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RIPPLE TANK

CAT NO. PH0767A

Experiment Guide

BACKGROUND INFORMATION:

Ripple tanks are used to study water wave behavior in two dimensions. The more abstract concepts of reflection, refraction, dispersion, and interference can be demonstrated by a ripple tank and then applied to other wave phenomena that occur with light and sound waves. The ripple tank provides a dramatic demonstration of the general properties of waves and propagation phenomenon by taking advantage of the optical properties of water waves.

There are three types of waves this wave generator can make. A single circular wave, a two point source wave, and plane parallel waves. The frequency of the waves can be adjusted by adjusting the motor. The propagation velocity can be changed by adjusting the depth of the water in the tank.

To set up your classroom for successful wave study using a ripple tank a dim room is recommended so students can more easily see the wave patterns. Also, the water in the tank can spill. Have paper towels on hand and have students keep only items that are absolutely necessary at their table. Extra books and other materials should be stored someplace else.

There are two types of waves commonly studied in high school and middle school courses. A wave is energy that travels from one location to another. As the energy passes by a particular point in space, it moves or jiggles the particles it is traveling through. If the particle is jiggling perpendicular to the direction that the wave is traveling this is called a transverse wave. To help students remember this, the T in transverse is the symbol for perpendicular upside down. When the particle jiggles back and forth parallel to the direction the wave travels, this is called a compression or longitudinal wave. To help remember this, the first 'l' and the last 'l' in longitudinal make the symbol for parallel lines.

We will concern ourselves with transverse waves for this apparatus. Although superposition is a phenomenon that occurs in both longitudinal and transverse waves, we will look at superposition in transverse waves as well as review some other wave terminology to help us explain what a standing wave is.

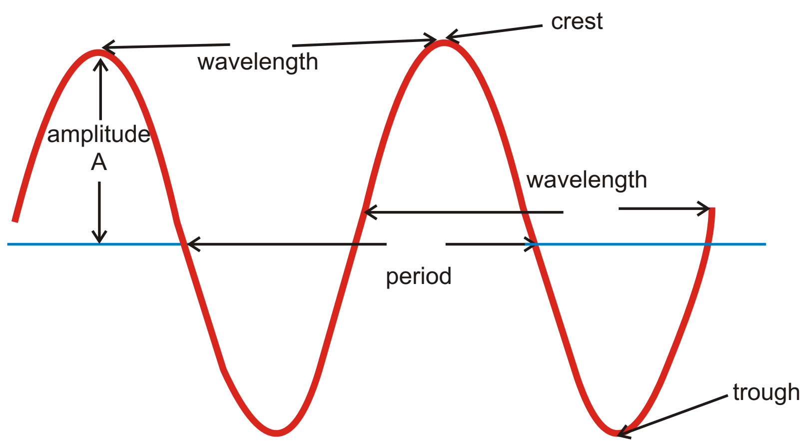


Diagram 1

The amplitude 'A' of a wave is the maximum displacement of a particle from its original rest position. The wavelength or ‘ ’ of a wave is the distance between two corresponding points of the wave . The period 'T' of the wave is the amount of time it takes for a particle to go through one complete cycle and return back to the position it was when it started. The crest is the highest point of the wave and the trough is the lowest part of the wave.

The frequency of a wave 'f' is the number of cycles a wave goes through in one second. Written as a formula,

$$f = 1/T \quad \text{or} \quad T = 1/f$$

Equation 1

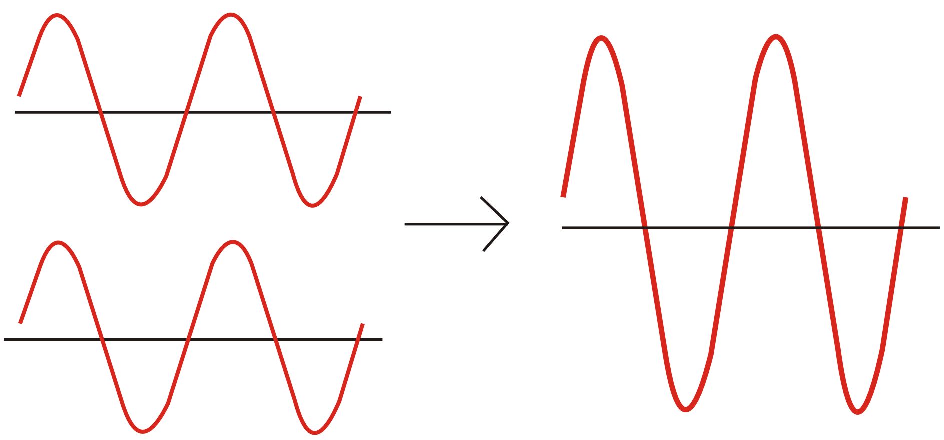
The speed of a wave 'v' is given by the formula

$$v = f$$

Equation 2

Interference is a property of waves by which two waves, when occupying the same space at the same time, will either add together (constructive interference) or cancel each other out (destructive interference). After the waves pass by each other they retain their original properties.

Constructive Interference



Destructive Interference

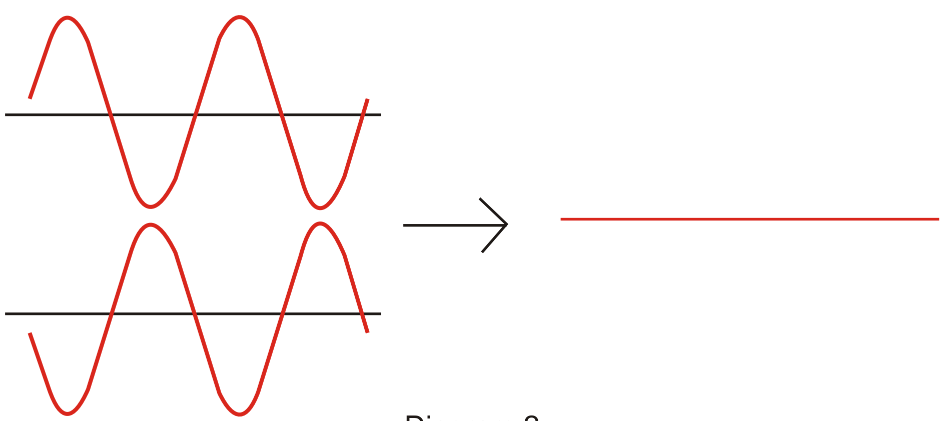


Diagram 2

Amplitudes of waves that are in phase add together to form a larger amplitude. Amplitudes of waves that are out of phase can cancel each other out to form smaller amplitudes.

Christian Huygen's Principle:

In the 1600's Christen Huygen's principle states that all points on a wave front serve as point sources of spherical secondary wavelets. At time "t_1" the new position of the wave front will be that of a surface perpendicular to the secondary waves.

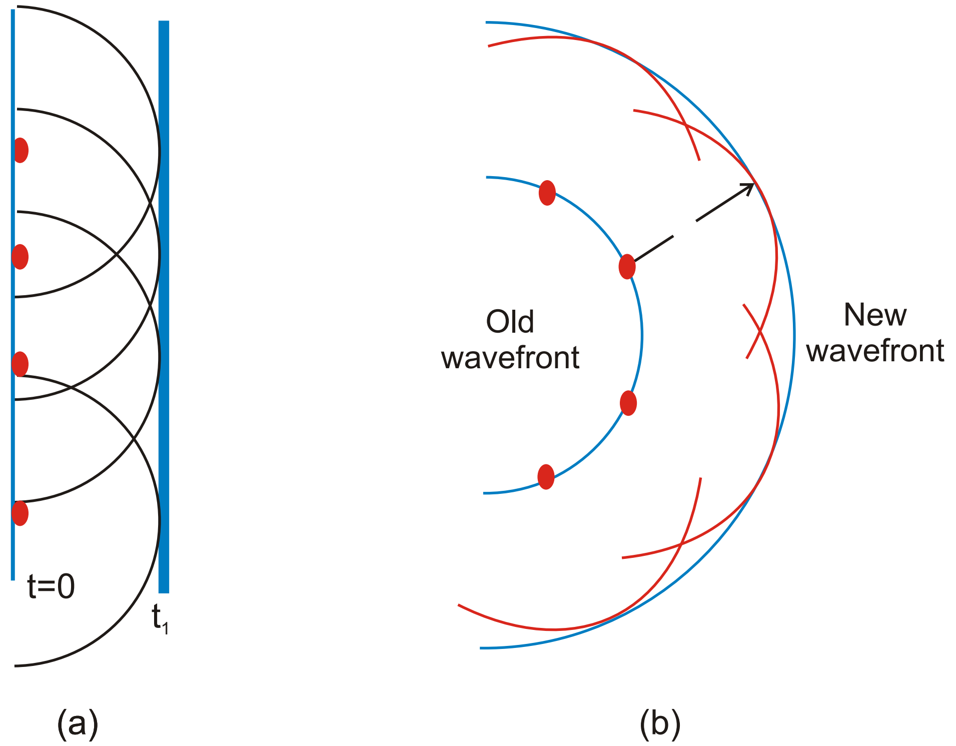


Diagram 3

There are infinitely many red dots along the wave front at time t=0. Since each individual wavelet that started at a red dot at time t=0 would constructively interfere at time t_1 along the line above t_1, then the wave front would look like a straight line in the second position at time t_1.

