(18 points, 3 points each): 6 Multiple-choice questions / fill-in-the-blanks on various topics.

Directions for multiple-choice questions: COMPLETELY FILL THE SQUARE for the best answer.
Directions for fill-in-the-blank questions: Your answer should be entirely in the boxed region. Include the number of significant figures ("sig. figs.") requested in the problem.

1. Two guitar strings (A and E) are under the same tension and produce standing waves of the same wavelength. The frequency of the A string is 110.00 Hz, and the frequency of the E string is 82.41 Hz. Which of the following best describes how the linear mass densities of the two strings compare with one another?
   - The A string has a linear mass density that is 16% higher than that of the E string.
   - The A string has a linear mass density that is 33% higher than that of the E string.
   - The A string has a linear mass density that is 16% lower than that of the E string.
   - The A string has a linear mass density that is 44% lower than that of the E string.

2. The figure below shows the displacement $y(x = 0, t)$ for a transverse wave on a string. To one significant figure, what is the maximum speed that particles on the string move?

   $$V_{\text{max}} = \omega A = \frac{2\pi f A}{T} = \frac{2\pi (2.00 \text{ cm})}{4.0 \text{ sec}}$$

   - 1 cm/sec
   - 2 cm/sec
   - 3 cm/sec
   - 4 cm/sec
   - 5 cm/sec

3. When standing 3.0 meters from a stereo, the sound is 65.0 decibels. Assuming that the sound is emitted isotropically, what is the total power output of the stereo? (2 sig. fig. answer, in mW)

Recall the threshold of hearing is $10^{-12}$ W/m$^2$ (the intensity corresponding to 0 decibels)

$$I = 10^{-5.5} \frac{W}{m^2}$$

$$P = I (4\pi R^2) = (3.16 \times 10^{-6} \frac{W}{m^2})(4\pi)(3.0^2 \text{ m}^2)$$

$$P = 0.36 \text{ mW}$$
4. When a sound wave passes from air into water, the frequency of sound waves ______ and the wavelength of sound waves ______. The speed of sound in air is 343 m/s and the speed of sound in water is 1500 m/s.

- remains the same, increases
- remains the same, decreases
- increases, increases
- decreases, remains the same
- increases, decreases

\[ v = 2f \]

\[ \frac{v}{f} = \left( \frac{\lambda}{f} \right) \text{(const.)} \]

5. A 7.0-cm-diameter pipe narrows to half its initial diameter. Liquid flows through the 7.0-cm section at a speed of 4.0 m/s. What is the speed of the liquid in the second segment, and what is the volume flow rate through the pipe?

- 2.0 m/s in the second segment, and a total flow rate of 0.015 m³/sec.
- 2.0 m/s in the second segment, and a total flow rate of 0.062 m³/sec.
- 16.0 m/s in the second segment, and a total flow rate of 0.015 m³/sec.
- 16.0 m/s in the second segment, and a total flow rate of 0.062 m³/sec.

\[ A_2 = \frac{1}{4} A_1 \Rightarrow v_2 = 4v_1 = 16.0 \text{ m/s} \]

\[ \text{(Vol. flow rate)} = v_1 A_1 = (4 \pi) \left( 0.035 \right)^2 \text{ m}^3 \text{ sec}^{-1} \]

6. Gas flows through the pipe of the following figure (the liquid is in equilibrium). You can’t see into the pipe to know how the inner diameter changes. Where is the gas moving the fastest?

- Point a
- Point b
- Point c

\[ \text{lowest pressure} \]

\[ \text{needs greater column of water underneath, so that the pressure here is the same everywhere.} \]
7. (10 points, 5 points each): When an object of mass $M$ is completely submerged in water, it requires an upward force $T$ to keep the object in equilibrium ("T" for "Tension" in the string holding it up). When the same object is completely submerged in "Liquid X," the tension required in the string is $3T$.

(a) Does "Liquid X" have a density that is greater than water or less than water? Explain using free-body diagrams.

(b) Given $T = 250\text{ N}$ and $Mg = 1250\text{ N}$, find the density of the object in SI units.

