Title:	**Exploring Wave Phenomena**
Revision:	April 7, 2006
Authors:	Joan Taber, Sharon Gerbode, Mark Buckley, Jacob Grose
Appropriate Level:	Grades 9-12
Abstract:	Students use their observations of water waves in a ripple tank constructed from common materials to develop an understanding of reflection, refraction, and diffraction. Extensions are included that allow for quantitative measurement of these observations.
Time Required:	One 45-minute period, minimum
NY Standards Met:	4.3 Students can explain variations in wavelength and frequency in terms of the source of vibrations that produce them, e.g. molecules, electrons, and nuclear particles. h. When a wave strikes a boundary between two media, reflection, transmission, and absorption occur. A transmitted wave may be refracted. l. Diffraction occurs when waves pass by obstacles or through openings. The wavelength of the incident wave and the size of the obstacles or opening affect how the wave spreads out. m. When waves of similar natures meet, the resulting interference may be explained using the principle of superposition. Standing waves are a special case of interference.
Special Notes:	**Exploring Wave Phenomena** is available as a kit from the CIPT Equipment Lending Library, Xraise.classe.cornell.edu. Created by the CNS Institute for Physics Teachers via the Nanoscale Science and Engineering Initiative under NSF Award # EEC-0117770, 0646547 and the NYS Office of Science, Technology & Academic Research under NYSTAR Contract # C020071

Objectives:

- Students will be able to define reflection, refraction, diffraction and standing waves.
- Students will be able to recognize and draw, using wave fronts, the following wave phenomena: reflection, refraction, and diffraction.

Class Time:

One 45-minute period, minimum

Teacher Preparation Time:

30 minutes

Materials Needed per Group:

- ripple tank (16"x20" clear picture frame)
- stand (can be made from PVC tubing)
- rigid foam block (approximately 16"x2"x1.5")
- 4 paraffin blocks
- 45°-45°-90° Plexiglas plate, 3/8" thick, 16" on short sides
- socket for incandescent bulb
- 75 Watt clear incandescent bulb
- ringstand and clamps to hold bulb centered above tank
- paper or (better) dry erase surface
- container for water
- sponge
- 2 rulers (for extensions)
- protractor (for extensions)

To build PVC stand, use 1/2" SCH-40 parts:

- 4 elbows
- 4 tees
- 4 1-1/2" pieces of tubing
- 2 17-1/2" pieces of tubing
- 6 11" pieces of tubing

With CPVC glue, glue together everything except the legs in the following order:

1. elbow
2. 1-1/2" tube
3. tee
4. 11" tube
5. tee
6. 1-1/2" tube
7. elbow
8. 17-1/2" tube
9. repeat items 1-8 to finish the square frame
10. insert 11" legs (no glue!) in base of tees

Assumed Prior Knowledge of Students:

Students should be knowledgeable of the following vocabulary words: incident, wave, pulse, wavelength, frequency, wave front.

Background Information for Teacher:
Students are observing the top view of waves. The teacher should emphasize the relation between what is seen in a side view of wave pulses and what is viewed when looking from above.

Tips for Teacher:

- The picture frame can easily be scratched. Use only soft edge material with the frame and, when storing it, place newspaper over the surface.
- Make sure the picture frame ripple tank is level before starting the lab. Pour some water into the inverted frame and view the water level from all sides. Where the tank is too high, push on the PVC frame (over the appropriate leg) to make it lower.
- Position the light at least 2' above the ripple tank. Orient the filament of the clear incandescent bulb so that it is vertical (this will make it act more like a point source and therefore produce clearer images of the waves).
- Instruct students that the best waves are produced when tapping the foam block on the top surface near the edge of the block that faces the center of the tank. Avoid tapping too vigorously, which can cause the tank to vibrate and excite other waves. This can also lead to volume flow of water which propagates differently than a surface disturbance.
- Emphasize to students that the clearest way to see the image of the waves is to look underneath the ripple tank, not through it.
- When emptying the ripple tank, sponge out most of the water first. Then pick up the frame by the short sides and dump it into a bucket or sink.

