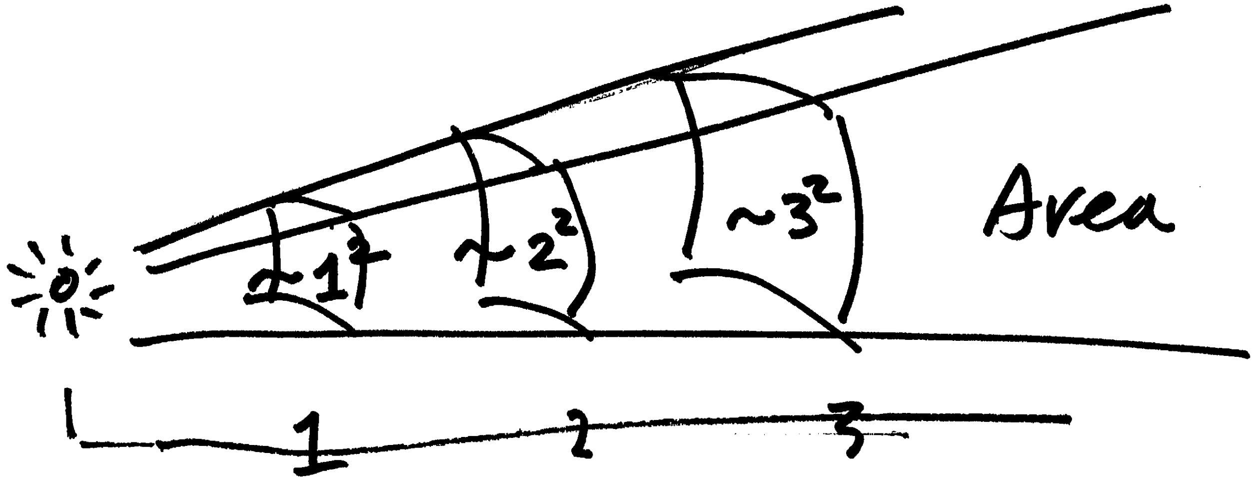
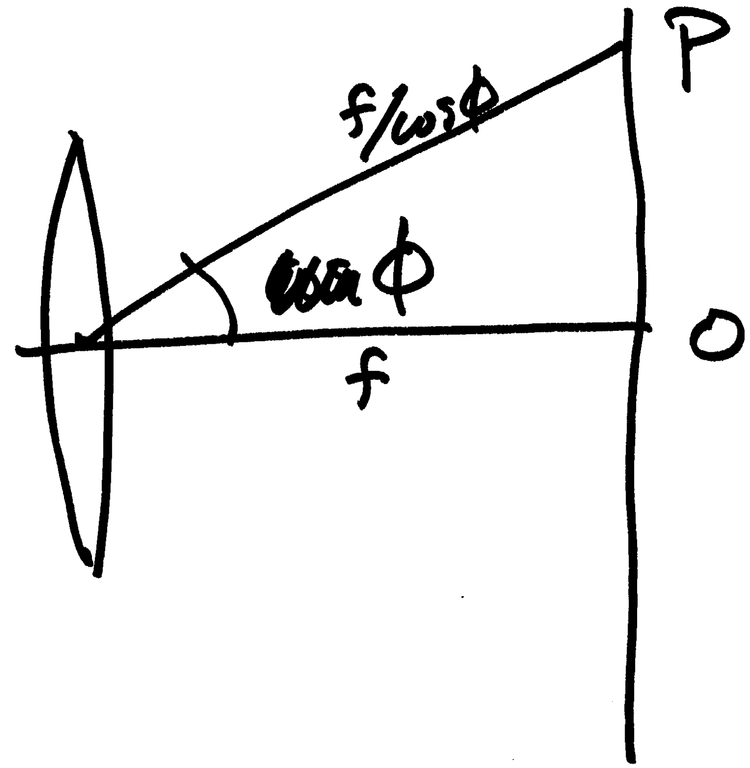




