Big Idea 3: The interactions of an object with other objects can be described by forces.		profi-cient
Essential Knowledge 3.B.3: Restoring forces can result in oscillatory motion. When a linear restoring force is exerted on an object displaced from an equilibrium position, the object will undergo a special type of motion called simple harmonic motion. Examples should include gravitational force exerted by the Earth on a simple pendulum, mass spring oscillator a. For a spring that exerts a linear restoring force the period of a mass-spring oscillator increases with mass and decreases with spring stiffness. b. For a simple pendulum oscillating the period increases with the length of the pendulum. c. Minima, maxima, and zeros of position, velocity, and acceleration are features of harmonic motion. Students should be able to calculate force and acceleration for any given displacement for an object oscillating on a spring.	**Learning Objective (3.B.3.1):** The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties.	
	Learning Objective (3.B.3.2): The student is able to design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.	
	Learning Objective (3.B.3.3): The student can analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown.	
	Learning Objective (3.B.3.4): The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force.	
Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.		
Essential Knowledge 6.A.1: Waves can propagate via different oscillation modes such as transverse and longitudinal. a. Mechanical waves can be either transverse or longitudinal. Examples should include waves on a stretched string and sound waves	**Learning Objective (6.A.1.1):** The student is able to use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave.	
	Learning Objective (6.A.1.2): The student is able to describe representations of transverse and longitudinal waves.	
Essential Knowledge 6.A.2: For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.	**Learning Objective (6.A.2.1):** The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples.	
Essential Knowledge 6.A.3: The amplitude is the maximum displacement of a wave from its equilibrium value.	**Learning Objective (6.A.3.1):** The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.	
Essential Knowledge 6.A.4: Classically, the energy carried by a wave depends upon and increases with amplitude. Examples should include sound waves.	**Learning Objective (6.A.4.1):** The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example.	
Essential Knowledge 6.B.1: For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time.	**Learning Objective (6.B.1.1):** The student is able to use a graphical representation of a periodic mechanical wave (position versus time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation.	
Essential Knowledge 6.B.2: For a periodic wave, the wavelength is the repeat distance of the wave.	**Learning Objective (6.B.2.1):** The student is able to use a visual representation of a periodic mechanical wave to determine wavelength of the wave.	
Essential Knowledge 6.B.4: For a periodic wave, wavelength is the ratio of speed over frequency.	**Learning Objective (6.B.4.1):** The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.	

Essential Knowledge 6.B.5: The observed frequency of a wave depends on the relative motion of source and observer. (This is a qualitative treatment only.)	**Learning Objective (6.B.5.1):** The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer.	
Essential Knowledge 6.D.1: Two or more wave pulses can interact in such a way as to produce amplitude variations in the resultant wave. When two pulses cross, they travel through each other; they do not bounce off each other. Where the pulses overlap, the resulting displacement can be determined by adding the displacements of the two pulses. This is called superposition.	**Learning Objective (6.D.1.1):** The student is able to use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses.	
	Learning Objective (6.D.1.2): The student is able to design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves).	
	Learning Objective (6.D.1.3): The student is able to design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium	
Essential Knowledge 6.D.2: Two or more traveling waves can interact in such a way as to produce amplitude variations in the resultant wave.	**Learning Objective (6.D.2.1):** The student is able to analyze data or observations or evaluate evidence of the interaction of two or more traveling waves in one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes.	
Essential Knowledge 6.D.3: Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string, and sound waves in both closed and open tubes.	**Learning Objective (6.D.3.1):** The student is able to refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively.	
	Learning Objective (6.D.3.2): The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes.	
	Learning Objective (6.D.3.3): The student is able to plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air.	
	Learning Objective (6.D.3.4): The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.	
Essential Knowledge 6.D.4: The possible wavelengths of a standing wave are determined by the size of the region to which it is confined. a. A standing wave with zero amplitude at both ends can only have certain wavelengths. Examples should include fundamental frequencies and harmonics. b. Other boundary conditions or other region sizes will result in different sets of possible	**Learning Objective (6.D.4.1):** The student is able to challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region.	
	Learning Objective (6.D.4.2): The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments.	
Essential Knowledge 6.D.5: Beats arise from the addition of waves of slightly different frequency. a. Because of the different frequencies, the two waves are sometimes in phase and sometimes out of phase. The resulting regularly spaced amplitude changes are called beats. Examples should include the tuning of an instrument. b. The beat frequency is the difference in frequency between the two waves.	**Learning Objective (6.D.5.1):** The student is able to use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats.	

Oscillation Reading Assignment

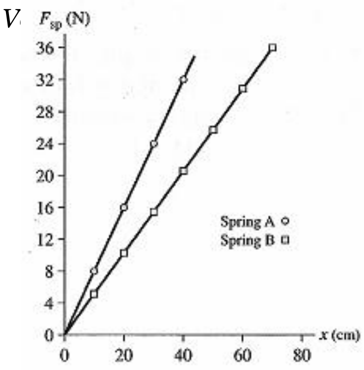
Research is what I'm doing when I don't know what I'm doing. ~Wernher Von Braun

Directions: Read Chapter 14 (skip section 14.7) As you read answer all Stop to Think questions (Check your answers on page 469) and work through all example problems. Below is a list of what you need to take away from your reading.

1. **Define/Know**
   a. equilibrium position
   b. restoring force
   c. oscillation
   d. period
   e. equation for period of a spring
   f. equation for period of a pendulum
   g. frequency (and units)
   h. the shape of a graph of an object moving in simple harmonic motion
2. **Explain:**
   a. the difference in equilibrium position for a mass oscillating on a horizontal spring vs. one oscillating on a vertical spring?
   b. Where the following quantities are zero or at a maximum for an oscillating object: velocity, acceleration, kinetic energy, and potential energy
   c. How mass, spring constant and amplitude affect the period/frequency of a spring
   d. How mass, length, acceleration due to gravity and amplitude affect the period/frequency of a pendulum.
3. **Be able to:**
   a. Draw a position vs. time graph for an object moving in simple harmonic motion. Label a period (T) and amplitude (A) on the graph.
   b. Derive the equation for velocity max using conservation of energy for an oscillating mass on a spring

Oscillation Problems

Research is what I'm doing when I don't know what I'm doing. ~Wernher V



1) The graph to the right shows the stretching of two different springs, A and B, when different forces were applied.

   a) Which spring is stiffer (harder to pull).

   b) Determine the spring constant for each spring.
   k_a = k_b =

2) A spring has an upstretched length of 10 cm. It exerts a restoring force F when stretched to a length of 11 cm.
   a) For what length of the spring is the restoring force 3F?

   b) At what compressed length is the restoring force 2F?

3) A 255 g mass is hooked up to a spring (k = 175 N/m) and moves back and forth on your basic frictionless surface. If the mass is released from rest at x = 0.200 m,
   (a) find the force acting on the mass when it's released

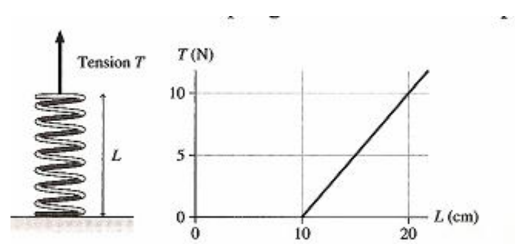
   (b) the max acceleration

   (c) it's acceleration at x = 0 m

   (d) its total energy

   (e) its period

4) A spring is attached to the floor and pulled straight up by a string. The spring's tension is measured. The graph shows the tension in the spring as a function of spring's length L.
   a) Does this spring obey Hooke's Law? Explain.



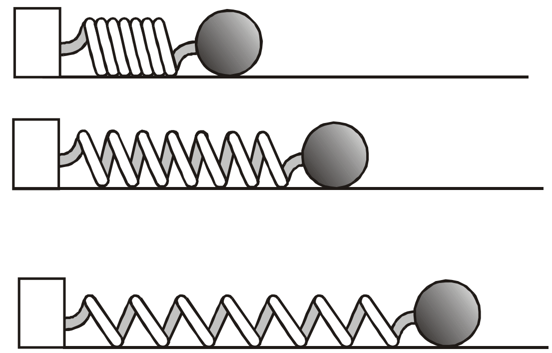
   b) If it does what is the spring constant?