Both of these patterns can be seen in the ripple tank. The pattern in diagram 3a can be seen by using the plastic roller bar, and the pattern in diagram 3b can be seen by dropping a single drop off water out of a medicine dropper.

Diffraction:

As a wave passes through a narrow slit, the part of the wave that passes through the slit will spread out into the region beyond the barrier. The narrower the slit, the more the waves' path will spread out around the barrier.

When students begin to study light waves, Huygen's principle can be applied to light waves to help explain the phenomenon in Young's Double Slit experiment. It is often difficult for students to visualize what is happening when Young's interference pattern is formed on a screen since the crest and troughs of light waves are not visible to our eyes. However, we can model what is happening in Young's experiment by using the ripple tank as a model.

Young's Double Slit Interference Experiment:

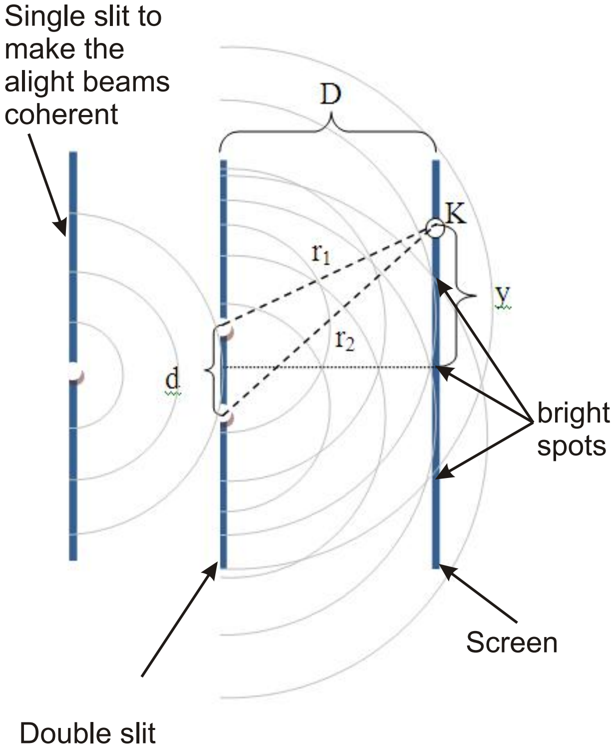
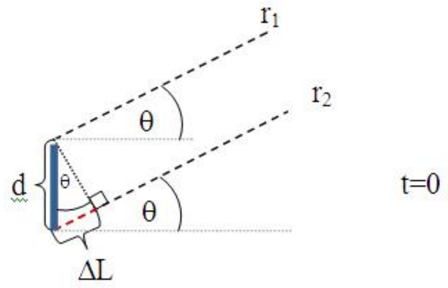


Diagram 4a



If d <<D then we can assume that r_1 and r_2 are parallel to each other.
Diagram 4b

If the light is coherent when it passes through the double slit, then the phase difference when the light hits the screen at point K will be determine by the path length difference   L.

Any integer multiple of the wavelength that is equal to the path length difference of ray r_1 and ray r_2 would yield total constructive interference by the waves. For light waves, the amplitude of a wave is shown by the wave's intensity. Therefore total constructive interference would appear as a bright spot.

A difference in length between r_1 and r_2 that is an integer multiple of the wavelength plus one half of a wavelength would yield a total destructive interference and therefore a dark spot.

It follows that if   L = m , a bright spot will appear at point K

Equation 3

Also if   L = (m + 0.5) , a dark spot will appear at point K

Equation 4

Next Generation Science Standards:

- HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Disciplinary Core Ideas

PS4-A: Wave Properties:

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
- Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other.

Science and Engineering Practices

- Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
- Using Mathematics and Computational Thinking: Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.
- Engaging in Argument from Evidence: Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

Cross-Cutting Concepts:

- Cause and effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.
- Cause and effect: Systems can be designed to cause a desired effect.
- Systems and System Models: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions- including energy, matter, and information flows- within and between systems ant different scales.

Common Core State Standards Connections:

- RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address a question or solve a problem.
- RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
- MP.2 Reason abstractly and quantitatively.
- MP.4 Model with mathematics.
- HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context.

- HSA-SSE.B.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.
- HSA-CED.A.1 Create equations and inequalities in one variable and use them to solve problems.
- HSA-CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	Quantity
Ripple Tank 40 x 40 cm	1
Screw Fit Legs	4
Rippler Motor with eccentric cam mounted on PVC bar	1
Supports for illuminator and motor	3
Motor hanging clamps	2
Halogen Lamp Unit	1
Springs for motor support	2
Hand stroboscope	1
Rectangular Perspex plate	1
Concave and Convex Perspex plate	1
Curved reflector	1
Plastic Roller Bar	1
Small Barrier	1
Large Barrier	2
Bosshead Clamp	1
Banana plug leads	2

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	Quantity
Water	
Bucket or tub to drain water into	1
Power supply with 12 V AC or DC voltage	1
Power supply with variable DC voltage	1
OR EPR 1331 will work to replace the two types of power supplies listed above	1
Large sheet of white paper, at least 40cm x 40cm	1

RECOMMENDED COMPONENTS (NOT INCLUDED)

Name of Part	Quantity
Small medicine dropper	2
Small ruler (clear)	1
Protractor	1
Stopwatch	1
Video recorder/camera	1

SAFE HANDLING OF APPARATUS:

Warning: Outside of the lamp casing gets extremely hot and can cause burns. Do not handle or touch lamp during use or after use until completely cooled.

Beware of water on the laboratory floor. Make sure you have a sponge and bucket handy to mop up spills immediately. Place the power supply for the lamp somewhere protected from water spills.

PHOTO-INDUCED EPILEPSY : In all work with flashing lights, teachers must be aware of any student suffering from photo-induced epilepsy. This condition is very rare. However, make sensitive inquiry of any known epileptic to see whether an attack has ever been associated with flashing lights. If so, the student could be invited to leave the lab or shield his/her eyes as deemed advisable. It is impracticable to avoid the hazardous frequency range (7 to 15 Hz) in these experiments.

MAINTENANCE REQUIRED:

After using your ripple tank, empty the tank and dry all parts, allowing the tank to drip dry or allowing water to evaporate in the tank can cause hard water build up on your surface making it difficult to see wave phenomenon.

DIAGRAM LABELING ALL PARTS:

