A. The Speed of Water Waves

The motion of water waves is fairly slow, and water waves are easy to see. They cannot spread out in three dimensions, but instead are confined to two. That makes it easy for you to draw water wave patterns. They can even be photographed.

1. The first step in your investigation of spring waves was to make a single pulse on a stretched wave spring. You saw the pulse travel down the spring without changing its shape significantly. Can you do that with water waves? ___ (Try it in a puddle, a pond, or a ripple tank. The effect is also shown clearly in the film loop called "Superposition of Pulses".)

2. As periodic circular waves move outward from a point source their energy is spread over an ever-widening region.
   a. What happens to their amplitude as they move outward?
   b. What happens to the wavelength as the waves spread out?
   c. What happens to the frequency of the waves?
   d. What can you conclude about wave speed? (Does it depend on amplitude?)
   e. Can you think of any other kind of wave for which that conclusion is *not* valid?

* 3. If you read about "Fourier's theorem" you learn that a pulse is actually a combination of many periodic waves with different frequencies, all superimposed. If you did #1 carefully you noticed that some of the waves in that combination move faster than others. Remember that a periodic wave can be described by giving its frequency, amplitude, and wavelength.
   a. Are any other quantities necessary for a complete description?
   b. What properties do the faster-moving waves have that seems to account for their higher speeds?
   c. The speed of a wave does *not* seem to depend on its _________. (frequency, amplitude, wavelength)

* 4. According to the observations made so far, what do you know about the graph of water-wave speed vs frequency? Be sure to describe your evidence and your logic clearly.
   a. Do you know whether or not it goes through the origin?
   b. Do you know whether or not it goes close to the origin?
   c. Do you know whether its slope is positive or negative?
   d. Do you know whether it is straight or curved?

5. What did the graphs of wave speed vs frequency look like for:
   a. wave springs? b. guitar strings?

* 6. Try stretching a long wave spring or slinky as you did in the pulse experiments on page 147. Place your ear near one end of it, and have someone tap the other end lightly with a pen to produce some very small transverse pulses.
   a. Describe the sound you hear.
   b. How do the vibrations arriving earliest differ from the vibrations arriving a little later?
   c. Make a conclusion about the wave speed vs frequency graph for this medium.
   d. Does this conclusion contradict #4, or can they both be correct? Explain.

* 7. Have you ever listened to sounds coming from a distant source? Would you have noticed if the sound wave speed depended on frequency in air? (What would you hear? -How would music and clapping sounds be affected?) Use your personal experience to figure out what the graph of sound wave speed vs frequency must look like for air.

* 8. On page 145 you calculated the speed of sound for several different frequencies. Do these results agree with #6? *Explain your decision.*

9. **Dispersion** is the dependency of wave speed on frequency. Some media "exhibit a lot of dispersion", which means that wave speed depends strongly on frequency for those media. Other media are "non-dispersive", which means that waves in those media all travel at the same speed, regardless of their frequencies. Give two examples of each type of medium.

1. Observe straight periodic water waves crossing a boundary from deep water into very shallow water.
   a. Is there a difference between the wave speeds in the two regions? ____
   b. In which region do the waves move faster? ____
   c. In which region is the wavelength greater? ____

2. What can you conclude about the graph of wavespeed vs depth?
   a. Do you know for certain whether it is straight or curved? ____
   b. Do you know whether it goes through the origin? ___
   c. Do you know whether it goes close to the origin? ___
   d. Do you know whether its slope is positive or negative?____

3. Define "frequency". (Copy the definition from RS I or RS VII.)

4. Suppose it takes five seconds for ten waves to arrive at the boundary.
   a. How much time will it take for ten waves to cross the boundary? ___ ___
   b. What was the frequency of the waves before crossing the boundary? ___ ___
   c. What frequency did they have after crossing the boundary? ____ ___

* 5. Is the frequency of the waves affected as they cross the boundary?

6. Imagine a ripple tank which is not quite level. When we put some water into it part of the glass bottom will remain dry. The edge of the water will be like a beach. Let's generate some periodic straight waves at the opposite side, so they move toward the beach. Will the wavelength remain constant as the waves move toward the beach? ___ Illustrate your answer by sketching the wave pattern as seen from above.

7. Now suppose the straight wave generator is perpendicular to the beach so that it makes straight waves which initially move in a direction *parallel to the beach.* Sketch the wave pattern that you expect to see.

8. In order to make the sketch in #5 you must make an assumption about the shape of the wavespeed vs depth graph that was discussed in #2. If the graph is linear you get one pattern. If the graph is curved you get a different pattern. If the graph is curved the other way you get still another pattern.
   a. Do you know whether the graph is curved or straight? __ (If so, explain.)
   b. Sketch *all* of the possible wave patterns for #7.
   c. Also sketch the corresponding wavespeed graphs.

* 9. Find a photograph of waves in water with non-uniform depth, as in #7. Use that evidence to decide something about the shape of the wavespeed vs depth graph. Explain your reasoning.

10. Why do waves at a real beach always travel toward the shore, never moving in a direction parallel to the shore?