Diffraction, Geometrical Optics, Huygens Principle, Refracting Media, Laws of Reflection + Refraction, Fermat's Principle

Geometrical Optics: light like <u>particles</u>, straight lines that get reflected, refracted.

$\updownarrow$ QM!

Diffraction: wave properties matter.

How to tell?

(1) Dimensions $\gg \lambda$

(2) Huygens Principle:

All points on a wavefront can be considered as point sources for the production of spherical secondary wavelets. After time t the new position of a wavefront is the surface tangent to these secondary wavelets.

Figures 8, 1, 2 from RHK4.

Key: $\gg \lambda$, mention Kirchoff

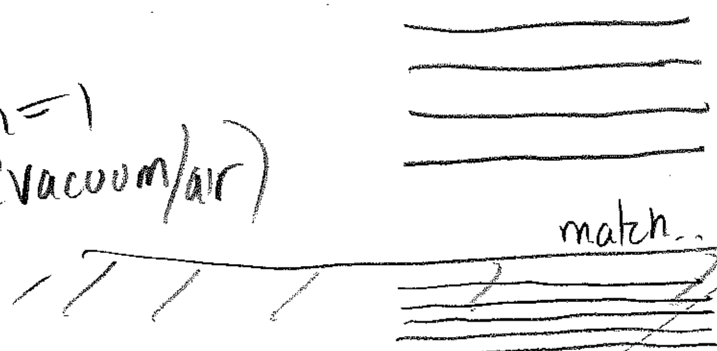
Refracting Media

$v = \frac{c}{n}$ $\quad$ n = index of refraction $\sim \sqrt{\varepsilon(\omega)}$

table

Causes reflection/refraction.

$v = \nu \cdot \lambda$ $\quad$ $\nu \Rightarrow$ stays same. $\lambda \Rightarrow$ changes



λ_0

$n=1$ (vacuum/air)

