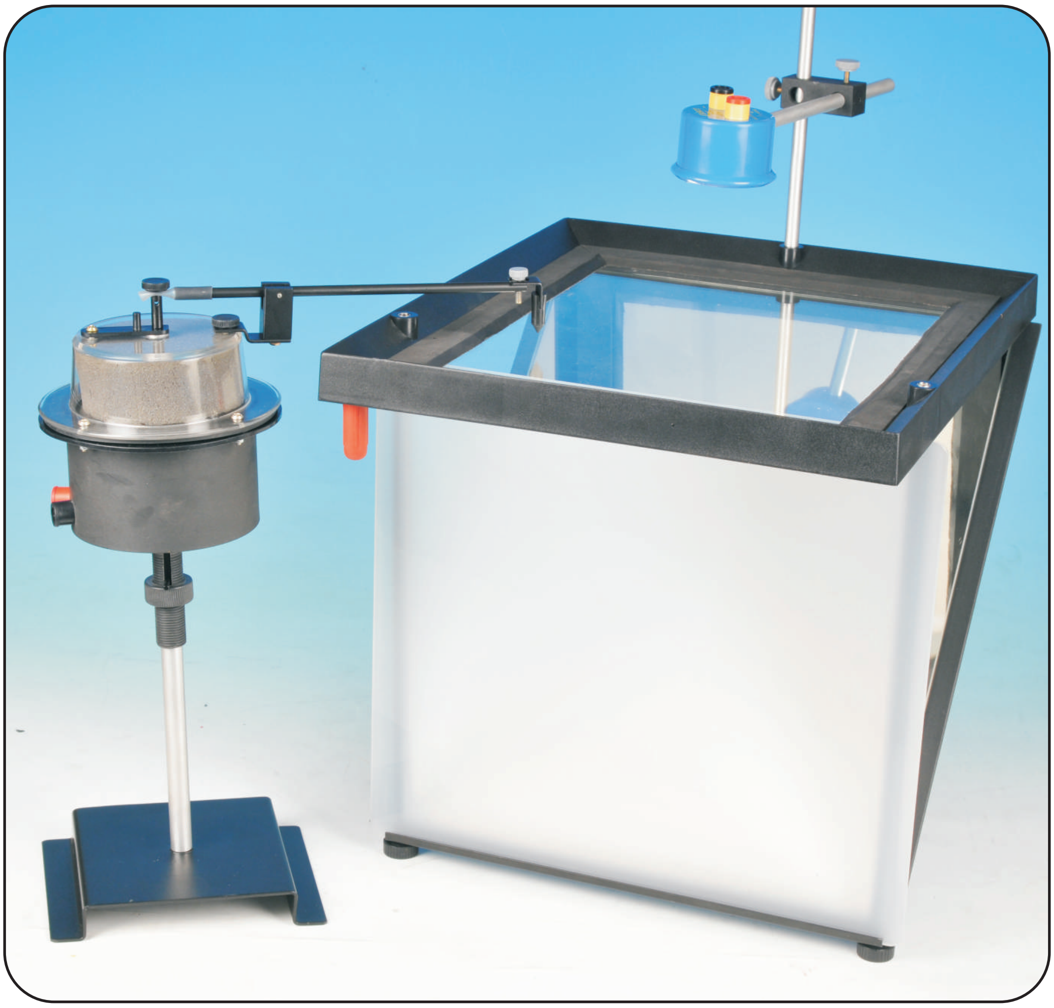
RIPPLE TANK-ADVANCED

CAT NO. PH 0769



Experiment Guide

GENERAL BACK GROUND OR THEORY ON THE EXPERIMENT:

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 four types of waves this wave generator can make. A single circular wave, a two point source wave, plane parallel waves, and a multiple point source wave (similar to a diffraction grating). The frequency of the waves can be adjusted by regulating the motor. The propagation velocity can be changed by adjusting the depth of the water in the tank.

To set up a 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.

REQUIRED COMPONENTS (INCLUDED)

Name of Part	*Quantity*
Ripple Tank 32 x 38 cm	1
Mirror mounted on black backing 33 x 40 cm	1
Frosted plastic screen 33 x 30 cm	1
Red rubber plug	1
Adjustable legs with leveling screws on the bottom	3
Asymmetric metal trough with two screw holes	1
Aluminum rod, 10mm in diameter	1
Rippler Motor	1
Plastic support arm with thumb screw to attach dippers	1
Square ring stand base	1
Aluminum ring stand rod, 18mm diameter	1
Plastic screw-on height adjuster for the motor (comes attached to the 18mm diameter rod)	1
Strobe lamp unit	1
Banana clip wires	4
Wave motor and strobe light power supply (Wave monitor)	1
Concave and convex Perspex plate	1
Rectangular Perspex plate	1
Curved reflector	1
Single point dipper	1
Double point dipper	1
Plane wave dipper	1
Multiple point source dipper	1
Small Barrier	1
Large Barrier	2
Right angle clamp (bosshead clamp)	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Water (distilled or demineralized water is recommended to avoid lime scale build up)	
Bucket or tub to drain water into	1
Soap	1 tsp

RECOMMENDED COMPONENTS (NOT INCLUDED)

Name of Part	*Quantity*
Adjustable DC voltage power supply	1
Lamp that can be adjusted over top of the ripple tank	1
Video camera	1
Graphing software	1
Clear plastic ruler	1
Masking tape	1 roll
Calipers	1

SAFE HANDLING OF APPARATUS:

Make sure that the rubber stopper is securely in place before adding water to the ripple tank.