Exploring Waves

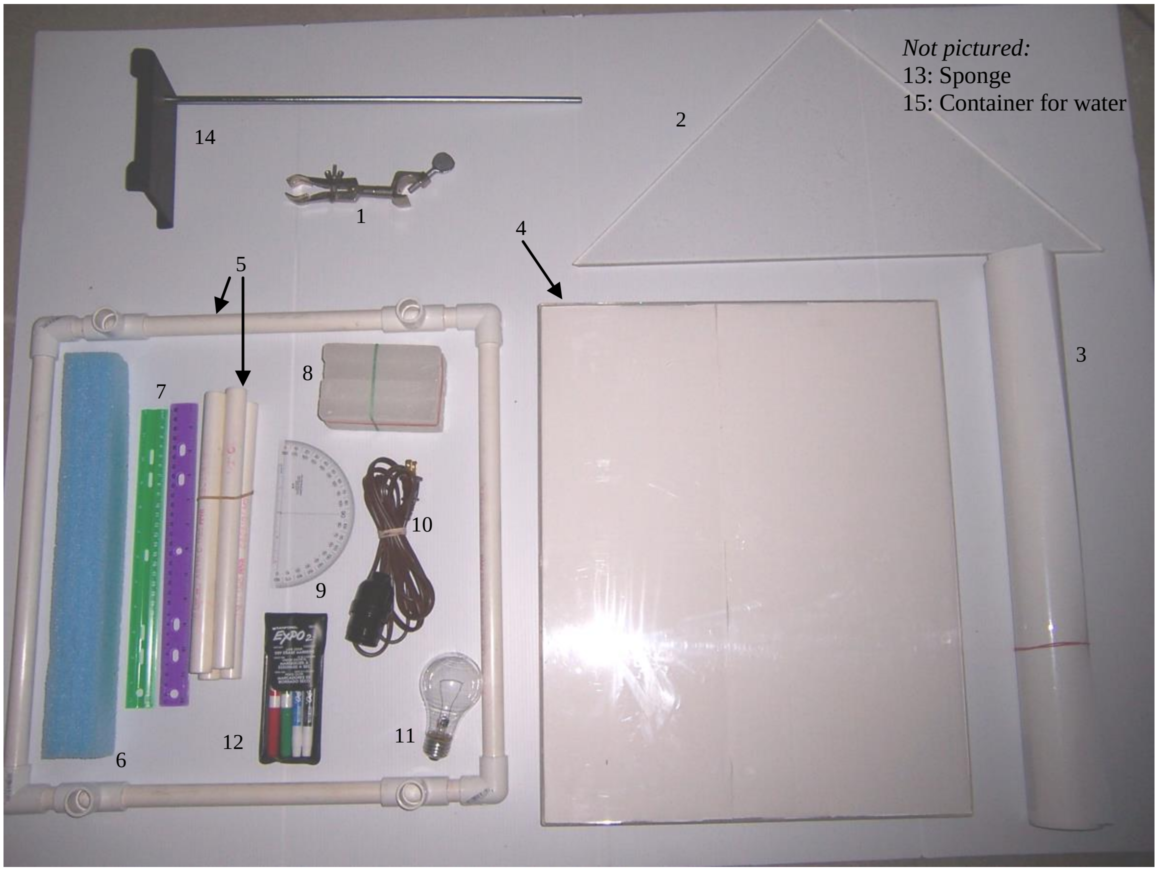
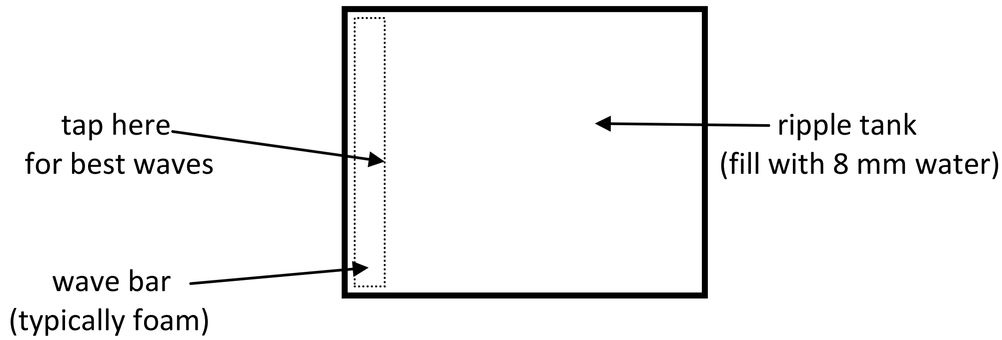


