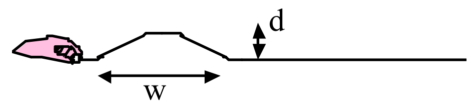
Phys122

Homework 2: Due Tuesday, February 14, 2006

A. A method for generating a wavepulse is to move one end of a spring quickly up a distance *d* and then back down (see figure). The hand takes the same amount of time to move up as to move down. Consider a second wavepulse generated with the same amplitude, *d*, on a different spring (spring 2). It is observed that the wave speed on spring 2 is half that in the original spring (spring 1).



1. How can you account for the difference in speed of the wavepulse on the two springs? Explain.

2. What could you change about the creation of the second wavepulse or spring 2 so that the wavepulse on spring 2 traveled at the same speed as the wavepulse on spring 1? Explain.

B. The pulse shown in the figure at the right is moving to the right at 50 cm/s.

1. Draw velocity vectors to indicate the instantaneous velocity of the piece of spring located at the horizontal midpoint of each square.

2. Using qualitative reasoning explain how the velocity of a piece of spring is related to the slope of that piece of spring.

Equations for sinusoidal waves

Show that

$$y = y_m \sin k(x - vt) \qquad y = y_m \sin 2\pi\left(\frac{x}{\lambda} - ft\right)$$

$$y = y_m \sin \omega\left(\frac{x}{v} - t\right) \qquad y = y_m \sin 2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)$$

are all equivalent to $\sin(kx-\omega t)$. Explain what λ and T mean physically and use one of the above forms to demonstrate what you mean mathematically.

Making a pulse move

A transverse wave pulse is traveling in the $+x$ direction along a long stretched string. The origin is taken at a point on the string which is far from the ends. The speed of the wave is v (a positive number). At time $t = 0$, the displacement of the string is described by the function;

$$y = f(x,0) = \begin{cases} A\left(1 - \left|x/\ell\right|\right) & |x| \le \ell \\ 0 & |x| \ge \ell \end{cases}$$

(a) Construct a graph that portrays the actual shape of the string at $t = 0$ for the case $A = l/2$.

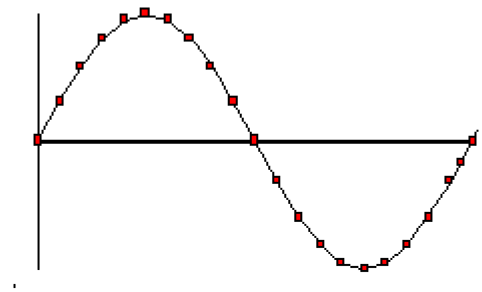
(b) Sketch a graph of the wave form at the following times:

1) $t = \ell/v$
2) $t = 2\ell/v$
3) $t = -3\ell/2v$

Comparing waves

The picture below shows a snapshot of a piece of a wave at a time $t = 0$. Make four copies of this picture and sketch what each pulse would look like at a slightly later time (a time small compared to the time it would take the pulse to move a distance equal to its own width but large enough to see a change in the shape of the string) for the following four cases:

1) The pulse is a traveling wave moving to the right.
2) The pulse is a traveling wave moving to the left.
3) The pulse is a standing wave whose amplitude is growing.
4) The pulse is a standing wave whose amplitude is shrinking.



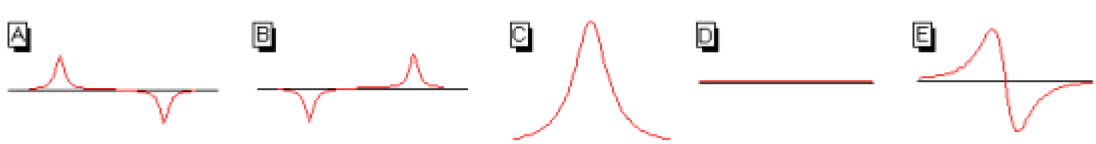
On each picture draw arrows to show the velocity of the marked points at time $t = 0$.

Combining pulses

In the figure below are shown graphs which could represent properties of pulses on a stretched string. For the situation and the properties (a) - (e) below, select which graph provides the best representation of the given property. If none of the graphs are correct, write "none".

Two pulses are started on a stretched string. At time $t=t_0$, an upward pulse is started on the right that moves to the left. At the same instant, a downward pulse is started on the left that moves to the right. At t_0 their peaks are separated by a distance $2s$. The distance between the pulses is much larger than their individual widths. The pulses move on the string with a speed v_0. The scales in the graphs are arbitrary and not necessarily the same.

(a) Which graph best represents the appearance of the string at time t_0?
(b) Which graph best represents the appearance of the string at a time $t_0 + s / v_0$?
(c) Which graph best represents the appearance of the string at a time $t_0 + 2s / v_0$?
(d) Which graph best represents the velocity of the string at a time $t_0 + s / v_0$?
(e) Which graph best represents the appearance of the string at a time $t_0 + s / v_0 + \varepsilon$ where ε is small compared to s/v_0?



Modified harmonics

A taut string is tied down at both ends. Assume that the fundamental mode of oscillation of the string has a period T_0. For each of the changes described below give the factor by which the period changes. For example, if the change described resulted in a period twice as long, you would put the number "2". Do not cumulate changes. That is, before each change, assume you are back at the original starting situation.

a. The string is replaced by one of twice the mass but of the same length.

b. The wave length of the starting shape is divided by three.

c. The amplitude of the oscillation is doubled.

d. The tension of the string is halved.

Speed of Sound vs Light

Imagine that you are in Baltimore on the 4th of July. You are standing on the rooftop of a friend's house observing the fireworks over the city. You see a burst of fireworks and then count 3.5 seconds until you hear the sound of the explosion.

a) Estimate how far away you are from the point where the fireworks exploded (assume that the light reaches you instantaneously).
b) Using the distance you found above, how much time does it take the light from the explosion to reach your eyes? How does this time compare to the 3.5s it took to hear the explosion? What does this mean in terms of the assumption that the light travels instantaneously made in part a?

Doppler-Shifted Sounds of the City

An ambulance approaches the scene of an accident from the east and a police rescue unit approaches from the west. The ambulance siren produces a 3500-Hz blare.

a) What is the frequency heard by the police officers when they momentarily come to a stop while the ambulance is still moving toward the accident site at 20 m/s?
b) A minute later the ambulance is stopped at the accident site and with the siren still blaring. The police are now moving towards the site at 20 m/s. What frequency do they hear now?
c) When the rescue operations are complete the ambulance and police head off in opposite directions, both at 20 m/s. What frequency do the police hear at this point?