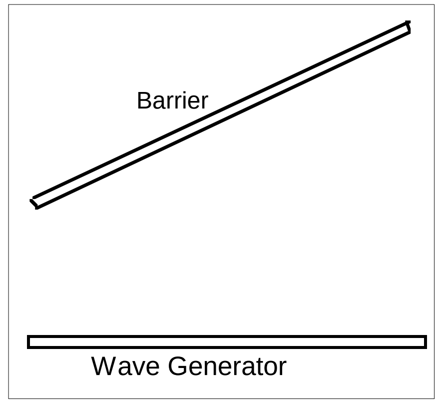

1. A ripple tank with uniform depth has a 16-inch diagonal barrier arranged as in the illustration at the right. A straight wave is produced by tapping the "wave generator", which is 8” from the left end of the barrier and 16” from the right end. Show what the wave will look like at a time when it has moved about twelve inches from the generator. (Part of the wave will have been reflected at this time, and part of it will not yet have reached the barrier.) Draw both parts of the wave, as they will appear at one instant. *Draw no more than two line segments.*

2. The wave's "angle of incidence" is the acute angle between the arriving wave and the barrier.
   a. Label the angle of incidence in the diagram with an "*i*".
   b. Calculate the degree measure of the angle of incidence.
   c. What can you say about the angle of reflection?

3. A circular wave is generated by dipping a finger into a pool of water at a point 15 cm. from a straight barrier. Use a compass and ruler to do the following:
   a. Draw the unreflected portion of the wave as it will appear when the radius of the circle is 20 cm. Also draw the barrier.
   b. Finish the picture by drawing the reflected part of the wave as it appears at that time. (Use the compass!)
   c. How far has the reflected part of the wave moved from the barrier at that time? ____

* 4. It’s not hard to prove that the reflected portion of the circular wave in #3 forms a circular arc. (That's why you used a compass to draw it.) The place where you stick the point of the compass into the paper when you draw that arc is called the “center of curvature” of the arc. Describe a precise procedure for locating that point. Make it a general procedure, so that it will work in all problems of this type.

5. Using the same scale as in #3, draw another diagram showing the same circular wave as it would appear at a later time. *Remember that you cannot change history. The point where the original wave was generated is still ___ cm. from the barrier.*

* 6. Does the center of curvature of the reflected wave move? ___
   -Does it remain at the same location as in 3b? ___

7. Draw many short arrows on the waves in the diagrams for #1 and #5 to indicate the direction in which each part of the wave is moving.

8. Bonus Question: An expanding circular wave reflects off a curved barrier.
   Let "R_b" represent the barrier's radius of curvature.
   Let "R_w" represent the radius of the expanding circular wave.
   The reflected wave will not be a perfect circular arc in this case, but it is approximately circular while it is a short arc, i.e. when it has moved only a small distance from the barrier. (That distance must be small compared to R_b.)
   a. Make an accurate drawing.
   b. Draw straight lines connecting the four special points in the diagram.
   c. At one of the points where the curved lines meet, draw tangent lines.
   Make them dotted lines or else use a different color. Label them clearly.
   d. Figure out how the small angles in the diagram must be related to each other.
   e. Use that relation to discover a formula for the radius of the reflected wave in terms of the other two radii.

When waves cross a boundary from deep water into shallow water their speed changes suddenly, as you saw on page 146. If the boundary is diagonal, the waves must bend as they cross it. This bending process is called "refraction". Look carefully at a film or photograph of water waves being refracted in a ripple tank. Then answer the questions below.

1. Make a careful sketch of two waves from a straight generator being refracted as they cross a diagonal boundary from deep water into shallow water.

2. If you erased the boundary line from your sketch, leaving only the two waves, would you have two bent lines, or would you have four disconnected lines? ________ *Make your sketch agree with the photographs in this respect.*

3. Suppose you take two photographs of periodic straight waves crossing a diagonal boundary, as in #1. The second photograph is taken exactly one wave period after the first. Will the two pictures differ in any way? ___

4. Does the wave frequency change when the waves cross the boundary? ____

5. Draw arrows onto the diagram to indicate the direction of the wave velocity in each region.

6. Let "d" represent the acute angle between the deep-water wave crest and the boundary. Let "s" represent the acute angle between the shallow-water wave crest and the boundary.
   a. Which angle is always greater? ____
   b. Why?
   c. Is your answer and explanaton still valid when the waves move in the opposite direction, i.e. from shallow to deep water? _____

7. Does the wavespeed depend on the history of the wave, or does it depend only on local properties of the “medium” or material which carries the waves?

8. Now imagine that the wave generator is shifted to a new position so that the waves approach the boundary from a different direction. In other words, we are changing angle "d" without changing the depths or the frequency. Classify each of the following and *affected* or *unaffected* by the change. *Do not guess. If it is not possible to figure out the answer logically by using your present knowledge then say so and keep a record of those unanswered questions for future work.*
   a. angle "s"
   b. the frequency.
   c. the shallow-water wavelength.
   d. the deep-water wavelength.
   e. the wavelength ratio.
   f. the shallow-water wavespeed.
   g. the deep-water wavespeed.
   h. the wavespeed ratio.
   i. the ratio of the angles.

9. A wave in a ripple tank is like a row of people marching in a parade. The path followed by one of the marchers is a line that is always in the same direction as the wave's local velocity.
   a. Predict the measure of the angle between the wave and the path line. ____
   b. Wherever the wave crosses a diagonal boundary, the path lines must bend. How must the angle between the path and the boundary be related to the angle between the wave and the boundary? ___ *A diagram will help you figure out the answer.*

10. Imagine straight waves being sent across a shallow region like the one in the sketch at the right. Show what the waves will look like after passing over the shallow region. Then do the same for the shapes sketched below.