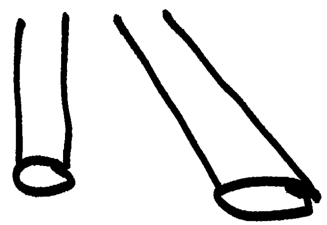
illuminated area increases with square of distance

irradiance flux/unit area decrease with square of distance

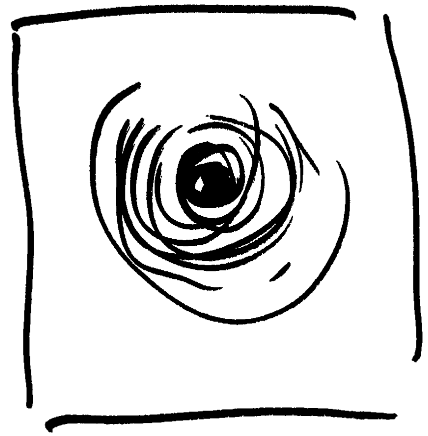
$$\sim \frac{1}{d^2}$$

3 factors cause off-axis illumination to be less

1. circular aperture from O, eliptial aperture from P
   $\cos\phi$



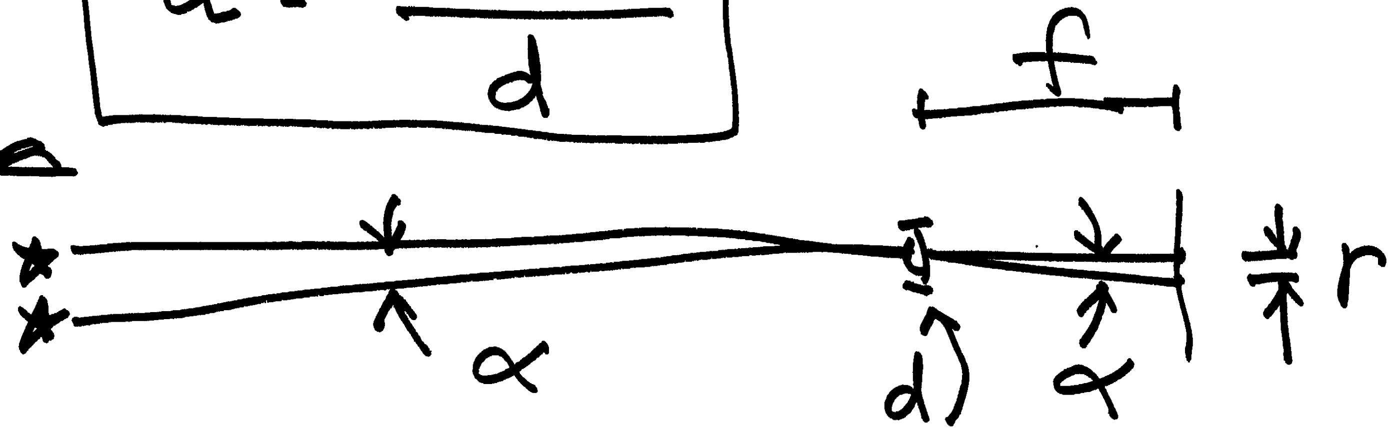
2. obliquity of beam
   $\cos\phi$
3. difference in distance
   $\cos^2\phi$



$$\boxed{E_\phi = E_0 \cdot \cos^4\phi}$$

Resolving Power : Rayleigh Criterion

$$\boxed{\alpha = \frac{1.22\,\lambda}{d}}$$



small angle $\alpha \approx \tan\alpha = \dfrac{r}{f} = \dfrac{1.22\,\lambda}{d}$

$$r = \frac{1.22\,\lambda \cdot f}{d}$$

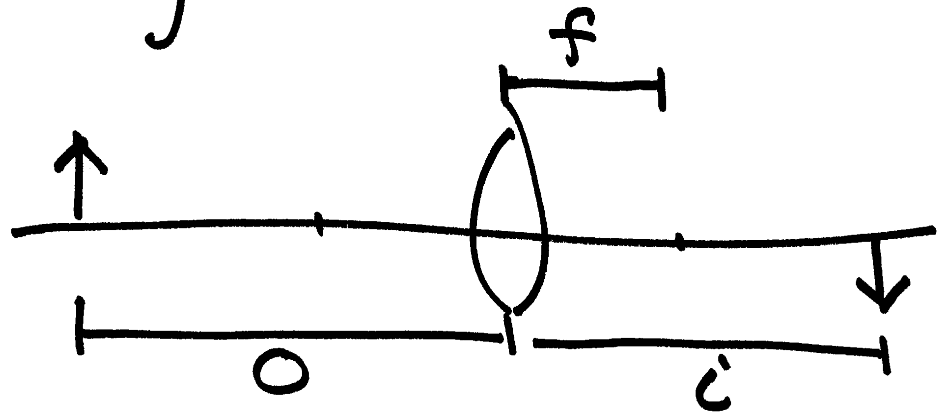
$\dfrac{f}{d}$: fnumber

$\frac{f}{d}$: f-number   1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16

