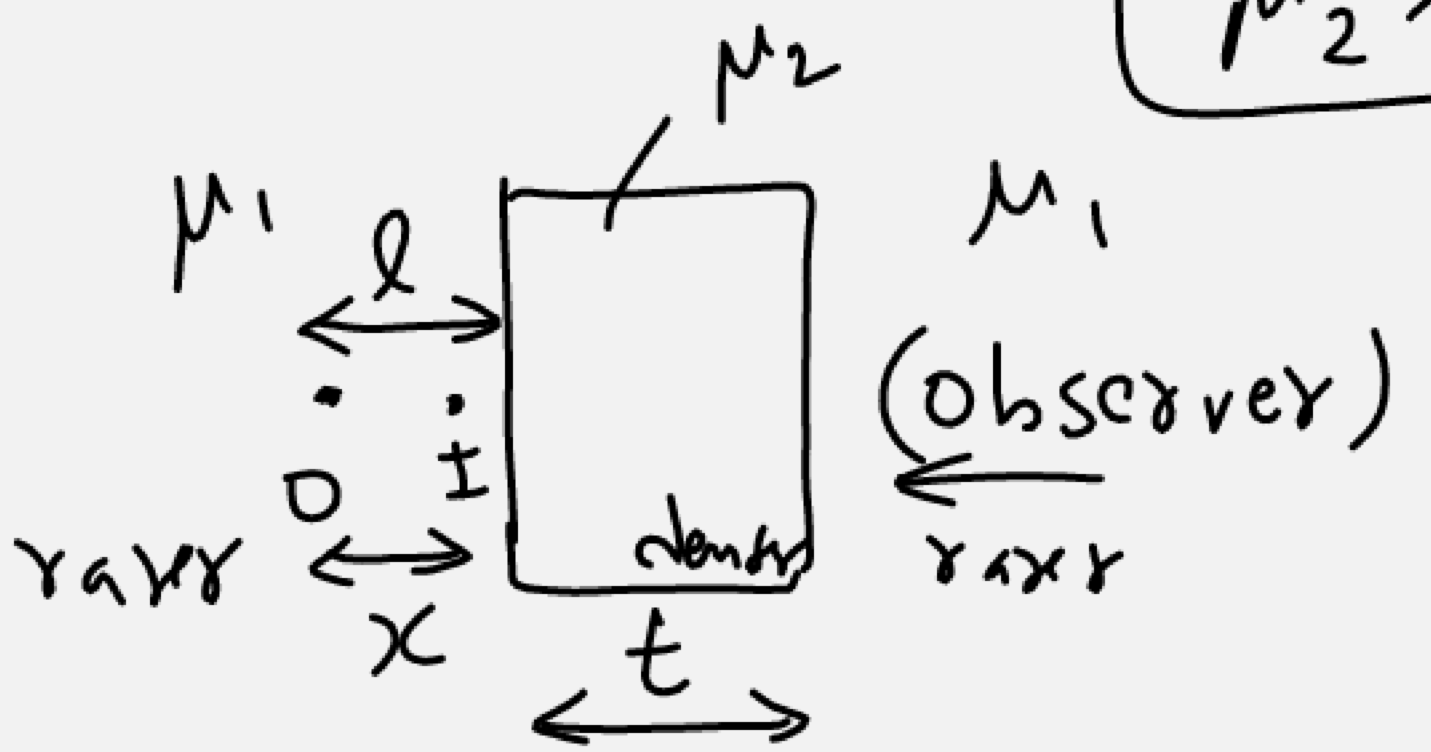


$$\boxed{m = \frac{h_I}{h_o} = 1}$$

m
- magnitude
  - size of image
  - position of image
- Sign
  - orientation of image (erect or inverted)
    - erect → (+ve)
    - inverted → (−ve)
  - nature of image
    - real obj → real img (−ve)
    - virtual obj → virtual img (−ve)
    - real obj → virtual img (+ve)
    - (& vice versa)

Refraction through glass slab (involves two refractions).