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.

BREAKABLE WARNING:

Do not use any other voltage source beside the EISCO Wave Monitor to supply power to the strobe light. Make sure to plug the strobe light into the right hand side of the wave motor. Using any other power source could cause the bulb to blow and the lamp to not function.

Handle the mirror and rippler motor with care. Do not drop, hit, strike, or place other apparatus on top of these components as they can damage easily.

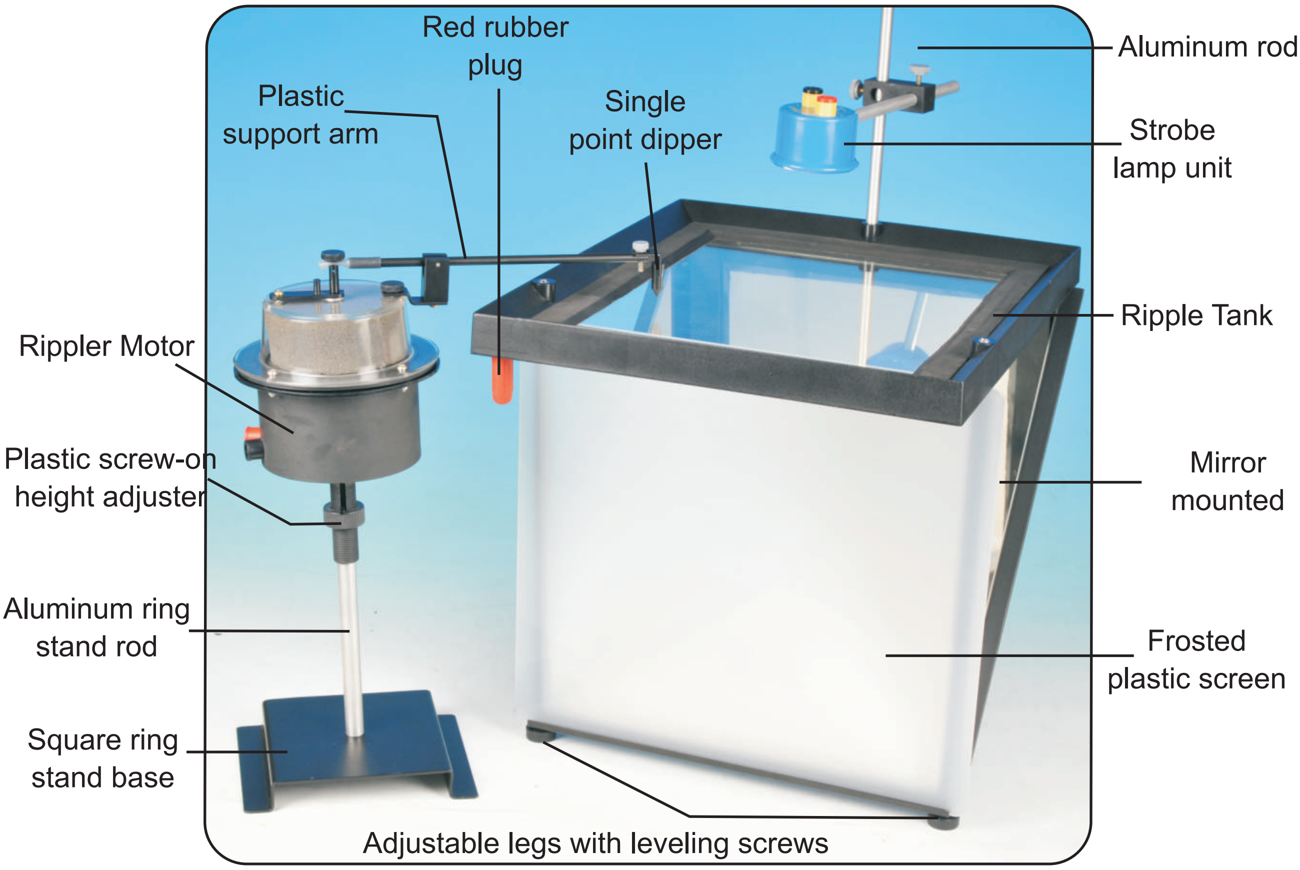
The surface of the frosted screen scratches easily. Lay only on soft smooth surfaces to protect the screen from scratches.

