Chemeketa Community College

Ray Optics Tip Sheet

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Overview

Ray optics (also referred to as "geometric optics") is a model of light based on the assumption that light travels in a straight line until it interacts with matter. It is particularly useful for making testable predictions for lenses and mirrors.

Lenses use curved surfaces to change the direction of light passing through them based on Snell's law of refraction. Mirrors use curved surfaces to change the direction of light based on the law of reflection. Predictions can be made based on the use of principal ray diagrams or equations.

Lenses and mirrors can be referenced by their behavior (converging or diverging) or by their physical construction (convex or concave).

Principal ray diagrams

Draw the locations of the object (source of light), the lens or mirror, and the focal point(s) on each side of the lens. A line connecting the two focal points for a lens (or connecting the center of the circle and the center of the mirror) is referred to as the "optical axis". Choose a point on the object (typically farthest from the optical axis) and draw rays according to the following rules:

Converging (biconvex) lens

Ray name	Direction before lens	Direction after lens
P	Parallel to the optical axis	Through the focal point
F	Through the focal point (unless the object is inside the focal point in which case you draw the ray as if it came from the focal point and passed through the point on the object)	Parallel to the optical axis
C or M	Towards the center of the lens	Straight

Diverging (biconcave) lens

Ray name	Direction before lens	Direction after lens
P	Parallel to the optical axis	As if it came from the focal point on the same side as the object
F	Toward the focal point on the opposite side	Parallel to the optical axis
C or M	Towards the center of the lens	Straight

Diverging (convex) mirror

The single focal point of a convex mirror is behind the mirror.

Ray name	Direction before reflecting	Direction after reflecting
P	Parallel to the optical axis	As if it came from the focal point.
F	Toward the focal point	Parallel to the optical axis

Converging (concave) mirror

The single focal point of a concave mirror is in front of the mirror.

Ray name	Direction before reflecting	Direction after reflecting
P	Parallel to the optical axis	Through the focal point
F	Through the focal point (unless the object is inside the focal point in which case you draw the ray as if it came from the focal point and passed through the point on the object)	Parallel to the optical axis

For all principal ray diagrams, the image is real if the rays converge to a point. The distance from the lens or mirror to the image is the image distance (positive). If the rays diverge, then draw **dotted lines** straight backwards to where they appear to have originated from; this is the location of the virtual image. The distance between this virtual image (negative) and the lens or mirror is the image distance.

If the image is on the same side of the optical axis as the object, then the image is upright. If the image is on the opposite side of the optical axis, then the image is inverted.

Sign Conventions

Symbol	Name	> 0	< 0
f	focal length	Biconvex lenses and concave mirrors	Biconcave lenses and convex mirrors
s (or d_o)	object distance	almost always	only possible with a compound system
s' (or d_i)	image distance	real image	virtual image
m	magnification	upright image	inverted image

Equations

The (thin) lens equation and the mirror equation are identical:

$$1/f = 1/s + 1/s'$$

The magnification for a lens or mirror can be determined two ways (h' = image height, h = object height):

$$m = h'/h = -s'/s$$

Note that the second formula for magnification is wrong in the first edition of the textbook as it is missing a minus sign.

The focal length of a mirror can be determined based on its physical construction. The radius of curvature, R, is the only relevant variable. See above for the sign convention:

$$f = \pm R/2$$

The focal length of a thin lens can also be determined based on its physical construction. The index of refraction and the radii of curvature of the two surfaces are the relevant variables:

$$f = [(n - 1)(1/R_1 - 1/R_2)]^{-1}$$

For biconvex lenses, $R_1 > 0$ and $R_2 < 0$. For biconcave lenses, the reverse is true. A flat surface has $R = \infty$.

Since the focal length depends upon the index of refraction and this in turn depends in a subtle way on the wavelength of the light, the focal length is not the same for all wavelengths for a simple lens. This results in a phenomenon called chromatic aberration.