5) A 355 g mass is attached to a spring (k = 435 N/m). If the system is allowed to oscillate on a frictionless surface, what is the period and frequency of the motion?

Oscillation Problems

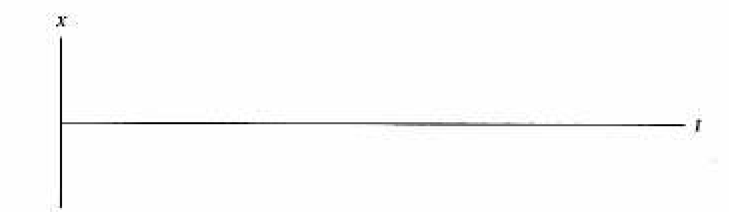
Research is what I'm doing when I don't know what I'm doing. ~Wernher Von Braun

6) The drawing shows the harmonic motion of a mass on a spring at the extremes of its motion. The middle drawing shows the midpoint of travel. Indicate on the drawing
   a) the points of greatest and least velocity,
   b) the points of greatest and least acceleration,
   c) the points of greatest and least potential and kinetic Energy.

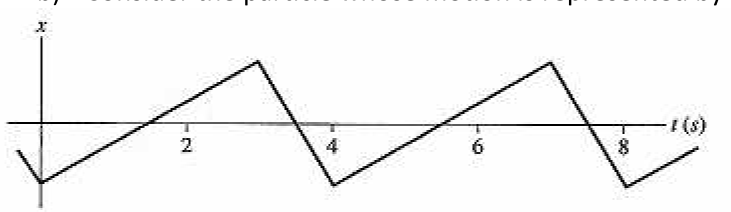


7) On the axes below, sketch three cycles of a position versus time graph for:
   a) A particle undergoing simple harmonic motion.

b. A particle undergoing periodic motion that is not simple harmonic motion.



   b) Consider the particle whose motion is represented by the x vs. t graph below.



   i) Is this periodic motion? ______________ iii) What is the period? __________________
   ii) Is this motion SHM? _______________ iv) What is the frequency? _______________

8) Using this graph of position vs time for the simple harmonic motion of a weight on a string, find
   (a) the amplitude of the motion

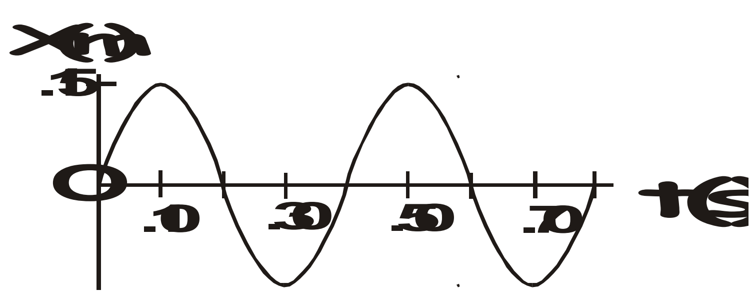
   (b) the period of the motion

   (c) the frequency of the motion

   (d) the times where the velocity is zero

   (e) the times where the acceleration is max

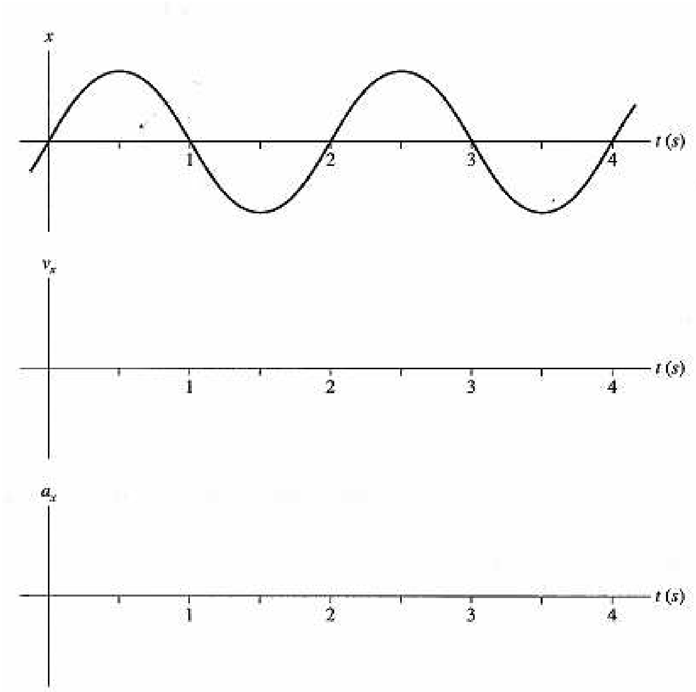
   (f) the times when the particle is instantaneously at rest?



Oscillation Problems

Research is what I'm doing when I don't know what I'm doing. ~Wernher Von Braun

9) The graph shown is the position vs time graph of an oscillating particle.
   a) Draw the corresponding velocity vs. time graph.
   b) Draw the corresponding acceleration vs. time graph.
   Hint: remember that velocity is the slope of the position graph, and acceleration is the slope of the velocity graph.



   c) At what times is the position a maximum?

   At those times is velocity a maximum, minimum or zero?

   At those times is acceleration a maximum, minimum or zero?

   d) At what times is the position a minimum (most negative)?

   At those times is velocity a maximum, minimum or zero?

   At those times is acceleration a maximum, minimum or zero?

   e) At what times is velocity a maximum?

   At those times, where is the position of the particle?

   f) What is the relationship between the sign of the position and the sign of the acceleration at the same instant of time?

10) A mass on a spring oscillates with period T, amplitude A, maximum speed v_{max}, and a maximum acceleration a_{max}.
   a) If T doubles without changing A
      i) how does v_{max} change?

      ii) how does a_{max} change?

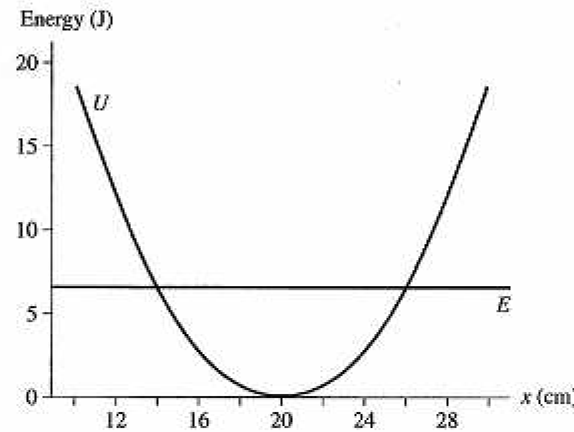
   b) If A doubles without changing T.
      i) how does v_{max} change?

      ii) how does a_{max} change?

Oscillation Problems

Research is what I'm doing when I don't know what I'm doing. ~Wernher Von Braun

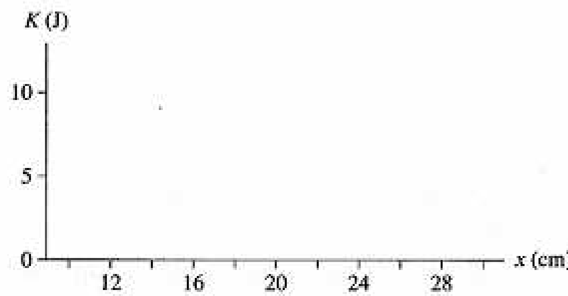
11. Energy in Simple Harmonic Motion



The figure shows a graph of the potential energy of a block oscillating on a spring. The horizontal line represents the block's total energy E.

a. What is the spring's equilibrium length?

b. Where are the turning points of the motion? Explain how you identify them.

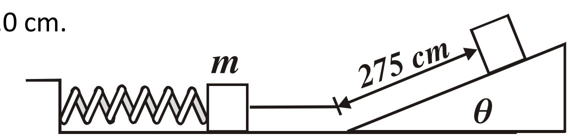


c. What is the block's maximum kinetic energy?

d. Draw a graph of the block's kinetic energy as a function of position.

e. What will be the turning points if the block's total energy is doubled?