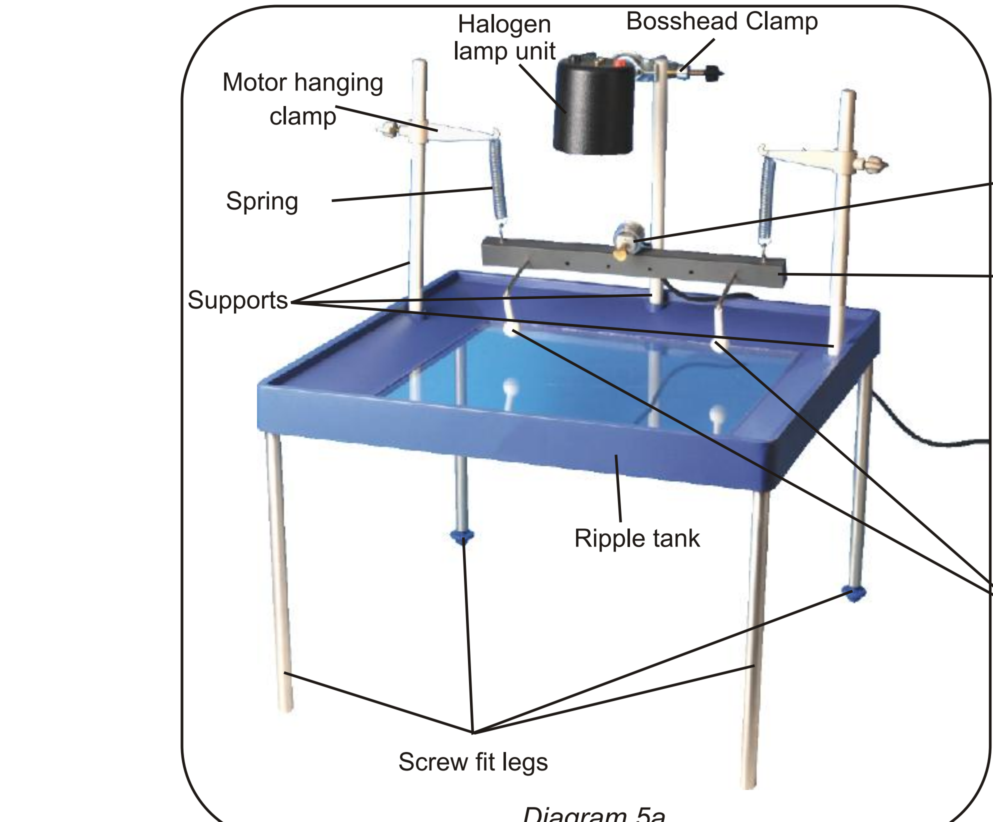


Diagram 5a

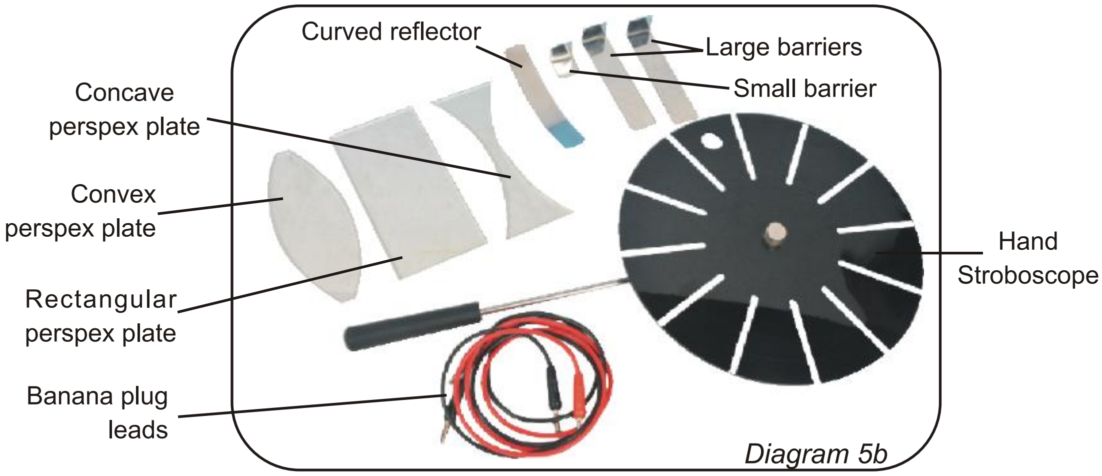


Diagram 5b

SET-UP OF APPARATUS:

Legs:

Begin assembly of your wave tank by screwing the four metal legs into the screw holes on the underside of the ripple tank. Two legs have blue plastic adjustable bottoms. These two feet should be next to each other on the wave table. Unscrew or screw in the blue plastic to adjust the table and make the surface of the wave level. If the surface is not level, the water will be deeper in some areas of the ripple tank and the speed of the waves will change leading to a distorted image.

Diagram 6: Basic Apparatus set up

Supports:

Now that your table is level, there are three plastic support rods that push into the top of the ripple tank. Push them in firmly so they do not slide around. The supports are shown in diagram 6.

***Lamp*:**

The lamp stand is labeled in diagram 6. Use the right angle clamp to attach the lamp to the support. Plug the two leads (one red and one black) into the top of the lamp and then connect these to a power supply that gives out 12 AC volts of voltage.

White Paper Screen:

Place a white sheet of paper underneath the ripple tank that covers the entire area between all four feet.

***Lamp Adjustment*:**

Be aware that the reflection seen below the ripple tank is influenced a great deal by the position of the lamp. The further the lamp is from the surface of the water, the smaller the image will be below on the white paper. Also the angle between the lamp and the water will affect the size and magnification of the image seen. If you wish to observe what happens when a wave strikes a barrier or crosses over a prism, make sure the shadow of that barrier or prism are visible on the white paper under the apparatus. To view the wave pattern or record the wave pattern, make sure your eye, or the eye of the camera, is looking at the pattern without looking through the water in the ripple tank.

***Adding Water*:**

Add some water to the ripple tank until the depth of the tank is to the level suggested by the experiment you are studying. Most experiments require about 5mm of water in the ripple tank, but studying the effect of water depth on wave speed requires starting with 3mm of water. The depth of the water can be most easily measured with a caliper as rulers typically have a few millimeters of space at the end of them before the actual measurement starts, however, if you take that into account a typical ruler can be used as well.

Add a drop of dish soap to the water to decrease the surface tension of the water and minimize the reflection that occurs as the waves hit the sides of the ripple tank.

Setting up a Camera:

To take pictures or record videos of the wave it is helpful to have ring stand and clamp that will hold your camera or recorder firmly in place. In order to get good quantitative results, keep the following thing in mind.

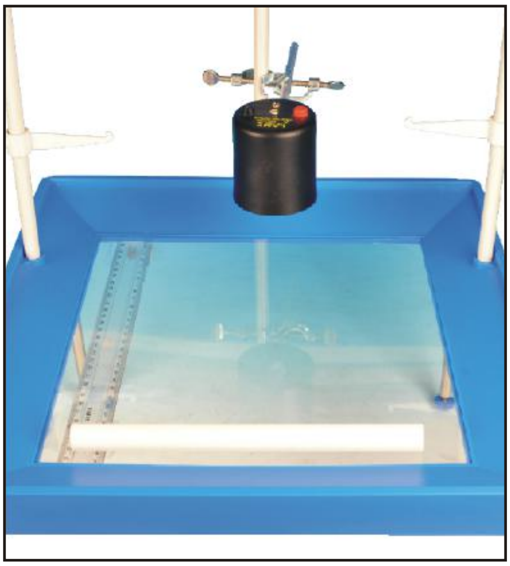


Diagram 7

1. The camera should be set up perpendicular to the event you are recording.
2. There must be something in the picture in order to give the relative distance that the wave is traveling. Taping a clear plastic ruler to the underside of the ripple tank works really well. It doesn't interfere with the wave pattern and the numbers on the ruler get magnified onto the screen just like the waves' shadows, so you can obtain pretty accurate results.
3. Place the camera under the ripple tank. As close to directly overhead of the image you wish to capture as possible, without letting the shadow from the camera block your view.
4. Do not take pictures of the white screen looking through the ripple tank, the image will be distorted by the water.

MAKING WAVES USING THE ROLLER:

Set up apparatus as shown in diagram 5a. The lamp should be connected to a 12V AC power supply. Simply roll the bar quickly forward and backward to make a quick pulse as shown in diagram 8.

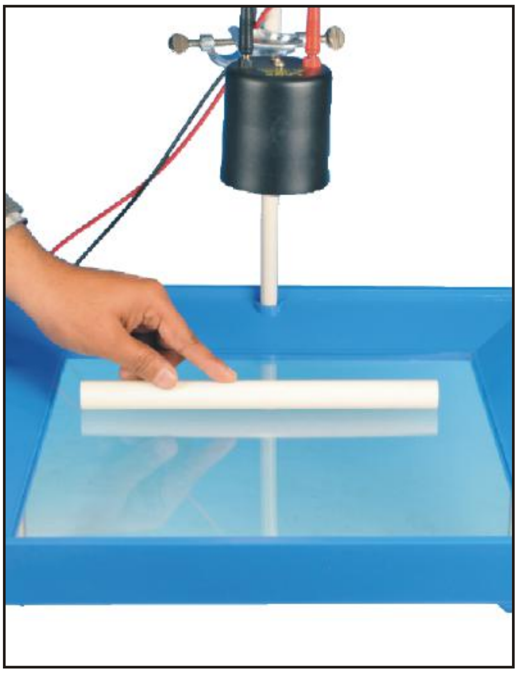


Diagram 8

MAKING WAVES USING A MEDICINE DROPPER:

Have students use a medicine dropper or pipet to drop single drops of water in the ripple tank at a time as shown in diagram 9b. Have students record the shape of the wave as shown in diagram 9a. Students can also drop two drops in at the same time. Some of the following questions are interesting to propose to your students. Ask the questions first, have them predict what will happen, and then let them observe their results.