Photo ID	No.	Item
1	1	Clamp (for light bulb)
2	1	45^o-45^o-90^o Plexiglas plate
3	1	Dry-erase sheet
4	1	Ripple tank (16”x20” clear picture frame)
5	1	Stand with 4 detachable legs
6	1	Rigid foam block (approx. 16” x 2” x 1.5”)
7	2	Rulers (30 cm)
8	4	Paraffin blocks
9	1	Protractor
10	1	Bulb socket
11	1	75-watt *clear* incandescent bulb
12	1	Pack of dry-erase markers
13	1	Sponge

EXPLORING WAVE PHENOMENA

Name:_____________________
Partners:____________________

What happens to a wave when it hits another surface? What happens to a wave when the water depth changes? What happens to a wave when it goes around an obstruction? And what happens to a wave when it goes through a small opening? You will observe what happens to a water wave in each of these situations.



Pour water in the ripple tank so that it is about 8 mm deep. Turn on the light.
NOTE: Bulb will get hot!! Do not touch it.

Waves

1. Tap the wave bar gently to generate straight pulses.
   a. Describe what you see on the paper placed below the ripple tank.

   b. What do the lines represent?

2. Tap the wave bar faster.
   a. Does the wavelength of the wave change? If so, how?

   b. Does the velocity of the wave change? If so, how? Hint: Observe the speed of each line.

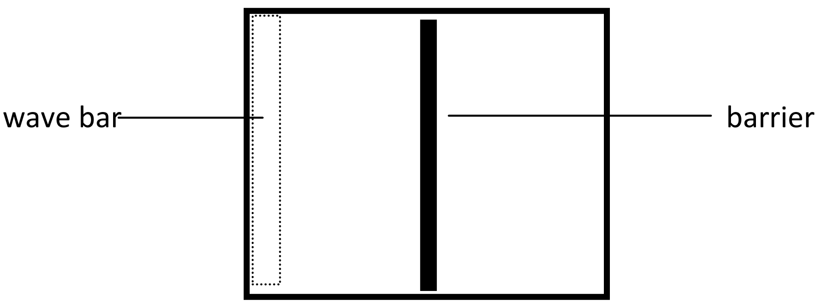
   c. Does the frequency of the wave change? If so, how?

Reflection

3. Place a straight barrier made of paraffin blocks in the middle of the tank (see diagram in part 3c). Make sure the barrier extends to the edges of the tank. Send a single pulse toward the opposite side of the tank by tapping the wave bar.
    a. What happens when the wave pulses reaches the barrier? This is known as reflection.

    b. How does the shape of the wave pulse approaching the barrier compare to the wave pulse after hitting the barrier?

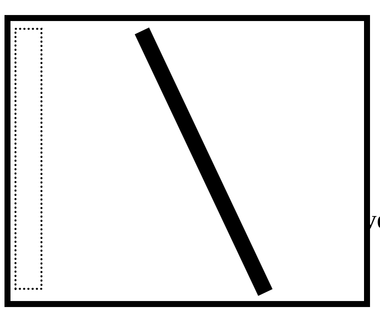
    c. Draw the incident wave pulse as a solid line and the reflected wave pulse as a dotted line. Indicate the direction of each wave with an arrow.



4. Now place the barrier at an angle (see diagram in part 4c). Send a single pulse toward the barrier.
    a. What happens when the wave pulse reaches the barrier?

    b. How does the shape of the wave pulse approaching the barrier compare to the wave pulse after hitting the barrier?

    c. Draw the incident wave pulse as a solid line and the reflected wave pulse as a dotted line. Indicate the direction of each wave with an arrow



d. How is the reflected wave pulse like the one produced in part 3?

e. How is the reflected wave pulse different from the one produced in part 3?

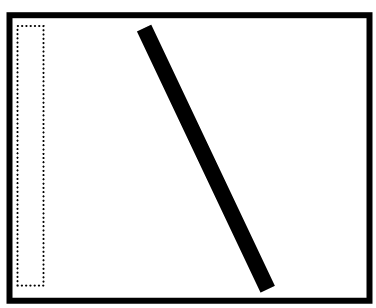
f. What happens to the reflected wave pulse if the angle of the barrier changes?