decrease diameter by $\sqrt{2}$

decrease area by 2

f-stop

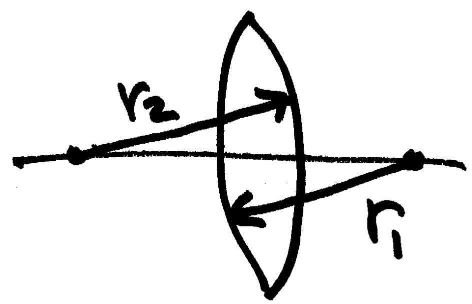


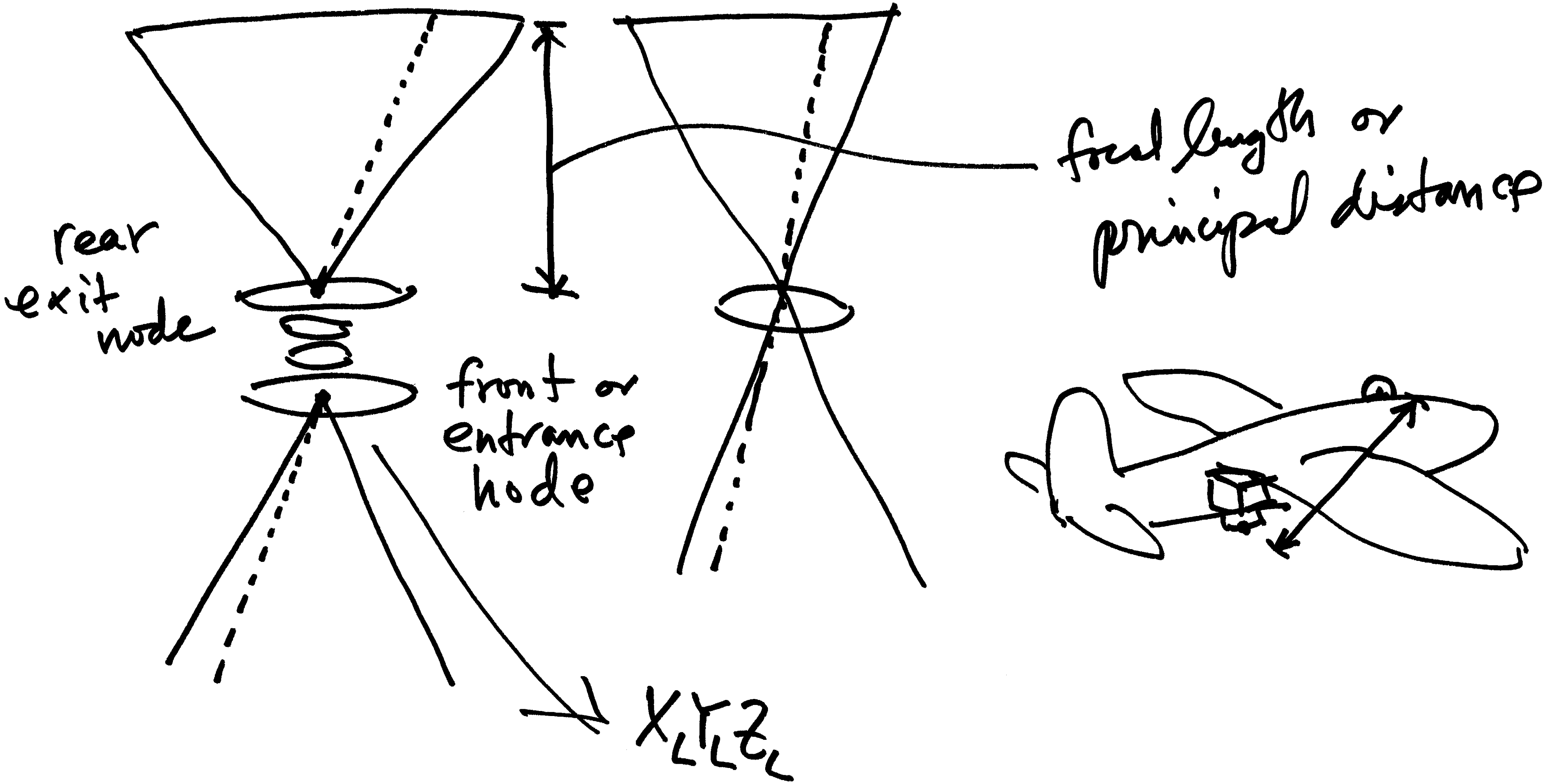
<u>focus</u> : thin lens equation