QUESTIONS:

1. What happens when the waves occupy the same space, do the waves travel through each other? (yes)
2. Does the shape of the waves change? (no)
3. Does the speed of the wave change? (no)

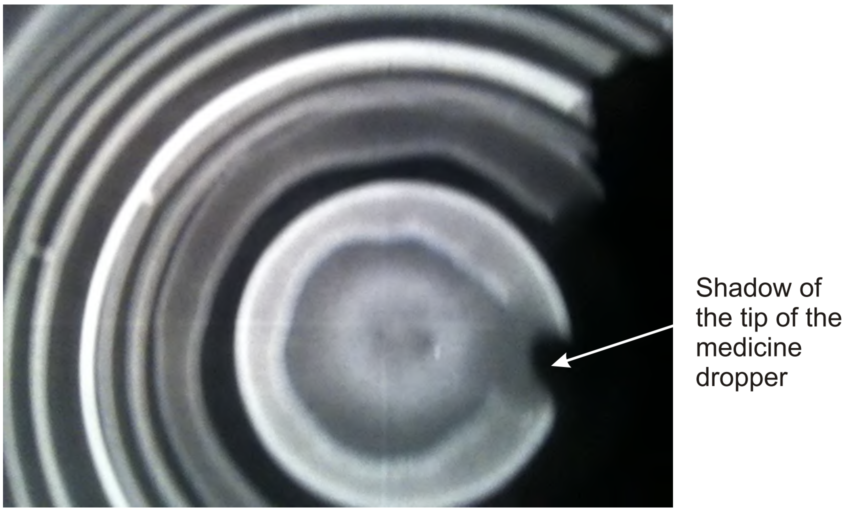


Diagram 9a

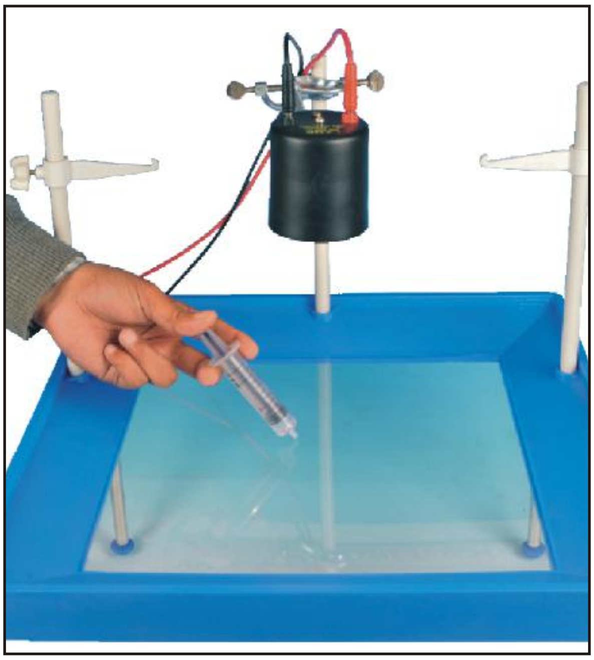


Diagram 9b

MAKING WAVES USING THE WAVE GENERATOR:

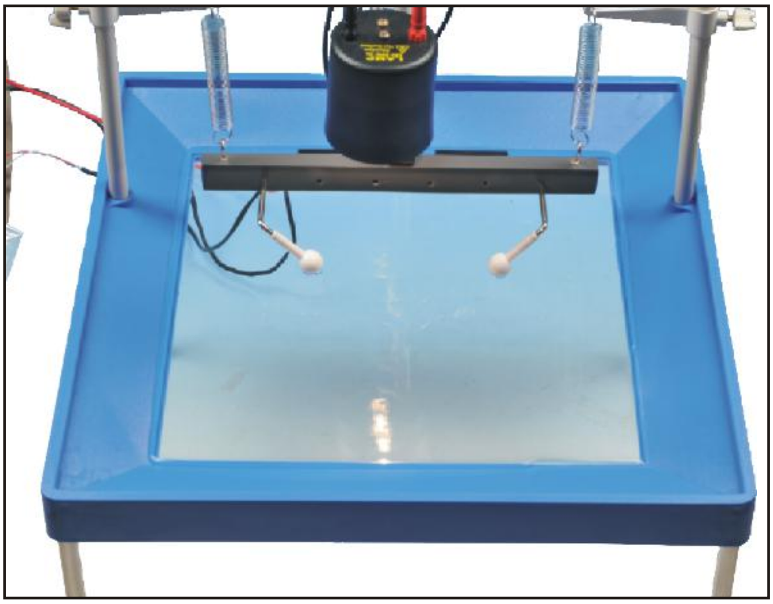


Diagram 10

In order to use the wave generator, the depth of the water must be around 5mm or there will be significant interference from the waves reflecting off the sides of the ripple tank. Using a caliper is the easiest way to measure the depth of the water, but using a plastic ruler and accounting for the extra few millimeters on the end will work well too.

Adding a drop of dish soap to the water will reduce the surface tension of the water to be able to see the waves more clearly. The water will not adhere to itself as much and change depth near any surface it comes in contact with, such as barriers or the sides of the ripple tank.

Set up the ripple tank as shown in diagram 10. You will need to attach the motor hanging clamps to each of the support rods on either side of the rod holding the lamp, then hang one spring off of each clamp and then hang the wave generator from the springs.

Adjust the height of the springs until the round ball shaped dippers just touch the surface of the water.

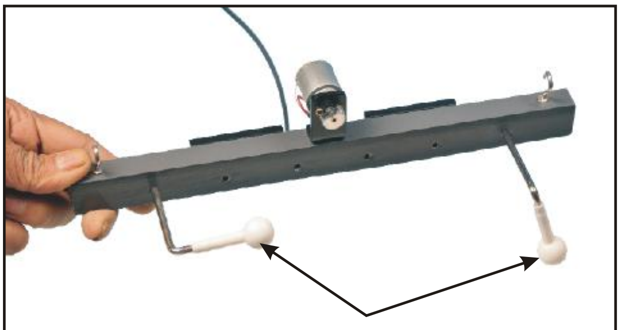


Diagram 11

Plug the leads into a variable DC voltage source such as a power supply. You can estimate the frequency of the wave generator by knowing the velocity of a wave in your given depth of water and measuring the wavelength by finding the distance between the crest in the waves using stroboscope to slow the wave image down, or by taking a picture and using a clear plastic ruler taped to the bottom of the ripple tank.

Rotating the two round plastic dippers clockwise or counter clockwise as shown in diagram 11 will allow you to make either one circular wave front or adjust the distance between to two wave sources.

USING THE STROBOSCOPE:

To use the stroboscope, you must first get in a position so that you can see the paper only through the slots of the stroboscope. If you look through the water on the wave table to see the paper you will get a double image.

There is a small hole on one of the petals of the stroboscope as shown in diagram 12. Stick your finger in the hole and pull down hard on the petal to get the stroboscope to rotate.

You can adjust the speed of the stroboscope by lightly touching the back of your finger nail to the middle of the stroboscope. The waves will appear to slow down or even stop if you can match the speed of the waves with the speed of the stroboscope.

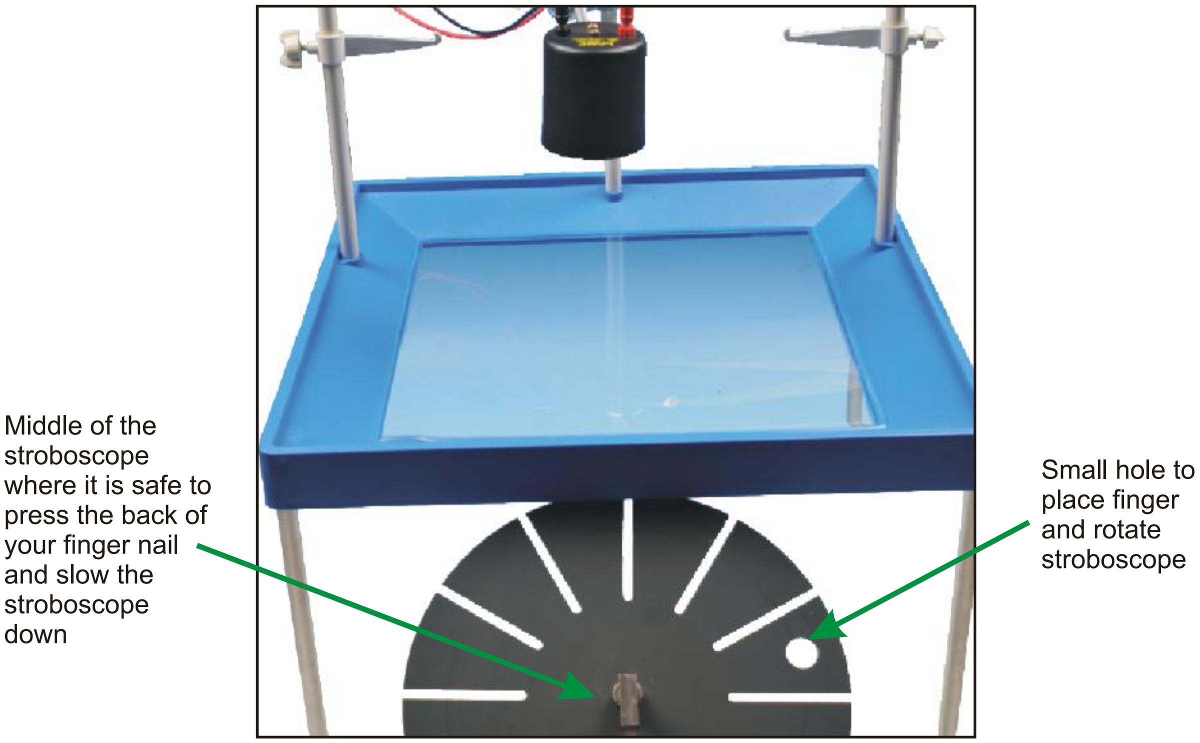


Diagram 12

ACTIVITY 1: DOES WATER DEPTH CHANGE WAVE SPEED? (TEACHER ANSWERS)

QUESTION: How does changing the depth of the water in the wave table affect the speed of the wave?