5. Touch the surface of the water with one fingertip.

   a. What is the shape of the wave front?

   b. What happens when the wave front hits the barrier?

   c. Draw the incident wave pulse as a solid line and the reflected wave pulse as a dotted line. Indicate the direction of each wave with an arrow.



   d. How are the incident and reflected waves alike?

   e. How are the incident and reflected waves different?

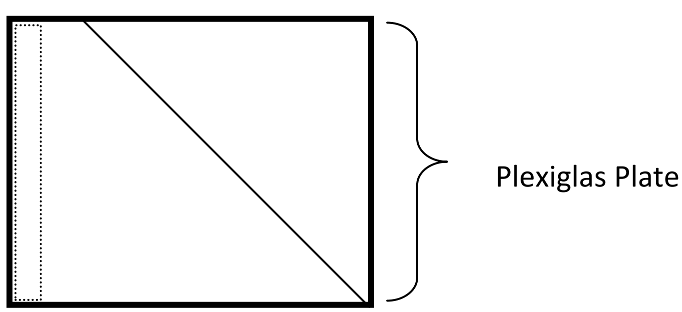
Refraction

6. Remove the barrier and place the triangular Plexiglas plate at the end of the tank (see diagram in part 6c). Make sure that the water over the Plexiglas is very shallow, at most 2 mm. Remove water with sponge if necessary.
   a. Draw the edge of the Plexiglas on the paper located below the ripple tank. Draw a normal to the edge line.

   b. Tap the wave bar at a constant frequency creating a series of evenly spaced pulses. Using the intersection of the normal and the Plexiglas edge as a reference, carefully observe the pulses that go over the boundary between the deep and shallow water. Compare the wave pulses in the deep water and in the shallow water.

   c. What happens to the pulses at the boundary between the shallow and deep water? This is known as refraction.

   d. Draw the wave pulses in the diagram below, paying close attention to what happens at the boundary. Indicate the direction of the wave pulses with arrows.



   e. How do the wavelengths compare in the deep and shallow water?

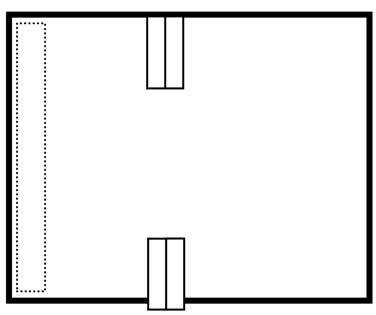
f. How does the rate at which the pulses hit the boundary compare to he pulses generated at the boundary?

Diffraction

7. Remove the Plexiglas plate and arrange four paraffin blocks to form a barrier with an opening in the middle. The paraffin blocks should be located approximately one third of the tank length from the wave bar (see diagram part 7b). Tap the wave bar to send wave pulses through the opening between the two blocks.

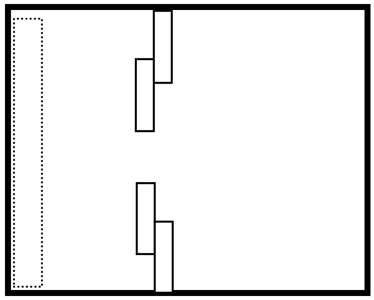
   a. What happens to the wave pulses as they move through the opening? This is known as diffraction.

   b. Draw an incident wave pulse as a solid line and a diffracted wave pulse as a dotted line. Indicate the direction of each wave pulse with an arrow.



   c. Slide two of the paraffin blocks toward each other and make the opening narrower. What happens to the wave fronts as they go through the opening?

   d. Draw the incident wave pulse as a solid line the diffracted wave pulse as a dotted line. Indicate the direction of each wave pulse with an arrow.



Standing Waves

8. Remove everything from the tank (except the water). Tap the bottom of the tank once. Carefully observe what happens. Tap the bottom of the tank repeatedly until the wave pattern on the paper appears to be standing still. You may need to adjust the frequency and/or location of the tapping. You have created a "standing wave."
   a. What happens when you tap the bottom of the tank once?

   b. Sketch your observations of the standing wave below.

   c. What do you notice about the surface of the water in the ripple tank when you create a standing wave?

Analysis and Conclusions:

Reflection

1. In your own words, what is the definition of reflection?

2. How did the angle at which the wave pulses hit the barrier seem to compare to the angle at which they reflected off the barrier?

