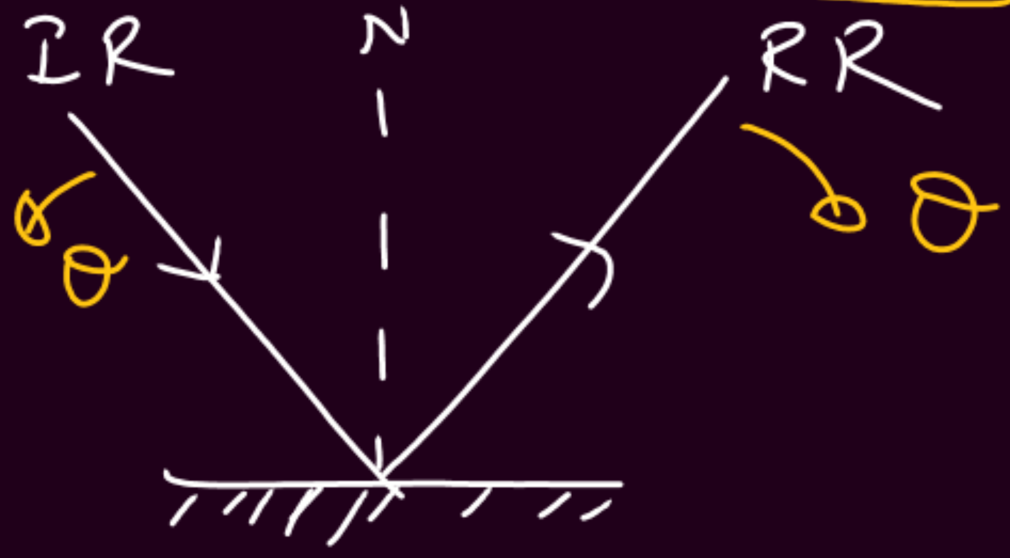
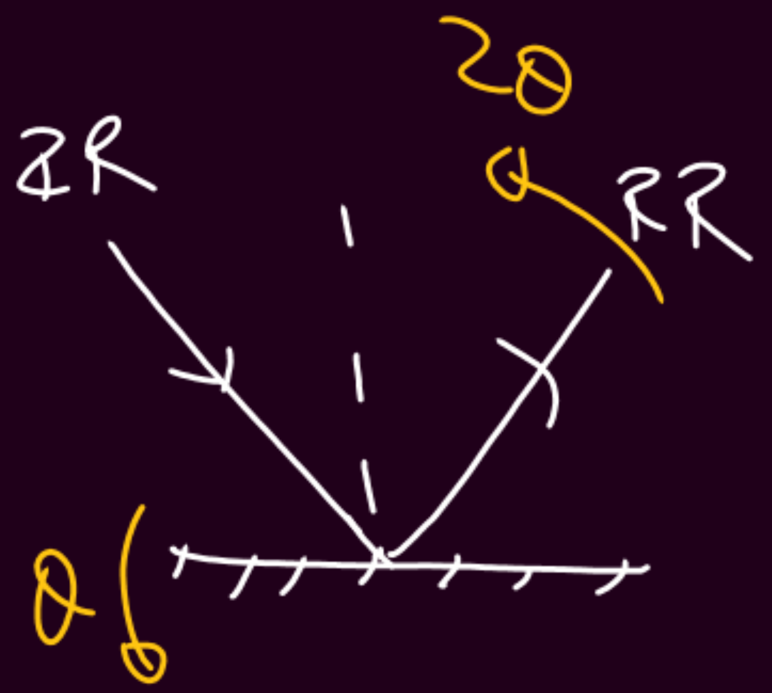
Rotation

		RR
IR	θ	$-\theta$
M	θ	2θ





Q. IR $\longrightarrow$ 10° CW

M $\longrightarrow$ 15° ACW

10° ACW
30° ACW

$\underline{40^\circ \text{ ACW}}$

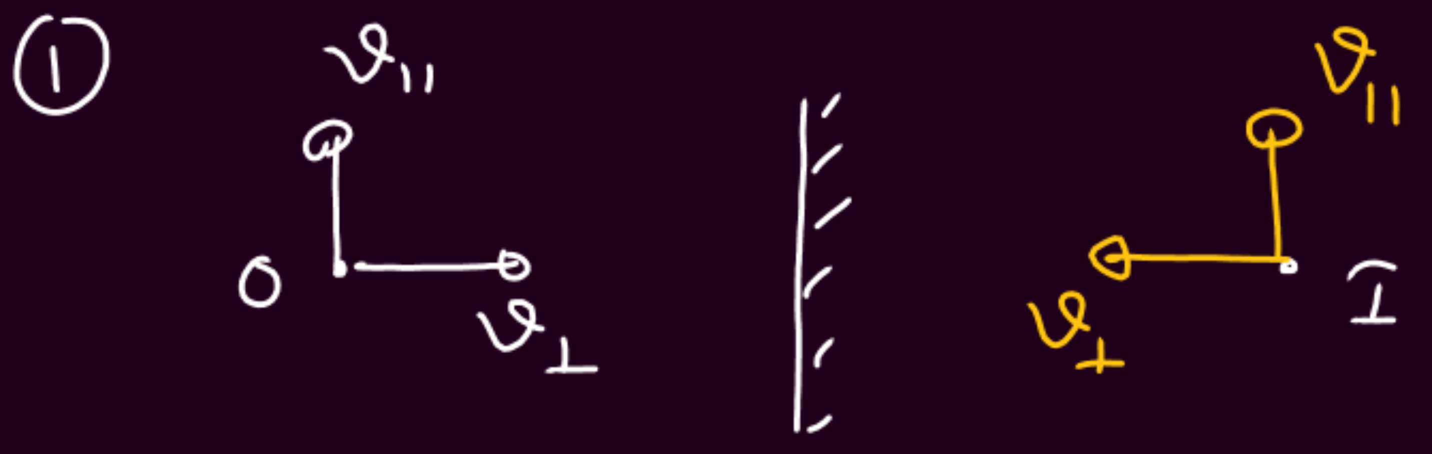
Q. IR $\longrightarrow$ 4 rad/s CW

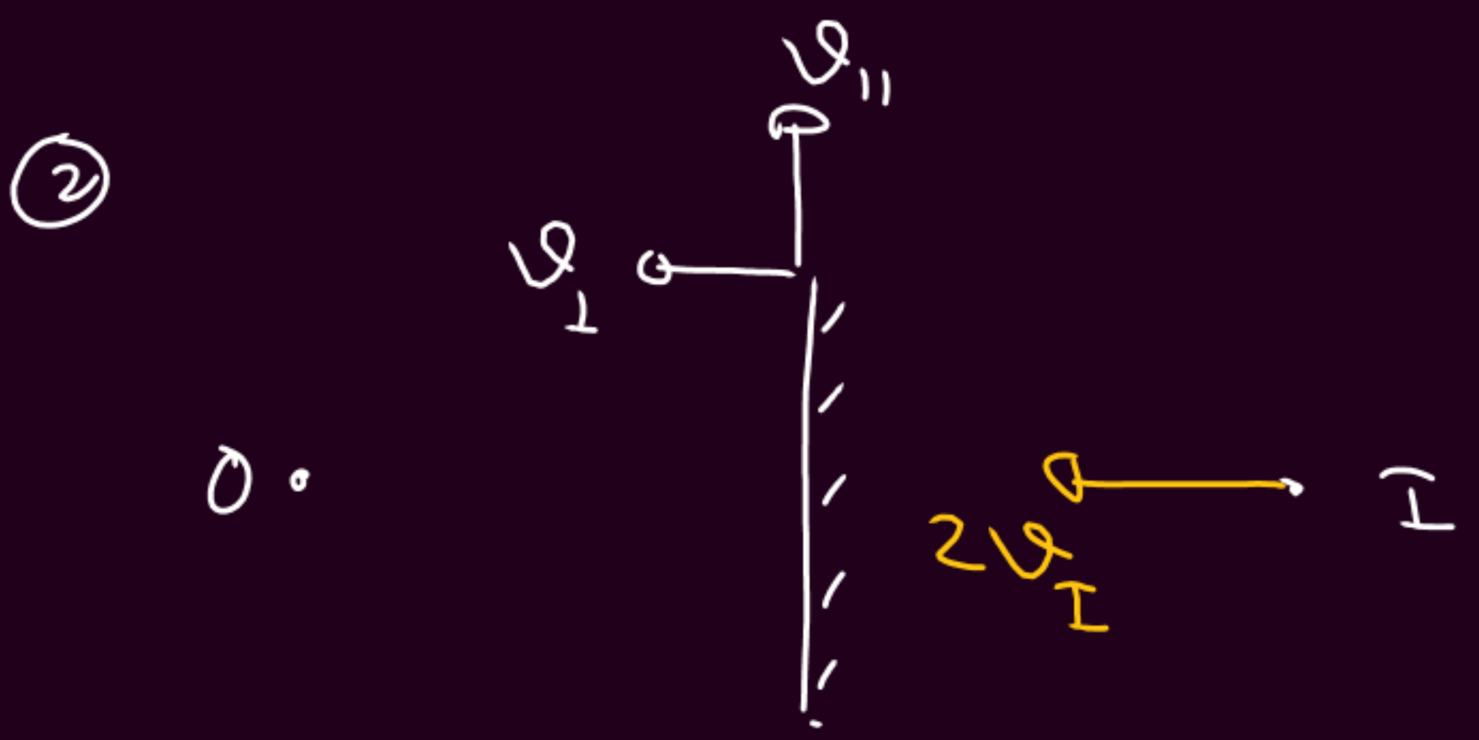
M $\longrightarrow$ 10 rad/s CW

4 ACW
20 CW

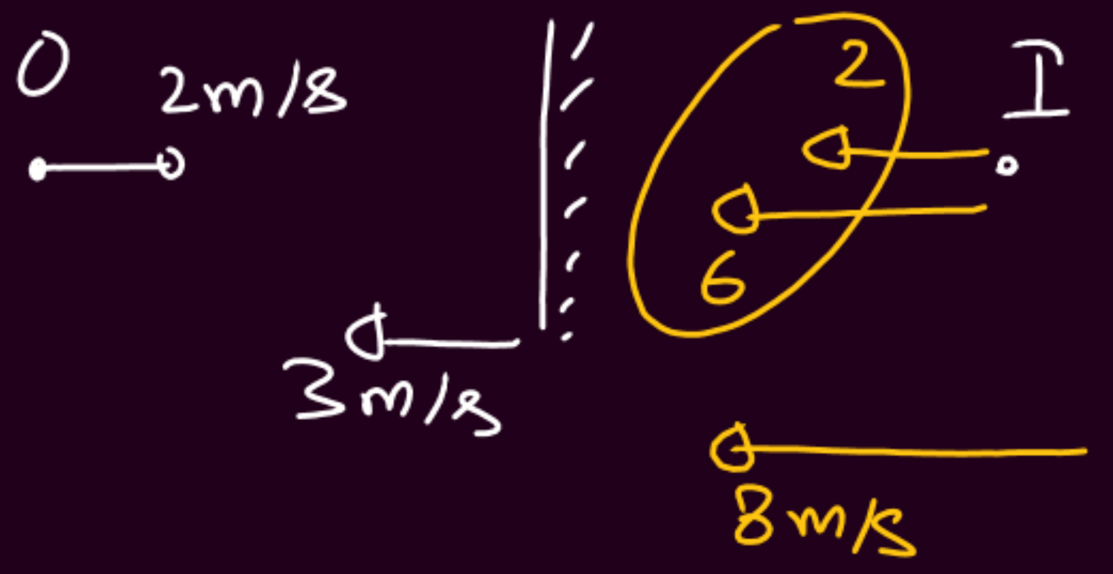
$\underline{16 \text{ CW}}$

Disp. & Vel

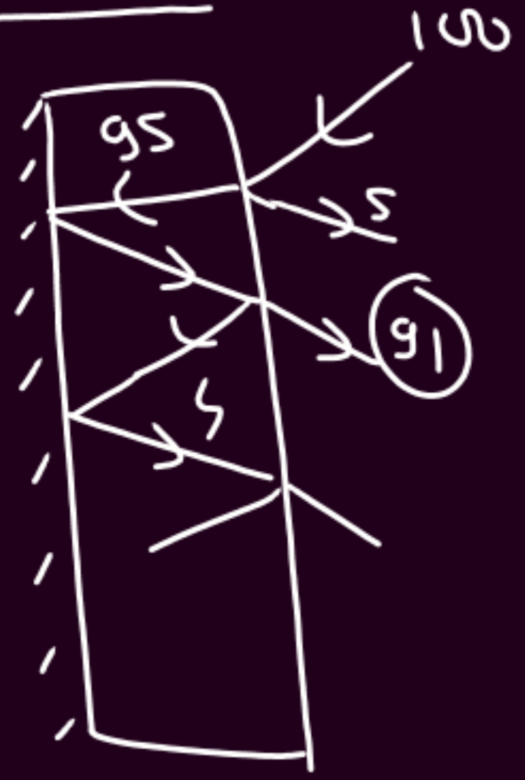




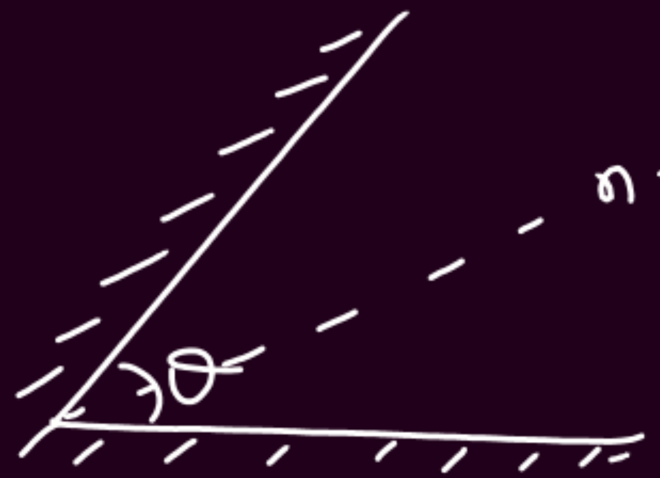
Q.



Thick Mirror

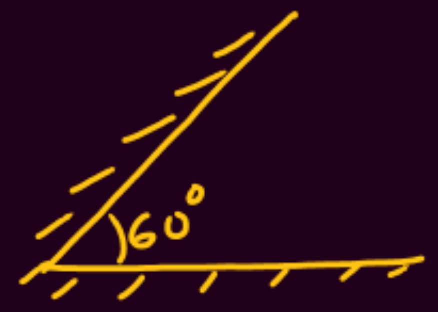


no. of Images



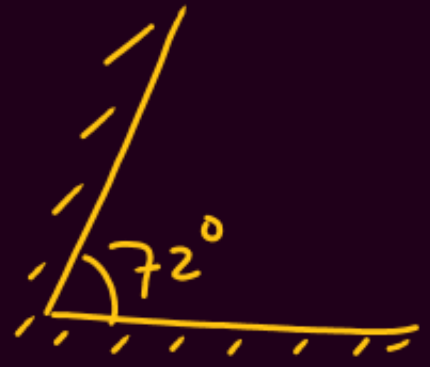
$$n = \frac{360^\circ}{\theta}$$

		Images
①	n = even	$(n-1)$
②	n = odd, Symm	$(n-1)$
	n = odd, Asymm	n



$$n = \frac{360^\circ}{60^\circ} = 6$$

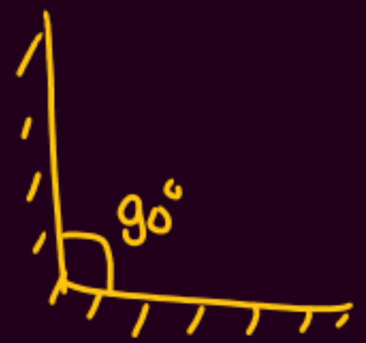
Images: 5



$$n = \frac{360^\circ}{72^\circ} = 5$$

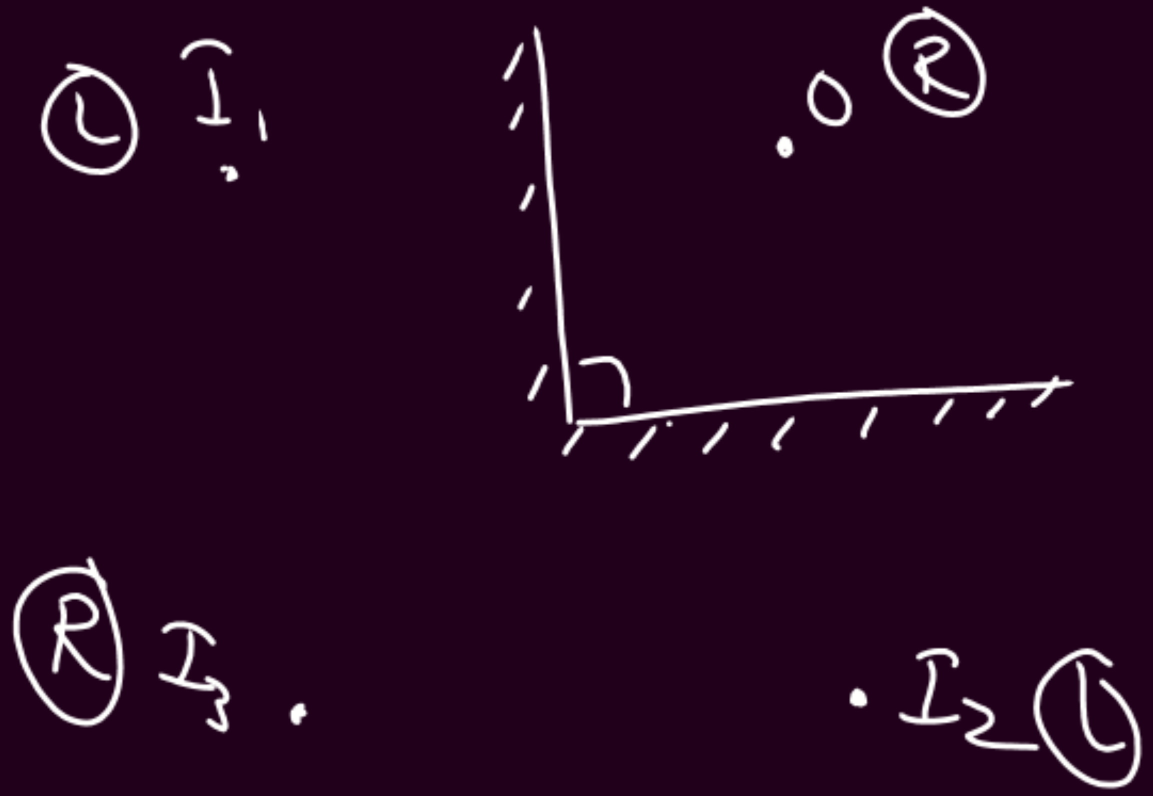
Sym → 4

Asym → 5

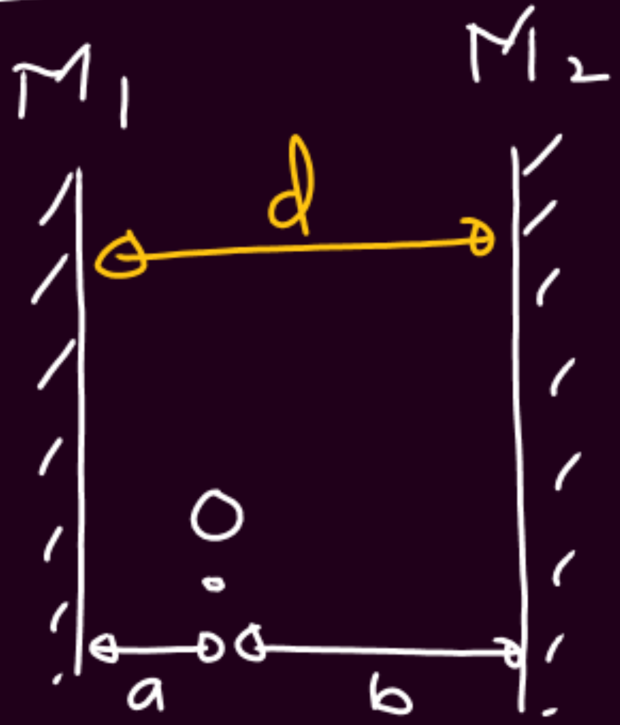


$$n = \frac{360^\circ}{90^\circ} = 4$$

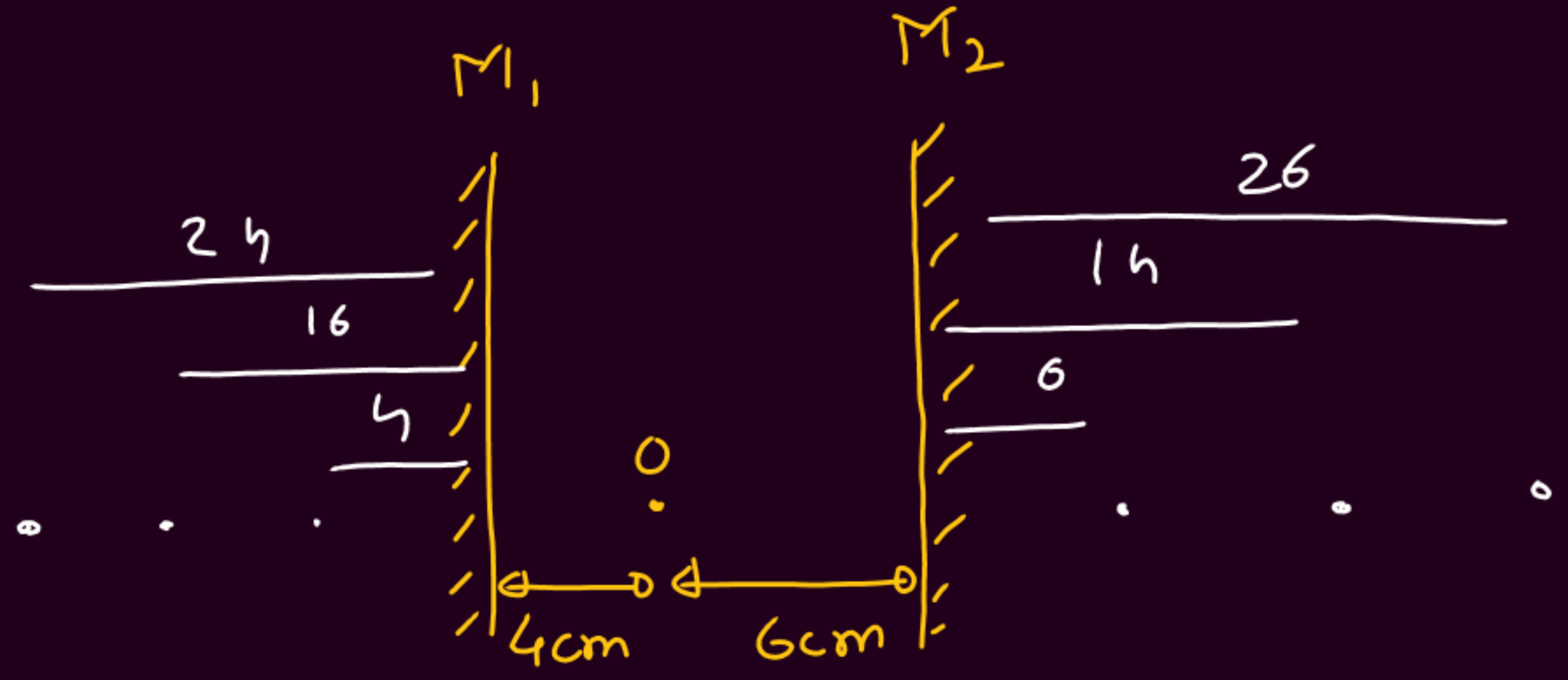
3



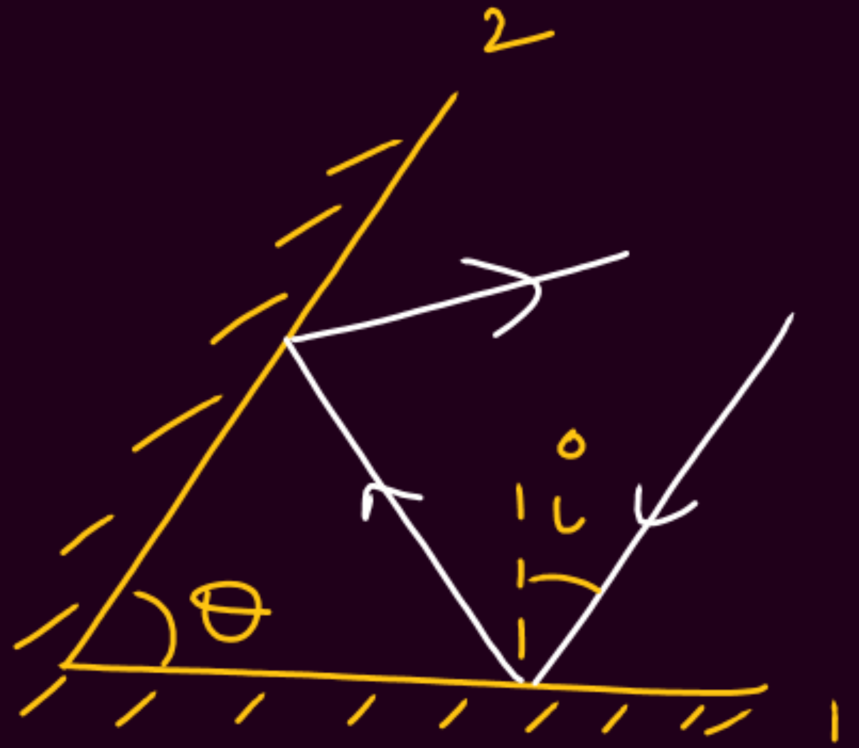
Parallel M



①	a	b
②	$b+d$	$a+d$
③	$a+2d$	$b+2d$
④	$b+3d$	$a+3d$

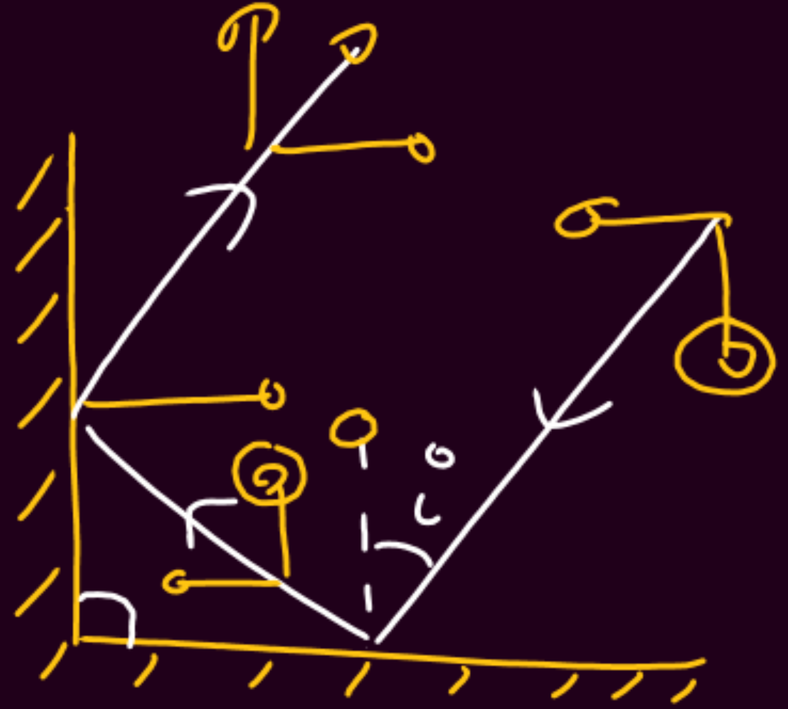


①	4	6
②	16	14
③	24	26
④	36	34



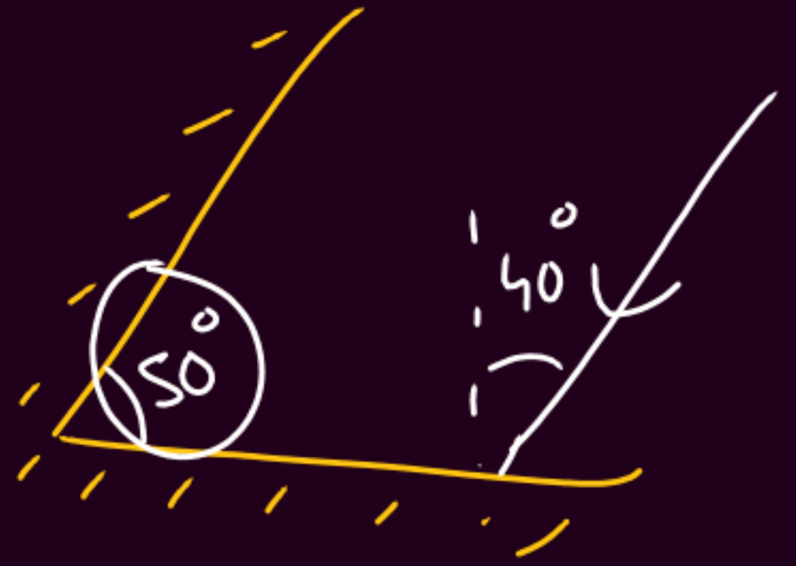
$$\boxed{\delta = 360^\circ - 2\theta}$$

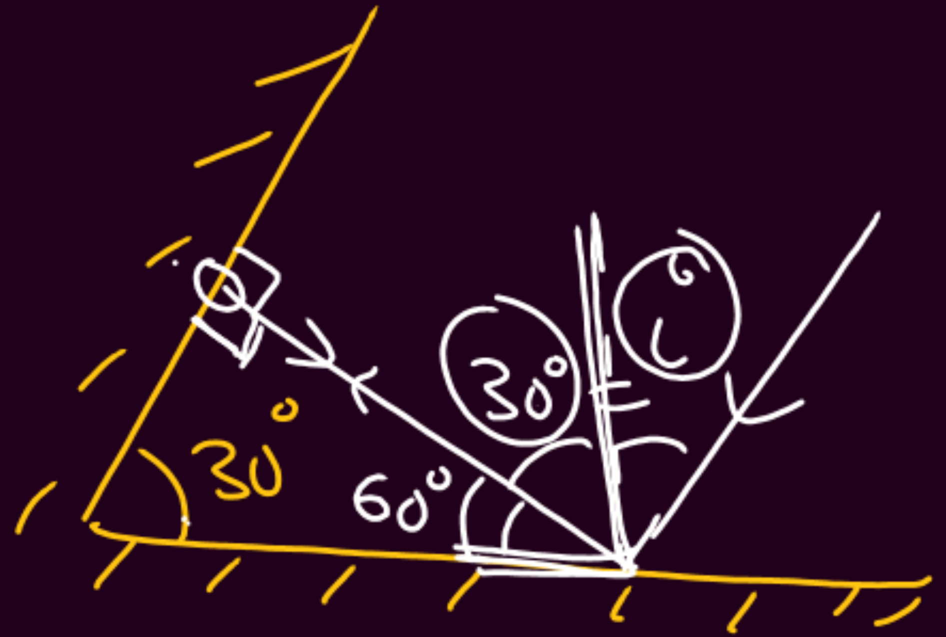
① 2D



$\delta = 180^\circ$

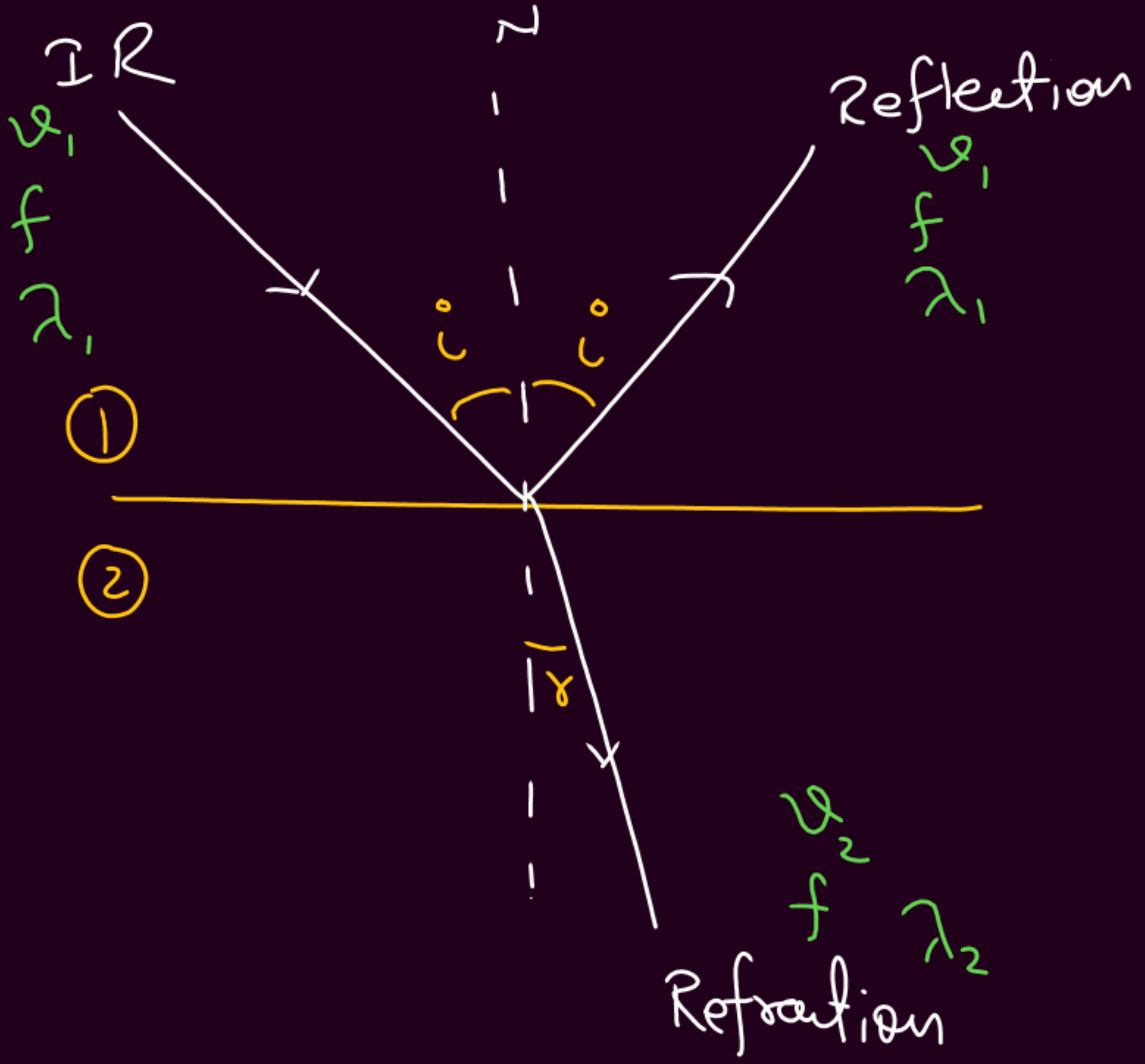
② 3D





$$\delta_{net} = 360^\circ - (2 \times 50^\circ)$$
$$= \underline{\underline{260^\circ}}$$

Refraction of Light



r = Angle of Refraction

$v \rightarrow$ Medium

$f \rightarrow$ Source

$\boxed{v = f\lambda}$

$\boxed{\text{Color} \rightarrow \text{freq}}$

Denser $\rightarrow v \downarrow$

Rarer $\rightarrow v \uparrow$

	Light	Sound
Air	3×10^8 m/s (R)	330 m/s (D)
Water	2.25×10^8 m/s (D)	1500 m/s (R)

Speed of Light

① Vacuum

$$C = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3\times10^8 \ m/s$$

ϵ_0 = Permitivity of free space

μ_0 = Permeability —— " ——

② In a medium

$$v = \frac{1}{\sqrt{\epsilon \mu}} = \frac{1}{\sqrt{\epsilon_0 \mu_0 \epsilon_r \mu_r}} = \frac{C}{\sqrt{\epsilon_r \mu_r}} = \frac{C}{R.I.}$$

ϵ = Permitivity of medium

μ = Permeability of — " ——

$$\epsilon = \epsilon_0 \epsilon_r = \epsilon_0 K$$

$$\boxed{K \geq 1}$$

$\epsilon_r = K$ = Relative Permitivity of med.

= Dielectric constant — " —

$$\mu = \mu_0 \mu_r$$

μ_r = Relative permeability of med.

$$\boxed{\mu_r \geq 0}$$

Air/Vacuum $\Rightarrow$ $K=1$, $\mu_r = 1$

Refractive Index $= \sqrt{\epsilon_r \mu_r}$

$\mu_D > \mu_R$

$$\boxed{\mu = \frac{c}{v} = \frac{\lambda_{air}}{\lambda_m}}$$

unitless

Dimensionless

$c \geq v$

$\mu \geq 1$

Air	3×10^8 m/s	$\mu_{air} = 1$
water	2.25×10^8 m/s	$\mu_w = 4/3 = 1.33$
glass	2×10^8 m/s	$\mu_g = \frac{3}{2} = 1.5$

Relative R. I.

$${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

μ_{21}

Relative R.I. of 2 wrt 1

$$\boxed{{}_1\mu_2 \; {}_2\mu_3 \; {}_3\mu_4 \; {}_4\mu_1 = 1}$$

$$\frac{\mu_2}{\mu_1} \; \frac{\mu_3}{\mu_2} \; \frac{\mu_4}{\mu_3} \; \frac{\mu_1}{\mu_4}$$

Extra

Cauchy's Relation

$$\boxed{\mu = A + \frac{B}{\lambda^2}}$$

→ for same med

→ Diff. R.I. for diff λ

$$\left\{ \begin{array}{l} \lambda_v < \lambda_R \\ \mu_v > \mu_R \end{array} \right.$$

Q $\ {}_w\mu_g = \frac{\mu_g}{\mu_w} = \frac{3/2}{4/3} = \frac{9}{8}$

Q $\mu = 5/3$

$$\boxed{v = \frac{c}{\mu}} = \frac{3\times10^8}{5/3}$$

$$v = \frac{9}{5}\times10^8 \ m/s$$

Q. $\lambda_g = 5000\ \mathring{A}$

$\lambda_{air} = ?$

$$\mu_g = \frac{\lambda_{air}}{\lambda_g}$$

$$\frac{3}{2} = \frac{\lambda_{air}}{5000\ \mathring{A}}$$

$$\lambda_{air} = 7500\ \mathring{A}$$

Q $\lambda_w = 6000\ \mathring{A}$

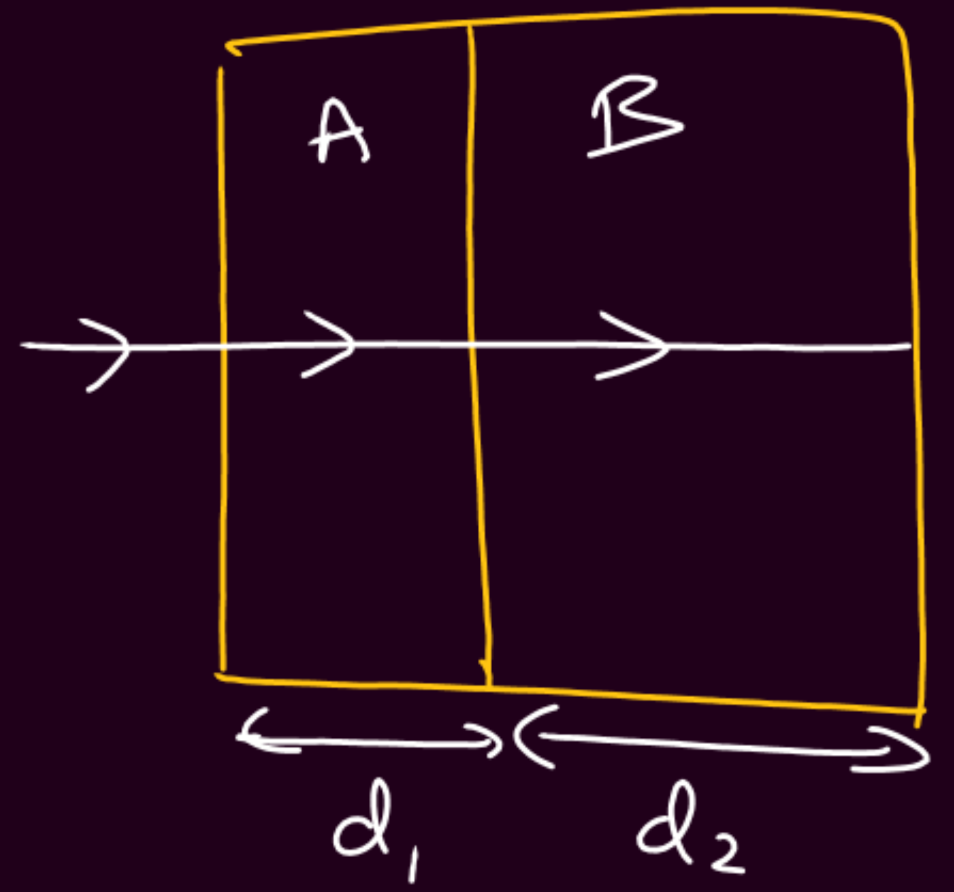
$\lambda_m = 5000\ \mathring{A}$ $\quad v = ?$

$$\frac{v_m}{v_w} = \frac{\lambda_m}{\lambda_w}$$

$$\frac{v_m}{2.25\times10^8} = \frac{5}{6}$$

$$v_m = \left(\frac{5}{6}\times2.25\times10^8\right) m/s$$

Q



$$d_1 : d_2 = 2 : 5$$

$$\frac{\mu_A}{\mu_B} = \frac{v_B}{v_A} = \frac{d_2}{d_1} = 5/2$$

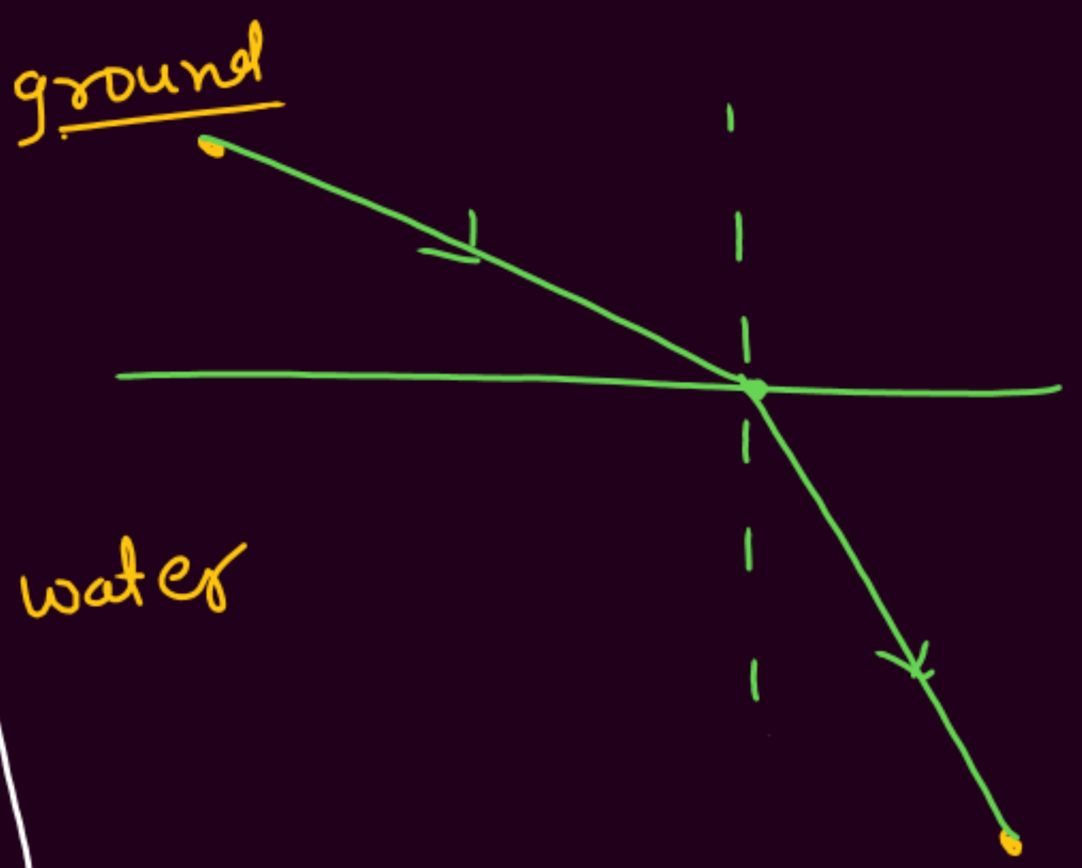
① IR, RR & N (Same plane)

② <u>Snell's law</u> $\mu_1 \sin i = \mu_2 \sin r$

$$\boxed{\mu_1 \sin\theta_1 = \mu_2 \sin\theta_2}$$

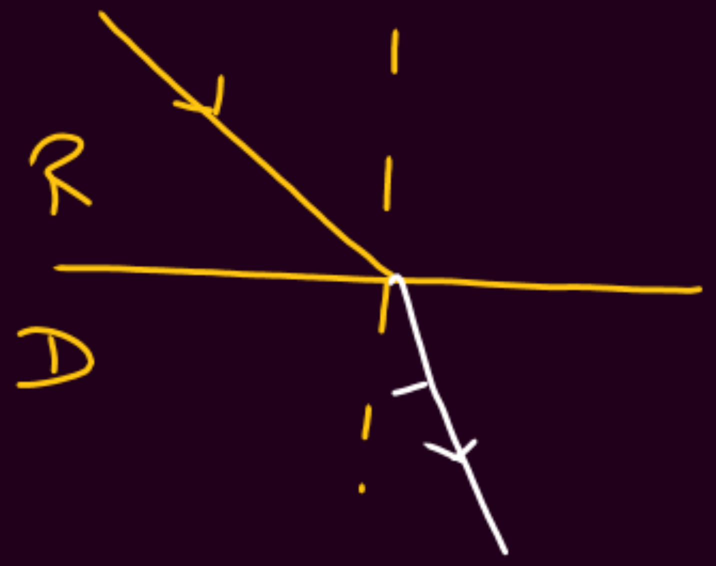
<u>Fermat's principle</u>

→ [min time]



