HW 10 Help

28. ORGANIZE AND PLAN We are given values for wavelength and speed and asked to determine frequency. We will employ the fundamental relationship: $f = \frac{v}{\lambda}$

SOLVE Plugging in values: Part (a): $f = \frac{343 \text{ m/s}}{1.10 \text{ m}} = 312 \text{ Hz}$

Part (b): If the wavelength is halved the frequency is doubled:

$$f = \frac{343 \text{ m/s}}{0.55 \text{ m}} = 624 \text{ Hz}$$

REFLECT These frequencies correspond roughly to D sharp in the middle of the piano keyboard and one octave above. So now we know that the frequencies near middle C on the piano correspond to wavelengths of roughly 1 meter.

29. ORGANIZE AND PLAN We assume the waves originated from the same spot at $t = 0$. The time of travel between source and observer is $t = d/v$ where d is the distance between source and observer and v is the velocity of the wave.

The time of travel for the p waves is $t_p = d/v_p$ while the time of travel for the s waves is $t_s = d/v_s$. Since the p waves are faster than the s waves $t_p < t_s$.

We are given the difference in arrival times $\Delta t = 24\ s$. We can derive the relationship between d and Δt as follows:

$$\Delta t = t_s - t_p = d \times \left(\frac{1}{v_s} - \frac{1}{v_p}\right)$$

Solving for d yields:

$$\Delta t \frac{v_p v_s}{v_p - v_s} = d$$

SOLVE Plugging in values:

$$d = 24 \text{ s} \frac{6 \times 4 \frac{\text{km}^2}{\text{s}^2}}{6 \frac{\text{km}}{\text{s}} - 4 \frac{\text{km}}{\text{s}}} = 288 \text{ km}$$

REFLECT P waves (primary waves) and s waves (secondary waves) are used to deduce many things including location of earthquakes and the structure of the interior of the earth. Fundamental in making the connections between the phenomena and the deduced information is an understanding of waves.

38. ORGANIZE AND PLAN We are given the linear mass density and tension in a string. This will allow us to deduce the velocity v of the wave on the string using the relationship $v = \sqrt{\frac{T}{\mu}}$.

The wavelengths of the first three harmonics (standing wave modes) are $\lambda_1 = 2L\ \lambda_2 = L\ \lambda_3 = \frac{2L}{3}$. Using the fundamental relationship $f = v/\lambda$ we find the frequencies of the first three harmonics.

SOLVE Plugging in values:

Part (a): The wave velocity is $v = \sqrt{\frac{36.5\ \text{M}}{2.1 \times 10^{-4}\ \text{kg/m}}} = 417\ \text{m/s}$

Part (b): The frequencies of the first three harmonics are: $f_1 = \frac{417\ \text{m/s}}{2 \times 0.75\ \text{m}} = 278\ \text{Hz},\quad f_2 = 2f_1 = 556\ \text{Hz},$ and

$f_3 = 3f_1 = 834\ \text{Hz}$

REFLECT The fundamental frequency of the string corresponds to C sharp just above middle C. The second harmonic is one octave above the fundamental frequency.

42. ORGANIZE AND PLAN The standing wave modes on a string occur when $L = \frac{1}{2}\lambda_1,\ L = \frac{2}{2}\lambda_2$ and $L = \frac{3}{2}\lambda_3$ corresponding to 1, 2, and 3 anti-nodes, respectively. The wavelength associated with a standing wave mode with 3 anti-nodes is given by $L = \frac{3}{2}\lambda_3$.

Given the tension and the linear mass density we can determine the velocity of the wave on the string using $v = \sqrt{T/\mu}$. The derived velocity and wavelength we can determine the frequency of the third harmonic using the fundamental relationship $f_3 = v/\lambda_3$.

SOLVE Part (a): The wavelength of the third harmonic is $\lambda_3 = \frac{2\,L}{3} = \frac{2}{3}0.76\ \text{m} = 0.51\ \text{m}$

Part (b): The velocity of the wave on the string is $v = \sqrt{\frac{10.2\ \text{N}}{3.86 \times 10^{-5}\ \text{kg/m}}} = 514\ \text{m/s}$

The corresponding frequency of the third harmonic is $f_3 = \frac{514\ \text{m/s}}{0.51\ \text{m}} = 1.0\ \text{kHz}$

REFLECT The fundamental frequency is $f_1 = \frac{f_3}{3}$ which reveals this string to be a high E string on a guitar. The guitar player can reduce the amplitude of the third harmonic by placing the finger lightly on one of the anti-nodes 1/3 of the way down the length of the string.

47. **ORGANIZE AND PLAN** The distance traveled over the time it took the signal to reflect off the bottom and come back is twice the distance the submarine is from the bottom. Recalling that rate times time equals distance we obtain the required distance as follows:

$$2\,h = vt$$

The depth of the ocean D at that point is simply the depth of the submarine d plus the distance between the sub and the sea floor.

$$D = d + h = d + \frac{vt}{2}$$

Note: The velocity of sound in water is $v = 1480\ \text{m/s}$

SOLVE Plugging in values:
The depth of the ocean is

$$D = 65\ \text{m} + \frac{1480\ \text{m/s} \times 0.86\ \text{s}}{2} = 700\ \text{m}$$

REFLECT The Abyssal Plain (the deepest flat part of the ocean) is around 4000 m so this part of the ocean is one of the shallower parts. For example, about 30 miles west of the San Francisco coast has an ocean depth of about 700 m.

