EXAMPLE 22–3 ESTIMATE Voice speed through the wires. When you speak on the telephone from Los Angeles to a friend in New York some 4000 km away, how long does it take the signal carrying your voice to travel that distance?

APPROACH The signal is carried on a telephone wire or in the air via satellite. In either case it is an electromagnetic wave. Electronics as well as the wire or cable slow things down, but as a rough estimate we take the speed to be $c = 3.0 \times 10^8\,\mathrm{m/s}$.

SOLUTION Since speed = distance/time, then time = distance/speed = $(4.0 \times 10^6\,\mathrm{m})/(3.0 \times 10^8\,\mathrm{m/s}) = 1.3 \times 10^{-2}\,\mathrm{s}$, or about $\frac{1}{100}$ s.

NOTE Such a small amount of time normally goes unnoticed.

EXERCISE C If your voice traveled as a sound wave, how long would it take in Example 22–3?

22–4 Measuring the Speed of Light

Galileo attempted to measure the speed of light by trying to measure the time required for light to travel a known distance between two hilltops. He stationed an assistant on one hilltop and himself on another, and ordered the assistant to lift the cover from a lamp the instant he saw a flash from Galileo's lamp. Galileo measured the time between the flash of his lamp and when he received the light from his assistant's lamp. The time was so short that Galileo concluded it merely represented human reaction time, and that the speed of light must be extremely high.

The first successful determination that the speed of light is finite was made by the Danish astronomer Ole Roemer (1644–1710). Roemer had noted that the carefully measured orbital period of Io, a moon of Jupiter with an average period of 42.5 h, varied slightly, depending on the relative motion of Earth and Jupiter. When Earth was moving away from Jupiter, the period of Io was slightly longer, and when Earth was moving toward Jupiter, the period was slightly shorter. He attributed this variation in the apparent period to the change in distance between the Earth and Jupiter during one of Io's periods, and the time it took light to travel this distance. Roemer concluded that the speed of light—though great—is finite.

Michelson measures c

Since then a number of techniques have been used to measure the speed of light. Among the most important were those carried out by the American Albert A. Michelson (1852–1931). Michelson used the rotating mirror apparatus diagrammed in Fig. 22–10 for a series of high-precision experiments carried out from 1880 to the 1920s. Light from a source was directed at one face of a rotating eight-sided mirror. The reflected light traveled to a stationary mirror a large distance away and back again as shown. If the rotating mirror

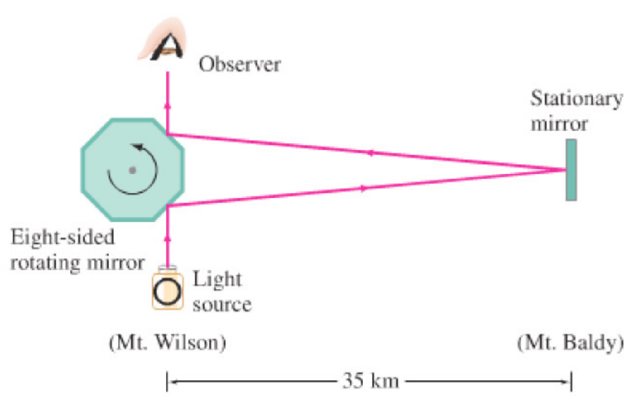

FIGURE 22–10 Michelson's speed-of-light apparatus (not to scale).