Deviation $\boxed{\delta = i - r}$

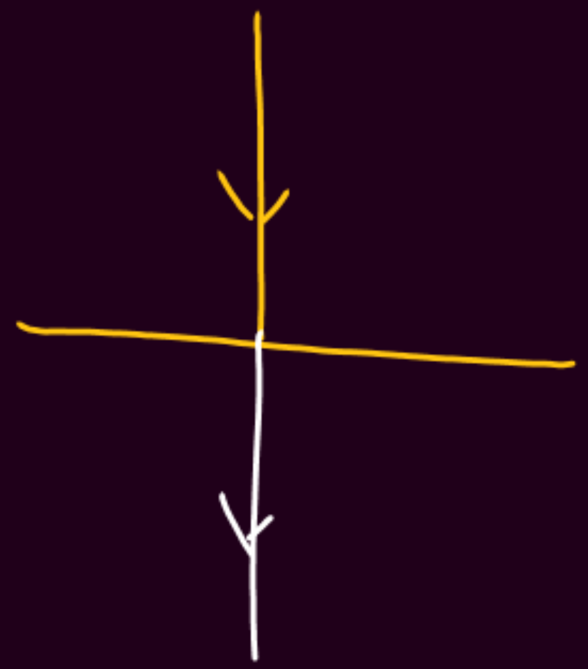
R→D



Bends towards Normal

D→R

Bends away from N



{Normal Incidence undeviated (No refraction)

Q:

$r = ?$

$\delta = ?$

(1) $\sin 60^\circ = \sqrt{3} \sin r$

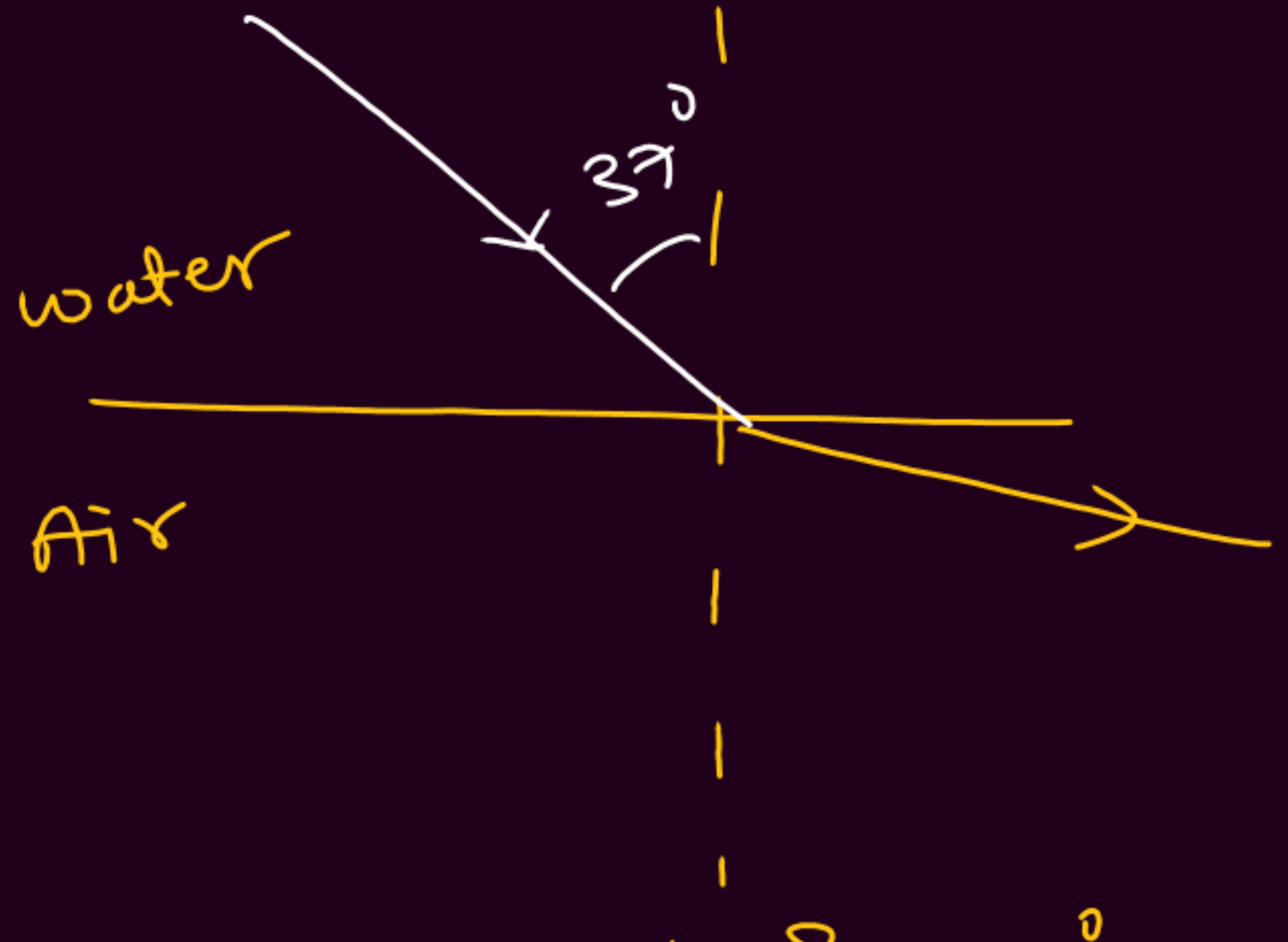
$\frac{\sqrt{3}}{2} = \sqrt{3} \sin r$

$\sin r = \frac{1}{2}$

$r = \underline{\underline{30^\circ}}$

$\delta = 60^\circ - 30^\circ = \underline{\underline{30^\circ}}$

Q:



$r = ?$

$\delta = ?$

$\frac{4}{3} \sin 37^\circ = 1 \sin r$

$\frac{4}{3}\left(\frac{3}{5}\right) = \sin r$

$\sin r = \frac{4}{5}$

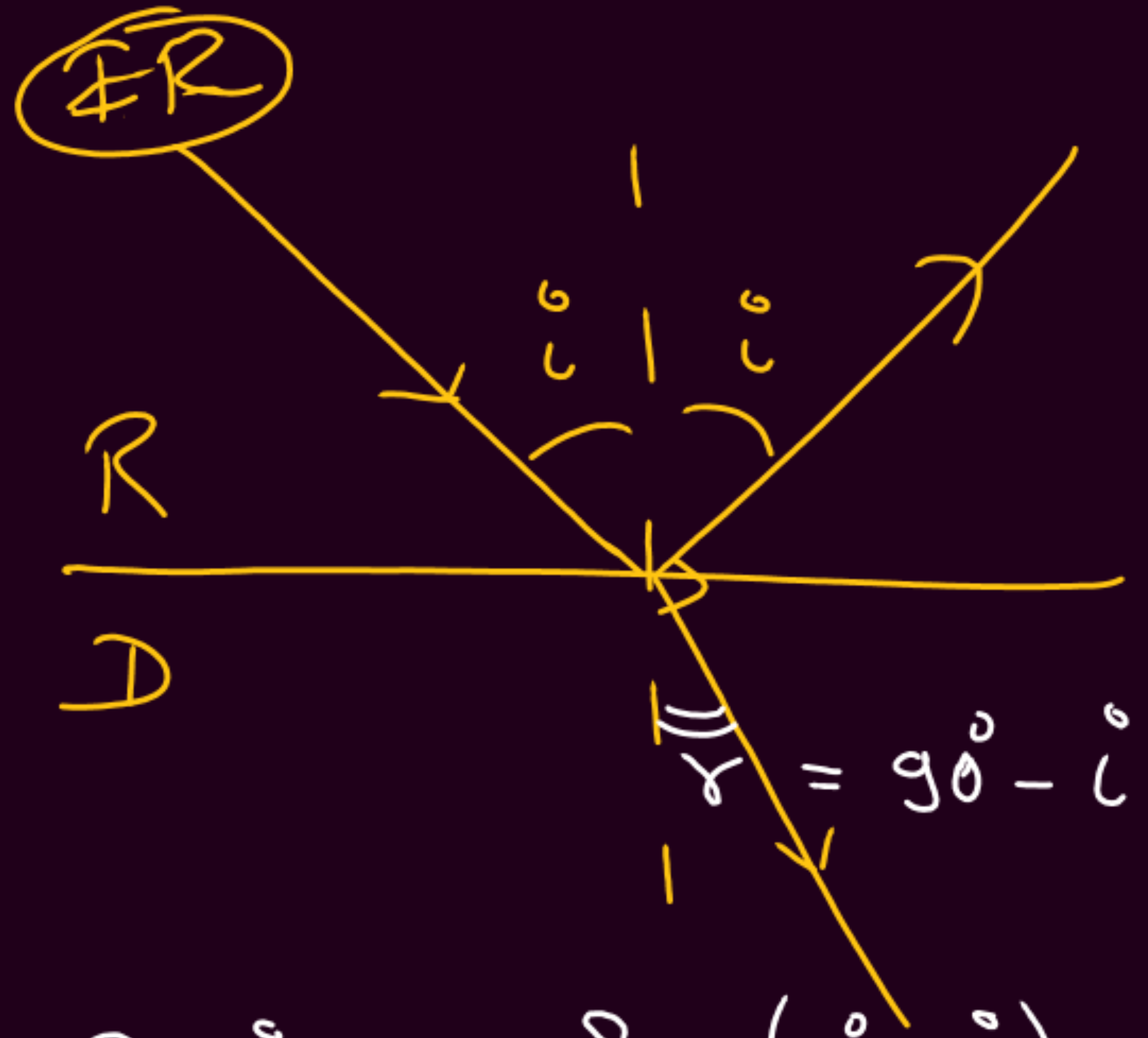
$\boxed{r = 53^\circ}$

$\boxed{\delta = 53^\circ - 37^\circ = 16^\circ}$

$\boxed{\text{Away}}$ from N

$R \rightarrow D$

Reflected $\perp$ Refracted



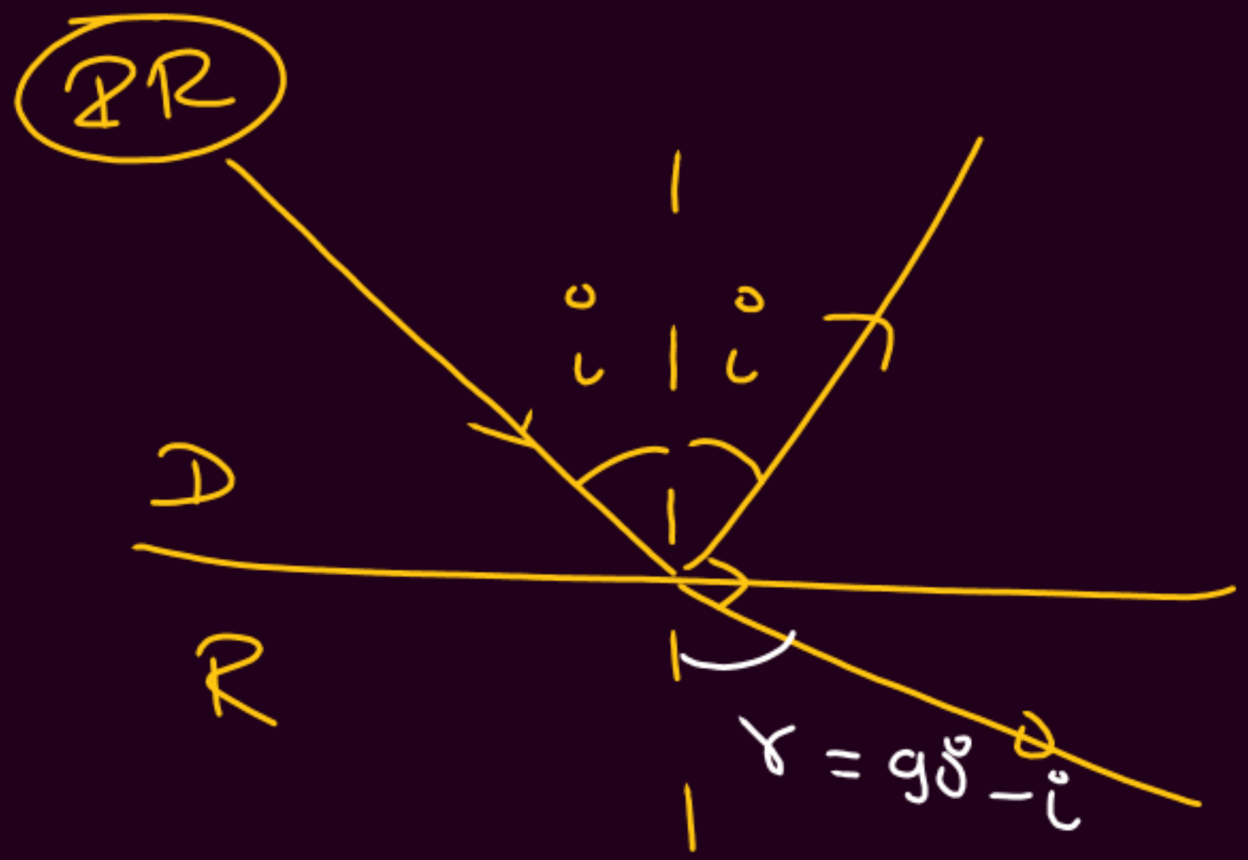
$$\boxed{\frac{\mu_D}{\mu_R} = \mu}$$

$$\mu_R \sin i = \mu_D \sin(90^\circ - i)$$

$$\boxed{\tan i = \mu}$$

$D \rightarrow R$

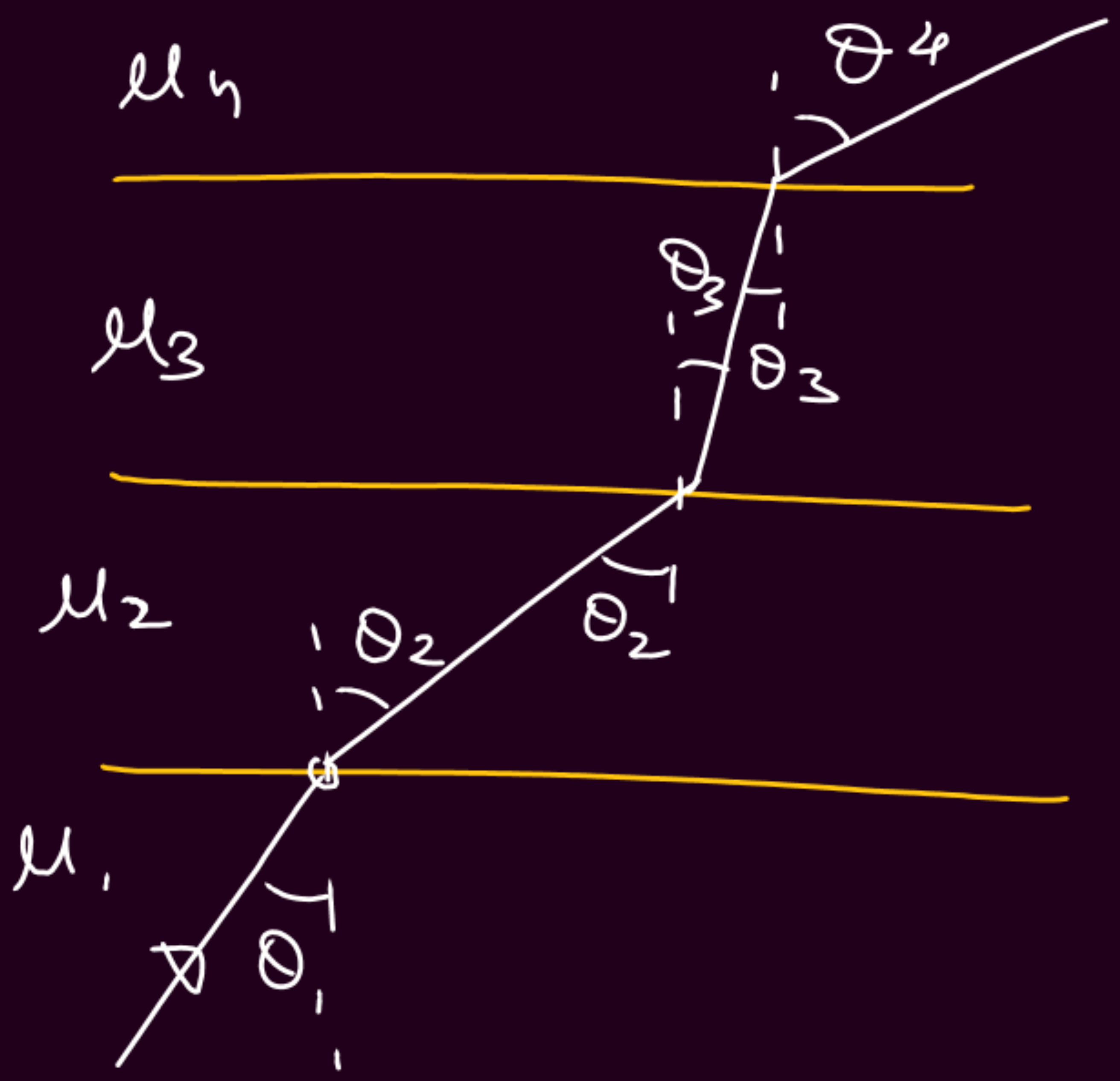
Reflected $\perp$ Refracted



$$\mu_D \sin i = \mu_R \sin(90^\circ - i)$$

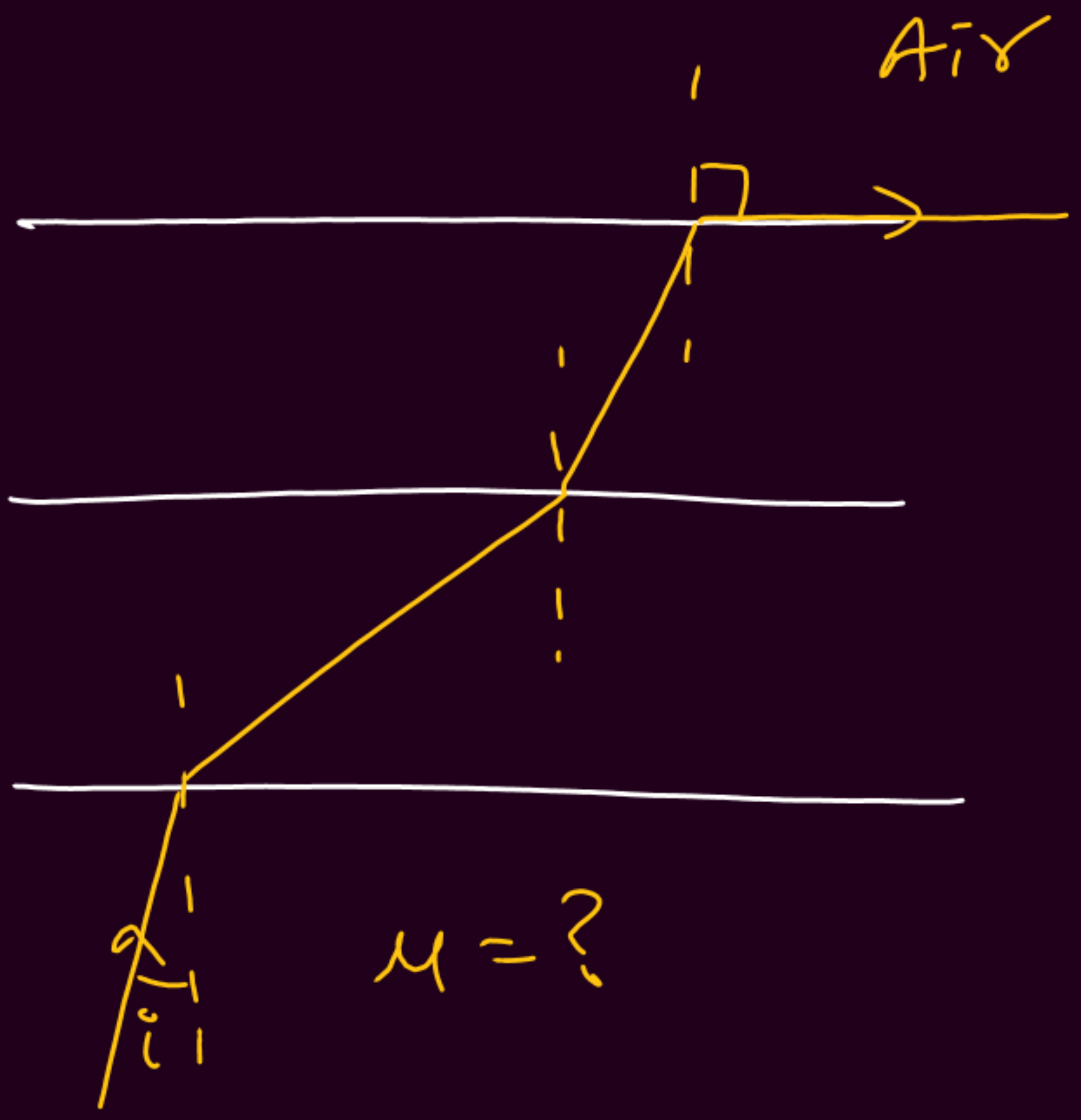
$$\boxed{\tan i = \frac{1}{\mu}}$$

Parallel Media



$$\mu_1 \sin\theta_1 = \mu_2 \sin\theta_2 = \mu_3 \sin\theta_3 = \mu_4 \sin\theta_4$$

Q.



$\mu = ?$

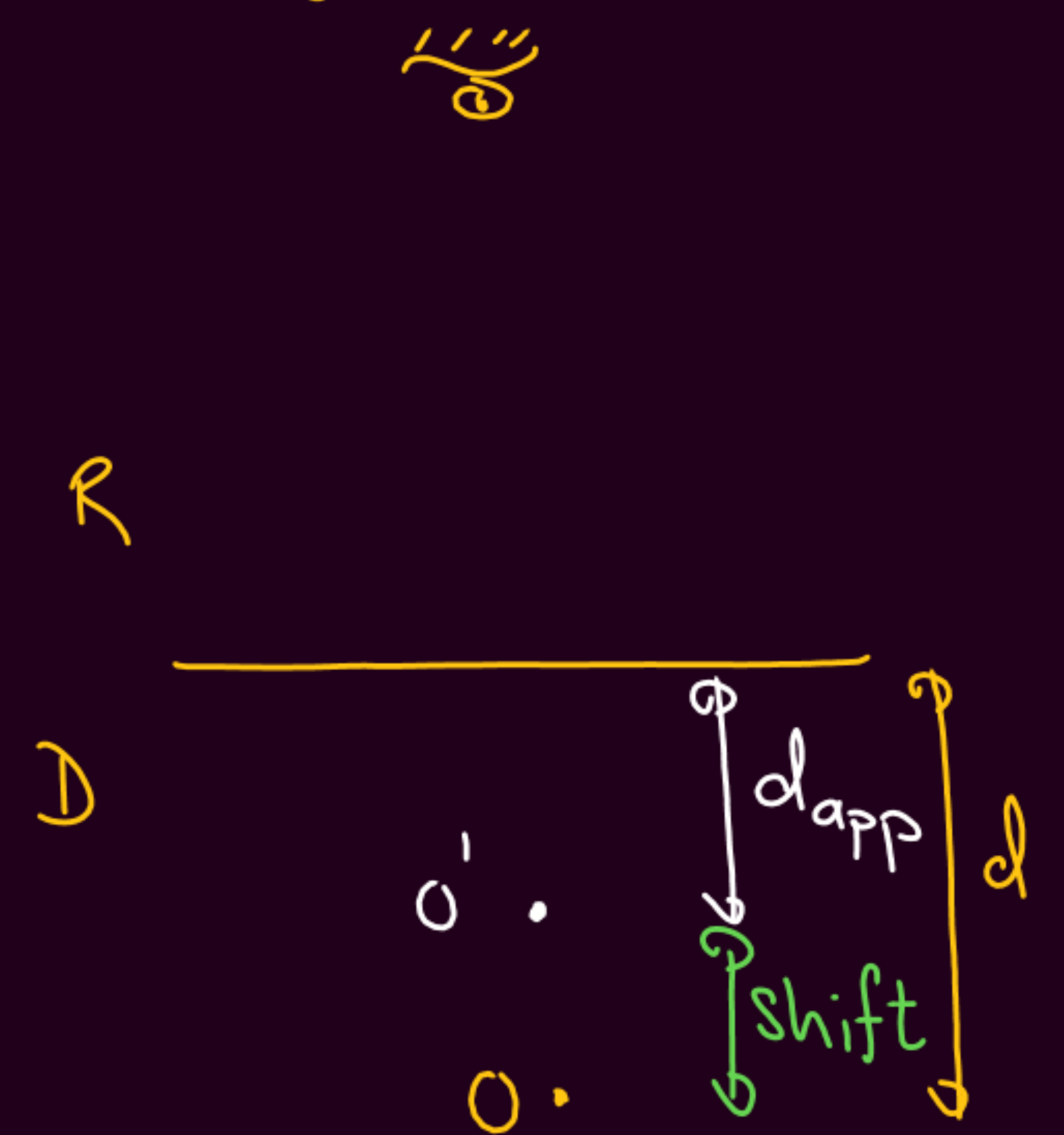
$$\mu \sin i = (1) \sin 90^\circ$$

$$\boxed{\mu = \frac{1}{\sin i}}$$

Apparent Depth

(Near Normal Incidence)

① object in Denser

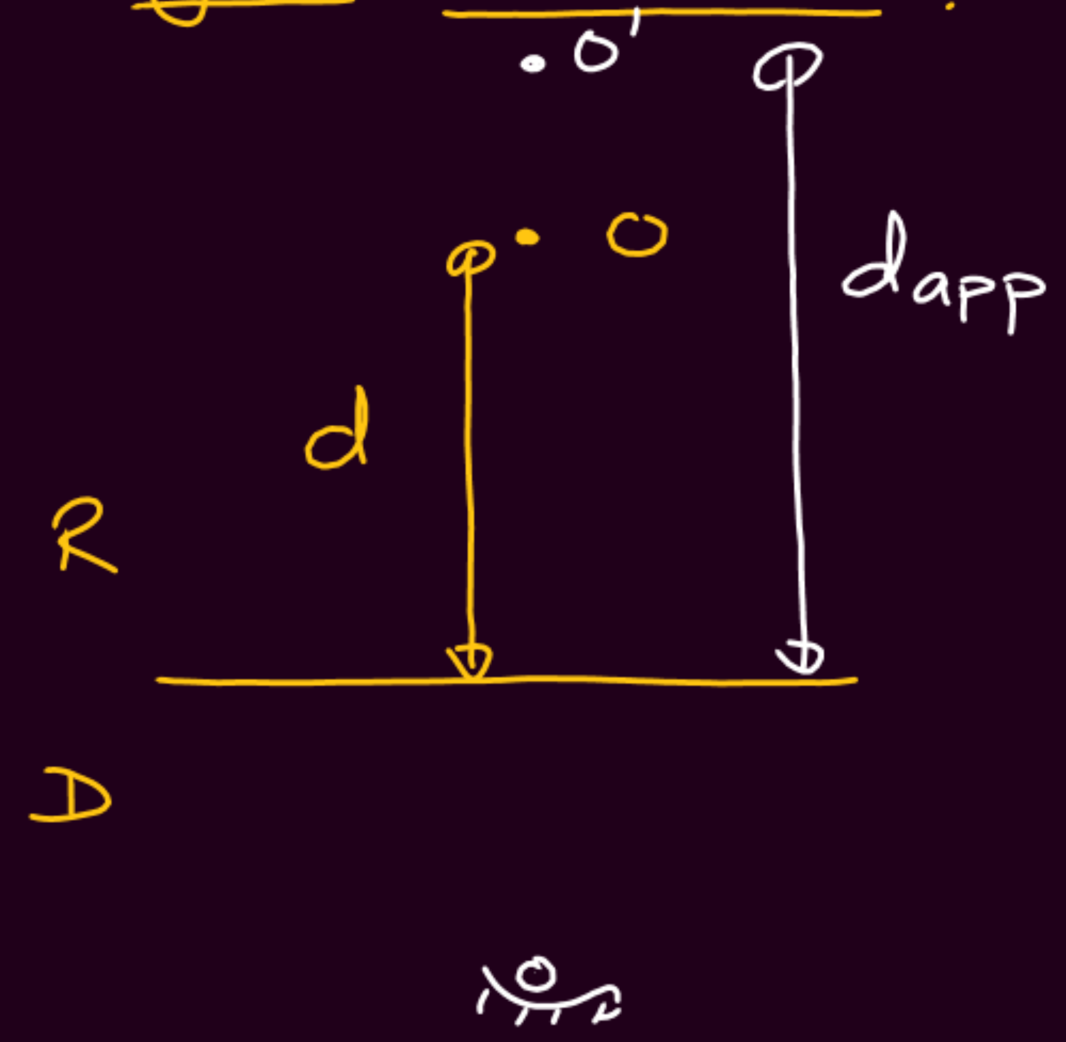


$$\boxed{d_{app} = \frac{d}{\mu}}$$

$$\boxed{\text{Shift} = d\left(1 - \frac{1}{\mu}\right)}$$

$$\left\{ \mu = \frac{\mu_D}{\mu_R} \right\}$$

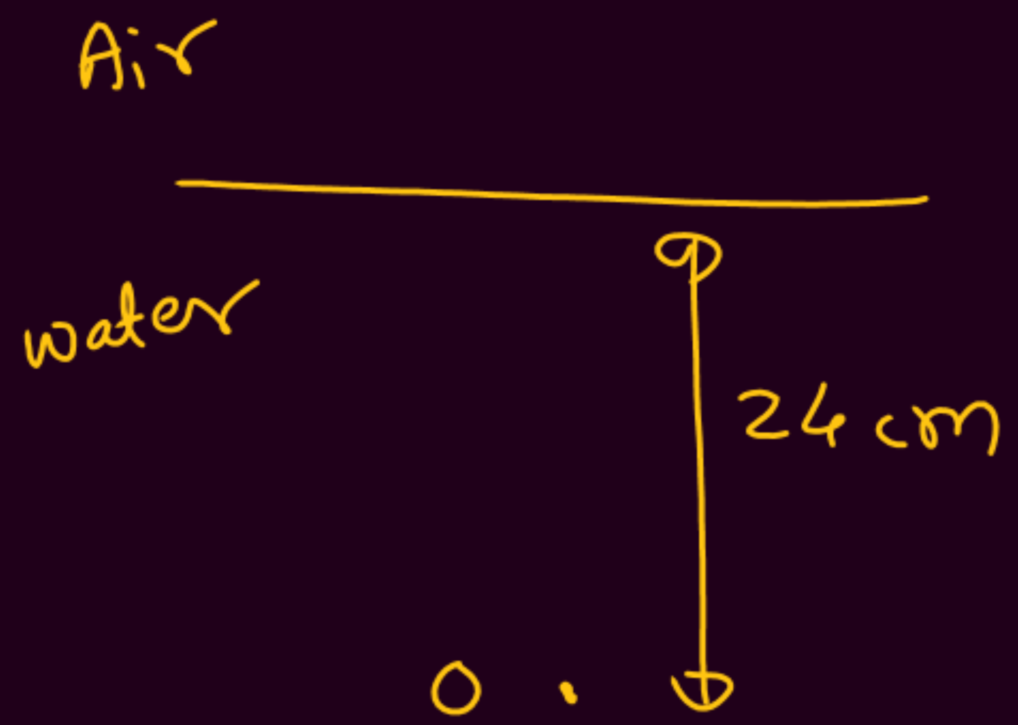
② Object in Rarer.



$$\boxed{d_{app} = \mu d}$$

$$\boxed{\text{Shift} = d(\mu - 1)}$$

Q

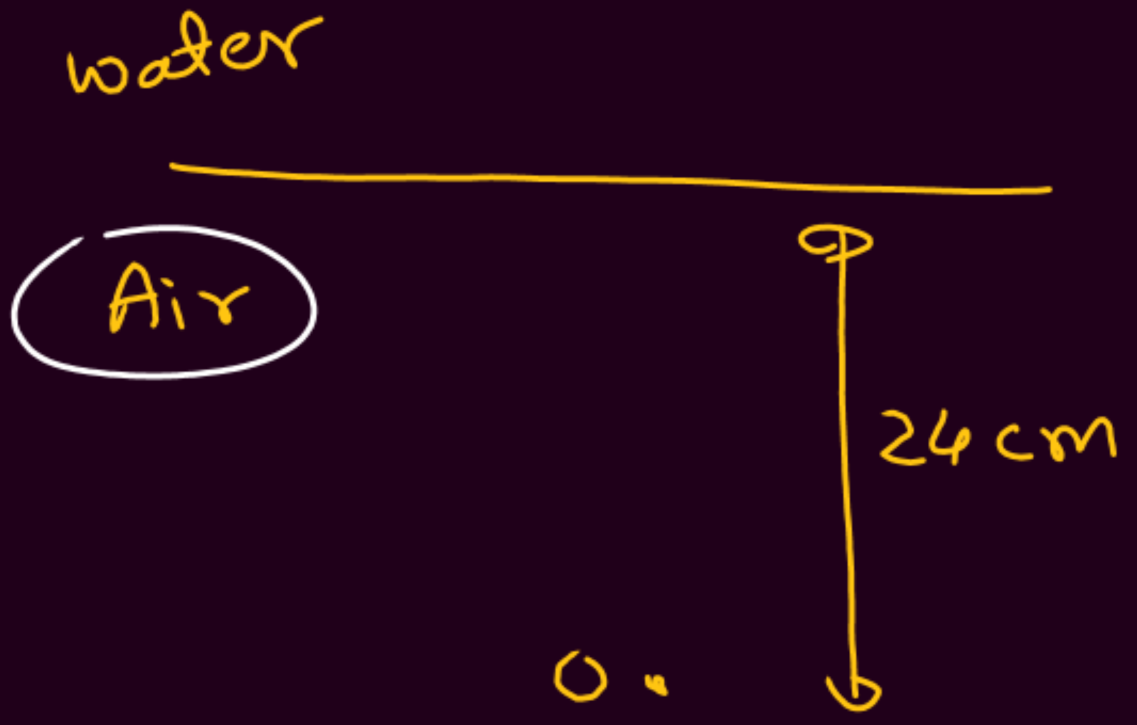


$$d_{app} = \frac{24}{4/3} = 18\,cm$$

$$\text{Shift} = 24\left(1 - \frac{1}{4/3}\right) = \underline{\underline{6\,cm}}$$

Towards the obs.

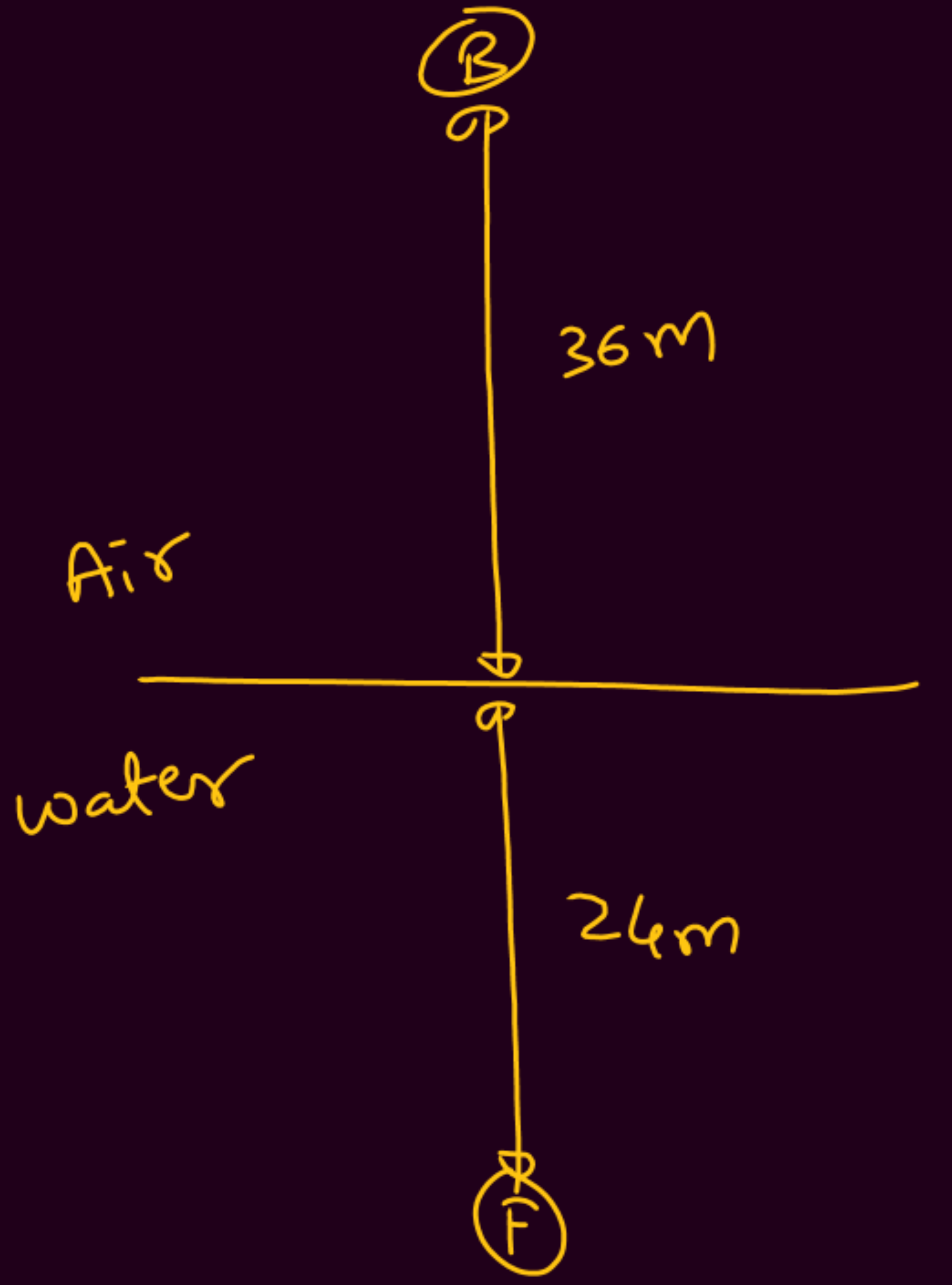
Q.



$$d_{app} = \frac{4}{3}(24) = 32\,cm$$

$$\text{Shift} = 32 - 24 = \underline{\underline{8\,cm}}$$

Away from obs.



① Dist. of B as seen by F

$$= \frac{4}{3}(36) + 24$$

② Dist. of F as seen by B

$$= \frac{26}{4/3} + 36$$

B ↓ 6 m/s

1. Vel. of F wrt B

$$= \frac{12}{4/3} + 6$$

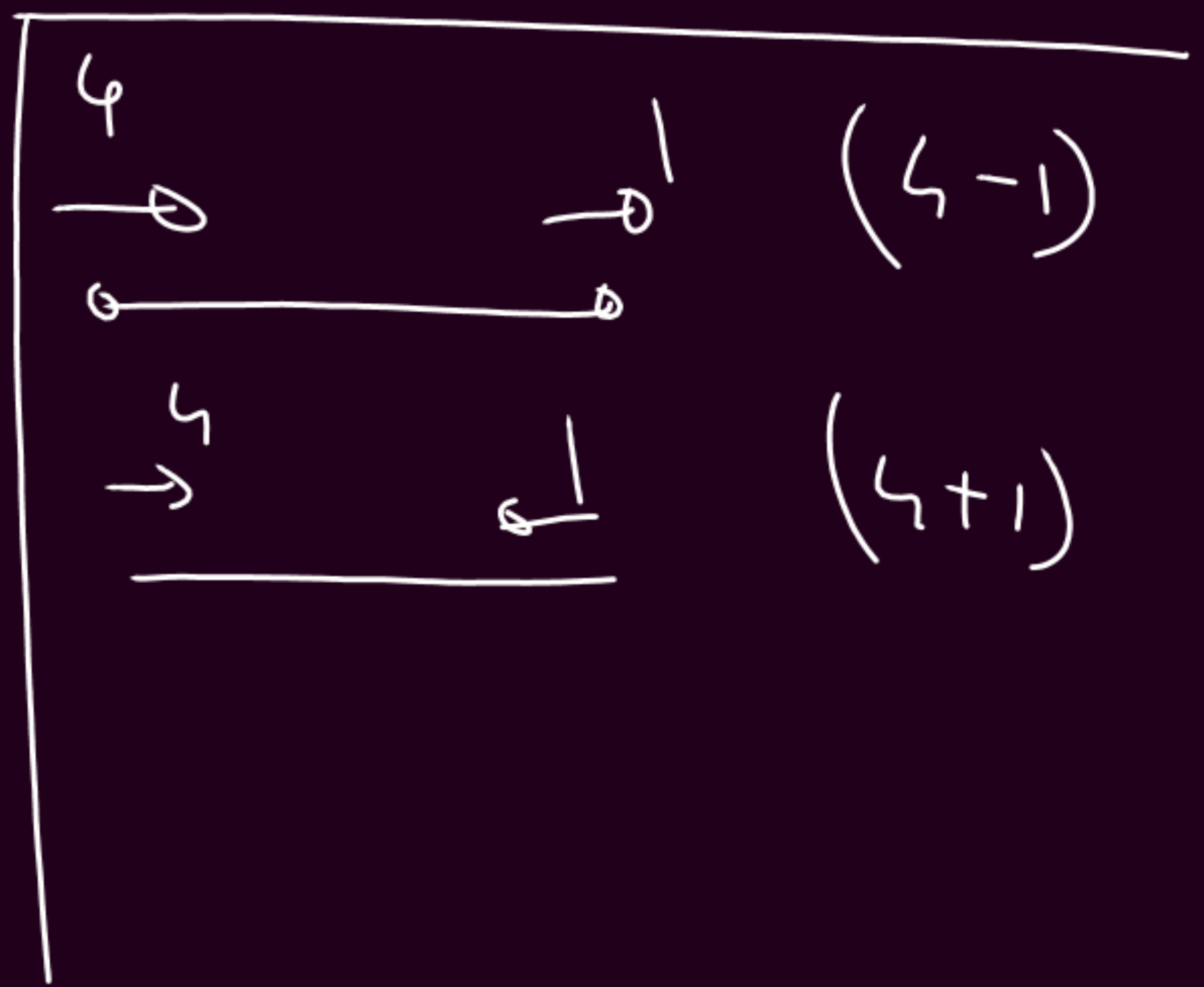
Air

Water

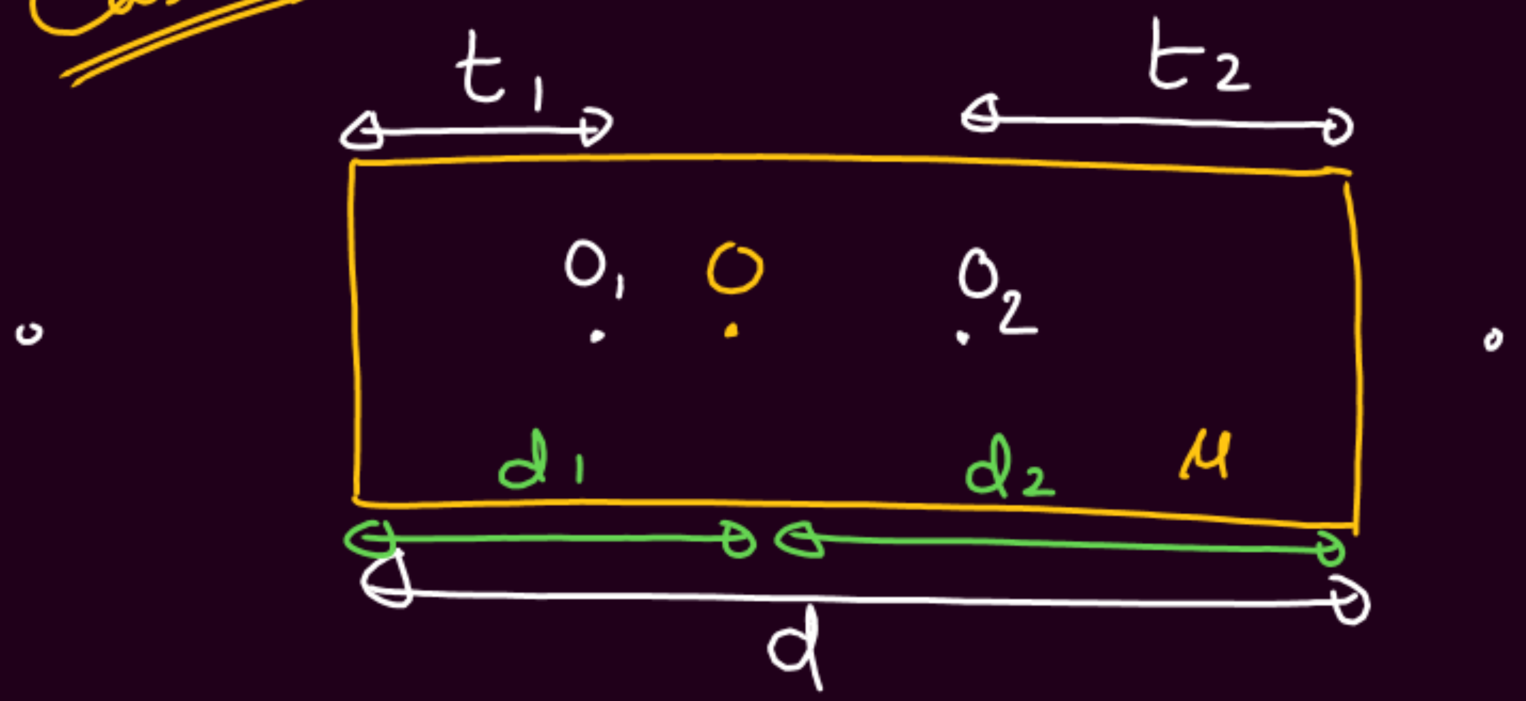
2. Vel. of B wrt F

$$= \frac{4}{3}(6) + 12$$

F ↑ 12 m/s



Case



$$t_1 = \frac{d_1}{\mu}$$

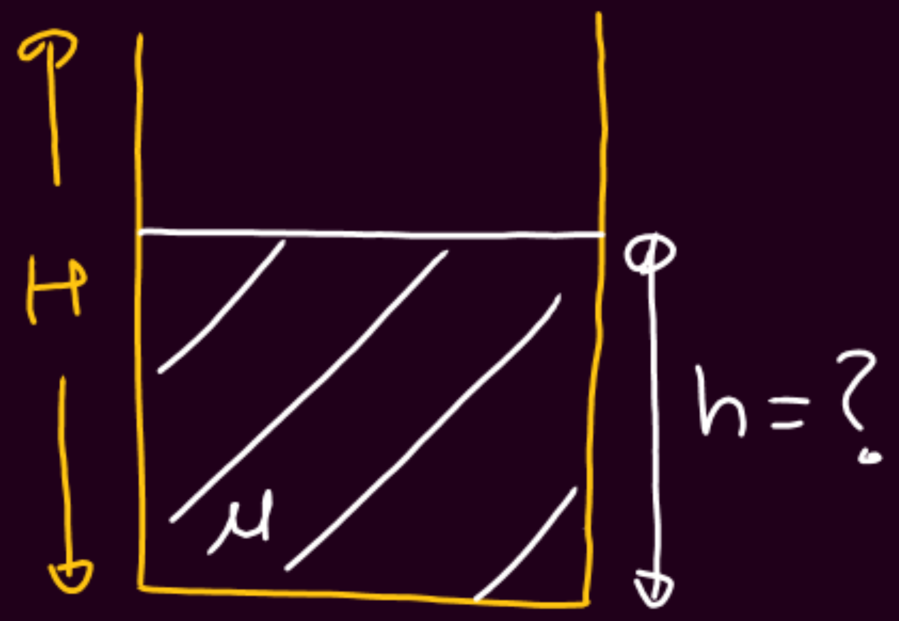
$$t_2 = \frac{d_2}{\mu}$$

$$d = d_1 + d_2$$

$$d = \mu t_1 + \mu t_2$$

$$\boxed{d = \mu(t_1 + t_2)}$$

Case



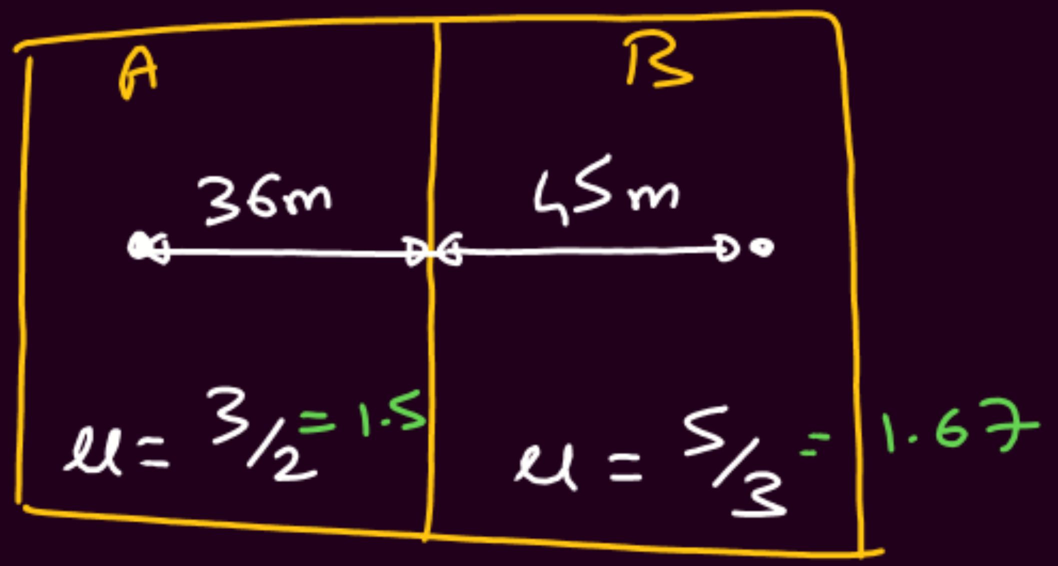
Empty = (Appears to be filled)