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

lens maker's equation

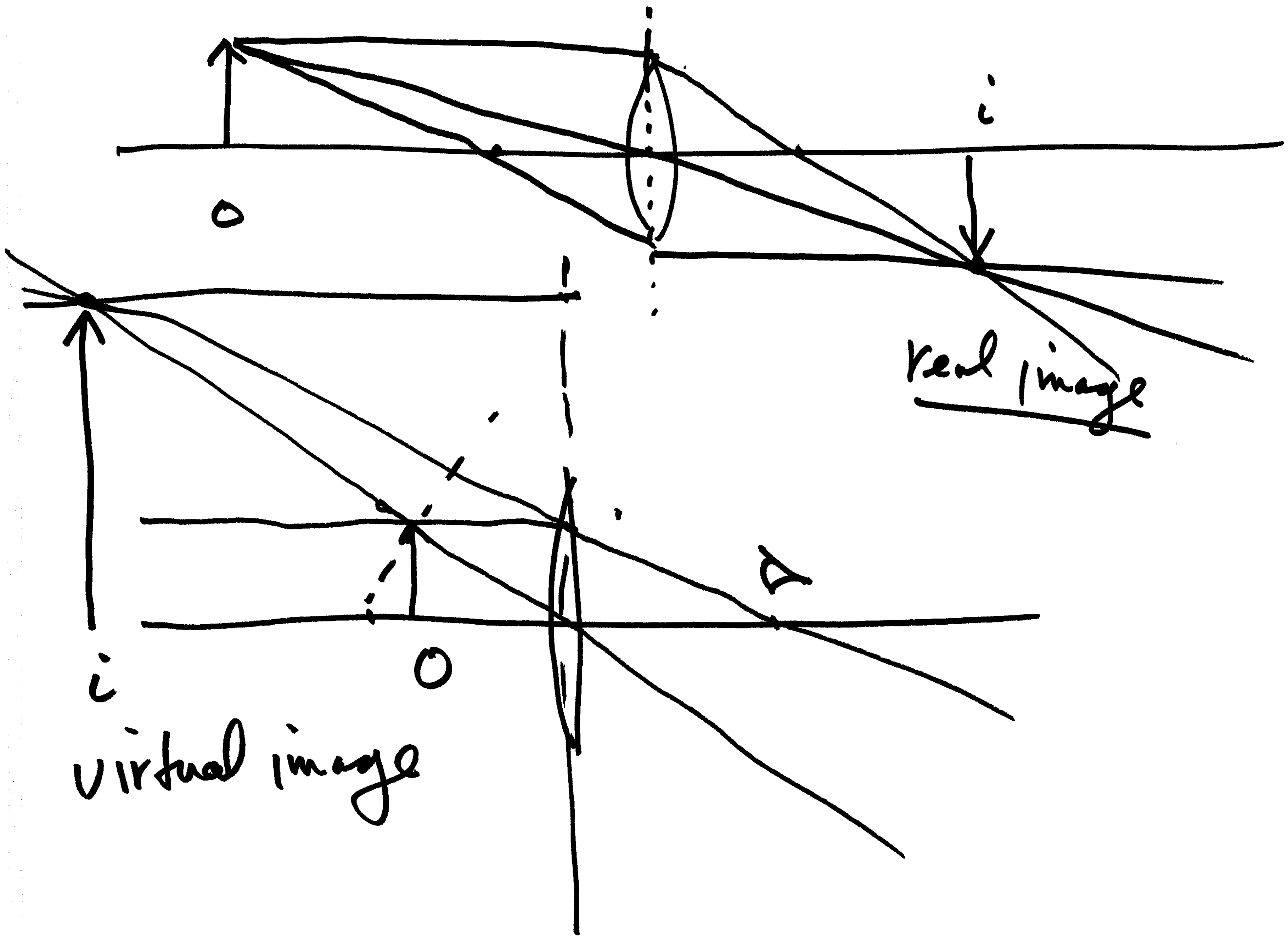
$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$