$c = \lambda_0 \nu$

match.. boundary conditions

$\frac{\lambda}{n}$

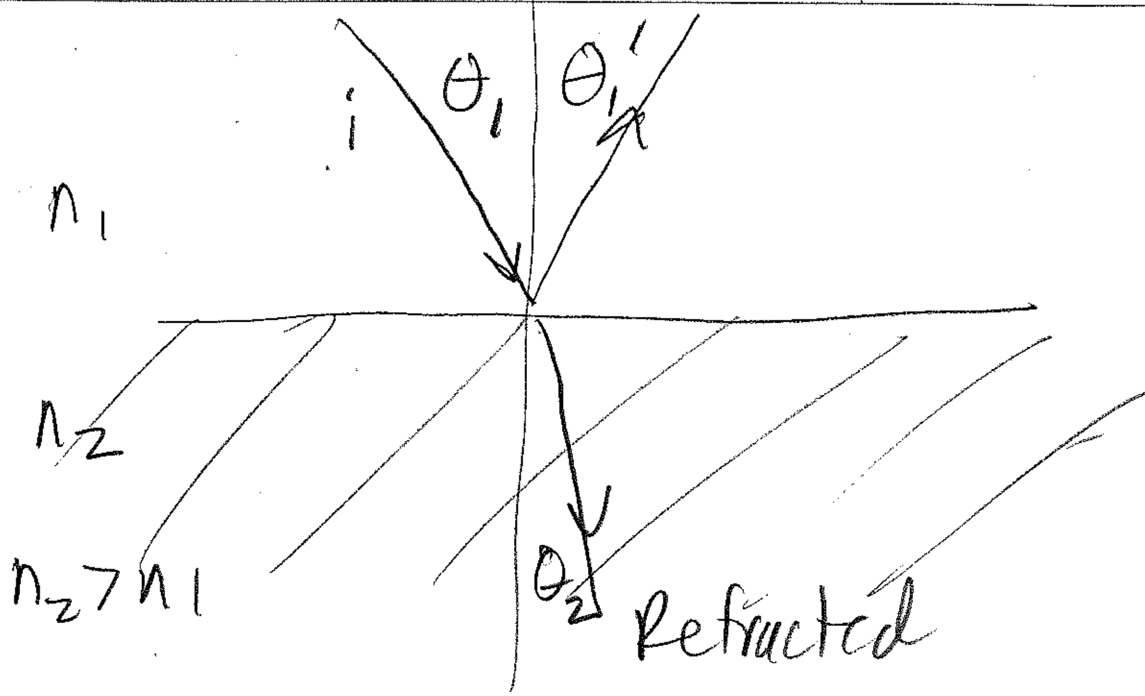
$n=1.33$

$v = \frac{c}{n} = \lambda\nu$

$\lambda = \frac{c}{\nu} \cdot \frac{1}{n}$

$\lambda = \frac{\lambda_0}{n}$

$\boxed{\text{a reflected wave!}}$



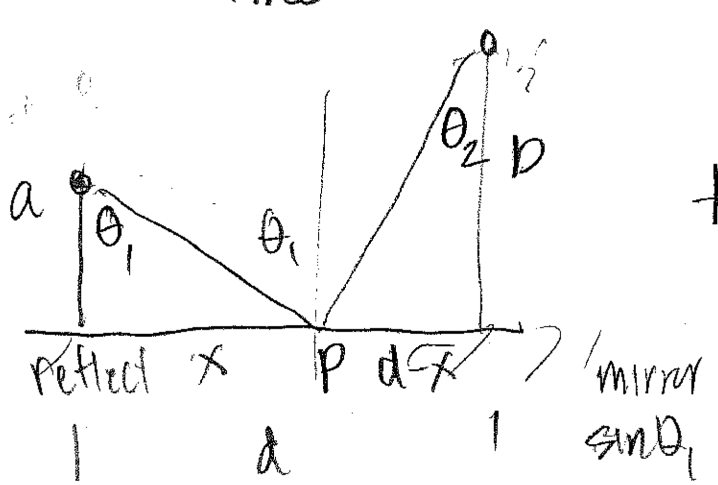
Law of reflection ...

$$\theta_1 = \theta_1'$$

Law of refraction.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Proof by Fermat's Principle:
time either max or min



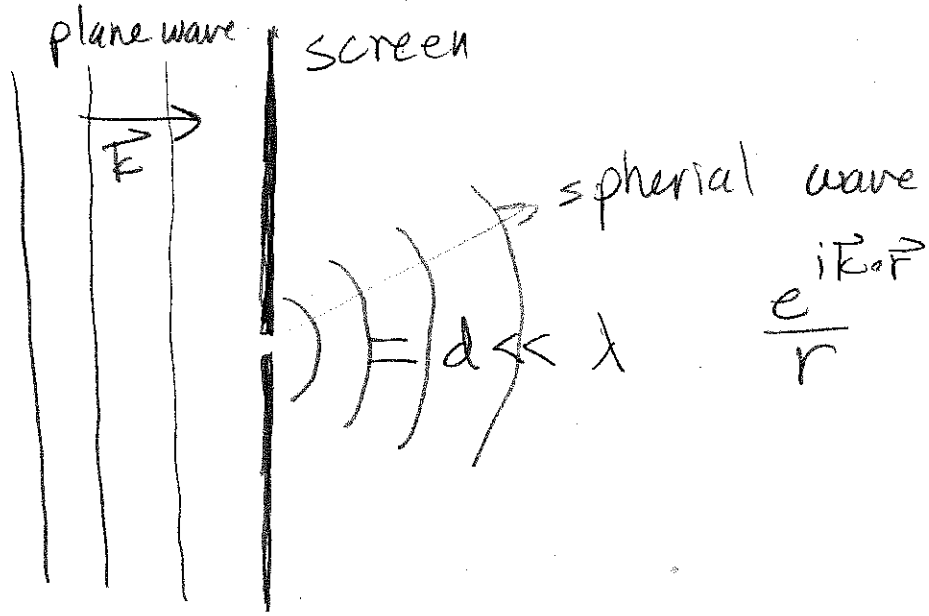
$$L = \sqrt{a^2+x^2} + \sqrt{b^2+(d-x)^2}$$

$$t = \frac{L}{c}$$

$$\frac{dt}{dx} = \frac{1}{c}\left(\frac{1}{2}\frac{2x}{\sqrt{a^2+x^2}} + \frac{1}{2}\cdot\frac{2(d-x)(-1)}{\sqrt{b^2+(d-x)^2}}\right)$$

$$\sin\theta_1 = \frac{x}{\sqrt{a^2+x^2}} = \frac{d-x}{\sqrt{b^2+(d-x)^2}} = \sin\theta_2$$

meaning



integrate to
over wavefront propagat.

