PHYSICS 202
Practice Exam
Waves, Sound, Reflection and Refraction

Name _____________________________________________________

Constants and Conversion Factors

Speed of sound in Air $= 340 \, \text{m/s}$
$1609 \, \text{meters} = 1 \, \text{mile}$

Note: For those problems where needed, assume that the speed of sound in air is $340 \, \text{m/s}$ unless otherwise stated.

Useful Equations

Doppler Shift Equation, $f_o = f_s \left[ \frac{v \pm v_o}{v \mp v_s} \right]$

Velocity of Waves on String, $v = \sqrt{\frac{F}{\mu}}$

Velocity of Waves in Gas, $v = \sqrt{\frac{\gamma RT}{\mu}}$

Velocity of Sound in Air, $v[m/s] = 331[m/s] \sqrt{1 + \frac{T[^\circ C]}{273}}$

Note: Assume that all numbers on this test are given to three significant figures, so that your answers should be given to three significant figures. [Note: You should maintain more than the three significant figures in your calculations to avoid round-off errors.] Be sure to enclose your answers in a box, and to include the units. To receive full credit, you must show all your work on this test paper.
Part I. Short answer questions and multiple choice. For the multiple choice questions circle the letter corresponding to the correct statement. Remember that there may be several correct answers, or there may be no correct answer.

1. During an earthquake, the rocks within the earth experience what is called elastic rebound, i.e., the deformed rock bounces back. This rebound releases energy which propagates through the earth in the form of waves. Two different types of waves are produced, $P$-waves (compressional or longitudinal waves) and $S$-waves (sheer or transverse waves).
   a) The longitudinal waves travel faster than the transverse waves.
   b) The sheer waves cannot pass through liquids.
   c) The waves speed up when passing through rock which is more rigid, and slow down when passing through rock that is less rigid.
   d) The waves speed up when passing through more dense rock, and slow down when passing through rock that is less dense.
   e) The $P$-wave is similar to sound waves in air, while the $S$-waves are similar to waves on the surface of water.

2. The piano is a stringed instrument with a large number of strings which allow one to play a very large range of frequencies.
   a) The speed of a wave on a piano wire depends upon the tension in the string.
   b) The speed of a wave on a piano wire is larger for the larger piano strings.
   c) The fundamental frequency of a piano string depends only upon the length of the string.
   d) The fundamental frequency of a piano string depends upon the speed of sound in air.
   e) A piano string produces only odd harmonics.

3. To obtain the low-frequency notes on a piano, the strings are often wound with additional wire to increase the mass of the string. If a string 0.8m long normally has a resonant frequency of 50 Hz, what would be the resonant frequency of this same string if it were wrapped so that its mass increased by a factor of two.
4. Explain the difference between a violin note and the same note sung by a human voice that enables us to distinguish between them?

5. A xylophone is made of rectangular bars (pieces of metal or wood) which rest upon supports that are positioned an equal distance from each end of the rectangular bar (as shown below). The length of the rectangular bars are varied to produce the different notes. Draw a vertical displacement diagram of the fundamental and the first overtone which can be produced on the xylophone bar shown below. [Hint: What points are not free to move?]

![Diagram of xylophone bar with points labeled.]

6. If a violin string is tuned to a fundamental frequency of 500 Hz, what is the second harmonic (first overtone) of this string?
7. You have a long pipe partially filled with water. The distance from the top of the pipe to the water is 50 cm. What is the fundamental resonance frequency of this pipe?

8. What is the wavelength of light in water (index of refraction equal to 1.3) when the wavelength in air is 500 nm?

9. A piano tuner is tuning a piano string against a tuning fork which oscillates at a known frequency of 256 Hz. He is tuning the piano by listening for beats. When he first notices the beats, he hears a beat frequency of approximately 5 Hz. When the piano tuner tightens the string (i.e., increases the tension), the beat frequency increases to 10 Hz. What is the frequency with which the piano string is vibrating when the beat frequency is 10 Hz?
10. A flute can be treated as a resonant pipe open at both ends. Suppose the fundamental frequency of this flute were 300 Hz at 20° C. By how much does the fundamental frequency change when the temperature of the room increases by 5° C? Assume that the length of the flute does not change significantly.

11. Without the computer running, the background sound level in my office is measured to be 40 dB. When I turn on the computer system, the sound level in the office is found to be 50 dB. By what amount is the sound intensity in my office increased when I turn on the computer (i.e., what is the ratio of the intensity with the computer on to that when the computer is off)?
12. A stove is connected to a 2 meter length of stove pipe. When the wind blows, the pipe sometimes "sings" (just like blowing across the top of a coke bottle). It is the fundamental frequency which is usually heard.

a. Draw a sound pressure diagram for the fundamental resonance of this tube, assuming that the stove pipe is "open" on both ends, and determine the frequency of the sound that is produced.

b. Now, assume that the pipe is "open" on one end and "closed" on the other. Again draw a sound pressure diagram for this case and determine the frequency of sound that is produced.

13. The equation of a traveling wave is given as:

\[ y = (1.5) \sin (4\pi x - 8\pi t) \]

where \( x \) is measured in meters and \( t \) in seconds.

(a) What is the wavelength of this wave?

(b) What is the frequency of this wave?

(c) How fast and in what direction is the wave moving?
14. Two speakers are placed on the floor 4 meters apart. You stand at point \( P \), 3 meters directly in front of one of the speakers as shown.

(a) Determine the lowest frequency sound for which maximum constructive interference occurs.

(b) Determine the lowest frequency sound for which maximum destructive interference occurs.
15. In the diagram below, light from a laser shines through water (index 1.3) and is incident on a glass block (index 1.5) which is at the surface of the water.

\[ n = 1.0 \]
\[ n = 1.3 \]
\[ n = 1.5 \]

a. Determine the critical angle \( \phi \) where the laser light will be totally reflected at the air glass interface.

b. Now a substance of index 1.25 is poured on top of the glass plate. Determine the new value for the critical angle in this situation. (This is one method of determining the index of refraction for different liquids.)
16. Two radio antenna ($S_1$ and $S_2$) are separated by a distance equal to twice the wavelength of the transmitted signal. Determine the smallest angle $\theta$ at which the resultant signal from both sources will be zero.
17. Train $A$ and train $B$ are approaching each other on the same track. Train $A$ is instructed to pull onto a side track to allow train $B$ to pass. The frequency of the horn on each train is set to 1000 Hz.

a. As train $B$ is approaching, the engineer gives a greeting “toot” of his horn. If the engineer in train $A$, which sits at rest on the side track, hears a frequency of 1100 Hz, how fast is train $B$ moving toward train $A$ (in mi/hr)?

b. While train $B$ is still approaching, the engineer of train $A$ returns the greeting “toot”. What frequency will the engineer of train $B$ hear?