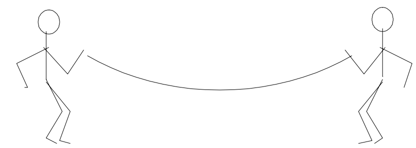
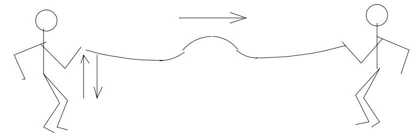
A. Pulses on a Stretched Spring



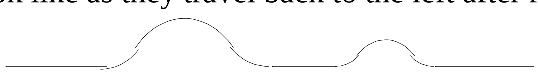


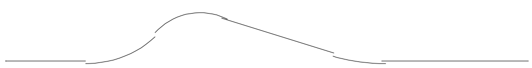
1. Hold the ends of a long spring and stretch it across the lab, as in the illustrations. Do not try to eliminate all of the sag by pulling harder; that can only damage the spring. Generate a "pulse" by suddenly moving one end of the spring up and back down or left and right. Try to make pulses that are short and hump-shaped.
   a. Estimate the speed of your pulses *as a range,* with *SI units. Explain your estimate.*
   b. See if the pulse speed depends in any way upon the size or shape of the pulses. (See if you can make one pulse overtake another.)

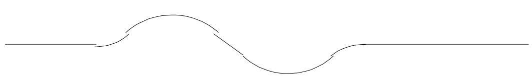
2. Imagine repeating #1 in gravity-free space with two segments cut from one very long spring: One is a mile long, and the other is two miles long. The two segments have equal tensions.
   a. Will the pulse speeds be equal? ___
   If not, which segment will transmit pulses with the greater speed and how do you know? ____
   b. Suppose you want a new spring that will carry pulses at a *greater* speed when held with exactly the same tension: Common sense and dimensional analysis both show that the new spring must have _______er "linear density" than the old one. (Linear density is the number of kilograms per meter.)

3. You may have noticed that pulses always bounce back from the end of the spring that is held stationary. This process is called "reflection". If the reflected pulse is *inverted,* it has experienced "hard" reflection. If it is *not* inverted, we say that the reflection was "soft".
   a. What kind of reflection do you observe at an end that is held rigidly? ____
   b. What kind of reflection occurs at an end that is completely free to move? ______
   (That condition can be achieved by holding one end with a very long string.)

4. The sketches below show several pulses travelling toward the right end of a wave spring. That end is held rigidly in each case. Make similar sketches showing what the pulses will look like as they travel back to the left after reflection.

a. 

b. 

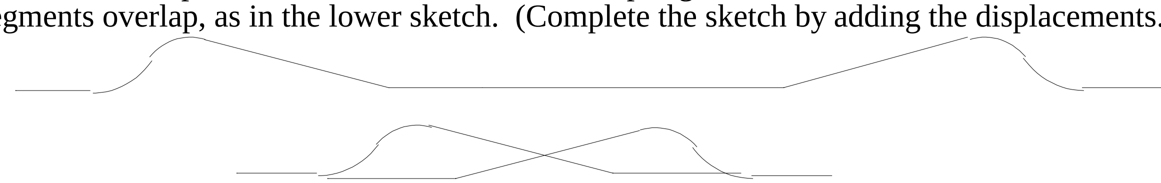
c. 

d. 

* 5. See what happens when two pulses travelling in opposite directions meet. Do they reflect off each other, travel through each other, or do something else? (See pages 455 and 463 in PSSC, 5th ed.)

6. Imagine that you are a bug sitting on a wave spring. When no waves are going by, you remain stationary at your "equilibrium" position. When an "up" pulse goes by (like the one illustrated in #1) you are moved upward briefly and then back down. If two waves go by at the same time in opposite directions then you will be displaced simultaneously by both of them.
   a. If the wave travelling to your right moves you up 5 centimeters and the wave moving to your left moves you up 4 centimeters at the same time, how far will you be from your equilibrium position?
   b. Where will you be if the first wave moves you up 5 cm and the second wave moves you *down* 7 cm?
   * c. Write the rule used in 6a & 6b to predict the displacement of any point on a spring that is simultaneously influenced by more than one wave. (Check it with the photos on p. 453, 455, & 463 in PSSC Physics, 5th ed.) -This "**superposition principle**" has been saved in #__ on RS ___.