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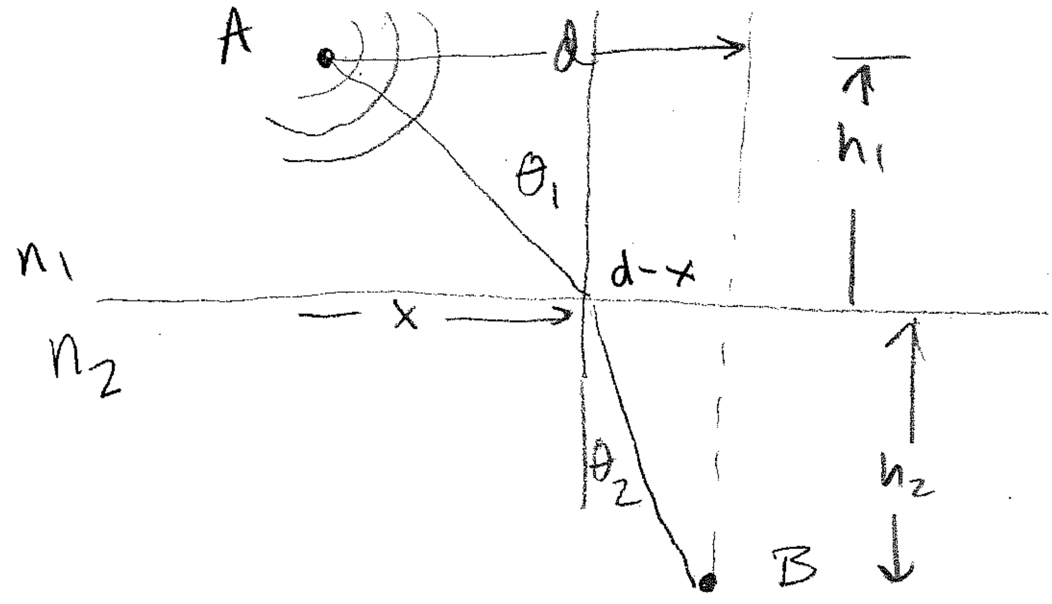
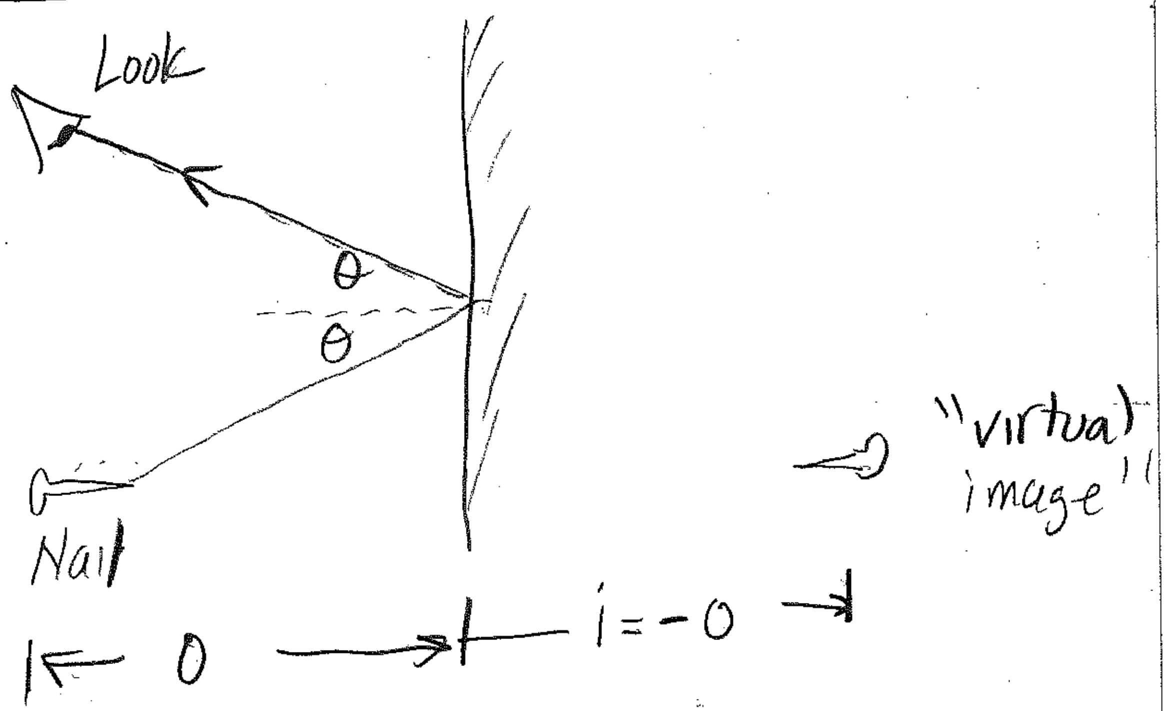
another view of Snell's Law.