12) A 545 g block is pushed into a spring (k = 485 N/m) a distance of 18.0 cm.



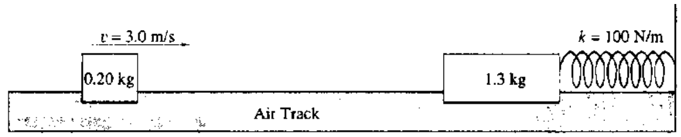
a) When the block is released from the spring, what is its velocity?

b) The block slides across a smooth surface once it leaves the spring and then up a ramp. It travels up the ramp a distance of 275 cm. What is the elevation angle of the ramp?

Oscillation Problems

Research is what I'm doing when I don't know what I'm doing. ~Wernher Von Braun

13) As shown to the right, a 0.20-kilogram mass is sliding on a horizontal, frictionless air track with a speed of 3.0 meters per second when it instantaneously hits and sticks to a 1.3-kilogram mass initially at rest on the track. The 1.3-kilogram mass is connected to one end of a massless spring, which has a spring constant of 100 newtons per meter. The other end of the spring is fixed.



a. Determine the following for the <u>0.20-kilogram mass</u> immediately <u>before</u> the impact.

i. Its linear momentum

ii. Its kinetic energy

b. Determine the following for the <u>combined masses</u> immediately <u>after</u> the impact.

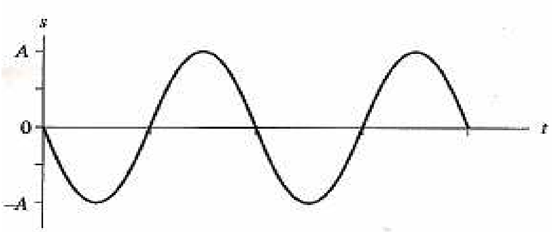
i. The linear momentum

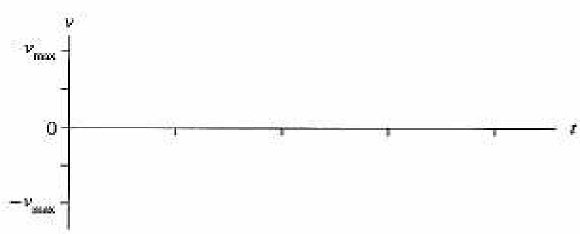
ii. The kinetic energy

c. How far does the spring compress after the collision?

14)

The graph shows the displacement s versus time for an oscillating pendulum.





a. Draw the pendulum's velocity-versus-time graph.

b. In the space at the right, draw a *picture* of the pendulum that shows (and labels!)
- The extremes of its motion.
- Its position at $t = 0$ s.
- Its direction of motion (using an arrow) at $t = 0$ s.

Oscillation Problems

Research is what I'm doing when I don't know what I'm doing. ~Wernher Von Braun

15) A pendulum on planet X, where the value of g is unknown, oscillates with a period of 2 seconds. What is the period if:

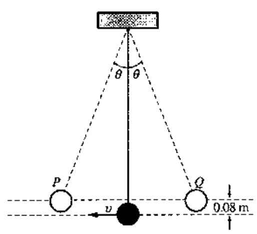
a) The mass is increased by a factor of 4?

b) Its length is increased by a factor of 4?

c) Its oscillation amplitude is increased by a factor of 4?

16) You are designing a pendulum clock. You have determined that the pendulum must have a period of 0.500 s. What should be the length of the rotating arm?

17) A simple pendulum consists of a bob of mass 0.085 kg attached to a string of length 1.5 m. The pendulum is raised to point *Q*, which is 0.08 m above its lowest position, and released so that it oscillates with small amplitude θ between the points *P* and *Q* as shown below.



Note: Figure not drawn to scale.

a. On the figures below, draw free-body diagrams showing and labeling the forces acting on the bob in each of the situations described.

i. When it is at point P

ii. When it is in motion at its lowest position

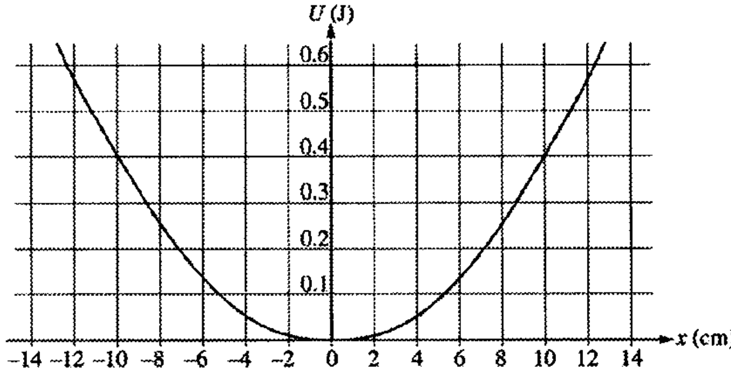
b. Calculate the speed v of the bob at its lowest position.

c. Calculate the tension in the string when the bob is passing through its lowest position.

d. Describe one modification that could be made to double the period of oscillation

Oscillation Problems

Research is what I'm doing when I don't know what I'm doing. ~Wernher Von Braun



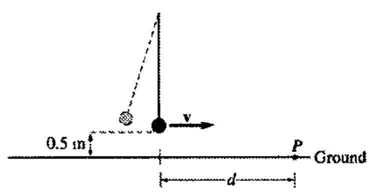
18) A 3.0 kg object subject to a restoring force *F* is undergoing simple harmonic motion with small amplitude. The potential energy *U* of the object as a function of distance x from its equilibrium position is shown above. This particular object has a total energy *E*: of 0.4 J.

(a) What is the object's potential energy when its displacement is +4 cm from its equilibrium position?

(b) What is the farthest the object moves along the x-axis in the positive direction? Explain your reasoning.

(c) Determine the object's kinetic energy when its displacement is -7 cm.

(d) What is the object's speed at x = 0 ?



Note: Figure not drawn to scale.

(e) Suppose the object undergoes this motion because it is the bob of a simple pendulum as shown above. If the object breaks loose from the string at the instant the pendulum reaches its lowest point and hits the ground at point *P* shown, what is the horizontal distance *d* that it travels?

Oscillation Problems

Research is what I'm doing when I don't know what I'm doing. ~Wernher Von Braun

19. 1. A simple harmonic oscillator consists of a mass of 0.5 kg sliding on a frictionless surface under the influence of a force exerted by a spring connected to the mass. The spring constant of the spring is 500 N/m. The total mechanical energy of the oscillator is 1 J.

(a) Find the amplitude, A, of the oscillation.

A =

(b) Find the period, T, of the oscillation.

T =

(c) Determine the maximum speed, v_{max}, of the mass.

v_{max} =

(d) Find the acceleration of the system at a displacement x = -0.01 m.

a (-0.01m) =

Wave Motion Reading Assignment

Directions: Read Chapters 15-16 (skip 16.5). As you read answer all Stop to Think questions (Check your answers on page 499 and 529) and work through all example problems. Below is a list of what you need to take away from your reading.

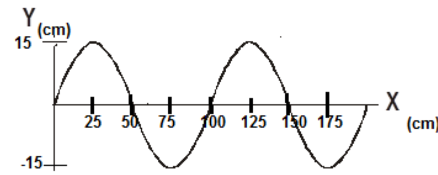
4. **Define/Know:**
   a. transverse wave (with example)
   b. longitudinal wave (with example)
   c. linear density
   d. the speed of light in a vacuum
   e. the equation for speed of a wave if frequency and wavelength are known
   f. compression and rarefaction
   g. the range of the electromagnetic spectrum
   h. the Doppler effect
   i. the principle of superposition
   j. constructive and destructive interference
   k. standing wave including node, antinode, & mode
   l. in phase, out of phase
5. **Explain:**
   a. what is transferred during the oscillation of the wave and what is not transferred
   b. the factors that affect the speed of a wave in a string
   c. the factors that affect the speed of a sound wave (temperature, density)
   d. how power and intensity are related in spherical waves
   e. why the Doppler effect occurs and how a pitch is changed when an object is moving toward a sound vs. away from the sound
   f. the relationship between frequency and pitch
   g. the orientation and effect on amplitude of a wave that reflects off a fixed or unfixed boundary
   h. the standing wave pattern in an open-open tube vs. an open-closed tube and the possible modes for each
   i. what causes beats
6. **Be able to:**
   a. calculate the speed of a wave in a string using tension and linear density
   b. calculate the speed of sound if the temperature is known
   c. draw a series of snapshot graphs for a moving wave and then transfer then to a history graph
   d. translate a position vs time wave graph into a velocity versus time graph
   e. determine the mode of a standing wave by looking at the standing wave pattern
   f. calculate the wavelength and fundamental frequency of a standing wave on a string of length L
   g. calculate the wavelength and fundamental frequency of a standing wave in an open-open tube AND open-closed tube
   h. draw the resulting wave that occurs when two waves move through a medium to show the constructive or destructive interference
   i. calculate beat frequency

Wave Problems:

1) Draw a picture of a transverse wave and give an example of a type of wave that is transverse.