$\boxed{\mu_2 > \mu_1}$



$\boxed{\frac{\mu_2}{\mu_1} > 1}$

$$x = \text{normal shift} = t\left(1 - \frac{1}{(\mu_2/\mu_1)}\right)$$

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

$$\boxed{\mu = \frac{\mu_2}{\mu_1}}$$

$$\text{dist of obj from observer} = \underbrace{\cancel{l}}_{0} + t$$

$$= t$$

$$\text{dist of image from observer} = (l + t) - x$$

$$= l + t - x$$

$$= l + t - t(1 - 1/\mu)$$

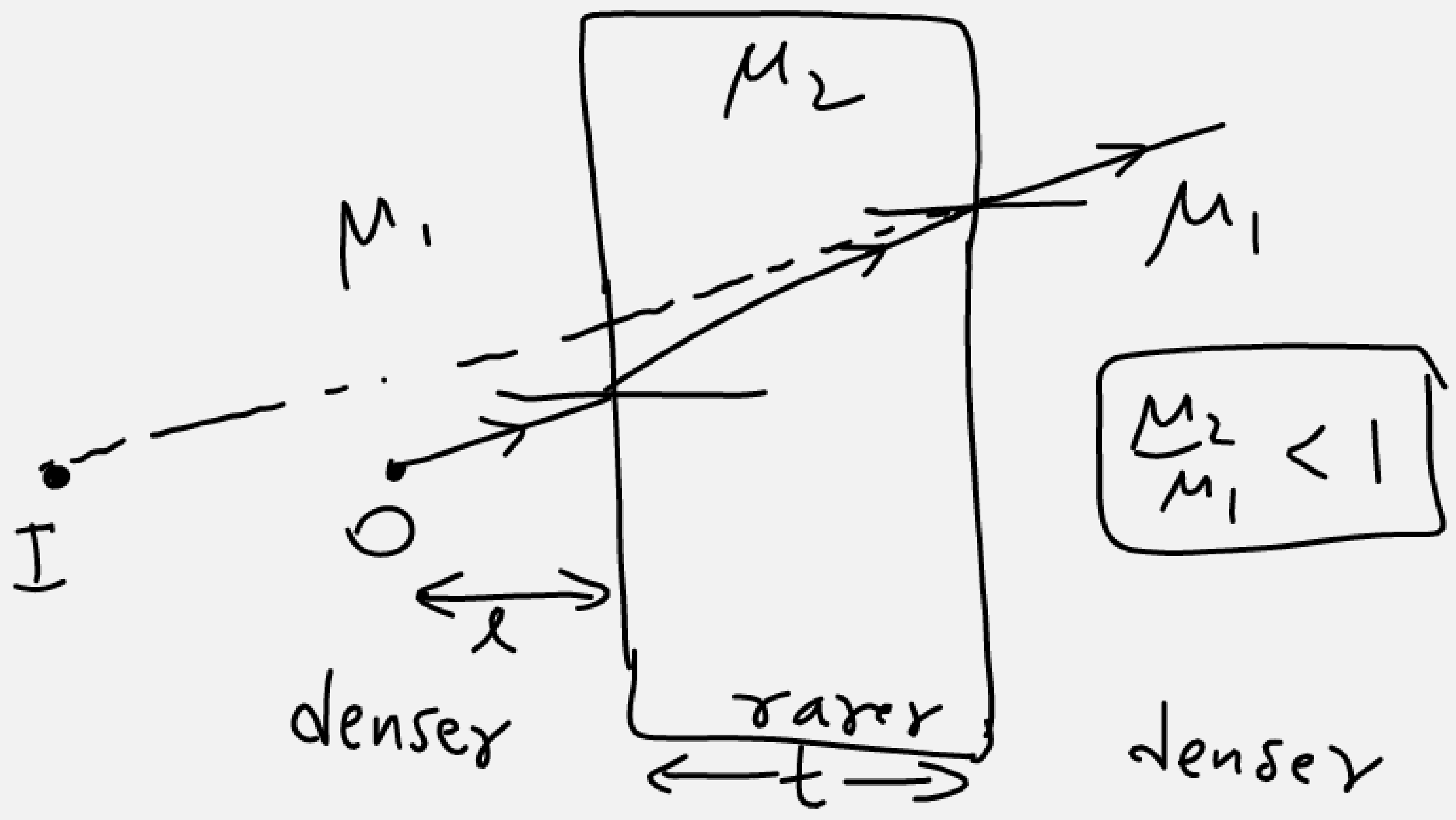
$$= l + \cancel{t} - \cancel{t} + t/\mu$$