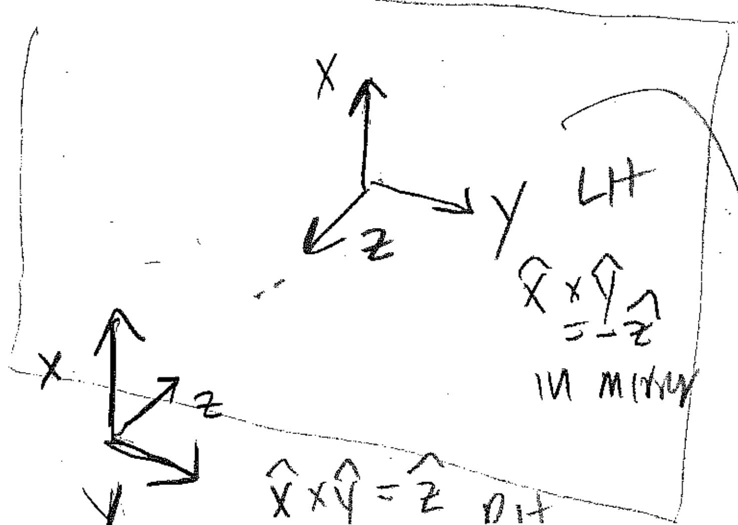
Snell's law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$
is the path that minimizes the time
it takes to go from point A to point B

Plane mirrors



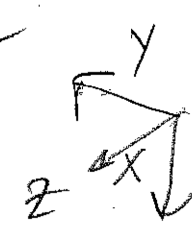
Virtual means: rays never actually touch or pass through the image (really)

