24-2 Thin Lenses

Important Ideas

- For a convex lens, parallel light rays converge through the focal point. The focal length of a convex lens is positive. The lens is a *converging* lens.
- For a concave lens, parallel light rays diverge away from the focal point. The focal length of a concave lens is negative. The lens is a *diverging* lens.
- The focal length of a lens is determined by its index of refraction (along with the medium) and the radius of curvature of the near side and far side of the lens. This is called the lensmaker's equation.

$$\frac{1}{f} = \left(\frac{n_{lens}}{n_{medium}} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

  For greater radius of curvature, the lens is flatter (and thinner) and the focal length is longer. For smaller radius of curvature, the lens bulges at the center and the focal length is shorter.

  If you increase the index of refraction of the lens, the rays bend more and the focal length is shorter.

- The thin-lens equation:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

- magnification:

$$m = \frac{h_i}{h_0} = \frac{-d_i}{d_o}$$

- To locate the image by sketching rays, use two of three easy rays. For a convex lens

  1. A ray parallel to the principal axis converges through the (far) focal point.
  2. A ray incident at the center of the lens does not refract.
  3. A ray that travels through the (near) focal point refracts parallel to the principal axis.

  For a concave lens,

  1. A ray parallel to the principal axis diverges away from the (near) focal point.
  2. A ray incident at the center of the lens does not refract.
  3. A ray that is aligned with the (far) focal point refracts parallel to the principal axis.

  The intersection of the rays is the image point.

- An image formed by converging rays is a *real* image. An image formed by diverging rays is a *virtual* image. The image distance for a virtual image is negative.
- Here is a summary of images formed by convex and concave lenses.

Thin Lenses

Type of lens	Focal length	Image characteristics
Diverging (usually concave)	Negative	The image is virtual, upright, smaller than the object, and between the lens and the focal point on the side of the lens the object is on.
Converging (usually convex)	Positive	The image can be real or virtual, and larger than, smaller than, or the same size as the object. See the table below for details.

Table 24.2: A summary of the lenses we investigated in this chapter.

Images formed by a Converging Lens

Object position	Image position	Image characteristics
∞	At the focal point.	Real image with height of zero.
Moving from ∞ toward twice the focal length.	Moving from the focal point toward twice the focal length.	The image is real, inverted, and smaller than the object. The image moves closer to twice the focal length, and increases in height, as the object is moved closer to twice the focal length from the lens.
At twice the focal length.	At twice the focal length.	The image is real, inverted, and the same size as the object.
Moving from twice the focal length toward the focal point.	Moving from twice the focal length toward infinity.	The image is real, inverted, and larger than the object. The image moves farther from the lens, and increases in height, as the object is moved closer to the focal point.
At the focal point.	At infinity.	The image is at infinity, and is infinitely tall.
Closer to the lens than the focal point.	On the same side of the lens as the object.	The image is virtual, upright, and larger than the object. The image moves closer to the lens, and decreases in height, as the object is moved closer to the lens.

Table 24.3: A summary of the image positions and characteristics for a converging lens.