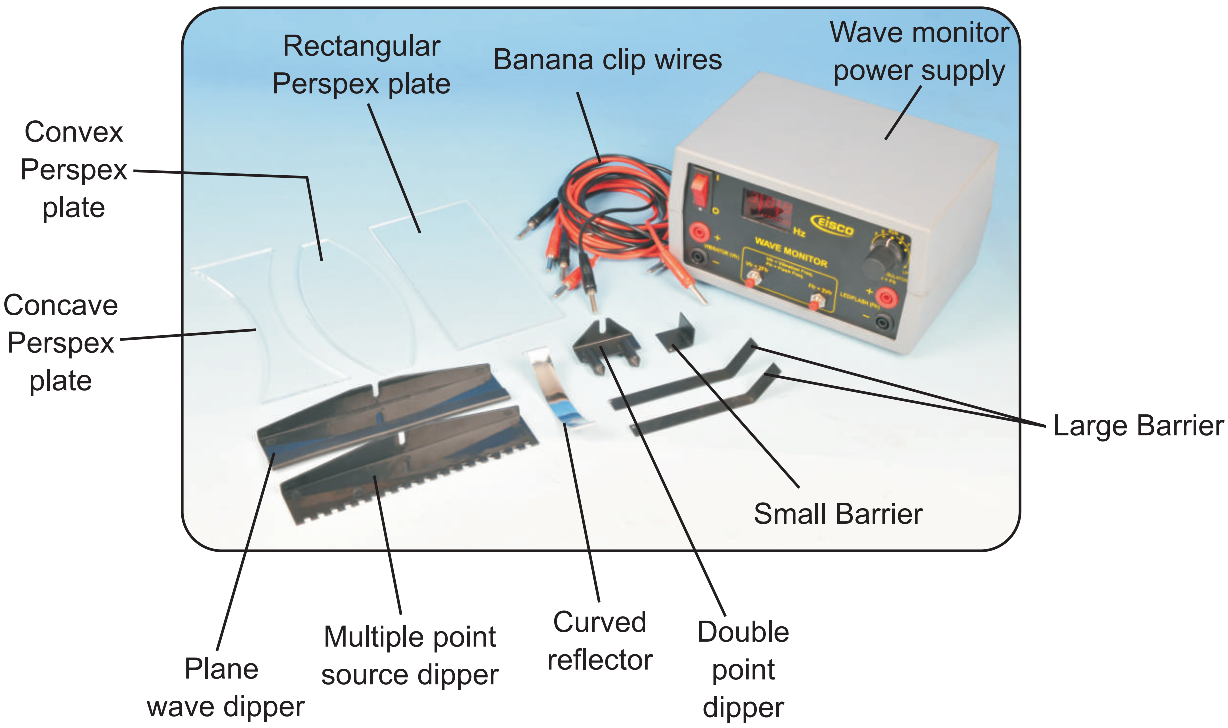
MAINTENANCE REQUIRED:

After using your ripple tank, empty the tank, rinse all parts in use with distilled water 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.

It is recommended that distilled or demineralized water is used to avoid problems with lime scale build up. This can be purchased at most grocery stores in 1 gallon jugs.

DIAGRAM LABELING ALL PARTS:





THEORY ON WAVES :

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.

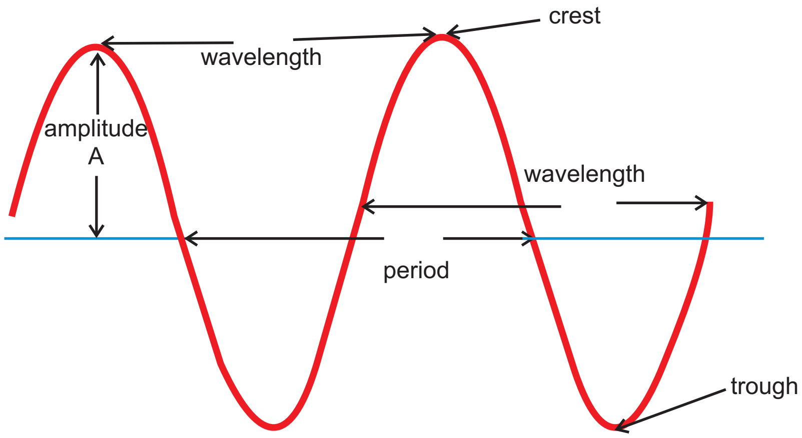


Diagram 1

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 adjacent 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

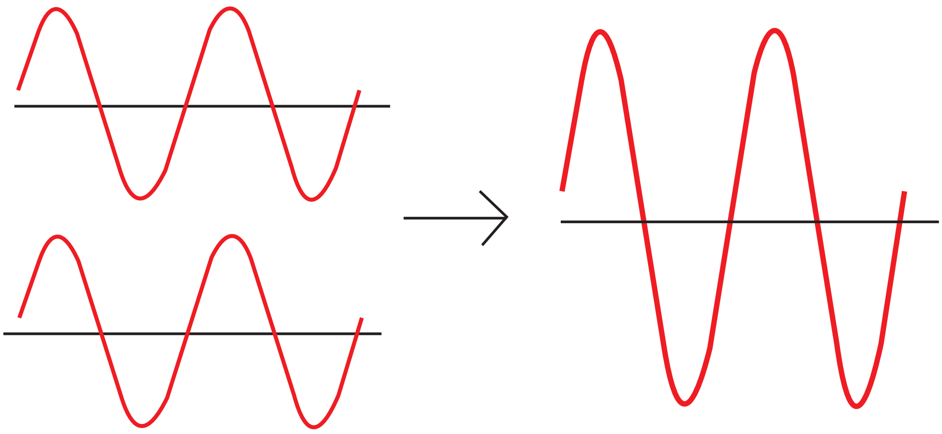
The speed of a wave 'v' is given by the formula

