EXAMPLE 25–8 **Telescope magnification.** The largest optical refracting telescope in the world is located at the Yerkes Observatory in Wisconsin, Fig. 25–20. It is referred to as a "40-inch" telescope, meaning that the diameter of the objective is 40 in., or 102 cm. The objective lens has a focal length of 19 m, and the eyepiece has a focal length of 10 cm. (*a*) Calculate the total magnifying power of this telescope. (*b*) Estimate the length of the telescope.

APPROACH Equation 25–3 gives the magnification. The length of the telescope is the distance between the two lenses.

SOLUTION (*a*) From Eq. 25–3 we find

$$M = -\frac{f_o}{f_e} = -\frac{19\ \text{m}}{0.10\ \text{m}} = -190\times.$$

(*b*) For a relaxed eye, the image I_1 is at the focal point of both the eyepiece and the objective lenses. The distance between the two lenses is thus $f_o + f_e \approx 19$ m, which is essentially the length of the telescope.

FIGURE 25–20 This large refracting telescope was built in 1897 and is housed at Yerkes Observatory in Wisconsin. The objective lens is 102 cm (40 inches) in diameter, and the telescope tube is about 19 m long. Example 25–8.

EXERCISE C A 40× telescope has a 1.2-cm focal length eyepiece. What is the focal length of the objective lens?

For an astronomical telescope to produce bright images of distant stars, the objective lens must be large to allow in as much light as possible. Indeed, the diameter of the objective lens (and hence its "light-gathering power") is an important parameter for an astronomical telescope, which is why the largest ones are specified by giving the objective diameter (such as the 10-meter Keck telescope in Hawaii). The construction and grinding of large lenses is very difficult. Therefore, the largest telescopes are **reflecting telescopes** which use a curved mirror as the objective, Fig. 25–21. A mirror has only one surface to be ground and can be supported along its entire surface† (a large lens, supported at its edges, would sag under its own weight). Often, the eyepiece lens or mirror (see Fig. 25–21) is removed so that the real image formed by the objective mirror can be recorded directly on film or on a CCD digital sensor (Section 25–1).

Reflecting telescopes

† Another advantage of mirrors is that they exhibit no chromatic aberration because the light doesn't pass through them; and they can be ground in a parabolic shape to correct for spherical aberration (Section 25–6). The reflecting telescope was first proposed by Newton.

FIGURE 25–21 A concave mirror can be used as the objective of an astronomical telescope. Either (a) a lens or (b) a mirror can be used as the eyepiece. Arrangement (a) is called the Newtonian focus, and (b) the Cassegrainian focus. Other arrangements are also possible. (c) The 200-inch (mirror diameter) Hale telescope on Palomar Mountain in California. (d) The 10-meter Keck telescope on Mauna Kea, Hawaii. The Keck combines thirty-six 1.8-meter six-sided mirrors into the equivalent of a very large single reflector, 10 m in diameter.