$$H - h = \frac{h}{\mu}$$

$$H = h + \frac{h}{\mu} = h\left(1 + \frac{1}{\mu}\right)$$

$$H = h\left(\frac{\mu+1}{\mu}\right)$$

$$\boxed{h = \frac{\mu H}{\mu+1}}$$



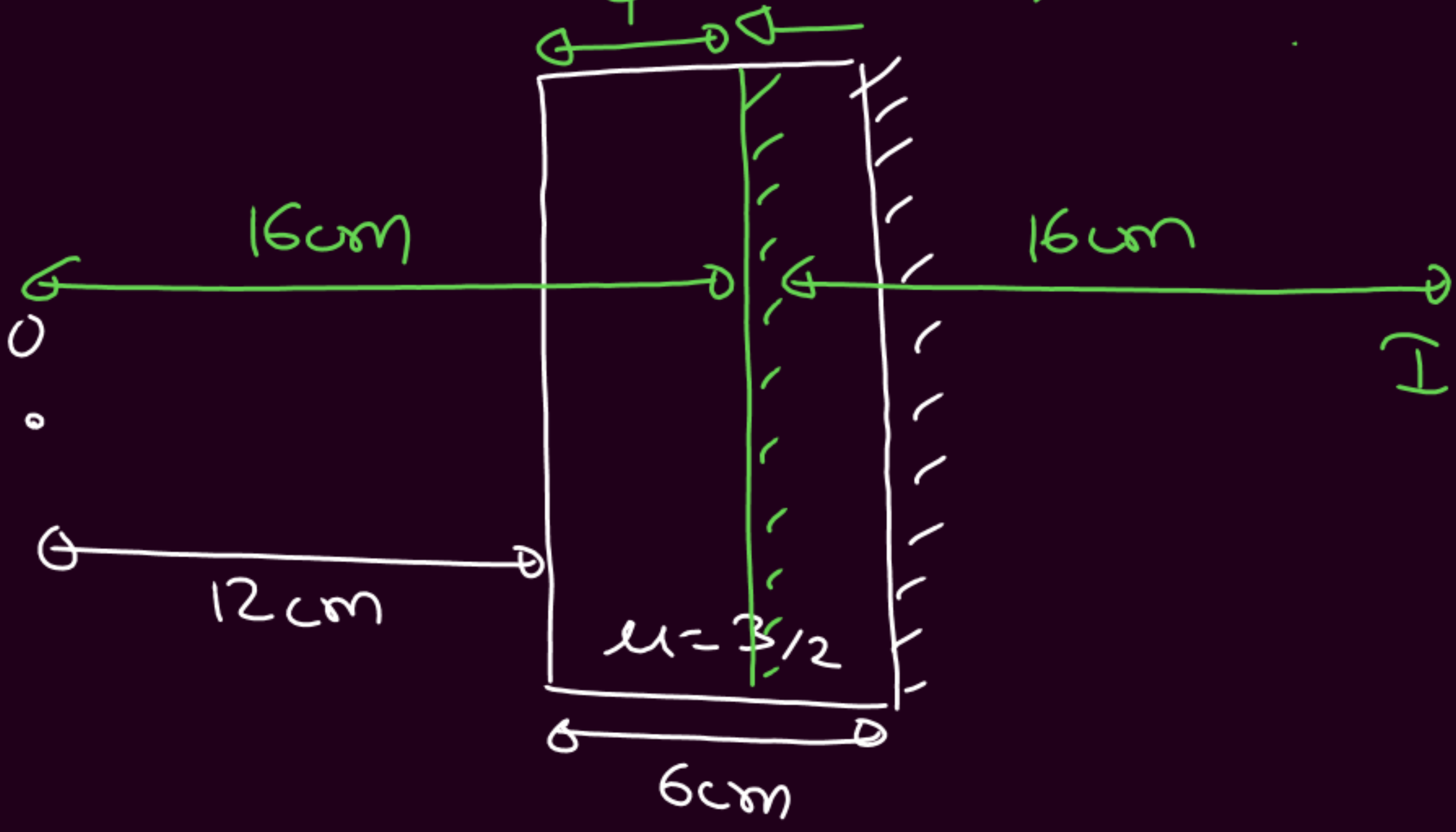
Dist. of B as seen by A

$$= \frac{3}{2}\left[\frac{45}{5/3} + \frac{36}{3/2}\right]$$

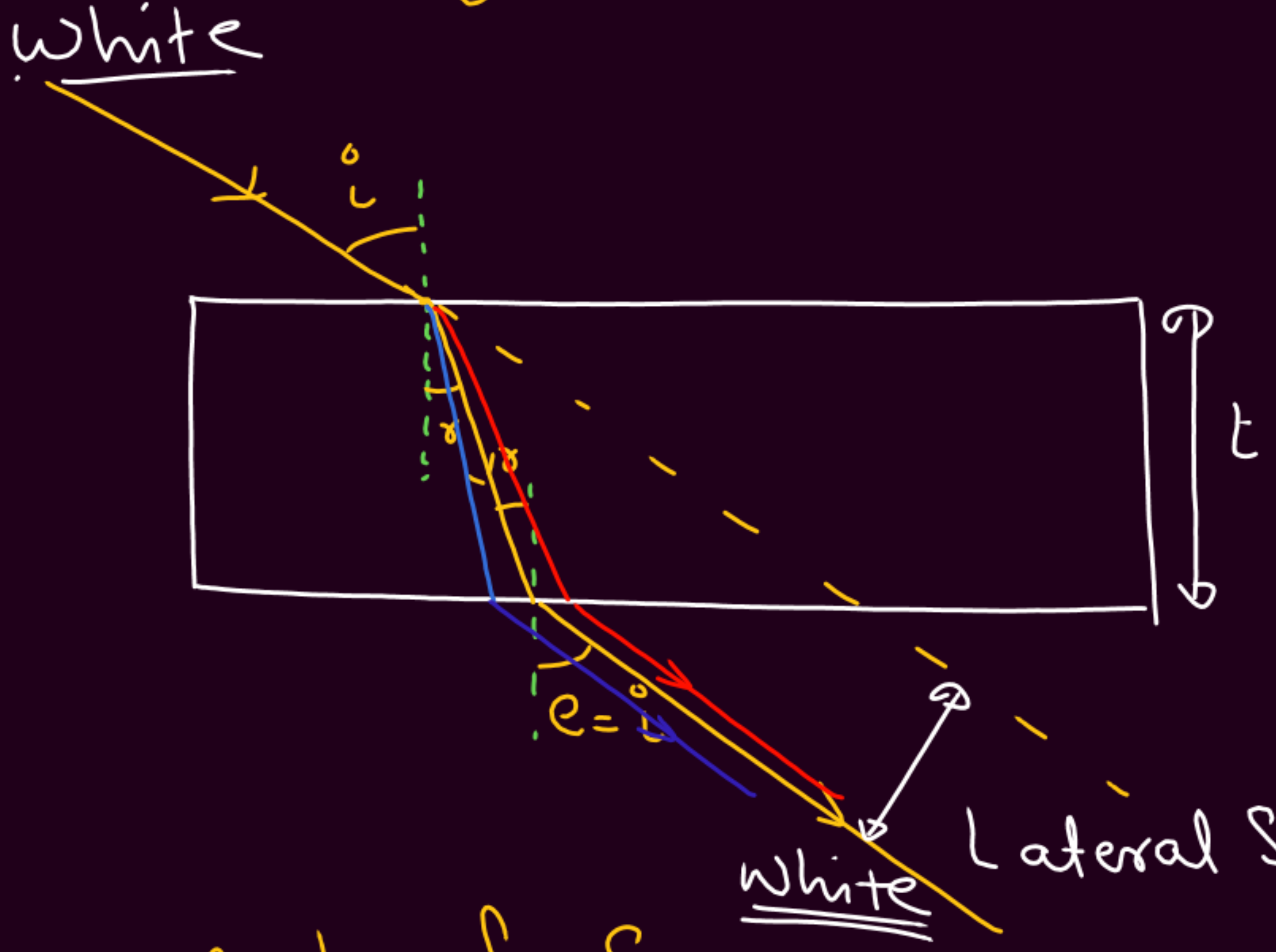
$$= \frac{3/2}{5/3}(45) + (36)$$

Q

$$6\left(1 - \frac{1}{3/2}\right) = \underline{\underline{2\text{cm}}}$$



Rectangular glass Slab



Lateral Shift $= \dfrac{t\sin(i-r)}{\cos r}$

Extra

e = Angle of Emergence

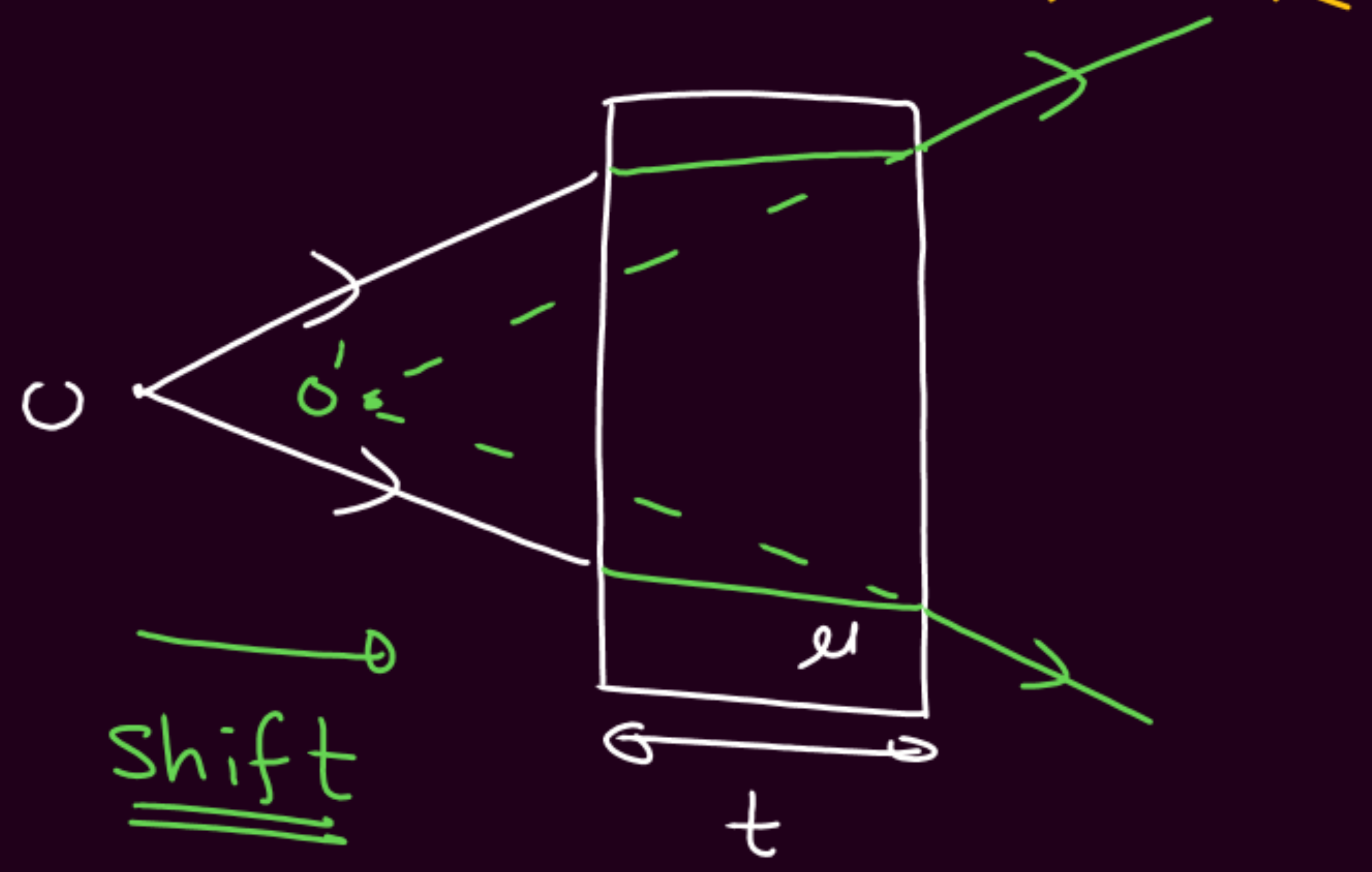
① No net Deviation

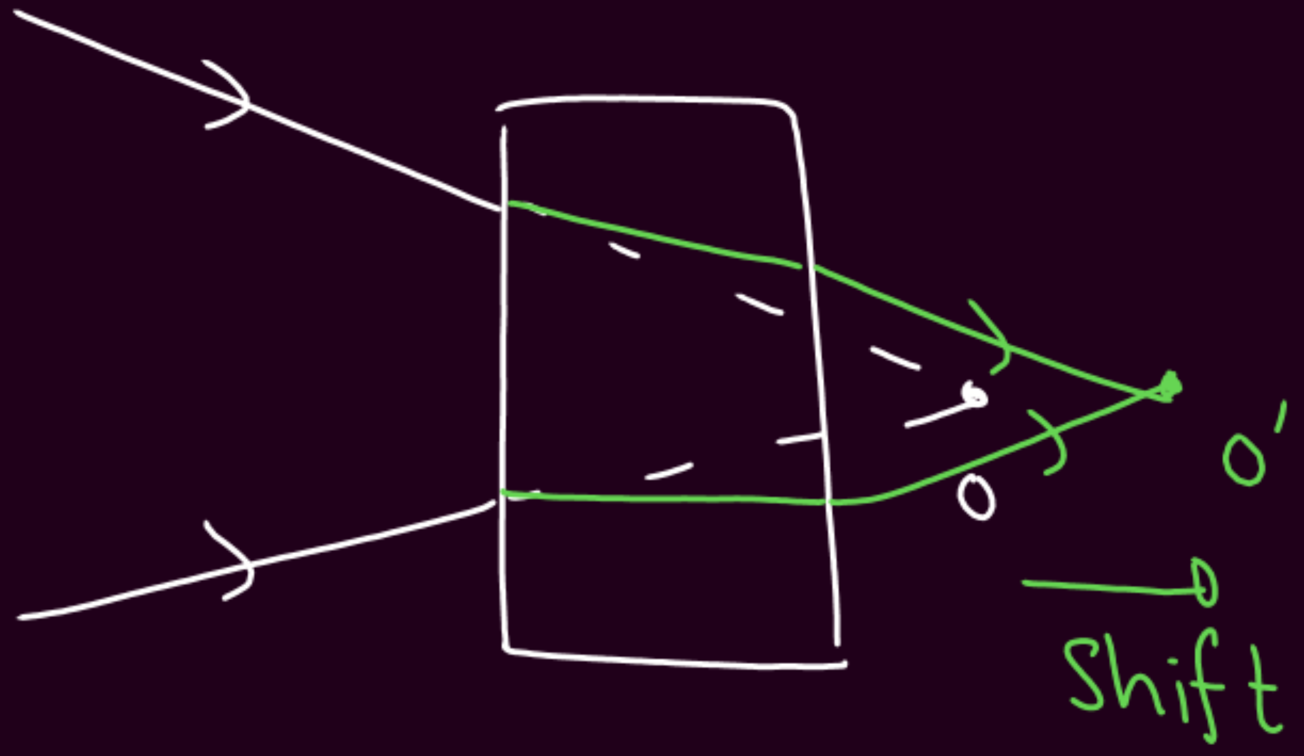
② No net Dispersion

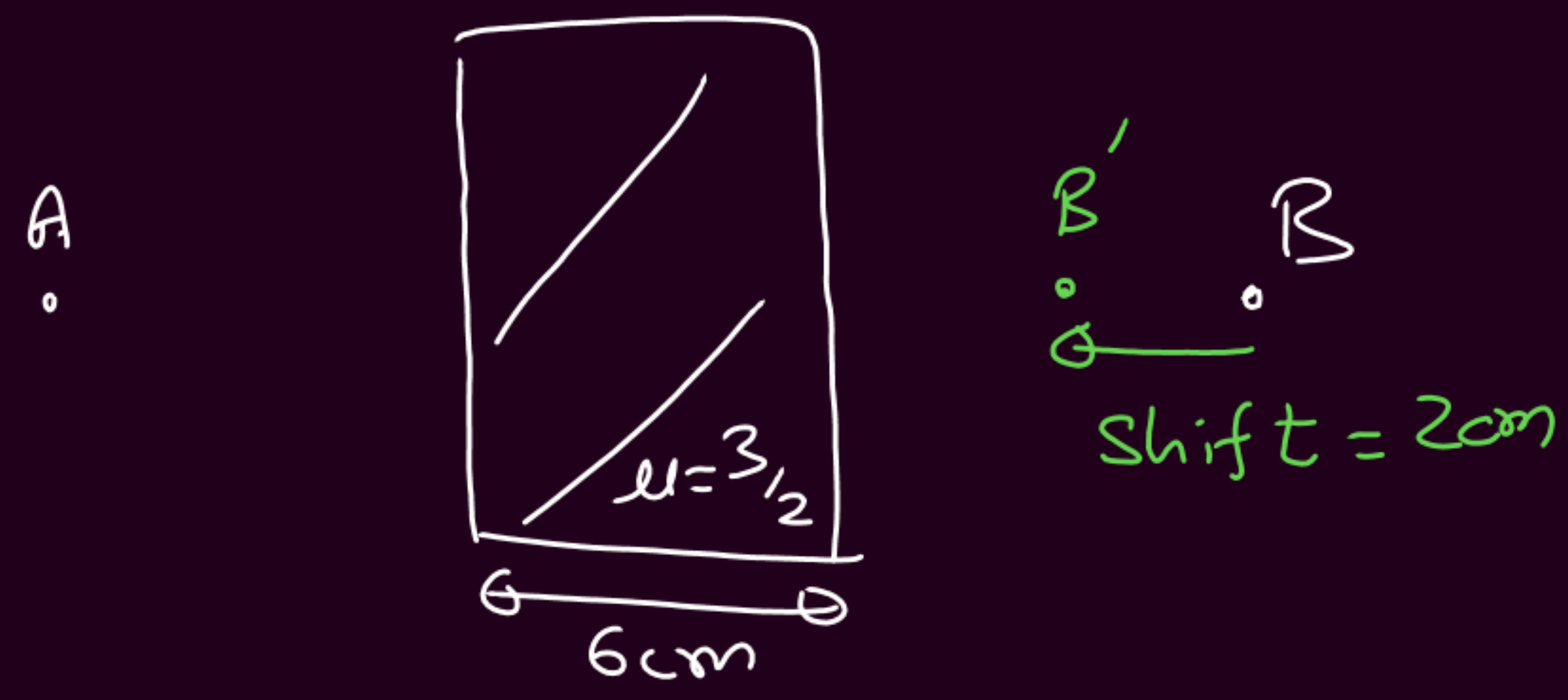
③ Lateral Shift

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

→ in the dir of IR







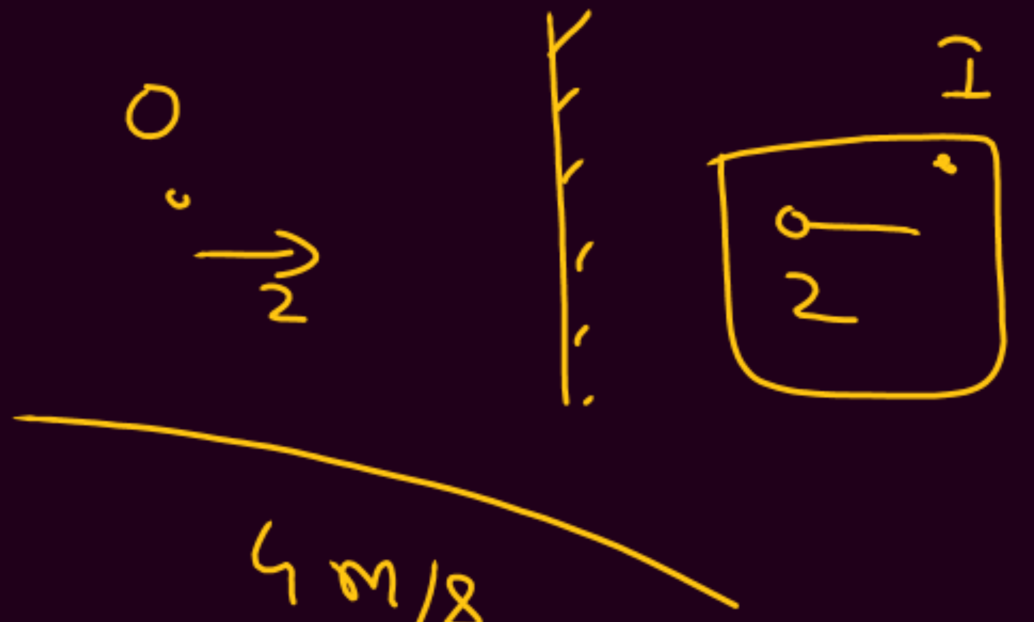
$$\text{Shift} = 6\left(1-\frac{1}{3/2}\right) = 2\text{cm}$$

(5) M RR

20 ACW 40 ACW

(4) $\delta = 180^\circ - (2 \times 30^\circ)$

(7)

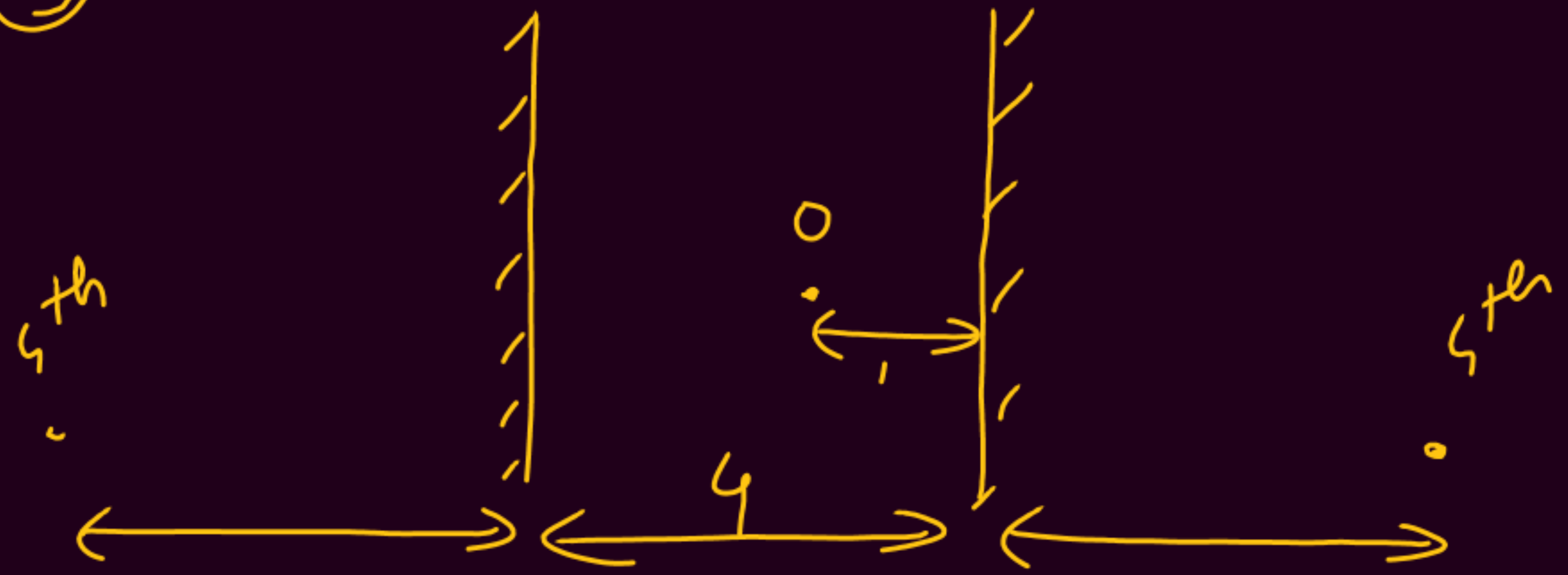


4 m/s

(1)

$2i = 90^\circ$

(9)

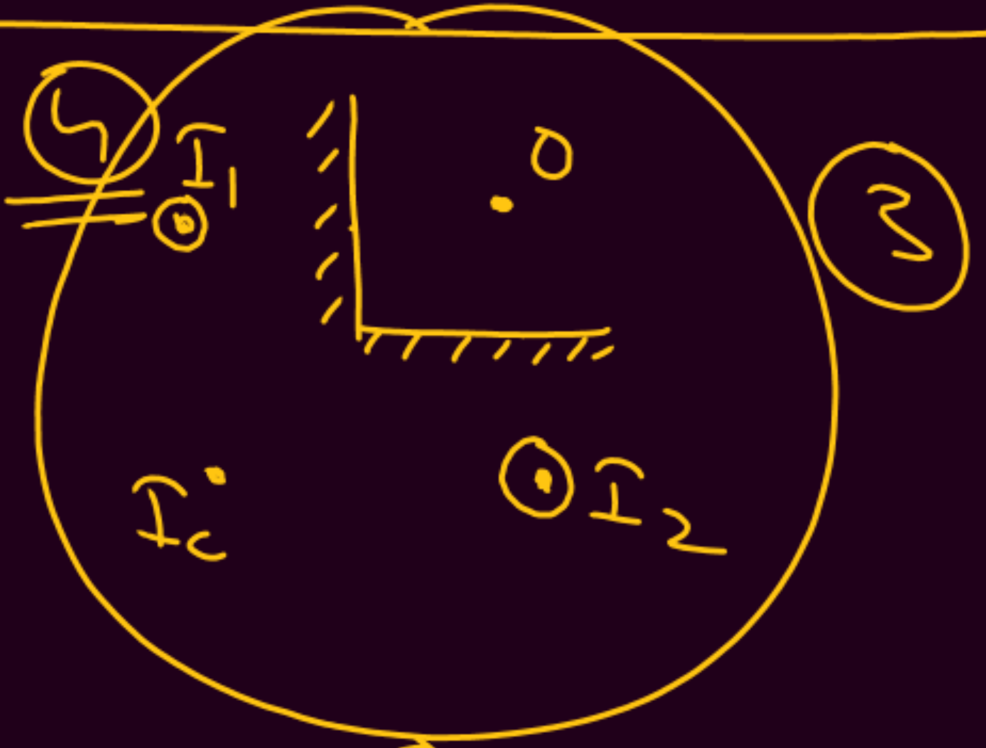


(8) $\dfrac{\mu_A}{\mu_B} = \dfrac{v_B}{v_A} = \dfrac{1}{1.25}$

(6) $RI = \sqrt{\epsilon_r \mu_r}$

$= \sqrt{\dfrac{\epsilon}{\epsilon_0} \dfrac{\mu}{\mu_0}}$

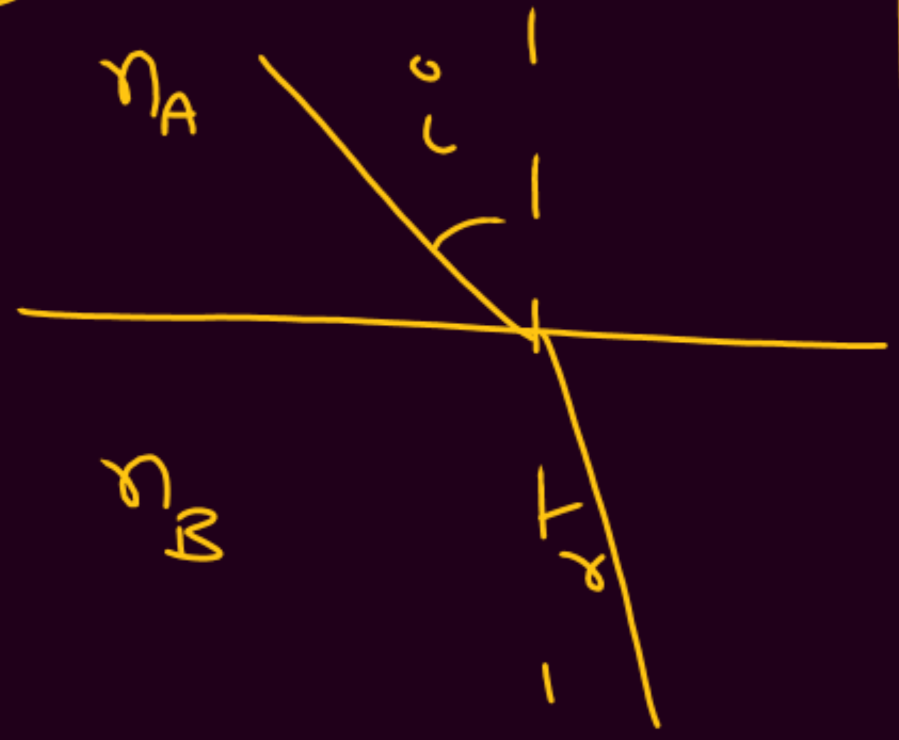
(4)



$3 + 3 + 1$

(3)

(8)



$\tan\theta \simeq \theta$

(for small θ)

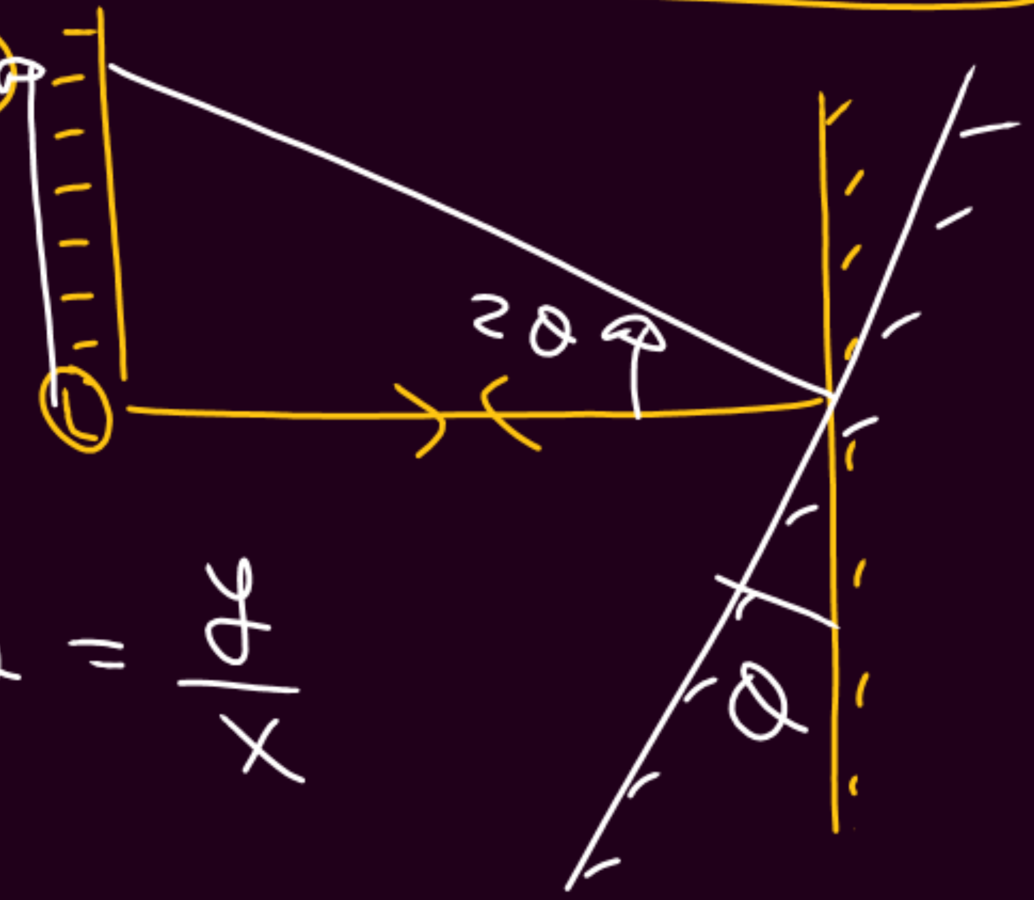
(14)

$\frac{R}{D}$ 1.22

$\tan i = \mu = \boxed{1.62}$

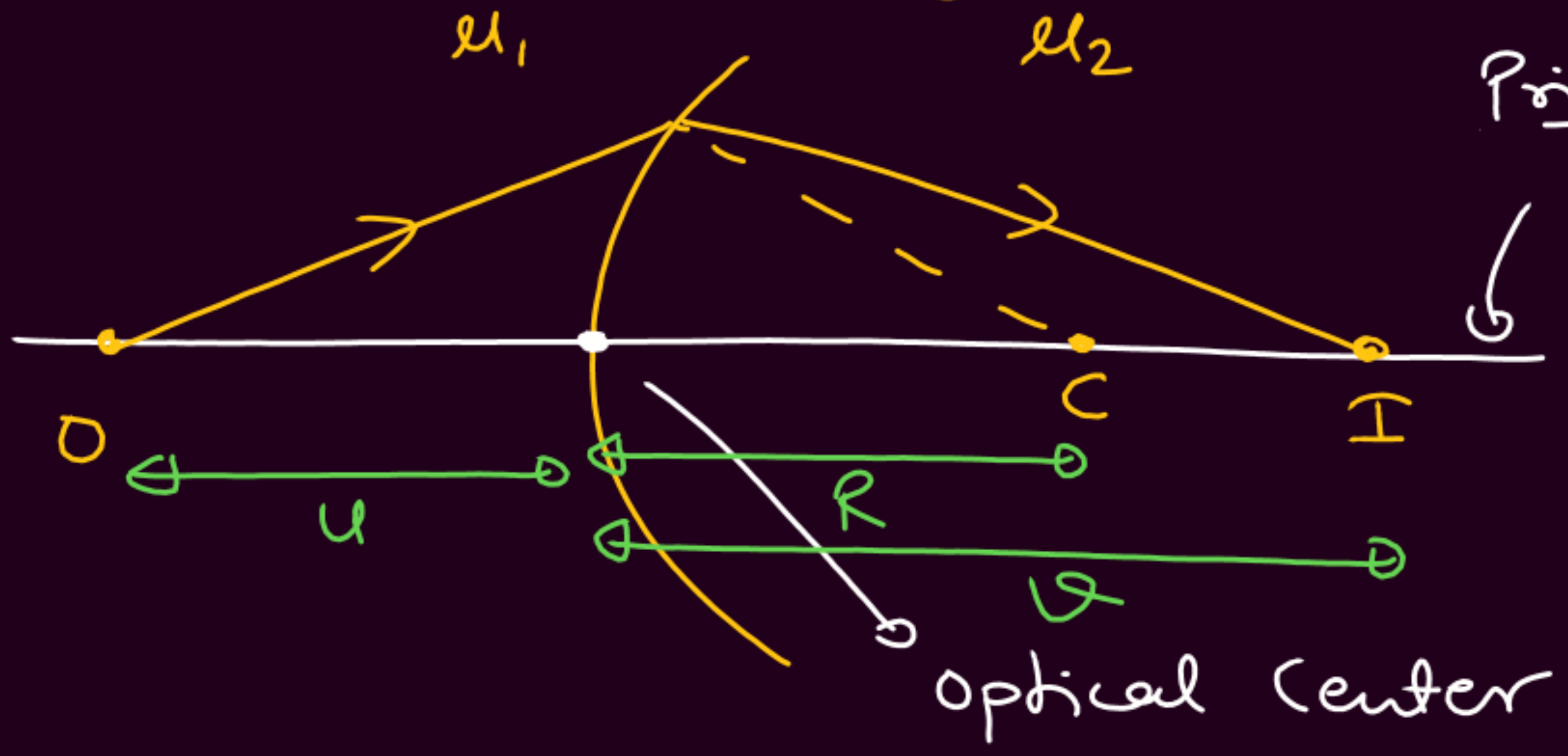
60°	1.73
53°	$\frac{4}{3} = 1.33$
45°	1

(22)



$2\theta = \frac{y}{x}$

Refraction by Curved Surface



C = Center of Curvature
u = object distance
v = Image distance
R = Radius of Curvature

Sign Convention / Rules

→ Dist → optical Center
→ In the dir IR → +
→ opp. IR → −
→ height { + / − }

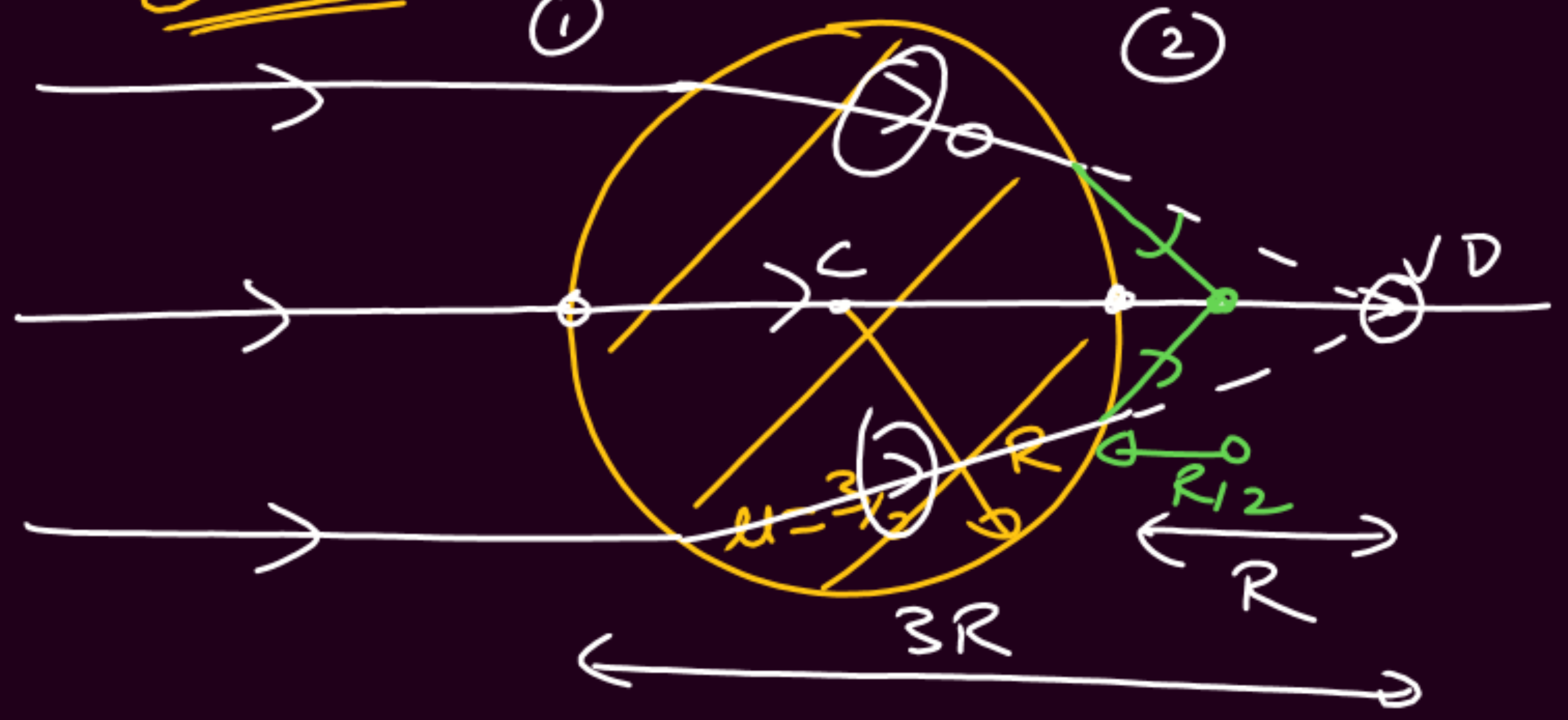
Curved Surface Refraction Formula

Extra

$$\boxed{\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}}$$

$$m = \frac{\mu_1 v}{\mu_2 u} \quad \text{(magnification)}$$

Extra



①

$$\frac{3/2}{v_1} - \frac{1}{-\infty} = \frac{3/2 - 1}{+R}$$

$$\frac{3/2}{v_1} = \frac{1/2}{R}$$

$$\boxed{v_1 = 3R}$$

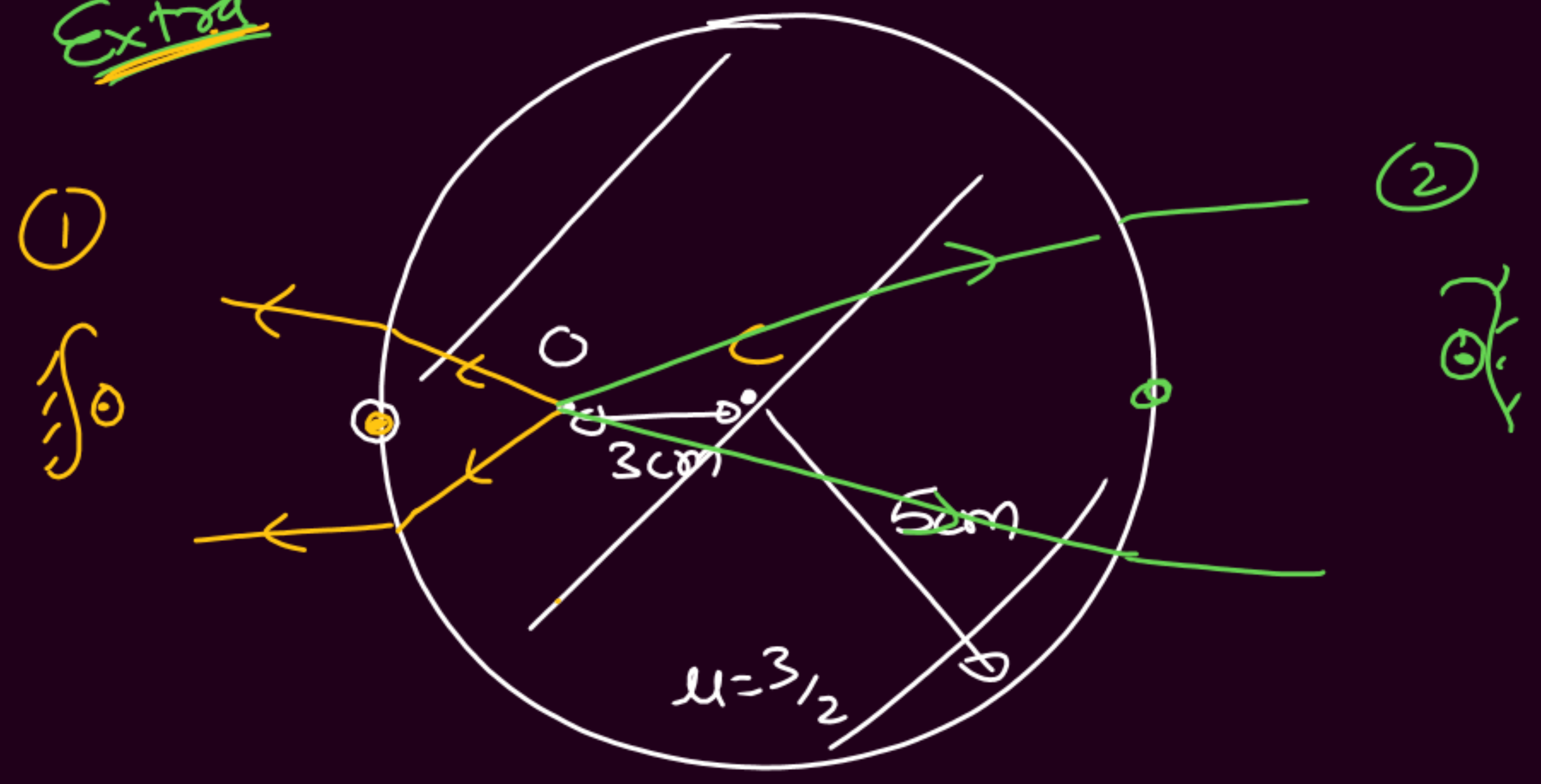
②

$$\frac{1}{v_2} - \frac{3/2}{+R} = \frac{1 - 3/2}{-R}$$

$$\frac{1}{v_2} = \frac{3/2}{R} + \frac{1/2}{R}$$

$$\boxed{v_2 = \frac{R}{2}}$$

Extra



① $\dfrac{1}{v_1} - \dfrac{3/2}{-2} = \dfrac{1 - 3/2}{-5}$

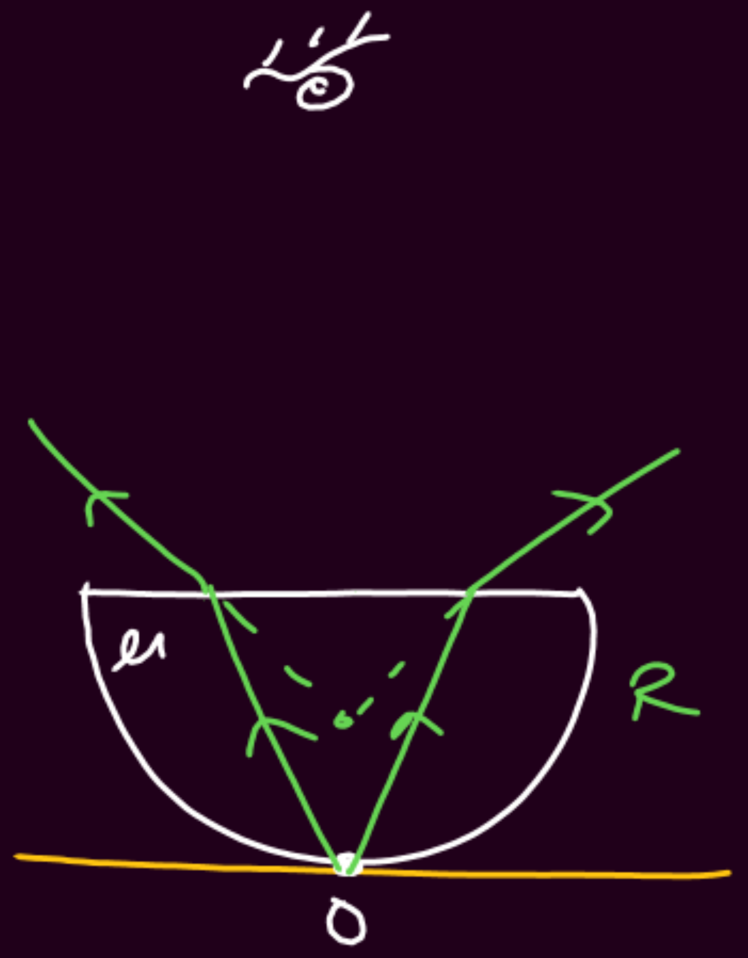
$v_1 = -\dfrac{20}{13}$ cm

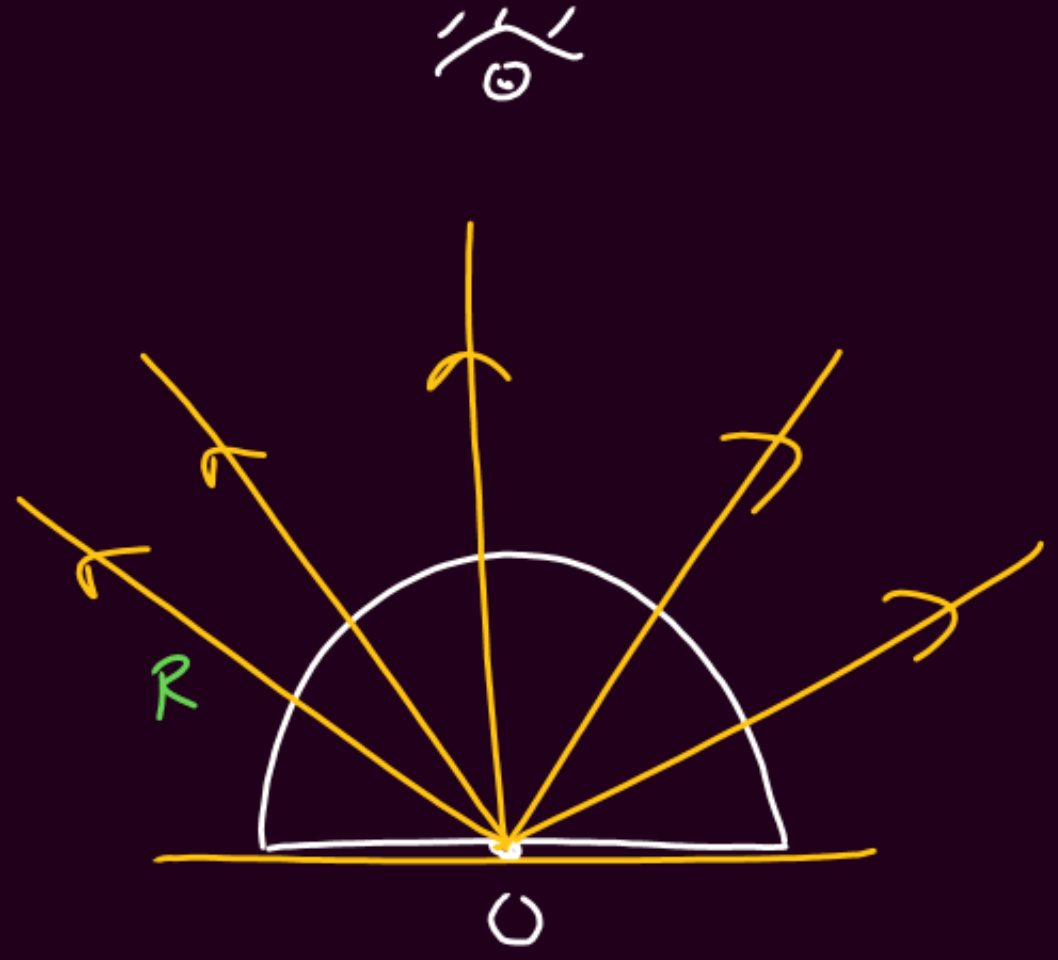
② $\dfrac{1}{v_2} - \dfrac{3/2}{-8} = \dfrac{1 - 3/2}{-5}$

$v_2 = -\dfrac{80}{7}$ cm

Q.

