PHYS 3038 Optics
L7 More on Geometrical Optics
Reading Material: Ch6.1-6.2

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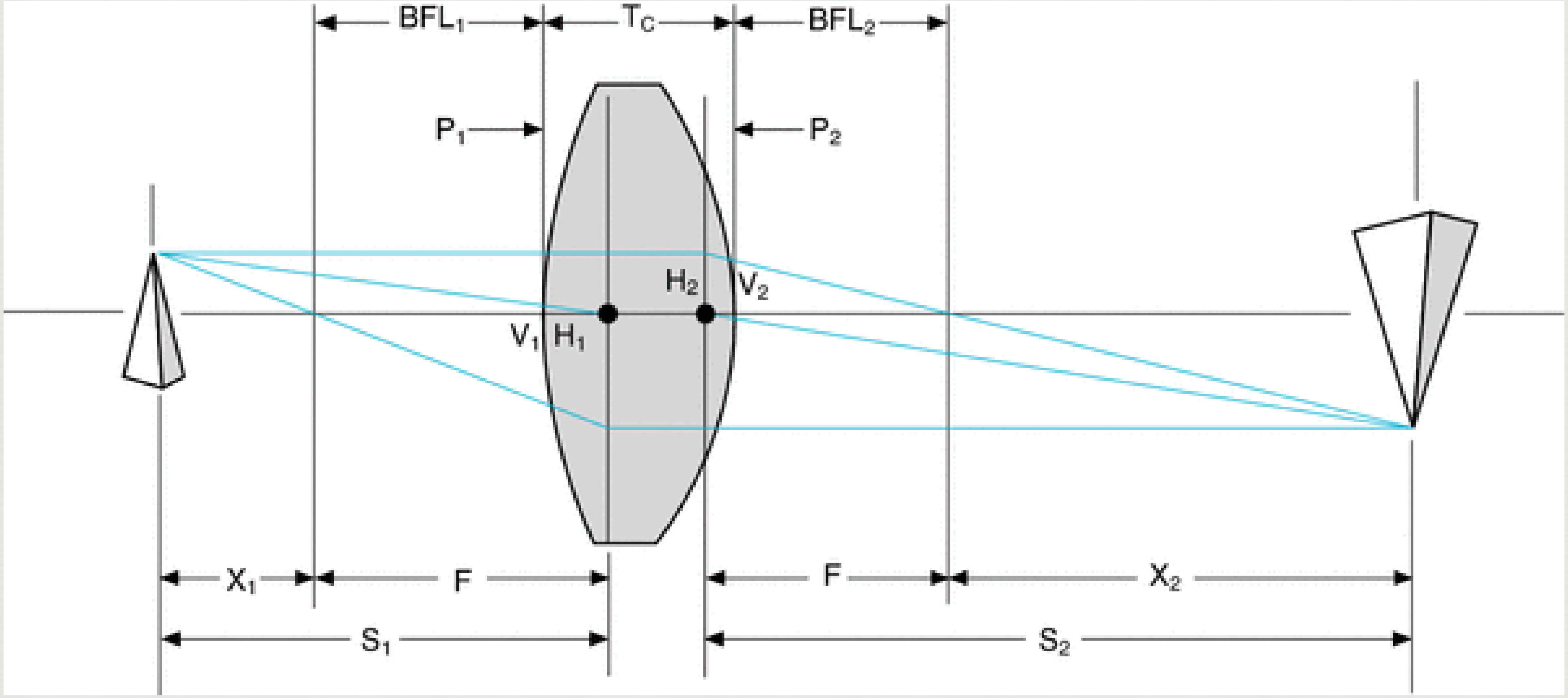
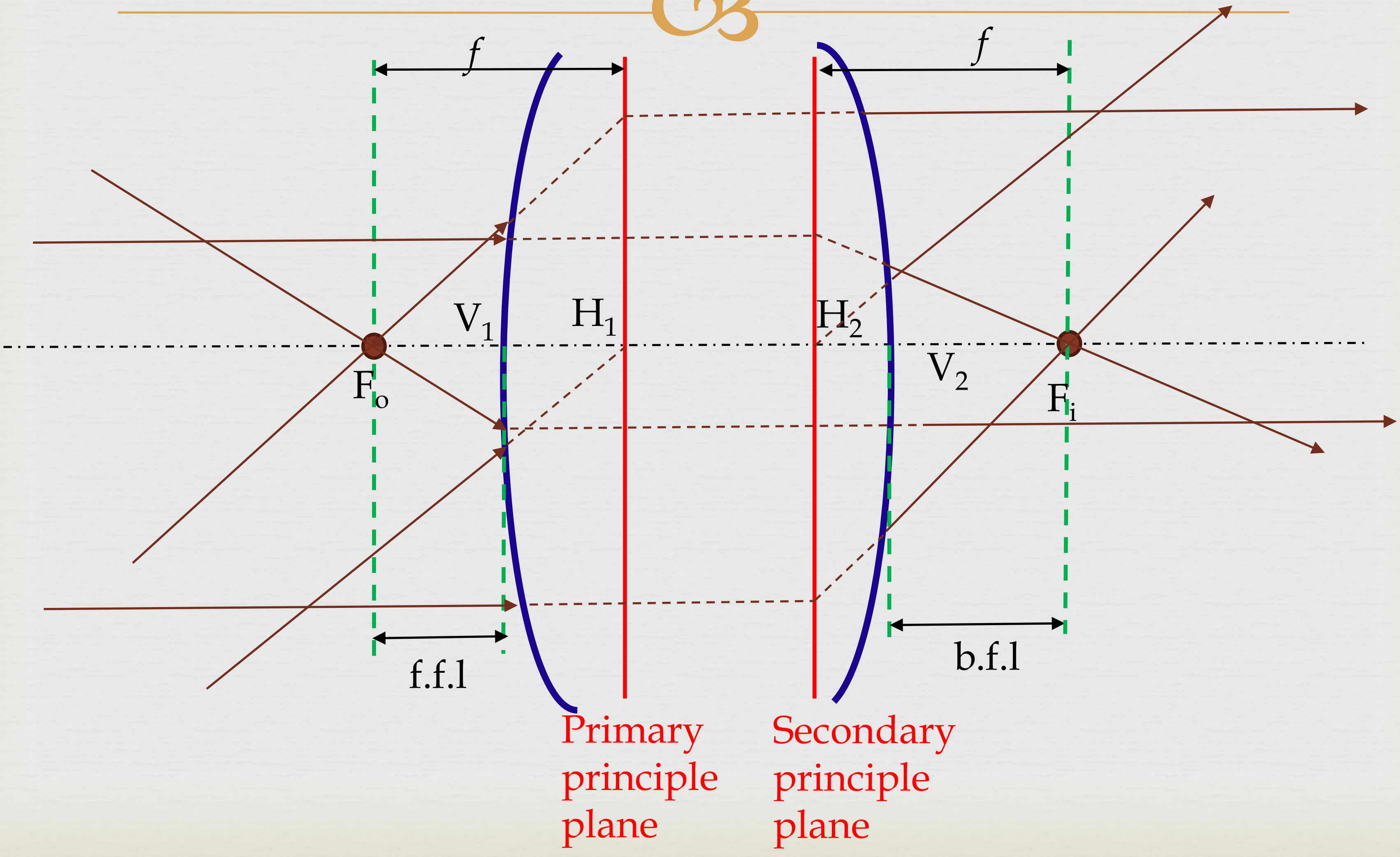
2015, the Year of Light