HYPOTHESIS:

PROCEDURE:

1. Set up your wave table as shown in diagram 1.
2. Add 3mm of water to the table and measure with a ruler.
3. Set up a video recorder over the top of the white screen. Setting the recorder on an immoveable platform is best so that the distance between the camera and the wave table remains constant.
4. Start the video and record one pulse traveling across the tank.
5. Add one or two more mm of water to the table and record the depth of the water and video record the pulse moving across the water.
6. Repeat step 5 until the depth of the water is about 12mm deep.

DATA ANALYSIS:

1. Use your video analysis software to graph velocity vs. time or distance vs. time for each pulse.
2. Attach one graph to this lab showing how you calculated velocity.

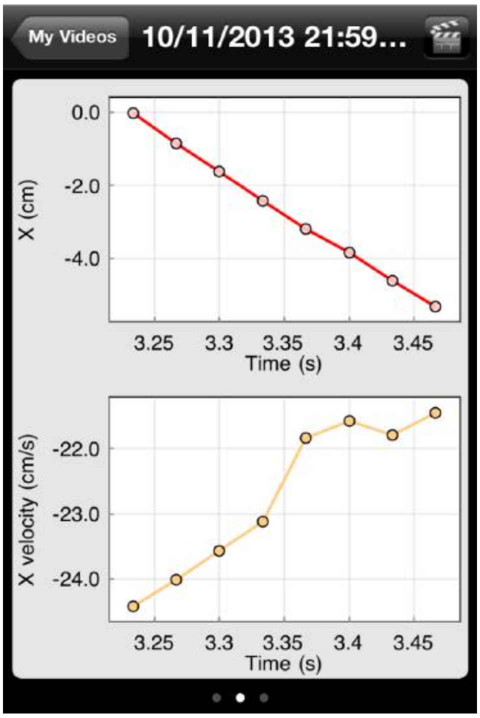


Diagram 13: Actual data using Vernier's "Video Physics" app on a smart phone for a depth of 8mm.

3. Make a table in the space provided below of speed of the wave and depth of the water.

Depth of the Water (mm)	Speed of the wave (cm/sec)
3.7	18.7
4	17.7
5	20.7
6.2	22
6.8	21
6.8	19.5
8	23
10.5	30
13.6	30

4. What is the relationship between velocity and depth? Explain how you reached this conclusion.

As the speed of the depth of the water increased, the speed of the wave increased, therefore depth and wave speed are directly proportional.

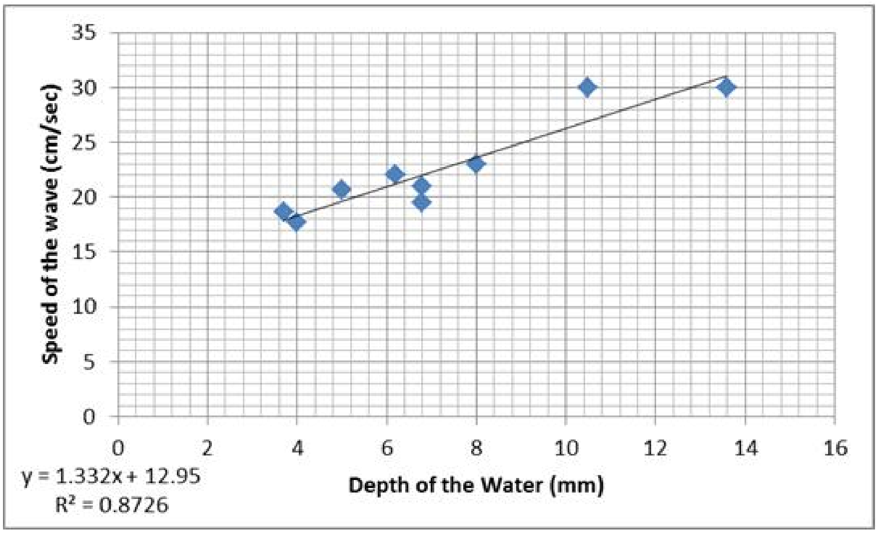


Diagram 14

CONCLUSION:

Write a conclusion that answers your original question. State if your hypothesis was correct or incorrect. Give supporting evidence from your experiment that proves the answer to your question. Be sure to discuss any limitations of your answer as well as anything that happened during your experiment that may have affected your results.

Name:____ Date:________________

ACTIVITY 1: DOES WATER DEPTH CHANGE WAVE SPEED?

QUESTION: How does changing the depth of the water in the wave table affect the speed of the wave?

HYPOTHESIS:

____

____

PROCEDURE:

1. Set up your ripple tank as shown in diagram 7.

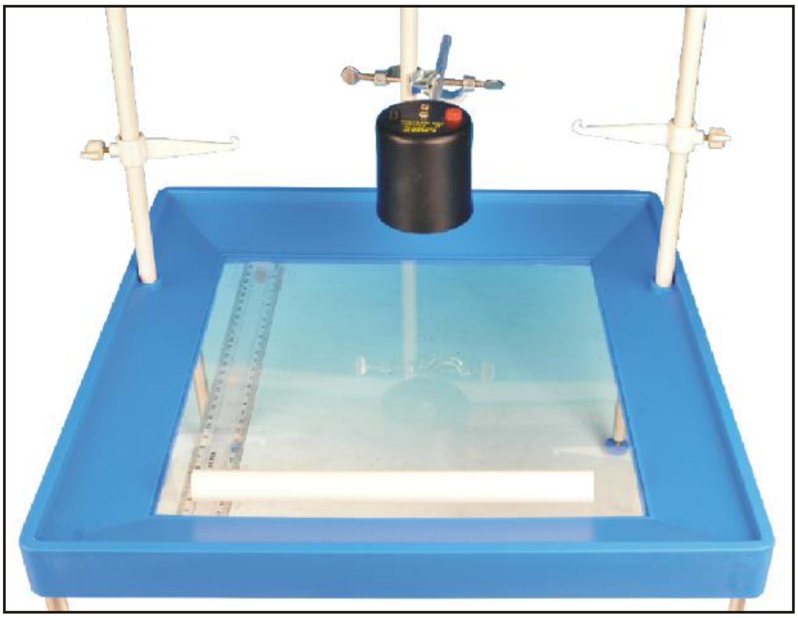


Diagram 7

2. Add 3mm of water to the table and measure with a ruler.
3. Set up a video recorder over the top of the white screen. Setting the recorder on an immoveable platform is best so that the distance between the camera and the wave table remains constant.
4. Start the video and record one pulse traveling across the tank.
5. Add one or two more mm of water to the table and record the depth of the water and video record the pulse moving across the water.
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DATA ANALYSIS:

1. Use your video analysis software to graph velocity vs. time or distance vs. time for each pulse.

2. Attach one graph to this lab showing how you calculated velocity.

3. Make a table in the space provided below of speed of the wave and depth of the water.

Depth of the Water (mm)	Speed of the wave (cm/sec)

4. What is the relationship between velocity and depth? Explain how you reached this conclusion.

___

___

___

CONCLUSION:

Write a conclusion that answers your original question. State if your hypothesis was correct or incorrect. Give supporting evidence from your experiment that proves the answer to your question. Be sure to discuss any limitations of your answer as well as anything that happened during your experiment that may have affected your results.

ACTIVITY 2: DIFFRACTION

TEACHER INSTRUCTIONS

QUESTION: What happens to a wave as it moves around a barrier?

HYPOTHESIS: Draw what the plane waves will look like as they move around each of the following barriers and then perform the experiment by using your roller bar to make a plane wave. Use your camera to capture what the waves look like as they pass through the barrier or draw a sketch of what the waves look like.