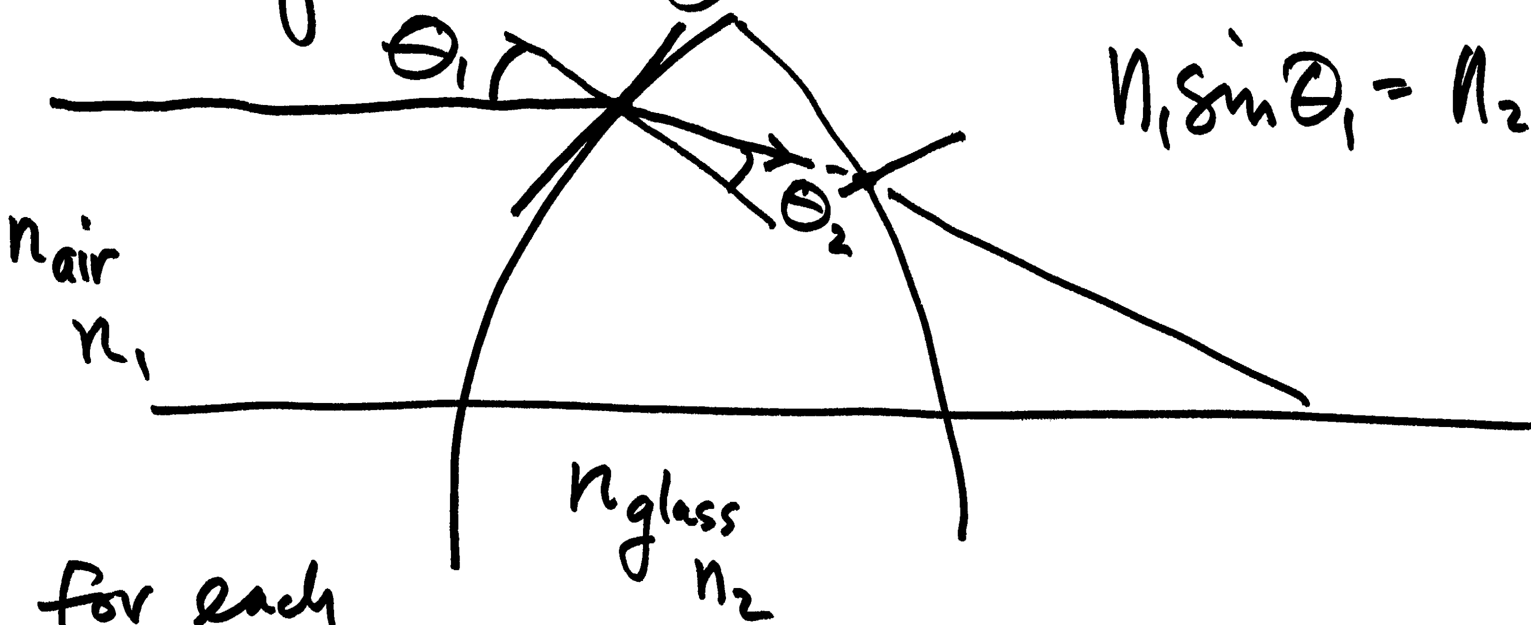

rear exit node
front or entrance node
focal length or principal distance
$X_L Y_L Z_L$

Approximate Ray Trace

1. ray enters from left parallel to optical axis, emerge through opposite focal point
2. ray through center of lens is undeviated
3. ray through near focal point emerges parallel to optical axis


o
i
real image
i
o
virtual image

Rigorous Ray Trace, Refractive Optics (lenses)



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

for each surface

1. equation of ray
2. intersection with surface
3. determine surface normal
4. ray & normal – incidence angle
5. apply Snell's law
6. apply θ_2 to normal direction $\Rightarrow$ refracted ray
7. go back to 1

