Geometrical Optics Review
Phys 375

Mirrors
Spherical mirror – a section of a sphere
Principal Axis – A line drawn from the center of the sphere (C) to the center of the spherical segment. Note that C is a distance R from the spherical segment.

\[
\begin{align*}
C & \quad R \\
& \quad f
\end{align*}
\]

Rays from infinity parallel to the principal axis all go through the focal point, f.

An object a distance \(s_O\) in front of the mirror will create an image a distance \(s_i\) from the mirror according to:

\[
\frac{1}{s_O} + \frac{1}{s_i} = \frac{1}{f}
\]

where \(f\) is the focal length of the mirror: \(f = R/2\), where \(R\) is the radius of curvature of the spherical mirror. The lateral magnification is \(M = -s_i/s_O\). \(M < 0\) means that the image is inverted, \(M > 0\) means that the image is upright.

Whenever light actually passes through a point, the image formed there is real. Otherwise the image is virtual (that is virtual images are formed by rays of light that appear to diverge from a point, even if they did not originate there – see below.)

Sign Convention for Mirrors:

\[
\begin{array}{c|c}
\text{Mirror Surface} & \\
\hline
\text{Front or real side} & \text{Back or virtual side} \\
\hline
s_O > 0 & s_O < 0 \\
s_i > 0 & s_i < 0
\end{array}
\]

For a concave mirror:
If the object is in front with \(s_O > f\), the image is also in front (real) but is inverted.
If the object is in front with \(s_O < f\), the image is behind (virtual) and upright.

\(f < 0\) for convex mirror
\(f > 0\) for concave mirror

Ray-tracing rules for mirrors are summarized on page 32 of P³.
Lenses

Lenses are made up of refracting spherical surfaces or flat (R → ∞ spherical) surfaces. A principal axis can also be defined for lenses, as above. The lens equation is identical to the mirror equation above!

\[ \frac{1}{s_0} + \frac{1}{s_i} = \frac{1}{f} \]

A group of rays approaching parallel to the optic axis will converge at the focal point of the lens. This defines the focal length f for the lens.

Sign Conventions:

- \( s_i > 0 \) when the image is on the opposite side of the lens from the object.
- \( s_i < 0 \) when the image is on the same side of the lens as the object.
- \( f > 0 \) for a converging lens (Thicker in the middle than at the edges)
- \( f < 0 \) for a diverging lens (Thinner in the middle than at the edges)

The lens-maker’s equation is:

\[ \frac{1}{f} = (n-1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]

where n is the index of refraction of the lens, and \( R_1 \) and \( R_2 \) are the radii of curvature of the front and back surfaces of the lens, respectively.

As before, the lateral magnification is \( M = - \frac{s_i}{s_0} \)
Some examples of ray tracing and image formation with thin lenses:

Ray-tracing rules for thin lenses are summarized on pages 36-37 of P³.