50. **ORGANIZE AND PLAN** We shall treat the sound source as a point source in open space. The sound intensity is inversely proportional to the distance squared, $I_1 = P_1/(d_1)^2$ where P_1 is a property of the source only and $d_1 = 25\ \text{m}.$ The intensity at $d = 50\ \text{m}$ is $I_2 = \frac{I_1}{4}$ while the intensity at $d = 250\ \text{m}$ is $I_2 = \frac{I_1}{100}$.
The sound intensity level is defined to be

$$SIL = 10\ \log\frac{I}{I_o}$$

Manipulating the SIL into a form more appropriate for the given information we note:

$$SIL = 10\ \log\frac{I_1}{\gamma I_o} = 10\ \log\frac{I_1}{I_o} - 10\ \log\gamma$$

We are given $55\ \text{dB} = 10\ \log\frac{I_1}{I_o}$ so the SIL for this problem is:

$$SIL = 55\ \text{dB} - 10\ \log\gamma$$

SOLVE Part (a): The SIL for $d = 50\ \text{m}$ (corresponding to $\gamma = 4$) is: $49\ \text{dB}$
Part (b): The SIL for $d = 250\ \text{m}$ (corresponding to $\gamma = 100$) is: $35\ \text{dB}$
REFLECT The SIL of this source at around $2.5\ \text{m}$ corresponds to roughly $80\ \text{dB}$ (a busy city street). At approximately 1.5 blocks away the SIL diminishes to below that of a soft conversation heard at a distance. A useful thing to know if you are a real estate agent or home buyer on the hunt.

62. ORGANIZE AND PLAN The fundamental frequency of a flute is $f_1 = v/2L$, where v is the velocity of sound in air and L is the length of the pipe. As shown in the text, playing low B of frequency 247 Hz requires a length of 0.694 m.

If the length is changed by $\pm 0.01\text{ m}$ the frequency will be determined by:

$$f_1^{\pm} = \frac{v}{2(L_o \pm 0.01\text{ m})}$$

SOLVE If the flute is made 1 cm longer, then the fundamental frequency is:

$$f_1^{\pm} = \frac{343\text{ m/s}}{2(0.704\text{ m})} = 244\text{ Hz}$$

If the flute is made 1 cm shorter, then the fundamental frequency is:

$$f_1^{\pm} = \frac{343\text{ m/s}}{2(0.684\text{ m})} = 251\text{ Hz}$$

REFLECT These frequency shifts are not enough to produce a half-step difference in pitch required to reach another note on the scale. For example, a half-step lower than low B (B flat) has a frequency of 233 Hz. A change of length of 1 cm is a tuning change of the instrument. In fact, this is how a flute is tuned. There is a movable junction called the headjoint between the mouthpiece and the body of the flute. By sliding this, the length of the flute is changed, tuning the instrument.

67. ORGANIZE AND PLAN The wavelength required for a particular frequency is given by the fundamental relationship:

$$\lambda = v/f$$

For open-closed pipes the wavelength of the fundamental is 4 times the length of the pipe. In other words, the length of the pipe $L = \frac{\lambda}{4}$. Combining the relationships:

$$L = \frac{v}{4f}$$

SOLVE Plugging in values for the different frequencies:

Part (a): L for 56 Hz: $L = \frac{343\text{ m/s}}{4 \times 56\text{ Hz}} = 1.53\text{ m}$

Part (b): L for 262 Hz: $L = \frac{343\text{ m/s}}{4 \times 262\text{ Hz}} = 0.33\text{ m}$

Part (c): L for 523 Hz: $L = \frac{343\text{ m/s}}{4 \times 523\text{ Hz}} = 0.16\text{ m}$

Part (d): L for 1200 Hz: $L = \frac{343\text{ m/s}}{4 \times 1200\text{ Hz}} = 0.07\text{ m}$

REFLECT This is a very wide range of sizes. The details of how pipe organs are constructed and how they produce their sound is beyond the scope of this book but you know enough now to ask some of the right questions if you are interested in knowing more.

70. ORGANIZE AND PLAN The expression for the observed frequency f' when the source is in relative motion to the medium (where the observer is stationary with respect to the medium) is:

$$f' = \frac{f}{1 \mp v_s/v}$$

where f is the emitted frequency of sound, v is the speed of sound in the medium, $-v_s$ corresponds to the velocity of the source approaching the observer, and $+v_s$ corresponds to the velocity of the source receding away from the observer.

We are given f and v_s in this problem.

SOLVE Observed frequency of sound when the jet approaches at $232\ \text{m/s}$:

$$f' = \frac{850\ \text{Hz}}{1-(232\ \text{m/s})/(343\ \text{m/s})} = 2630\ \text{Hz}$$

Observed frequency of sound when the jet recedes at $232\ \text{m/s}$:

$$f' = \frac{850\ \text{Hz}}{1+(232\ \text{m/s})/(343\ \text{m/s})} = 507\ \text{Hz}$$

REFLECT The jet is traveling at roughly 70% the speed of sound. The sound when approaching differs from the receding sound by roughly 2.5 octaves. Remember this the next time you hear a fighter plane fly toward you.

75. ORGANIZE AND PLAN To determine the observed frequency from the stationary helicopter we must know the velocity of the source (the parachutist). Recall kinematic equations for free-fall. After time t the velocity is $v = gt$ for constant acceleration. With the deduced velocity we employ the Doppler effect relation for a receding source:

$$f' = \frac{f}{1 + v_s/v}$$

In this problem:

$$f' = \frac{f}{1 + gt/\text{v}}$$

SOLVE Plugging in values:

The observed frequency of the shout is

$$f' = \frac{425\ \text{Hz}}{1 + \frac{9.8\ \text{m/s}^2 \times 4\ \text{s}}{343\ \text{m/s}}} = 381\ \text{Hz}$$

REFLECT The frequency is diminished as expected and the effect is noticeable. The glissando of the falling man is embedded in our cultural experience. What you hear in movies (or mimic with your voice when you are pretending you are falling) is a mixture between the Doppler effect and free-fall under constant acceleration.