Hemispherical paper weight





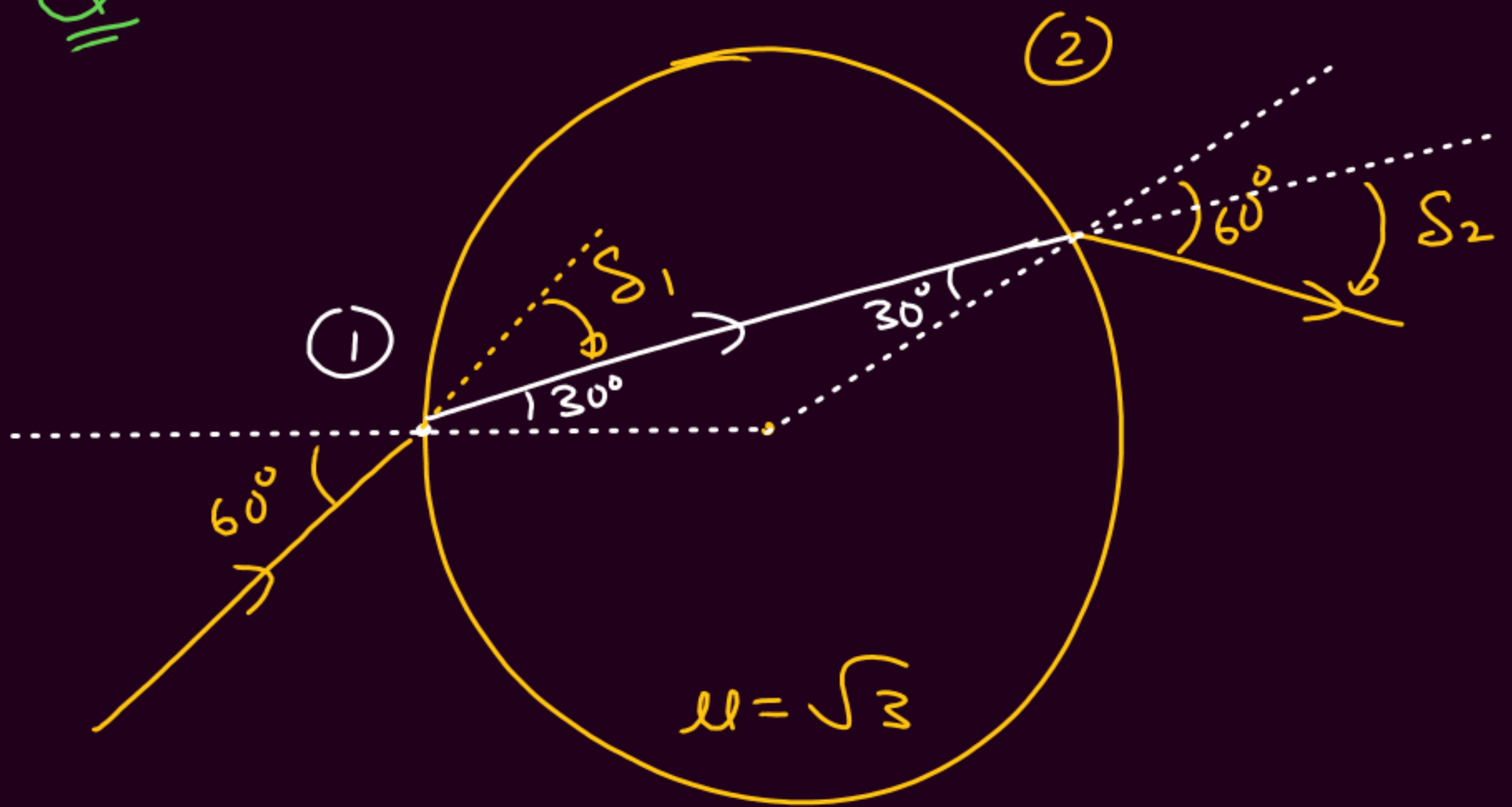
"Refr from plane Surface"

$$d_{app} = \frac{R}{\mu}$$

Refraction by curved Surface

$$\boxed{d_{app} = R}$$

Q



$$\delta_{net} = \delta_1 + \delta_2$$
$$= 30^\circ + 30^\circ$$
$$= \underline{\underline{60^\circ}}$$

Snell's law

① $1 \sin 60^\circ = \sqrt{3} \sin r$

$$\frac{\sqrt{3}}{2} = \sqrt{3} \sin r$$

$$\sin r = \frac{1}{2}$$

$$\boxed{r = 30^\circ}$$

Thin lenses

Convex

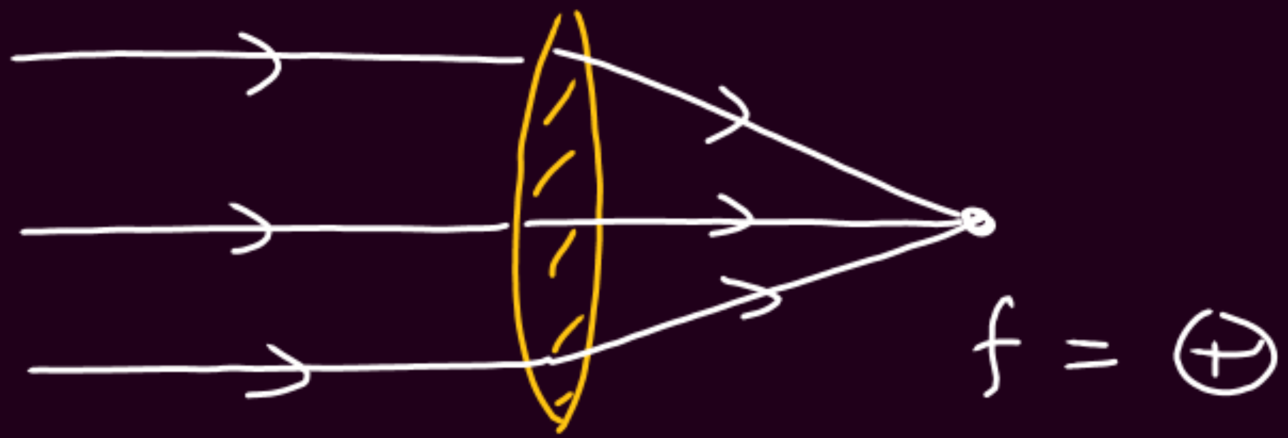
Bi | Equi | Plano

Concave

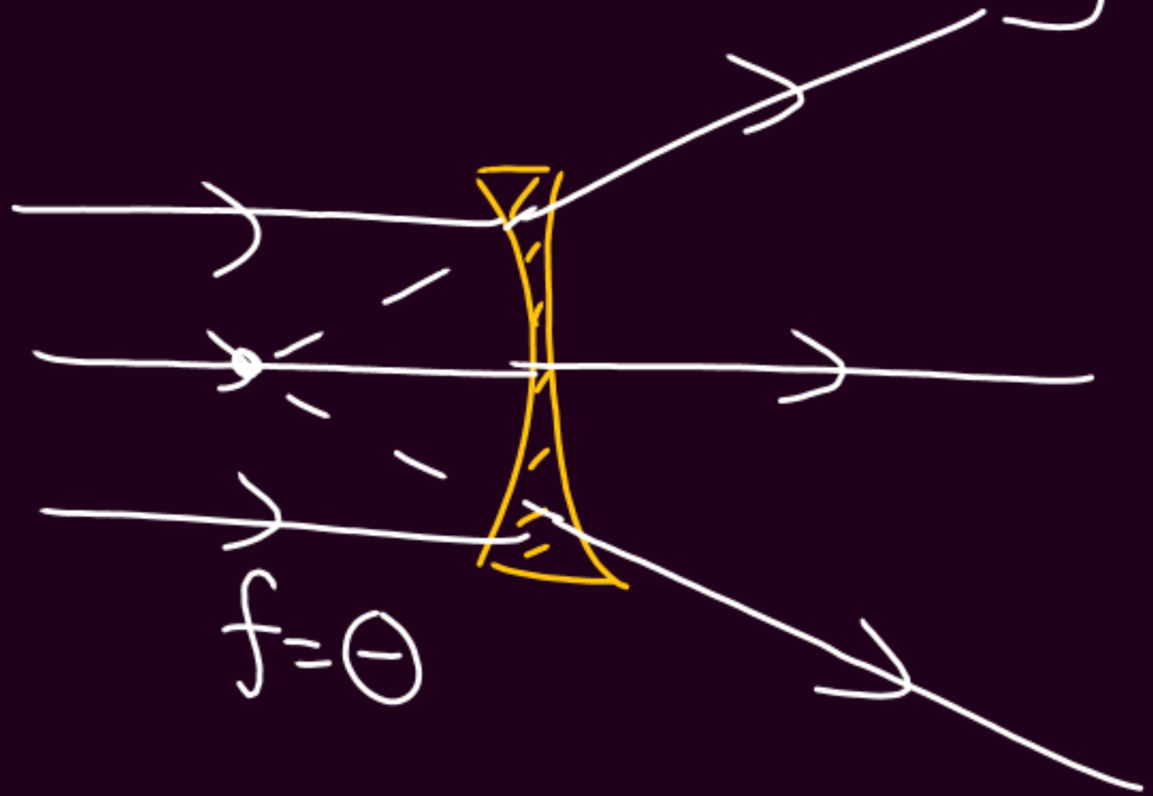
Concavo - Convex

Convexo - Concave

Convex → Converging



Concave → Diverging



Power of Lens

$$\boxed{P_L = \frac{1}{f_L}}$$ f_L in m

Unit → D (Dioptre)

$P = \oplus$ Converging

$P = \ominus$ Diverging

Lens - Maker's Formula

$$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\boxed{\mu = \frac{\mu_L}{\mu_m}}$$

Convex

① Bi $\quad \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

② Equi $\quad \boxed{f_{equi} = \frac{R}{2(\mu - 1)}}$

③ Plano $\quad \boxed{f_{plano} = \frac{R}{(\mu - 1)}}$ $\quad \boxed{f_{plano} = 2 f_{equi}}$

Q. Equi Convex (glass) $R = 20\,cm$

$f = ?$

$$f = \frac{R}{2(\mu - 1)}$$

$$f = \frac{20}{2\left(\frac{3/2}{1} - 1\right)} = 20\,cm$$

Special Case

→ Equi
→ glass
→ in Air

$f = R$

Q. Plano Concave (glass)

$R = 40cm$

$f = ?$

$$f = \frac{-R}{(\mu - 1)}$$

$$f = \frac{-40}{3/2 - 1} = -80cm$$

Q. Convex (glass) in water

$R_1 = 20cm$ & $R_2 = 30cm$

$f = ?$

$$\frac{1}{f} = \left(\frac{3/2}{4/3} - 1\right)\left(\frac{1}{20} + \frac{1}{30}\right)$$

$$1/f = \frac{1}{8} \times \frac{5}{60}$$

$$\boxed{f = 96cm}$$

Q. Equi convex lens $(\mu_L = 5/3)$

$$P = 2D = \frac{1}{f}$$

$$R = ?$$

$$f = \frac{1}{2}m = 50cm$$

$$50 = \frac{R}{2\left(\frac{5}{3} - 1\right)}$$

$$\boxed{R = \frac{200}{3} cm}$$

Q. Convex lens (glass) $f = 30cm$

dipped in water $f_{new} = ?$

$$\frac{f_w}{30} = \frac{f_w}{f_{air}} = \frac{\left(\frac{3/2}{1} - 1\right)}{\left(\frac{3/2}{4/3} - 1\right)} = \frac{1/2}{1/8} = 4$$

$$\boxed{f_w = 120 cm}$$

$$\frac{1}{f} = \left(\frac{\mu_L}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\boxed{\frac{f_2}{f_1} = \frac{\left(\frac{\mu_L}{\mu_{m_1}} - 1\right)}{\left(\frac{\mu_L}{\mu_{m_2}} - 1\right)}}$$

Q. Convex (glass) $f = 40\text{cm}$

dipped in liq $(\mu = 5/3)$ $f = ?$

$$\frac{f}{40} = \frac{\left(3/2 - 1\right)}{\left(\frac{3/2}{5/3} - 1\right)} = \frac{\left(1/2\right)}{\left(-\frac{1}{10}\right)} = -5$$

$$\boxed{f = -200\text{ cm}}$$

$$P = \frac{1}{f} = \left(\frac{\mu_L}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

1) $\mu_L > \mu_m$ — $f = \oplus$ Converging — $f = \ominus$ Diverging

2) $\mu_L = \mu_m$ — $f \to \infty$ — $f \to \infty$ — $P = 0$

(neither converging nor diverging) → Undeviated

3) $\mu_L < \mu_m$ — $f = \ominus$ Diverging — $f = \oplus$ Converging

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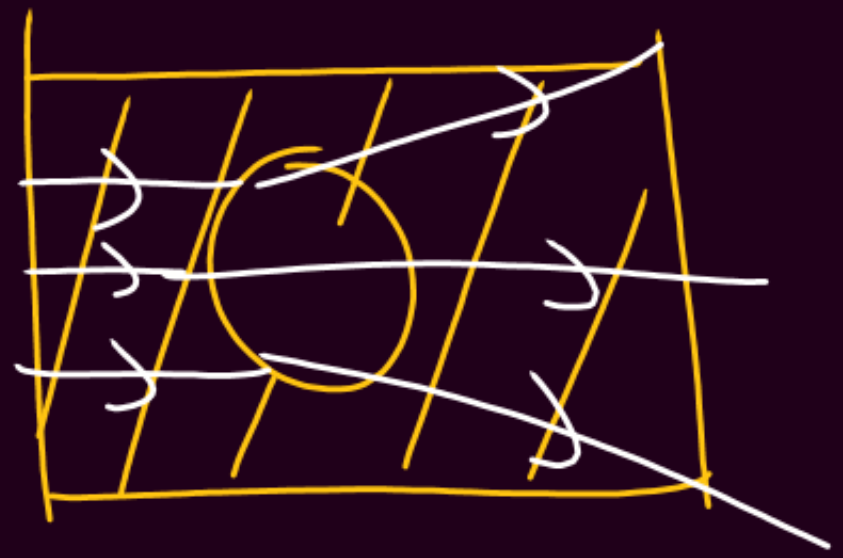
Water Drop in Air

Air bubble in water



① Lenses in contact

$$P = P_1 + P_2$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

② Lenses at Sep. d

$$P = P_1 + P_2 - dP_1P_2$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

Q. Convex $f_1 = 20cm$
Convex $f_2 = 30cm$ } contact $f_{eq} = ?$

$$f_{eq} = 12cm$$

Q. Concave $f = 30cm$
Convex $f = 20cm$ } $f_{eq} = ?$

$$\frac{1}{f} = \frac{1}{20} + \frac{1}{-30}$$

$$f = 60cm$$

Q. Convex $f = 40cm$

$P_{eq} = 2D = \frac{1}{f}$

$f_{other} = ?$

$$\frac{1}{50} = \frac{1}{40} + \frac{1}{f_2}$$

$$\boxed{f_2 = -200cm}$$

Q. Two Convex $\rightarrow$ $f_1 = 20cm$, $f_2 = 30cm$

sep $= 10cm$

$f_{eq} = ?$

$$\frac{1}{f} = \frac{1}{20} + \frac{1}{30} - \frac{10}{(20)(30)}$$

$$\boxed{f = 15cm}$$

Q. Convex $= 30cm$

Concave $= 40cm$

sep. $= 10cm$

$$\frac{1}{f} = \frac{1}{30} - \frac{1}{40} + \frac{10}{30 \times 40}$$

$$\boxed{f = 60cm}$$

Lenses are cut into parts

①

P
f

=>

Ⓟ f

P f

②

$P/2$ $P/2$

$2f$ $2f$

$P/2$ $P/2$

P
f

P
f

2P

$f/2$

2P

$f/2$

Images

O

$\boxed{2}$

$\boxed{3}$

$\boxed{2}$

$(\text{Intensity}) \propto (\text{Refracting Area})$

Dia = Aperture

πr^2

$\boxed{I_0}$

$\pi r^2 - \pi (r/2)^2$

$\boxed{\frac{3 I_0}{4}}$

$\frac{\pi r^2}{4}$

$\frac{I_0}{4}$

Q.

Equi glass

Air

$f_1 = 30 = R_1$

$f_2 = 40 = R_2$

$$\frac{1}{f_w} = -\left(\frac{4/3}{1} - 1\right)\left(\frac{1}{30} + \frac{1}{40}\right)$$

$$\frac{1}{f_w} = -\frac{1}{3}\left(\frac{7}{120}\right)$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_w} + \frac{1}{f_2}$$

$$\frac{1}{f} = \frac{1}{30} - \frac{1}{3}\left(\frac{7}{120}\right) + \frac{1}{40}$$

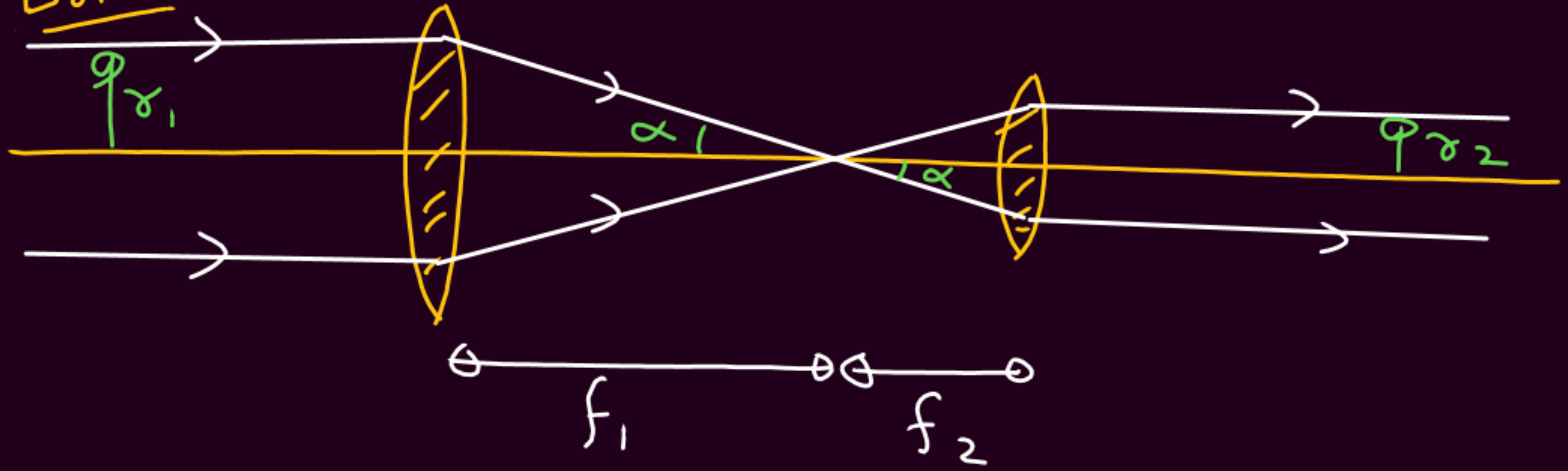
$$\frac{1}{f} = \frac{2}{3} \times \frac{7}{120}$$

$$\boxed{f = \frac{180}{7}\text{ cm}}$$

Incident & Emergent → Parallel

$\tan\alpha = \frac{r_1}{f_1} = \frac{r_2}{f_2}$

① Both convex

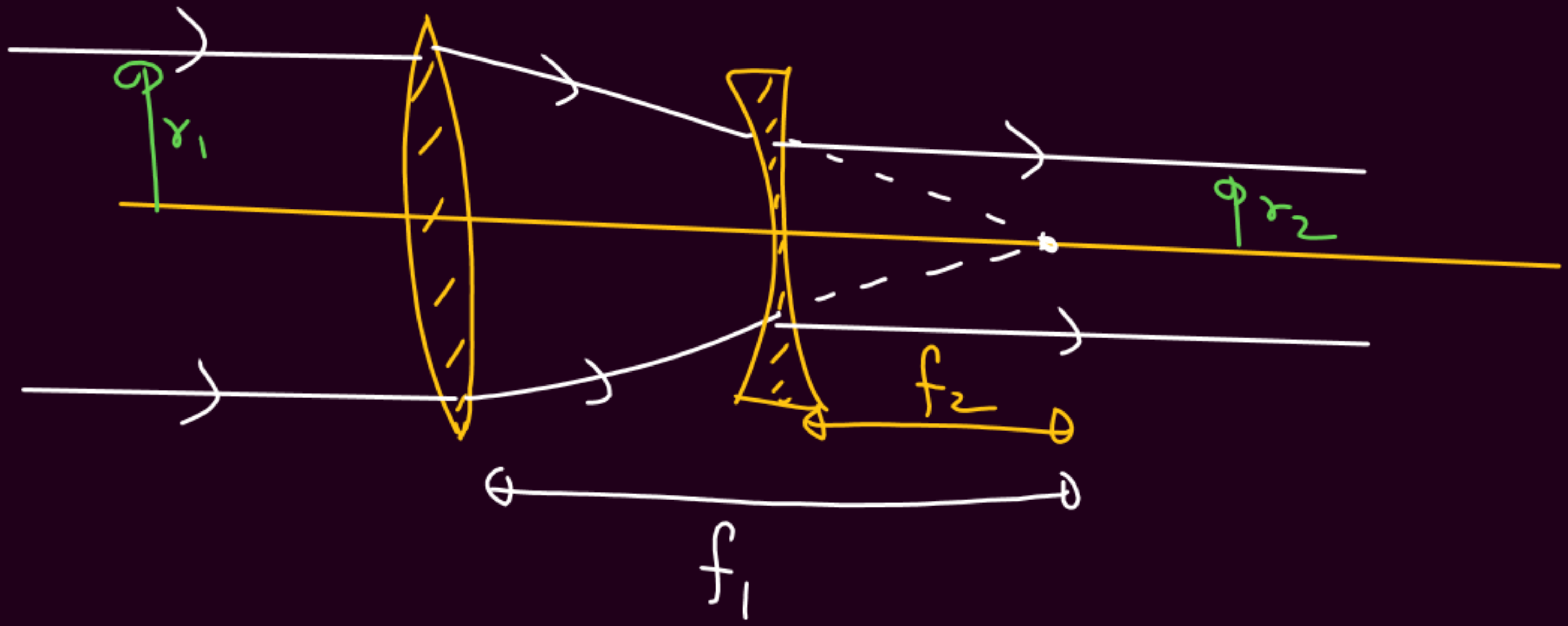


① Separation

$$\boxed{d = f_1 + f_2}$$

② $\frac{r_1}{r_2} = \frac{f_1}{f_2}$

② Convex & Concave



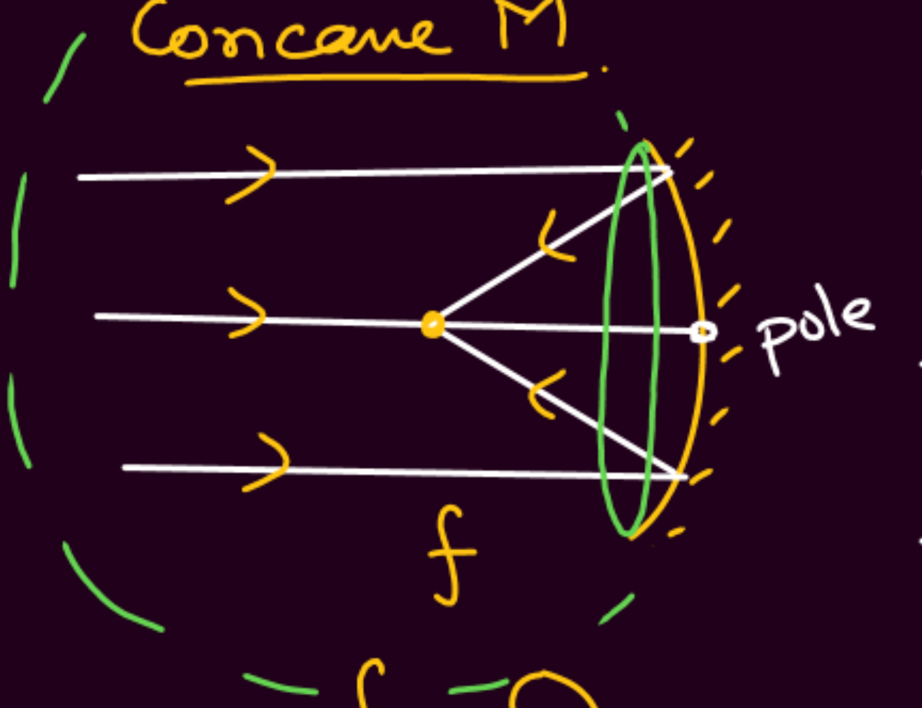
① $d = f_1 - f_2$

② $\frac{r_1}{r_2} = \frac{f_1}{f_2}$

Spherical Mirrors

$$\boxed{P_M = -\frac{1}{f_M}}$$

Concave M



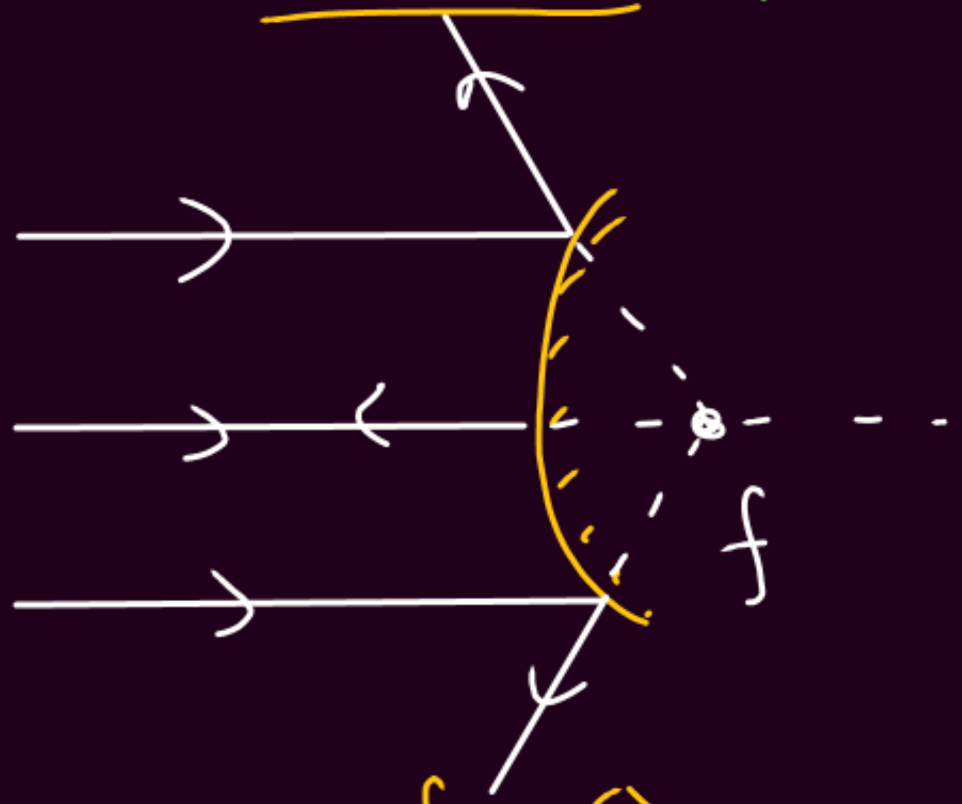
$f = -$

Converging

$P = +$

$$\boxed{f = \frac{R}{2}}$$

Convex M



$f = +$

Diverging

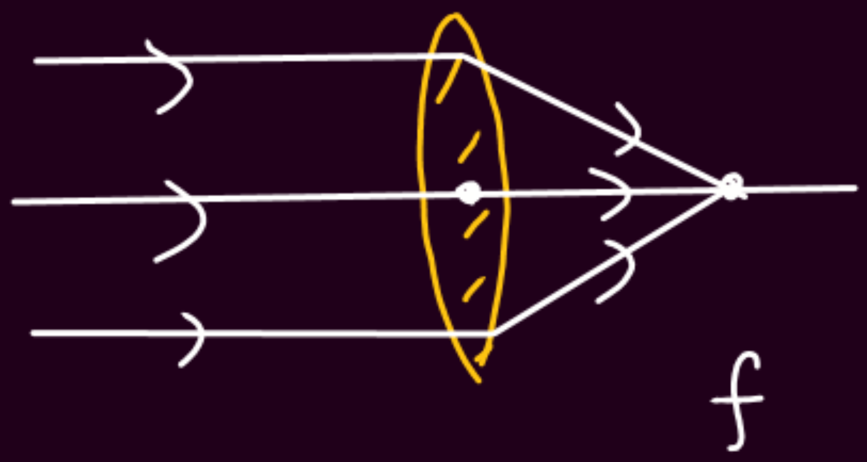
$P = -$

$$\boxed{2f = R = C}$$

Lenses

$$\boxed{P_L = \frac{1}{f_L}}$$

Convex L



$f = +$

Converging

$P = +$

$\boxed{f = R}$ provided → { Equi, glass, Air

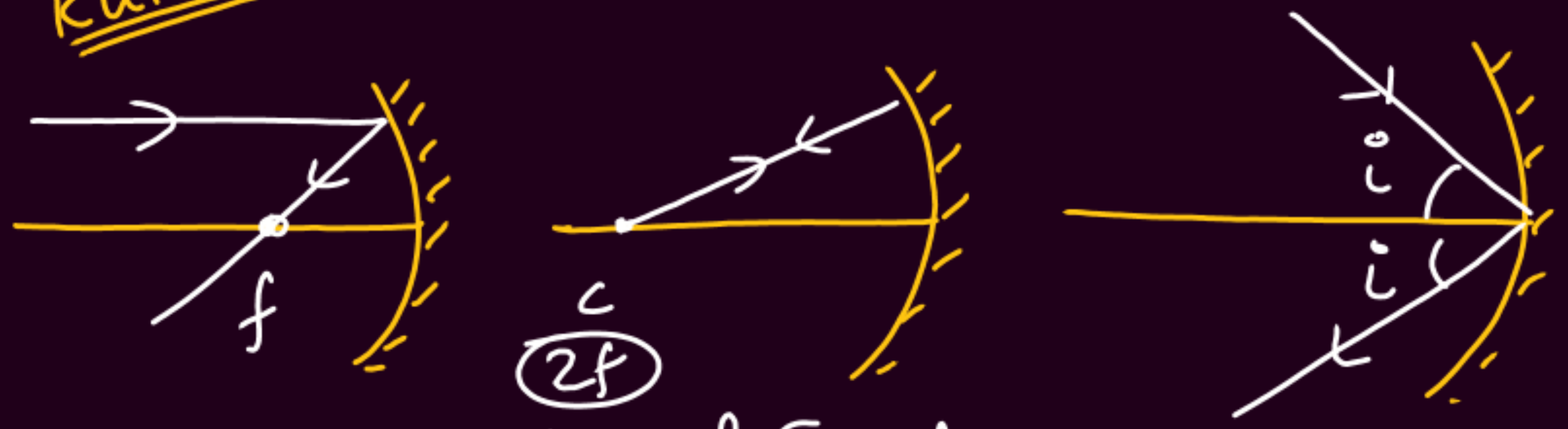
Concave L

$f = -$

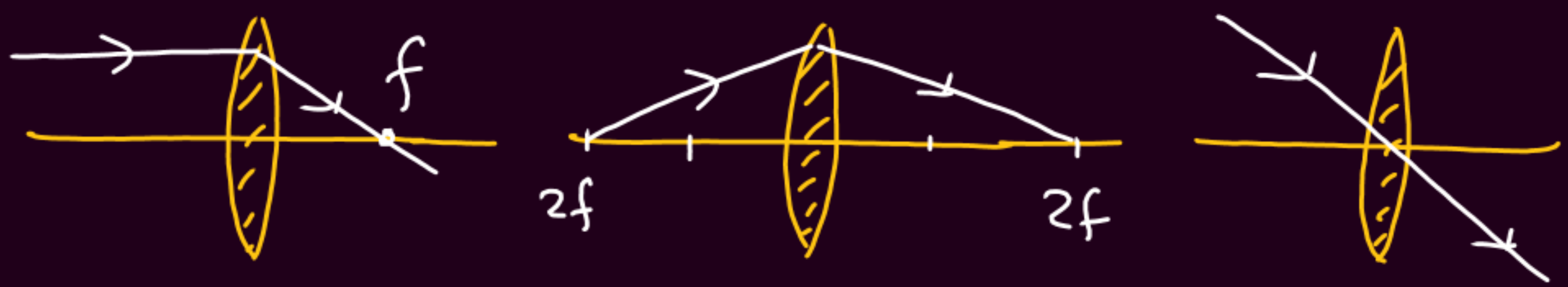
Diverging

$P = -$

Rules



Normal Incidence
(Retraces path)



Sign convention

RO  VO

RI  VI

− +

RO  VO

VI  RI

− +

Mirror - formula

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

mag. (Transverse/Linear)

$$\frac{h_i}{h_o} = \boxed{m = -\frac{v}{u} = \frac{f}{f-u}} = \frac{f-v}{f}$$

m → ⊕ Upright/Erect

m → ⊖ Inverted

Superficial mag. (Area) $= m^2$

Lens formula

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

mag:

$$\boxed{m = \frac{v}{u} = \frac{f}{f+u}} = \frac{f-v}{f}$$

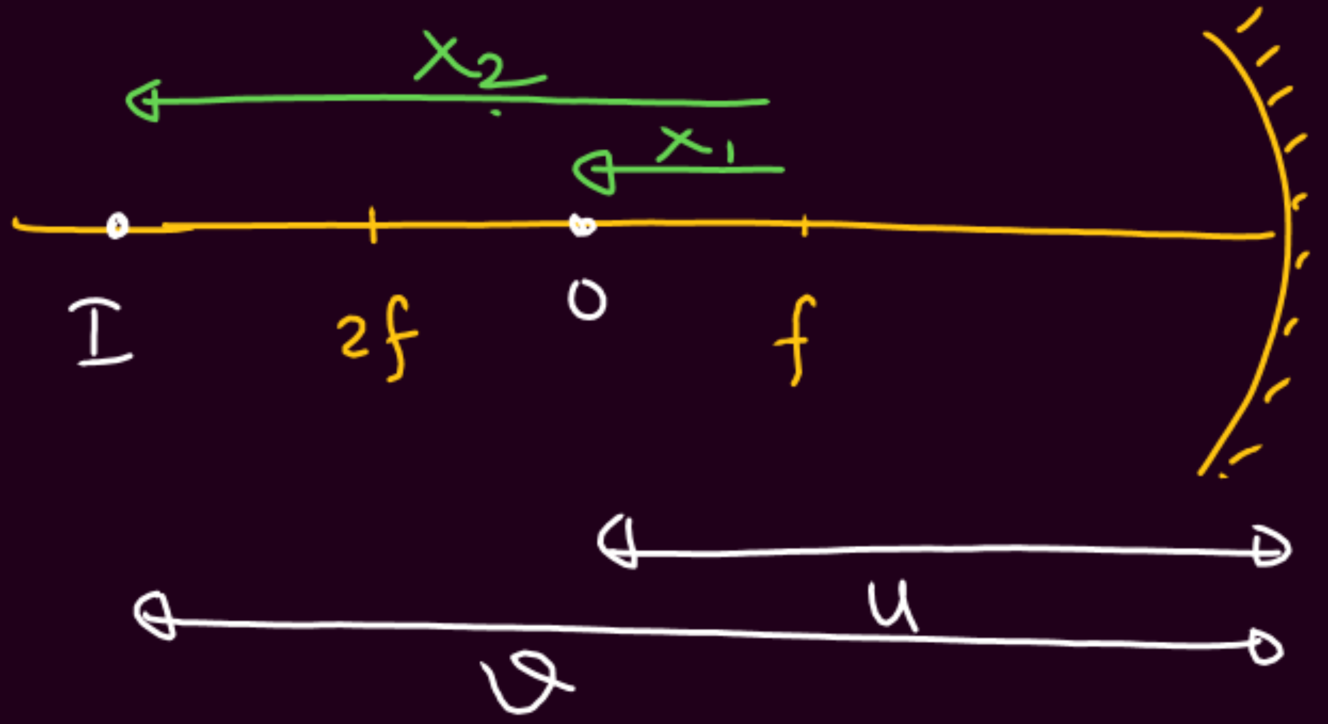
$|m|$ → less than 1 (Diminished)

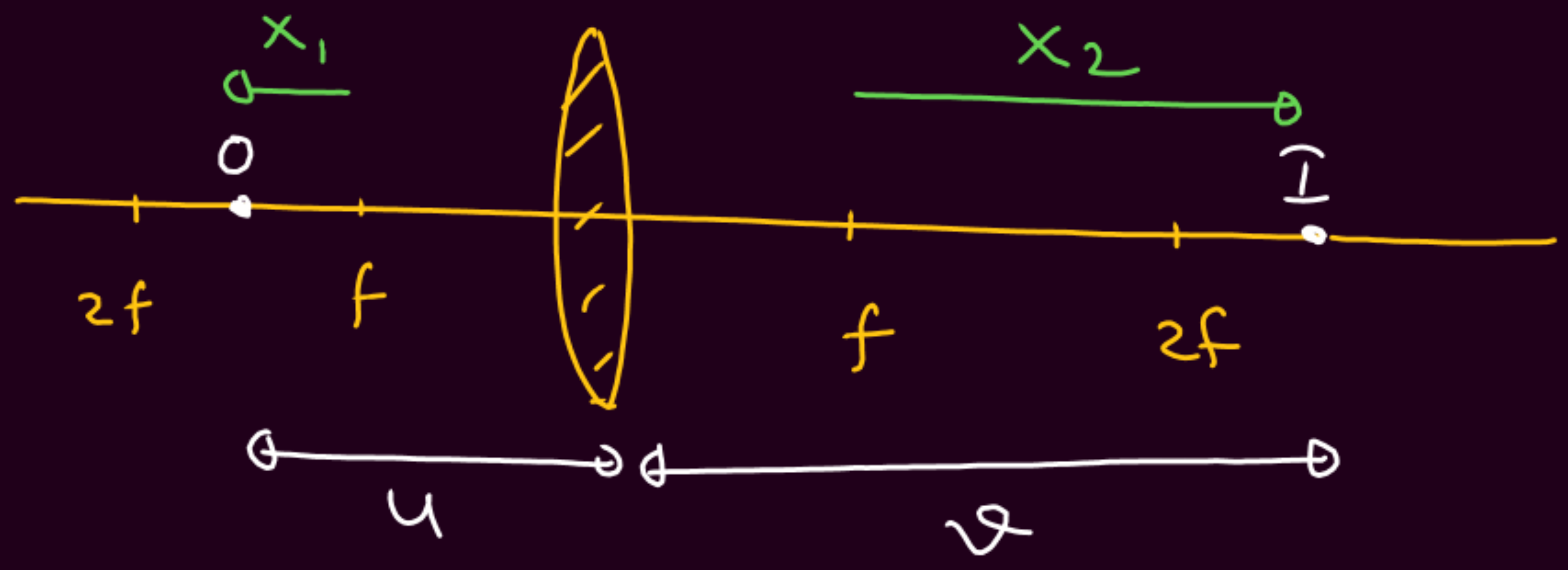
$|m|$ → Equal to 1 (Same size)

$|m|$ → More than 1 (Enlarged)

Newton's Formula

$$\boxed{x_1 x_2 = f^2}$$



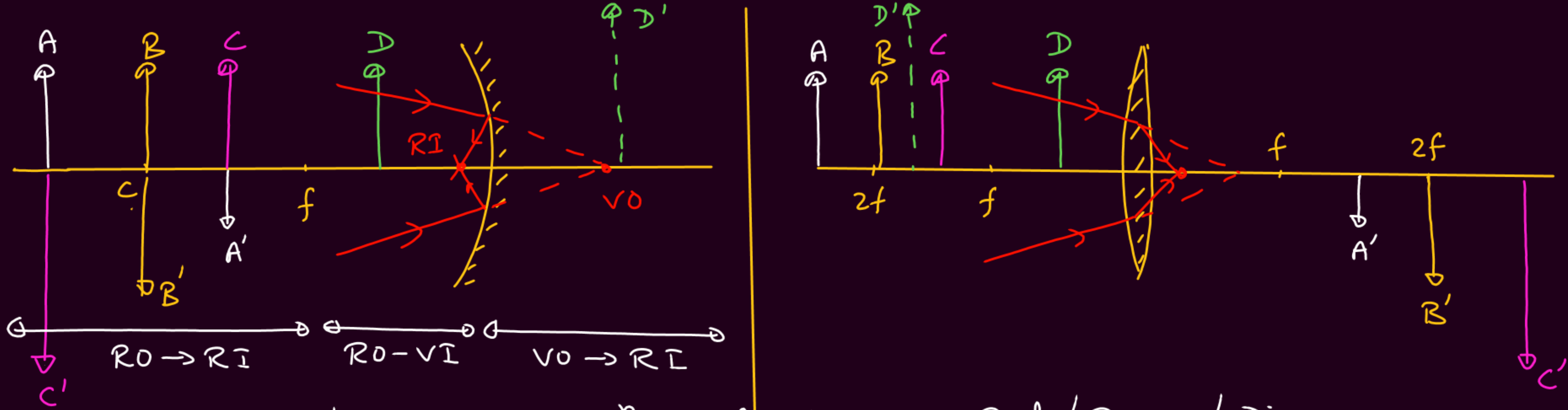


u
- ⊕ VO
- ⊖ RO

v
- ⊕ VI
- ⊖ RI

u
- ⊕ VO
- ⊖ RO

v
- ⊕ RI
- ⊖ VI



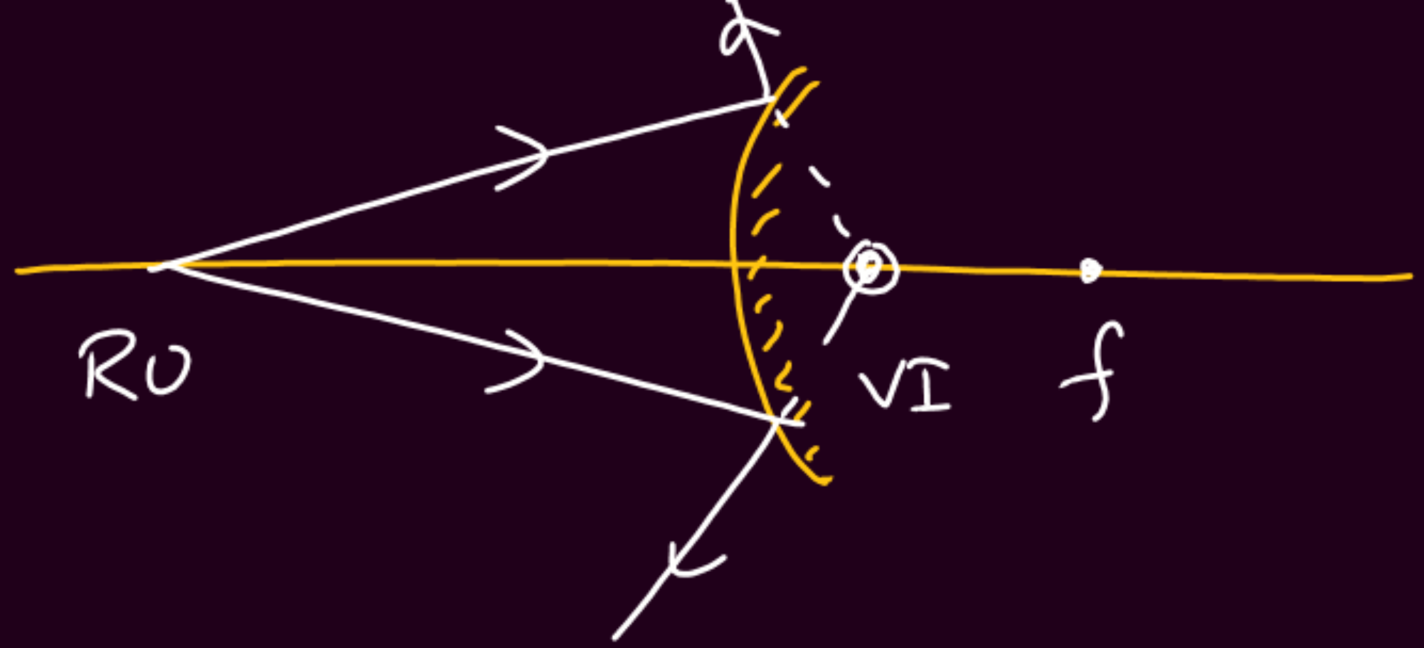
(A) O beyond C/2f → I betⁿ f & 2f → Real / Inv. / Dim

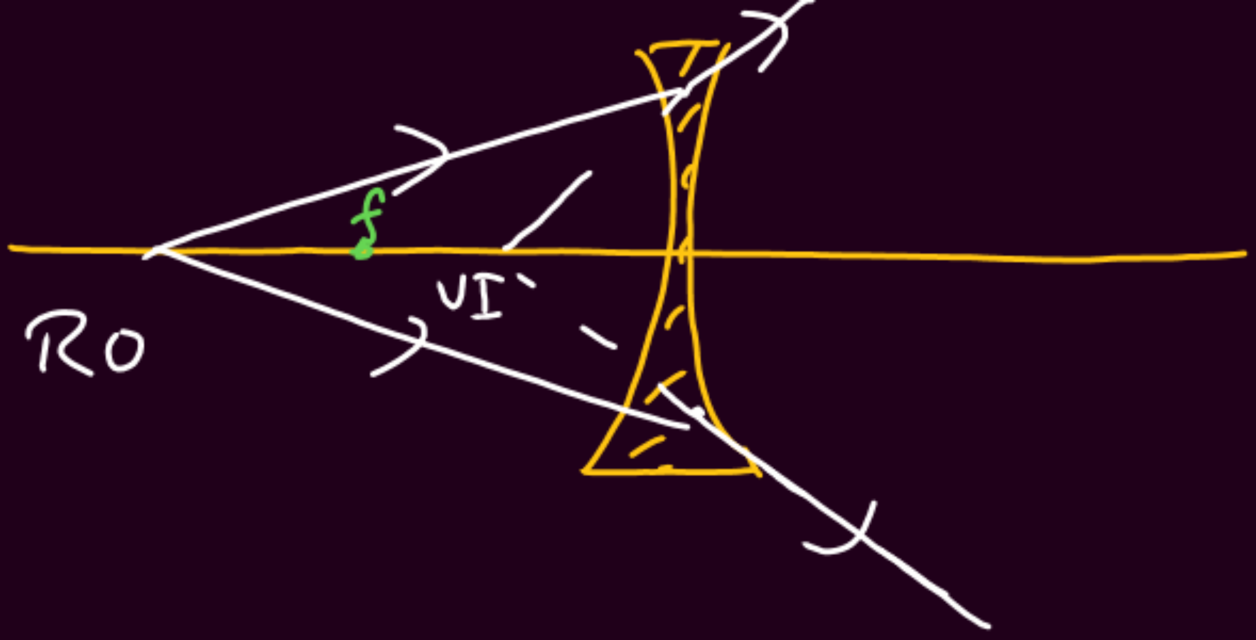
(B) O at C/2f → I at C/2f → Real / Inv / Same Size

(C) O betⁿ f & 2f → I beyond 2f → Real / Inv / Enlarged

(D) O betⁿ f & pole → Virtual / Erect / Enlarged Image

VO anywhere → Real / Erect / Dim. image → betⁿ f & pole





RO anywhere → Virtual / Erect / Dim. Image → bet^n f & pole

→ Min. Dist bet^n RO & RI formed by Concave M is '0'.

