Physics 23

Assignment 2 Solutions

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E19-6

a) In miles per second, the speed of sound is 02.06 mi/s. In five seconds, the sound of the lightning travels approximately 1.03 miles, which is about 3 percent too large.
b) Simply count in seconds and divide by 3.

E19-20

Let one person speak with an intensity I_1. N people would have an intensity $I_2 = NI_1$. The sound levels and intensities are related by

$$SL_1 - SL_2 = 10Log\left(\frac{I_1}{I_2}\right) = 10Log\left(\frac{1}{N}\right). \tag{1}$$

Using $SL_1 = 65dB$ and $SL_2 = 80dB$, we obtain $N \cong 32$.

E19-24

a) The path length difference (the extra distance that a wave from the upper speaker has to travel compared to the lower one in order to reach the listenser) between the waves from the speakers is

$$\Delta L = [(2.12m)^2 + (3.75m)^2]^{1/2} - 3.75m \cong 0.56m. \tag{2}$$

In order to have a minimum when reaching the listener, upon traveling the path length difference a wave from the upper speaker must be completely out of phase with the wave from the lower speaker. (we assume that the speakers emit waves at the same time with the same wavelength and frequency) Therefore ΔL must be a half integer number of the wavelengths so that

$$\Delta L = \left(n - \frac{1}{2}\right)\lambda \cong 0.56m, \tag{3}$$

where n is an integer. Since

$$f = \frac{c_s}{\lambda}, \tag{4}$$

where c_s is the speed of sound in air, the listener will hear a minimum at the frequencies

$$f \cong \left(n - \frac{1}{2}\right) 615Hz. \tag{5}$$

b) Now ΔL must be an integer number of the wavelengths so that the waves arrive at the listener in phase. We therefore have

$$\Delta L = n\lambda \cong 0.56m. \tag{6}$$

The frequencies for which the listener hears a maximum are thus

$$f \cong n(615Hz). \tag{7}$$

E19-32

Since the tunnel is open on both ends, the air pressure perturbation at the ends must be zero, therefore the resonance condition for sound waves inside the tunnel is exactly the same as for that of standing waves on a string,

$$f = \frac{nc_s}{2L}. \tag{8}$$

Here n is an integer, L is the length of the tunnel and c_s is the speed of sound in air. Assuming that 135Hz and 138Hz are two consecutive resonances (or overtones) of the tunnel, the conditions on the shortest possible L are

$$L = \frac{nc_s}{2f_n} \tag{9}$$

and

$$L = \frac{(n+1)c_s}{2f_{n+1}}, \tag{10}$$

where $f_n = 135Hz$ and $f_{n+1} = 138Hz$. Solving the two equations, we obtain $L \cong 57.2m$.

P19-6

a) To obtain a minima at D, the wave traveling through SBD must destructively interfere with that through SAD. Conversely, position D will see a maxima only if waves from the two paths interfere constructively. Therefore changing the length of the SBD has to add half a wavelength to the path length difference between SBD and SAD. Since the same length is added on both sides of the tube, we see that $2(1.65cm) \cong \lambda/2$ and thus $\lambda \cong 6.6cm$, corresponding to approximately 5200Hz.

b) Let the amplitude of the wave from SAD and SBD be S_1 and S_2, respectively. When D hears a minima, the waves destructively interfere and so their amplitudes subtract in order to give the detected intensity:

$$I_{min} \propto (s_1 - s_2)^2. \tag{11}$$

On the other hand, the amplitudes add when we have complete constructive interference, so that

$$I_{max} \propto (s_1 + s_2)^2. \tag{12}$$

Solving for the ratio s_1/s_2, we obtain

$$\frac{s_1}{s_2} = \frac{I_{max}^{1/2} + I_{min}^{1/2}}{I_{max}^{1/2} - I_{min}^{1/2}} \cong 2. \tag{13}$$

P19-12

a) The sound wave in the tube is in the fundamental (n=1) mode with frequency

$$f_1 = \frac{nc_s}{4L_t} = \frac{c_s}{4L_t} \cong 72.7Hz, \tag{14}$$

where L_t is the length of the tube. Note that we have a factor 4 instead of 2 in the denominator of Eqn.(14) since one end of the tube is closed.

b) Since the string also vibrate at f_1, the tension is

$$T = \mu v^2 = \mu(\lambda f_1)^2 = \mu(L_s f_1)^2 \cong 67.1N. \tag{15}$$

Here $\lambda = 2L_s$, where L_s is the string length, since we have an n=1 mode.

P19-16

a) The observer is stationary while both sources are moving. The Doppler shifted frequencies are

$$f_{\mp} = f\frac{c_s}{c_s \pm v_s}, \tag{16}$$

where v_s is the speed of the source, f is the original frequency and f_+ is the up shifted frequency due to the source moving closer, corresponding to the minus sign in the formula. f_- gives the reverse. The observer hears the beat frequency of the up and down shifted waves:

$$\Delta f = f_+ - f_- \cong 81Hz. \tag{17}$$

b) Now the sources are stationary while the observer moves, resulting in Doppler shifted frequencies of

$$f_\pm = f\frac{c_s \pm v_o}{c_s}. \tag{18}$$

Here v_o is the speed of the observer. The plus sign in the equation gives the up shifted frequency f_+ with the observer moving towards the source. The minus sign indicates the opposite. The observer hears a beat frequency of approximately 81Hz.

P19-20

The submarine moves at 75.2km/h wrt to the ocean floor but only $75.2km/h - 30.5km/h \cong 12.4m/s$ wrt to the medium, namely the ocean current. Since the Doppler shift equations are derived in the reference frame of the medium, we effectively have a stationary observer listening to a moving source, since the observing ship is stationary wrt to the current. The resulting shifted frequency is therefore

$$f' = f\frac{c_s}{c_s - v_s} \cong 997Hz. \tag{19}$$

Note that the speed of sound in water is approximately 1482m/s, much greater than in air.