6.1 Thick Lenses



Lens Systems

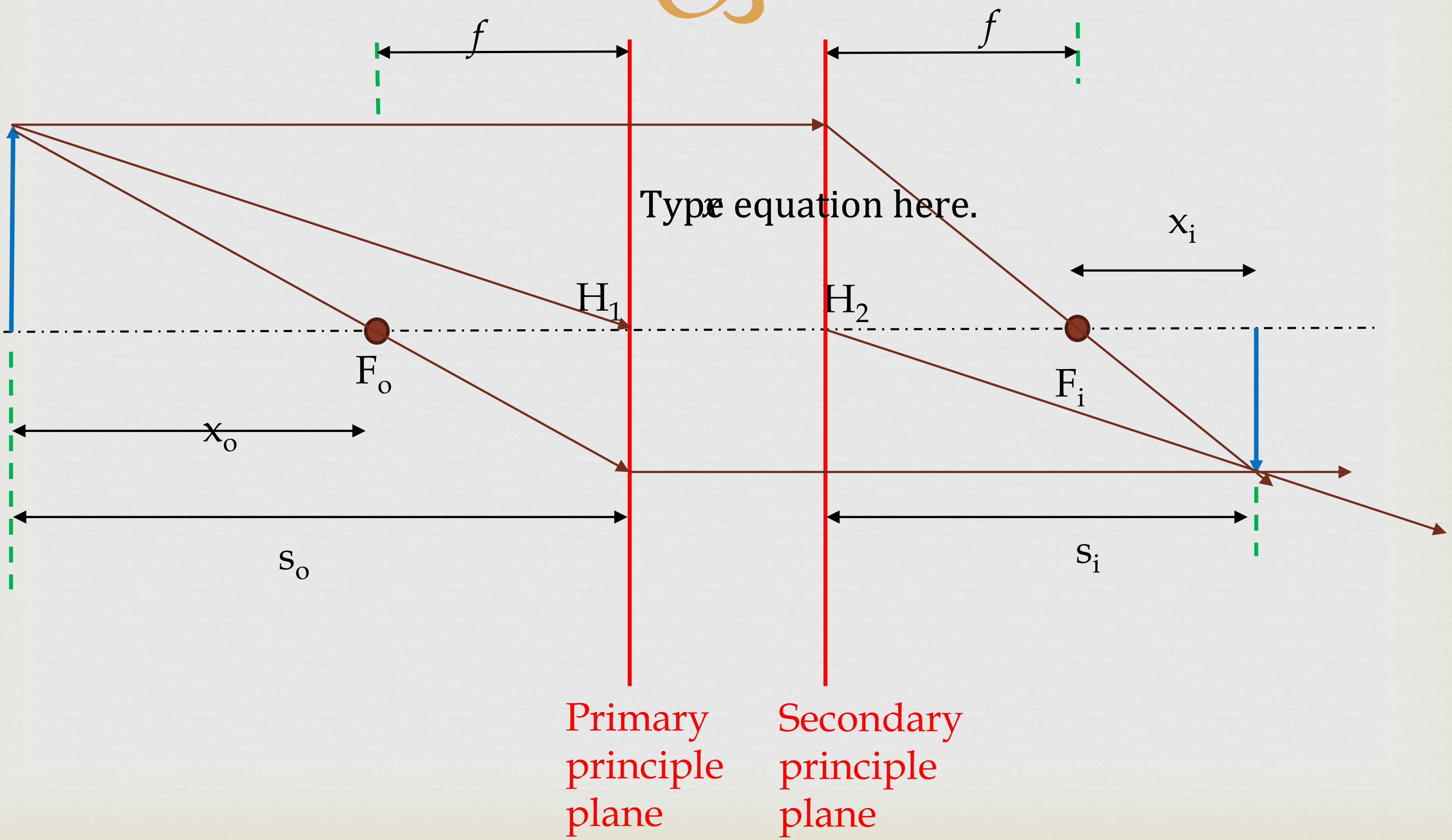
Principal Planes



$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$$

Imageing

$$x_o x_i = f^2$$



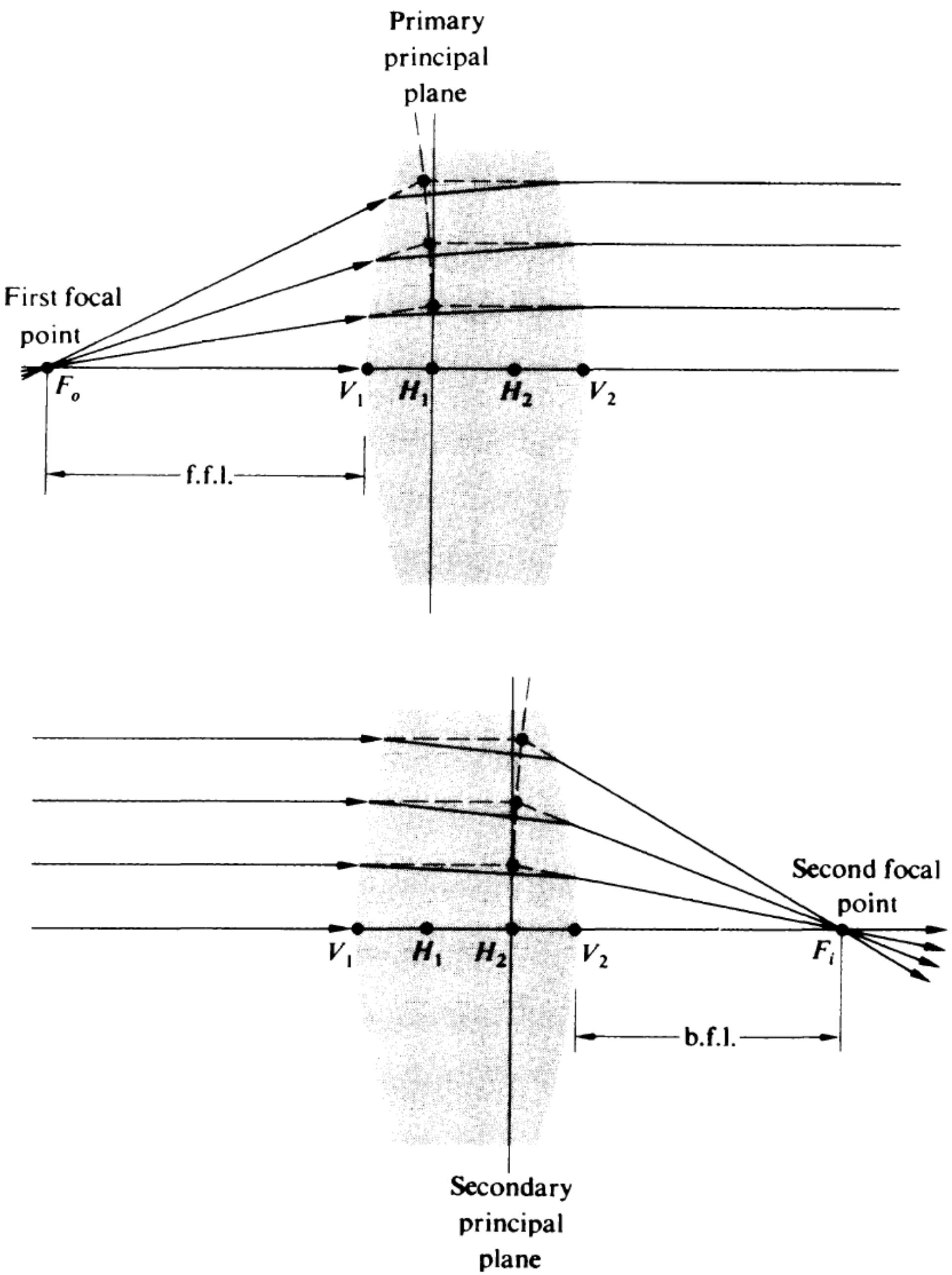
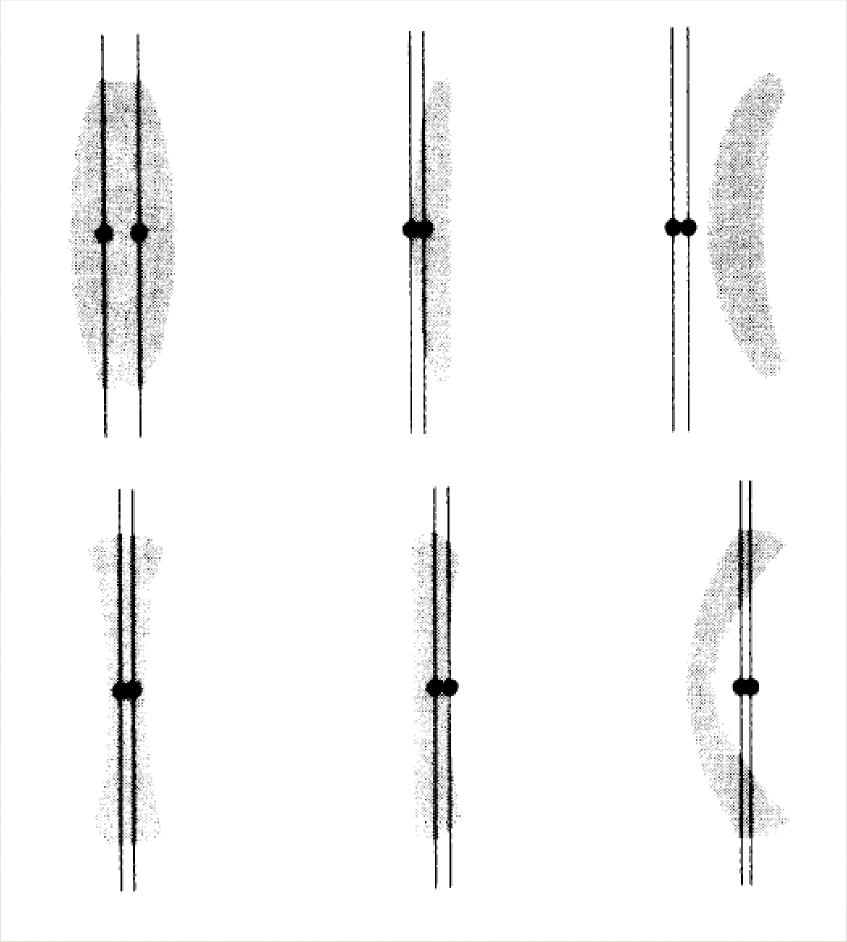