→ ______ " ______ " ______ Convex L is '4f'.

→ Mirror always forms VI of RO → Plane M / Convex M

→ RI of RO is always inverted → [True]

→ VI of RO is always Erect → [True]

→ RI of VO is always Erect → [True]

→ Convex M / Concave L always forms VI of RO → [True]

→ Concave M / Convex L always forms RI of RO → [false]

Q. Concave M $R = 20cm$

object → 40cm

$h_o = 10cm$

position & nature of I?

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

$$m = -\frac{v}{-40} = \frac{-10}{-10-(-40)} = -\frac{1}{3}$$

Inv

Dim

$$\boxed{v = -\frac{40}{3}\,cm}$$

Real

$$h_i = -\frac{10}{3}\,cm$$

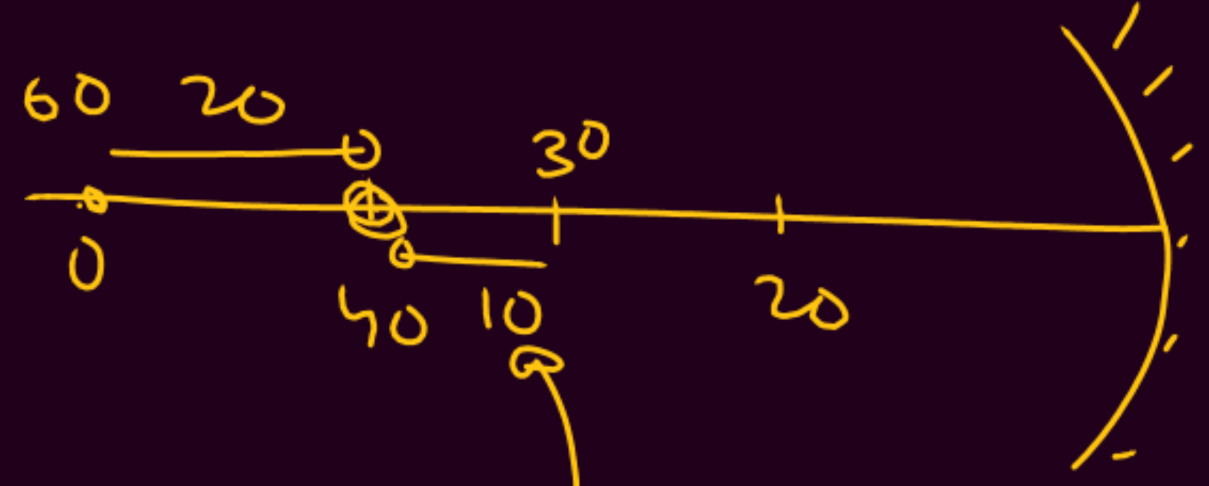
Q. Concave M $f = 20cm$

Object is at 60cm

① position & nature of I

$$m = -\frac{v}{-60} = \frac{-20}{-20+60} = -\frac{1}{2}$$

$$v = -30cm$$



② if obj. moves 20cm towards M then dist. moved by I

Q. Concave M $R = 20cm$

object 5cm

Dist. betn O & I ?

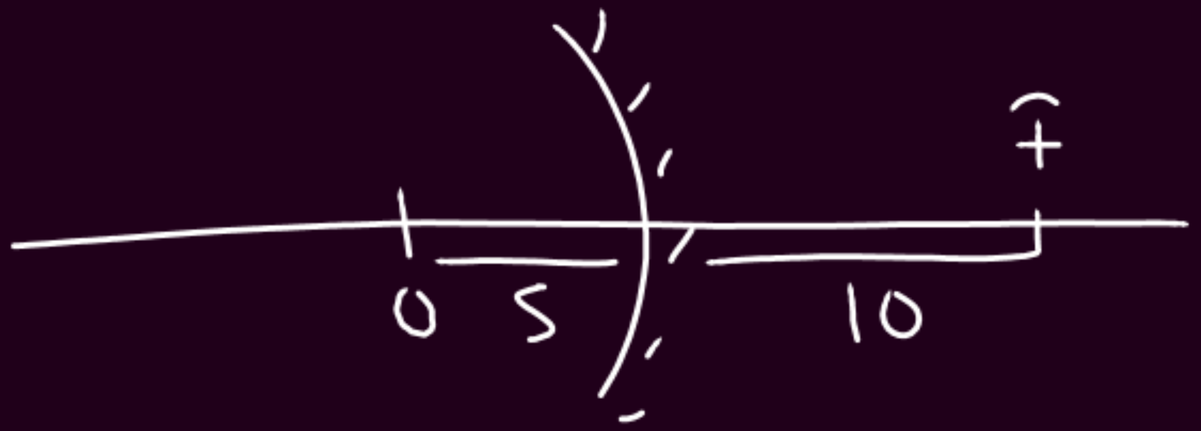
$$m = -\frac{v}{-5} = \frac{-10}{-10+5} = +2$$

+ → Erect

2 → Enlarged

$v = +10cm$

+ → virtual



$\boxed{15cm}$

Q. Concave M

→ RI Double the Size of 'O' placed at 120cm.

$$m = \frac{f}{f-u}$$

$$-2 = \frac{f}{f-(-120)}$$

$f = -80cm$

$\boxed{R = -160cm}$

Q. Convex L $f = 20cm$

object → 12 cm

nature & position of I ?

$$m = \frac{v}{u} = \frac{f}{f+u}$$

$$\frac{v}{-12} = \frac{20}{20-12} = \frac{20}{8} = +\frac{5}{2}$$

Erect

Enlarged

$$\boxed{v = -30\,cm}$$

Virtual

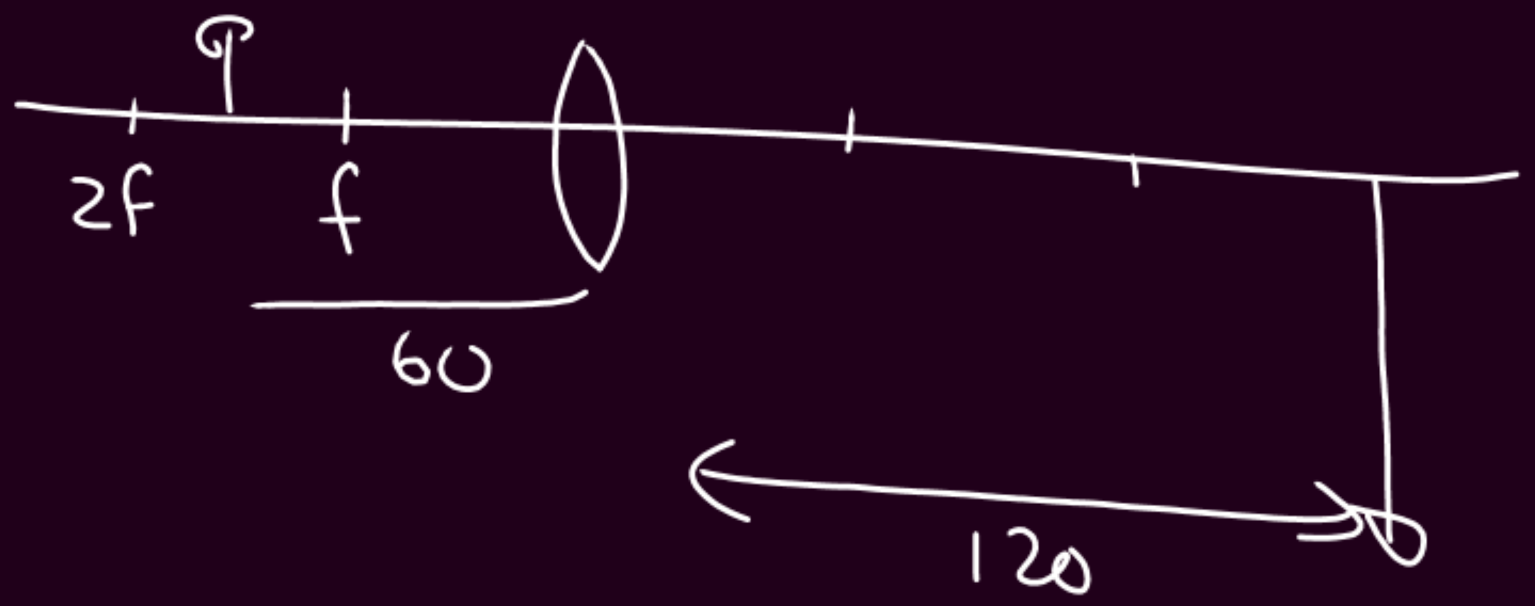
Q Convex L (glass) $R = 40cm$

object is 60 cm

Dist. betn O & I ?

$$m = \frac{v}{-60} = \frac{40}{40+(-60)} = -2$$

$$v = +120\,cm$$



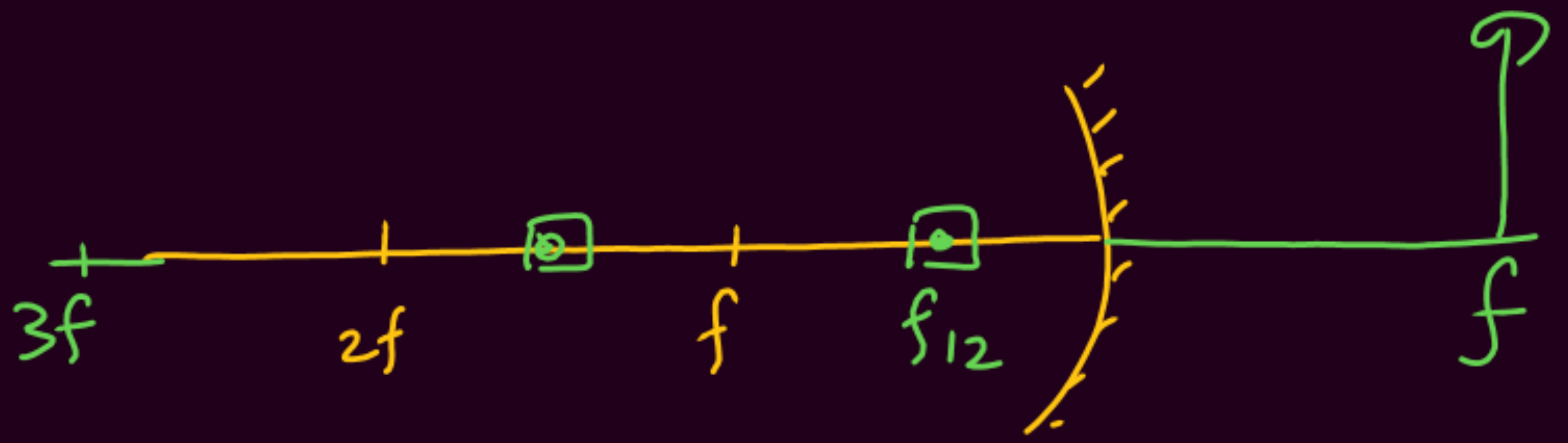
Q. Convex L

Erect Image double the size of object placed at 10cm.

$f = ?$

$$m = +2 = \frac{f}{f + (-10)}$$

$$\boxed{f = 20\text{cm}}$$



Q. Convex M $f = 10$cm

object 20cm

$$m = -\frac{v}{-20} = \frac{10}{10-(-20)} = +\frac{1}{3}$$

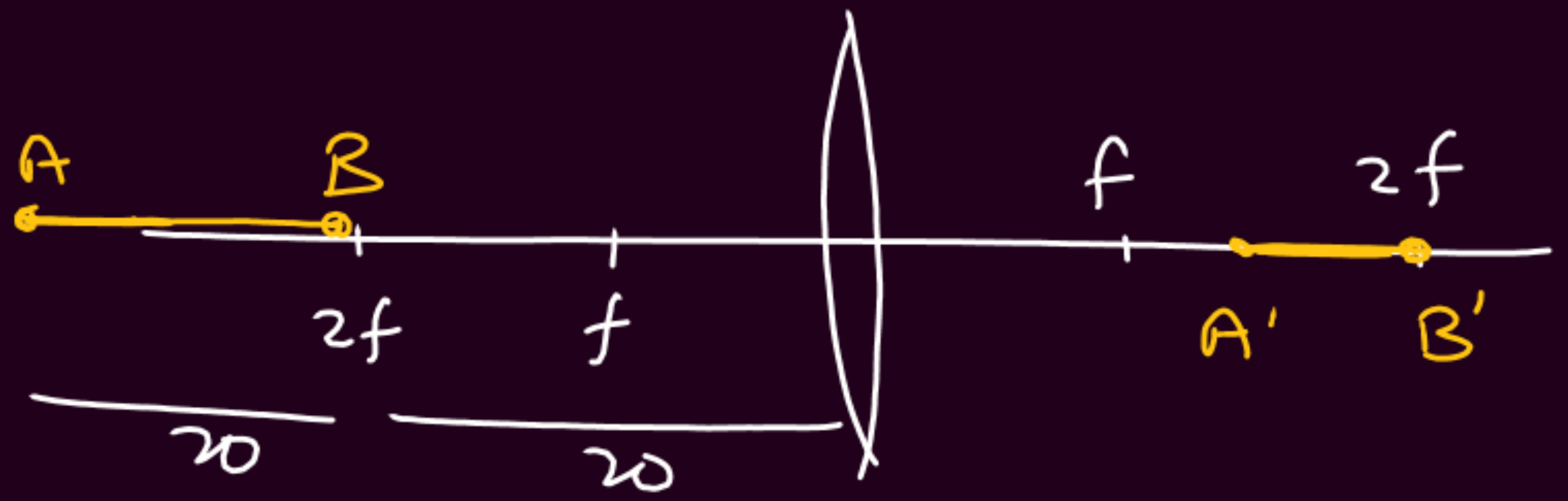
$$\boxed{v = \frac{20}{3}\text{ cm}}$$

Virtual / Erect / Dim.

Q Rod $l = 20\,cm$

Convex $L \Rightarrow f = 10\,cm$

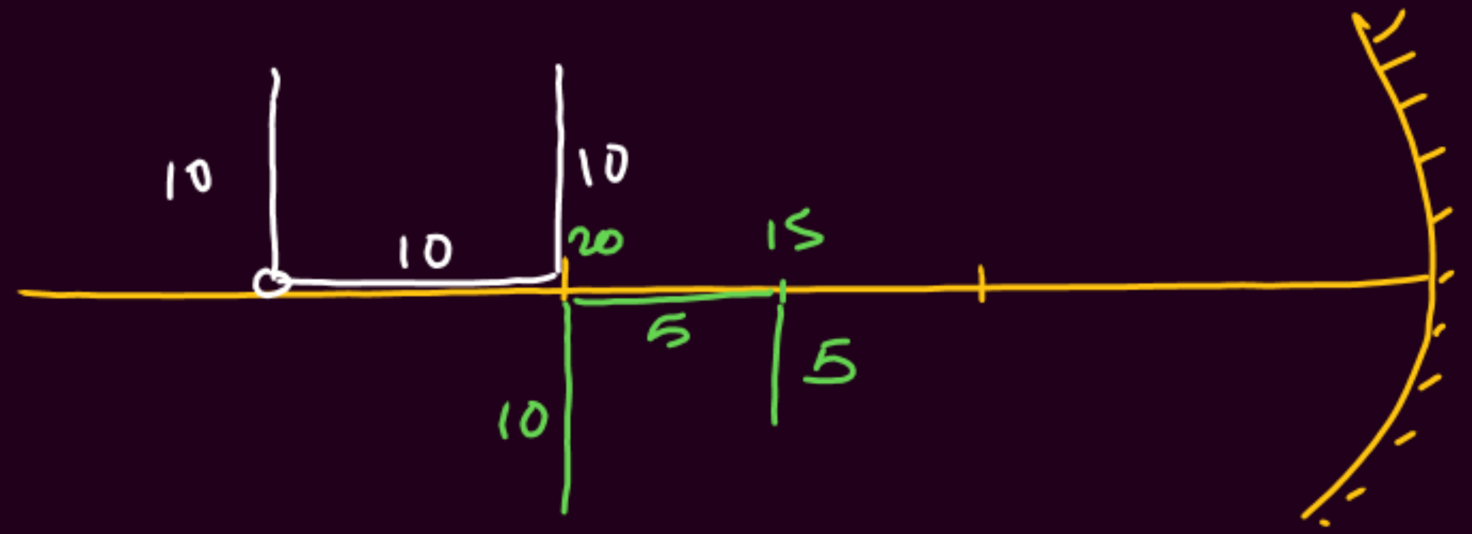
near End is 20 cm from lens



$$m = \frac{v}{-40} = \frac{10}{10 + (-40)} = -\frac{1}{3}$$

$$v_A = \frac{40}{3}$$

$$l' = 20 - \frac{40}{3} = \frac{20}{3}\,cm$$



$f = 10\,cm$

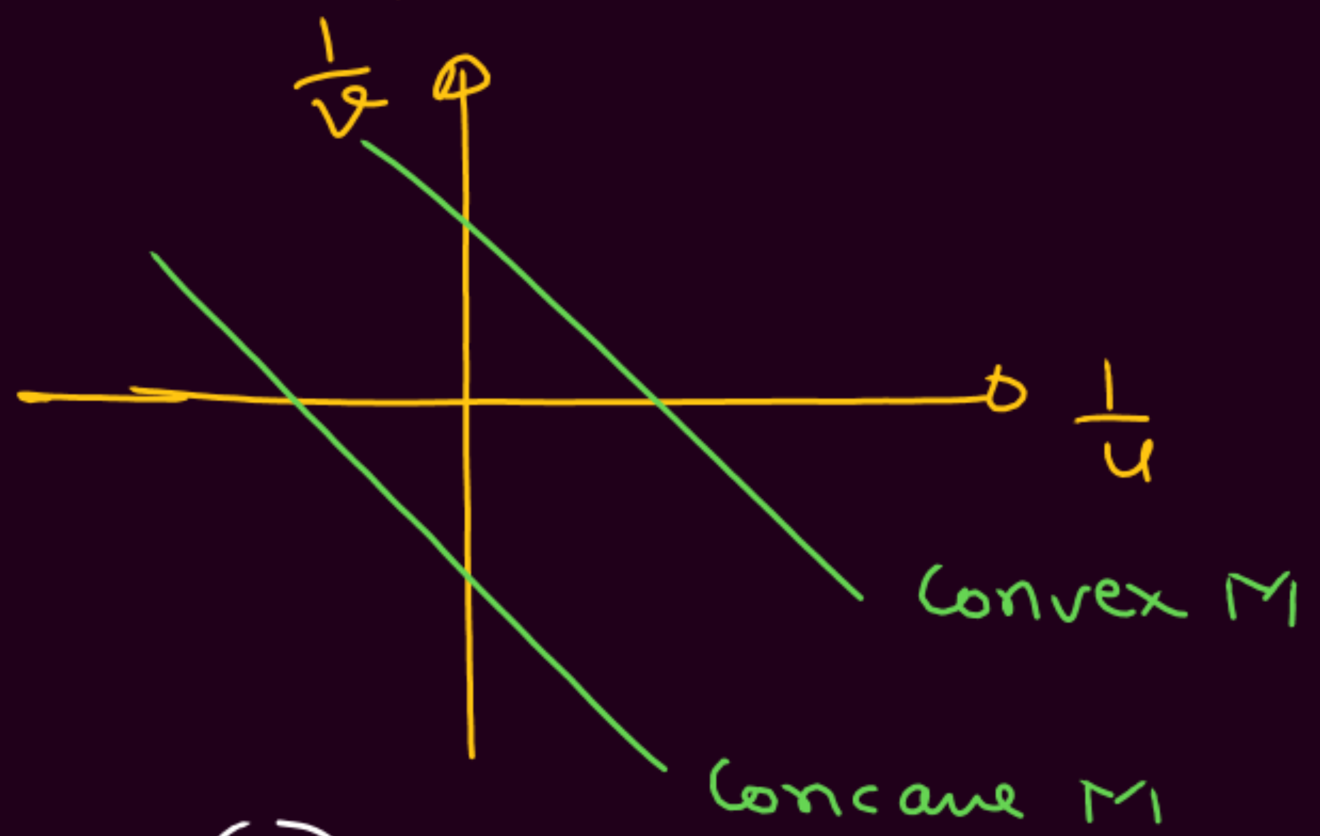
$$\frac{-v}{-30} = \frac{-10}{-10-(-30)} = \boxed{-\frac{1}{2}}$$