2) Draw a picture of a longitudinal wave and give an example of a type of wave that is transverse.

3) The drawing shows a transverse wave's snapshot (displacement vs distance) graph. The wave is travelling at a speed of 2.50 m/s. Determine:
   (a) the wavelength,



   (b) the frequency of the wave,

   (c) the amplitude of the wave.

4) A wave has a frequency of 262 Hz. What is the time interval between successive wave crests?

5) A long spring runs across the floor. A pulse is sent along the spring. After a few seconds, an ***inverted*** pulse returns. Is the spring attached to the wall or lying loose on the floor? Why?

6) A wave pulse travels along a string at a speed of 200 cm/s. What will the speed be if:
   a) The string's tension is doubled?

   b) The string's mass is quadrupled (but its length is unchanged)?

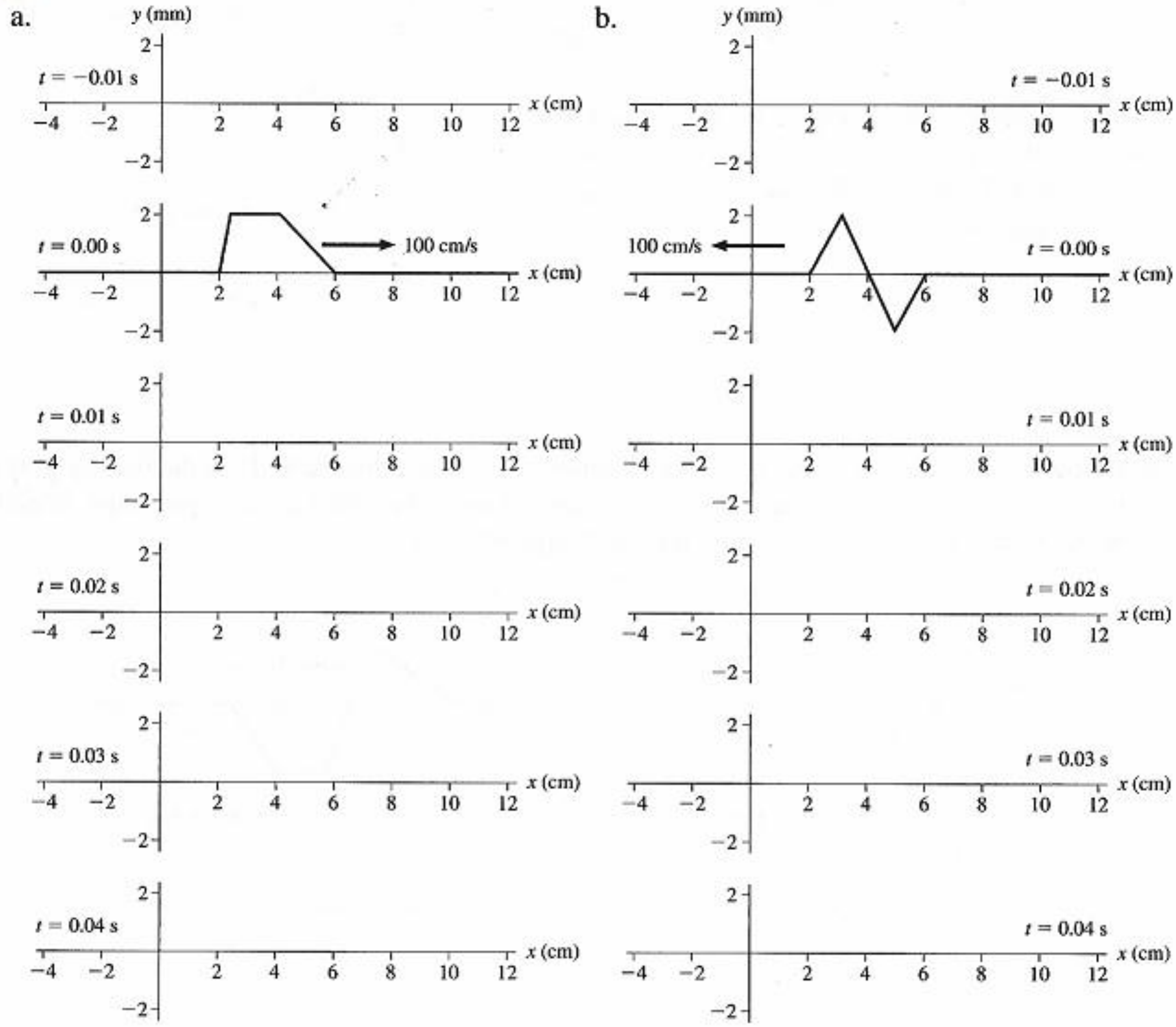
   c) The string's length is quadrupled (but its mass is unchanged)?

   d) The string's mass and length are both quadrupled?

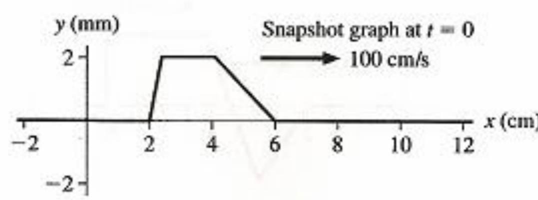
7) A 2.0 m long string is under 20 N of tension. A pulse travels he length of the string in 0.050 s. What is the mass of the string? (hint calculate speed first)

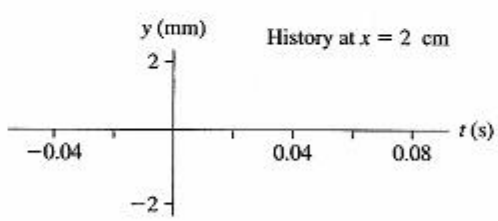
Wave Problems:

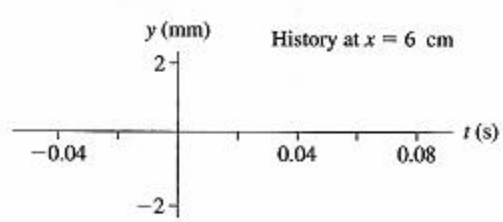
8. Each figure below shows a snapshot graph at time $t = 0$ s of a wave pulse on a string. The pulse on the left is traveling to the right at 100 cm/s; the pulse on the right is traveling to the left at 100 cm/s. Draw snapshot graphs of the wave pulse at the times shown next to the axes.



9. This snapshot graph is taken from Exercise 6a. On the axes below, draw the *history* graphs $y(x = 2\text{ cm}, t)$ and $y(x = 6\text{ cm}, t)$ showing the displacement at $x = 2$ cm and $x = 6$ cm as functions of time. Refer to your graphs in Exercise 6a to see what is happening at different instants of time.







