Intro to Geometrical Optics

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1 Geometrical Optics

The controlled manipulation of wavefronts (or rays) by interpositioning refecting and/or refracting bodies, neglecting any diffraction effects.

"Optics of objects much larger than wavelengths."

2 Foci

A point from which a portion of a spherical wave *diverges*, or one toward which the wave segment *converges* is known as a **focus** for a bundle of rays.

Or: rays converge to, or diverge from, a point at a focus.

3 Curved interfaces and lenses

Refracting devices that reconfigure a transmitted energy distribution.

3.1 Aspherical Surfaces

Converting spherical wavefronts to plane waves and vice versa at refracting interfaces can be done with *hyperbolic and ellipsoidal* surfaces. (figs. 5.3,4) These are known as *aspherics*. With computer-controlled lens grinding and polishing devices, they are becoming more common and important.

Practically and historically, spherical lenses dominate because small-curvature conics can be approximated by spherical surface, and because spherical surfaces are much easier to manufacture with simple equipment. Random grinding motions can be made to average to a spherical shape. Most aberrations can be controlled by careful placement of multiple spherical elements.

3.1.1 A hyperbolic refracting surface

Look at figure 5.3: For the optical path lengths in the two media we want

$$OPL_i + OPL_t = \text{constant}$$

where OPL_i is from a point, and the rays along OPL_t are parallel. This is

$$n_i(\overline{F_1A} + n_t(\overline{AD}),$$

F_1 is from focus to surface, A is on surface, D is from A to planar wavefront. Rearranging:

$$\overline{F_1A} + \left(\frac{n_t}{n_i}\right)\overline{AD} = \text{constant}.$$

This is the point-locus condition for A to be on a **hyperbola** of eccentricity $\frac{n_t}{n_i} > 1$.

If the source is in the higher index medium, an elliptical surface can produce a plane wave front exiting the medium by a similar analysis.

3.2 Convex, concave, and lens medium vs. ambient medium

For lenses of index greater than the surrounding medium:

Convex lenses bend rays toward their axis: **converging** lenses.

Concave lenses bend rays away from axis: **diverging** lenses.

If the surrounding medium has a *smaller* index, these reverse their convergence!

When a parallel bundle of rays passes through a converging (diverging) lens, a point which the rays converge toward (diverge from) is a focal point of the lens.

3.3 Real and virtual images

If a source is placed at one focal point of a converging lens, rays from it will **converge on** the other focal point. This convergence will produce a luminous **real image** on a screen placed there.

Images **from which rays diverge** are **virtual** (fig 5.5c). Made by single diverging lenses.

Hint for keeping this straight: if you see an image looking **at a screen** in an optical system—it's real. If you look **through** a system (eyepiece, etc.) you are usually looking at a virtual image.

3.4 Sign conventions for spherical surfaces and lenses.

Look at figure 5.6 and table 5.1 carefully. The table is very important! Sign errors are a problem with optical problems.