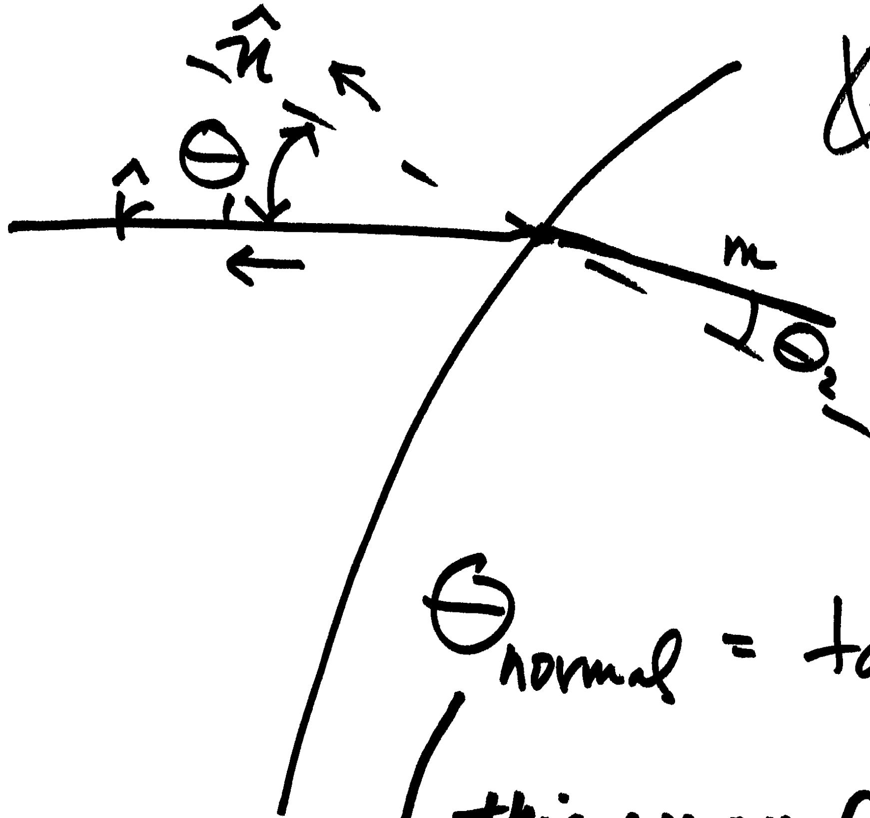
$$y = mx + b$$

$$r^2 = (x - x_c)^2 + (y - y_c)^2$$

$$\Downarrow$$

$$Ax^2 + Bx + C = 0$$

$$x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$



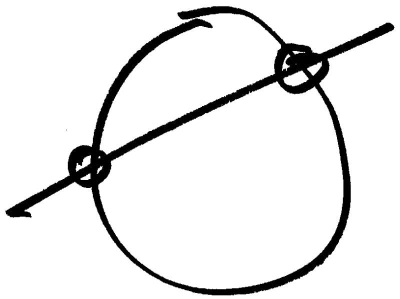
$$\cancel{|\vec{A}| \cdot |\vec{B}| =}$$

$$\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}| \cos\theta$$

$$\boxed{\hat{n} \cdot \hat{r} = \cos\theta}$$

$$\theta_{normal} = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right)$$

this $\Delta y, \Delta x$ from normal vector
n_y, n_x



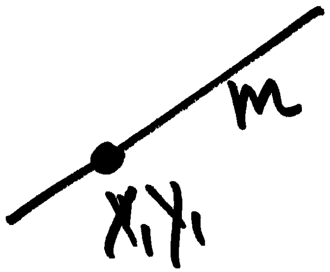
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\theta_{ref.ray} = \theta_{normal} + \theta_2$$

$$\Delta x = \cos(\theta_{ref\,ray})$$

$$\Delta y = \sin(\theta_{ref\,ray})$$

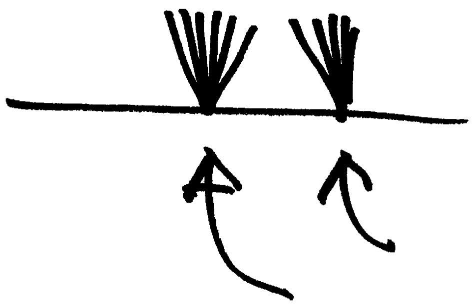
$$\text{slope} = \frac{\Delta y}{\Delta x} = m$$



