CNS Institute for Physics Teachers

Title:	**Exploring Wave Phenomena**
Revision:	April 7, 2006
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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.

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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° plexiglass 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.

Answers to Questions:

1. Tap the wave bar gently to generate straight pulses.

   a) Describe what you see on the paper placed below the ripple tank. Bright lines, moving across the paper.

   b) What do the lines represent? The peaks of the individual wave pulses, or the "wave fronts."

2. Tap the wave bar faster.

   a) Does the wavelength of the wave change? If so, how? It decreases.

   b) Does the velocity of the wave change? If so, how? Hint: Observe the speed of each line. The velocity does not change.

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

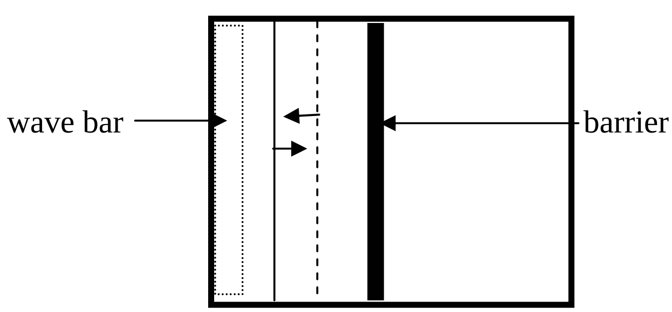
Reflection

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. The wave pulses bounce off the wood and go back in the direction in which they came.

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

   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.

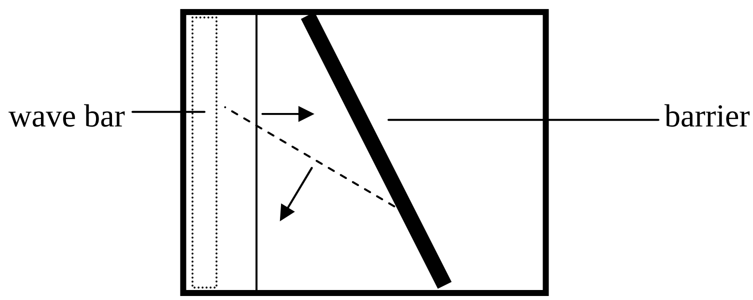


4. Now place the barrier at an angle (see diagram in part 4c). Send a single pulse toward the barrier.

   a) What happens when the wave pulse reaches the barrier? It bounces off the surface.

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

   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? They are straight lines.

   e) How is the reflected wave pulse different from the one produced in part 3? They bounced off at an angle.

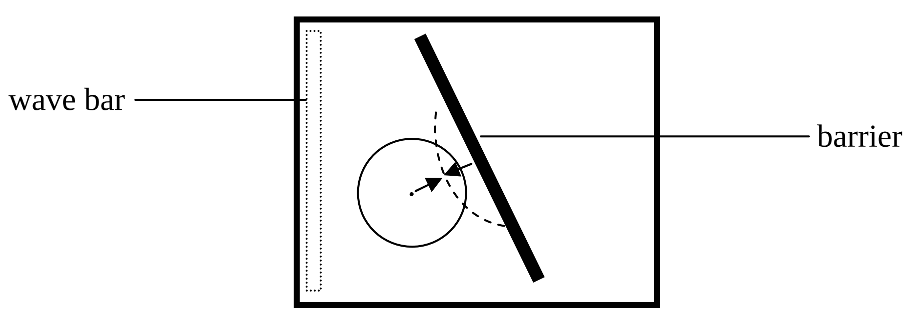
   f) What happens to the reflected wave pulse if the angle of the barrier changes? As the angle of the barrier increases, the angle of the reflected wave pulse increases.

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

   a) What is the shape of the wave front? A circle.

   b) What happens when the wave front hits the barrier? It comes back circular and the radius keeps expanding.

   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? They are both circular.

e) How are the incident and reflected waves different? The circles (half circles) are moving in opposite directions.

