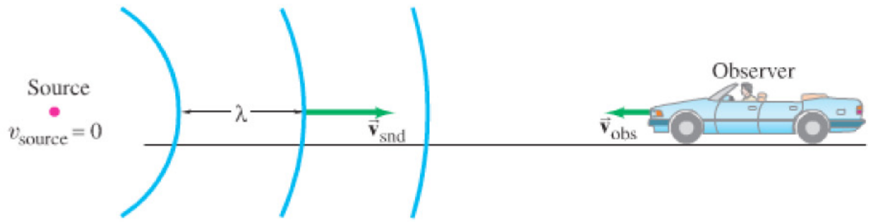

FIGURE 12–21 Observer moving with speed v_{obs} toward a stationary source detects wave crests passing at speed $v' = v_{snd} + v_{obs}$ where v_{snd} is the speed of the sound waves in air.

Frequency change, fixed source, moving observer

The Doppler effect also occurs when the source is at rest and the observer is in motion. If the observer is traveling *toward* the source, the pitch heard is higher than that of the emitted source frequency. If the observer is traveling *away* from the source, the pitch heard is lower. Quantitatively the change in frequency is different than for the case of a moving source. With a fixed source and a moving observer, the distance between wave crests, the wavelength λ, is not changed. But the velocity of the crests with respect to the observer *is* changed. If the observer is moving toward the source, Fig. 12–21, the speed v' of the waves relative to the observer is a simple addition of velocities: $v' = v_{snd} + v_{obs}$, where v_{snd} is the velocity of sound in air (we assume the air is still) and v_{obs} is the velocity of the observer. Hence, the frequency heard is

$$f' = \frac{v'}{\lambda} = \frac{v_{snd} + v_{obs}}{\lambda}.$$

Because $\lambda = v_{snd}/f$, then

$$f' = \frac{(v_{snd} + v_{obs})f}{v_{snd}},$$

or

$$f' = \left(1 + \frac{v_{obs}}{v_{snd}}\right)f. \quad \left[\begin{array}{l}\text{observer moving toward}\\ \text{stationary source}\end{array}\right] \quad \textbf{(12–3a)}$$

If the observer is moving away from the source, the relative velocity is $v' = v_{snd} - v_{obs}$, so

$$f' = \left(1 - \frac{v_{obs}}{v_{snd}}\right)f. \quad \left[\begin{array}{l}\text{observer moving away}\\ \text{from stationary source}\end{array}\right] \quad \textbf{(12–3b)}$$

EXAMPLE 12–14 **A moving siren.** The siren of a police car at rest emits at a predominant frequency of 1600 Hz. What frequency will you hear if you are at rest and the police car moves at 25.0 m/s (*a*) toward you, and (*b*) away from you?

APPROACH The observer is fixed, and the source moves, so we use Eqs. 12–2. The frequency you (the observer) hear is the emitted frequency f divided by the factor $(1 \pm v_{source}/v_{snd})$ where v_{source} is the speed of the police car. Use the minus sign when the car moves toward you (giving a higher frequency); use the plus sign when the car moves away from you (lower frequency).

SOLUTION (*a*) The car is moving toward you, so (Eq. 12–2a)

$$f' = \frac{f}{\left(1 - \frac{v_{source}}{v_{snd}}\right)} = \frac{1600\text{ Hz}}{\left(1 - \frac{25.0\text{ m/s}}{343\text{ m/s}}\right)} = 1726\text{ Hz}.$$

(*b*) The car is moving away from you, so

$$f' = \frac{f}{\left(1 + \frac{v_{source}}{v_{snd}}\right)} = \frac{1600\text{ Hz}}{\left(1 + \frac{25.0\text{ m/s}}{343\text{ m/s}}\right)} = 1491\text{ Hz}.$$

EXERCISE F Suppose the police car of Example 12–14 is at rest and emits still at 1600 Hz. What frequency would you hear if you were moving at 25.0 m/s (*a*) toward it, and (*b*) away from it?