$$v = f$$

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

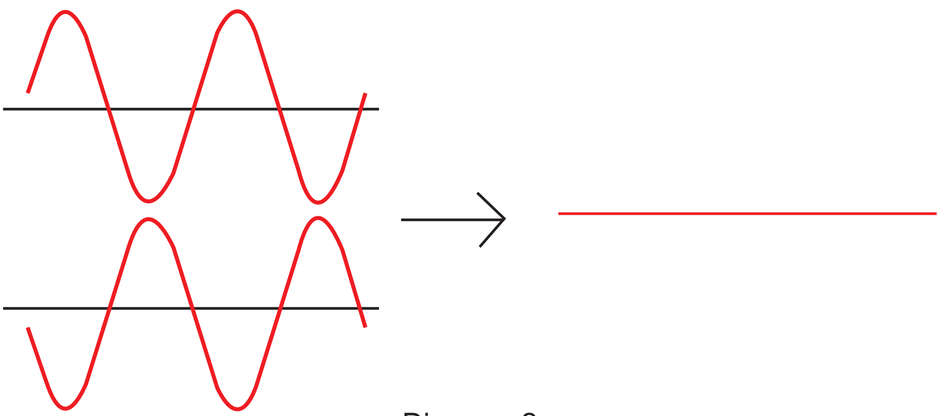
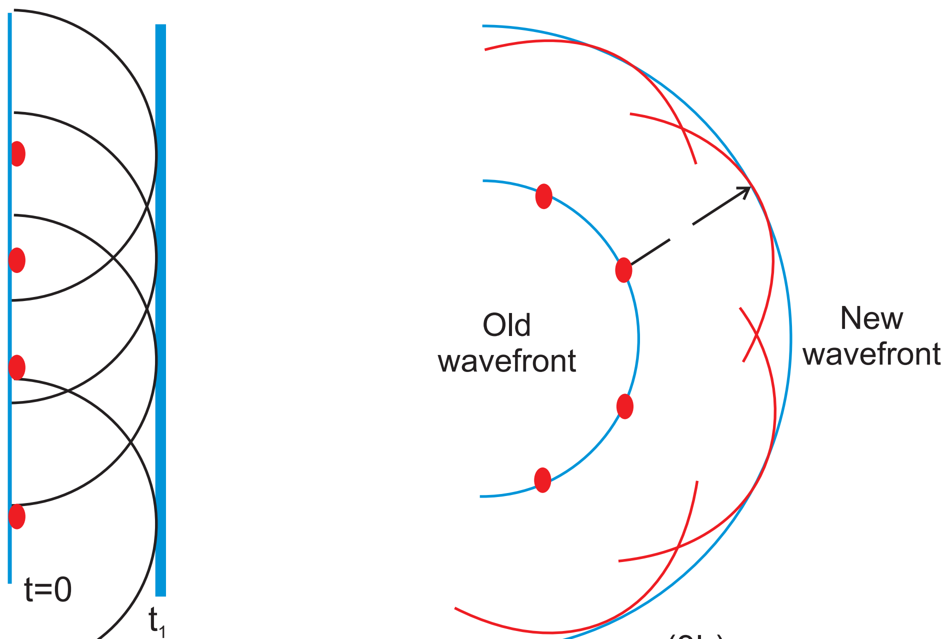


Diagram 2

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.



(3a) (3b)

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 as shown in diagram 3a. In diagram 3b, it is shown that the wave front would be a circle equidistant from the original wave front at time t_o.

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

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.

Young's Double Slit Interference Experiment:

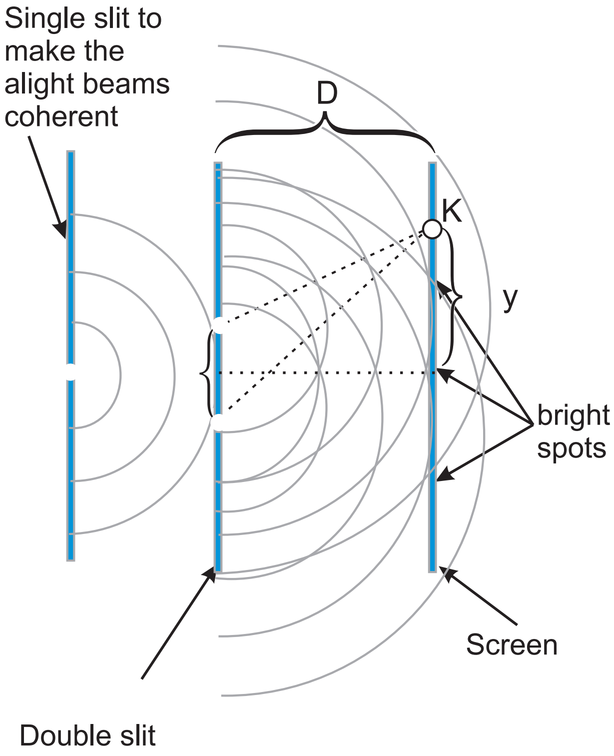
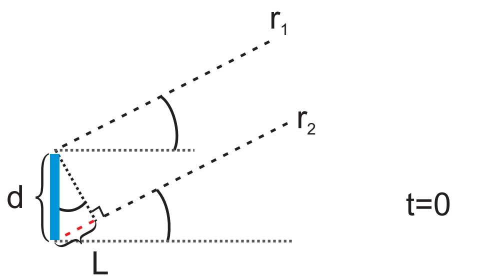


Diagram 4a



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.