Figure 6.1 A thick lens.

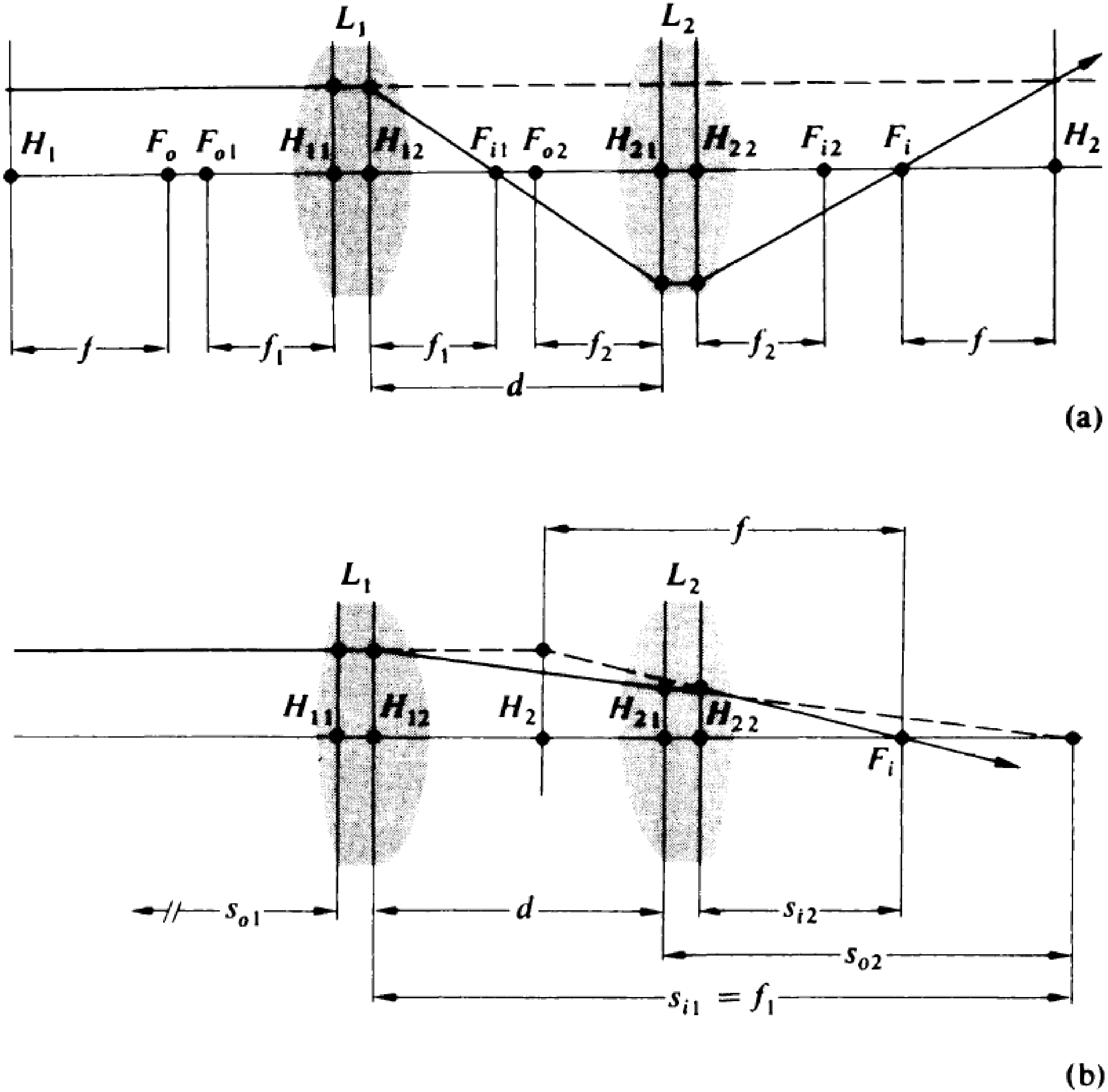
Thick Lens

$$\frac{1}{f} = (n_l - 1)\left[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n_l - 1)d_l}{n_l R_1 R_2}\right]$$