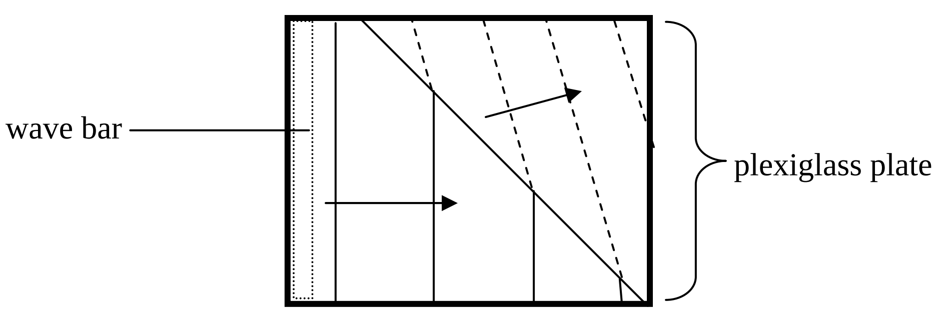
Refraction

6. Remove the barrier and place the triangular plexiglass plate at the end of the tank (see diagram in part 6c). Make sure that the water over the plexiglass is very shallow, at most 2 mm. Remove water with sponge if necessary. Tap the wave bar at a constant frequency creating a series of evenly spaced pulses.

   a) 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. The wave pulses are slower in the shallow water. The wavelength is smaller in the shallow water.

   b) What happens to the pulses at the boundary between the shallow and deep water? This is known as refraction. The wave pulses bend or change direction.

   c) 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.



   d) How do the wavelengths compare in the deep and shallow water? The wavelength is smaller in shallower water.

   e) Knowing that the frequency remains the same, what must be true about the velocities of the wave pulses? The velocity of the pulses must decrease.

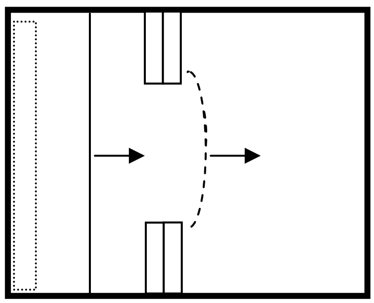
   f) Can you observe what you predicted in part 6e? Yes (if the water is shallow enough on top of the plexiglass).

Diffraction

7. Remove the plexiglass 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.

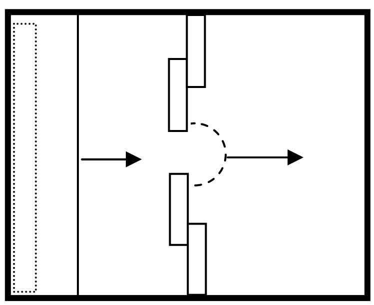
   a) What happens to the wave pulses as they move through the opening? This is known as diffraction. <u>They become rounded at the edges.</u>

   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 the go through the opening? <u>They become more round.</u>

   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? Traveling waves originate from the edges of the tank.

b) Sketch your observations of the standing wave below. Diagrams will vary.

c) What do you notice about the surface of the water in the ripple tank when you create a standing wave? It sometimes has "jumps" and has very large amplitude vibrations.

Analysis and Conclusions

Reflection:

1. In your own words what is the definition of reflection? Reflection is the bouncing of waves off a surface.

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? As the angle of hitting the barrier increases, the angle of reflection off the barrier increases.

3. Where could you observe examples of reflection in the real world? Possible answers include:_reflection off of any shiny surface, sound, objects bouncing off a surface as in a ball bouncing off a floor*

**Note: Many students will give an answer similar to this. This would give an opportunity to discuss reflection of an object vs. reflection of waves.*

4. Explain why, at a concert or a sports stadium, the sound often appears to come from a wall of the room and not from the stage. Depending on where you are located in the room it is possible to get the sound from the reflection of sound waves off the wall and not the waves emitted by the band on stage.

Refraction:

5. In your own words give a definition of refraction. Refraction is the bending of a wave at a boundary between two different regions.

6. What is needed in order for refraction to occur? Students may say the you need a different depth. Emphasize that in general you need a different medium.

7. Where could you observe examples of refraction in the real world? Possible answers include:_looking at a straw or finger half in/half out of the water.

Diffraction:

8. In your own words give a definition of diffraction. Diffraction is the bending of

waves around an object.

9. What is needed in order for diffraction to occur? You need an obstacle. Students may way the an opening is needed.

10. What direction did the pulses curve relative to their direction of their travel? The waves bend away from their direction of travel.

11. What happened to the bending of the wave pulses as the opening became smaller and smaller? The waves curve more as the opening decreases.

12. What do you suppose would happen to the shape of the wave if the opening became infinitesimally small? The waves would make half circles.

13. Where could you observe examples of diffraction in the real world? Light being bent around a hair or other small object, water moving around rocks.

Standing Waves:

14. In your own words, give a definition of a standing wave. A wave that appears not to travel any direction.

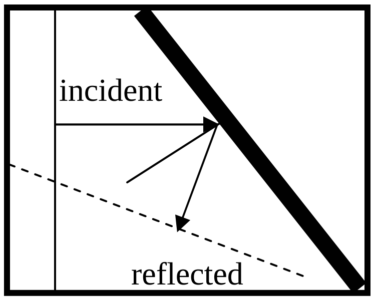
15. What is needed in order for a standing wave to occur? A standing wave is made from traveling waves moving in opposite directions.

