THIN-LENS EQUATION

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

$$\frac{1}{\text{distance from object to lens}}+\frac{1}{\text{distance from image to lens}}=\frac{1}{\text{focal length}}$$

When using the thin-lens equation, we often illustrate it using the ray diagram model in which, for clarity, we magnify the vertical axis and show the lens position as a thin line. Always remember that the actual light rays bend at the lens surfaces and that our diagram showing bending at a single central line is an idealized model, which is quite good for thin lenses. But the model, and the equation, must be modified to deal properly with thick lenses, systems of lenses, and object and image points far from the principal axis.

The thin-lens equation can be applied to both converging and diverging lenses if we adhere to a set of sign conventions. **Table 4** gives the sign conventions for lenses. Under this convention, an image in back of the lens (that is, a real image) has a positive image distance, and an image in front of the lens, or a virtual image, has a negative image distance. A converging lens has a positive focal length and a diverging lens has a negative focal length. Therefore, converging lenses are sometimes called *positive lenses* and diverging lenses are sometimes called *negative lenses.*

Table 4
Sign Conventions for Lenses

	+	−
p	real object in front of the lens	real object in back of the lens
q	virtual image in back of the lens	virtual image in front of the lens
f	converging lens	diverging lens

Magnification by a lens depends on object and image distances

Recall that magnification (M) is defined as the ratio of image height to object height. The following equation can be used to calculate the magnification of both converging and diverging lenses.

MAGNIFICATION OF A LENS

$$M=\frac{h'}{h}=-\frac{q}{p}$$

$$\text{magnification}=\frac{\text{image height}}{\text{object height}}=-\frac{\text{distance from image to lens}}{\text{distance from object to lens}}$$

If close attention is given to the sign conventions defined in **Table 4,** then the magnification will describe the image's size and orientation. When the magnitude of the magnification of an object is less than one, the image is smaller than the object. Conversely, when the magnitude of the magnification is greater than one, the image is larger than the object.

Additionally, a negative sign for the magnification indicates that the image is real and inverted. A positive magnification signifies that the image is upright and virtual.