7. The sketch below shows two pulses travelling toward each other. Notice that there is a *linear* section in each pulse. Use 6c to show what the spring will look like at a time when the two linear segments overlap, as in the lower sketch. (Complete the sketch by adding the displacements.)



1. Imagine holding the end of a wave spring and moving it up and down with simple harmonic motion. That motion will generate waves on the spring. If you take a picture of the spring it will look like a _____ curve or a _______ curve.

2. If you continue to generate those waves for a long time with constant frequency and amplitude some of the waves will reach the far end of the spring, where they will be _________ed.
   a. Ideally, how will the reflected waves compare with the original waves? _____
   b. Suppose we photograph the spring at a time when the peaks of the outgoing waves coincide with the peaks of the returning waves and the valleys of the outgoing waves coincide with the valleys of the returning waves: Describe the resulting picture in as much detail as possible. (Use the "Superposition Principle" in #1 on RS XVI.)
   c. Precisely how will that picture differ from the one in #1?

3. Another picture is taken a very short time later. During that short time one set of waves has moved a short distance to the right while the other set has moved a short distance to the left.
   a. If the time interval was very small compared to the wave period, then those distances must be very ______ compared to the wavelength. *Please show that clearly in your sketch.*
   b. How will photo #3 differ from photo #2?
   c. Draw small arrows onto picture #3 to show how some individual spots of paint on the spring have moved since #2. *Try not to confuse the motion of spots with the motion of the waves.*

4. Another photo of the spring is taken exactly one quarter-period after #2:
   a. Use the superposition principle to figure out what it will look like. (Show only *one* spring.)
   b. Use the same principle to figure out something about the velocities of several paint spots on the spring at this time. Indicate those velocities with small arrows on the sketch you made for 4a.
   c. If there are any spots with no velocity please *circle* them and label them as "**NODES**".
   d. If you believe that *all* spots on the spring have zero velocity at this time, then explain what happened to the kinetic energy that was in the spring in #3. (See the photos on page 453 in the book.)

5. Now sketch a *multiple-flash* photograph of the spring, showing many superimposed images over one full cycle, showing why waves of this type are called "standing waves".

6. The points with maximum motion in a standing wave are called "**ANTINODES**". Invent a name for the segment between two adjacent nodes: _____________ Write that name into the blanks in #7.
   a. Use the two words defined in #6 to label the diagram that you drew for #5.
   b. At a point where "hard" reflection occurs, you always find a _________.
   c. What do you find at a point where "soft" reflection occurs? _______ (Copy words from 4 & 6.)

* 7. Experiment: Make standing waves on a wave spring. Notice that nice standing wave patterns are possible only at certain frequencies. If the spring's straight-line length and tension are kept constant there is a relationship between the wave frequency and the number of _______s on the spring.
   a. Make sketches like the one in #5 for each of the standing wave patterns that you are able to produce. The number of "________s" in each sketched pattern should be clearly evident. Let's call that the "mode number". *You'll need that term in 7c. Has it been recorded on RS XVI?* ___
   b. Measure and record the frequency for each pattern as precisely as you can. Remember to explain your uncertainty estimates. *Try not to confuse "frequency" with "period". Both words are on RS I.*
   c. Make a data table and a graph to describe the relation between frequency and mode number.
   d. Write an equation beside the graph to describe the graph, using *symbols*, not numbers.
   e. Define your symbols clearly, including the one representing the proportionality constant. As always, give the value of the proportionality constant in range form, with SI units. *This range must agree with two reasonable lines on your graph.*
   f. Do you expect this equation to be valid for *all* wave springs?
   g. Do you expect the proportionality constant in that equation to be the same for all springs?

* 8. Does the law discovered in #7 work for guitar strings? Present your evidence carefully.

* 9. Optional: Prove that **sin(x + s) + sin(x - s) = A sin(x)**, where "A" depends on "s" but not "x". Also show how "A" can be calculated from "s", and explain how this relates to standing waves.