16. Where could you observe examples of standing waves in the real world? A standing wave on a string.

EXTENSIONS

Reflection:

1a) – f)



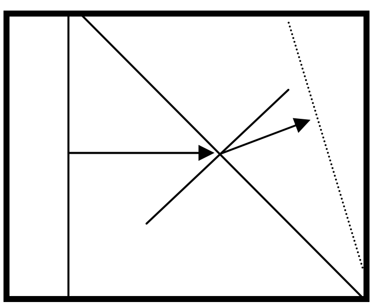
g) Measure the angle made between the incoming ray and the normal. Answer will vary.

h) Measure the angle made between the outgoing ray and the normal. Answers will vary but should be the same as 1g.

i) What is the relationship between the two angles? The two angles are equal.

Refraction:

2a) – f)



g) Measure the angle the inciden ray makes to the normal. Answers will vary.

h) Measure the angle the refracted ray makes to the normal. Answer should be less than the angle measured in 2f).

i) Compare the two angles. The angle of the refracted ray is less than the incident.

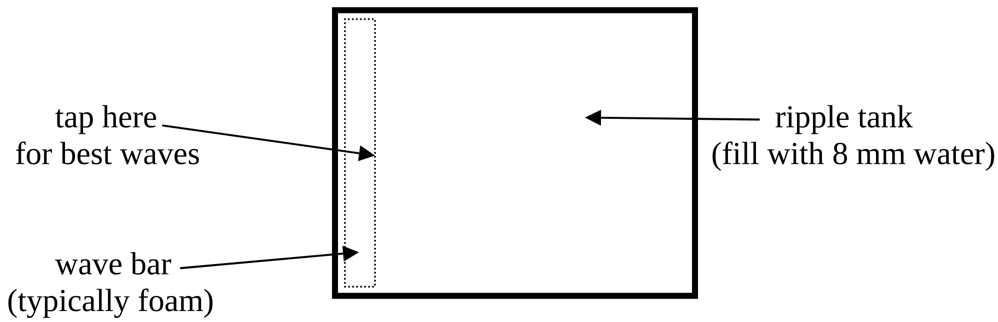
j) When the speed of the wave decreased (because it entered shallower water), what happened to its direction of travel relative to the normal? It bent toward the normal.

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?

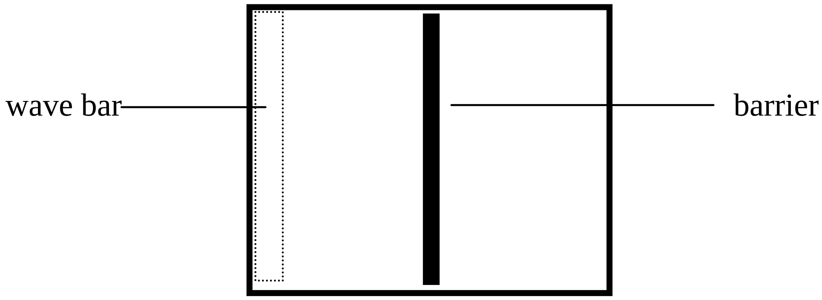
Reflection

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.

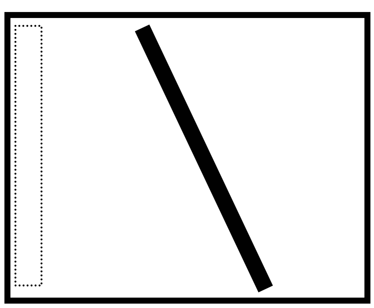


4. Now place the barrier at an angle (see diagram in part 4c). Send a single pulse toward the barrier.

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?

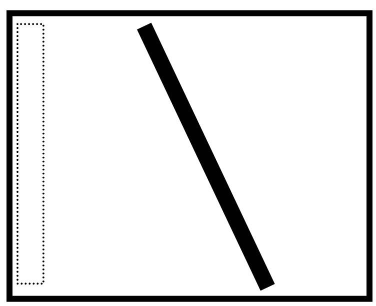
f) What happens to the reflected wave pulse if the angle of the barrier changes?

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?