BASIC APPARATUS SET UP:

Legs:

Begin assembly of your wave tank by screwing the three metal legs into the screw holes on the underside of the ripple tank. Note that there are screw holes on the top and the bottom of the ripple tank. The foam padded edge is the top of the ripple tank. The legs should be screwed in on the opposite side as shown in diagram 5.

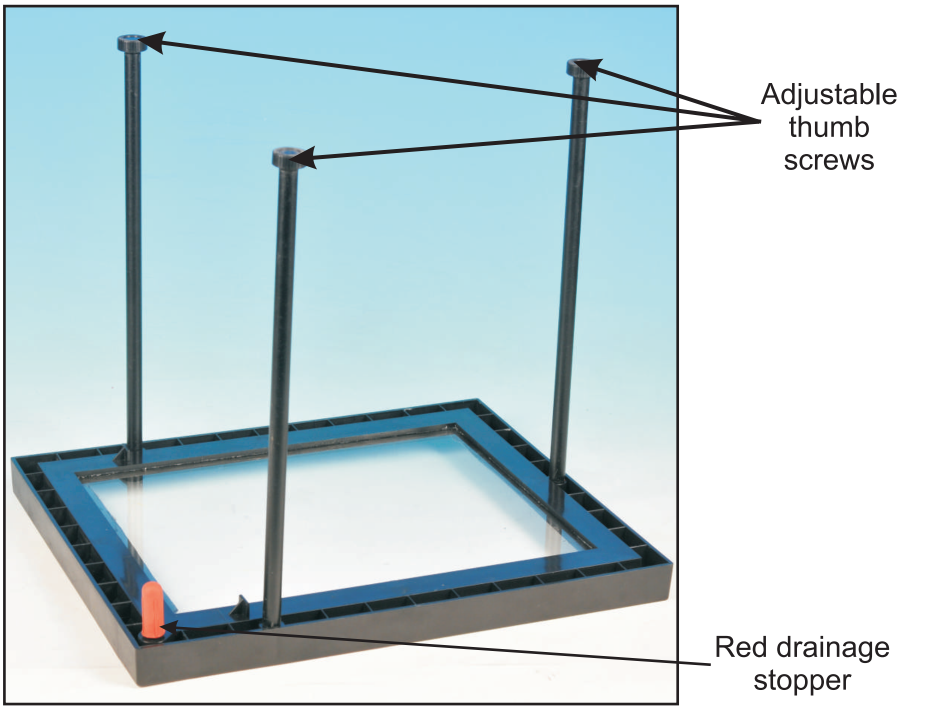


Diagram 5

Add the red rubber stopper over the water drainage hole in one corner of the ripple tank. The stopper just pushes over the drain as shown in diagram 5 above.

Metal Trough:

Remove the adjustable thumb screws at the base of the legs from the two legs closest to the red rubber drainage stopper. Position the metal trough so that the two holes in the trough are over the ends of the legs. There is an obtuse angle on the trough and an 90 degree angle. The obtuse angle should face inward towards the middle of the ripple tank, and the right angle should face outward towards the outside of the trough as shown in diagram 6.

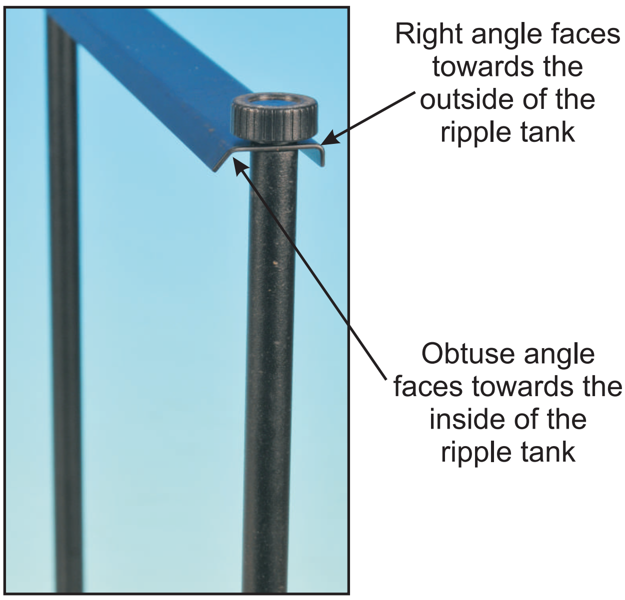


Diagram 6

Secure the trough in place by attaching the thumbscrews through the holes in the trough as shown in diagram 6.

Mirror:

Carefully take the mirror and slide it into the legs of the ripple tank at a 45 degree angle as shown in diagram 7. The surface of the mirror should be facing the ripple tank and the edge of the mirror should be supported by the trough.