Reversal   Left ⟺ Right



actually, in/out got reversed

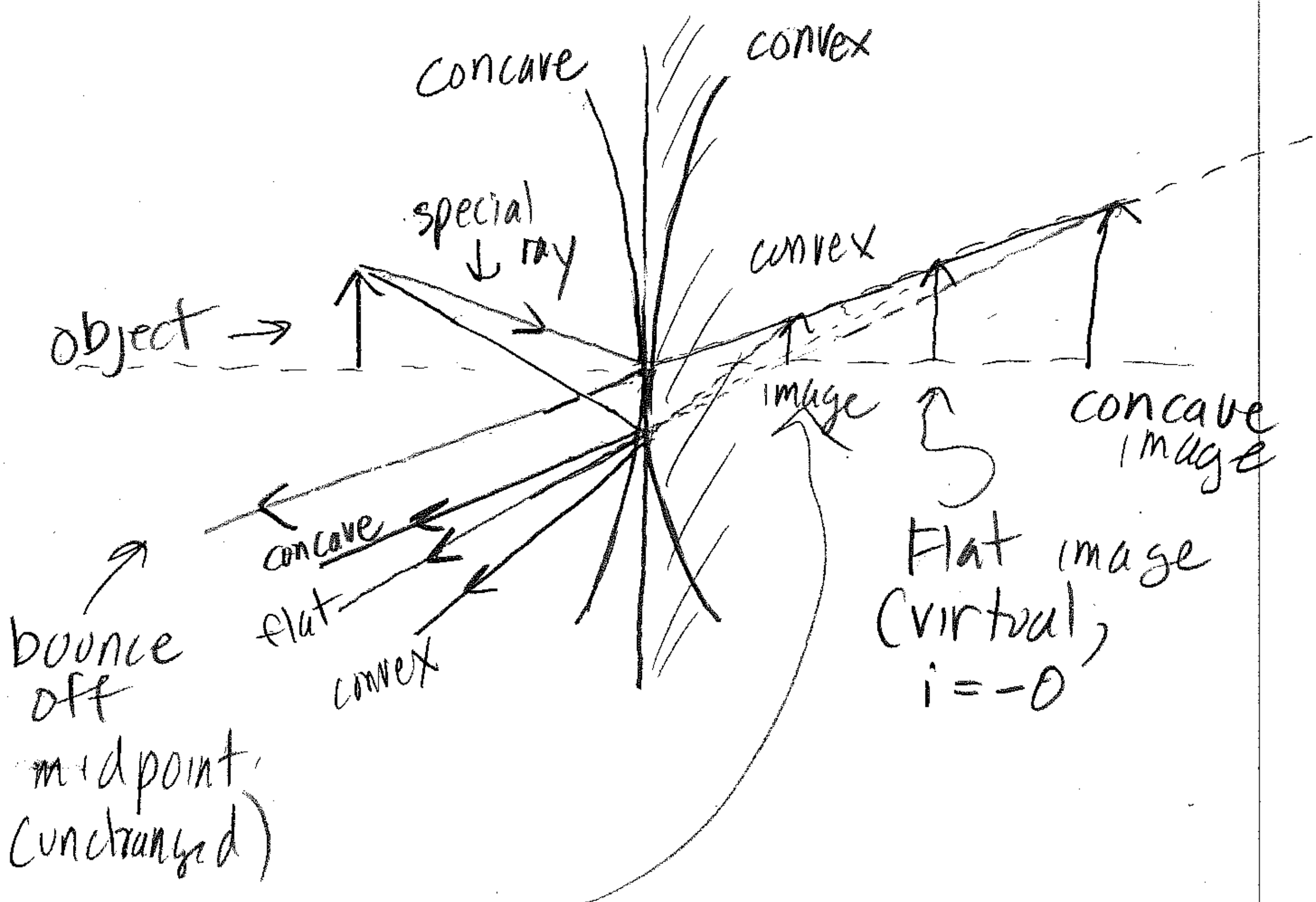
can rotate



← "total flip"

Corved Mirror

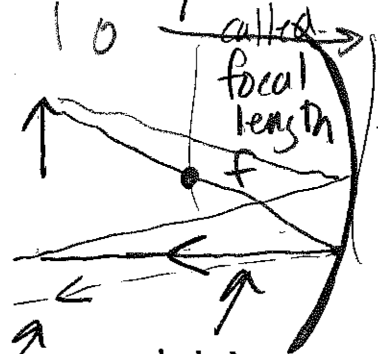
Reason from flat,



looking at special ray + congruent triangles,

$$\text{lateral mag} = -\frac{i}{o} \equiv m$$

Something special about concave... ray can go out parallel...



big curvature.

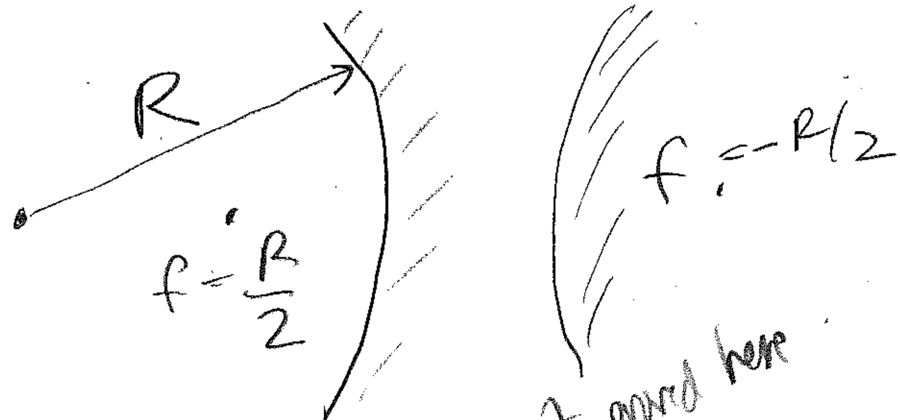
!!!

