Assignment 14

1. A harmonic wave in a string is described by \[ y(x, t) = 0.01 \cos(0.6 \cdot x - 60 \cdot t) \mod{[SI units].} \]
   a. What is the wavelength \( \lambda \)?
   b. What is the frequency \( f \)?
   c. What is the speed \( v \) of the wave?
   d. What is the power transmitted past a point on the string, if the mass per unit length of the string is 1 g/m? [See Waves 1, page 6.] \( \text{Ans: } 18 \text{ mW.} \)

2. Some questions about transmission and reflection of waves.
   a. A string consists of two pieces, attached as shown. It is stretched so the tension is \( T \) in both parts. A wave is sent down part \( A \) toward the interface, with power \( P_0 \). The masses per unit length obey \( \mu_B = 4 \mu_A \). Is the reflected wave inverted?
   b. What is the power reflected at the interface? [See Waves 1, page 7.] \( \text{Ans: } P_0 / 9. \)
   c. Explain why a sound wave reflected from a massive wall is not inverted, while a wave in a string attached to the wall is inverted.

3. Some questions about loudness and the db scale.
   a. An increase in loudness of 1 db represents what percent increase in intensity?
   b. Show that a decrease in intensity by a factor of 2 is represented by a decrease of about 3 db in loudness.
   c. The sound from a rock band at 10 m from the stage has loudness 138 db. A listener concerned about his hearing wishes to stand where the sound is 120 db in loudness. How far back must he move? \( \text{Ans: } 79.4 \text{ m from the stage.} \)
4. A source emits sound of frequency \( f_0 \), and a receiver hears the sound to have frequency \( 1.02f_0 \). Evaluate the following explanations.
   
   a. The receiver is at rest and the source is moving toward him at 2\% of the speed of sound.
   
   b. Both source and receiver are at rest, but the wind is blowing at 2\% of the speed of sound from source toward receiver.
   
   c. The source is at rest and the receiver is moving toward him at 2\% of the speed of sound.
   
   d. The source and receiver are moving toward each other, at 1\% of the speed of sound relative to the still air.

5. A child is running away from a wall and toward a stationary listener at speed 1\% of the speed of sound, blowing a whistle of frequency \( f_0 \). The listener hears 4 beats/s in the sound directly from the whistle and that reflected from the wall. What is \( f_0 \)? \textit{Ans:} 200 Hz.

6. In a radar speed detection system a stationary police car sends out radar waves of frequency \( f_0 = 10^9 \) Hz traveling at speed \( c = 3 \times 10^8 \) m/s. The wave is reflected by a moving car and the reflected wave is detected by the police car’s system, which measures the beats between outgoing and incoming waves to determine the speed of the car.

   Let the car be approaching the police car at \( v = 30 \) m/s, and (since this is very small compared to the speed of light) use the formulas for sound waves.

   a. What is the ratio of the frequency \( f_1 \) reflected by the car to \( f_0 \)? \textit{Ans:}\n   \[
   \frac{1 + v}{c}.
   \]

   b. What is the ratio of the frequency \( f_2 \) received back by the police car to \( f_0 \)? \textit{Ans:}\n   \[
   \frac{1 + v}{1 - v/c}.
   \]

   c. What is the beat frequency? \textit{Ans:} 200 Hz.
7. You are given a wave described by \( y_1(x,t) = A \cos(4\pi x - 1000\pi t) \), which you will superpose with a wave described by \( y_2(x,t) = A \cos(kx - \omega t + \phi) \). The intensity of the first wave alone is \( I_0 \).

   a. Write a function for the second wave that will give you a wave of the the same wavelength and frequency but intensity \( 4I_0 \).
   
   b. Write a function for the second wave that will give you a wave of the the same wavelength and frequency but intensity \( 2I_0 \).
   
   c. Write a function for the second wave that has the same wave speed as the first one, but gives beats of frequency 5 Hz. [Give both answers.]
   
   d. Suppose the second wave has the same wavelength and frequency as the first, but its amplitude is \( 3A \). What are the maximum and minimum intensities that result from the superposition?

8. A speaker sends out sound of wavelength \( \lambda \), which is received by a microphone at distance \( d \). A reflected wave from the ceiling interferes with the direct wave. Find the minimum height \( h \) of the ceiling that will give destructive interference of the waves reaching the microphone. Assume \( \lambda \) is small compared to the other dimensions, and that there is no phase change on the reflection. \( \text{Ans: } \frac{1}{2} \sqrt{d\lambda} \).

9. The identical loudspeakers shown emit waves, in phase, of wavelength \( \lambda \) and (separate) intensity \( I_0 \). We are interested in the intensity at the three points shown. Ignore changes in amplitude with distance.

   a. What is the intensity at \( A \)?
   
   b. What is the intensity at \( B \)?
   
   c. At what distance \( x_C \), on the line shown, will the intensity be \( 2I_0 \)? \( \text{Ans: } 3\lambda / 8 \).