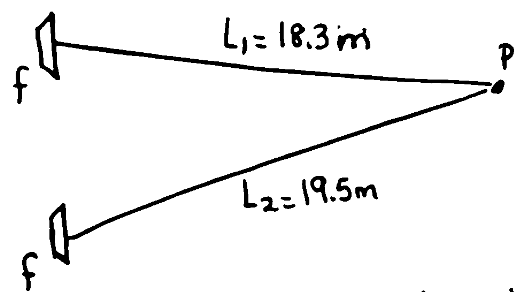
••19 Two loudspeakers are located 3.35 m apart on an outdoor stage. A listener is 18.3 m from one and 19.5 m from the other. During the sound check, a signal generator drives the two speakers in phase with the same amplitude and frequency. The transmitted frequency is swept through the audible range (20 Hz to 20 kHz). (a) What is the lowest frequency $f_{min,1}$ that gives minimum signal (destructive interference) at the listener's location? By what number must $f_{min,1}$ be multiplied to get (b) the second lowest frequency $f_{min,2}$ that gives minimum signal and (c) the third lowest frequency $f_{min,3}$ that gives minimum signal? (d) What is the lowest frequency $f_{max,1}$ that gives maximum signal (constructive interference) at the listener's location? By what number must $f_{max,1}$ be multiplied to get (e) the second lowest frequency $f_{max,2}$ that gives maximum signal and (f) the third lowest frequency $f_{max,3}$ that gives maximum signal?



$$\Delta L = 19.5\,m - 18.3\,m = 1.2\,m$$

a) minimum sound $\Rightarrow \Delta L = L_2 - L_1 = n\frac{\lambda}{2} = n\frac{v}{2f}$

$$\Rightarrow \boxed{f_n = n\frac{v}{2\Delta L}} \quad n = 1, 3, 5, \ldots$$

$$f_1 = \frac{v}{2\Delta L} = \frac{343}{2 \times 1.2} = \boxed{143\,Hz}$$

$$\boxed{f_3 = 3f_1}, \quad \boxed{f_5 = 5f_1}$$

b) maximum sound $\Rightarrow \Delta L = n\lambda = n\frac{v}{f}$

$$\Rightarrow \boxed{f_n = n\frac{v}{\Delta L}} \quad n = 0, 1, 2, \ldots$$

$$f_1 = \frac{v}{\Delta L} = \frac{343}{1.2} = \boxed{286\,Hz}$$

$$\boxed{f_2 = 2f_1}, \quad \boxed{f_3 = 3f_1}$$

••27 Suppose that the sound level of a conversation is initially at an angry 70 dB and then drops to a soothing 50 dB (Fig. 17-38). Assuming that the frequency of the sound is 500 Hz, determine the (a) initial and (b) final sound intensities and the (c) initial and (d) final sound wave amplitudes.

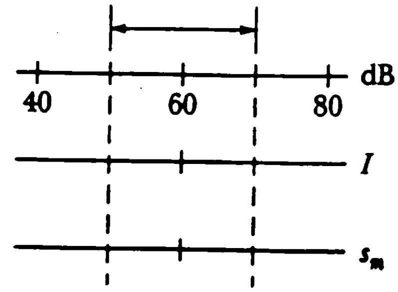


Fig. 17-38 Problem 27.

a) $\beta = 10 \log \frac{I}{I_0} \Rightarrow I = I_0 10^{\frac{\beta}{10}}$

$\beta_1 = 70\,\text{dB} \Rightarrow I_1 = 10^{7} \times 10^{-12} = \boxed{10^{-5}\ \text{W/m}^2}$

b) $\beta_2 = 50\,\text{dB} \Rightarrow I_2 = 10^{5} \times 10^{-12} = \boxed{10^{-7}\ \text{W/m}^2}$

c) $I_1 = \frac{1}{2} \rho v \omega^2 S_{m_1}^2$

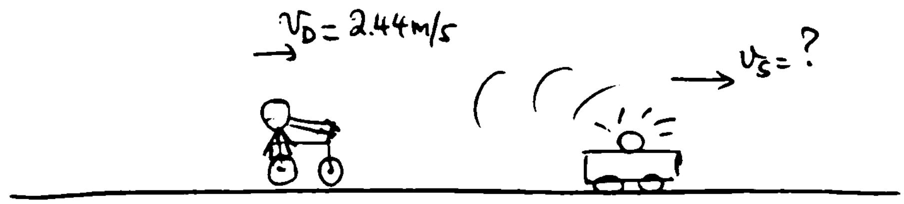
$S_{m_1} = \sqrt{\frac{2 I_1}{\rho v \omega^2}} = \sqrt{\frac{2 * 10^{-5}}{1.2 * 343 * (500 \times 2\pi)^2}}$