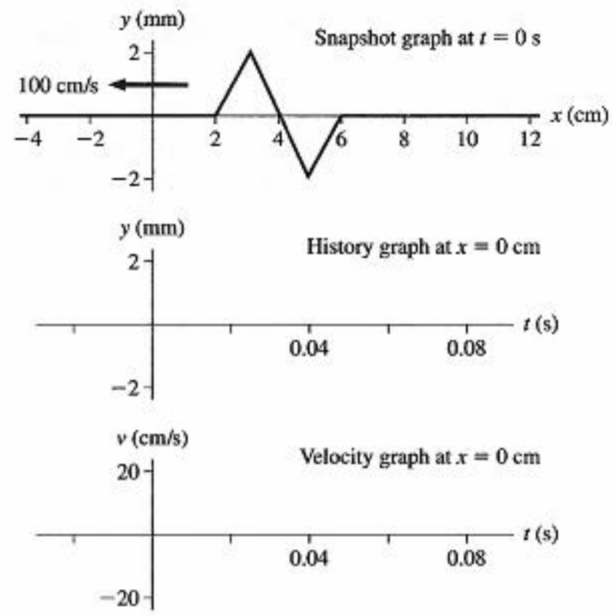
Wave Problems:

10. This snapshot graph is from Exercise 8b

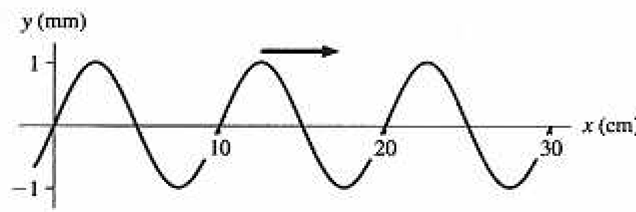
a. Draw the history graph $y(x = 0 \text{ cm}, t)$ for this wave at the point $x = 0$ cm.

b. Draw the *velocity*-versus-time graph for the piece of the string at $x = 0$ cm. Imagine painting a dot on the string at $x = 0$ cm. What is the velocity of this dot as a function of time as the wave passes by?

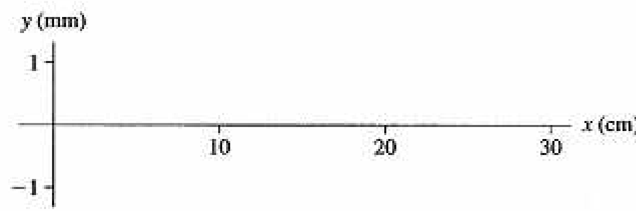
c. As a wave passes through a medium, is the speed of a particle in the medium the same as or different from the speed of the wave through the medium? Explain.



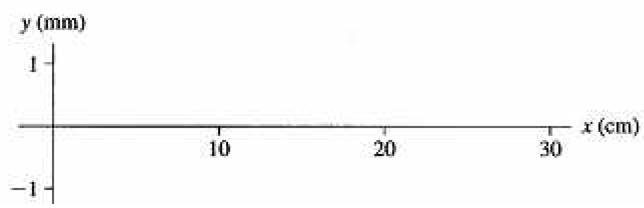
11. The figure shows a sinusoidal traveling wave. Draw a graph of the wave if:



a. Its amplitude is halved and its wavelength is doubled.



b. Its speed is doubled and its frequency is quadrupled.



Wave Problems:

12. The wave shown at time $t = 0$ s is traveling to the right at a speed of 25 cm/s.

a. Draw snapshot graphs of this wave at times $t = 0.1$ s, $t = 0.2$ s, $t = 0.3$ s, and $t = 0.4$ s.

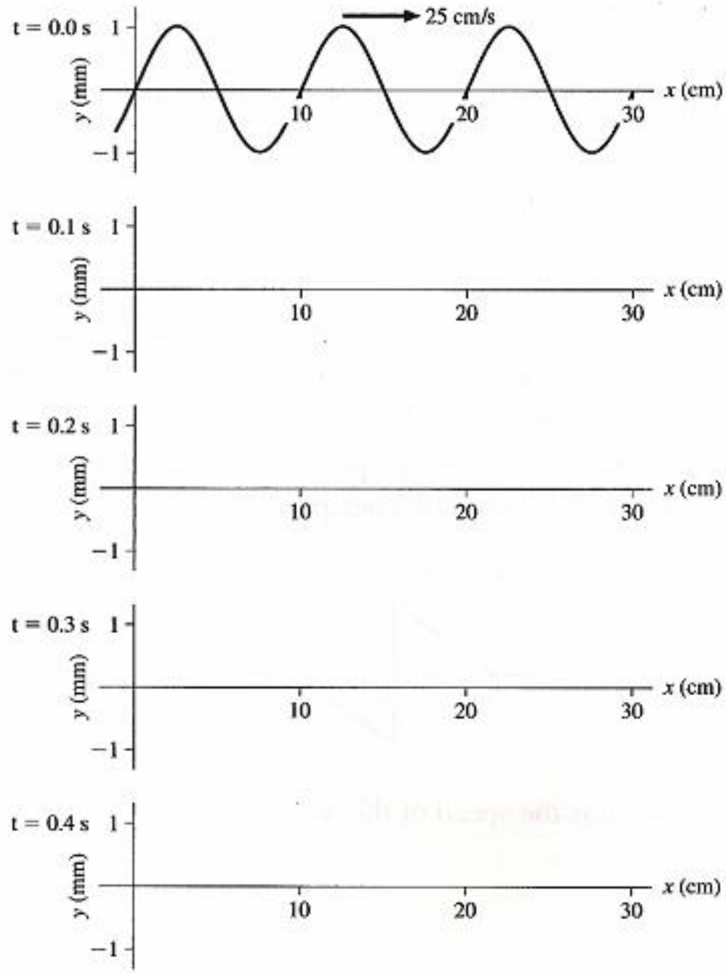
b. What is the wavelength of the wave?

c. Based on your graphs, what is the period of the wave?

d. What is the frequency of the wave?

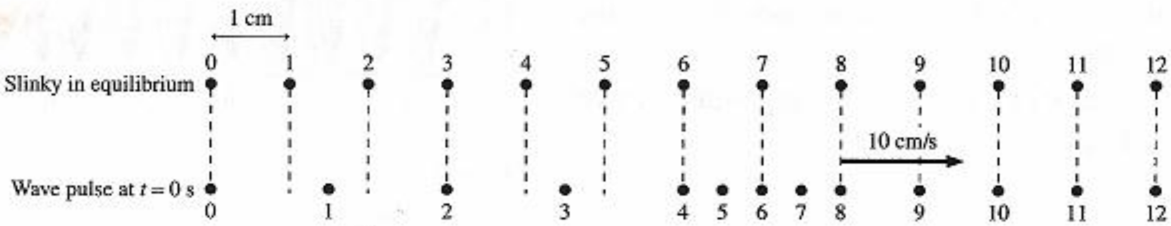
e. What is the value of the product λf?

f. How does this value of λf compare to the speed of the wave?

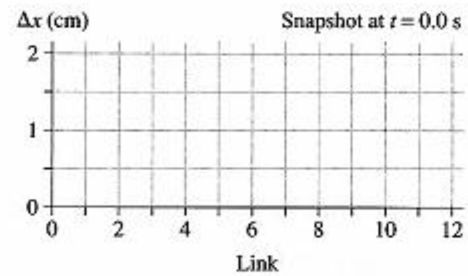


Wave Problems:

13. We can use a series of dots to represent the positions of the links in a Slinky. The top set of dots shows a Slinky in equilibrium with a 1-cm spacing between the links. A wave pulse is sent down the Slinky, traveling to the right at $10\ \text{cm/s}$. The second set of dots shows the Slinky at $t = 0$ s. The links are numbered, and you can measure the displacement Δx of each link from its equilibrium position.



a. Draw a snapshot graph showing the displacement Δx of each link at $t = 0$ s. There are 13 links, so your graph should have 13 dots. Connect your dots with lines to make a continuous graph.



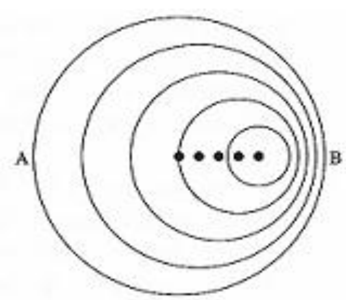
b. Is your graph a "picture" of the wave or a "representation" of the wave? Explain.

c. Which links are in compression? (list their numbers) ______________________

Which links are in rarefaction? (list their numbers) ______________________

14. Five expanding wave fronts from a moving sound source are shown. The dots represent the centers of the respective circular wave fronts, which is the location of the source when that wave front was emitted. The frequency of the sound emitted by the source is constant.

a. Indicate on the figure the direction of motion of the source. Which sound wave front was produced first? How do you know? Explain.



b. Do the observers at locations A and B hear the same frequency of sound? If not, which one hears a higher frequency and why?