Situation 1: waves around one large barrier

Hypothesis :

Actual Data :

Diagram 15

Situation 2: waves around one small barrier

Hypothesis :

Actual Data :

Diagram 16

Situation 3: narrow slit between two barriers

Hypothesis :

Actual Data :

Diagram 17

Situation 4: medium slit between two barriers

Hypothesis :

Actual Data :

Diagram 18

Situation 5: large slit between two barriers

Hypothesis :

Actual Data :

Diagram 19

Name:____ Date:_____________

ACTIVITY 2: DIFFRACTION

QUESTION: What happens to a wave as it moves around a barrier?

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Situation 1: waves around one large barrier

Hypothesis :

Actual Data :

Situation 2: waves around one small barrier

Hypothesis :

Actual Data :

Situation 3: narrow slit between two barriers

Hypothesis :

Actual Data :

Situation 4: medium slit between two barriers

Hypothesis :

Actual Data :

Situation 5: large slit between two barriers

Hypothesis :

Actual Data :

ACTIVITY 3: ANGLE OF REFLECTION USING A BARRIER

TEACHER INSTRUCTIONS

(See intro to student activity sheet for a brief explanation of the theory and terminology using in this activity.)

Diagram 20 Picture of a wave reflecting off of a barrier.

1. Set up apparatus as shown in diagram 20. Use the two larger barriers to make one long barrier and set them in the ripple tank at an angle to the roller bar.

2. Make a single pulse with the roller bar.

3. Use a video recorder or camera to capture the wave reflecting off of the larger barrier. Take a picture of what happens on the white sheet of paper without looking through the ripple tank. Make sure the shadow of the barrier can be clearly seen on your white paper screen.

4. In the data table record your angle of incidence and angle of reflection. The zero degree line will always be 90° from the surface of your plane mirror as you rotate your mirror. This imaginary line 90° from the surface of your plane mirror is called the <u>normal line</u>.

5. Reposition your barrier at six different angles, varying from the wave hitting the surface from 0 degrees to 90 degrees.

6. Take a picture or record the wave reflecting off of the barrier for each of your six angles.

DATA:

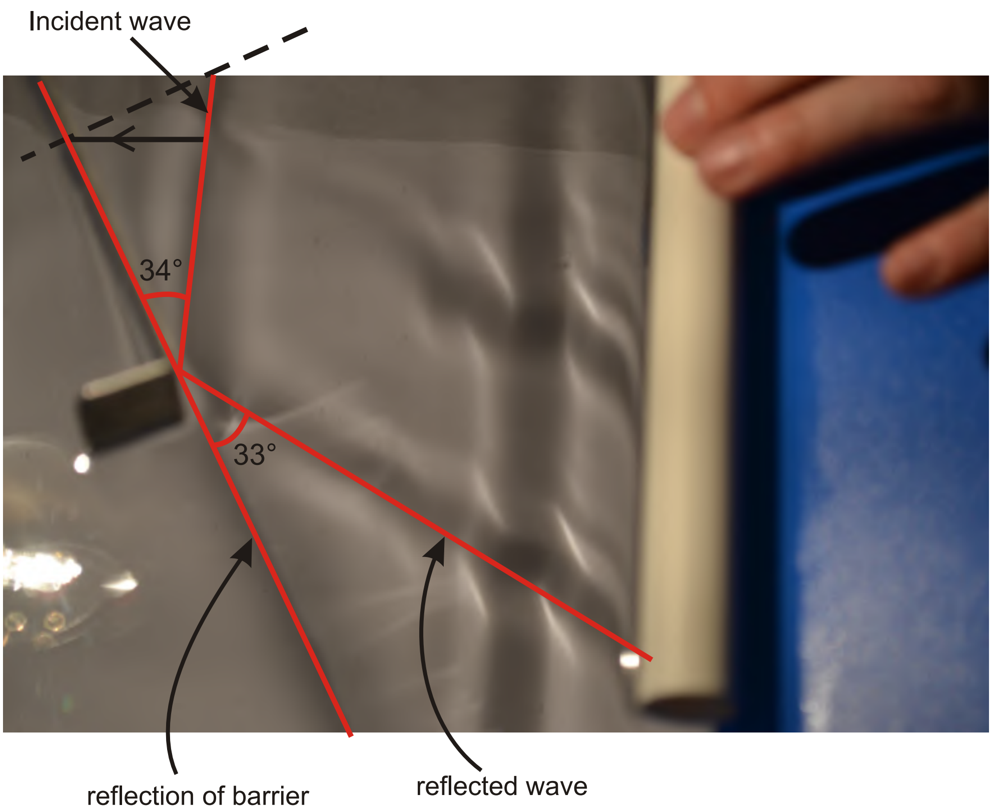


Diagram 21: The angles in this picture are distorted because the camera was not perpendicular to the screen

DATA ANALYSIS:

1. Print out a picture of each of your six different angles of reflection.
2. Use a straight edge and a protractor to draw a normal line from the surface of the barrier.
3. Measure the angle of incidence from the normal line.
4. Measure the angle of reflection from the normal line.

DATA TABLE:

Angle of Incidence (degrees)	*Angle of Reflection (degrees)*
0	0
10	10
20	21
30	30
40	40
50	48
60	60
70	68
80	82

Make a rule that describes how the angle of incidence affects the angle of reflection:
(The angle of incidence is always equal to the angle of reflection)

Name:____ Date:_____________

ACTIVITY 3: ANGLE OF REFLECTION USING A BARRIER

When measuring the angle that a wave or wave front strikes a surface, we begin with finding a normal line. A *normal line* is a line perpendicular to the surface of the mirror or barrier. It would seem natural to measure the angle between the surface and the incident ray. However, when the surface of reflection or refraction is curved, it is not possible to do this. The normal to a curved surface as well as a flat surface can easily be found and therefore we measure our angles to the normal line. The *angle of incidence* is the angle that the a wave going toward a surface makes with the normal line on the surface. The *angle of reflection* is the angle that the wave reflecting off of that surface makes with the normal line. When making a plane wave, the direction the wave is traveling is perpendicular to the wave front. The red arrow below shows the direction of the plane waves. The green arrow shows the direction of the reflected waves and the dashed line shows the normal line to the shadow of the barrier.

WARNING: *The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Do not leave the lamp on for any longer than necessary to complete the experiment. Turn the lamp off while not looking at the apparatus.*

Diagram 20 Picture of a wave reflecting off of a barrier.

1. Set up apparatus as shown in diagram 20. Use the two larger barriers to make one long barrier and set them in the ripple tank at an angle to the roller bar.

2. Make a single pulse with the roller bar.

3. Use a video recorder or camera to capture the wave reflecting off of the larger barrier. Take a picture of what happens on the white sheet of paper without looking through the ripple tank. Make sure the shadow of the barrier can be clearly seen on your white paper screen.

4. In the data table record your angle of incidence and angle of reflection. The zero degree line will always be 90° from the surface of your plane mirror as you rotate your mirror. This imaginary line 90° from the surface of your plane mirror is called the ___________________________.

5. Reposition your barrier at six different angles, varying from the wave hitting the surface from 0 degrees to 90 degrees.

6. Take a picture or record the wave reflecting off of the barrier for each of your six angles.

DATA:

Attach all six pictures to the back of this lab.

DATA ANALYSIS:

1. Print out a picture of each of your six different angles of reflection.
2. Use a straight edge and a protractor to draw a normal line from the surface of the barrier.
3. Measure the angle of incidence from the normal line.
4. Measure the angle of reflection from the normal line.

DATA TABLE:

Angle of Incidence (degrees)	*Angle of Reflection (degrees)*

CONCLUSION:

Make a rule that describes how the angle of incidence affects the angle of reflection:

ACTIVITY 4: REFRACTION
TEACHER INSTRUCTIONS

As shown in activity 1, changing the depth of the water in the ripple tank changes the speed of the wave or pulse. In this experiment it is very important to have the depth of the ripple tank close to 5mm. The water should completely cover the top of the prism so that the depth of the water is about twice the depth of the prism.

Refraction is often studied in school when students study light waves, however, refraction can be seen with water waves as well. Refraction, or the bending of a wave's path, happens when a wave's speed changes. In light waves, a wave traveling through a transparent medium will speed up or slow down depending on the index of refraction of the medium the light is traveling through.