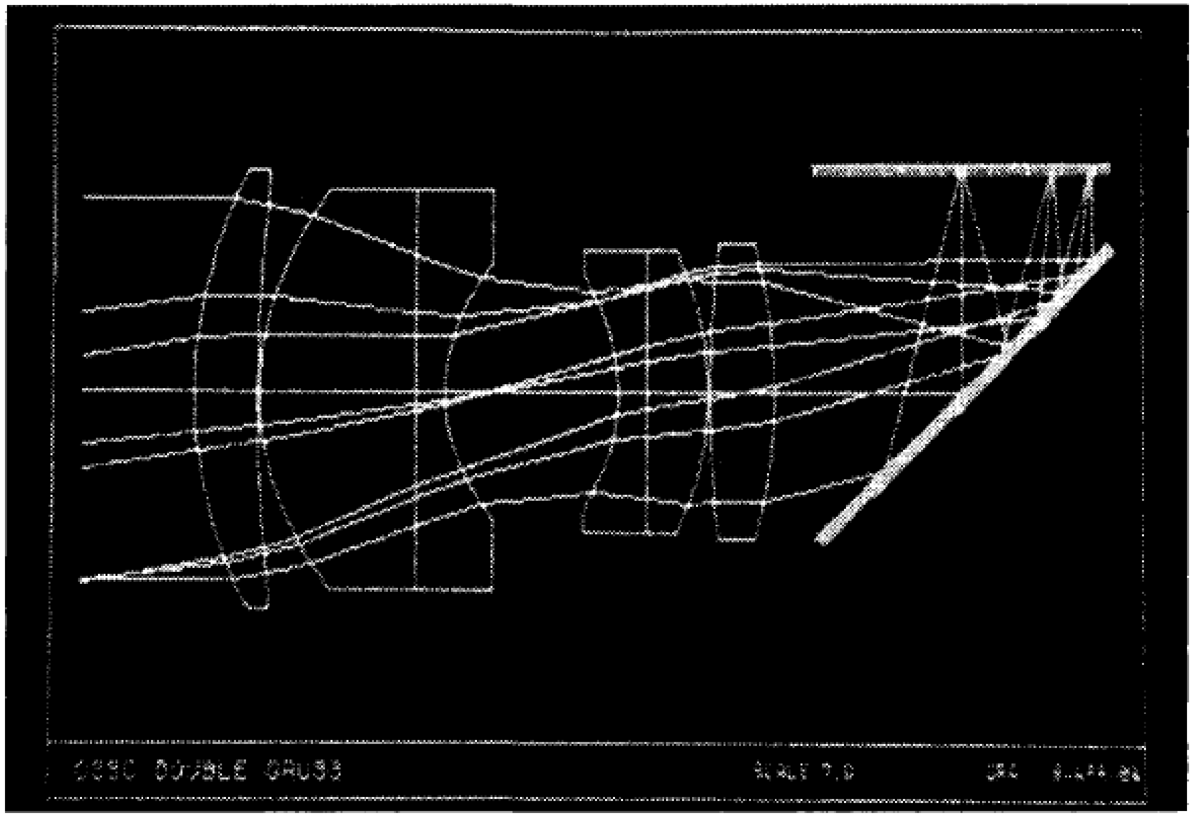
Lens Bending



A Compound Thick Lens



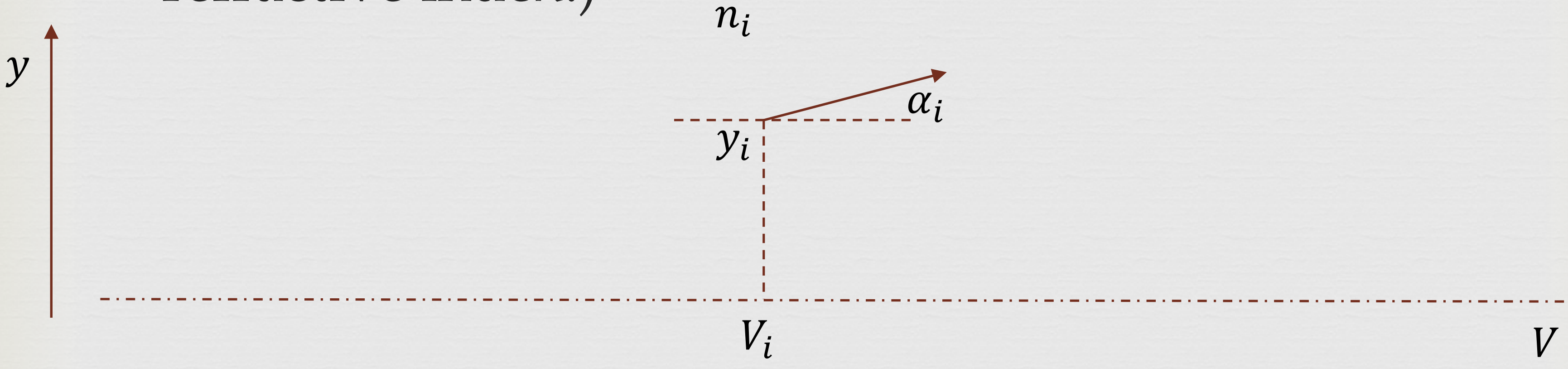
6.2 Analytical Ray Tracing



Computer ray tracing. (Photo courtesy of Optical Research Associates, Pasadena, California.)

Description of a Ray

- Position (height): y
- Direction: α (we use nα to represent it, where n is the refractive index.)



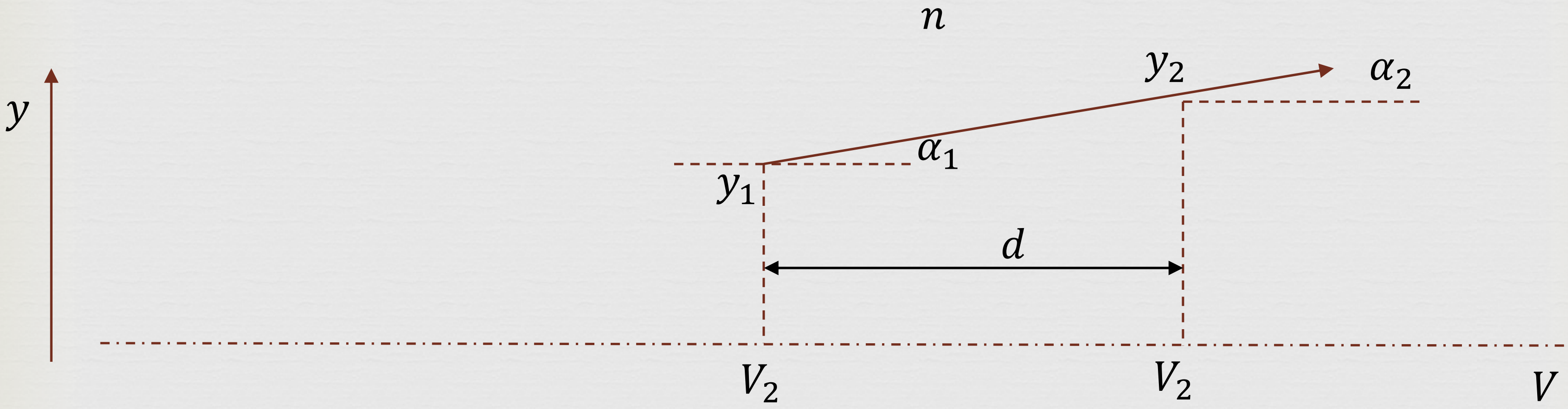
Ray vector $$\vec{r}_i = \begin{bmatrix} n_i\alpha_i \\ y_i \end{bmatrix}$$