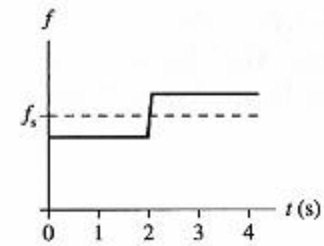
c. Assume that the sound wave you identified in part a as the first wave front produced marks the beginning of the sound. Do the observers at A and B first hear the sound at the same time? If not which one hears the sound first? Explain.

d. The speed of sound in the medium is v. Is the speed v_s of the source greater than, less than, or equal to v? Explain.

Wave Problems:

15) Sound Waves: Rank in order from largest smallest, the wavelengths having frequencies f_1 = 100 Hz, f_2 = 1000 Hz, f_3 = 10,000 Hz

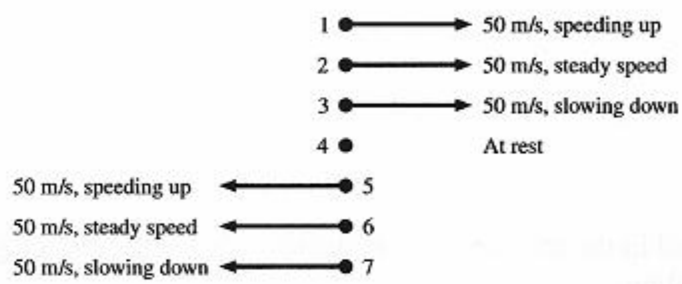
16. You are standing at $x = 0$ m, listening to a sound that is emitted at frequency f_s. The graph shows the frequency you hear during a four-second interval. Which of the following describes the sound source?



i. It moves from left to right and passes you at $t = 2$ s.
ii. It moves from right to left and passes you at $t = 2$ s.
iii. It moves toward you but doesn't reach you. It then reverses direction at $t = 2$ s.
iv. It moves away from you until $t = 2$ s. It then reverses direction and moves toward you but doesn't reach you.

Explain your choice.

17. You are standing at $x = 0$ m, listening to seven identical sound sources. At $t = 0$ s, all seven are at $x = 343$ m and moving as shown below. The sound from all seven will reach your ear at $t = 1$ s.



Rank in order, from highest to lowest, the seven frequencies f_1 to f_7 that you hear at $t = 1$ s.

Order:

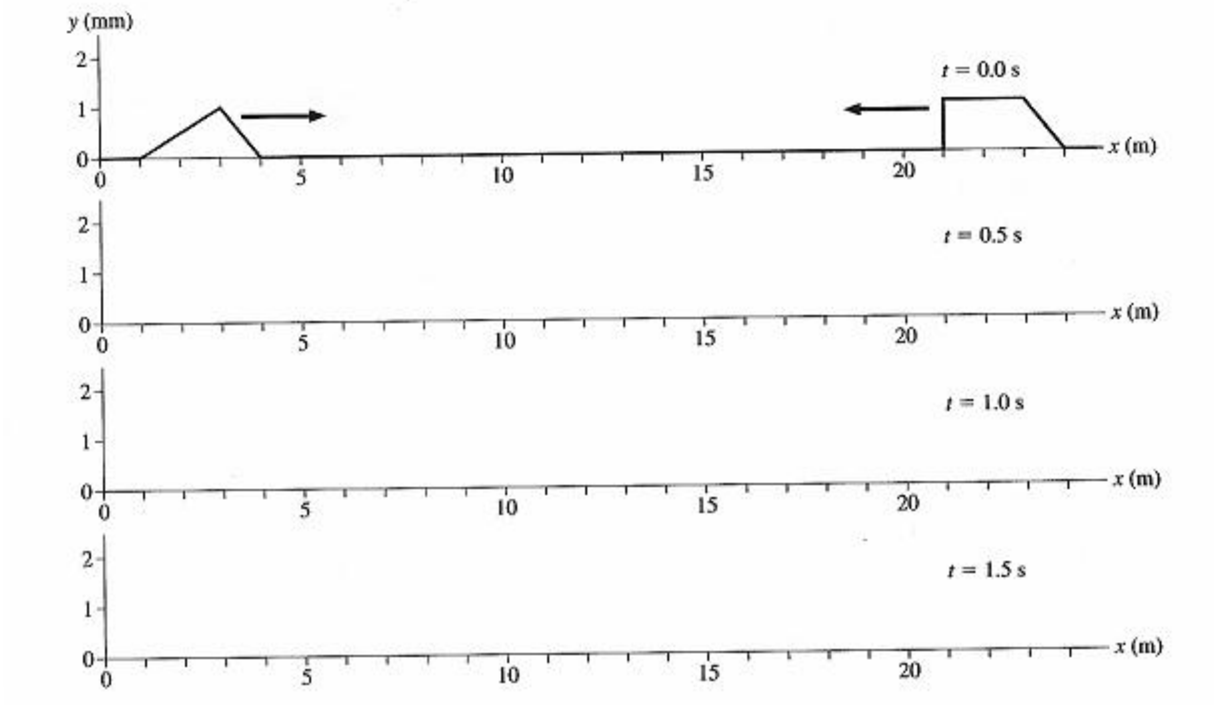
Explanation:

18) You have this really hot new convertible. It has one of the most outstanding sound systems available. Anyway it can like go faster than sound! When you are tooling down the test strip at Mach 2 (twice the speed of sound), could you hear the stereo? Explain the reasoning for your answer, whatever it is.

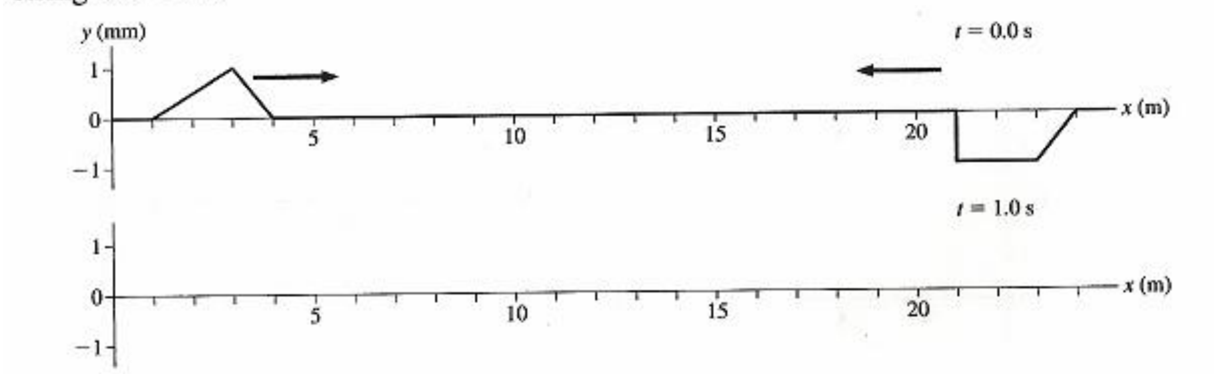
Wave Problems:

The Principle of Superposition

19. Two pulses on a string are approaching each other at 10 m/s. Draw snapshot graphs of the string at the three times indicated.



20. Two pulses on a string are approaching each other at 10 m/s. Draw a snapshot graph of the string at $t = 1$ s.



21) Create a depiction of a standing wave. Point out the nodes and antinodes.