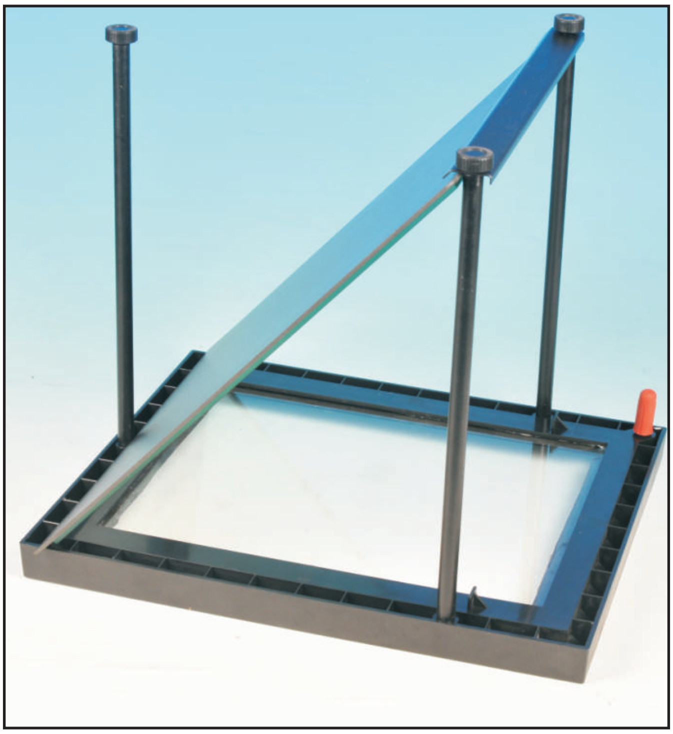


Diagram 7

Flip the table over so that the ripple tank is supported by the legs.

Making the Ripple Tank Level:

Unscrew or screw in the black plastic ends of the feet to adjust the table and make the ripple tank 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.

Viewing Screen:

Slide the viewing screen into place. It should be supported by the right angle lip of the metal trough as well as secured into place by the plastic lip on the underside of the ripple tank as shown in diagram 8.

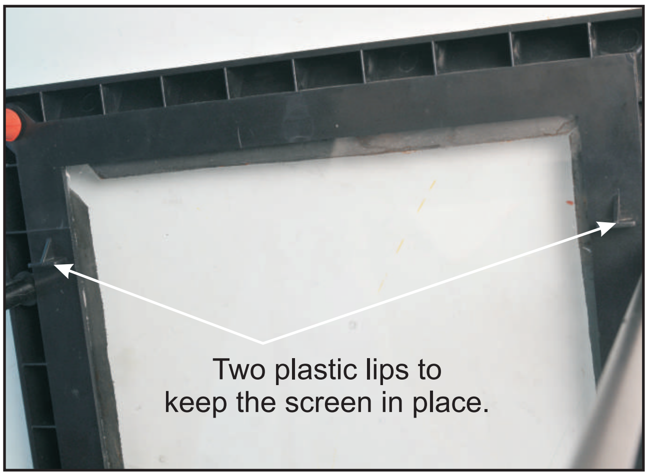


Diagram 8

Supports:

Now that your table is level, add the arm support for the strobe lamp. As shown in diagram 9. Use the right angle (boss head) clamp to secure the lamp into position and add the two banana clip leads from the top of the lamp to the included power supply. Be sure to plug the lamp into the side of the power supply designated for the lamp. It is very important that only this voltage and current gets used for this lamp. Any other voltage can ruin the lamp and blow the bulb.

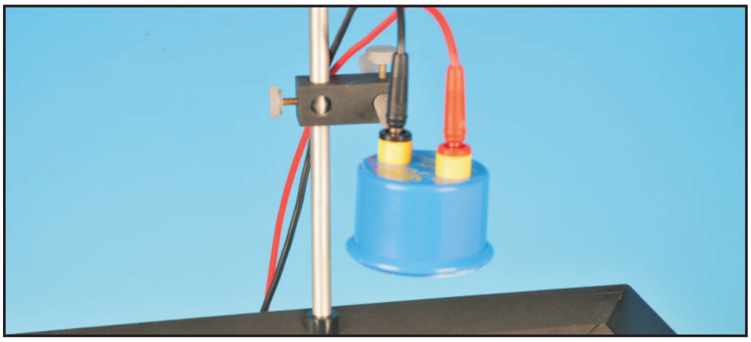


Diagram 9

Plug in the leads from the strobe light to the side of the included power supply entitled LED/FLASH.

The Rippler Motor:

Screw the larger diameter aluminum post into the square base. The plastic height adjustor comes already attached to the aluminum post, but if not, screw this on as well, as shown in diagram 10.

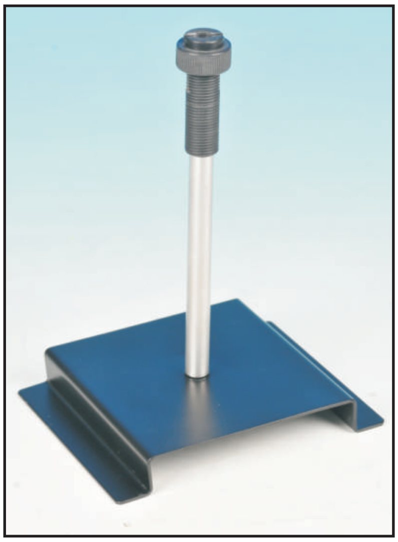


Diagram 10

Diagram 11

Screw the vibrator motor on to the top of the base as shown in diagram 11. The black screw can be turned clockwise or counter clockwise to adjust the height of the entire vibrator motor.

Add the plastic support arm to the top of the rippler motor and screw into place using the attached thumb screws. One thumb screw will go through the clear tubing attached to the top of the rippler motor as shown in diagram 12.