$$\boxed{v = -15\,cm}$$

$$l = 5 + 5 + 10 = 20\,cm$$

Graph

Spherical M

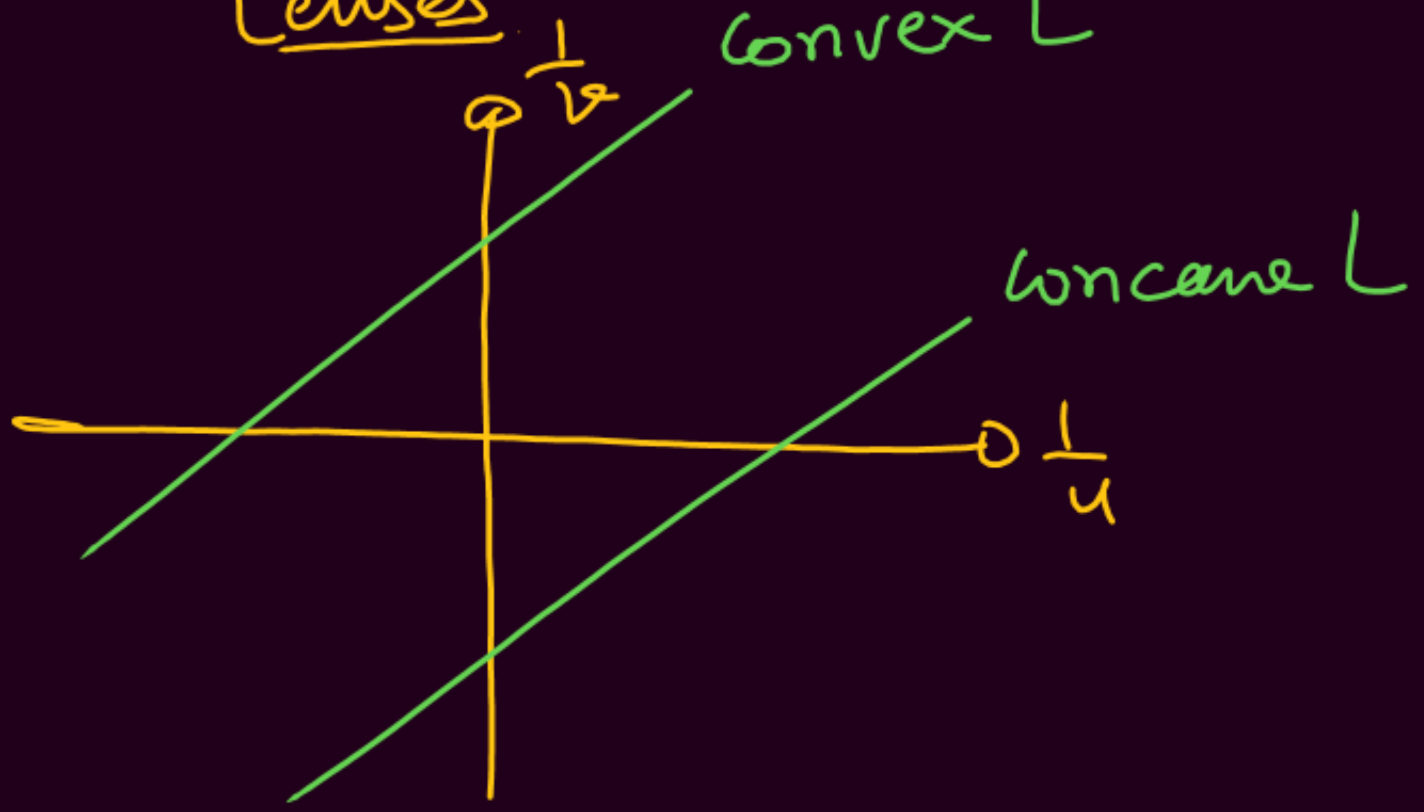


$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{f} = y + x$$

$$\boxed{y = -x + \frac{1}{f}}$$

Lenses

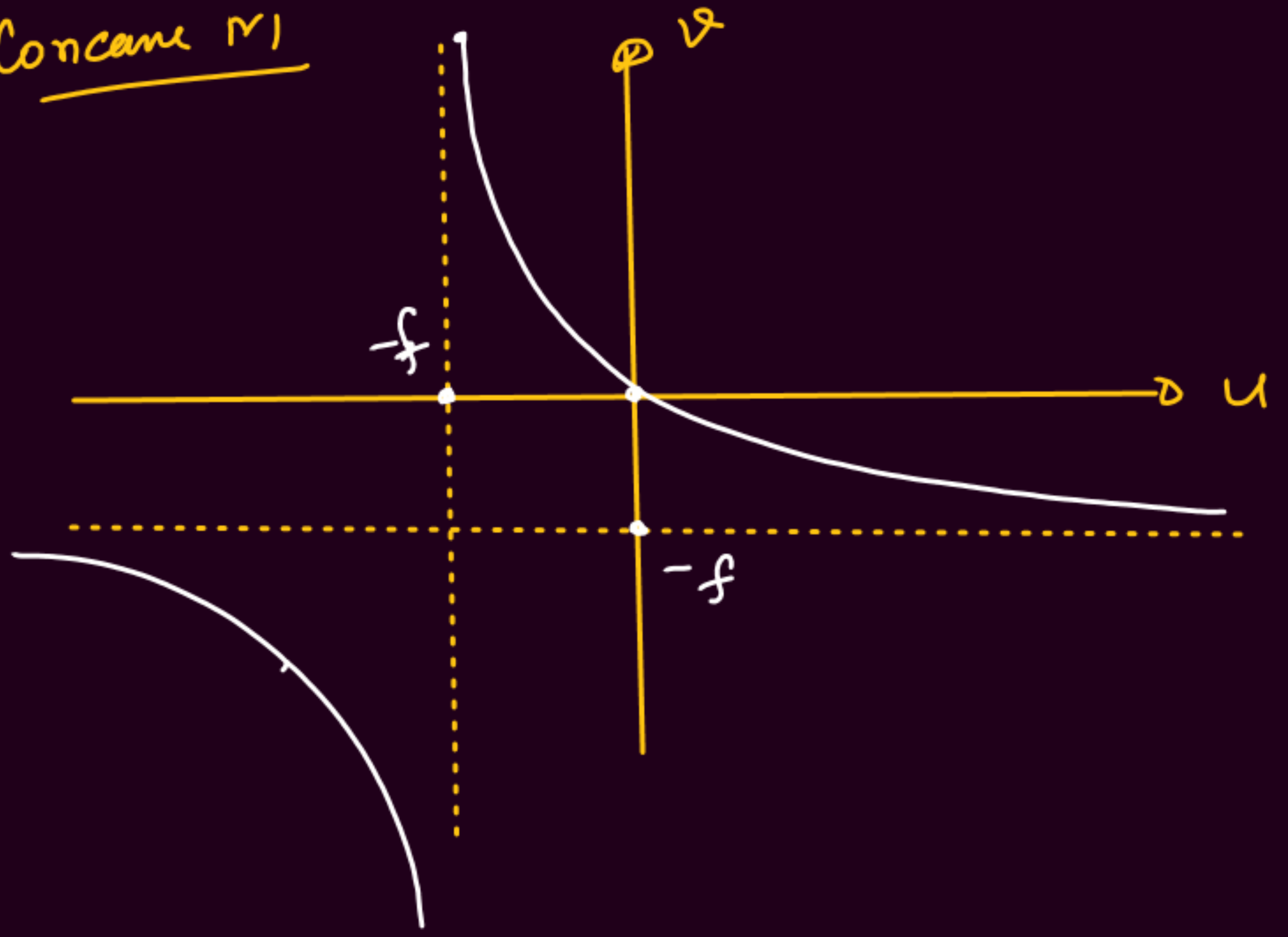


$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

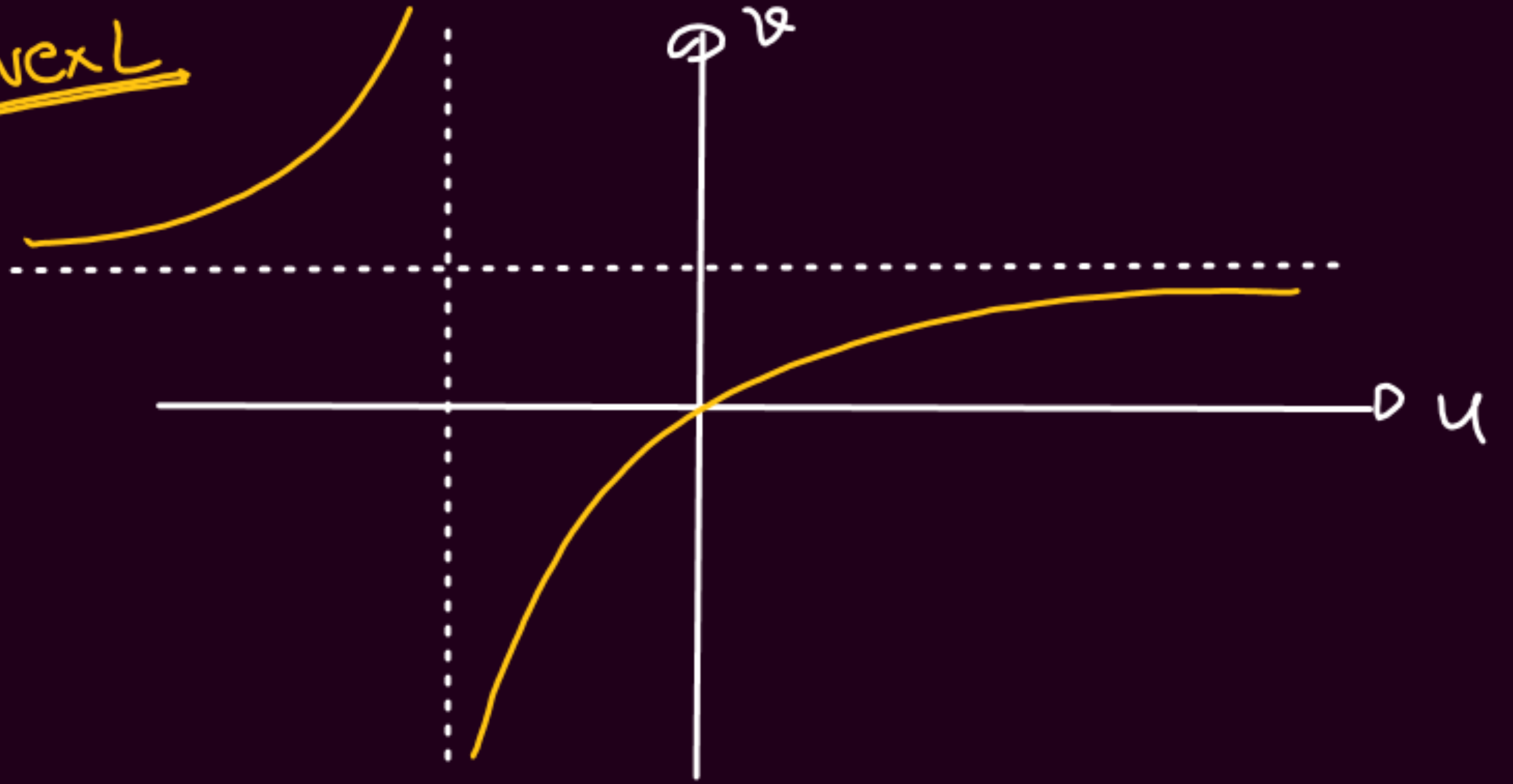
$$\frac{1}{f} = y - x$$

$$\boxed{y = x + \frac{1}{f}}$$

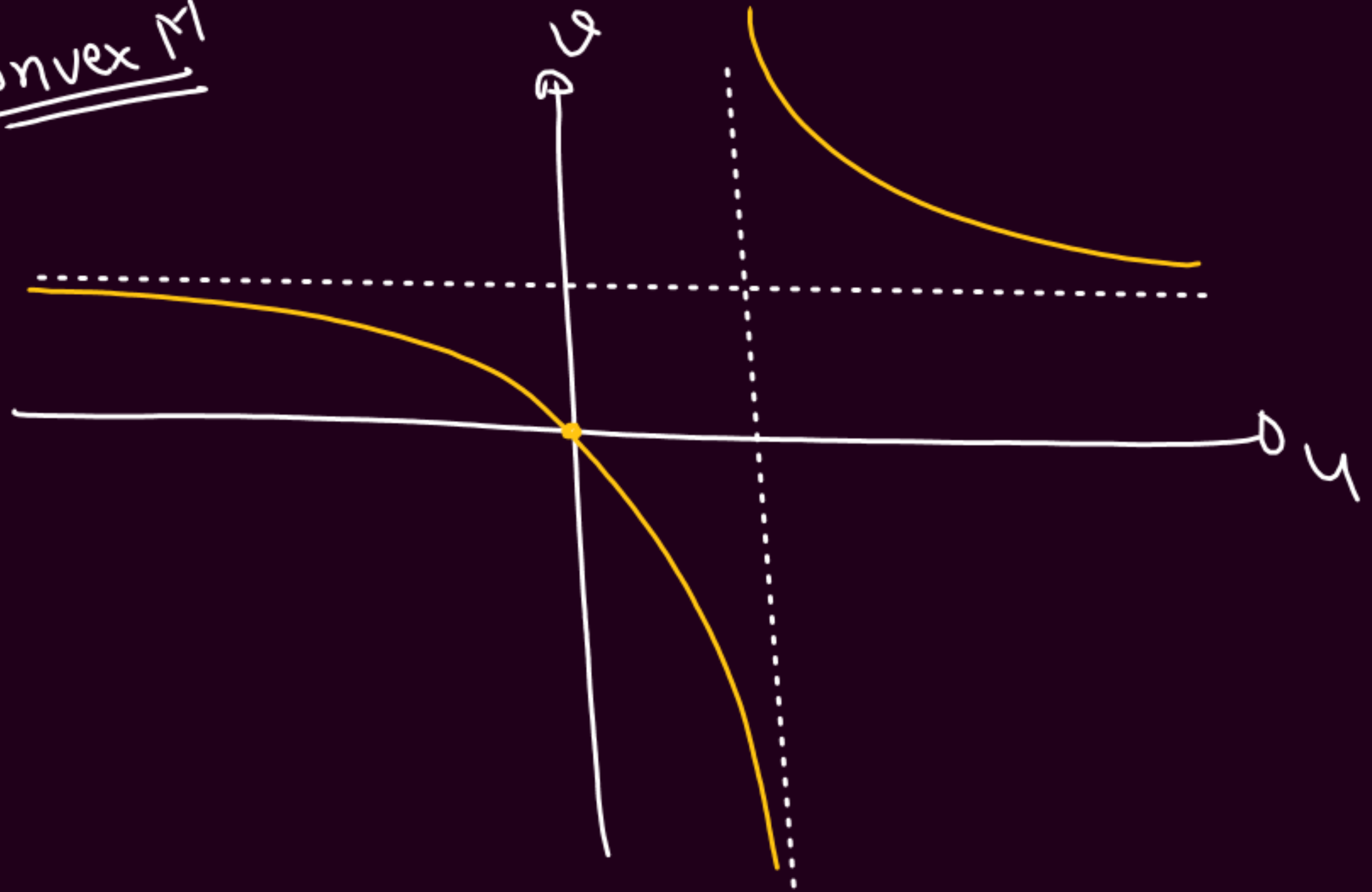
Concave M



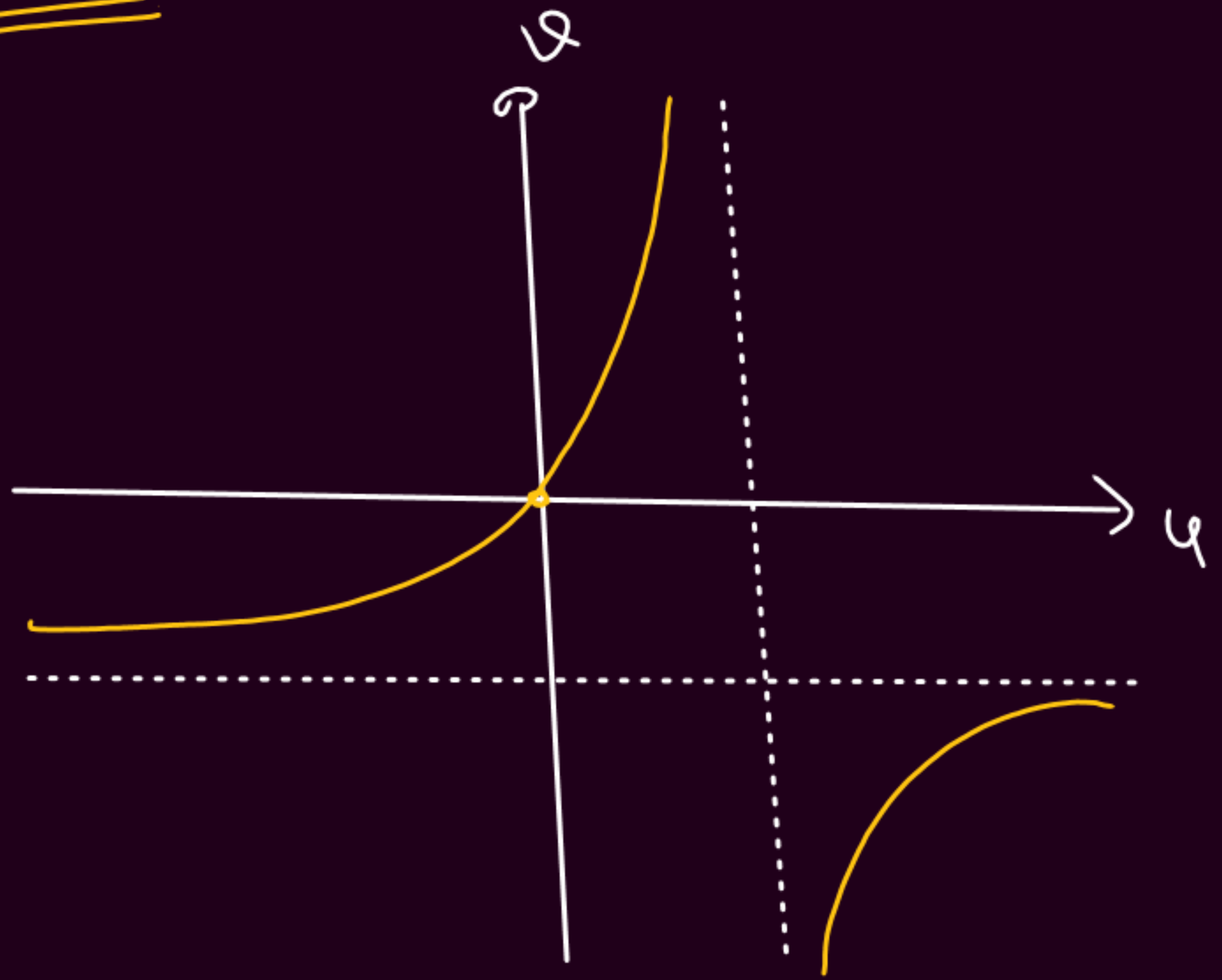
Convex L



Convex M



Concave L



Spherical Mirror

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

$$0 = -\frac{dv}{v^2} - \frac{du}{u^2}$$

$$dv = -\left(\frac{v}{u}\right)^2 du$$

Small length or disp. along principle Axis

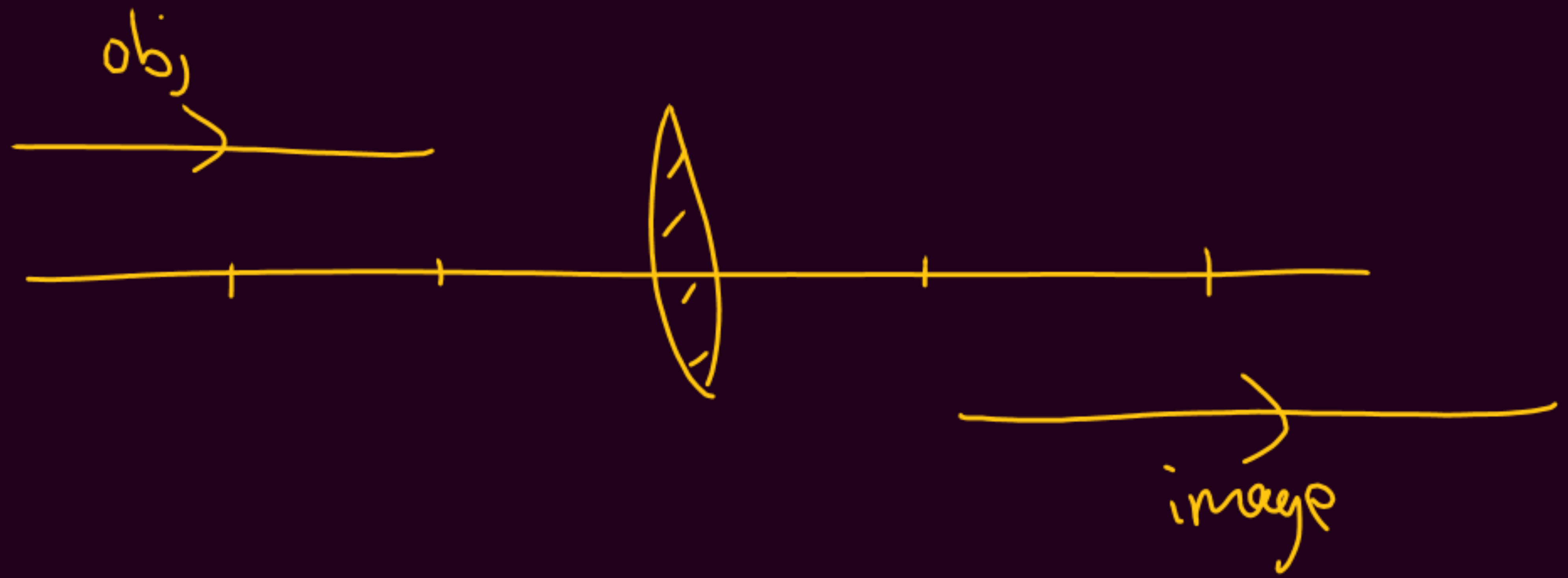
$$\boxed{dv = -m^2\, du}$$

Vel. wrt Mirror $\rightarrow$ $\boxed{v_{IM} = -m^2\, v_{OM}}$

Lenses

$$\boxed{dv = m^2\, du}$$

$$\boxed{v_{IL} = m^2\, v_{OL}}$$



Q object → 2 cm/s towards M

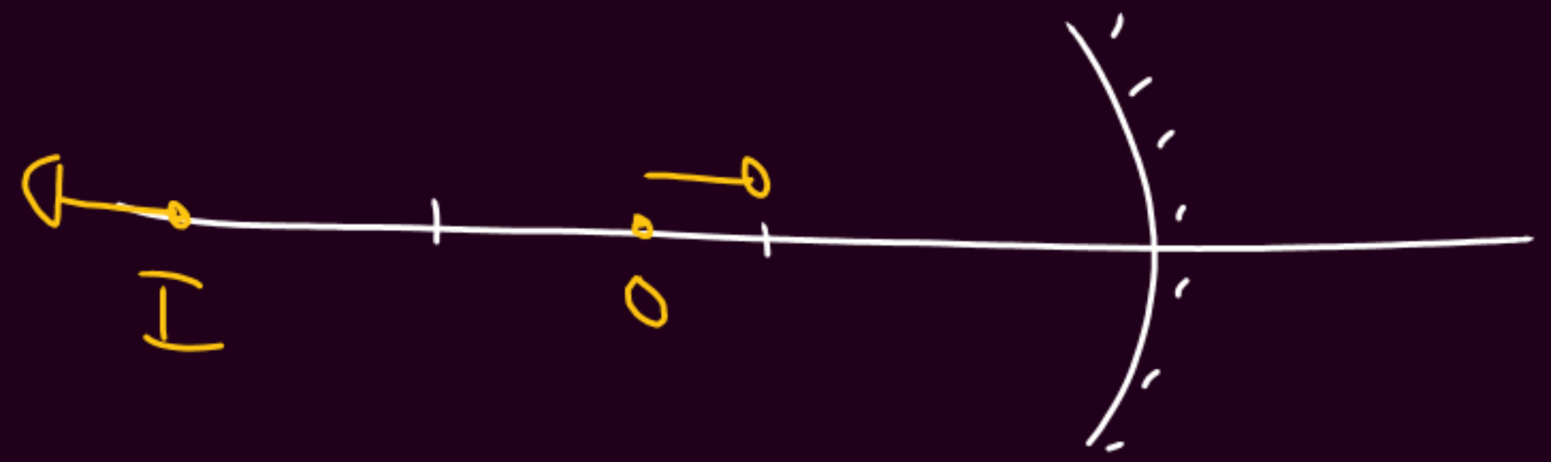
concave M → f = 20 cm

$v_{image} = ?$

when obj → 25 cm

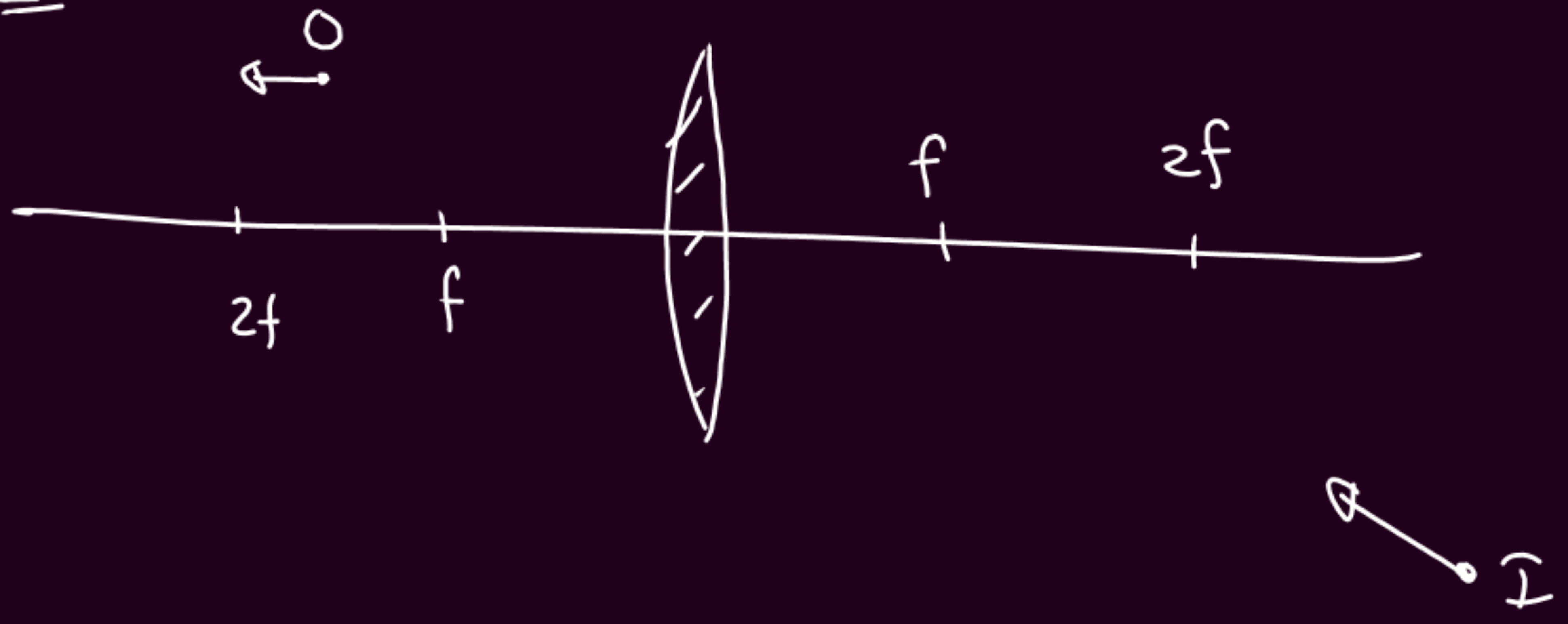
$$v_I = -\left(\frac{-20}{-20+25}\right)^2 (2)$$

$$v_I = -32 \text{ cm/s}$$

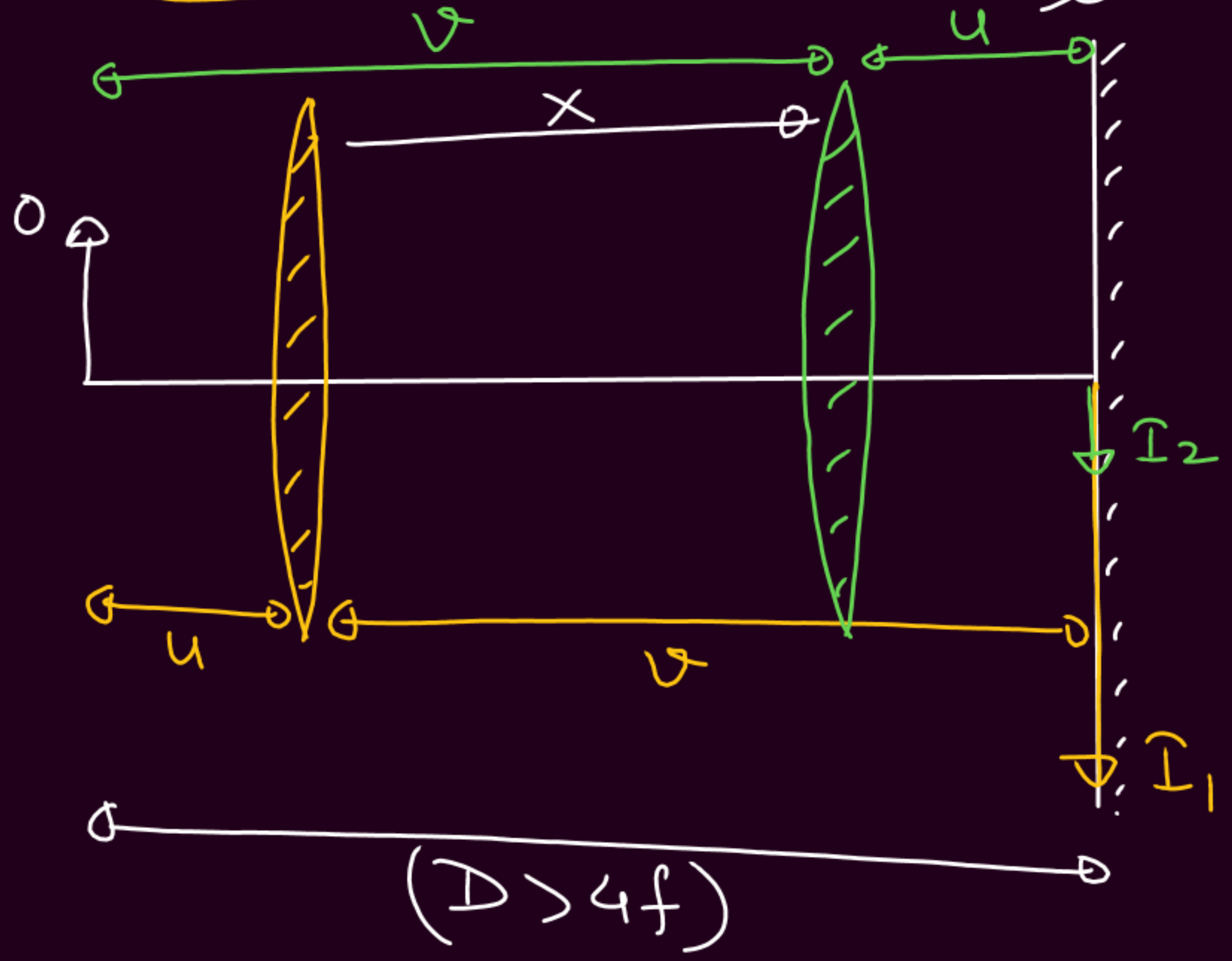


Q.

Q.



"Displacement" Method



① $f = \dfrac{D^2 - x^2}{4D}$

② $m_1 m_2 = 1$

$\dfrac{I_1}{O} \dfrac{I_2}{O} = 1$

③ $\boxed{O = \sqrt{I_1 I_2}}$

Q. Dist. bet^n obj & Screen = 50cm

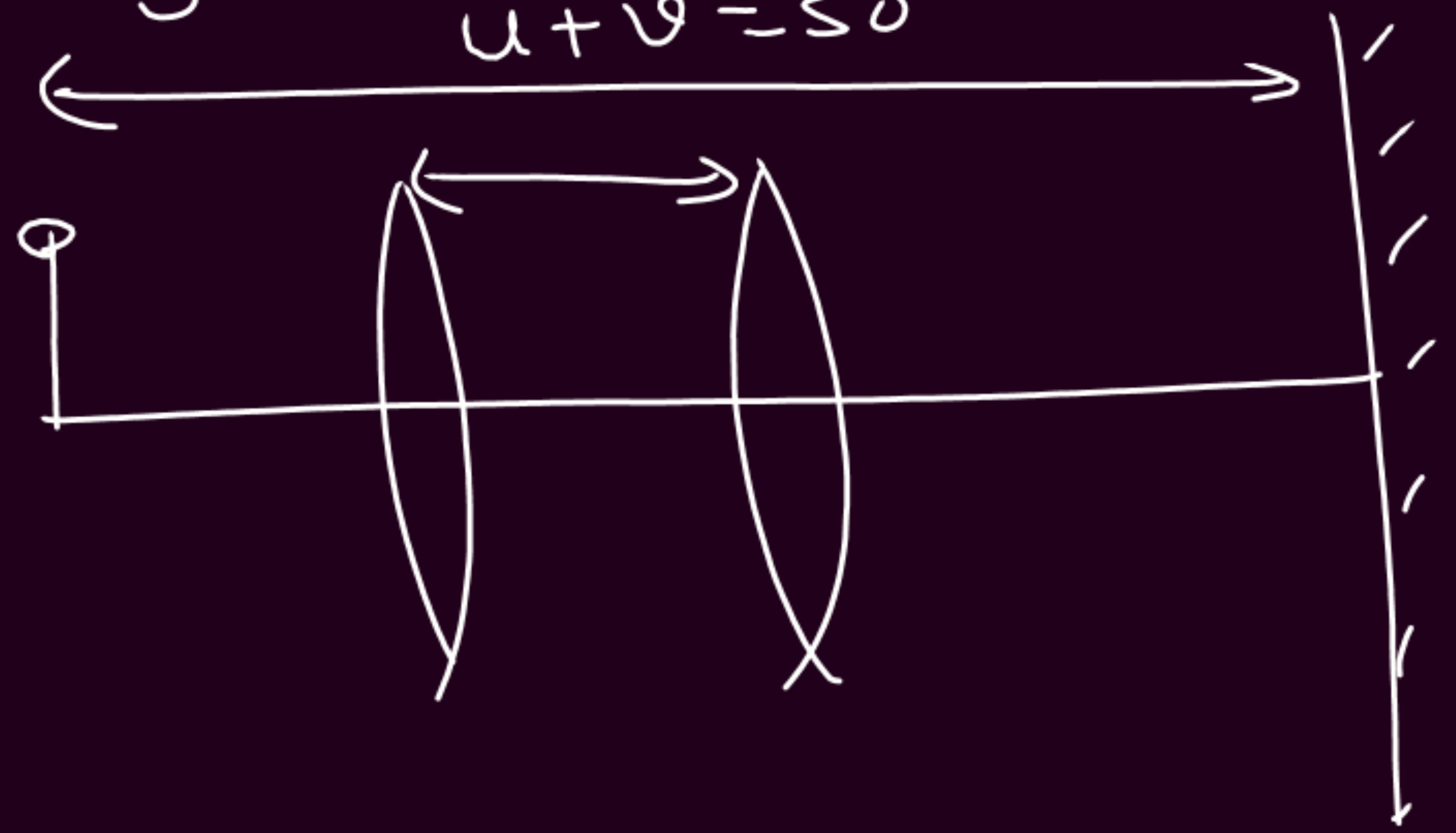
$x = 10$ cm

① $f = ?$

$$f = \frac{D^2 - x^2}{4D} = \frac{50^2 - 10^2}{4 \times 50} = 12 \text{ cm}$$

② mag. in both cases?

$u + v = 50$



$D = u + v$

$x = v - u$

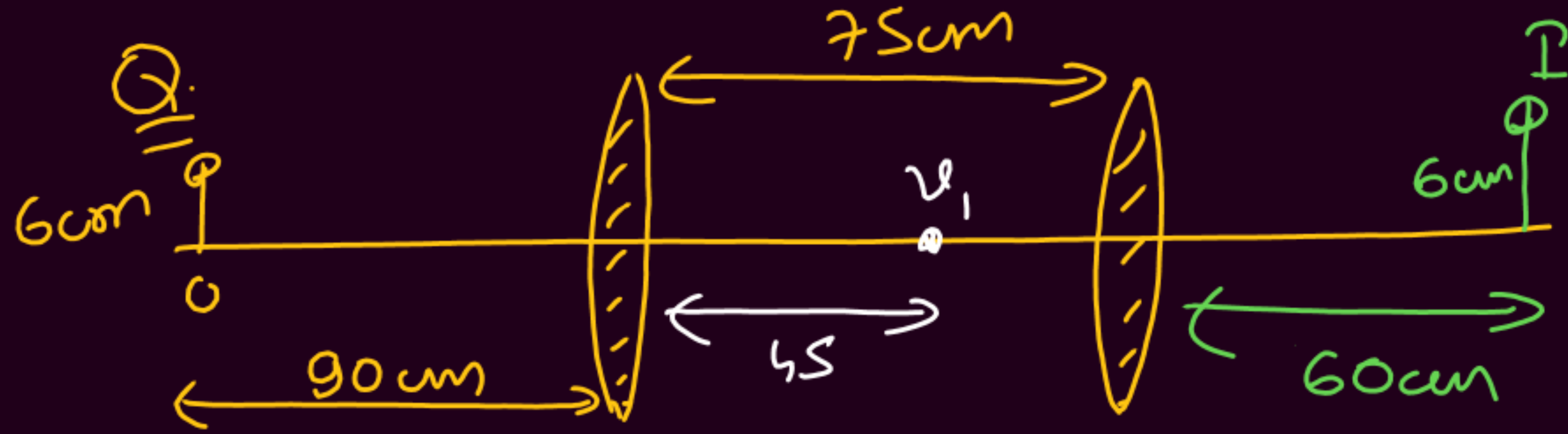
$u = 30$

$v = 20$

$m_1 = -\frac{3}{2}$

$m_2 = -\frac{2}{3}$

Q.



$f_1 = 30cm$ $\qquad$ $f_1 = 20cm$

(1) $m_1 = \frac{v_1}{-90} = \frac{30}{30+(-90)} = -\frac{1}{2}$

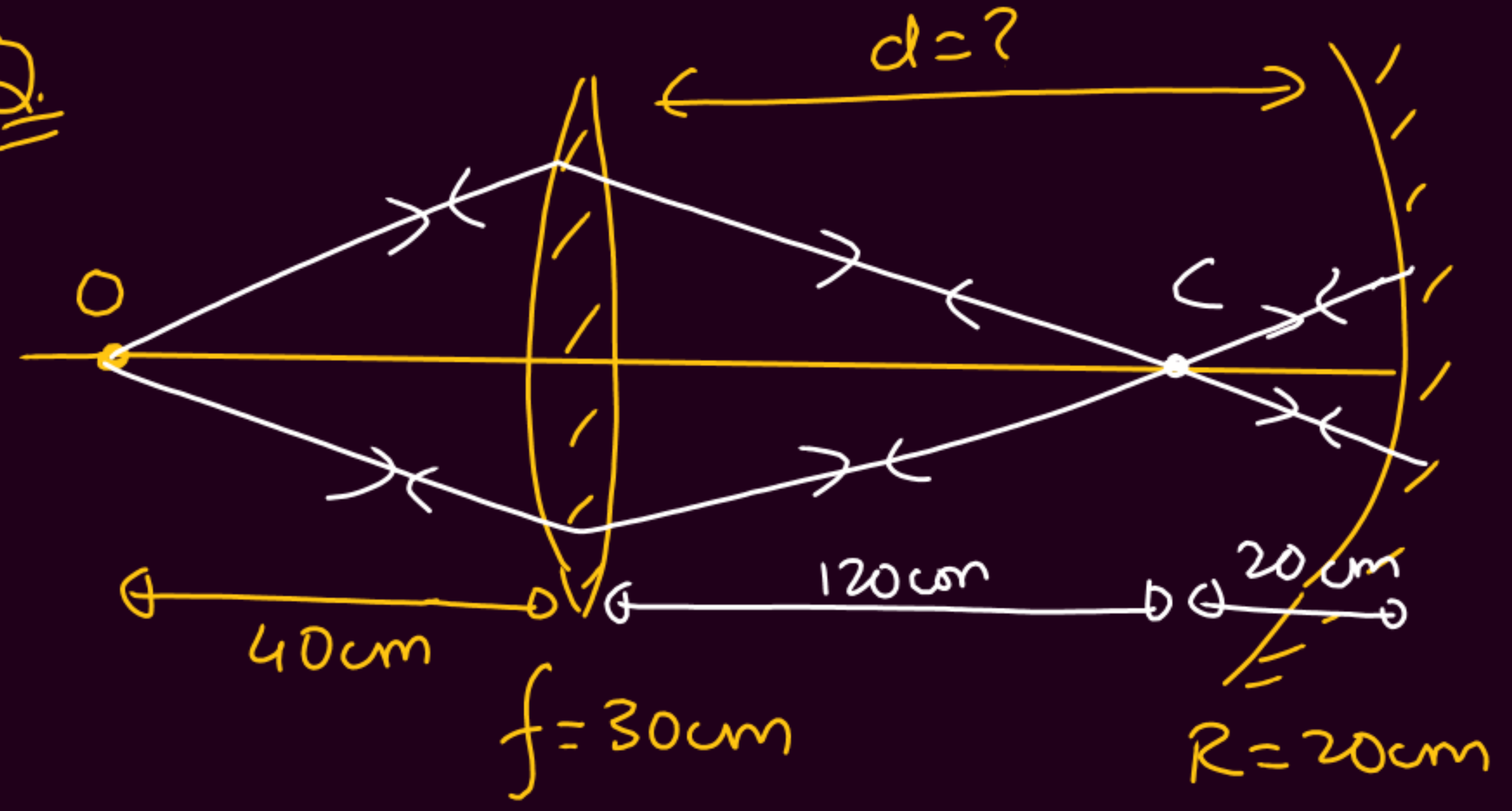
$$\boxed{v_1 = +45cm}$$

(2) $m_2 = \frac{v_2}{-30} = \frac{20}{20+(-30)} = -2$

$v_2 = +60cm$

$m = m_1 m_2 = \left(-\frac{1}{2}\right)(-2) = 1$

Q.



Find d if final image is on object itself.

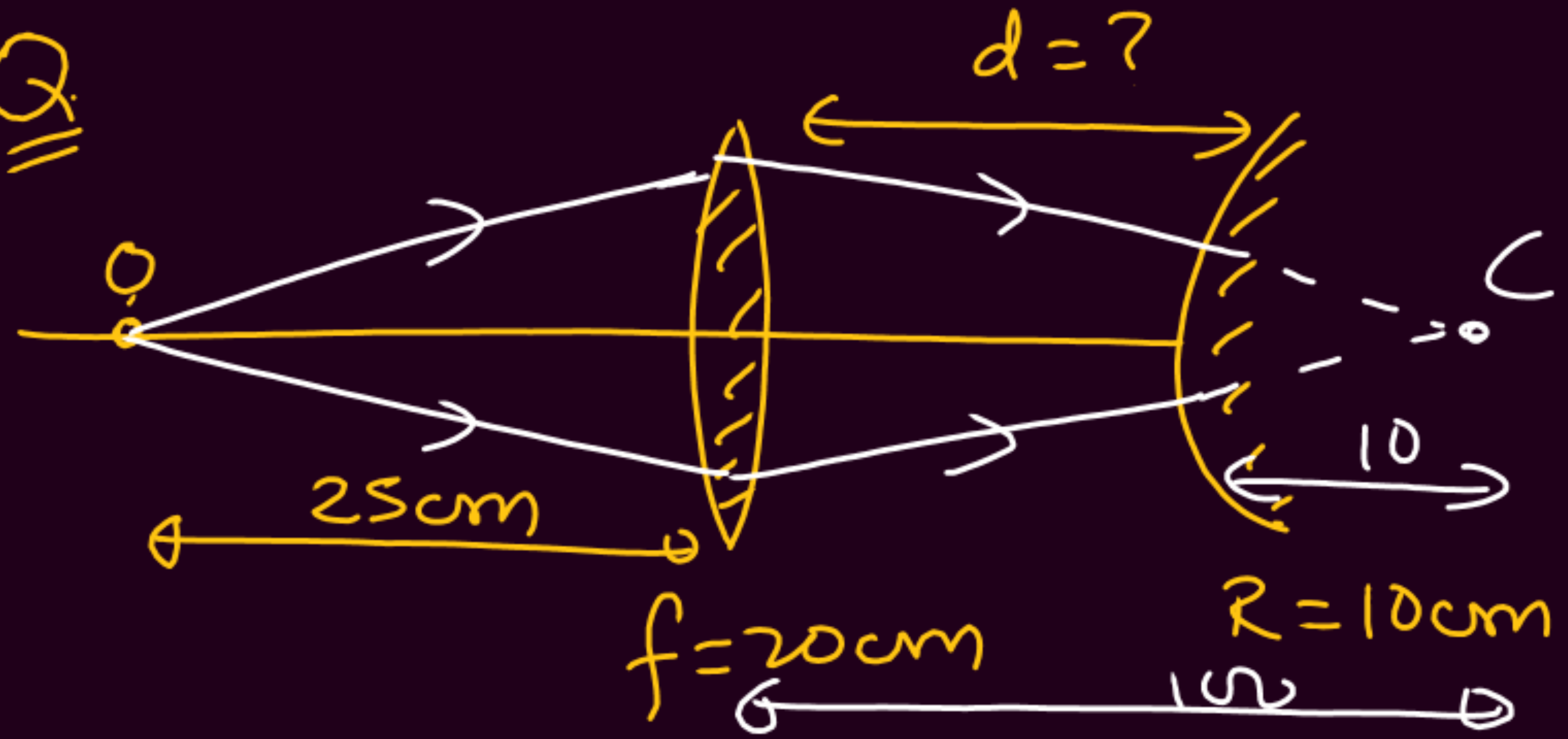
Lens

$$\frac{v}{-40} = \frac{30}{30+(-40)}$$

$$\boxed{v = +120\,cm}$$

$$\boxed{d = 120 + 20 = 140\,cm}$$

Q.



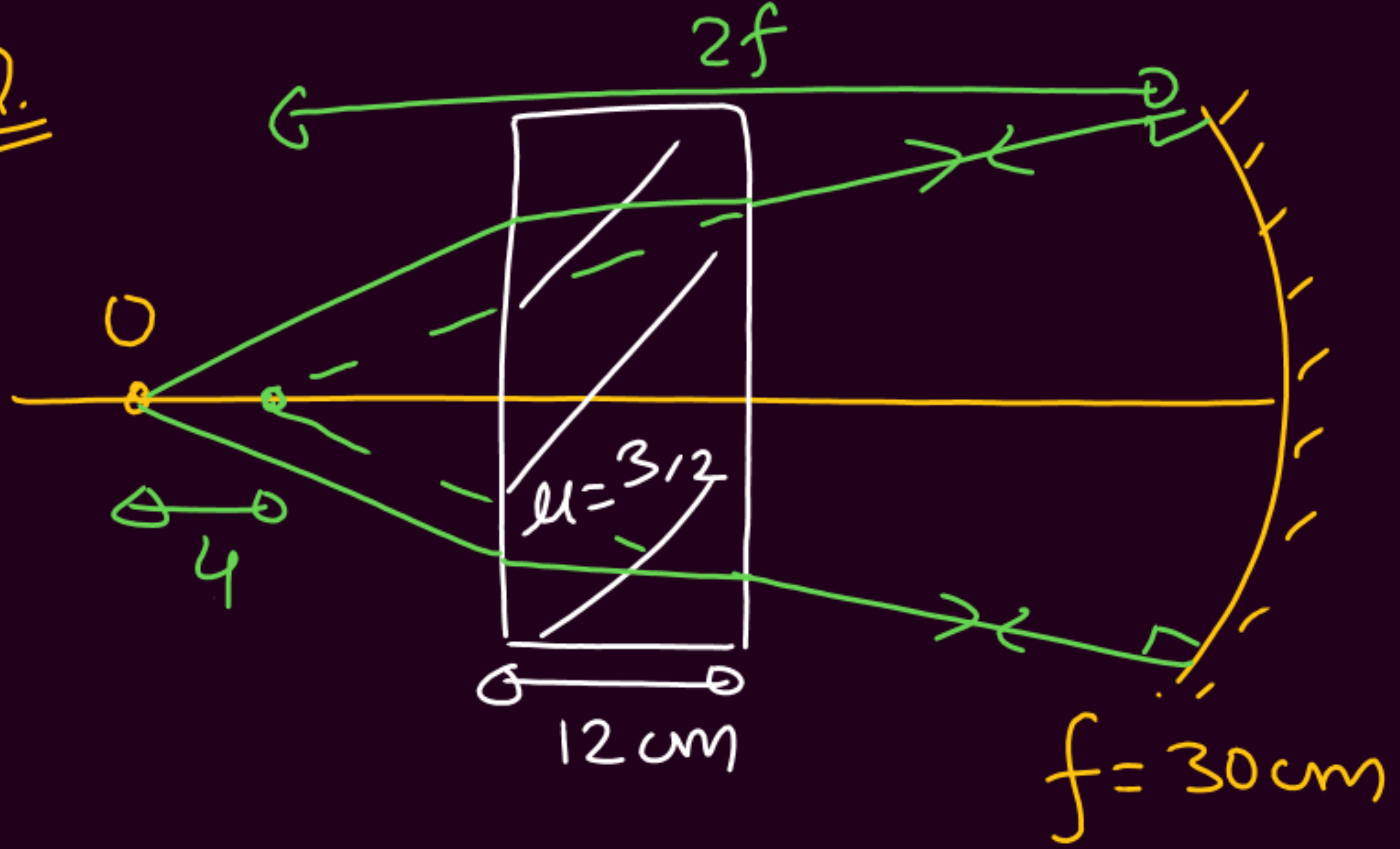
Find d if find image is on object itself

$$\frac{v}{-25} = \frac{20}{20+(-25)}$$

$$\boxed{v = +100\,cm}$$

$d = 100 - 10 = \underline{90\,cm}$

Q.



Find dist. of object from Mirror, s.t. final image is on object itself

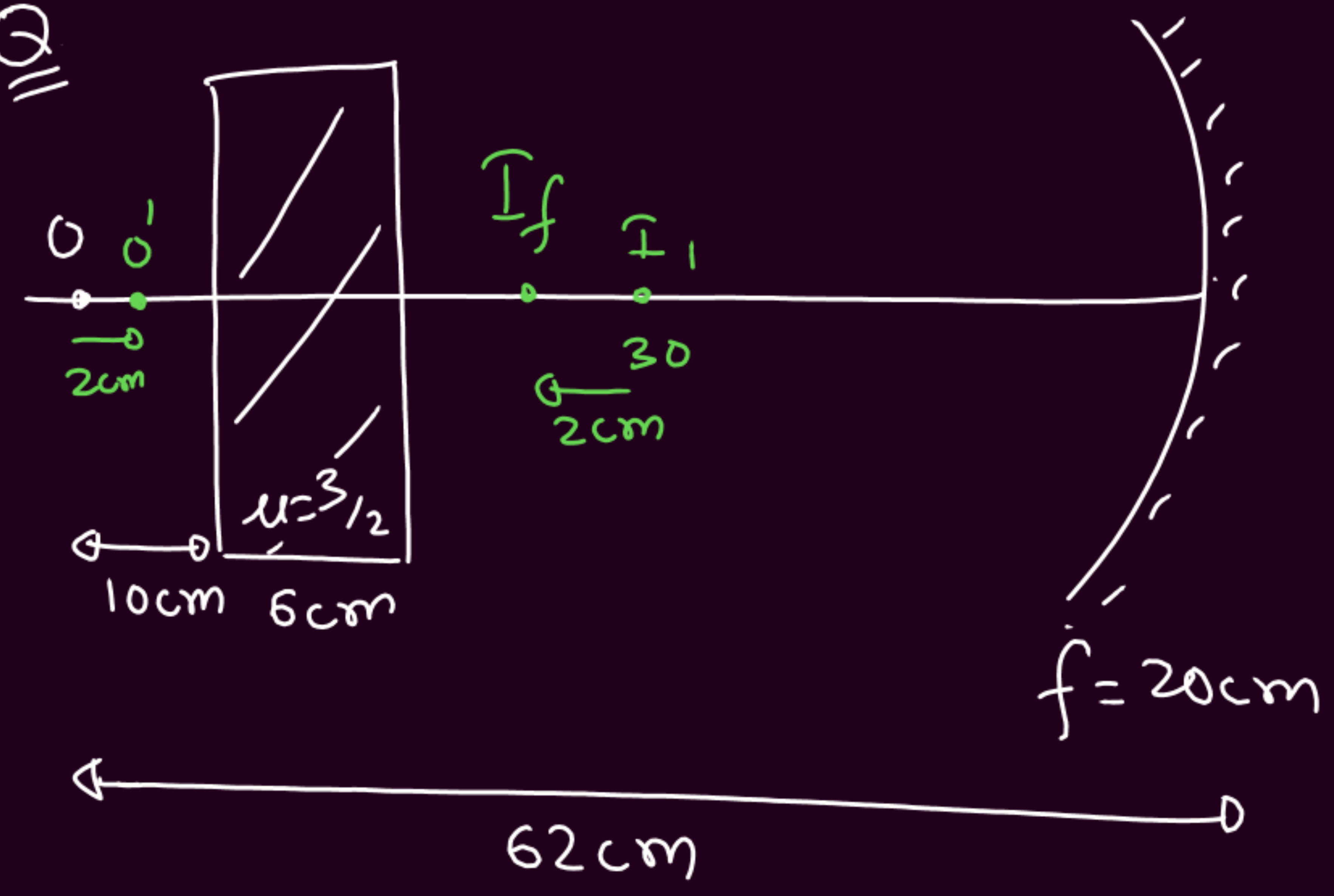
Normal Shift $= t\left(1 - \frac{1}{\mu}\right)$

$= 12\left(1 - \frac{1}{3/2}\right)$

$= \underline{4 cm}$

2f + Shift = $\underline{64 cm}$

Q



Position of final image?

① Shift $= 6\left(1 - \frac{1}{3/2}\right) = 2\,cm$

② $-\frac{v}{(-60)} = \frac{-20}{-20-(-60)}$

$v = -30\,cm$

③ $I_f = 30 + 2 = \underline{\underline{32\,cm}}$

Silvering of Lenses

$$P_{eq} = 2P_L + P_M$$

$$\boxed{-\frac{1}{f_{eq}} = \frac{2}{f_L} - \frac{1}{f_M}}$$

① Equi-Convex → Silvered

$$-\frac{1}{F_{eq}} = \frac{2}{f_L} - \frac{1}{f_M}$$

$$-\frac{1}{F_{eq}} = 2\left[\frac{2(\mu-1)}{R}\right] - \frac{1}{-R/2}$$

$$\boxed{F_{eq} = -\frac{R}{(4\mu-2)}}$$

Plano-Convex lens

① Curved Surface Silvered

$$-\frac{1}{F_{eq}} = \frac{2(\mu-1)}{R} - \left(\frac{2}{-R}\right)$$

$$\boxed{F_{eq} = -\frac{R}{2\mu}}$$

② Plane Surface Silvered

$$-\frac{1}{F_{eq}} = \frac{2(\mu-1)}{R} - 0$$

$$\boxed{F_{eq} = -\frac{R}{2(\mu-1)}}$$

Q. Plano-convex L $[f = 30\,cm]$ $(\mu = 3/2)$

→ curved surface is silvered

→ Position of I if obj is at 40 cm.

plano

$$f = \frac{R}{(\mu - 1)}$$

$$30 = \frac{R}{(3/2 - 1)}$$

$$R = 15\,cm$$

$$F_{eq} = -\frac{R}{2\mu}$$

$$= -\frac{15}{2 \times 3/2}$$

$$= -5\,cm$$

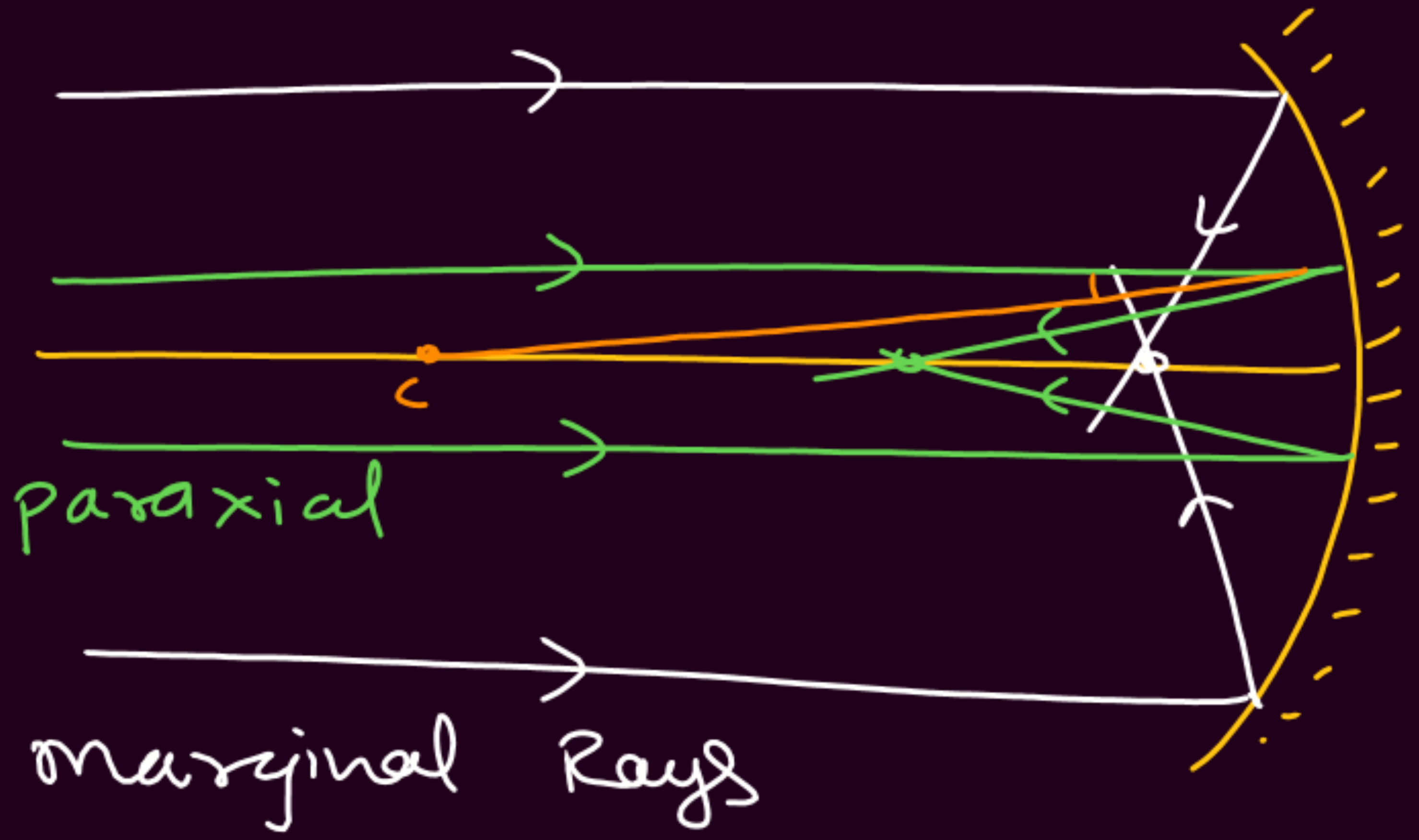
↓

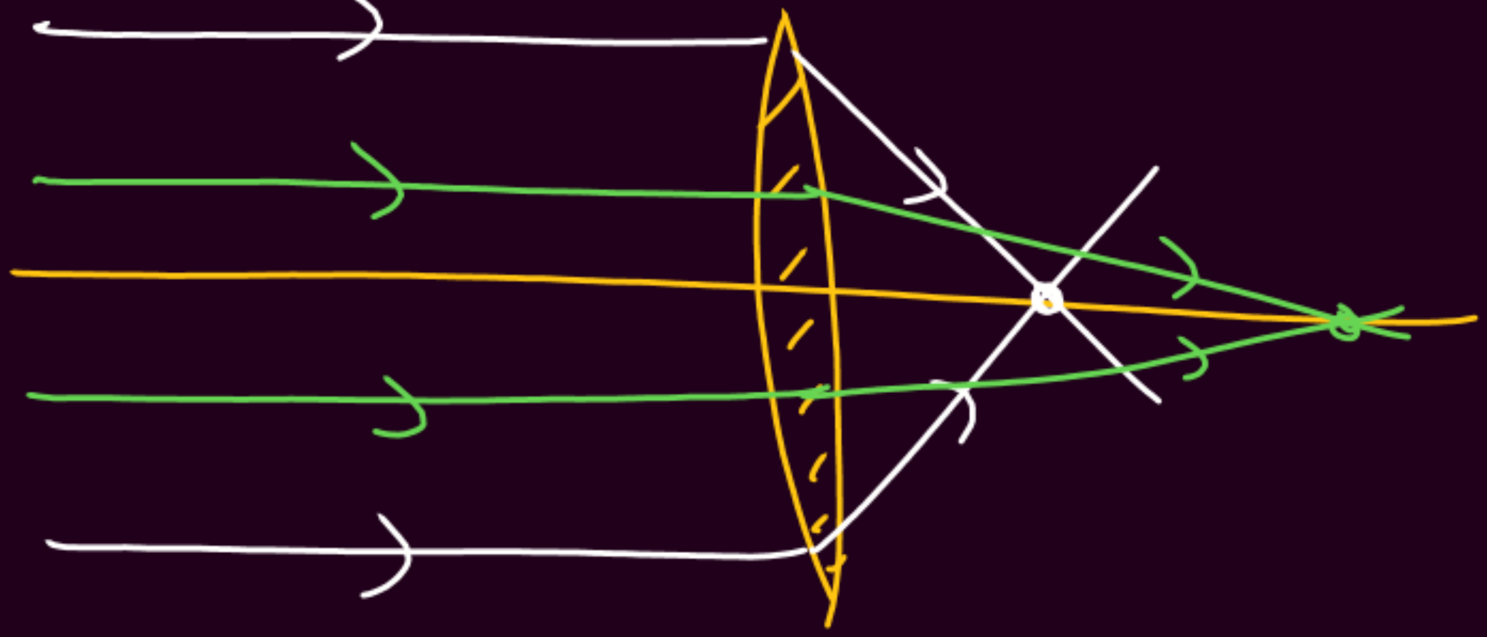
Concave M

$$-\frac{v}{(-40)} = \frac{-5}{-5-(-40)}$$

$$\boxed{v = -\frac{40}{7}\,cm}$$

Spherical Abberation (M)





Paraxial $\quad f = \frac{R}{2}$

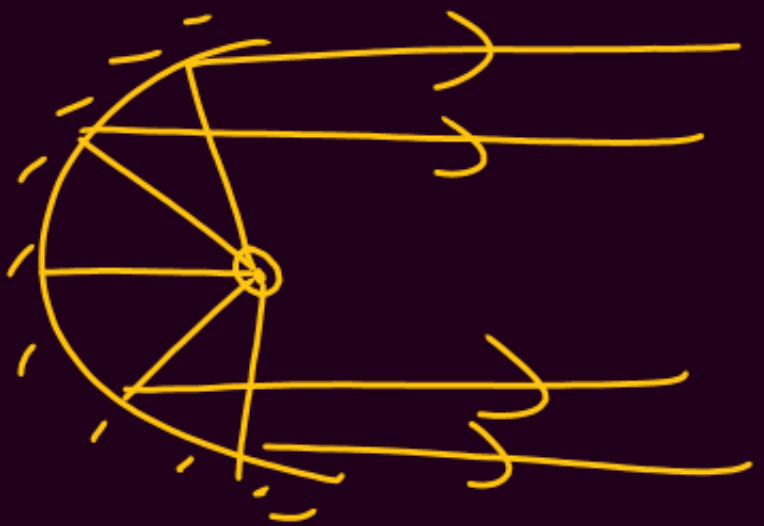
Marginal $\quad f = R - \frac{R}{2\cos i}$