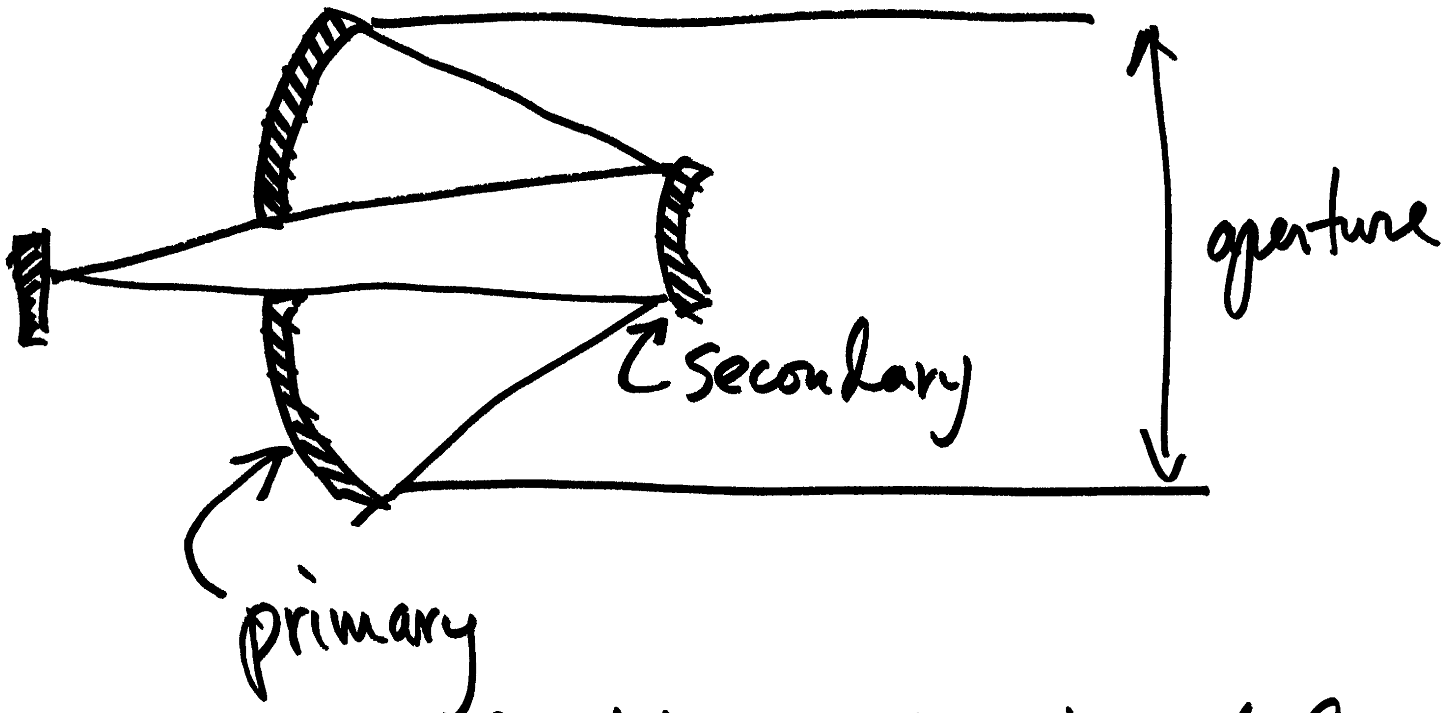
$$\frac{y - y_1}{x - x_1} = m, \qquad y = mx + (y_1 - mx_1)$$

equation of refracted ray

now, having equation of refracted ray you carry out same procedure again with the next surface ...



Rigorous Ray Trace : Reflective Optics (Mirrors)



newton:
prim : parabola
sec : plane

cassegrain :
prim : parabola
sec : hyperbola

ritchey-chretien prim : hyperbola
sec : hyperbola

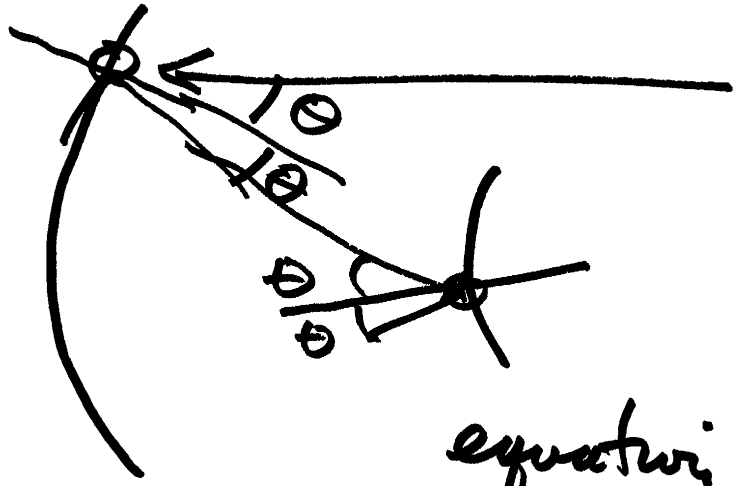
Landsat TM, HST $\pm 0.4°$ (field of view)

3 mirrors GeoEye, WV1, ...

add refractive element Schmidt telescope

SPOT

RCT: ritchey-chretien telescope

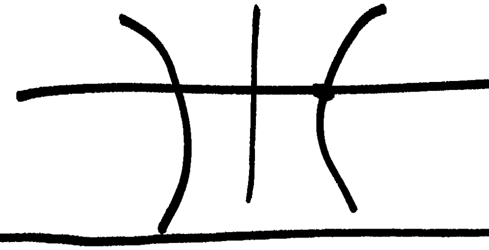


R : radius of curv. @ origin

K : conic constant, x_0 : loc

Equation for Hyp.