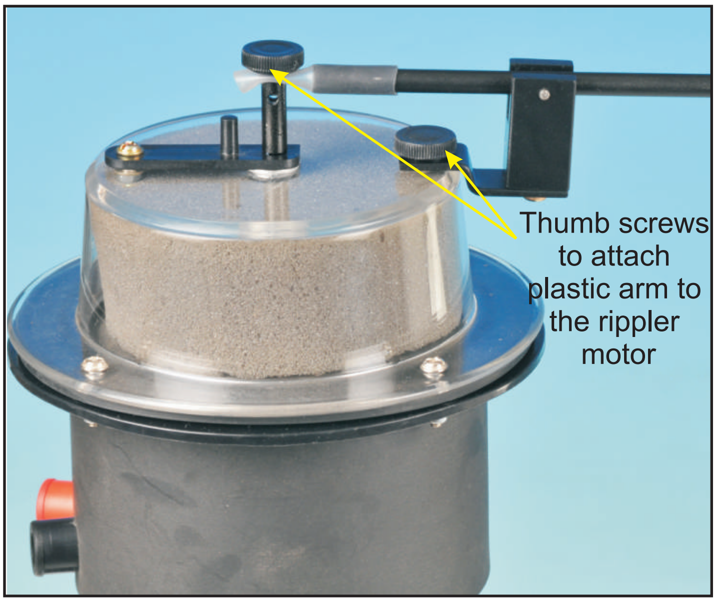


Diagram 12

There are four different dippers that can be attached to the support arm to create different types of waves: a single point wave, a double point wave, a plane wave, and a multi-point source wave. Decide which type of waves you wish to produce and attach the dipper to the end of the support rod by loosening and adjusting the thumb screw at the end of the support arm as shown in diagram 13.

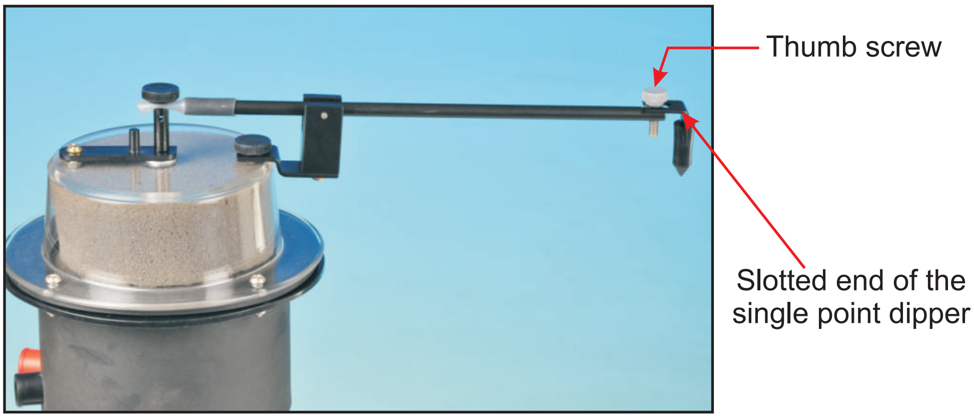


Diagram 13

To add the dipper, loosen the thumb screw, slide the slotted end of the dipper around the thumb screw and tighten the thumbscrew to hold the dipper in place.

Lamp Adjustment:

Be aware that the reflection seen on the screen of 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. 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 viewing screen. 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 ruler can be used as well.

Place a drop of dish soap on your index finger and run your finger around the edge of the foam dampening pads. This will decrease the surface tension of the water and keep the depth of the water more constant.

Placing a very small amount of soap on any barriers or prisms you use will also help obtain clearer and cleaner results.

Taking Measurements:

The image of the waves on the screen will be magnified. The position of the lamp determines how much magnification occurs. To take accurate measurements it is helpful to tape a clear ruler to the underside of the ripple tank as shown in diagram 14. Make sure the ruler shows on the viewing screen.

