Key Equations in Geometric Optics

Single Refractive Surface

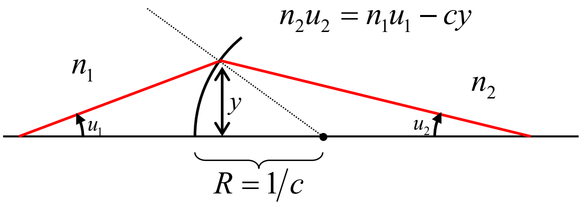
$$C = \frac{n'-n}{R} = -\frac{n}{f} = \frac{n'}{f'}$$

Thin Lens Equations

$$C = -\frac{n}{f} = \frac{n'}{f'} = \underbrace{\frac{N-n}{R_1} + \frac{n'-N}{R_2}}_{\text{General}} = \underbrace{(N-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}_{\text{Thin Lens in Air}}$$

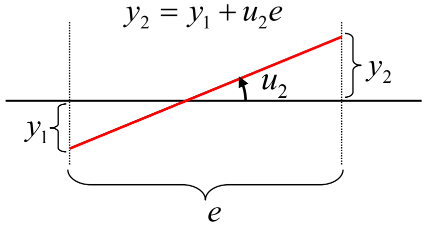
Paraxial Refraction

$$n_2 u_2 = n_1 u_1 - cy$$



Paraxial Transfer

$$y_2 = y_1 + u_2 e$$



Gaussian Systems

$$\frac{n'}{x'} = \frac{n}{x} + \frac{n'}{f'} \qquad m_y = \frac{y'}{y} = -\frac{f}{\overline{FA}} = -\frac{\overline{F'A'}}{f'} \qquad ny\alpha = n'y'\alpha' \qquad m_y = \frac{y'}{y} = \frac{x'}{x}\frac{n}{n'} \qquad m_\alpha = \frac{\alpha'}{\alpha} = -\frac{x}{x'}$$

Gaussian Association

$$C = C_1 + C_2 - \frac{d}{n_2}C_1C_2 = -\frac{\Delta}{n_2}C_1C_2 \qquad \overline{P_1P} = d\,\frac{n_1}{n_2}\frac{C_2}{C} \qquad \overline{P_2'P'} = -d\,\frac{n_3}{n_2}\frac{C_1}{C} \qquad d = \overline{P_1'P_2} \qquad \Delta = \overline{F_1'F_2}$$

$$f = -\frac{n_1}{C} \qquad f' = \frac{n_3}{C} \qquad \overline{F_1F} = \underbrace{\frac{f_1^2}{f_1 + f_1' - \Delta}}_{\text{Most General}} = \underbrace{-\frac{f_1^2}{\Delta}}_{n\text{ same}} \qquad \overline{F_2'F'} = \underbrace{\frac{f_2'^2}{\Delta - f_2 - f_2'}}_{\text{Most General}} = \underbrace{\frac{f_2'^2}{\Delta}}_{n\text{ same}}$$

Afocal Systems

$$m_y = \frac{h_2}{h_1} = -\frac{f_2'}{f_1'} \qquad m_\alpha = \frac{\alpha'}{\alpha} = -\frac{f_1'}{f_2'} = \frac{1}{m_y}$$

Stigmatic Imaging

$$n_1\overline{AI} + n_2\overline{IA'} = k$$

* Aplanetic Points

$$x = R\left(1 + \frac{n_2}{n_1}\right) \qquad x' = R\left(1 + \frac{n_1}{n_2}\right)$$

	Mirror Surface	Refractive Surface $n_1 > n_2$	Refractive Surface $n_1 < n_2$
Infinite Object:	Parabolic	Hyperbolic	Elliptical
Both real or virtual:	Elliptical	Spherical	Spherical
One real, other virtual:	Hyperbolic	* Spherical	* Spherical

Eccentricity
Object at Infinity

$$e = \frac{|IF'|}{|IH|} = \left|\frac{n_1}{n_2}\right|$$

e<1: Elliptical
e=1: Parabolic
e>1: Hyperbolic

Aberrations

Defocus	$W_{020} \cdot \rho^2$	
Tilt	$W_{111} \cdot r\,\rho\,\cos\phi$	
Spherical	$W_{040} \cdot \rho^4$	$W_{040} = \frac{1}{8}S_I$
Coma	$W_{131} \cdot r\,\rho^3\cos\phi$	$W_{131} = \frac{1}{2}S_{II}$
Astigmatism	$W_{222} \cdot r^2\rho^2\cos^2\phi$	$W_{222} = \frac{1}{2}S_{III}$
Field Curvature	$W_{220} \cdot r^2\rho^2$	$W_{220P} = \frac{1}{4}S_{IV}$
Distortion	$W_{311} \cdot r^3\rho\,\cos\phi$	$W_{311} = \frac{1}{2}S_V$

$r \equiv$ Normalized Height at Entrance Pupil
$\rho \equiv$ Normalized Height at Object/Image Plane
$\phi \equiv$ Azimuth of Ray at Entrance Pupil
$W_{\ell mn} \equiv$ Magnitude of Wavefront Aberration

$$S_I = -\sum_{\substack{\text{All}\\\text{Surfaces}}} y_i A_i \Delta\left(\frac{u_i}{n_i}\right) \qquad S_{IV} = -\sum_{\substack{\text{All}\\\text{Surfaces}}} M^2 c_i \Delta\left(\frac{1}{n_i}\right)$$

$$S_{II} = -\sum_{\substack{\text{All}\\\text{Surfaces}}} y_i A_i \overline{A}_i \Delta\left(\frac{u_i}{n_i}\right) \qquad S_V = \sum_{\substack{\text{All}\\\text{Surfaces}}} \frac{\overline{A}_i}{A_i}\left[(S_{III})_i + (S_{IV})_i\right]$$

$$S_{III} = -\sum_{\substack{\text{All}\\\text{Surfaces}}} y_i \overline{A}_i^2 \Delta\left(\frac{u_i}{n_i}\right)$$