$$= \boxed{l + t/\mu}$$

$$\boxed{\text{Apparent depth} = \underbrace{\cancel{l}}_{0} + t/\mu}$$

$$\boxed{= t/\mu} \quad (l = 0).$$

Refraction thru glass slab ($\mu_2 < \mu_1$)



$$\boxed{x = (\mu_{rel} - 1)t}$$

$$x = \left(\left(\frac{\mu_1}{\mu_2}\right) - 1\right)t$$

normal shift, $x = t\left(1 - \frac{1}{\mu}\right)$

$$= t\left(1 - \frac{1}{(\mu_2/\mu_1)}\right) = t\left(1 - \frac{1}{(\mu_2/\mu_1)}\right) \longrightarrow (-ve)$$

dist of image from obs. $= (l + t) + |x|$

$$= l + \cancel{t} + \left(\frac{\mu_1}{\mu_2}\right)t - \cancel{t}$$

$$= \underbrace{\cancel{l}}_{0} + \left(\frac{\mu_1}{\mu_2}\right)t$$

$$= \boxed{\mu_{rel}\, t}$$

Normal shift thru glass slab →

$$x = t\left(1 - \frac{1}{\mu_{rel}}\right)$$

$\boxed{x>0}$

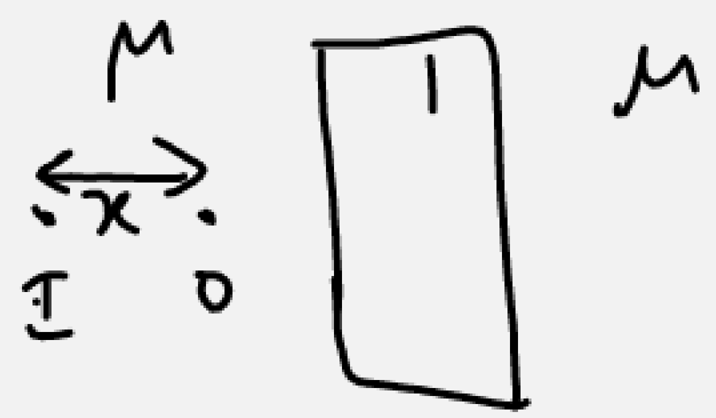
$$d_{app} = t/\mu_{rel}$$

$$x = (\mu_{rel} - 1)\,t$$

$\boxed{x>0}$

$$d_{app} = \mu_{rel}\, t$$

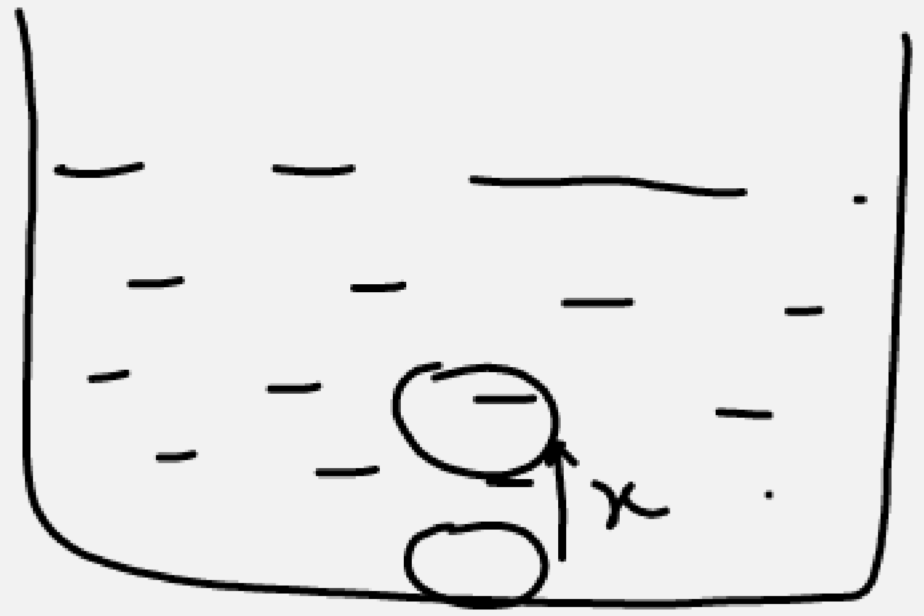
$\boxed{\mu_{rel} > 1}$