$\boxed{S_{m_1} = 7 \times 10^{-8}\ \text{m}}$

d) $S_{m_2} = \sqrt{\frac{2 I_2}{\rho v \omega^2}} = \sqrt{\frac{2 * 10^{-7}}{1.2 * 343 * (500 * 2\pi)^2}}$

$\boxed{S_{m_2} = 7 \times 10^{-9}\ \text{m}}$

•51 An ambulance with a siren emitting a whine at 1600 Hz overtakes and passes a cyclist pedaling a bike at 2.44 m/s. After being passed, the cyclist hears a frequency of 1590 Hz. How fast is the ambulance moving?



$f = 1600$ Hz

$f' = 1590$ Hz

Both source and detector are moving

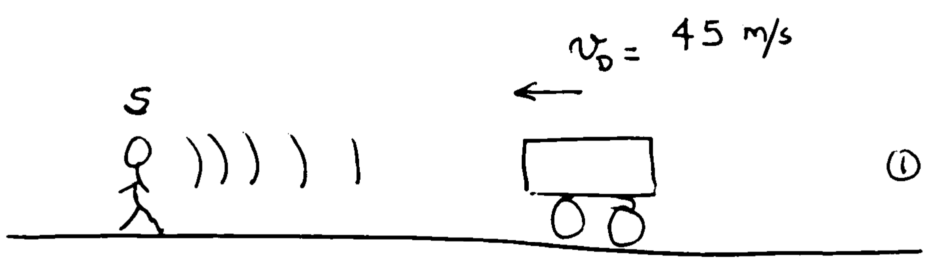
$$f' = f \, \frac{v + v_D}{v + v_S}$$

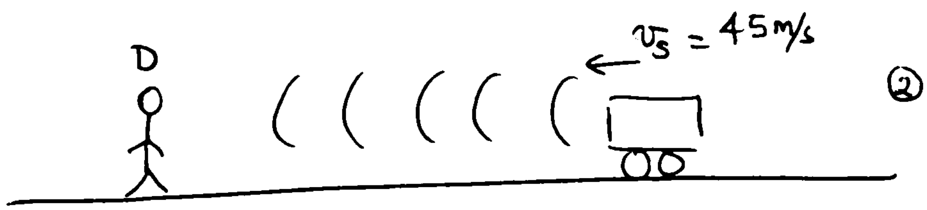
$$\frac{f'}{f} = \frac{v + v_D}{v + v_S} \Rightarrow v + v_S = \frac{f}{f'}(v + v_D)$$

$$v_S = -v + \frac{f}{f'}(v + v_D)$$

$$\boxed{v_S = 4.61 \text{ m/s}}$$

••52 A stationary motion detector sends sound waves of frequency 0.150 MHz toward a truck approaching at a speed of 45.0 m/s. What is the frequency of the waves reflected back to the detector?

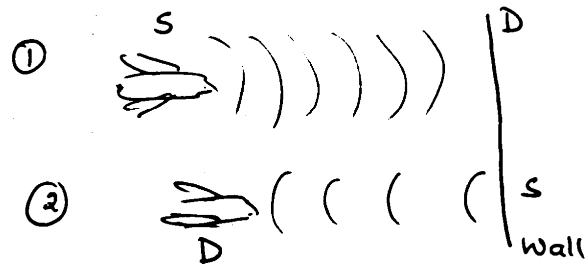




①
$$f' = f \frac{v + v_D}{v} = 0.15\times10^6 \frac{343+45}{343}$$
$$= 0.17\times10^6 \text{ HZ}$$

②
$$f'' = f' \frac{v}{v - v_S} = 0.17\times10^6 \frac{343}{343-45}$$
$$= \boxed{0.19\times10^6 \text{ HZ}}$$

(••57) A bat is flitting about in a cave, navigating via ultrasonic bleeps. Assume that the sound emission frequency of the bat is 39 000 Hz. During one fast swoop directly toward a flat wall surface, the bat is moving at 0.025 times the speed of sound in air. What frequency does the bat hear reflected off the wall?



① $f' = f \dfrac{v}{v - v_s} = 40 \text{ kHz}$

$v_s = 343 \times 0.025$

$= 8.6 \text{ m/s}$

② $f'' = \underset{\substack{\uparrow \\ 40 \text{ kHz}}}{f'} \dfrac{v + v_D}{v} = 4.1 \text{ kHz}$