(a) 

\[ \Sigma F = 0 \]

\[ Mg = (\text{tension}) + \rho_{\text{Liquid X}} g V_{\text{disp}} \]

\[ T + \rho_{\text{water}} g V = 3T + \rho_{\text{Liquid X}} g V \]

(b) 

\[ Mg = T + \rho_{\text{water}} g V \implies \frac{1}{\rho_{\text{water}}} = \frac{T}{Mg} + \frac{\rho_{\text{Liquid X}} g V}{Mg} \]

\[ \rho_{\text{water}} \frac{V}{M} = \frac{4}{5} \]

\[ \frac{M}{V} = \frac{5}{4} \rho_{\text{water}} = 1250 \frac{\text{kg}}{\text{m}^3} \]
8. (15 points, 5 points each): A snapshot graph at \( t = 0 \) of a traveling wave is shown below:

(a) What are the frequency (in cycles per second) and the wavelength (in meters) of this wave?
(b) Draw a history graph \((y \text{ vs. } t)\) for the particle at \( x = 0 \). The horizontal part of your graph should include the times \( t = 0 \) and \( t = T \) (where \( T \) is the period of the wave). Label your graph, including numerical values on both the horizontal as well as vertical axes.
(c) The wave can be described by the function \( y(x, t) = A \cos(kx \pm \omega t + \phi_0) \). Write down this function. That is, solve for the constants \( A, k, \) and \( \omega \) (all positive), find the sign, and find the value of \( \phi_0 \), assuming it is in the range \([0, 2\pi]\), then plug it all into \( y(x, t) \).

\[
\begin{align*}
\text{(a) } \lambda &= 16.0 \text{ cm} = 0.160 \text{ m} \\
\text{we read off the graph} \\
\frac{v}{\lambda} &= \frac{56.0 \text{ cm/s}}{0.160 \text{ m}} = 3.50 \text{ cycles/sec} \\
\text{(b) Note @ } (x, t) = (0, 0), \text{ the particle is} \\
at \ y = 0 \text{ and } y \text{ is increasing. Thus} \\
A &= 10 \text{ cm} \\
T &= 0.048 \text{ sec} \\
\text{(c) } y(x, t) &= A \cos\left[kx + \omega t + \frac{3\pi}{5}\right] \\
A &= 10 \text{ cm} \\
k &= \frac{2\pi}{\lambda} = 39.3 \text{ rad/m} \\
\omega &= \omega f = 2\pi \text{ rad/sec} \\
\phi_0 \text{ determined by the following: } y(x, t = 0) \text{ is a } \cos(kx) \text{ graph} \\
&\text{shifted left by } y = \frac{3}{4} \lambda, \text{ which corresponds to } \frac{3\pi}{5} \text{ in phase.}
\end{align*}
\]
9. (10 points, 5 points each): A pipe of length \( L \) is closed at one end. The 2nd-lowest harmonic frequency for the pipe is \( \omega \) (angular frequency). Answer the following in terms of \( L \):

(a) Draw the standing wave for this second-lowest harmonic. What is the wavelength of this harmonic?

(b) Suppose we want to cut the pipe so that it is open on both sides, and also so that the fundamental angular frequency of the newly-cut pipe matches the original angular frequency \( \omega \). How long should the pipe be after you cut it?

\[(\text{Note } \frac{\lambda}{2} = \frac{2\omega}{3L}) \]

\[\text{or } \lambda = \frac{4L}{3}\]

The pipe should be \( \frac{2}{3}L \).

Look at the right two-thirds of the graph of the standing wave in pt. (a), and the answer jumps out.
10. (10 points, 5 points each): At a distance $D$ away from a fire alarm, you hear the alarm sounding at 95.0 dB. Assume sound is emitted from the source isotropically in three dimensions.

(a) At what distance should you stand from the alarm in order for the sound intensity level to drop to 83.0 dB?

(b) As you’re walking from distance $D$ to the distance you found in part (a), you notice a beat frequency of 2.0 Hz because you happen to be moving from one alarm and towards another. Assuming both alarms are emitting sound at the same frequency, and assuming you walk at a speed of 1.0 m/s, what is the frequency of each alarm (the frequency emitted by the sources)?

(a) A decrease of sound level of 12.0 dB is a “halving” of absolute intensity four times: $I_f = \left(\frac{1}{2}\right)^4 I_0 = \frac{1}{16} I_0$.

If you stand at $r = 4D$, then the intensity drops by a factor of 16.

$$I \propto \frac{1}{r^2} \propto \frac{1}{r^4}$$

(b) $f' = f \left(1 + \frac{v}{c}\right)$

$$|\Delta f'| = 2f \frac{v}{c}$$

$$f = |\Delta f'| \frac{c}{2v} = (343 \text{ Hz}) \frac{343 \text{ m/s}}{(2)(1.0 \text{ m/s})}$$

$$f = 343 \text{ Hz}$$