Paraxial condition:
$\alpha \approx \sin\alpha \approx \tan\alpha$

Free Space

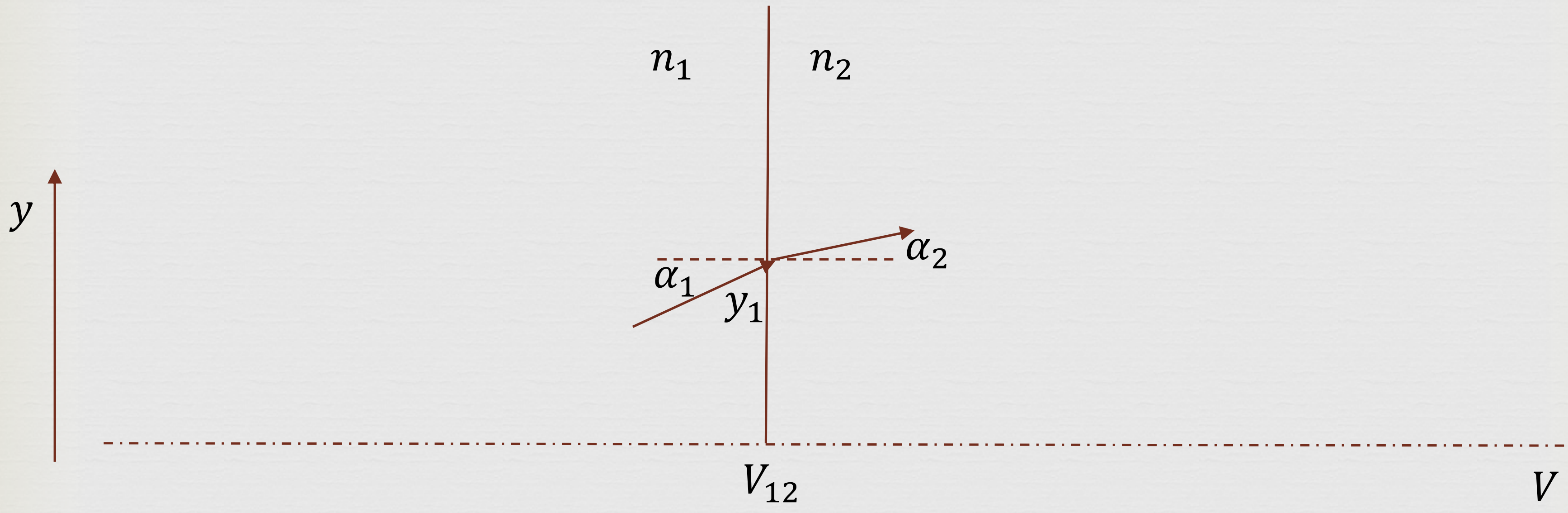
Paraxial condition:

$$\alpha \approx \sin\alpha \approx \tan\alpha$$



$$\vec{r}_2 = T(d/n)\vec{r}_1 \qquad T(d/n) = \begin{bmatrix} 1 & 0 \\ d/n & 1 \end{bmatrix}$$

Refraction on a vertical surface

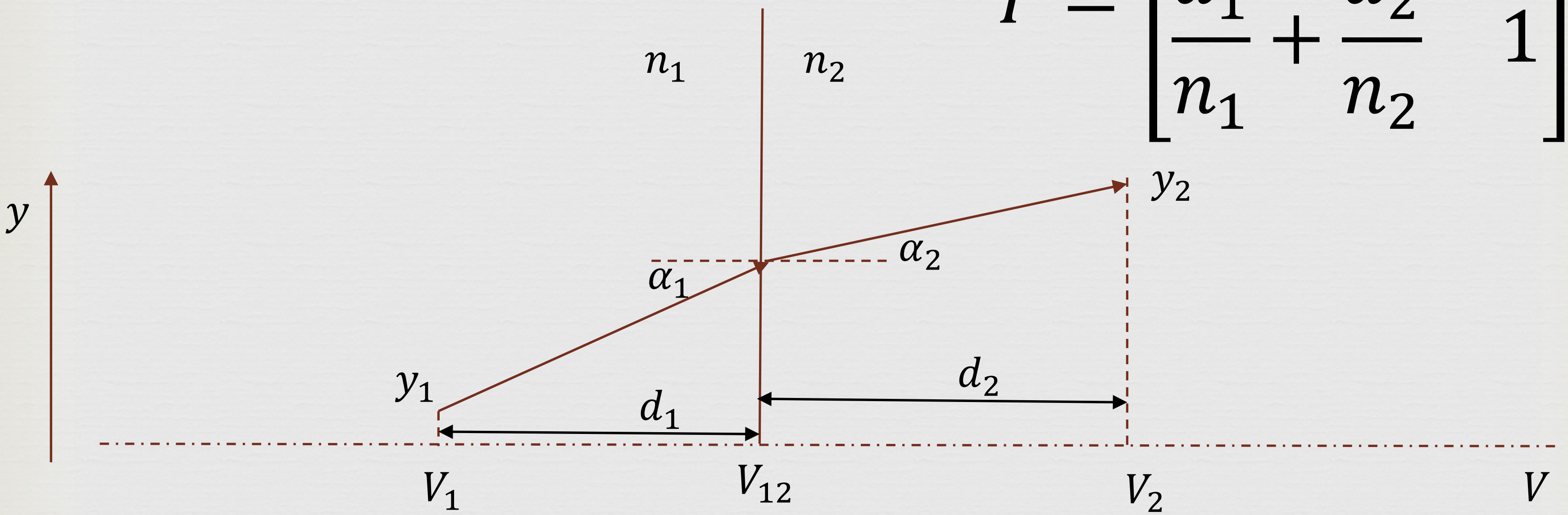


$$\vec{r}_2 = I\vec{r}_1 = \vec{r}_1$$

$$T(d, n) = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

Propagation from n1to n2

$$T = \begin{bmatrix} 1 & 0 \\ \frac{d_1}{n_1} + \frac{d_2}{n_2} & 1 \end{bmatrix}$$