PROCEDURE:

1. Use the rectangular shaped block and set up the ripple tank as shown in the diagram 21.

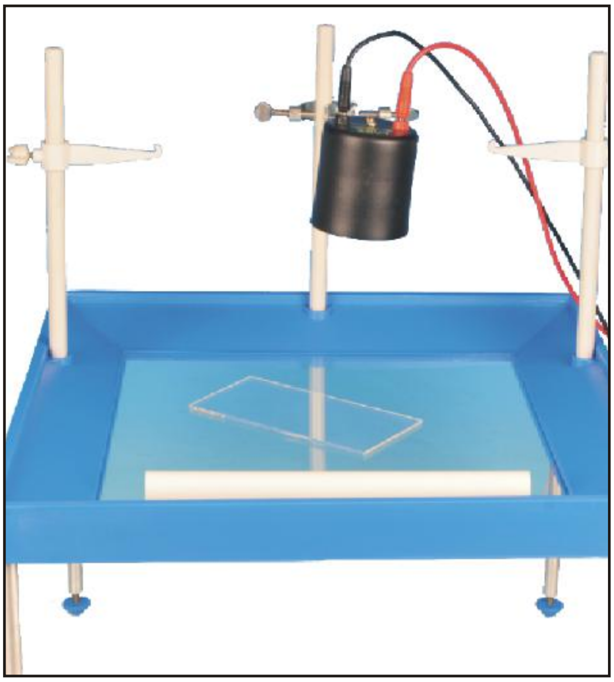


Diagram 21

2. Set up a camera to capture the image of a plane wave moving across the prism.

3. Make a plane wave by rolling the bar quickly forwards and backwards.

4. Take a picture as the wave moves over the prism, or make careful observations and sketch what you see. Attach that sketch to the back of this lab.

DATA:

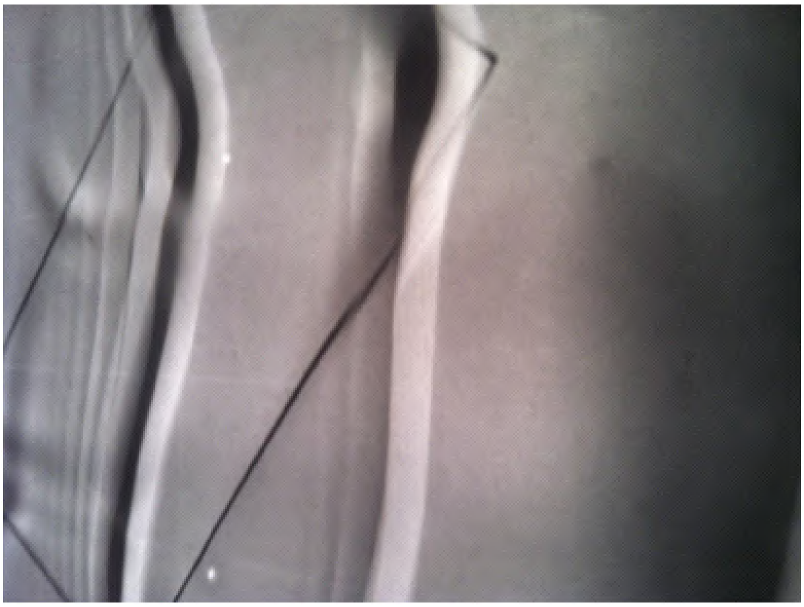


Diagram 22: This picture is of a plane wave passing over the top of rectangular prism.

DATA ANALYSIS: (FOR PHOTOS ONLY)

1. Draw an arrow (ray) perpendicular to incident wave front (perpendicular to the incident wave front is the direction that the wave front is traveling in. It may help to trace the edge of the wave front with a ruler and then use a protractor to measure 90 degrees from the wave front.) Label the beginning of this ray as point A.

2. Continue to draw the incident ray until it meets the edge of the prism and label the point where the prism and the ray representing the direction the incident wave front is traveling is as point B.

3. Draw a normal line perpendicular to the edge of the prism at point B. Label the end of the normal line as N_1.

4. Measure the angle of incidence ($_i$) $< ABN_1$ and record this on your paper.

5. Draw an arrow (ray) from where the incident ray meets the prism to the opposite side of the prism, perpendicular to the wave front moving over the prism. Label this arrow as the "direction of the refracted wave."

6. Label the point where the ray meets the opposite side of the prism as point C.

7. Draw a normal line perpendicular to the edge of the prism at point B directly opposite your first normal line N_1. Label the end of this normal line N_2.

8. Measure the angle of refraction ($_r$) <CBN_2 and record this on your paper.

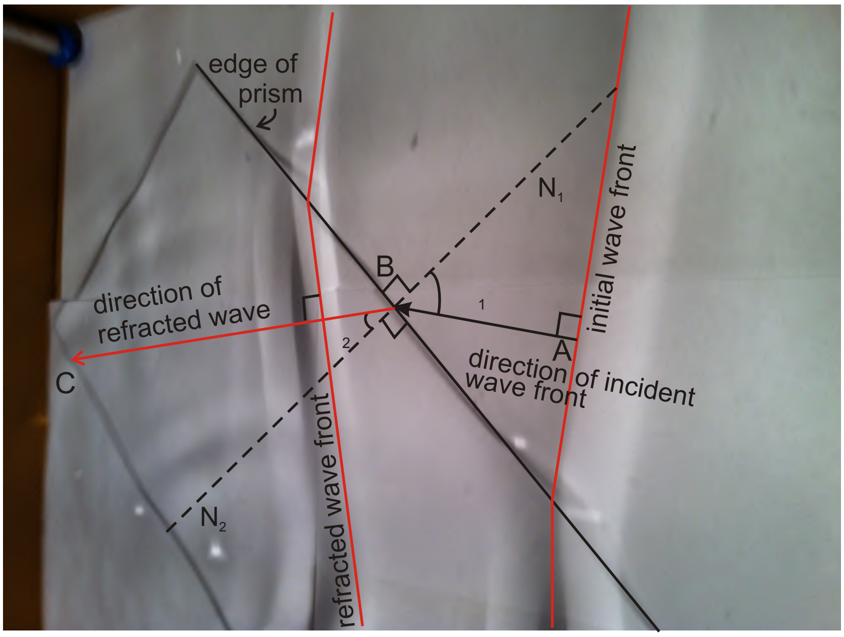


Diagram 23 This diagram shows how a student's paper should look after following data analysis steps 1-8. Image is not drawn to scale.

9. Measure the angles <ABN_1, <CBN_2 and write those values on the space provided below.
   ABN_1 <u>49°</u> CBN_2 <u>29°</u>

FOLLOW UP QUESTIONS:

1. When traveling from deep water into shallow, did the ray bend toward or away from the normal? *(towards)*

2. From previous experiments, what happens to the speed of a wave as it travels from deep water into shallow water, does it speed up, slow down, or stay the same?

   (From previous experiments I know that the deeper the water, the faster the wave travels, so a wave traveling from deeper water into shallow water would cause the wave to slow down.)

3. From studying refraction of light, when a light wave speeds up as it enters a new medium, does the wave bend away from or towards the normal line?

   (Away from the normal line.)

4. From studying refraction of light, when a light wave slows down as it enters a new medium, does the wave bend away from or towards the normal line?

   (The light wave bends towards the normal line as it slows down.)

5. Does a water wave exhibit the same behavior as a light wave as the speed of the wave changes?

   (Yes, as the water wave entered the shallow water, the speed of the wave slowed down, because of this slowing down, the wave's direction changed and it bent toward the normal line.)

Name:____ Date:_____________

ACTIVITY 4: REFRACTION

As shown in activity 1, changing the depth of the water in the ripple tank changes the speed of the wave or pulse. In this experiment it is very important to have the depth of the ripple tank close to 5mm. The water should completely cover the top of the prism so that the depth of the water is about twice the depth of the prism.

Refraction is often studied in school when students study light waves, however, refraction can be seen with water waves as well. Refraction, or the bending of a wave's path, happens when a wave's speed changes. In light waves, a wave traveling through a transparent medium will speed up or slow down depending on the index of refraction of the medium the light is traveling through.

PROCEDURE:

1. Use the rectangular shaped block and set up the ripple tank as shown in the diagram 21.

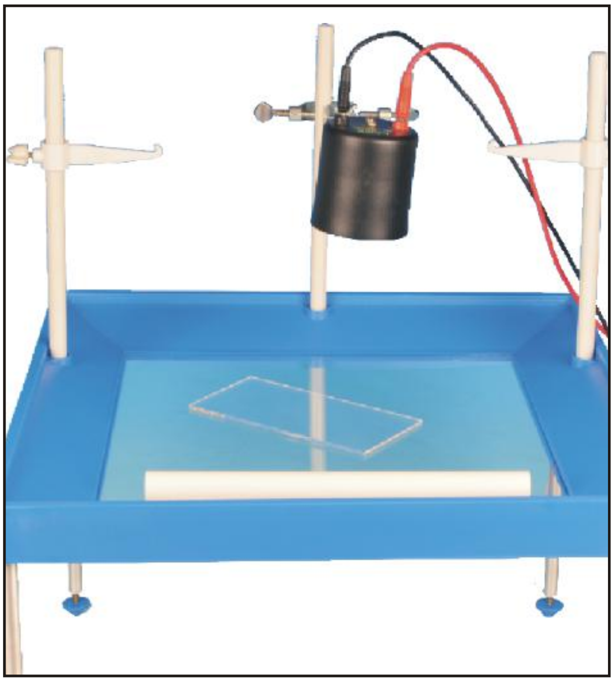


Diagram 21

2. Set up a camera to capture the image of a plane wave moving across the prism.

3. Make a plane wave by rolling the bar quickly forwards and backwards.

4. Take a picture as the wave moves over the prism, or make careful observations and sketch what you see. Attach that sketch to the back of this lab.