3. Where could you observe examples of reflection in the real world?

4. Explain why, at a concert or a sports arena, the sound often appears to come from a wall of the room and not from the stage.

Refraction

5. In your own words give a definition of refraction.

6. What is needed in order for refraction to occur?

7. Where could you observe examples of refraction in the real world?

Diffraction

8. In your own words give a definition of diffraction.

9. What is needed in order for diffraction to occur?

10. What direction did the pulses curve relative to their direction of their travel?

11. What happened to the bending of the wave pulses as the opening became smaller and
smaller?

12. What do you suppose would happen to the shape of the diffracted wave if the opening became infinitesimally small?

13. Where could you observe examples of diffraction in the real world?

Standing Waves

14. In your own words, give a definition of a standing wave.

15. What is needed in order for a standing wave to occur?

16. Where could you observe examples of standing waves in the real world?

EXTENSIONS

Reflection

1. Place the wave bar in the tank and arrange the paraffin blocks to form a barrier as shown in part 1k. Tap the wave bar to send pulses toward the barrier.

   a. On the paper below the tank, use a ruler to draw a line at the edge of the paraffin blocks.

   b. On the paper below the ripple tank, align a ruler parallel to the wave fronts made by the tapping of the bar, draw a line, and label it "incident."

   c. Draw a ray that is perpendicular to the incident line and touches the edge of the paraffin blocks.

   d. On the paper below the ripple tank, draw a normal to the edge of the blocks that also touches the tip of the incident ray.

   e. Measure the angle between the incident ray and the normal.

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   f. On the paper below the ripple tank, align a ruler parallel to the wave fronts that were reflected by the blocks, draw a line, and label it "reflected."

   g. Draw a ray that is perpendicular to the reflected line and touches the edge of the paraffin blocks.

   h. On the paper below the ripple tank, draw a normal to the edge of the blocks that also touches the tip of the reflected ray.

   i. Measure the angle between the incident ray and the normal.

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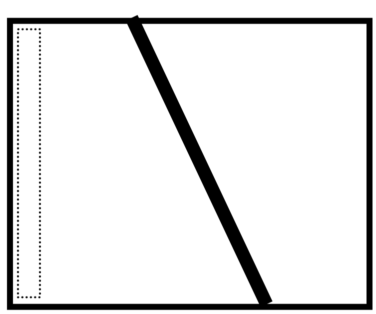
   j. Sketch your drawing in the figure below. Sketch your work in the diagram below.



k. What is the relationship between the two angles? ________________________

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Refraction

2. Place the wave bar and the Plexiglas triangle in the tank as shown in part 2f. Make sure the water level above the Plexiglas is very shallow, at most 2 mm. Tap the wave bar to send pulses toward the Plexiglas.

   a. On the paper below the tank, use a ruler to draw a line at the edge of the Plexiglas, which separates the regions of deep and shallow water.

   b. On the paper below the ripple tank, align a ruler parallel to the wave fronts in the deep water before they reach the Plexiglas, draw a line, and label it "incident."

   c. Draw a ray that is perpendicular to the incident line and touches the edge of the Plexiglas.

   d. On the paper below the ripple tank, draw a normal to the edge of the Plexiglas that also touches the tip of the incident ray.

   e. Measure the angle between the incident ray and the normal.
   ____

   f. On the paper below the ripple tank, align a ruler parallel to the wave fronts in the deep water after they passed over the edge of the Plexiglas, draw a line, and label it "refracted."

   g. Draw a ray that is perpendicular to the refracted line and touches the edge of the Plexiglas.

   h. On the paper below the ripple tank, draw a normal to the edge of the Plexiglas that also touches the tip of the refracted ray.

   i. Measure the angle between the refracted ray and the normal.
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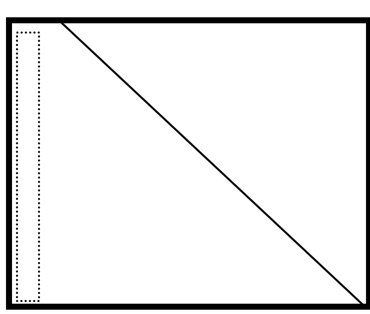
   j. Sketch your drawing in the figure below. Sketch your work in the diagram below.



k. Compare the two angles.

l. When the speed of the wave decreased (because it entered shallower water), what happened to its direction of travel relative to the normal?