i not at $-\infty$ yet

limiting case of $i \to -\infty$

$f < 0$ for that ray

what is f for a spherical mirror



$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} = \frac{2}{R}$$

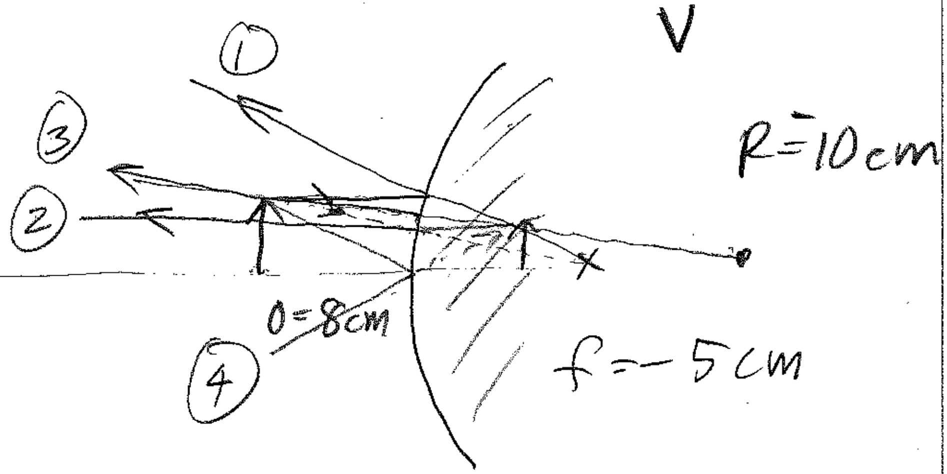
not proved here proof p. 927

case like flat mirror .. $R \to \infty$, $\frac{1}{f} \to 0$, $\frac{1}{i} = -\frac{1}{o}$

virtual image $i = -o < 0$

real image $i > 0$

V



① calc: $\frac{1}{i}+\frac{1}{o}=-\frac{1}{5}$ expect: $i<0$

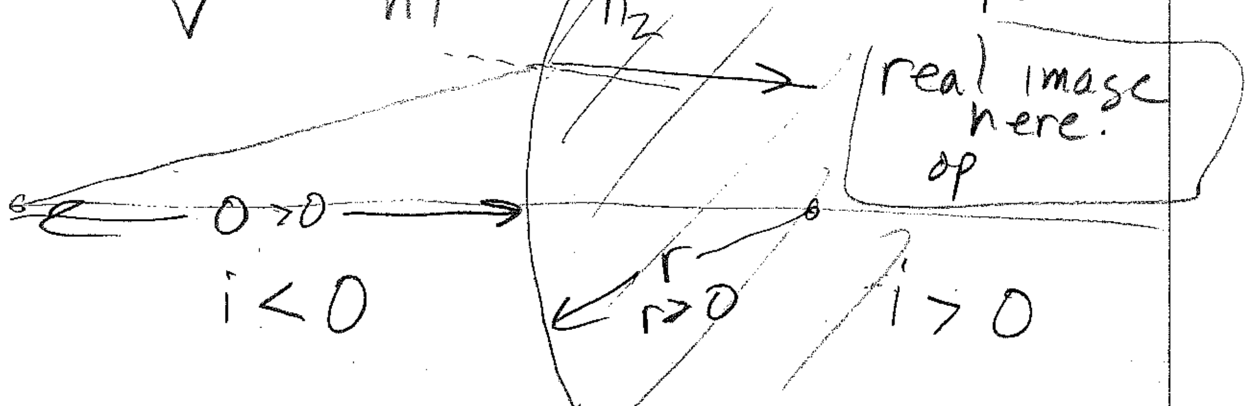
$$\frac{1}{i}=-\frac{1}{5}-\frac{1}{8}=-\frac{8}{40}-\frac{5}{40}=-\frac{13}{40}$$