→ M / L with small Aperture

↳ paraxial rays

→ Parabolic Reflectors

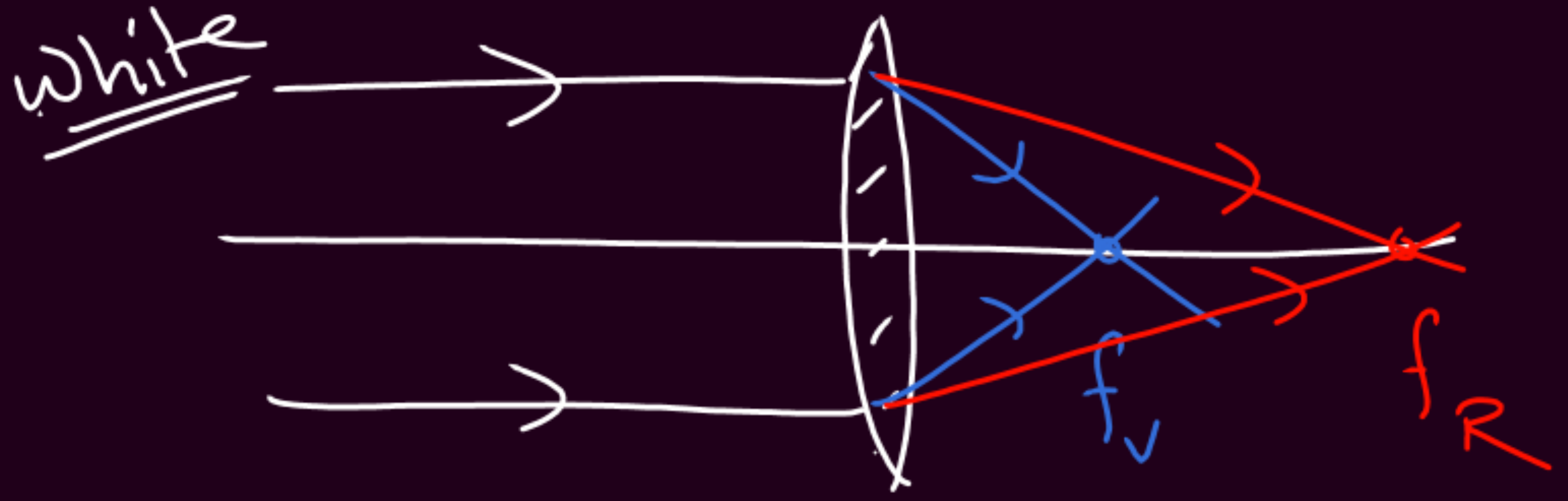
↳ Cassagrain Telescope



Chromatic Abberation

Mirror → Achromatic

Lens

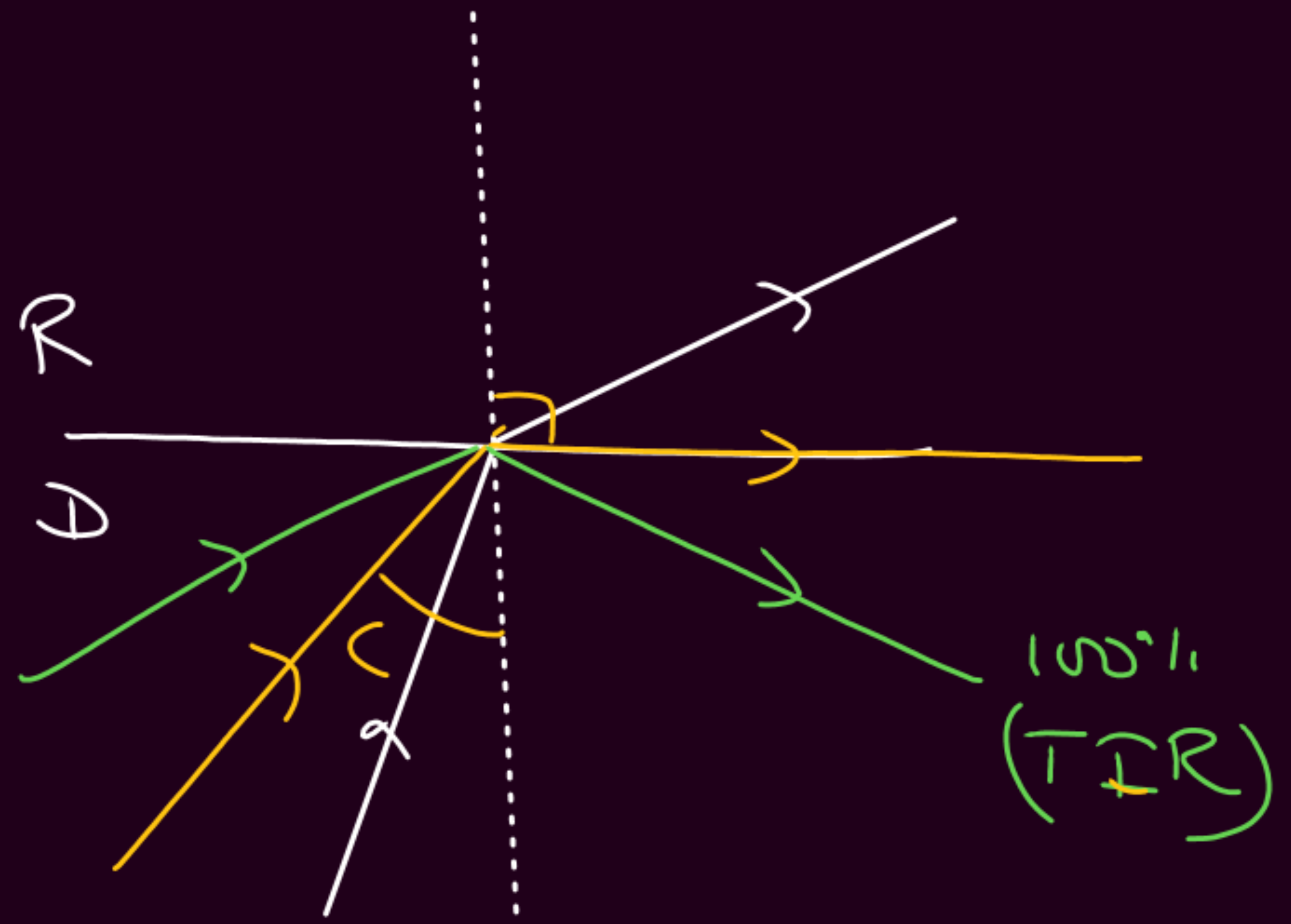


Achromatic

"Total" Internal Reflection (TIR)

→ R to D (always possible)

→ D to R



① $i < c$ | Refraction + Partial Reflection

② $i = c$ | { —— " —— ; grazing Emergence ($r = 90°$)

③ $i > c$ | (TIR)

$$\mu_D \sin c = \mu_R \sin 90°$$

$$\boxed{\sin c = \frac{\mu_R}{\mu_D} = \frac{1}{\mu}}$$

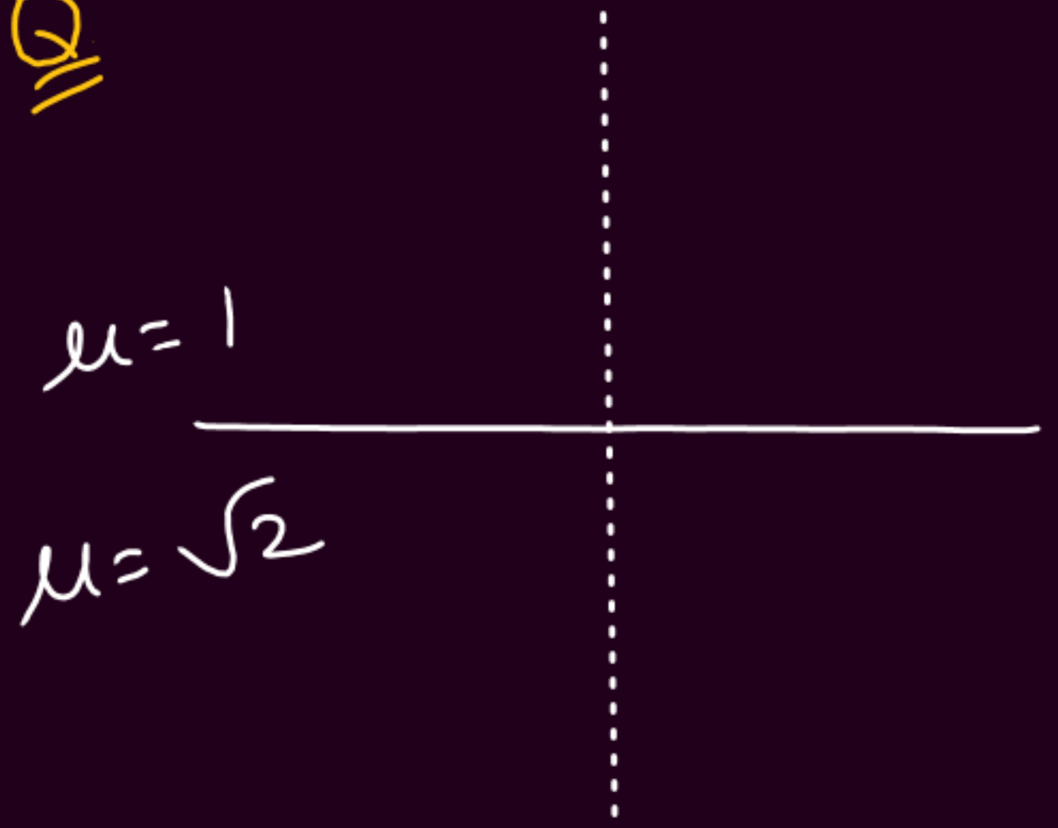
1. Air - water $\quad \sin c = \frac{3}{4} \quad c = 49^\circ$

2. Air - glass $\quad \sin c = \frac{2}{3} \quad c = 42^\circ$

3. Water - glass $\quad \sin c = \frac{4/3}{3/2} = \frac{8}{9} \quad c = 63^\circ$

4. Air - Diamond $\quad c = 24^\circ$

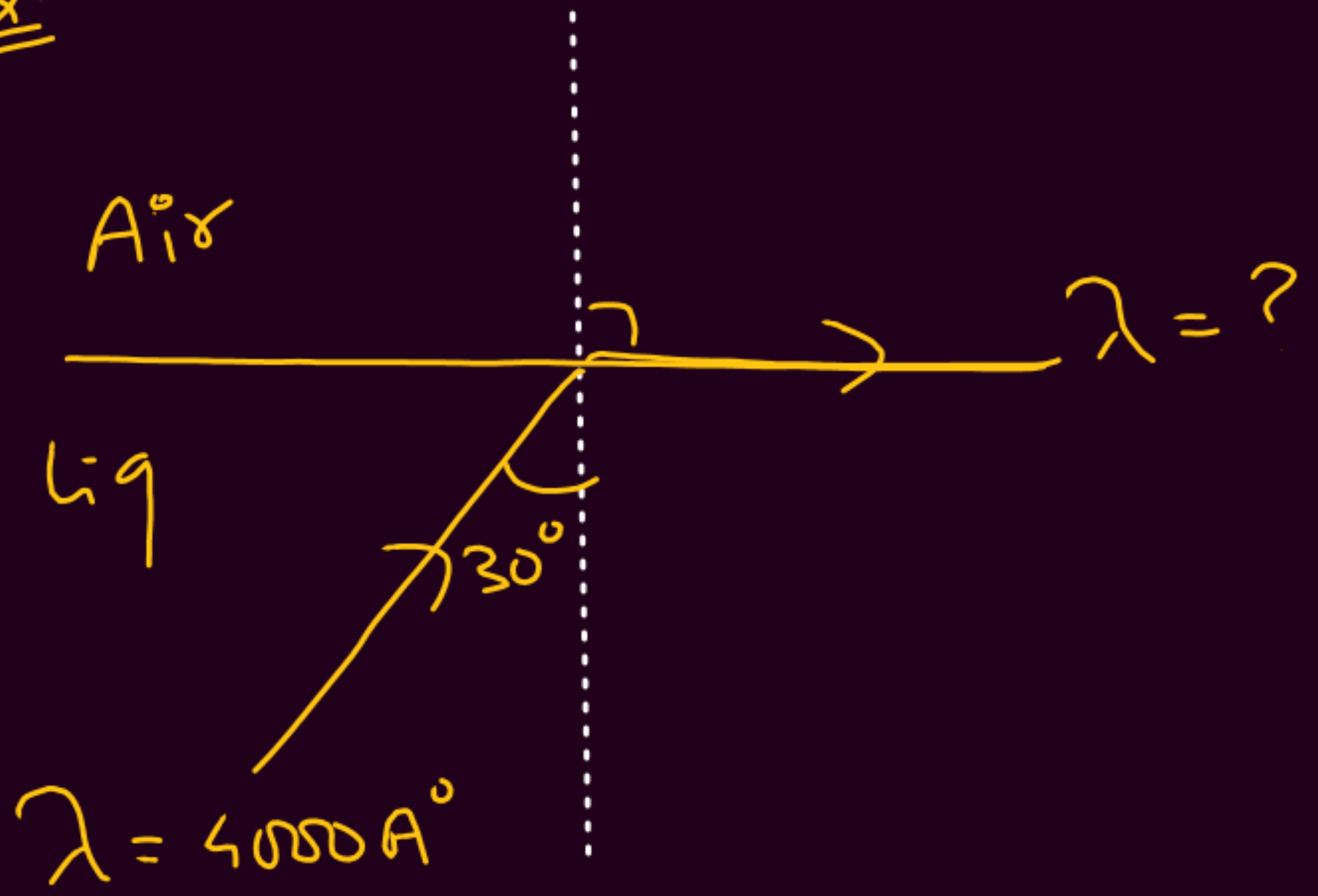
Q



$C = ?$

$$\boxed{C = 45^\circ}$$

Q



$$\frac{\mu_{Liq}}{\mu_{air}} = \frac{1}{\sin 30^\circ} = 2 = \frac{\lambda_{air}}{\lambda_{Liq}}$$

$$\boxed{\lambda_{air} = 8000\ \mathring{A}}$$

Q. D → R

$i = 30°$

S. t. Reflected ⊥ Refracted

$c = ?$

$\longrightarrow$ $\tan i = \frac{1}{\mu}$

$\tan 30° = \frac{1}{\mu} = \sin c$

$\sin c = \frac{1}{\sqrt{3}}$

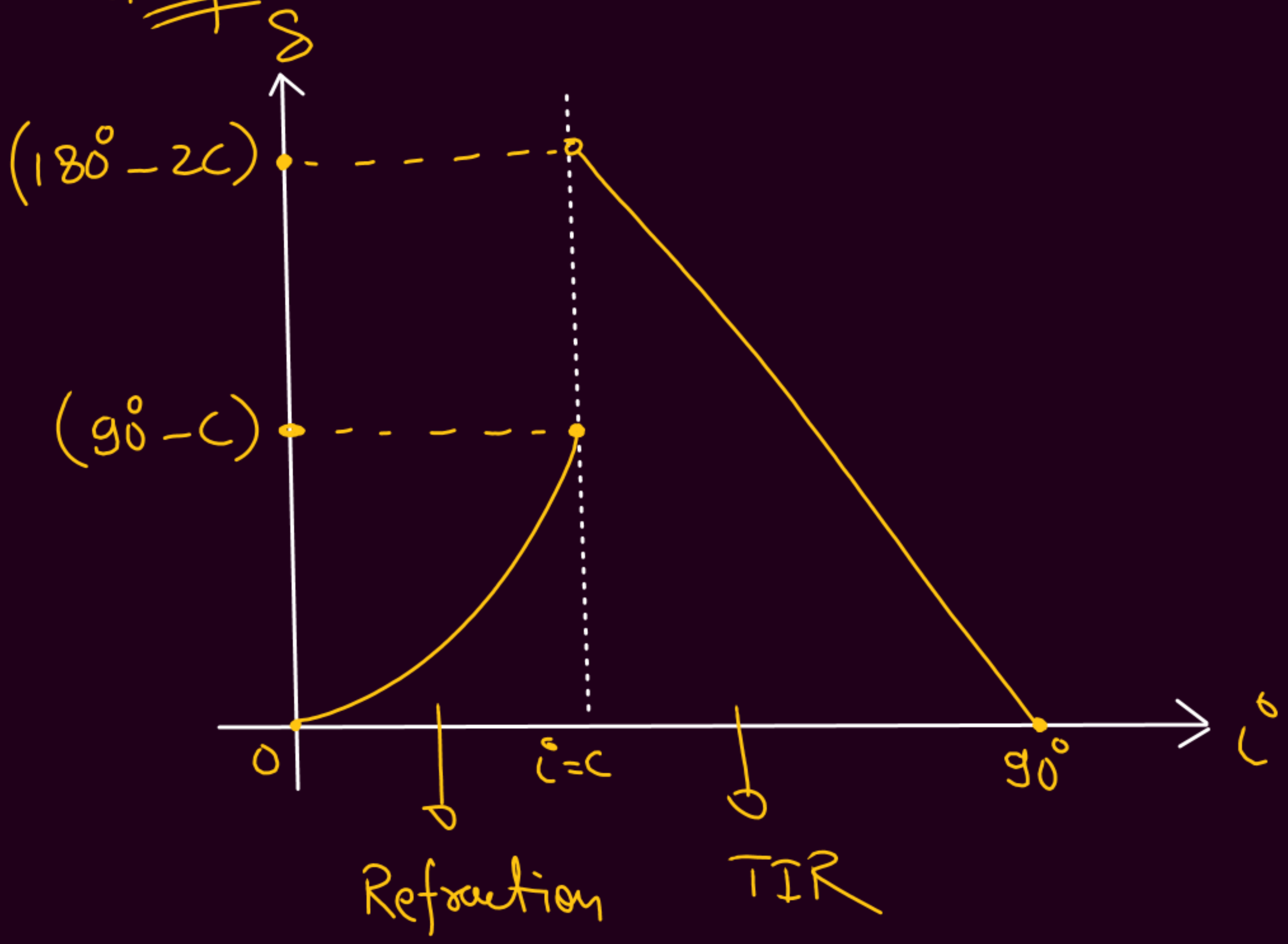
$\boxed{30° \quad 37°}$ 45° 53° 60°

$$\boxed{c = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)}$$

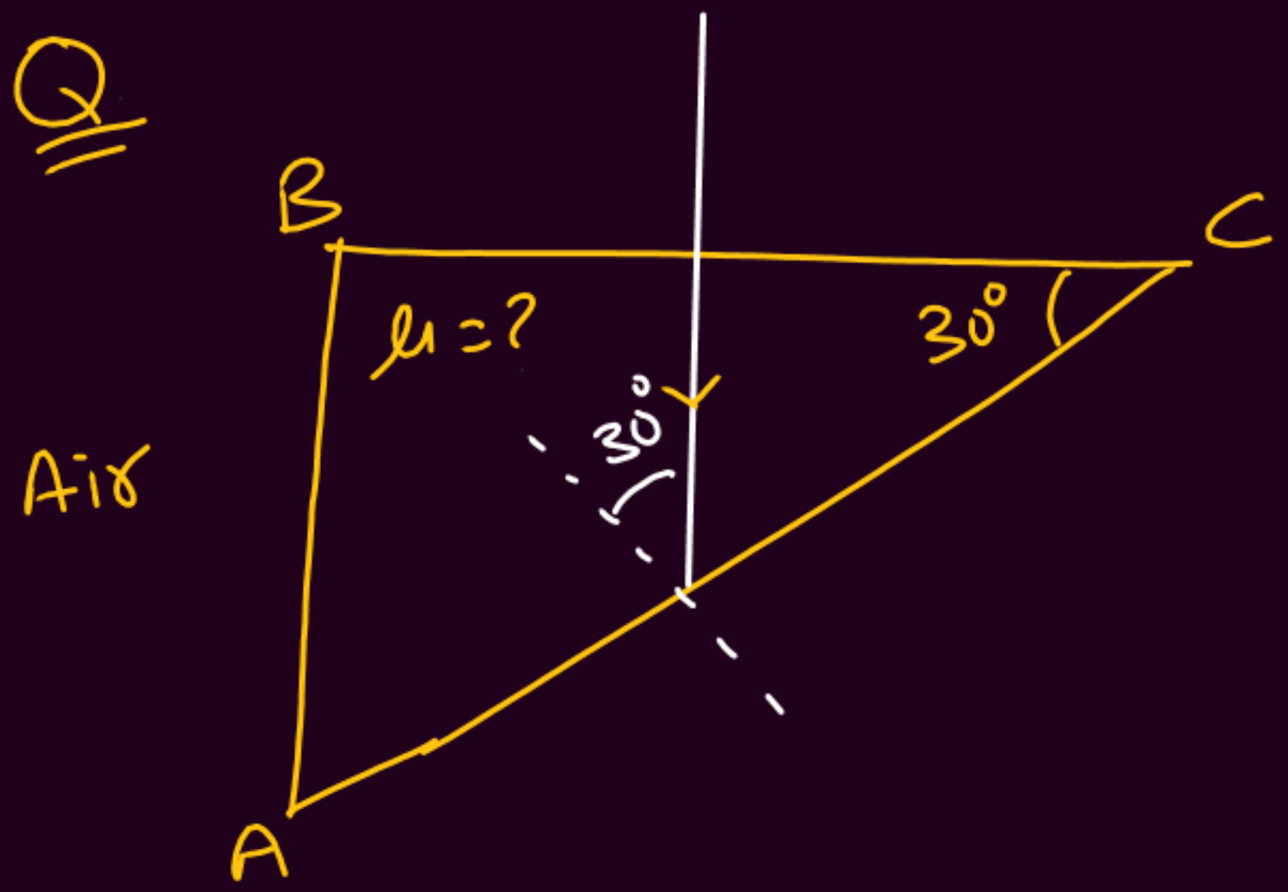
$\frac{1}{\sqrt{2}} = 0.707$

$\frac{1}{\sqrt{3}} = 0.577$

Graph



Q



$\mu = ?$ No emergence at AC

1) $\mu \le 2$ ✗

2) $\mu < 2$

3) $\mu \ge 2$ ✗

4) $\mu > 2$

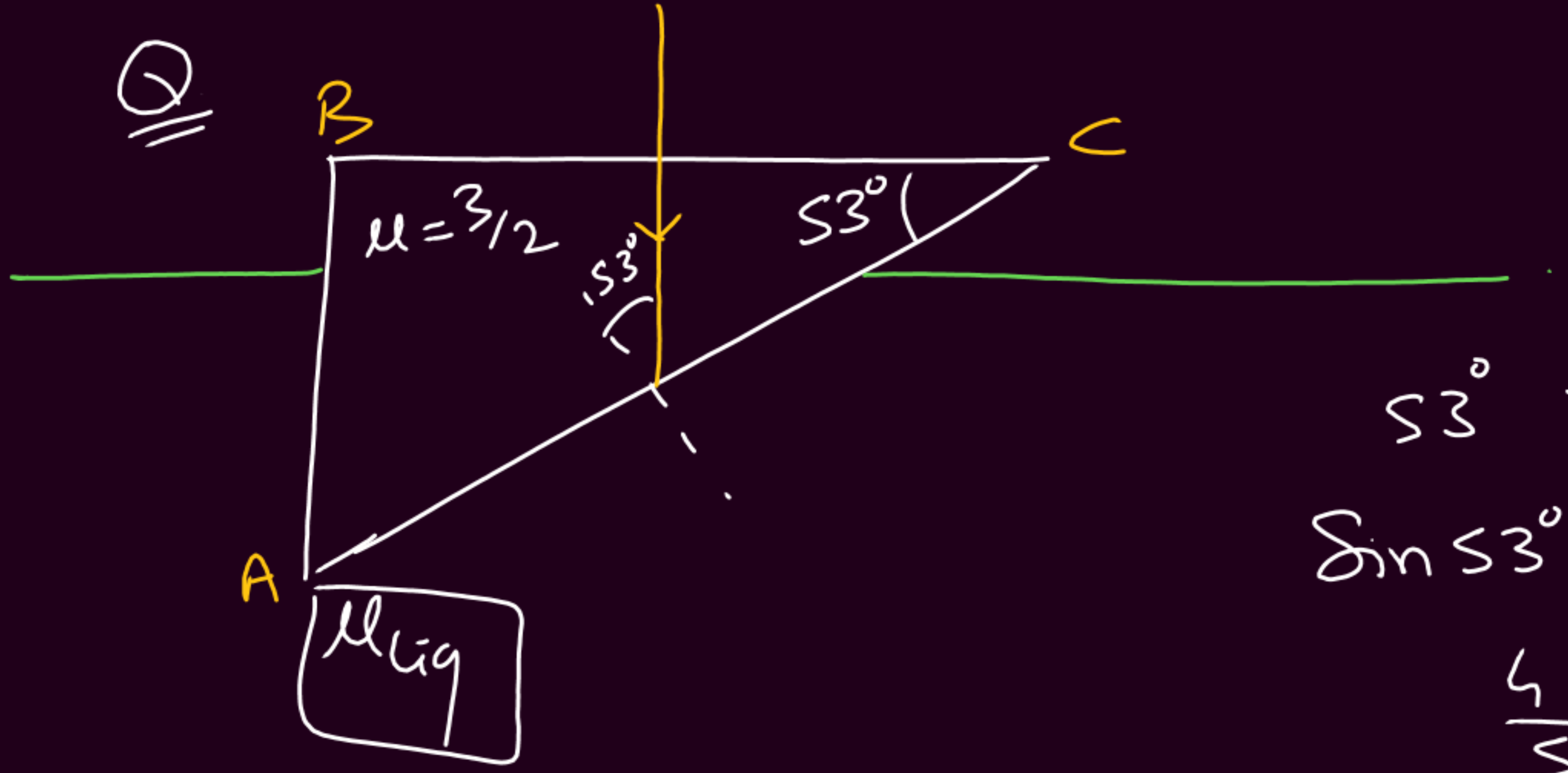
$30^\circ > C$

$\sin 30^\circ > \sin C$

$\frac{1}{2} > \frac{1}{\mu}$

$\boxed{\mu > 2}$

Q



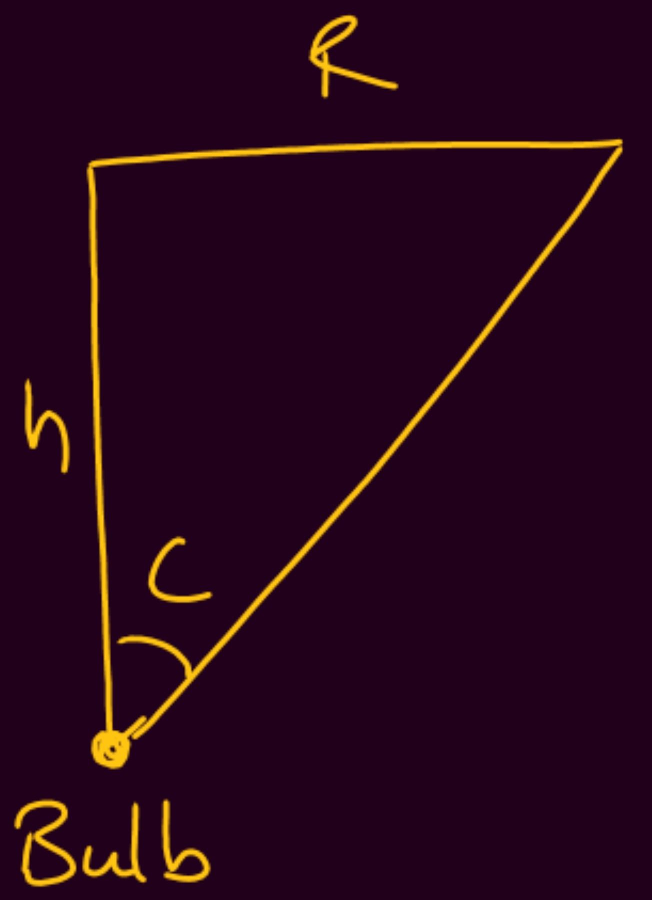
$$53^\circ > C$$

$$\sin 53^\circ > \sin C$$

$$\frac{4}{5} > \frac{\mu_{liq}}{3/2}$$

$$\boxed{\mu_{liq} < \frac{6}{5}}$$

Radius of Shiny Disc



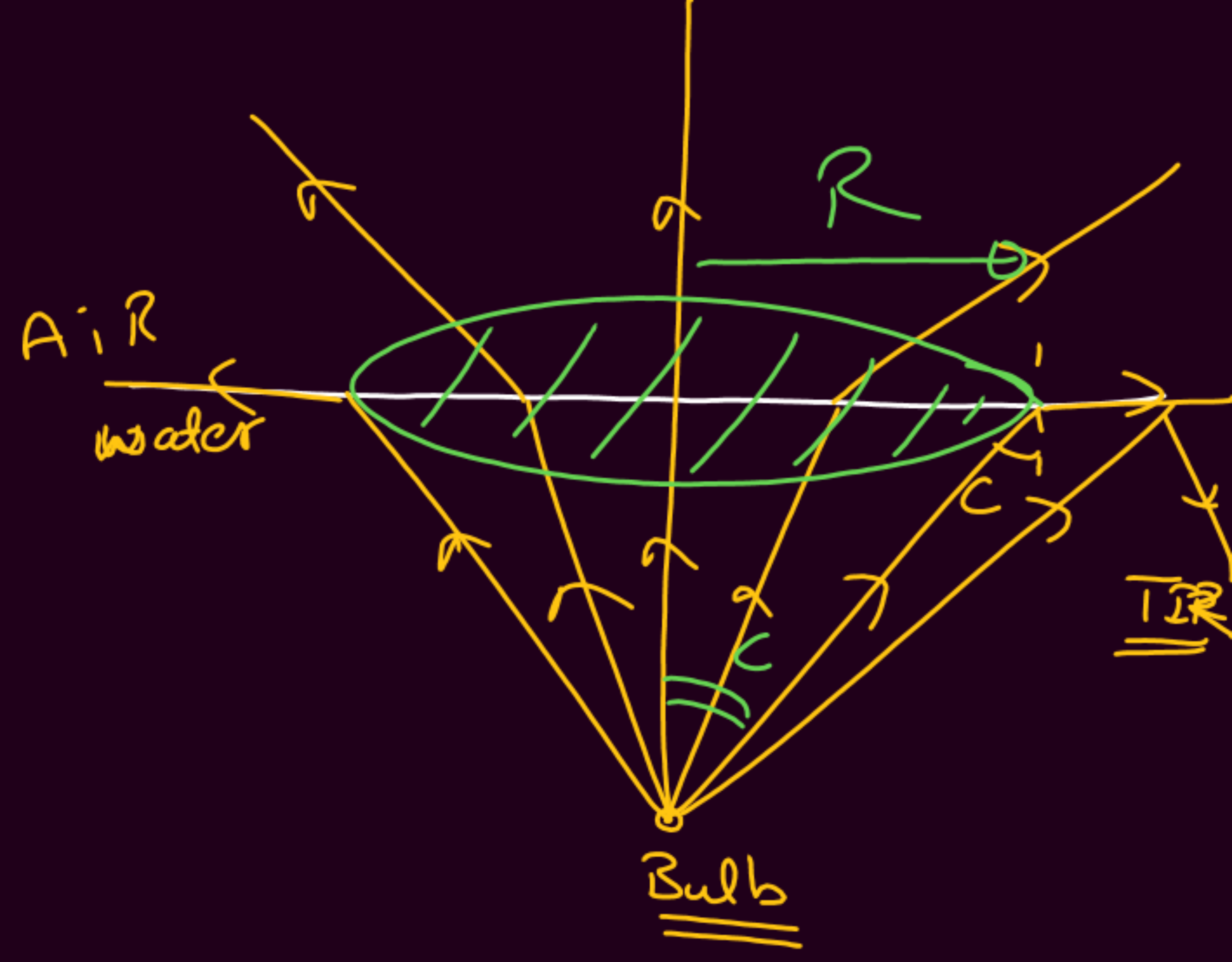
$$\boxed{R = \frac{h}{\sqrt{\mu^2 - 1}}}$$

Q. $h = 2\,m$

water

$$R = \frac{2}{\sqrt{\left(4/3\right)^2 - 1}}$$

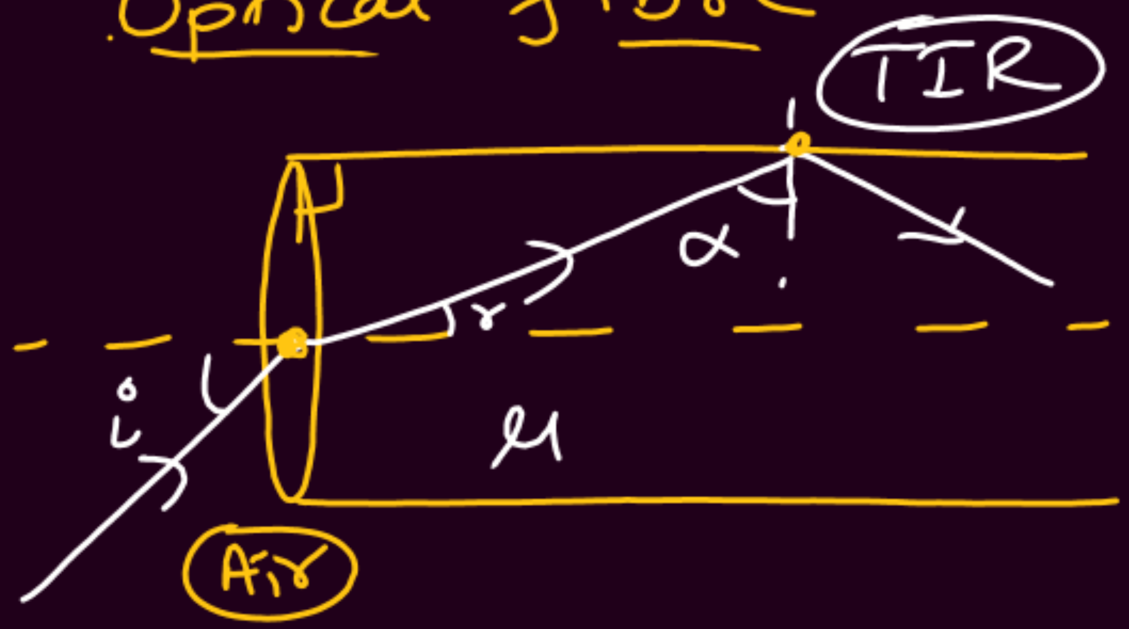
$$\boxed{R = \frac{6}{\sqrt{7}}\ m}$$



$$\sin c = \frac{1}{\mu}$$

$$\tan c = \frac{R}{h} = \frac{1}{\sqrt{\mu^2 - 1}}$$

Optical fibre



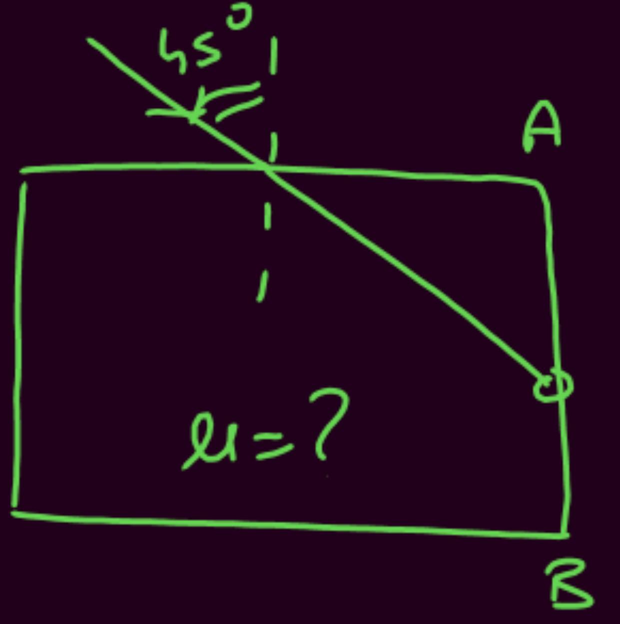
i should be less

$$\boxed{\sin i < \sqrt{\mu^2 - 1}}$$

$$\mu > \sqrt{1 + \sin^2 i}$$

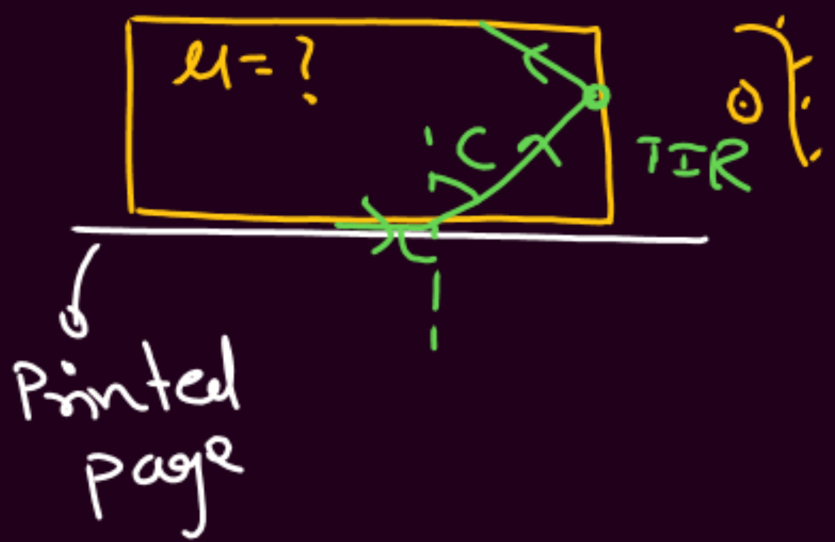
Condition for no emergence at 1^{r} surface.

Q



$\mu = ?$ for no emergence at face AB

$$\mu > \sqrt{1 + \sin^2 45^\circ} = \sqrt{3/2}$$



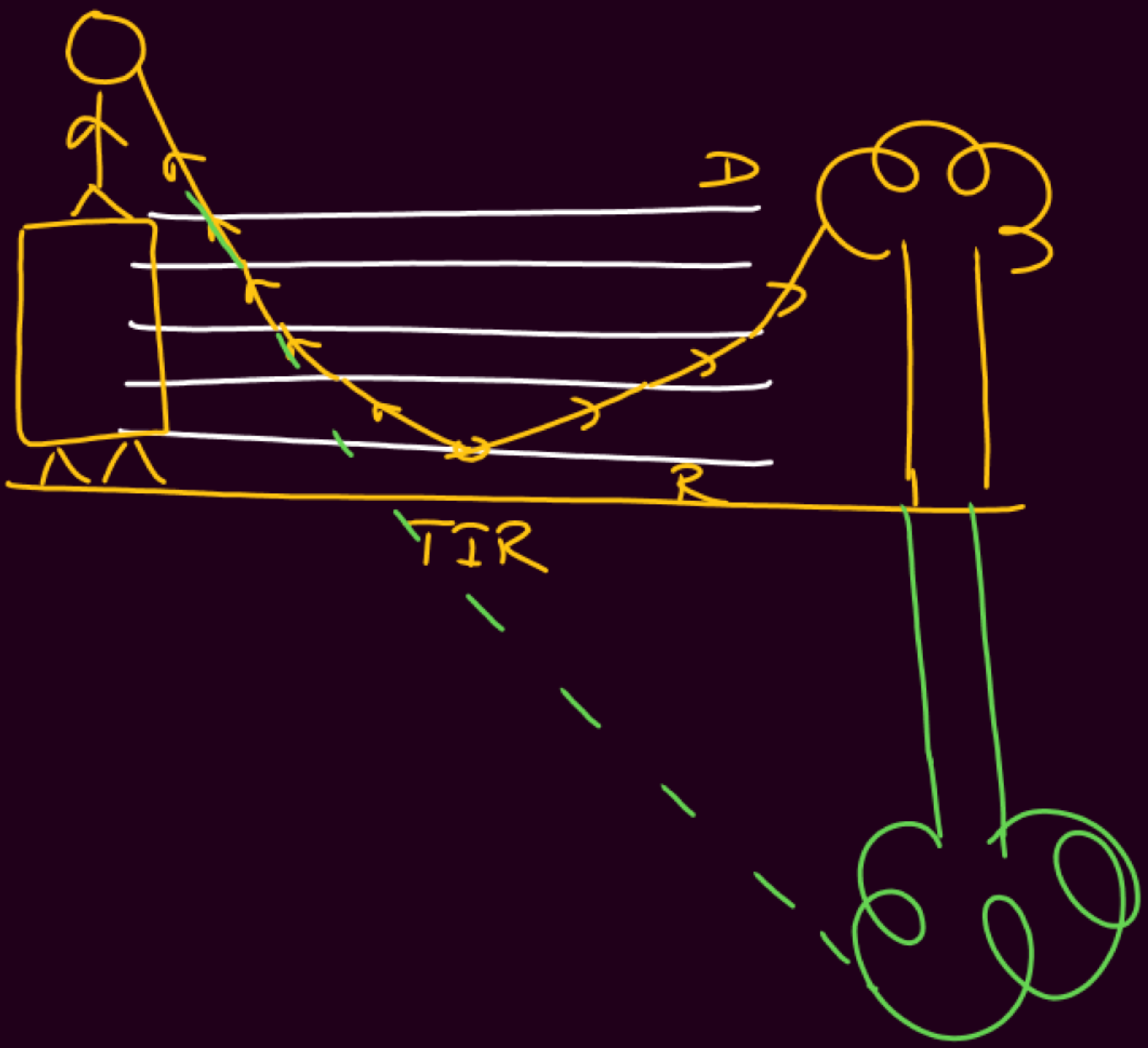
Find $\mu = ?$ such that print is not visible if seen through any vertical face?

$$\mu > \sqrt{1 + \sin^2 90^\circ}$$

$$\boxed{\mu > \sqrt{2}}$$

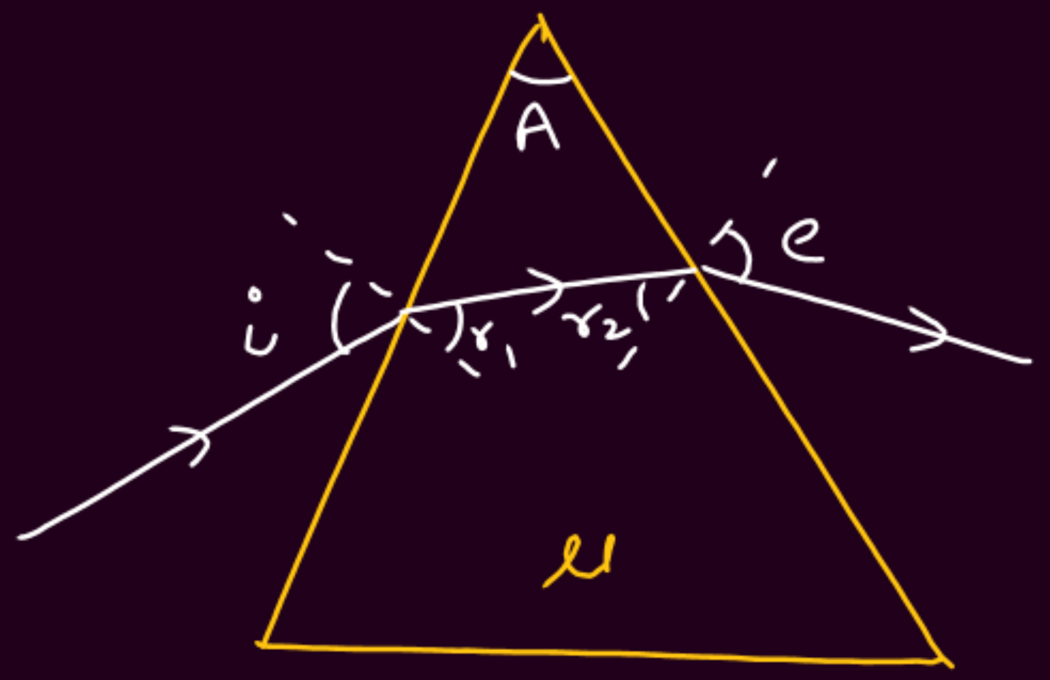
TIR

① Mirage → (Hot Desert)



② Looming → (Cold Desert)

Prism



A = Refracting Angle (Angle of Prism)

e = Angle of Emergence

① $\sin i = \mu \sin r_1$

$\sin e = \mu \sin r_2$

② $r_1 + r_2 = A$

③ $\delta = (i + e) - A$

$$\mu = \frac{\mu_{prism}}{\mu_{surrounding}}$$

Q. "Equilateral" Prism

$\mu = \sqrt{3}$

$i = 60^\circ$

① $e = ?$

② $\delta = ?$

$\sin 60^\circ = \sqrt{3} \sin r_1$

$\boxed{r_1 = 30^\circ}$

$r_1 + r_2 = 60^\circ$

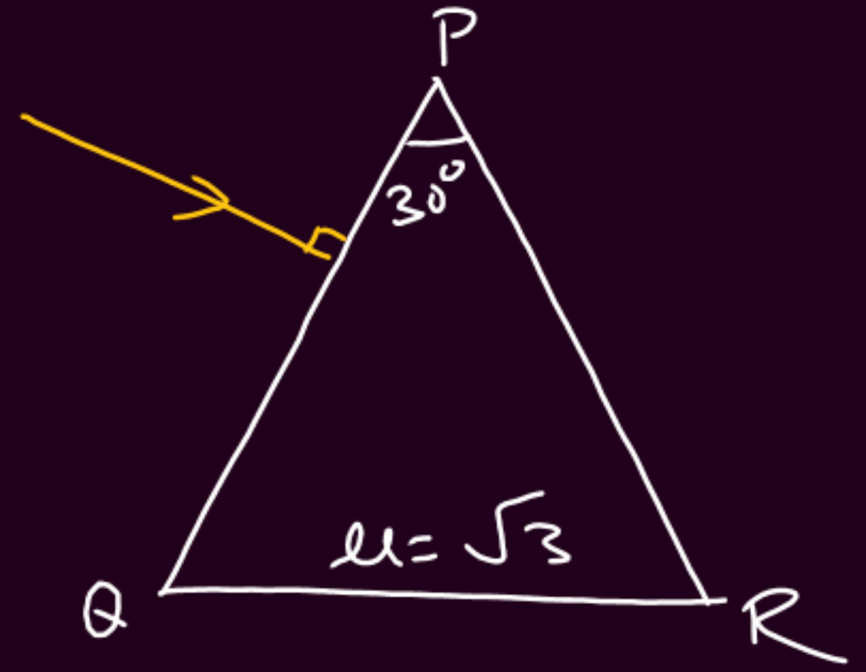
$\boxed{r_2 = 30^\circ}$

$\sin e = \sqrt{3} \sin 30^\circ$

$\boxed{e = 60^\circ}$

$\delta = 60 + 60 - 60 = \underline{\underline{60^\circ}}$

Q.



$\delta = ?$

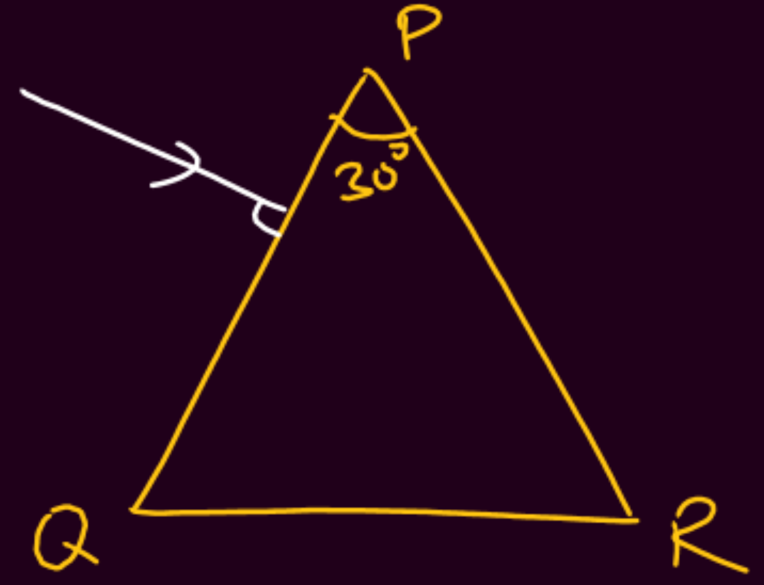
Normal incidence $\Rightarrow$ $i = 0$, $r_1 = 0$, $r_2 = A = 30^\circ$

$\sqrt{3} \sin 30^\circ = \sin e$

$\boxed{e = 60^\circ}$

$\delta = (0 + 60^\circ) - 30^\circ = \underline{\underline{30^\circ}}$

Q



grazing emergence at 'PR'

$\mu = ?$

$i = 0$

$r_1 = 0$

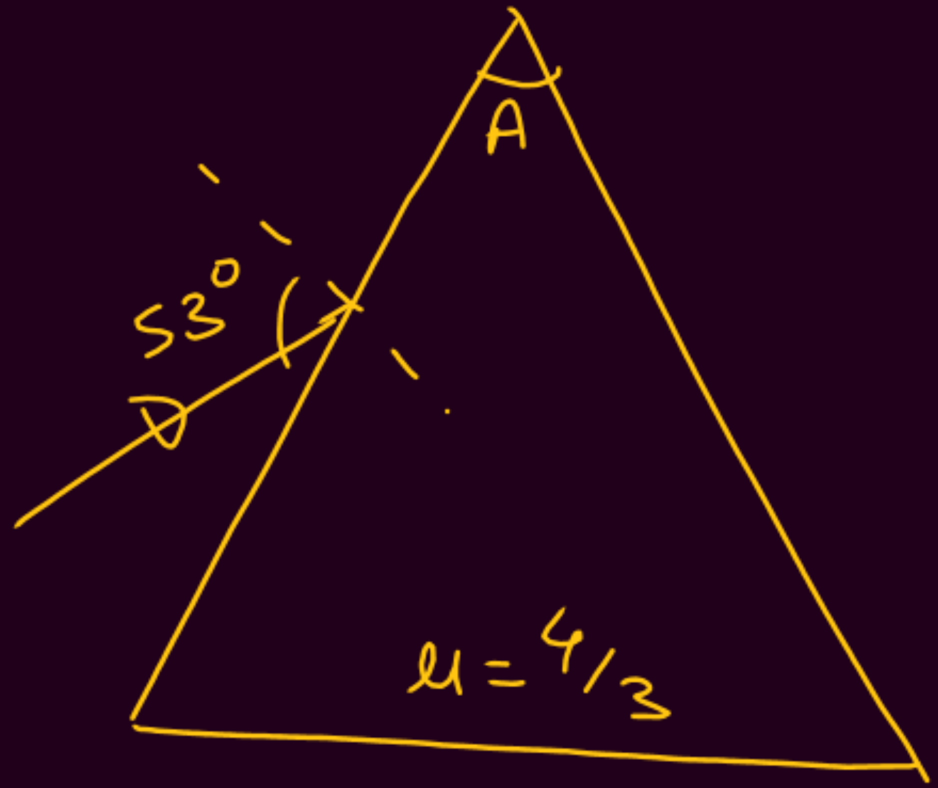
$r_2 = 30^\circ$

$e = 90^\circ$ (given)

$$\mu \sin 30^\circ = \sin(90^\circ)$$

$$\boxed{\mu = 2}$$

Q.



