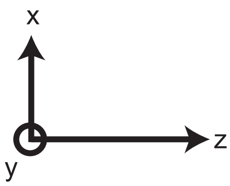
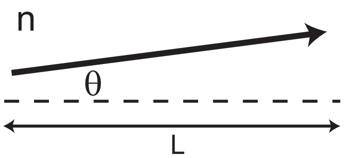
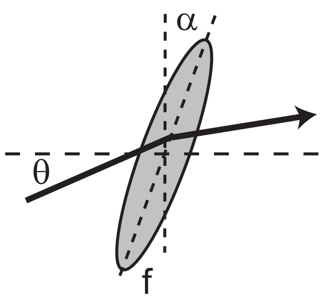


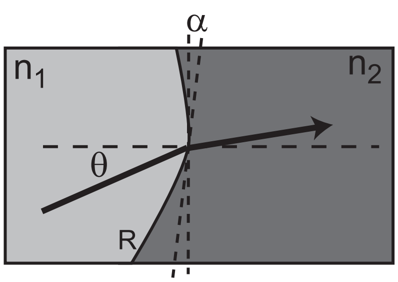
tangential (x-z) | sagittal (y-z)



$$\mathbf{M}_\mathrm{l} = \begin{pmatrix} 1 & l \\ 0 & 1 \end{pmatrix} \qquad \mathbf{M}_\mathrm{l} = \begin{pmatrix} 1 & l \\ 0 & 1 \end{pmatrix}$$

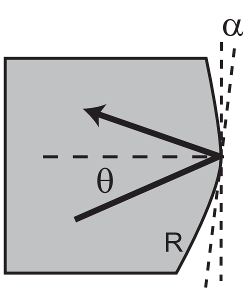


$$\mathbf{M}_\mathrm{lens,t} = \begin{pmatrix} 1 & 0 \\ \frac{-1}{f\cos\alpha} & 1 \end{pmatrix} \qquad \mathbf{M}_\mathrm{lens,s} = \begin{pmatrix} 1 & 0 \\ \frac{-\cos\alpha}{f} & 1 \end{pmatrix}$$



$$\mathbf{M}_\mathrm{tran,t} = \begin{pmatrix} \frac{\sqrt{n_r^2-\sin^2\alpha}}{n_r\cos\alpha} & 0 \\ \frac{\cos\alpha-\sqrt{n_r^2-\sin^2\alpha}}{R\cos\alpha\sqrt{n_r^2-\sin^2\alpha}} & \frac{\cos\alpha}{\sqrt{n_r^2-\sin^2\alpha}} \end{pmatrix}$$

$$\mathbf{M}_\mathrm{tran,s} = \begin{pmatrix} 1 & 0 \\ \frac{\cos\alpha-\sqrt{n_r^2-\sin^2\alpha}}{Rn_r} & \frac{1}{n_r} \end{pmatrix}$$



$$\mathbf{M}_\mathrm{refl,t} = \begin{pmatrix} 1 & 0 \\ \frac{-2}{R\cos\alpha} & 1 \end{pmatrix} \qquad \mathbf{M}_\mathrm{refl,s} = \begin{pmatrix} 1 & 0 \\ \frac{-2\cos\alpha}{R} & 1 \end{pmatrix}$$

Ray matrices in the tangential and sagittal planes.
The relative refractive index is $n_r = n_2/n_1$.

M. Saffman 2011.02.21