Homework Set 2

Due Wednesday, 07/06

Problem 1

A wave on a string has an amplitude of 1.5cm, a period of 0.12 seconds, and a wavelength of 1.1 meters.

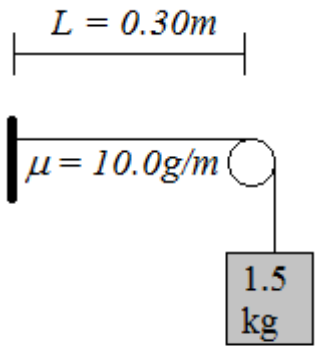
a. What is the wave's frequency, angular frequency, wave number and wave speed?

b. If the string is under tension of 5.0N, what is its mass per unit length, in grams per meter?

c. If the tension in the string changes to 10.0N but the frequency of the wave remains the same, what is its new wavelength?

Problem 2

A string with mass per unit length μ = 10.0g/m is tied down on one side, and runs over a pulley on the other side, 0.30 meters away. The end that runs over the pulley is attached to a 1.5 kilogram mass. Assume that the end of the string that is tied down and the point that runs over the pulley cannot move, but the piece between these points is free to oscillate.

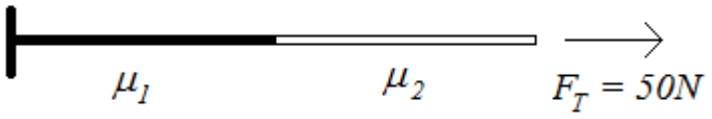


a. What is the string's fundamental frequency?

b. Now this system is placed in an accelerating elevator. The 3rd harmonic frequency is measured to be 204 hz. Is the elevator accelerating up or down? What is its acceleration?

Problem 3

Two strings with different masses per unit length are connected together and held at a tension of 50*N*:



An wave with an amplitude of 2.50cm and a frequency of 60.0 hz is incident from the left. The waves on the left-hand string are observed to have a wavelength of 30.0cm, while those on the right-hand string have a wavelength of 20.0cm.

a. What is the mass per unit length, μ_1, of the left string? What is the mass per unit length of the right string?

b. What is the amplitude of the transmitted waves on the right string?

c. What is the transmission coefficient? What is the reflection coefficient?

Problem 4

Suppose that a metal alloy has a density of 7.90g/cm^3. The speed of sound in this metal is measured to be 4.08km/s. We take a piece of this metal and submerge it to the bottom of the Mariana Trench, 10.9km below the surface of the ocean. The metal is compressed by the pressure of the water. By what fraction does the volume of this piece of metal change? Assume that the density of water stays approximately constant at 1g/cm^3.

Problem 5

A loudspeaker at a concert is capable of producing sound with intensity level of 120 decibels at a distance of 5 meters from the speaker.

a. Assuming that the sound is emitted in spherical waves, what is the power of this speaker in watts?

b. What is the sound intensity level, in decibels, 100 meters away from the speaker?

c. At a distance of 5 meters away from the speaker, what is the accoustic energy density in the air (in Joules of accoustic energy per cubic meter of air)? Assume that the speed of sound in air is 331m/s.

Problem 6
Submarine A is following another submarine B. Both are traveling along the same course in the same direction. Submarine A, traveling at a speed of 6.0 knots (1 knot = 1.85km/h) emits a sonar ping at a frequency of 2200 hz. The echo from submarine B returns 22 seconds later, with a frequency of 2185 hz. Assume that the speed of sound in water is 1500 m/s. How far away is submarine B, and how fast is it moving?

Problem 7
Two train whistles have identical frequencies of 220 hz. Suppose that one train is at rest, while another is approaching it on a collision course with a constant speed *v*. Both trains are sounding their whistles, and are 100 meters away from each other. An observer on the stationary train hears a beat frequency of 4.0 hz. How many seconds before the trains collide?

Problem 8
A flute generates a note at a frequency of 1440 hz. The air temperature is 25^{o}C.

a. If one were to attempt the same note on the flute at 0^{o}C, what frequency would be generated? What about at 40^{o}C?

b. Now suppose that the note is played in an atmosphere of helium at 25^{o}C. What is the frequency then? (Assume that $B_{HELIUM} \approx B_{AIR}$).

Problem 9 (Extra Credit)
Suppose that a type of wave obeys the following variant of the wave equation, known as the *Klein-Gordon equation*:

$$\frac{\partial^2 y}{\partial t^2} - c^2 \frac{\partial^2 y}{\partial x^2} + a^2 y = 0$$

a. Show that a sine wave, $y = A \sin(kx - \omega t)$, satisfies the Klein-Gordon equation.

b. What is the relationship between the angular frequency ω and the wave number k for a Klein-Gordon wave, in terms of the constants c and a?

c. What is the phase speed of Klein-Gordon waves? What is the group speed? Show that although the phase moves faster than c, wave packets always move slower than c.

Problem 10 (Extra Credit)

A whale is swimming 300 meters under the surface of the ocean. The whale emits a call, using a power output of 120 Watts.

A swimmer is in the water directly above the whale. If the swimmer's head is underwater, what is the intensity level of the sound he hears (in decibels)? If his head is above the water, what is the intensity level then? Hint: the transmission and reflection of sound waves works the same way as for waves on a string. Assume that the speed of sound in air is 331 *m/s*, and the speed of sound in water is 1550 *m/s*.