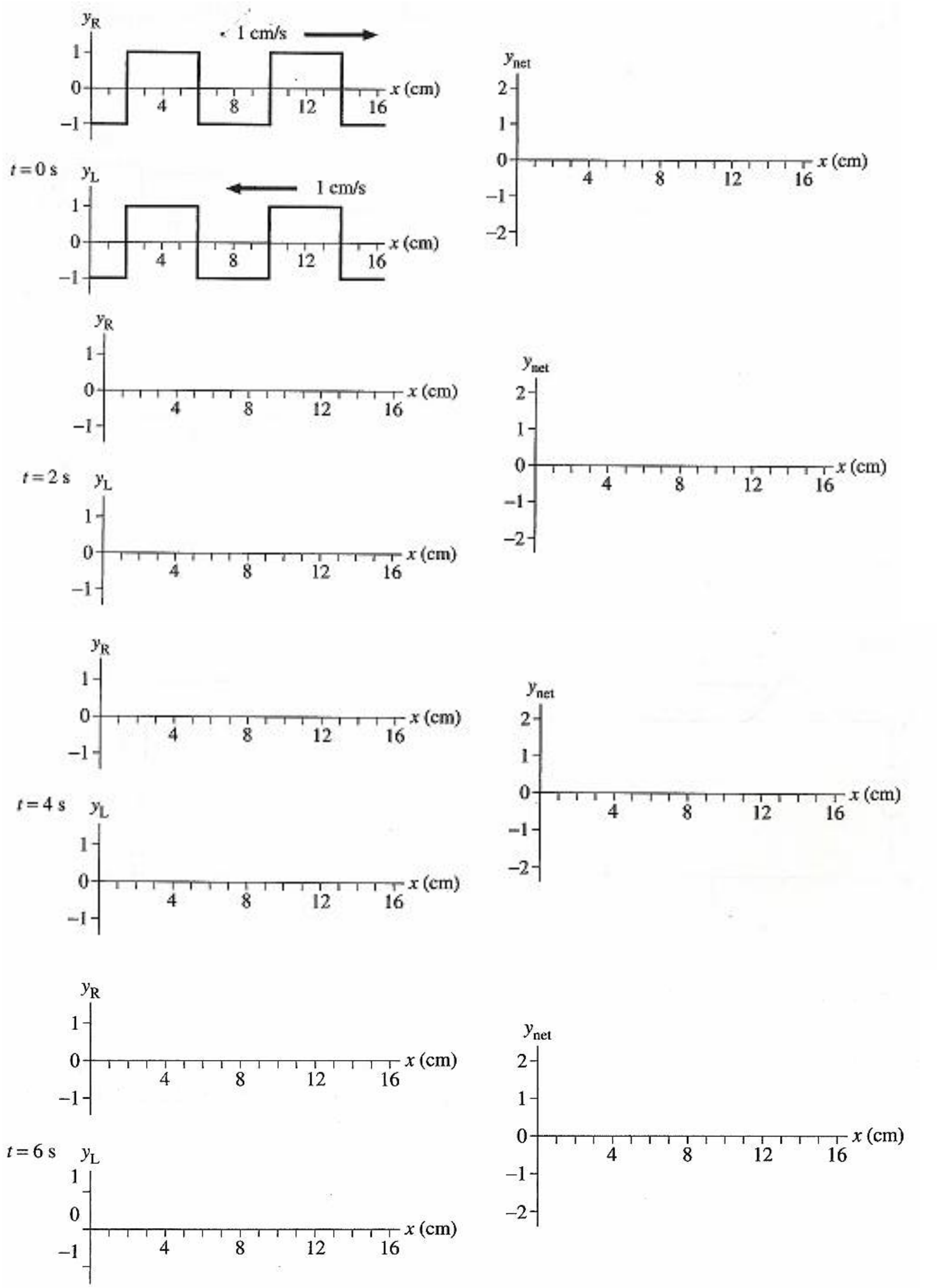
Wave Problems:

22) Two waves are traveling in opposite directions along a string. Each has a speed of 1 cm/s, and an amplitude of 1 cm. The first set of graphs below shows each wave at t = 0 s.

a) On the axis at the right, draw the superposition of these two waves at t = 0 s.

b) On the axis at the left draw each of the two displacements every 2 s until t = 8 s. The waves extend beyond the graph edges, so new pieces of the wave will move in.

c) On the axes at the right, draw the superposition of the two waves at the same instant.



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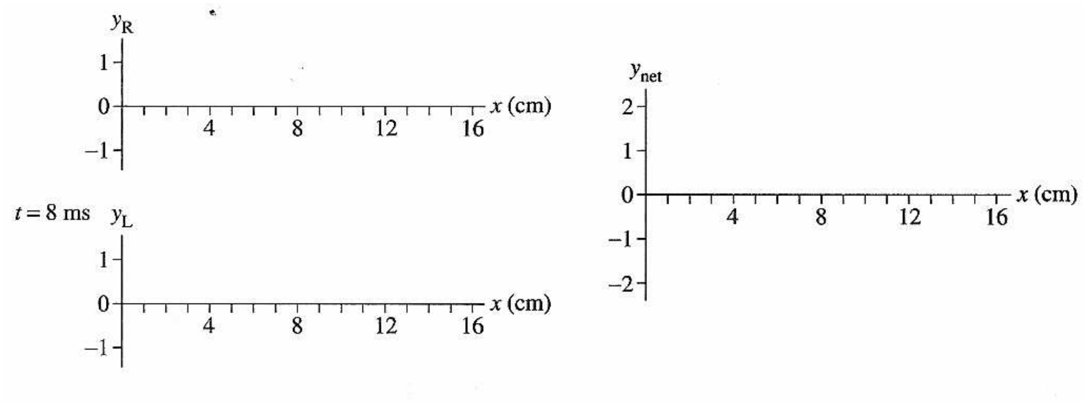
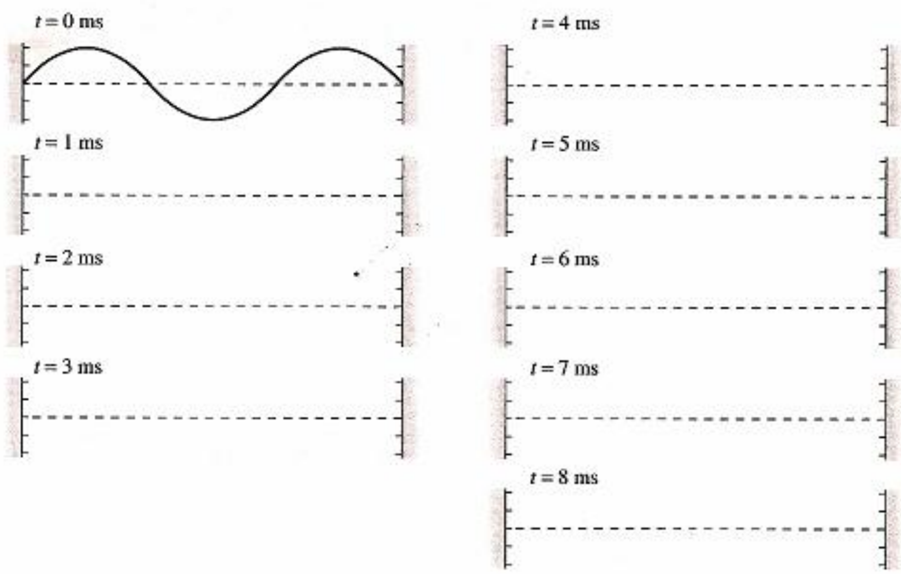
Wave Problems:

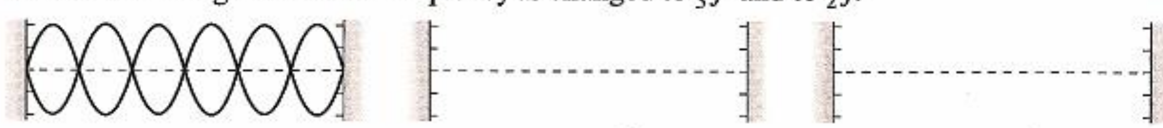


23. This standing wave has a period of 8 ms. Draw snapshot graphs of the string every 1 ms from $t = 1$ ms to $t = 8$ ms. Think carefully about the proper amplitude at each instant.



24. The figure shows a standing wave on a string. It has frequency f.

a. Draw the standing wave if the frequency is changed to $\frac{2}{3}f$ and to $\frac{3}{2}f$.

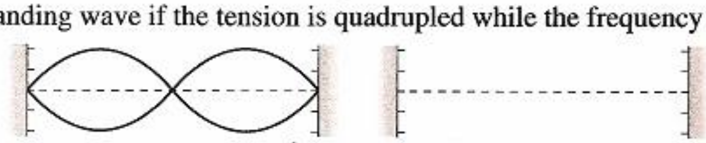


Original wave, frequency f | Frequency $\frac{2}{3}f$ | Frequency $\frac{3}{2}f$

b. Is there a standing wave if the frequency is changed to $\frac{1}{4}f$? If so, how many antinodes does it have? If not, why not?