$$i=-\frac{40}{13}\simeq-3\tfrac{1}{13}\text{ cm}=\underline{-3.08}\text{ cm}$$

② $m=-\frac{i}{o}=-\frac{-3.08}{5}=0.615$

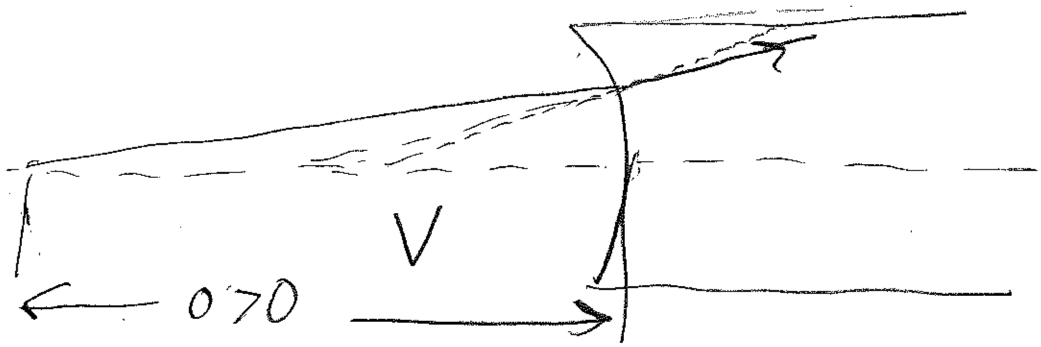
Spherical Refracting Surfaces

V R



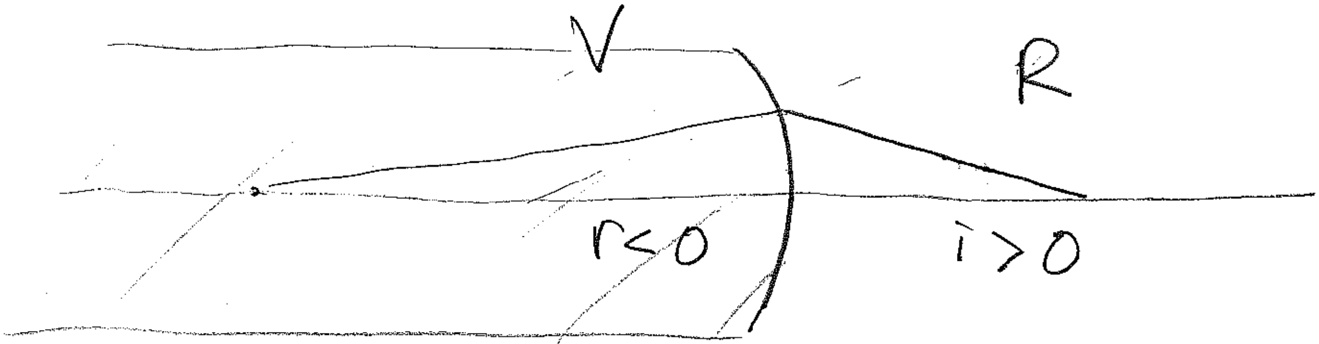
opposite to mirror.

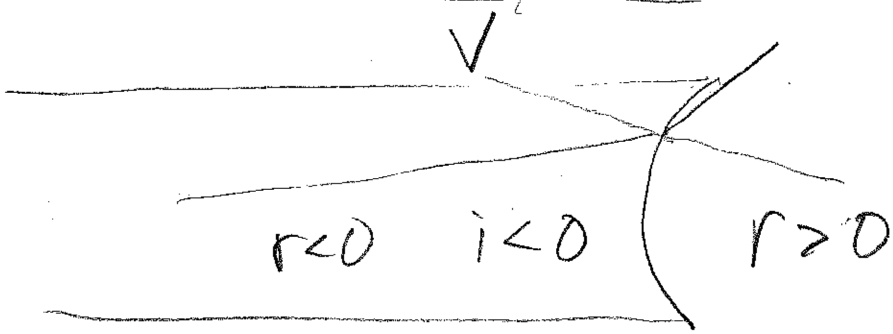
$$\frac{n_1}{o}+\frac{n_2}{i}=\frac{(n_2-n_1)}{r}$$ $r>0$ shown.



$i<0$

$r<0$

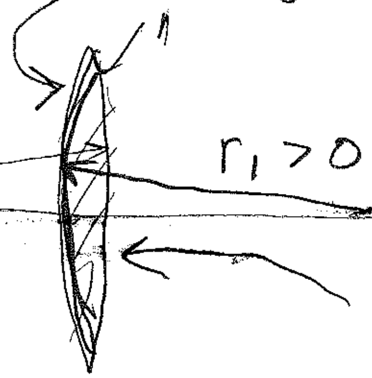




Thin lens : $\frac{1}{o}+\frac{n}{i}=\frac{(n-1)}{r_1}$

$n_1=1$

$\frac{n}{i}=\frac{(n-1)}{r_1}-\frac{1}{o}$ >0



but $o'=-i<0$

virtual object

$\frac{1}{o}-\frac{(n-1)}{r_1}+\frac{1}{i}=\frac{(1-n)}{r_2}$

→ ~~H~~ neglected $-\frac{n}{o'}$