6. Let ℓ be the length of the rod. Then the time of travel for sound in air (speed v_s) will be $t_s = \ell / v_s$. And the time of travel for compressional waves in the rod (speed v_r) will be $t_r = \ell / v_r$. In these terms, the problem tells us that

$$t_s - t_r = 0.12\,\text{s} = \ell\left(\frac{1}{v_s} - \frac{1}{v_r}\right).$$

Thus, with v_s = 343 m/s and v_r = 15v_s = 5145 m/s, we find $\ell = 44\,\text{m}$.

16. Let the separation between the point and the two sources (labeled 1 and 2) be x_1 and x_2, respectively. Then the phase difference is

$$\Delta\phi = \phi_1 - \phi_2 = 2\pi\left(\frac{x_1}{\lambda} + ft\right) - 2\pi\left(\frac{x_2}{\lambda} + ft\right) = \frac{2\pi(x_1 - x_2)}{\lambda} = \frac{2\pi(4.40\,\text{m} - 4.00\,\text{m})}{(330\,\text{m/s})/540\,\text{Hz}}$$
$$= 4.12\,\text{rad}.$$

17. Building on the theory developed in Section 17-5, we set $\Delta L/\lambda = n - 1/2,\ n = 1, 2, \ldots$ in order to have destructive interference. Since $v = f\lambda$, we can write this in terms of frequency:

$$f_{\min,n} = \frac{(2n-1)v}{2\Delta L} = (n - 1/2)(286\text{ Hz})$$

where we have used v = 343 m/s (note the remarks made in the textbook at the beginning of the exercises and problems section) and ΔL = (19.5 – 18.3) m = 1.2 m.

(a) The lowest frequency that gives destructive interference is (n = 1)

$$f_{\min,1} = (1 - 1/2)(286\text{ Hz}) = 143\text{ Hz}.$$

(b) The second lowest frequency that gives destructive interference is (n = 2)

$$f_{\min,2} = (2 - 1/2)(286\text{ Hz}) = 429\text{ Hz} = 3(143\text{ Hz}) = 3f_{\min,1}.$$

So the factor is 3.

(c) The third lowest frequency that gives destructive interference is (n = 3)

$$f_{\min,3} = (3 - 1/2)(286\text{ Hz}) = 715\text{ Hz} = 5(143\text{ Hz}) = 5f_{\min,1}.$$

So the factor is 5.

Now we set $\Delta L/\lambda = \frac{1}{2}$ (even numbers) — which can be written more simply as "(all integers n = 1, 2,…)" — in order to establish constructive interference. Thus,

$$f_{\max,n} = \frac{nv}{\Delta L} = n(286\text{ Hz}).$$

(d) The lowest frequency that gives constructive interference is (n =1) $f_{\max,1} = (286\text{ Hz})$.

(e) The second lowest frequency that gives constructive interference is (n = 2)

$$f_{\max,2} = 2(286\text{ Hz}) = 572\text{ Hz} = 2f_{\max,1}.$$

Thus, the factor is 2.

(f) The third lowest frequency that gives constructive interference is (n = 3)

$$f_{\max,3} = 3(286\text{ Hz}) = 858\text{ Hz} = 3f_{\max,1}.$$

Thus, the factor is 3.

27. (a) Let I_1 be the original intensity and I_2 be the final intensity. The original sound level is β_1 = (10 dB) log(I_1/I_0) and the final sound level is β_2 = (10 dB) log(I_2/I_0), where I_0 is the reference intensity. Since $\beta_2 = \beta_1$ + 30 dB, which yields

$$(10\text{ dB})\log(I_2/I_0) = (10\text{ dB})\log(I_1/I_0) + 30\text{ dB},$$

or

$$(10\text{ dB})\log(I_2/I_0) - (10\text{ dB})\log(I_1/I_0) = 30\text{ dB}.$$

Divide by 10 dB and use log(I_2/I_0) – log(I_1/I_0) = log(I_2/I_1) to obtain log(I_2/I_1) = 3. Now use each side as an exponent of 10 and recognize that $10^{\log(I_2/I_1)} = I_2/I_1$. The result is $I_2/I_1 = 10^3$. The intensity is increased by a factor of 1.0×10^3.

(b) The pressure amplitude is proportional to the square root of the intensity, so it is increased by a factor of $\sqrt{1000} \approx 32$.

28. The sound level β is defined as (see Eq. 17-29):

$$\beta = (10\text{ dB})\log\frac{I}{I_0}$$

where $I_0 = 10^{-12}\text{ W/m}^2$ is the standard reference intensity. In this problem, let the two intensities be I_1 and I_2 such that $I_2 > I_1$. The sound levels are $\beta_1 = (10\text{ dB})\log(I_1/I_0)$ and β_2 = (10 dB) log(I_2/I_0). With $\beta_2 = \beta_1 + 1.0\text{ dB}$, we have

$$(10\text{ dB})\log(I_2/I_0) = (10\text{ dB})\log(I_1/I_0) + 1.0\text{ dB},$$

or

$$(10\text{ dB})\log(I_2/I_0) - (10\text{ dB})\log(I_1/I_0) = 1.0\text{ dB}.$$

Divide by 10 dB and use $\log(I_2/I_0) - \log(I_1/I_0) = \log(I_2/I_1)$ to obtain $\log(I_2/I_1) = 0.1$. Now use each side as an exponent of 10 and recognize that $10^{\log(I_2/I_1)} = I_2/I_1$. The result is

$$\frac{I_2}{I_1} = 10^{0.1} = 1.26\,.$$

30. (a) The intensity is given by $I = P/4\pi r^2$ when the source is "point-like." Therefore, at $r = 3.00$ m,

$$I = \frac{1.00\times 10^{-6}\text{ W}}{4\pi(3.00\text{ m})^2} = 8.84\times 10^{-9}\text{ W/m}^2.$$

(b) The sound level there is

$$\beta = 10\log\left(\frac{8.84\times 10^{-9}\text{ W/m}^2}{1.00\times 10^{-12}\text{ W/m}^2}\right) = 39.5\text{ dB}.$$

53. Each wire is vibrating in its fundamental mode, so the wavelength is twice the length of the wire ($\lambda = 2L$) and the frequency is

$$f = v/\lambda = (1/2L)\sqrt{\tau/\mu}\,,$$

where $v = \sqrt{\tau/\mu}$ is the wave speed for the wire, τ is the tension in the wire, and μ is the linear mass density of the wire. Suppose the tension in one wire is τ and the oscillation frequency of that wire is f_1. The tension in the other wire is $\tau + \Delta\tau$ and its frequency is f_2. You want to calculate $\Delta\tau/\tau$ for $f_1 = 600$ Hz and $f_2 = 606$ Hz. Now, $f_1 = (1/2L)\sqrt{\tau/\mu}$ and $f_2 = (1/2L)\sqrt{(\tau + \Delta\tau/\mu}$, so

$$f_2/f_1 = \sqrt{(\tau + \Delta\tau)/\tau} = \sqrt{1 + (\Delta\tau/\tau)}.$$

This leads to $\Delta\tau/\tau = (f_2/f_1)^2 - 1 = [(606\text{ Hz})/(600\text{ Hz})]^2 - 1 = 0.020.$