Chapter 26  Geometrical Optics

Outline

26-1 The Reflection of Light
26-2 Forming Images with a Plane Mirror
26-3 Spherical Mirror
26-4 Ray Tracing and the Mirror Equation
26-5 The Refraction of Light
26-6 Ray Tracing for Lens
26-7 Thin Lens Equation
26-7 Thin Lens Equation

Derive of lens equation

In figure (a), we have

\[ \frac{h_o}{f} = \frac{-h_i}{d_i - f} \]  \hspace{1cm} (26–14)

In figure (b), we have

\[ \frac{h_0}{d_0} = \frac{-h_i}{d_i} \]  \hspace{1cm} (26–15)

Figure 26-36
Ray Diagrams Used to Derive the Thin-Lens Equation
Combining (26-14) and (26-15), we have

Thin-Lens Equation (suitable for both type lenses)

\[
\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \quad (26-16)
\]

From (26-15), \( h_i = -(d_i/d_o)h_0 \), therefore

Magnification, \( m \) (suitable for both type lenses)

\[
m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \quad (26-18)
\]
Sign conventions for lenses:

Focal length, $f$

$f$ is positive for converging (convex) lenses. (+ value)

$f$ is negative diverging (concave) lenses. (- value)

Magnification, $m$

$m$ is positive for upright images (same orientation as object);

$m$ is negative for inverted image (opposite orientation of object).

Image Distance, $d_i$

$d_i$ is positive for real image (image and object on the opposite sides);

$d_i$ is negative for virtual images (image and object on the same side).

(Object distance $d_o$

$d_o$ is positive for real objects.

($d_o$ is negative for virtual objects.)
Example 26-7

A lens produces a real image that is twice as large as the object and the image is located 15 cm from the lens. Find the focal length of the lens and the object distance.
Solution

Since image is real, the lens must be converging, and object and image must located at two lens sides respectively: \( m = -2 \). We have,

\[
m = -\frac{d_i}{d_o} = -2, \text{ so }
\]

\[
d_o = -\frac{d_i}{m} = -\left(\frac{15\text{cm}}{-2}\right) = 7.5 \text{ cm}
\]

And

\[
\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{7.5\text{cm}} + \frac{1}{15\text{cm}} = \frac{1}{5.0\text{cm}},
\]

\[
\text{so } f = 5.0 \text{ cm}
\]
Active example 26-2

An object is placed 12cm in front of a diverging lens with a focal length of 7.9 cm. Find (a) the imaging distance and (b) the magnification.
Solution

(a)

\[ \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \]

\[ \frac{1}{12\text{cm}} + \frac{1}{d_i} = \frac{1}{-7.9\text{cm}} \]

\[ d_i = -4.8\text{ cm}, \quad \text{Virtual Image!} \]

(b)

\[ m = -\frac{d_i}{d_o} = -\frac{-4.8\text{ cm}}{12\text{ cm}} = 0.40, \]

\[ \text{upright image!} \]
Summary

Thin-Lens Equation (suitable for both type lenses)

\[ \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \] (26–16)

Magnification, m (suitable for both type lenses)

\[ m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \] (26–18)