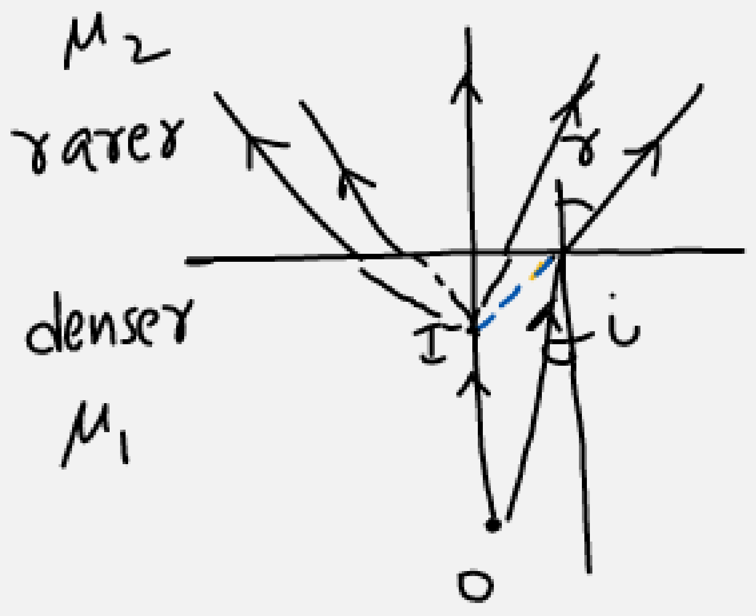


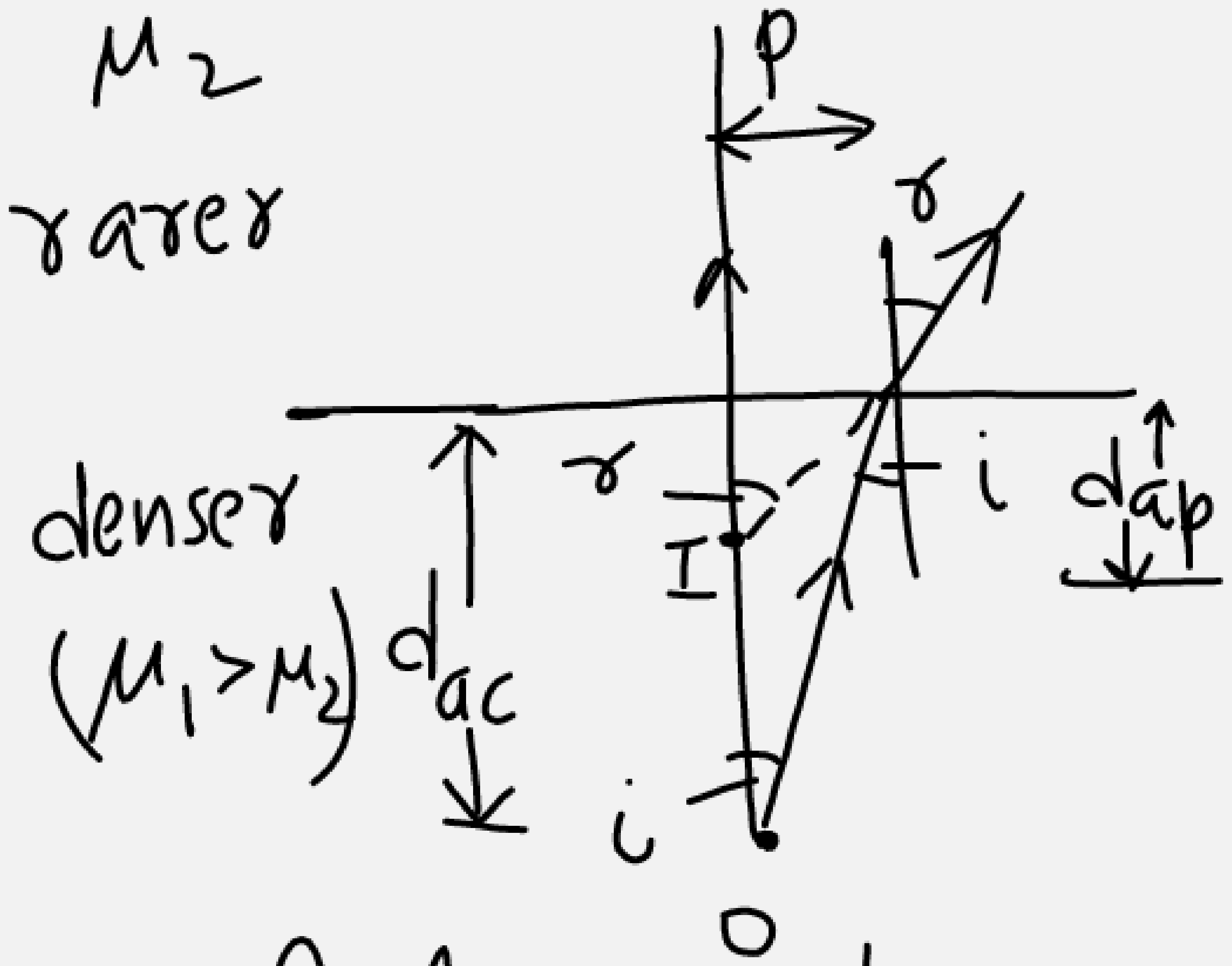
Lateral shift

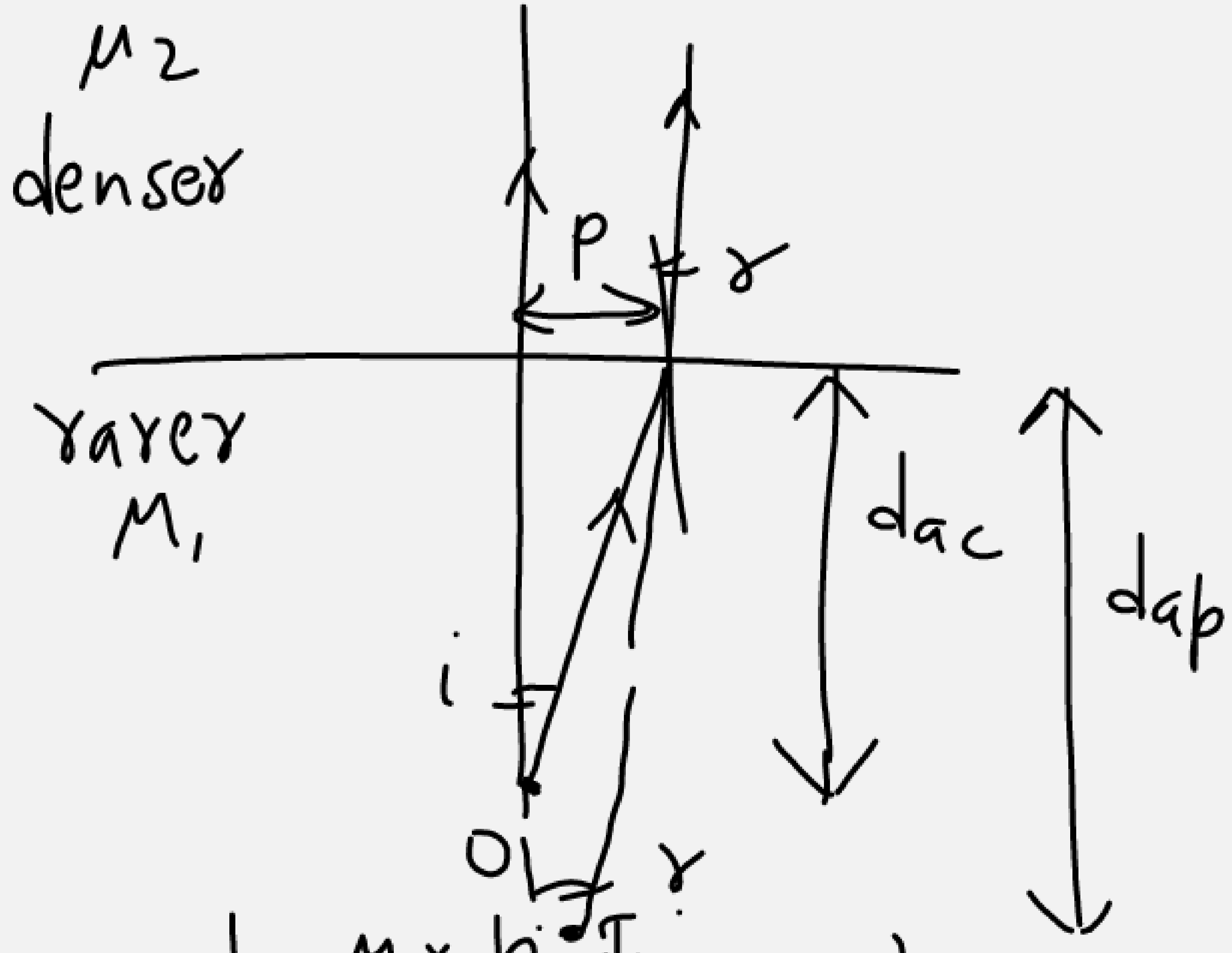
$$= \boxed{\frac{t}{\cos r}\sin(i-r)}$$

Normal shift (through single refraction)









Applying Snell's law

$$\mu_1 \sin i = \mu_2 \sin r$$

Considering near normal incidence.