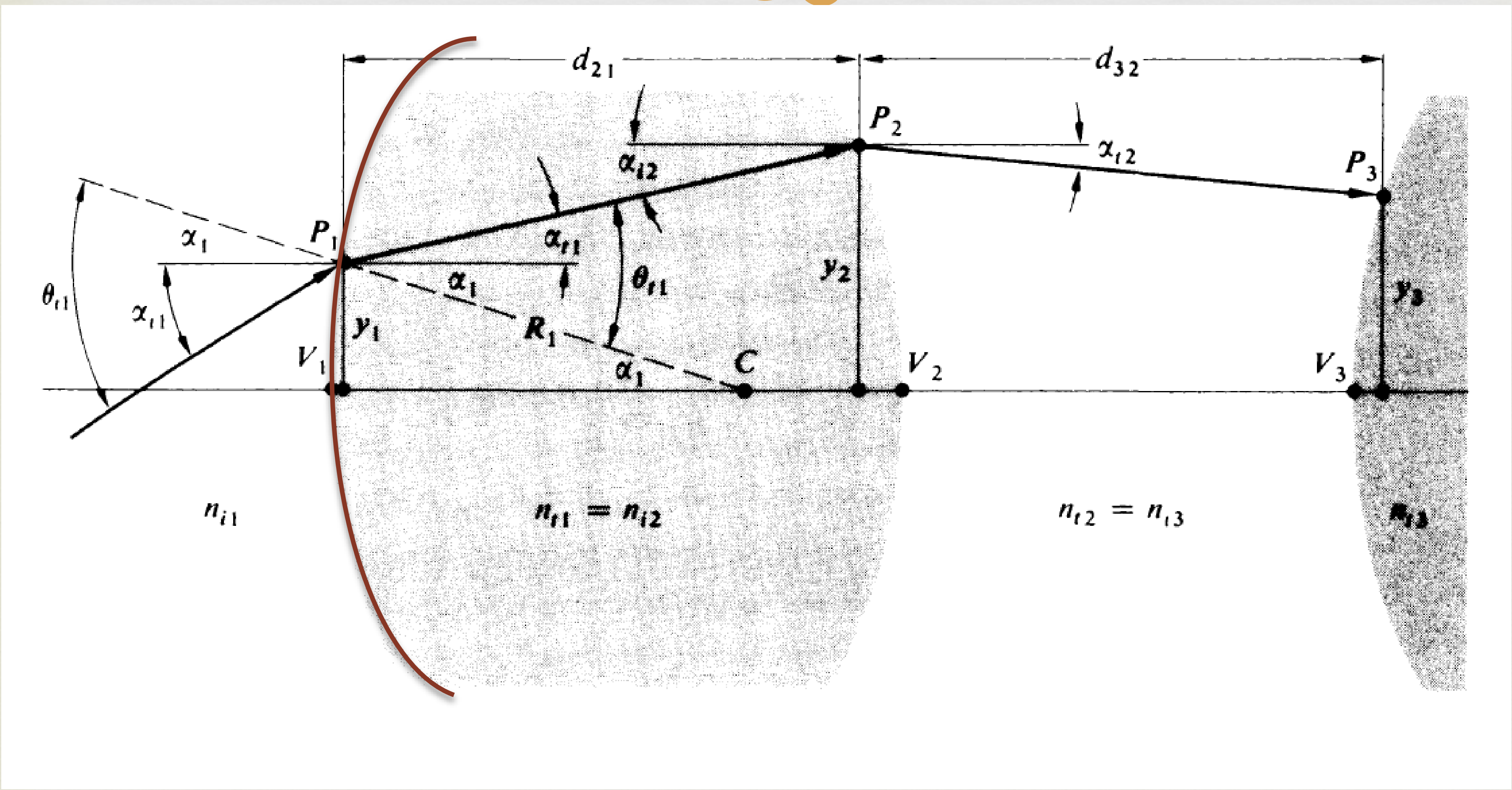


$$\vec{r}_2 = T(\frac{d_2}{n_2})T(\frac{d_1}{n_1})\vec{r}_1 = T(\frac{d_1}{n_1} + \frac{d_2}{n_2})\vec{r}_1$$

Spherical Surface

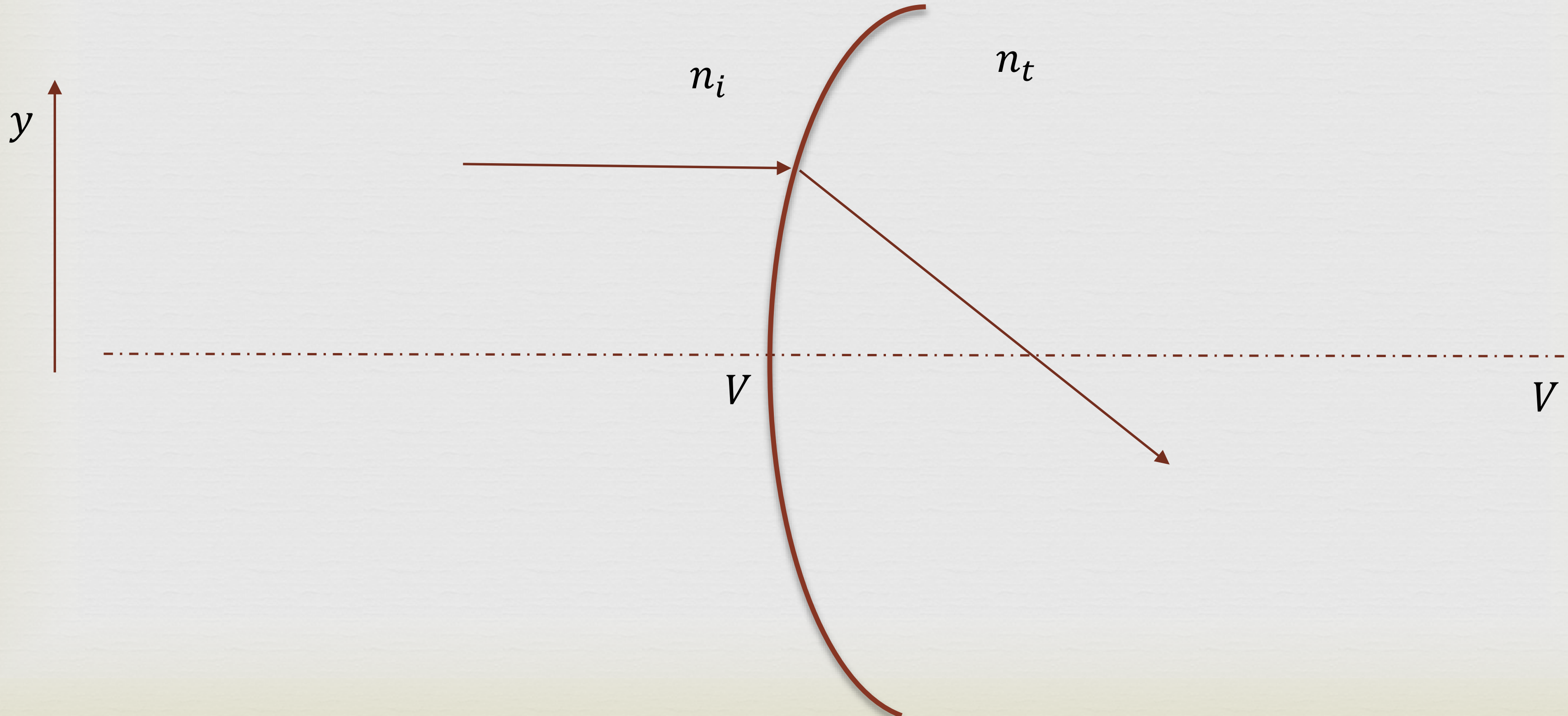
Refraction Matrix $R = \begin{bmatrix} 1 & -D \\ 0 & 1 \end{bmatrix}$

