55. We use $v_S = r\omega$ (with r = 0.600 m and ω = 15.0 rad/s) for the linear speed during circular motion, and Eq. 17-47 for the Doppler effect (where f = 540 Hz, and v = 343 m/s for the speed of sound).

(a) The lowest frequency is

$$f' = f\left(\frac{v+0}{v+v_S}\right) = 526\ \text{Hz}.$$

(b) The highest frequency is

$$f' = f\left(\frac{v+0}{v-v_S}\right) = 555\ \text{Hz}.$$

56. The Doppler effect formula, Eq. 17-47, and its accompanying rule for choosing ± signs, are discussed in Section 17-10. Using that notation, we have v = 343 m/s, v_D = 2.44 m/s, f' = 1590 Hz, and f = 1600 Hz. Thus,

$$f' = f\left(\frac{v+v_D}{v+v_S}\right) \Rightarrow v_S = \frac{f}{f'}(v+v_D) - v = 4.61\,\text{m/s}.$$

59. We denote the speed of the French submarine by u_1 and that of the U.S. sub by u_2.

(a) The frequency as detected by the U.S. sub is

$$f_1' = f_1\left(\frac{v+u_2}{v-u_1}\right) = (1.000\times10^3\ \text{Hz})\left(\frac{5470\ \text{km/h} + 70.00\ \text{km/h}}{5470\ \text{km/h} - 50.00\ \text{km/h}}\right) = 1.022\times10^3\ \text{Hz}.$$

(b) If the French sub were stationary, the frequency of the reflected wave would be $f_r = f_1(v+u_2)/(v-u_2)$. Since the French sub is moving toward the reflected signal with speed u_1, then

$$f_r' = f_r\left(\frac{v+u_1}{v}\right) = f_1\frac{(v+u_1)(v+u_2)}{v(v-u_2)} = \frac{(1.000\times10^3\ \text{Hz})(5470+50.00)(5470+70.00)}{(5470)(5470-70.00)}$$
$$= 1.045\times10^3\ \text{Hz}.$$

63. In this case, the intruder is moving *away* from the source with a speed u satisfying $u/v \ll 1$. The Doppler shift (with u = –0.950 m/s) leads to

$$f_{\text{beat}} = |f_r - f_s| \approx \frac{2|u|}{v} f_s = \frac{2(0.95\,\text{m/s})(28.0\ \text{kHz})}{343\,\text{m/s}}) = 155\,\text{Hz}.$$