$$\sin i \approx \tan i \ \& \ \sin r \approx \tan r$$

$$\tan i = \frac{p}{d_{ac}}, \quad \tan r = \frac{p}{d_{ap}}$$

$$\mu_1 \times \frac{p}{d_{ac}} = \mu_2 \times \frac{p}{d_{ap}}$$

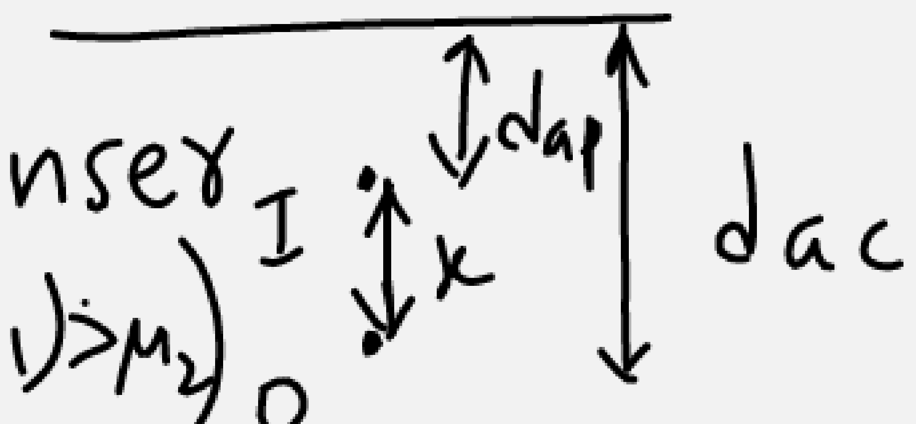
$$\Rightarrow \boxed{d_{ap} = \left(\frac{\mu_2}{\mu_1}\right) d_{ac}}$$

$$\boxed{d_{ap} = d_{ac}/\mu_{rel}}$$

Normal Shift & App depth (Result for single refraction)

(μ_2)
rarer

denser
($(\mu_1) > \mu_2$)



$$\boxed{d_{ap} = \frac{d_{ac}}{\mu_{rel}}}$$

$$x = d_{ac} - d_{ap}$$

$$x = d_{ac} - \frac{d_{ac}}{\mu_{rel}}$$

$\boxed{x > 0}$

$$\boxed{x = d_{ac}\left(1 - \frac{1}{\mu_{rel}}\right)}$$

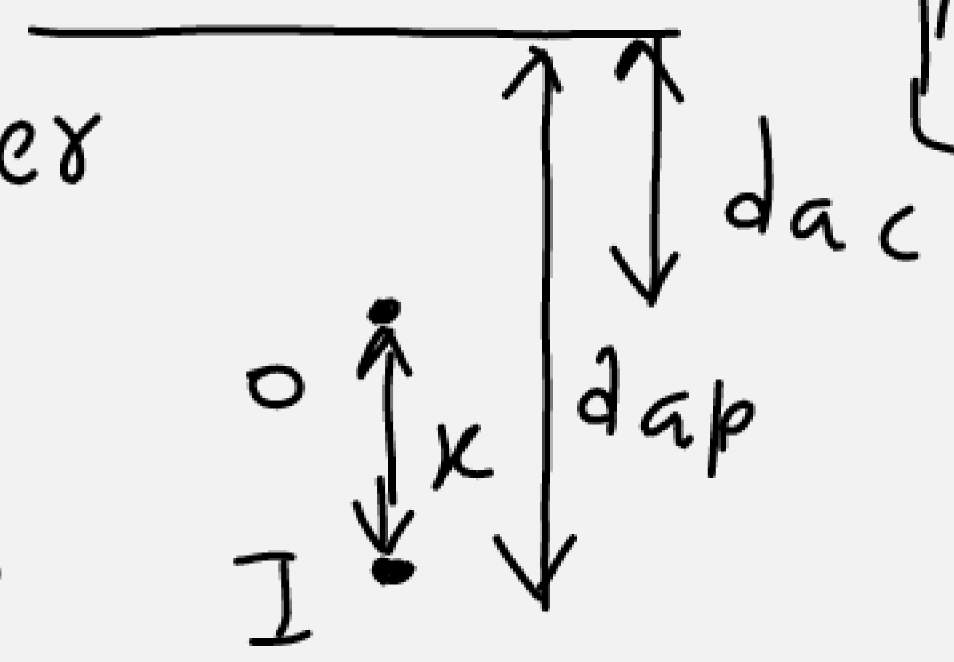
$\boxed{\mu_{rel} > 1}$

Make sure this is true.

denser
($\mu_2 > \mu_1$)

rarer
(μ_1)

$$\boxed{\mu_{rel} = \frac{\mu_2}{\mu_1}}$$



$$\boxed{d_{ap} = \mu_{rel}\, d_{ac}}$$

$$\boxed{x = (\mu_{rel} - 1)\, d_{ac}}$$

$(x > 0)$.