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$



$$\boxed{y^2 - 2R(x-x_0) + (K+1)(x-x_0)^2 = 0}$$

hyperbola equation for optics

1. intersect line with surface

$$y = mx + b$$

$$y^2 - 2R(x - x_0) + (K+1)(x - x_0)^2 = 0$$

$$x = (y - b)/m$$

either substitution (x or y) $\Rightarrow$ quadratic

x, y with quad. formula.

tangent $\begin{bmatrix} dx \\ dy \end{bmatrix}$, normal $\begin{pmatrix} dy \\ -dx \end{pmatrix}$ $\begin{pmatrix} -dy \\ dx \end{pmatrix}$

2. find surf. normal

$$y' = \frac{R - (K+1)(x - x_0)}{y}$$

implicit diff

numerical

$\Delta x : 10^{-6}$

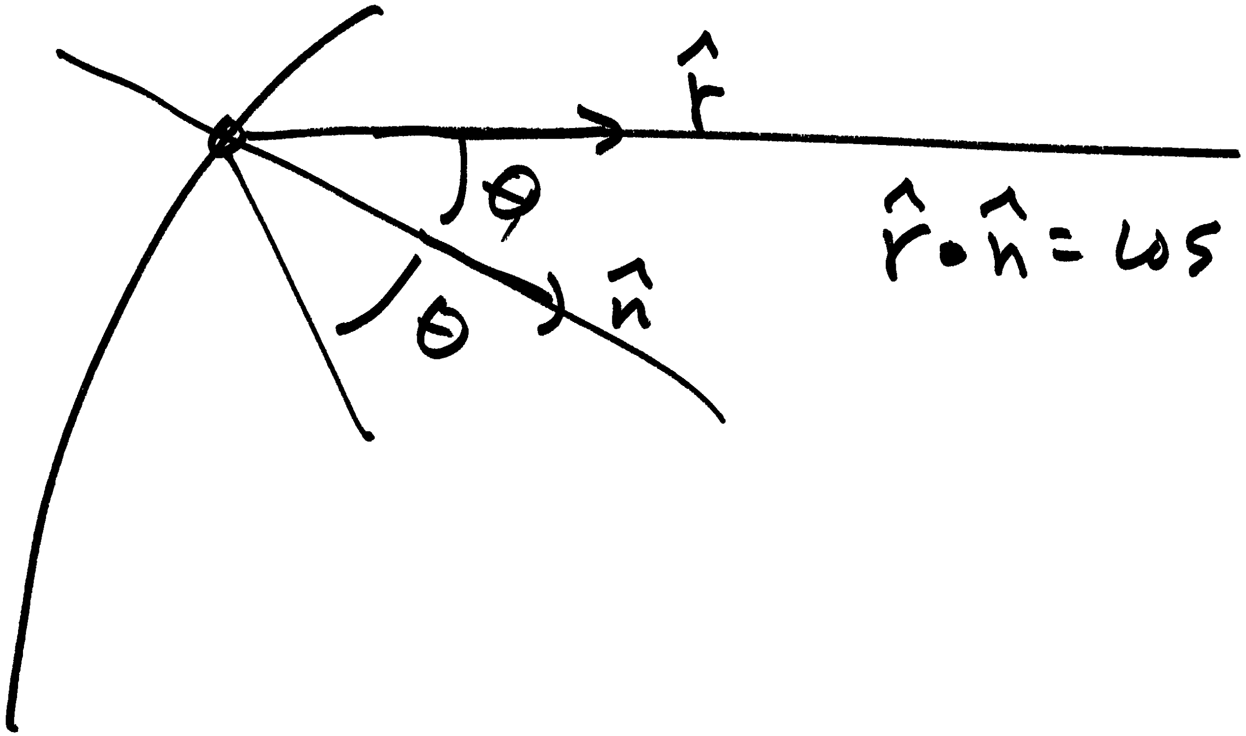
$$y' \approx \frac{\Delta y}{\Delta x}$$

obtain tangent at point either by

(1) analytical derivative

(2) numerical approximation

3. find incidence angle



$\hat{r} \cdot \hat{n} = \cos\theta$