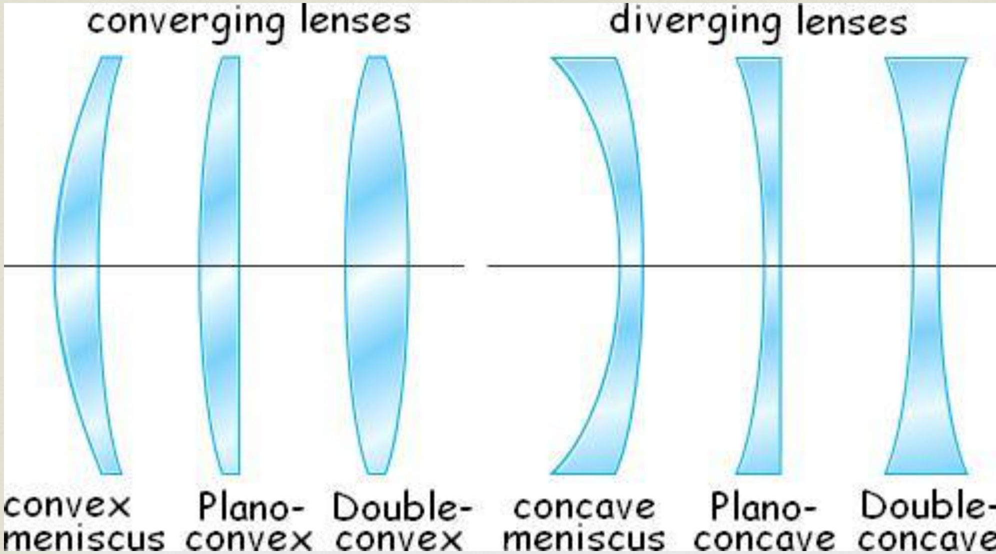
$D = \frac{n_t - n_i}{R}$



Refaction + Propagation

$$f_t = \frac{n_t}{n_t - n_i} \mathrm{R}$$





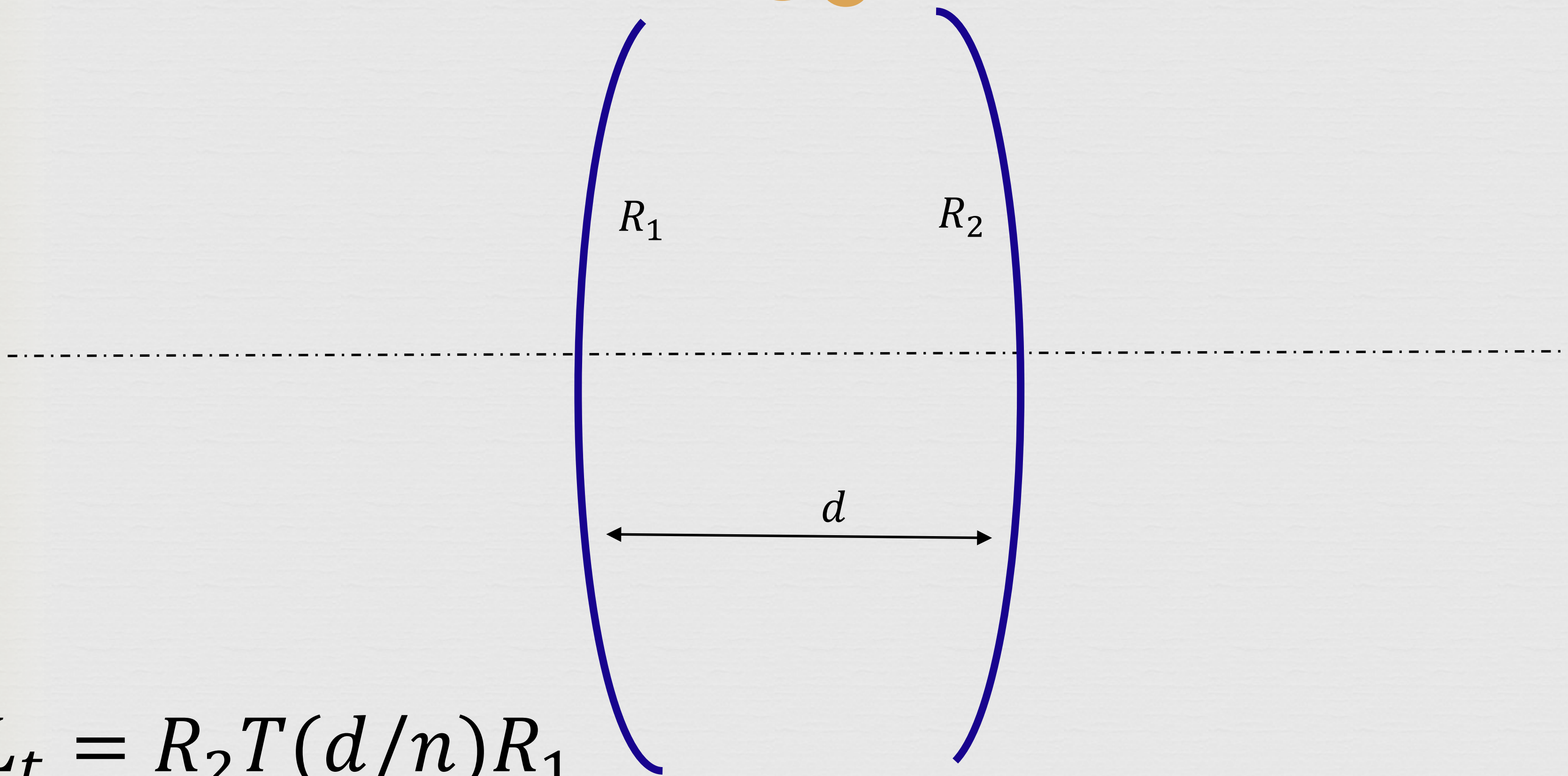
Thin Lens

$$D=\frac{n_t-n_i}{R}$$

$$\mathrm{L}=R_2R_1=\begin{bmatrix}1 & -(D_1+D_2)\\0 & 1\end{bmatrix}=\begin{bmatrix}1 & -1/f\\0 & 1\end{bmatrix}$$

$$\frac{1}{f}=D_1+D_2=\frac{n_l-1}{R_1}+\frac{1-n_l}{R_2}=(n_l-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

Thick Lens



$$L_t = R_2 T(d/n) R_1$$

Image Geometry

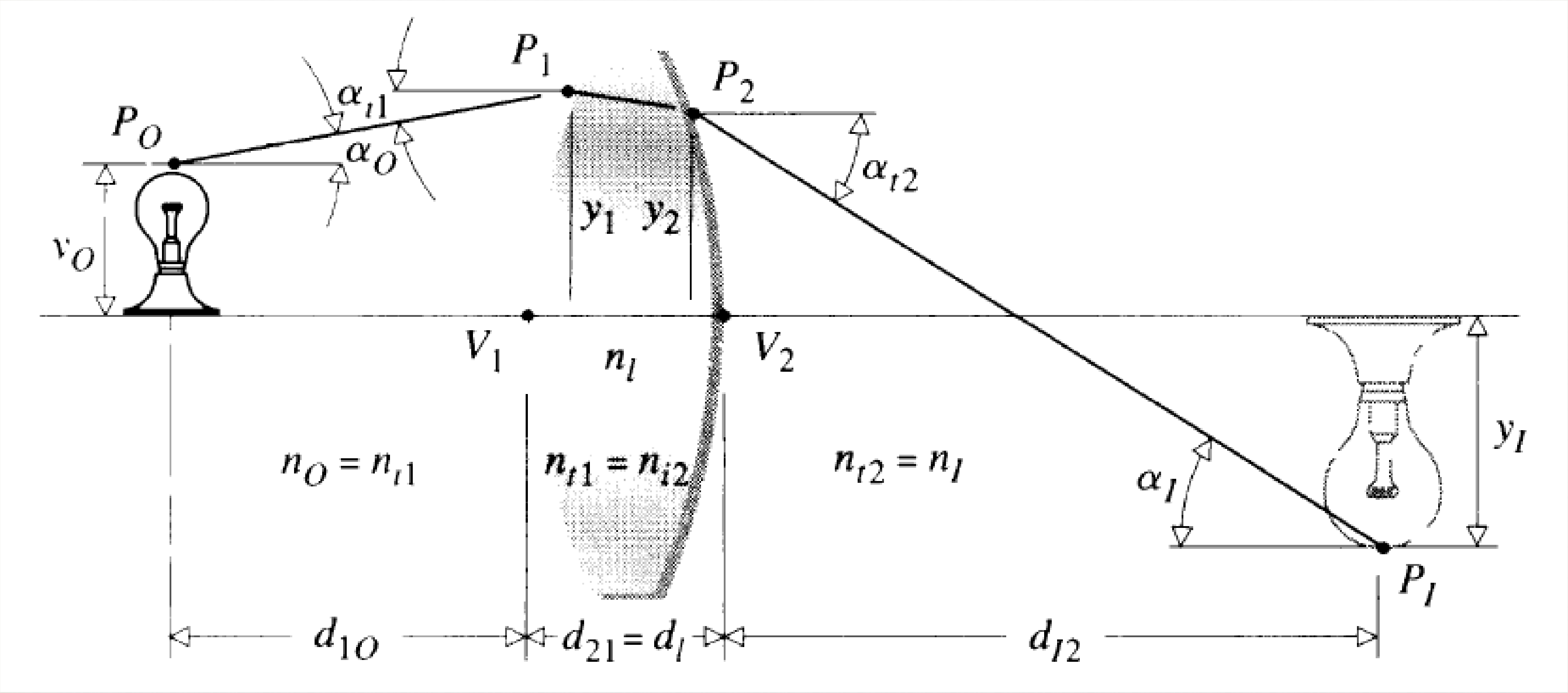
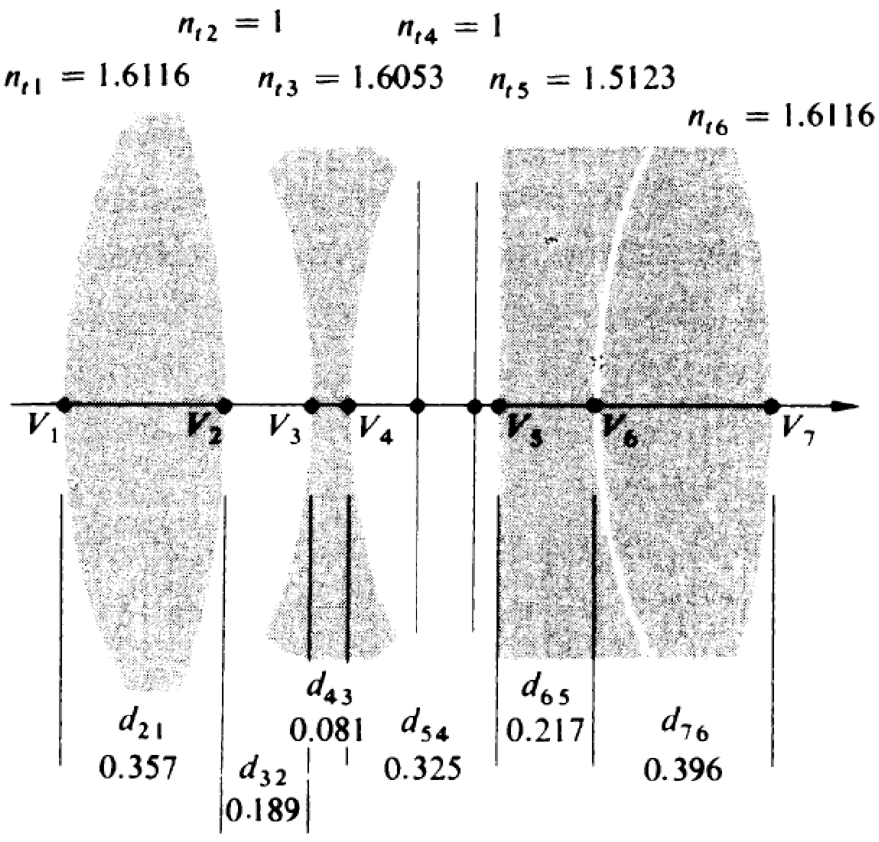


