SECTION 2

Thin Lenses

SECTION OBJECTIVES

- **Use ray diagrams to find the position of an image produced by a converging or diverging lens, and identify the image as real or virtual.**
- **Solve problems using the thin-lens equation.**
- **Calculate the magnification of lenses.**
- **Describe the positioning of lenses in compound microscopes and refracting telescopes.**

TYPES OF LENSES

When light traveling in air enters a pane of glass, it is bent toward the normal. As the light exits the pane of glass, it is bent again. When the light exits, however, its speed increases as it enters the air, so the light bends away from the normal. Because the amount of refraction is the same regardless of whether light is entering or exiting a medium, the light rays are bent as much on exiting the pane of glass as they were on entering.

Curved surfaces change the direction of light

When the surfaces of a medium are curved, the direction of the normal line differs for each spot on the surface of the medium. Thus, when light passes through a medium that has one or more curved surfaces, the change in the direction of the light rays varies from point to point. This principle is applied in media called **lenses.** Like mirrors, lenses form images, but lenses do so by refraction rather than by reflection. The images formed can be either real or virtual, depending on the type of lens and on the placement of the object. Recall that a real image is formed when rays of light actually intersect to form the image. Virtual images form at a point from which light rays appear to come but do not actually come. Real images can be projected onto a screen; virtual images cannot.

lens

a transparent object that refracts light rays such that they converge or diverge to create an image

Lenses are commonly used to form images in optical instruments, such as cameras, telescopes, and microscopes. In fact, transparent tissue in the front of the human eye acts as a lens, converging light toward the light-sensitive retina, which lines the back of the eye.

A typical lens consists of a piece of glass or plastic ground so that each of its two refracting surfaces is a segment of either a sphere or a plane. **Figure 5** shows examples of lenses. Notice that the lenses are shaped differently. The lens that is thicker at the middle than it is at the rim, shown in **Figure 5(a),** is an example of a *converging* lens. The lens that is thinner at the middle than it

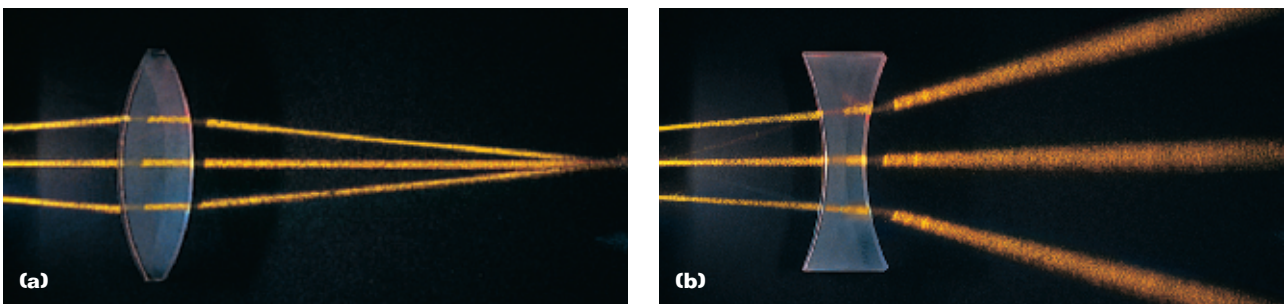

Figure 5
When rays of light pass through **(a)** a converging lens (thicker at the middle), they are bent inward. When they pass through **(b)** a diverging lens (thicker at the edge), they are bent outward.