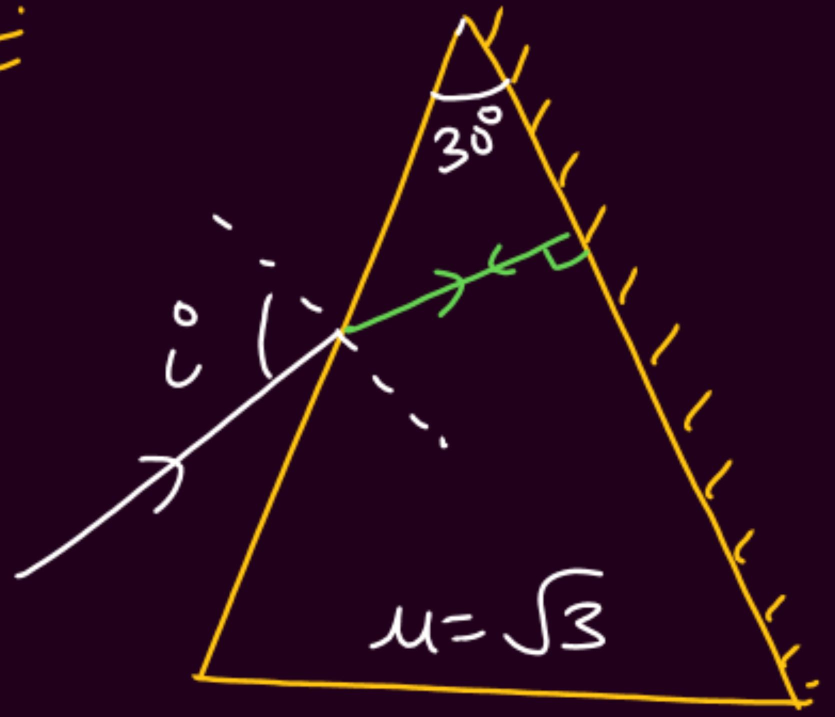
Find A if emerges normally

$$\begin{cases} e = 0 \\ r_2 = 0 \\ r_1 = A \end{cases}$$

$$\frac{4}{5} = \sin 53^\circ = \frac{4}{3} \sin(A)$$

$$\underline{A = 37^\circ}$$

Q.



- Retraces the path

↳ Normal incidence

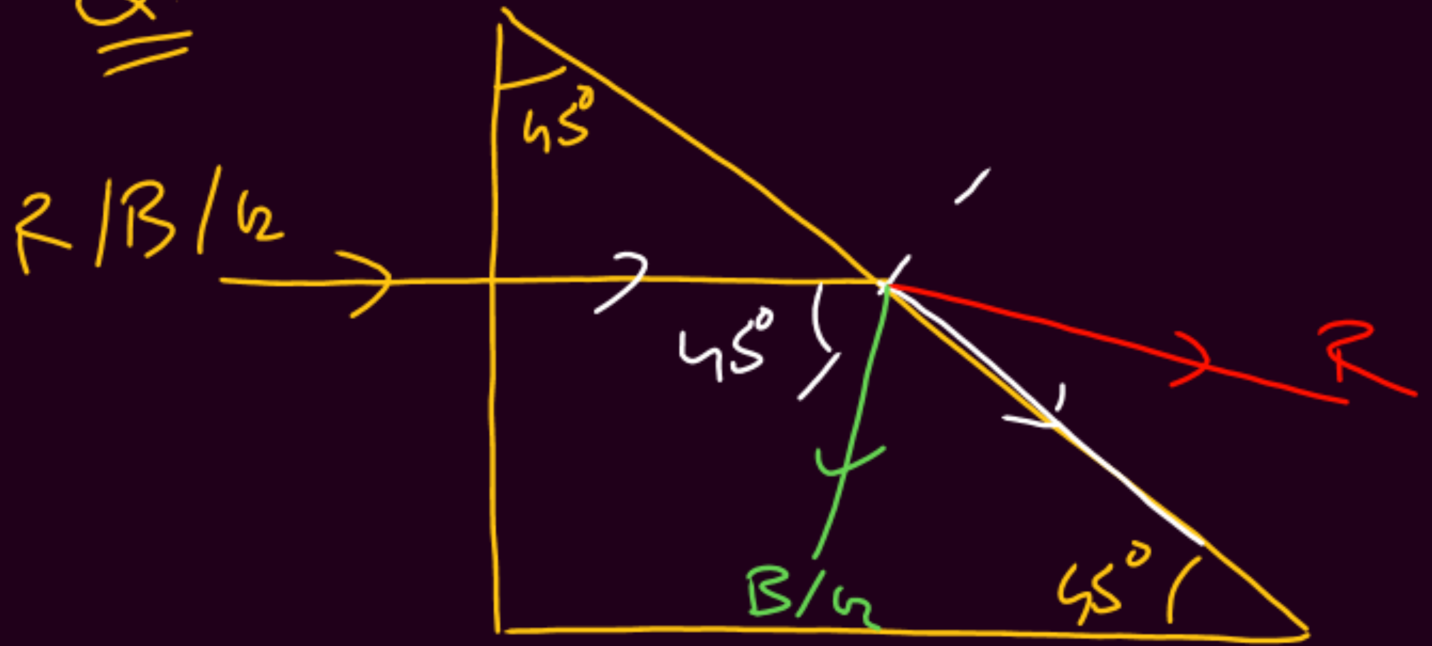
$r_2 = 0$

$r_1 = 30^\circ$

$\sin i = \sqrt{3} \sin 30^\circ$

$\boxed{i = 60^\circ}$

Q.



$\mu_R = 1.39$

$\mu_G = 1.44$

$\mu_B = 1.47$

$$\mu = \frac{1}{\sin c} = \frac{1}{\sin 45^\circ} = \sqrt{2} = 1.414$$

Red

$\boxed{\text{Green / Blue}}$

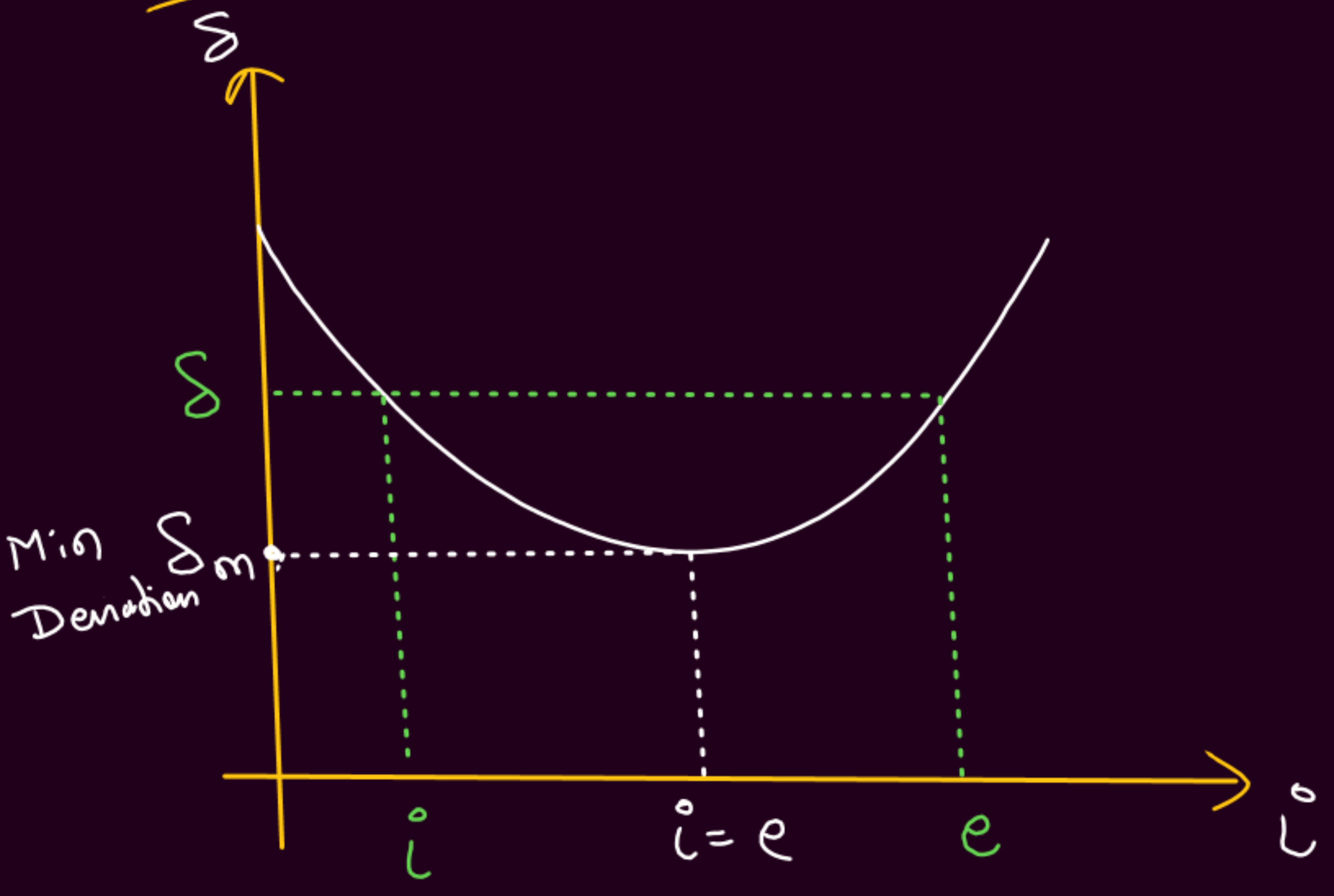
TIR

Let $\boxed{\mu = 1.45}$

⇓

All will sep

Graph



Minimum Deviation

① $i = e$

② $r_1 = r_2 = \frac{A}{2}$

③ $\delta_m = 2i - A$

$$i = \left(\frac{\delta_m + A}{2}\right)$$

④ $$\boxed{\mu = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}} = \frac{\sin i}{\sin r}$$

Q Equilateral Prism

$\mu = \sqrt{3}$

$\delta_m = ?$

$$\sqrt{3} = \frac{\sin\left(\frac{\delta_m + 60^\circ}{2}\right)}{\sin\left(\frac{60^\circ}{2}\right)}$$

$$\frac{\sqrt{3}}{2} = \sin\left(\frac{\delta_m + 60^\circ}{2}\right)$$

$$60^\circ = \left(\frac{\delta_m + 60^\circ}{2}\right)$$

$$\boxed{\delta_m = 60^\circ}$$

Q. given $\delta_m = A$

$\mu = ?$

$$\mu = \frac{\sin\left(\frac{A + A}{2}\right)}{\sin(A/2)} = \frac{\sin A}{\sin(A/2)}$$

$$\mu = \frac{2\sin(A/2)\cos(A/2)}{\sin(A/2)}$$

$$\boxed{\mu = 2\cos(A/2)}$$

Q. if $\mu = \cot(A/2)$

then $\delta_m = ?$

$$\frac{\cos(A/2)}{\cancel{\sin}(A/2)} = \cot\left(\frac{A}{2}\right) = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\cancel{\sin}(A/2)}$$

$$\sin\left(\frac{\pi}{2} - \frac{A}{2}\right) = \sin\left(\frac{\delta_m + A}{2}\right)$$

$$\frac{\pi}{2} - \frac{A}{2} = \frac{\delta_m + A}{2}$$

$$\boxed{\pi - 2A = \delta_m}$$

Thin Prism $(A < 5^\circ)$

Near Normal Incidence

small angle

$\sin\theta \approx \theta$

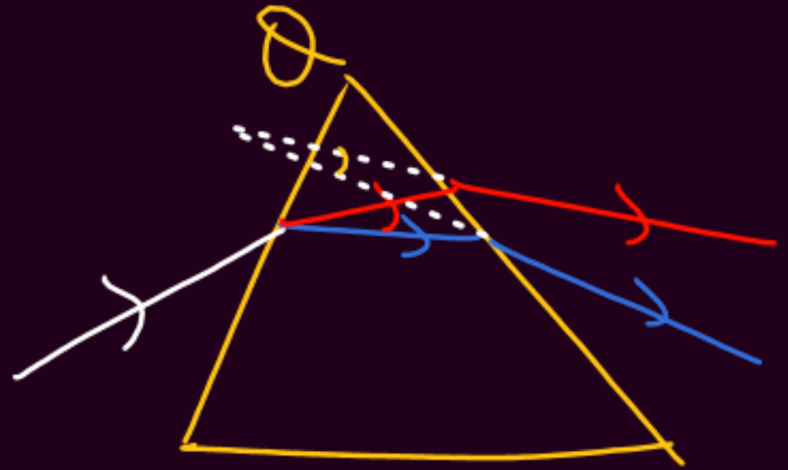
$i = \mu r_1$

$e = \mu r_2$

$i + e = \mu A$

$\delta + A = \mu A$

$$\boxed{\delta = A(\mu - 1)}$$



Angular Dispersion

$$\theta = \delta_V - \delta_R = A(\mu_V - \mu_R)$$

Dispersive Power

$$\omega = \frac{\theta}{\delta_Y} = \frac{\mu_V - \mu_R}{\mu_Y - 1}$$

if μ_Y is not given, $\mu_Y = \dfrac{\mu_V + \mu_R}{2}$

① Dispersion without deviation

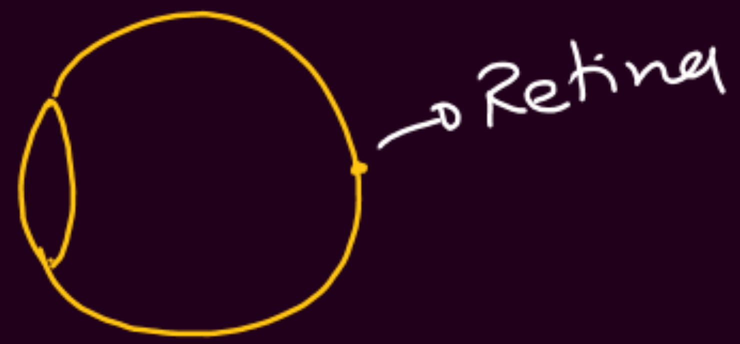
$A(\mu_Y - 1) = A'(\mu_Y' - 1)$

② Deviation without Dispersion

$A(\mu_V - \mu_R) = A'(\mu_V' - \mu_R')$

Defects of Vision

Normal Eye

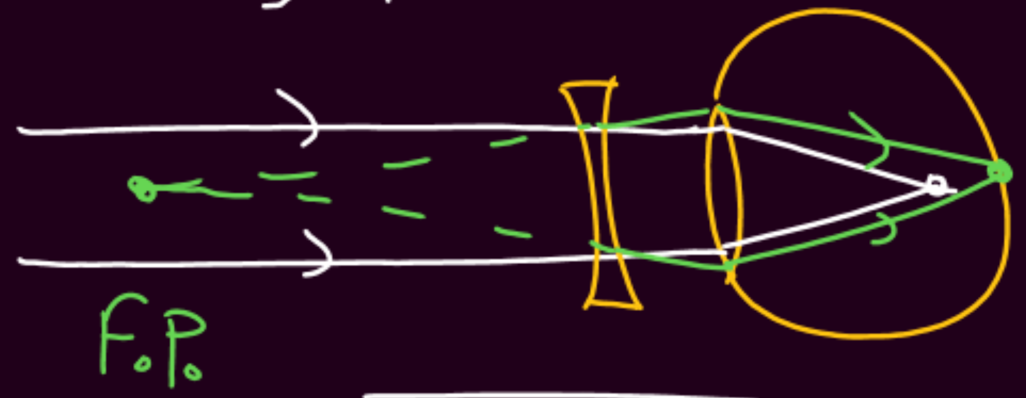


① Far Point → ∞

② Near Point → $D = 25$ cm

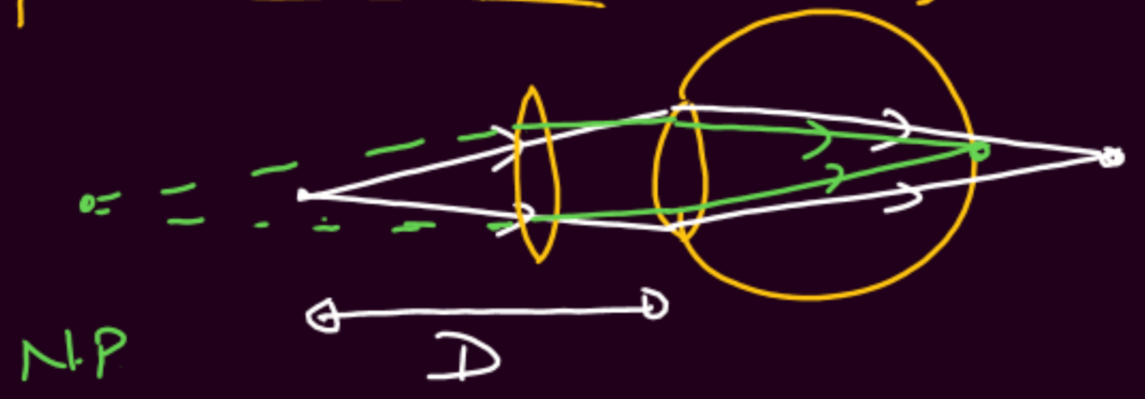
D → least distance of distinct vision

① Myopia → Shortsightedness

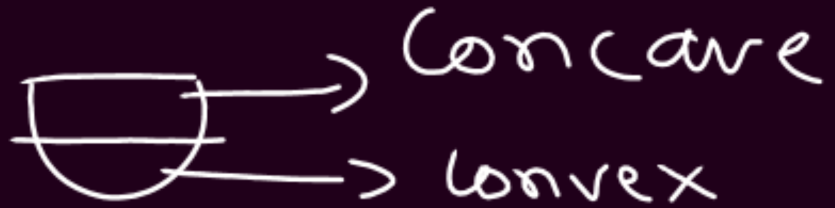


$$\boxed{P = -\frac{1}{F.P.}}$$

② Hypermetropia → farsightedness



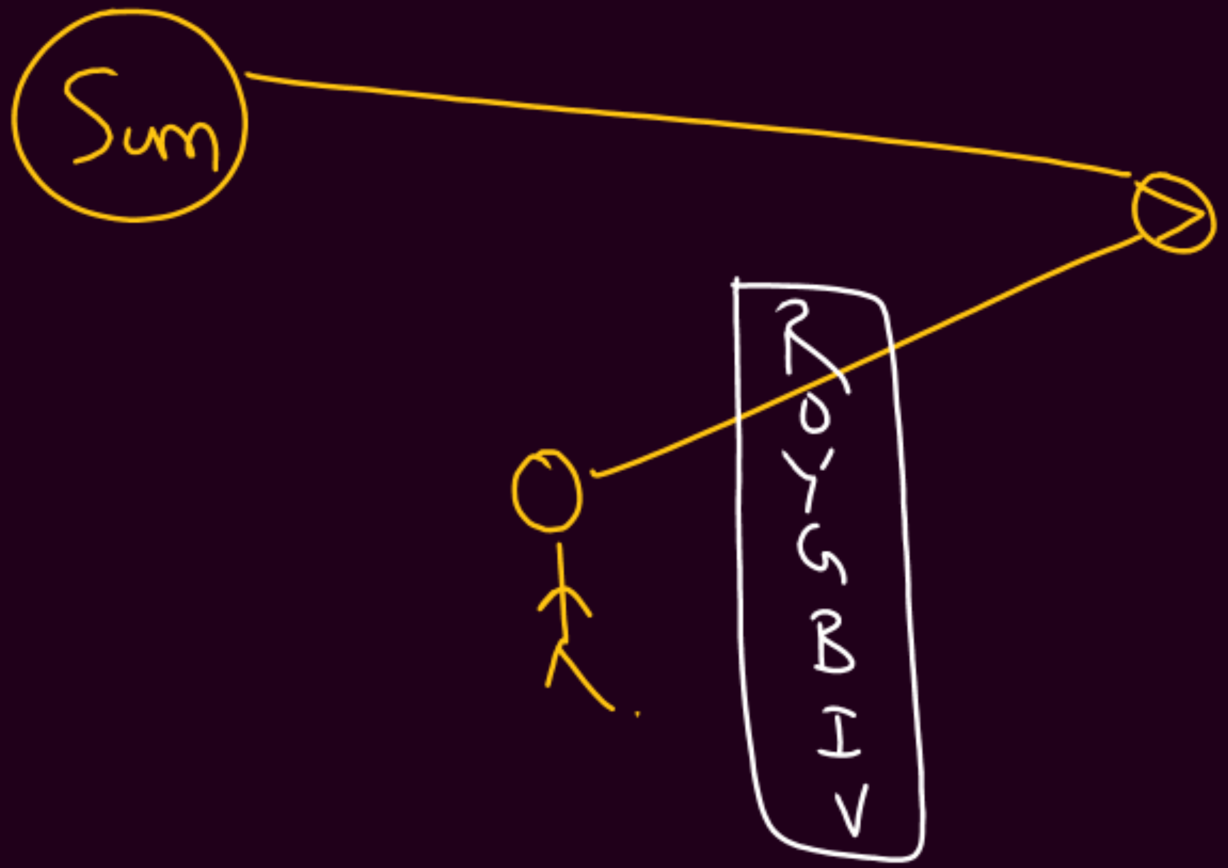
$$\boxed{P = \frac{1}{D} - \frac{1}{NP}}$$



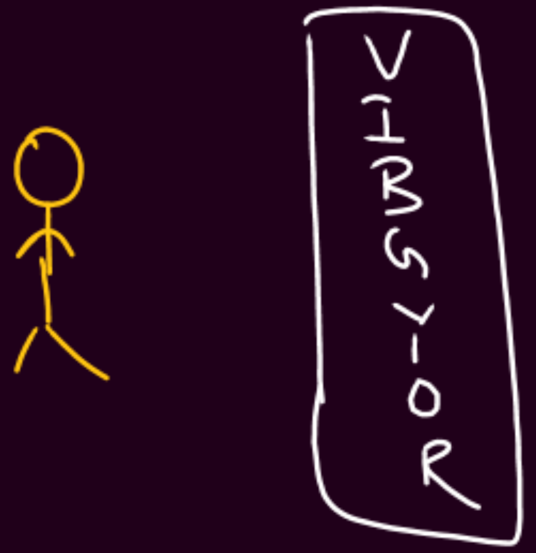
Rainbow

- Dispersion
- Partial Reflection

① Primary



② Secondary



Optical Instrument

Simple Microscope → (Magnifier Glass)

$$M.P. = \frac{\text{Visual Angle with Instrument}}{\text{Max. Visual Angle without Instrument}}$$

$$\boxed{M.P. = \frac{D}{u_e}}$$

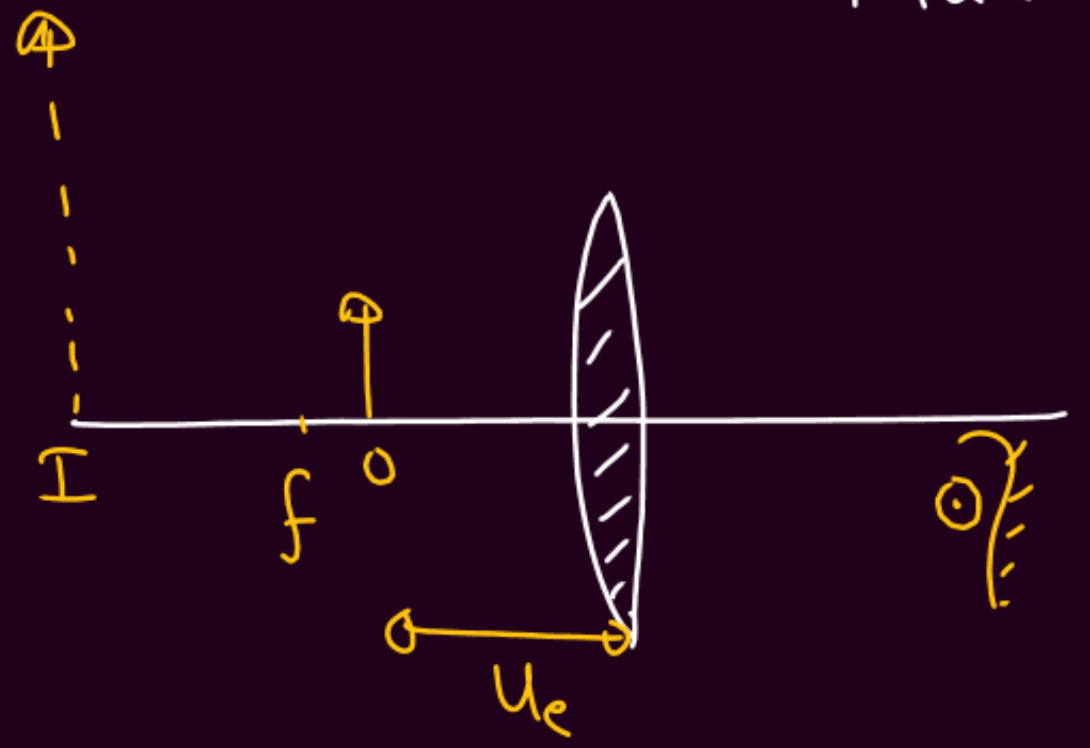


Image
↳ Virtual / Erect / Enlarged

① Image at ∞ (min strain)

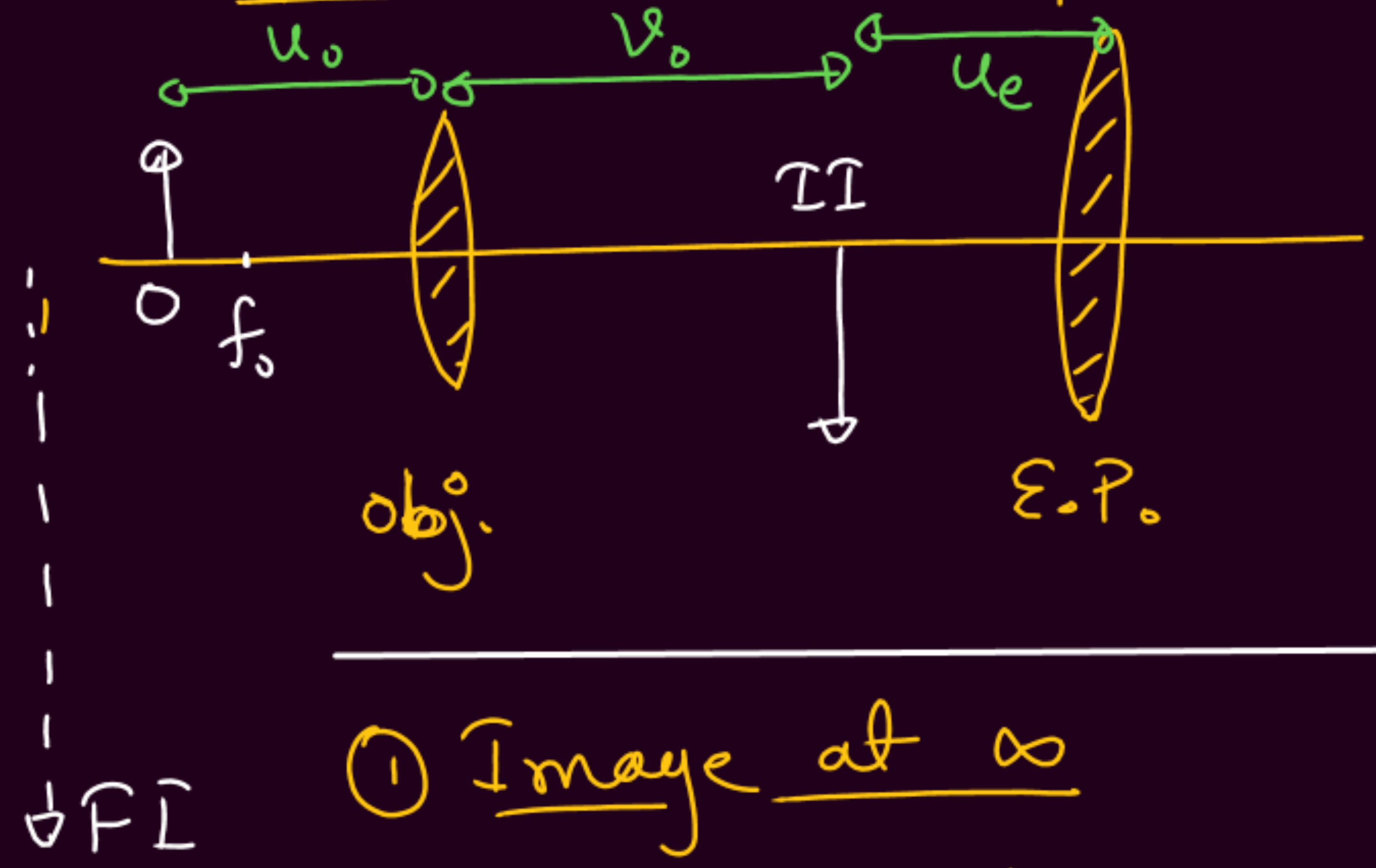
$$M.P. = \frac{D}{f_e}$$

$$\left\{\begin{aligned} \frac{1}{f} &= \frac{1}{v} + \frac{1}{u} \\ \frac{1}{f_e} &= -\frac{1}{D} - \frac{1}{u_e} \end{aligned}\right\} \rightarrow u_e = \frac{Df_e}{D+f_e}$$

② Image at D (max strain)

$$M.P. = \left(1 + \frac{D}{f_e}\right)$$

Compound Microscope



$$M.P. = -\left|\frac{v_o}{u_o}\right| \frac{D}{u_e}$$

$$L = v_o + u_e$$

II → Real / Inv. / Enlarged

FI → Virtual / Inv / Enlarged

① Image at ∞

$$M.P. = -\left|\frac{v_o}{u_o}\right| \frac{D}{f_e}$$

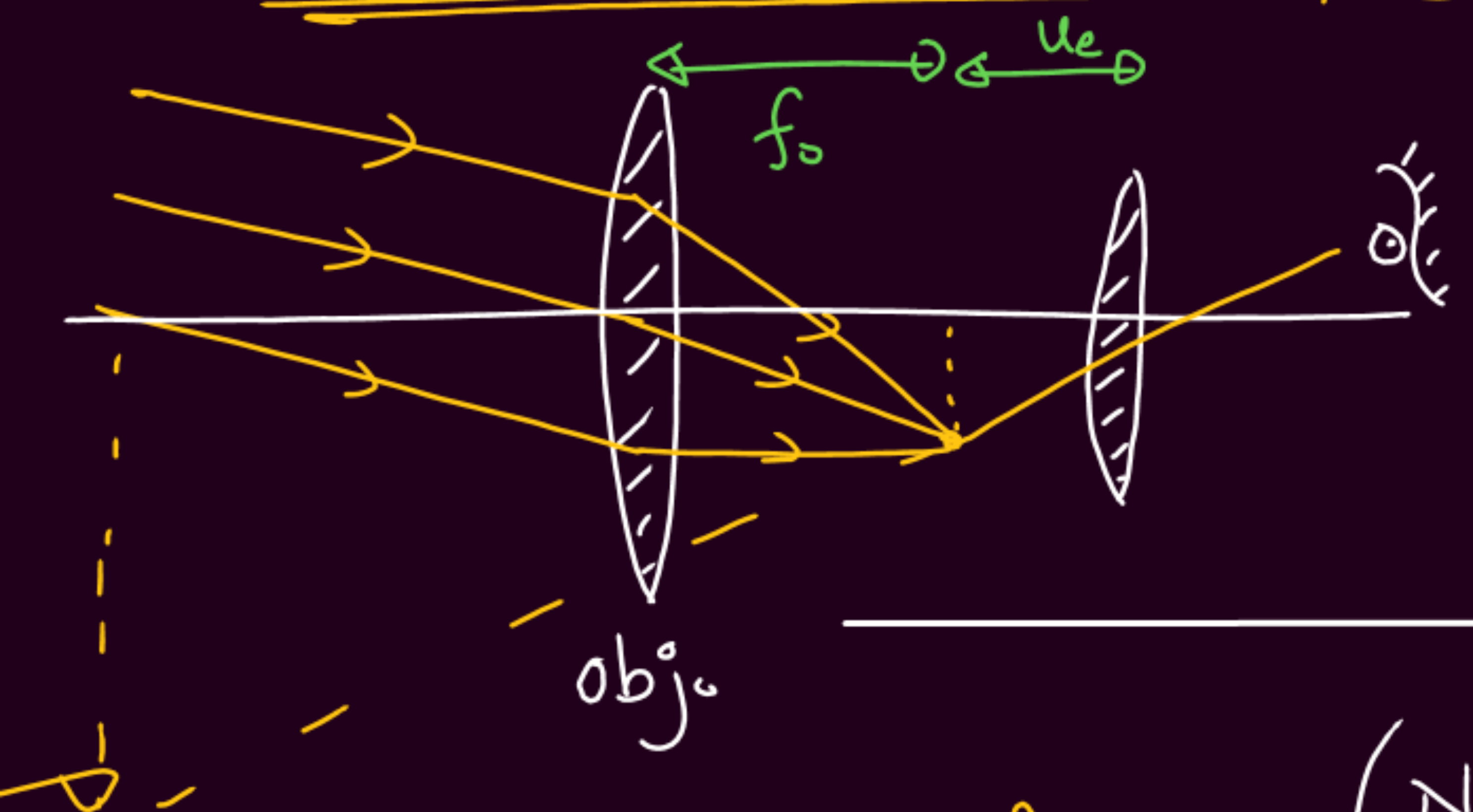
$$L = v_o + f_e$$

② Image at D

$$M.P. = -\left|\frac{v_o}{u_o}\right| \left(1 + \frac{D}{f_e}\right)$$

$$L = v_o + \frac{D f_e}{D + f_e}$$

Astronomical Telescope



$$M.P. = \frac{\text{Visual angle with instrument}}{\text{Visual angle without instrument}}$$

II → Real / Inv

FI → Virtual / Inv

① Image at ∞ (Normal Adjustment)

$$M.P. = -\frac{f_o}{f_e}$$

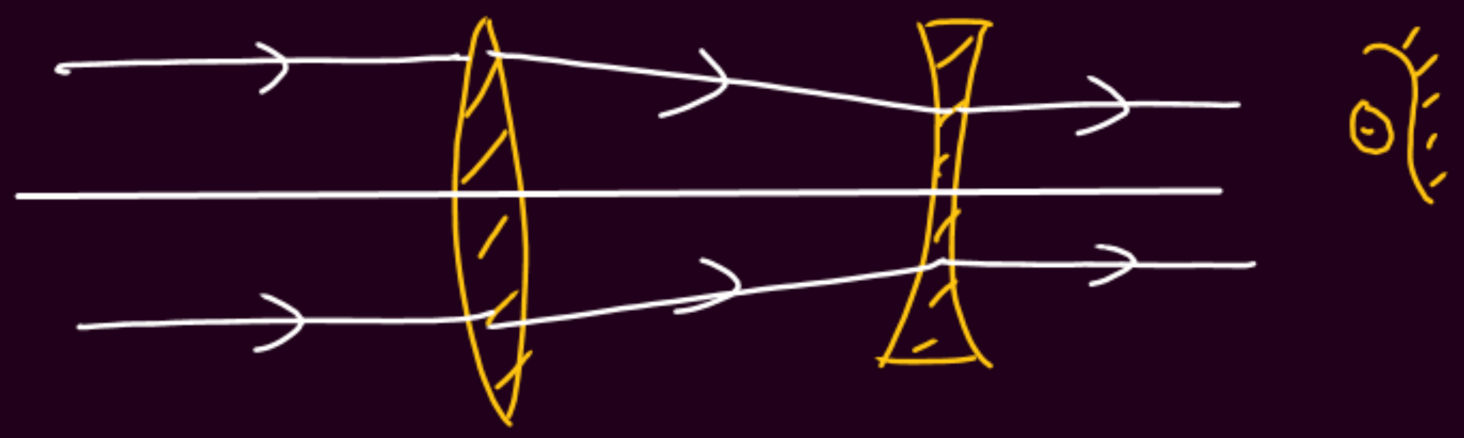
$$L = f_o + f_e$$

② Image at D

$$M.P. = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$L = f_o + \frac{Df_e}{D + f_e}$$

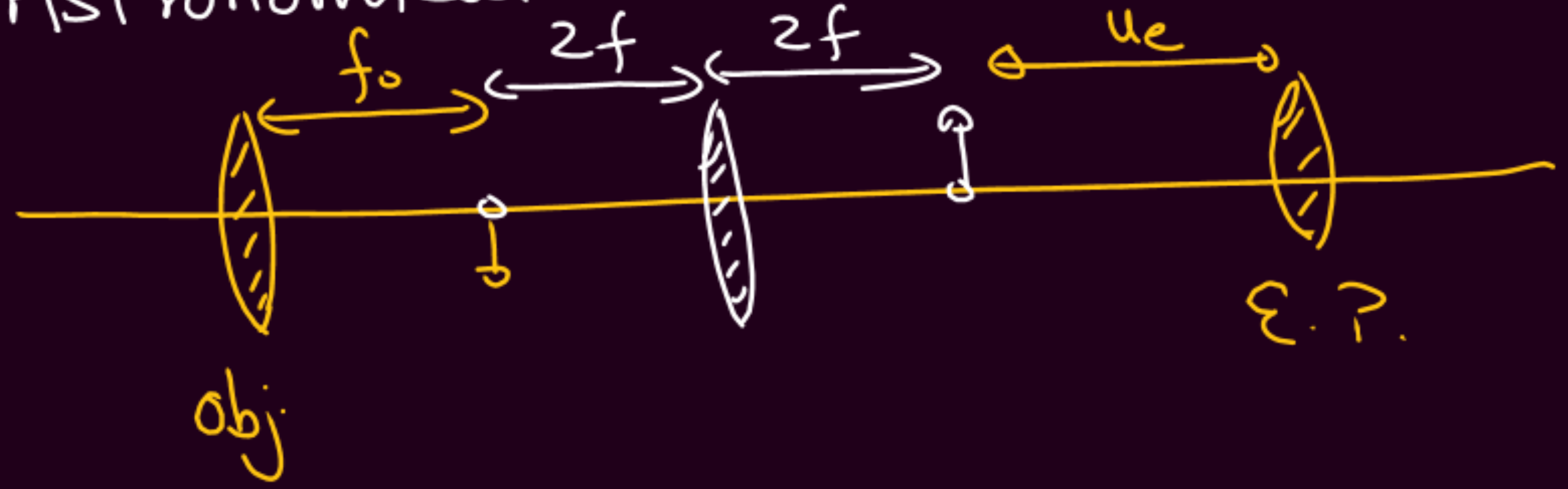
Galilean Telescope



FI → Erect (Terresstrial)

$$M.P. = \frac{f_o}{f_e} \qquad L = f_o - f_e$$

Astronomical → Terresstrial



$$L = f_o + 4f + u_e$$

Reflecting Telescope (Cassegrain)

→ Achromatic

→ Spherical Abb ×

→ Parabolic Reflector

Microscope

$$M.P. = -\frac{LD}{f_o f_e} \quad (\text{Approx})$$

→ Both f_o & f_e (small)

→ Obj & E.P → interchange

$\Downarrow$

M.P. ~ remains same

Telescope

$$M.P. = -\frac{f_o}{f_e}$$

→ $\left.\begin{array}{l} f_o \ (\text{large}) \\ f_e \ (\text{small}) \end{array}\right\}$ for large M.P.

→ obj. → large Aperture

- → Better Brightness
- → Better resolving power

→ obj & E.P. → interchange

$$\left(m \rightarrow \frac{1}{m}\right)$$

Q. M.P. = 5
(Simple Microscope)

① $f = ?$

$$5 = \frac{D}{f_e}$$

$$\boxed{f_e = 5\,cm}$$

② Max. M.P. = ?

$$= 1 + \frac{D}{f_e}$$

$$= 1 + 5 = 6$$

Q Compound Microscope $f_o = 4\,cm$

$f_e = 5\,cm$

if object is at 5cm from objective

① M.P. = ?

$$M.P. = -|m_o| \frac{D}{f_e}$$

$$= -(4)\left(\frac{25}{5}\right)$$

$$M.P. = -20$$

$$m_o = \frac{v_o}{u_o} = \frac{f_o}{f_o + u_o}$$

$$\frac{v_o}{-5} = \frac{4}{4 + (-5)} = -4$$

$$v_o = +20\,cm$$

② $L = ?$

$$L = v_o + f_e = 20 + 5 = 25\,cm$$

Q: Astronomical Telescope

$M.P. = 10$

$L = 44 cm$

$f_o = ?$ $f_e = ?$

① $10 = \frac{f_o}{f_e}$

② $L = f_o + f_e$

$f_o = 40 cm$ $f_e = 4 cm$

Q. Astronomical Telescope

$f_o = 50cm$ $f_e = 5cm$

used to view a building at 2km.
(in normal adjustment).

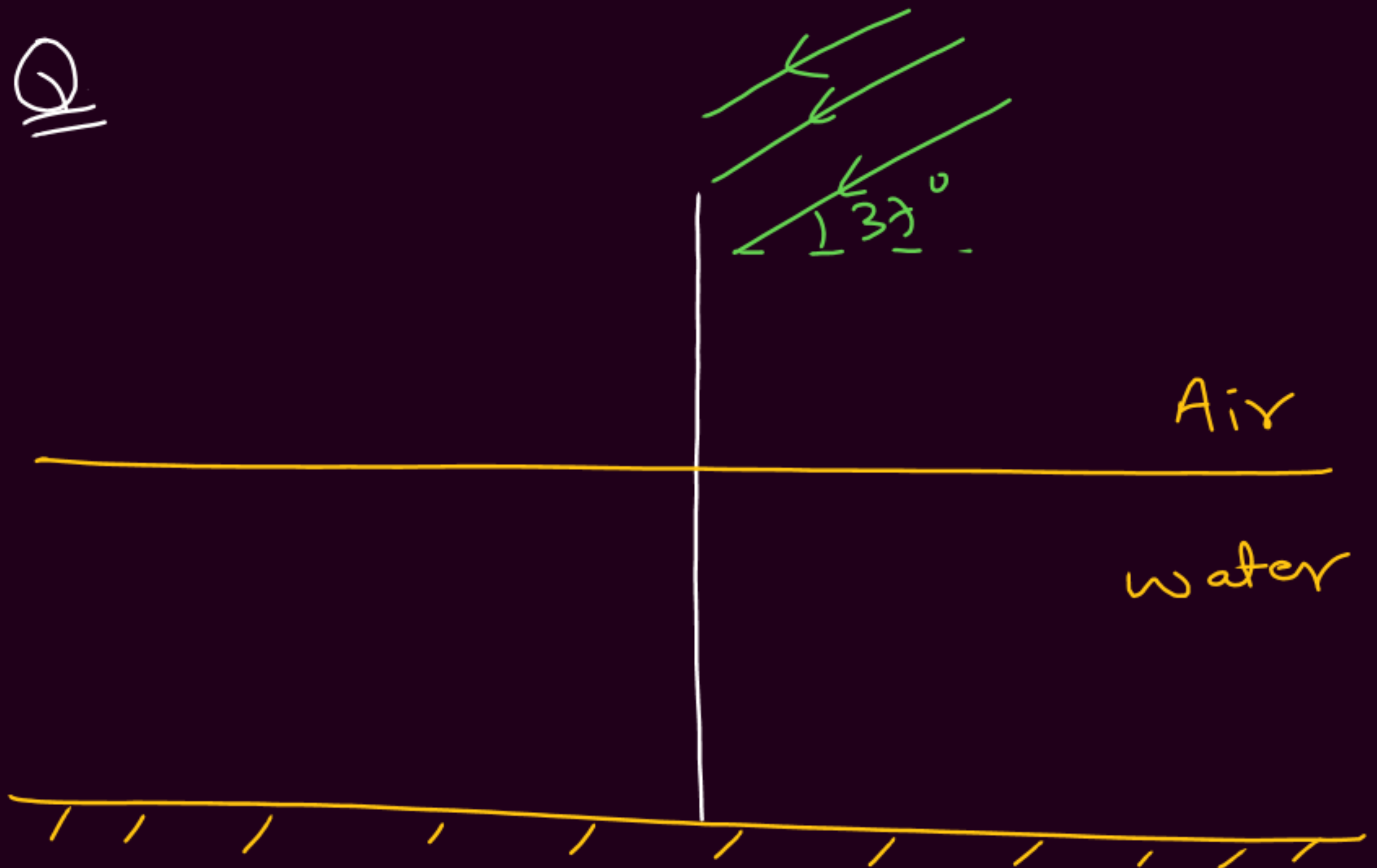
Sep. bet^n lenses?

$$\frac{v_o}{-2000} = \frac{0.5}{0.5 + (-2000)}$$

$v_o \approx 0.5m = 50cm$ (slightly greater)

$L = v_o + f_e = 50 + 5 = 55cm$

Q



Meter Rod

Half dipped

Length of shadow?