Image condition: y_i is independent of α_o

$$\vec{r}_i = T\left(\frac{d_{I2}}{n_I}\right) L_t T\left(\frac{d_{1o}}{n_o}\right) \vec{r}_1$$

Lens Combination



$R_1 = 1.628$
$R_2 = -27.57$
$R_3 = -3.457$
$R_4 = 1.582$

$R_5 = \infty$
$R_6 = 1.920$
$R_7 = -2.400$

Mirror

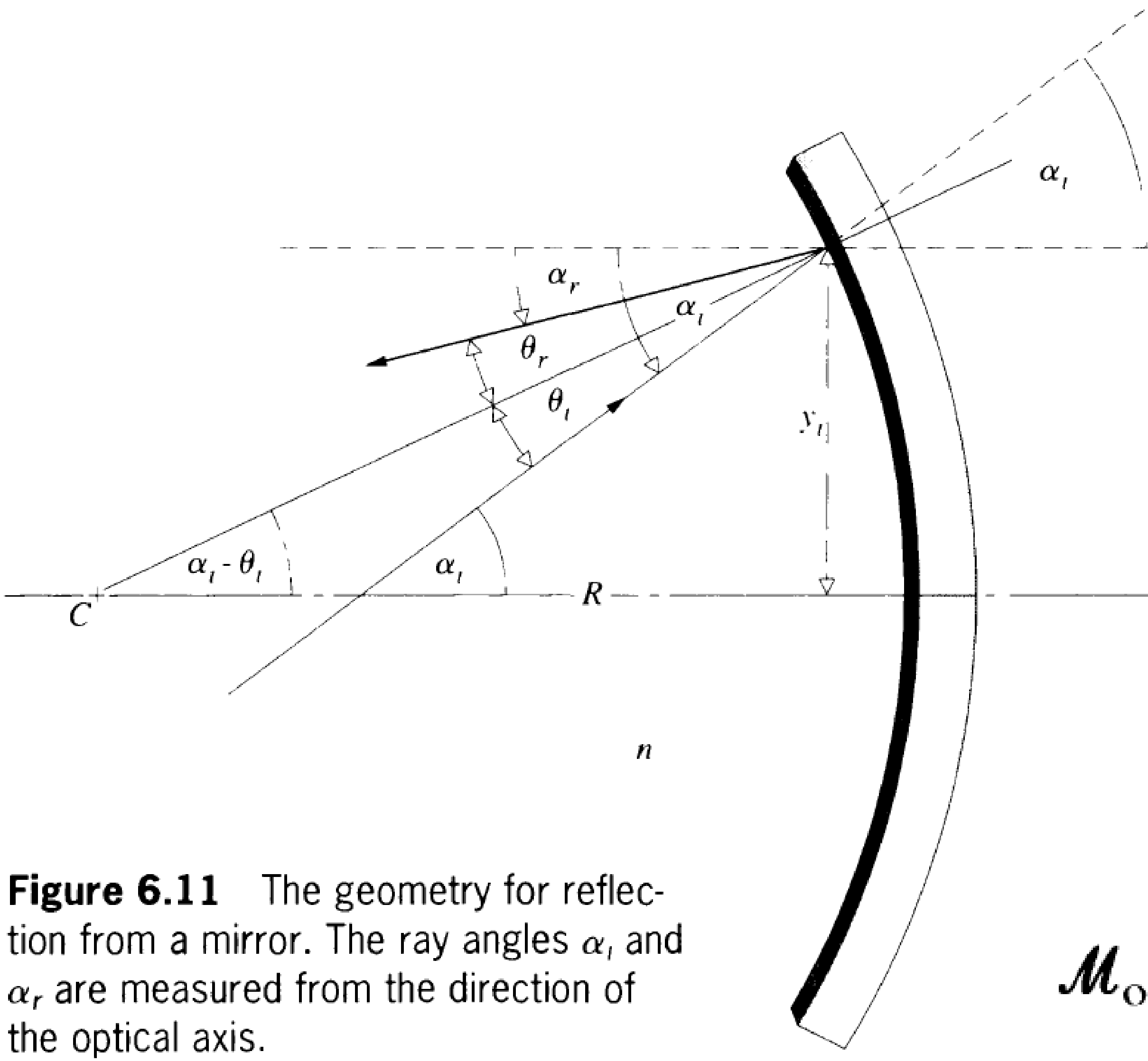


Figure 6.11 The geometry for reflection from a mirror. The ray angles α_i and α_r are measured from the direction of the optical axis.

$$f = -2/R.$$

$$\mathcal{M}_o = \begin{bmatrix} -1 & -2n/R \\ 0 & 1 \end{bmatrix}$$