25. The figure shows a standing wave on a string.

a. Draw the standing wave if the tension is quadrupled while the frequency is held constant.

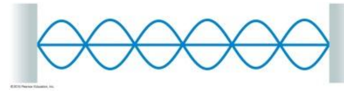


Original wave, tension T | Tension $4T$

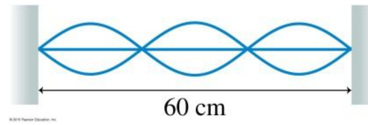
b. Suppose the tension is merely doubled while the frequency remains constant. Will there be a standing wave? If so, how many antinodes will it have? If not, why not?

Wave Problems:

26) A 2.0 meter long string is fixed at both ends and tightened until the wave speed is 40 m/s as shown to the right. What is the frequency of the standing wave?



27) The figure to the right shows a standing wave oscillating at 100 Hz on a string. What is the wave speed?



28) A pipe is 155 cm long and open on one of its ends.
(a) What are the frequencies of the first three harmonics that resonate in the pipe?

(b) What is the wavelength of the first harmonic?

29) A pipe is 18.5 cm long and open at both ends.
(a) What are the frequencies of the first three harmonics that resonate in the pipe?

(b) What is the wavelength of the third harmonic?

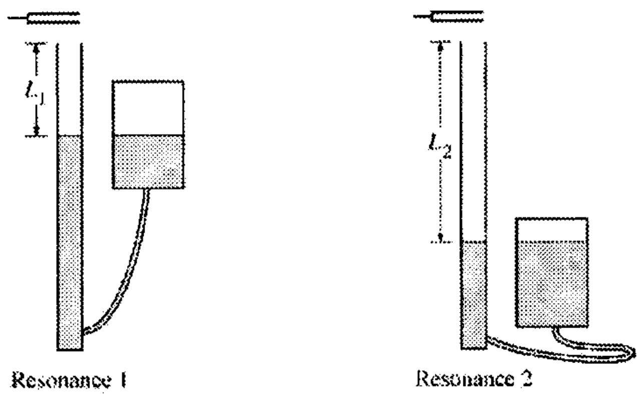
30) A drainage pipe running under a freeway is 30 m long. Both ends of the pipe ar open, and wind blowing across one end causes the air inside to vibrate.

a) If the speed of sound on a particular day is 340 m/s, what will be the fundamental frequency of the air vibration in the pipe?

b) If the range of frequencies hear by humans is 20 – 20,000 Hz, what is the frequency of the lowest harmonic that would be audible to the human ear?

c) What will happen to the frequency in the evening as the air begins to cool?

Wave Problems:



Note: Figure not drawn to scale.

31) A vibrating tuning fork is held above a column of air, as shown in the diagrams above. The reservoir is raised and lowered to change the water level, and thus the length of the column of air. The shortest length of air column that produces a resonance is L_1 = 0.25 m, and the next resonance is heard when the air column is L_2 = 0.80 m long. The speed of sound in air at 20°C is 343 m/s and the speed of sound in water is 1490 m/s.

a) Calculate the wavelength of the standing sound wave produced by this tuning fork.

b) Calculate the frequency of the tuning fork that produces the standing wave, assuming the air is at 20°C.

c) Calculate the wavelength of the sound waves produced by this tuning fork in the water.

d) The water level is lowered again until a third resonance is heard. Calculate the length L_3 of the air column that produces this third resonance.

e) The student performing this experiment determines that the temperature of the room is actually slightly higher than 20°C. Is the calculation of the frequency in part (b) too high, too low, or still correct?

_____Too high _____Too low _____Still correct

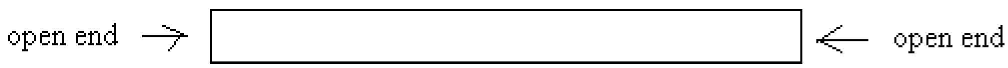
Justify your answer.

Wave Problems:

32) <u>The Trojan Mostaccioli</u>: In a fit of jealous rage, the directors of the Florence's Ufizzi museum decided to assassinate the curator of Madrid's Prado museum. The Ufizzi staff read a magazine article which mentions that the curator's home will collapse if subjected to a sustained tone of **30 Hz**. The Ufizzi directors decide to manufacture two giant mostaccioli (hollow, cylindrical noodles that are **open at both ends**) for him as a gift. They hope that the wind blowing across the ends of the mostaccioli will produce sounds which will destroy his home before Cassandra, the housekeeper, has a chance to cook the noodles. Assume that the **speed of sound is 330 m/s** throughout this problem. Ignore any end corrections.

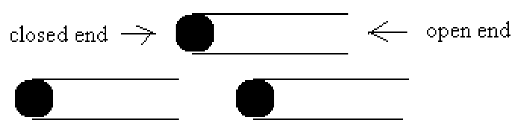
a) How long should the mostaccioli be to produce a 30 Hz fundamental frequency tone?

b) Draw the fundamental frequency in the noodle below:



Mostaccioli noodle, length L

c) Cassandra feels the house shaking as the mostaccioli begin to howl. She chops each noodle into thirds and jams a sausage into one end of each noodle to form an **open-closed pipe** with length **1/3 the length found in part a**. Find the new fundamental frequency for the shorter, sausage stuffed noodles.

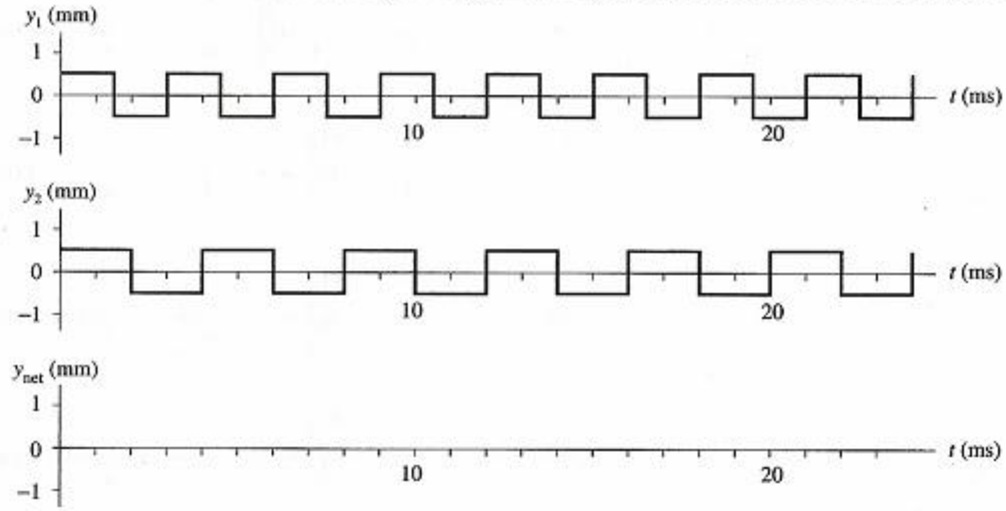


cut mostaccioli noodles, lenght L/3

d) Find the value of **the next highest frequency** that the sausage stuffed noodles will resonate.

Wave Problems:

33. The two waves arrive simultaneously at a point in space from two different sources.



a. Period of wave 1? ______________ Frequency of wave 1? ______________

b. Period of wave 2? ______________ Frequency of wave 2? ______________

c. Draw the graph of the net wave at this point on the third set of axes. Be accurate, use a ruler!

d. Period of the net wave? ______________ Frequency of the net wave? ______________

e. Is the frequency of the superposition what you would expect as a beat frequency? Explain.

34) Two strings are adjusted vibrate at exactly 200Hz. Then the tension in one string is increased slightly. Afterward three beats per second are heard when the stings vibrate at the same time. What is the new frequency of the string that was tightened?

35) Musicians can use beats to tune their instruments. One flute is properly tuned and plays the musical note A at exactly 440 Hz. A second player sounds the same note and hears that her instrument is slightly flat (that is at too low a frequency). Playing at the same time as the first flute, she hears to two beats per second. What is the frequency of her instrument?

Packet Answers