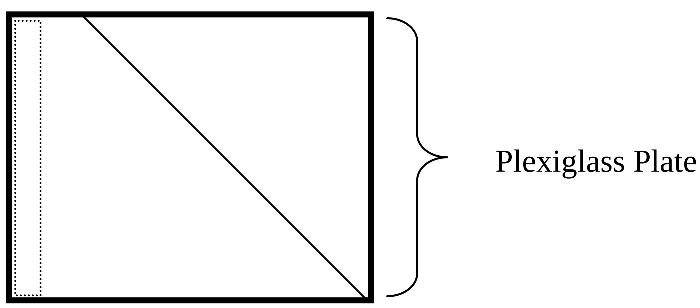
Refraction

6. Remove the barrier and place the triangular plexiglass plate at the end of the tank (see diagram in part 6c). Make sure that the water over the plexiglass is very shallow, at most 2 mm. Remove water with sponge if necessary. Tap the wave bar at a constant frequency creating a series of evenly spaced pulses.

   a) 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.

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

   c) 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.



   d) How do the wavelengths compare in the deep and shallow water?

   e) Knowing that the frequency remains the same, what must be true about the velocities of the wave pulses?

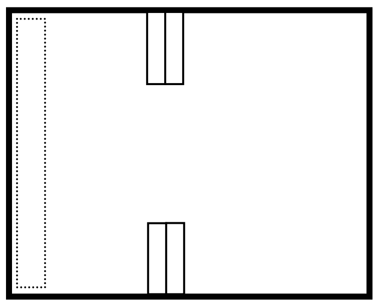
   f) Can you observe what you predicted in part 6e?

Diffraction

7. Remove the plexiglass 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.

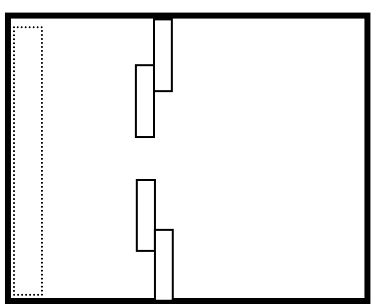
a) What happens to the wave pulses as they move through the opening? This is known as diffraction.

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?

<u>Analysis and Conclusions:</u>

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 1f. 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 barrier facing the wave bar.

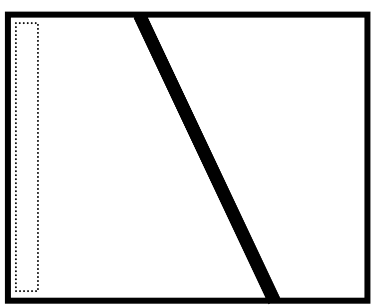
   b) On the paper below the ripple tank, align a ruler parallel to the incoming wave fronts, draw a line, and label it "incident."

   c) On the paper below the ripple tank, align a ruler parallel to the outgoing wave fronts, draw a line, and label it "reflected."

   d) Using a protractor and ruler, draw a ray from the incident wave front to the barrier that is perpendicular to the incident wave front.

   e) Using a protractor and ruler, draw a ray from the barrier to the reflected wave front that is perpendicular to the reflected wave front. Have the reflected ray originate at the same point on the barrier that the incident ray intersects it.

   f) Draw a line perpendicular to the barrier where both rays come together. This is known as the "normal." Sketch your drawing in the figure below.



   g) Measure the angle made between the incoming ray and the normal. ____________

   h) Measure the angle made between the outgoing ray and the normal. ____________

   i) What is the relationship between the two angles? ____________________________

   ____

Refraction:

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

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

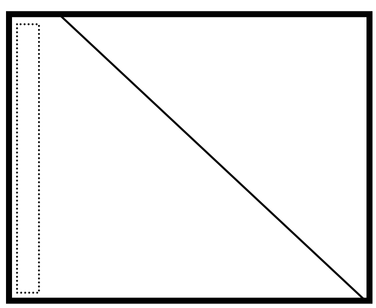
   b) On the paper below the ripple tank, align a ruler parallel to the wave fronts in the deep water before they reach the plexiglass, draw a line, and label it "incident."

   c) On the paper below the ripple tank, align a ruler parallel to the wave fronts traveling in the shallow water, draw a line, and label it "refracted."

   d) Using a protractor and ruler, draw a ray from the incident wave front to the plexiglass that is perpendicular to the incident wave front.

   e) Using a protractor and ruler, draw a ray from the barrier to the refracted wave front that is perpendicular to the refracted wave front. Have the refracted ray originate at the same point on the barrier that the incident ray intersects it.

   f) Draw a line perpendicular to the barrier where both rays come together. This is known as the "normal." Sketch your drawing in the figure below.



   g) Measure the angle the incident ray makes to the normal. ___________

   h) Measure the angle the refracted ray makes to the normal. __________

   i) Compare the two angles.

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