DATA:

DATA ANALYSIS: (FOR PHOTOS ONLY)

1. Draw an arrow (ray) perpendicular to incident wave front (perpendicular to the incident wave front is the direction that the wave front is traveling in. It may help to trace the edge of the wave front with a ruler and then use a protractor to measure 90 degrees from the wave front.) Label the beginning of this ray as point A.

2. Continue to draw the incident ray until it meets the edge of the prism and label the point where the prism and the ray representing the direction the incident wave front is traveling is as point B.

3. Draw a normal line perpendicular to the edge of the prism at point B. Label the end of the Normal line as N_1.

4. Measure the angle of incidence ($_i$) < ABN_1 and record this on your paper.

5. Draw an arrow (ray) from where the incident ray meets the prism to the opposite side of the prism, perpendicular to the wave front moving over the prism. Label this arrow as the "direction of the refracted wave."

6. Label the point where the ray meets the opposite side of the prism as point C.

7. Draw a normal line perpendicular to the edge of the prism at point B directly opposite your first normal line N_1. Label the end of this normal line N_2.

8. Measure the angle of refraction ($_r$) < CBN_2 and record this on your paper.

9. Measure the angles <ABN_1, <CBN_2 and write those values on the space provided below.

ABN_1_________ CBN_2_________

FOLLOW UP QUESTIONS:

1. When traveling from deep water into shallow, did the ray bend toward or away from the normal?

   ____

2. From previous experiments, what happens to the speed of a wave as it travels from deep water into shallow water, does it speed up, slow down, or stay the same?

   ____

   ____

3. From studying refraction of light, when a light wave speeds up as it enters a new medium, does the wave bend away from or towards the normal line?

   ____

   ____

4. From studying refraction of light, when a light wave slows down as it enters a new medium, does the wave bend away from or towards the normal line?

   ____

   ____

5. Does a water wave exhibit the same behavior as a light wave as the speed of the wave changes?

   ____

   ____

ACTIVITY 5: CONCAVE AND CONVEX LENSES AND MIRRORS

TEACHER INSTRUCTIONS

To make each of these images, set up your ripple tank as shown in diagram 5 and make a single parallel wave using the roller.

A convex lens has one or two spherical surfaces on it. The middle of the lens is the thickest point and the edges of the lens are the thinnest point of the lens. Convex lenses focus parallel beams of light into one specific and unique point known as the focal point.

Using the concave lens shaped prism, students can see that a parallel wave front behaves the same way as a light wave traveling through a convex lens. The wave front gets bent to focus on one point on the opposite side of the lens as shown in diagram 24.

Diagram 24: Here you can see one parallel wave front striking the convex prism on the left of the lens, and on the right hand side you can see the U shaped curve of the wave front focusing towards one point.

A concave lens is shaped so that the center of the lens is thinner than the outside end of the lenses. When a parallel beam of light strikes a concave lens, the light waves diverge or spread apart from each other on the opposite side.

Diagram 25 shows the same phenomenon is true with a parallel wave front passing over a concave shaped prism. The water is shallow over top of the prism and therefore slows down, causing the wave to bend.

A sample of ray diagrams of the concave lenses is shown in diagram 26

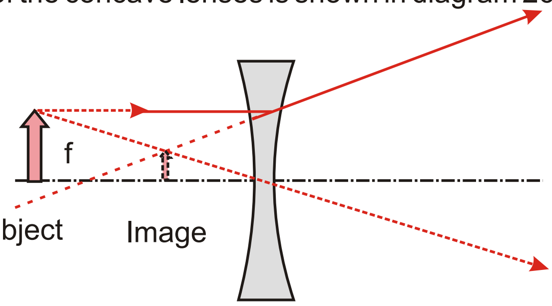


Diagram 26 See how the direction of the parallel water wave front diverges as does a light wave traveling through a concave lens.

A mirror is a reflecting surface for a beam of light. A barrier is a reflecting surface for a water wave. A parallel beam of light wave incident on a concave mirror will be reflected through the focal point. Likewise a parallel wave front will be reflected by a concave barrier as shown in diagram 27.

Diagram 27

A convex barrier will also behave like a convex mirror was a parallel wave front reflects off the barrier. This is shown in diagram 28.

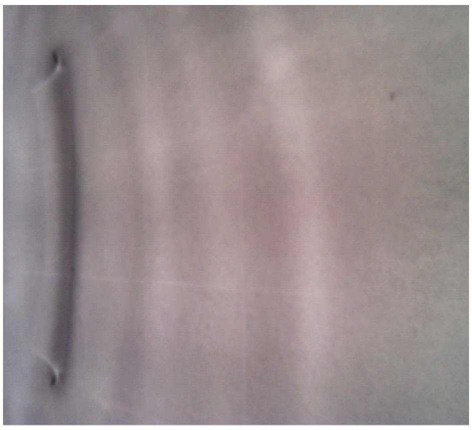


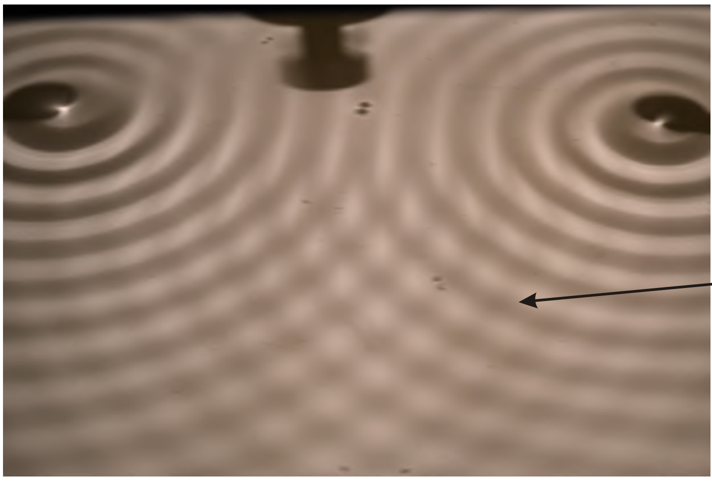
Diagram 28

ACTIVITY 6: YOUNG'S DOUBLE SLIT EXPERIMENT
TEACHER INSTRUCTIONS

In Young's double slit experiment, a series of dark and light spots appear on a screen when coherent light is passed through a double slit. This result was startling for scientist who believed at the time that light behaves as a particle. More detail on this is given in the background section in the beginning of this manual.

Using the wave table students can see the pattern that emerges as two point sources for a wave interfere with one another. In Young's experiment, one can only see a one-dimensional image on the screen. Using a ripple tank, students can see a two dimensional image that can help them to visualize why there are several bright spots instead of just two in Young's double slit experiment.

The interference pattern should look like the image in diagram 29. Increasing the voltage on the lead connected to the rippler will decrease the wavelength of the waves. Also moving the lamp as high up on its support post as possible is useful to get a good image.



You can see the wave pattern nicely portrayed here. Imagine putting a screen across these diamond shapes, you would see a pattern of bright and dark spots.

Diagram 29

Alternatively, you can get a similar pattern by arranging the two large barriers and one small barrier as shown in diagram 30.

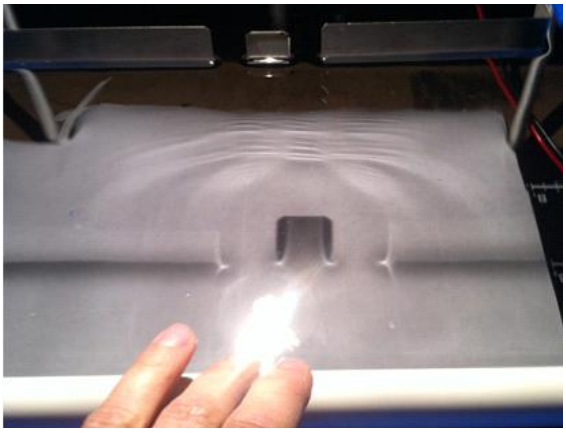


Diagram 30

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