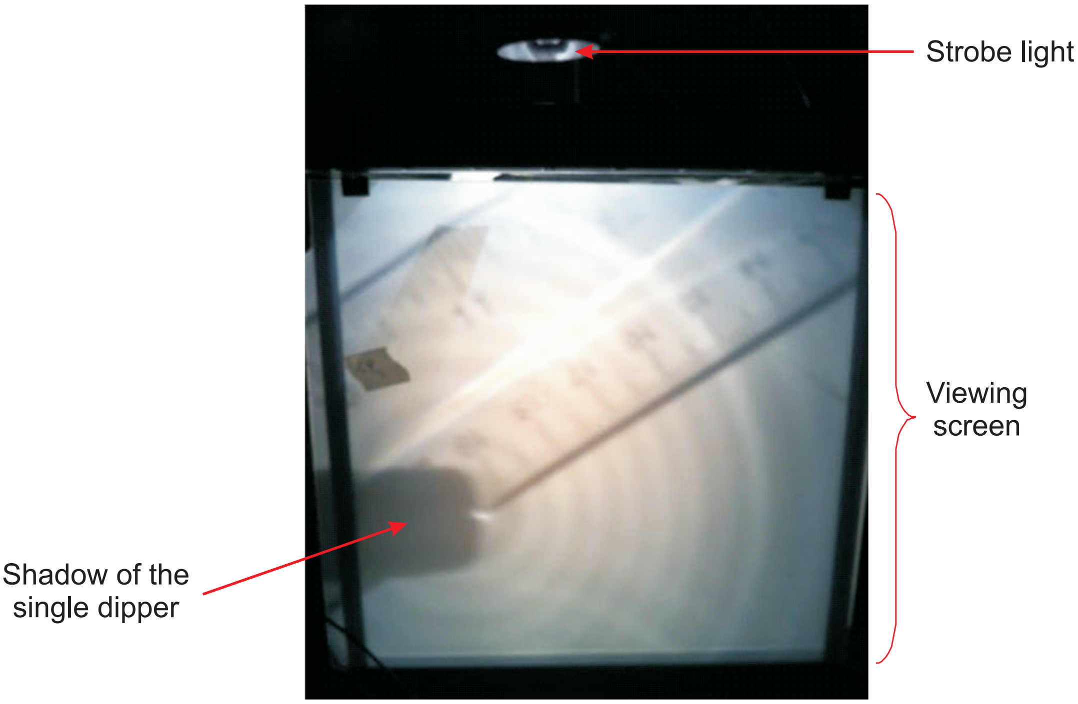


Diagram 14 Notice that each wave corresponds with 0.50 cm, which means the wavelength of this wave is 0.50cm

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.

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.

MAKING WAVES USING THE WAVE GENERATOR:

Diagram 15: Complete set up of apparatus, including a catch bucket.

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.

Set up the ripple tank as shown in diagram 15. You will need to connect the rippler motor to the power supply using the included banana plug wires. Make sure that the leads are in the side of the power supply labeled: VIBRATOR.

Adjust the height of the dipper until it just touches the surface of the water. The height of the rippler arm can be adjusted by turning the post in the height adjuster as shown in diagram 11.

Plug the power supply into the wall and turn the power supply on by flipping the switch in diagram 16.

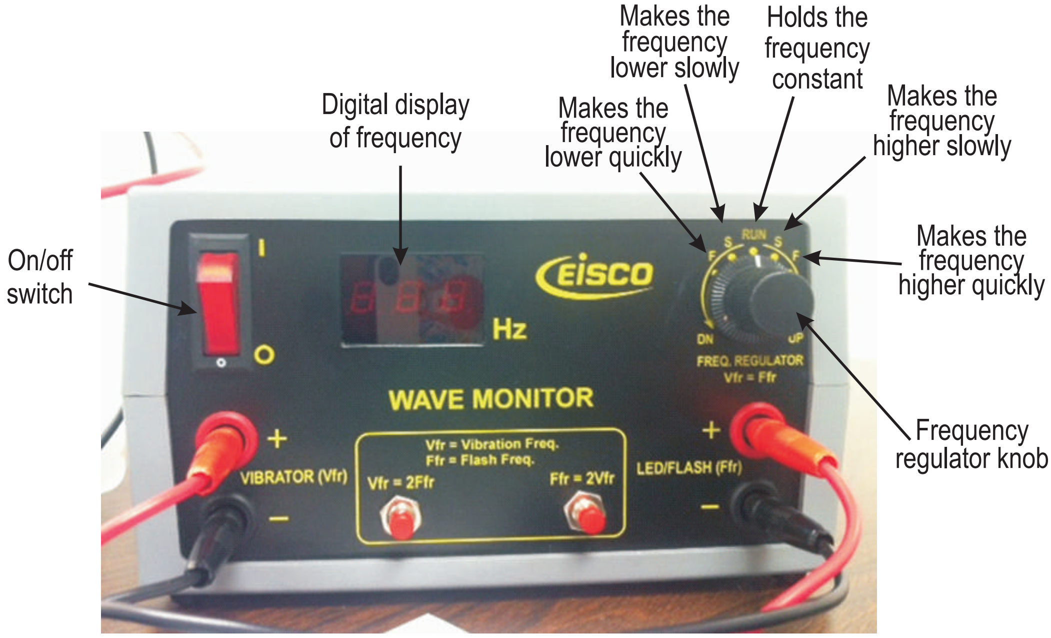


Diagram 16

The power supply will turn on with a frequency of 1 Hz, no matter which frequency the power supply was running when it was last turned off.

1.0 Hz will be displayed in the digital display box shown in diagram 15. The lowest setting for the frequency is 0.5 Hz. You should notice the strobe light as well as the dipper flash/dip, once every one second.

If you want the strobe light to flash twice as fast as the frequency of the vibrator, then you can press the red button labeled Ffr = 2Vfr.

To make the frequency of the dipper twice the frequency of the strobe light, press the red button labeled Vfr=2Ffr.

The frequency regulator adjusts the frequency of the strobe light and the vibrator simultaneously. To keep the vibrator at a constant frequency, adjust the knob to point at the word “run”.

Since the lowest frequency is 0.50 Hz, turning the knob counterclockwise will not change the frequency past this point. To increase the frequency turn the knob clockwise, once you are at the frequency you wish, turn the knob back to the word “run” and the power supply will hold the frequency constant. If you want the frequency to increase quickly, move the knob all the way counter clockwise. The frequency will stop increasing when it has reached its maximum value of 100 Hz.

ACTIVITY 1: THE RELATIONSHIP BETWEEN PERIOD AND FREQUENCY TEACHER ANSWERS

QUESTION: What is the relationship between frequency and wavelength in a ripple tank?

HYPOTHESIS: (typical student responses: "As the frequency increases, so does the wavelength." OR "The wavelength and frequency are inversely proportional to one another.")

SET UP PROCEDURE:

1. Set up the apparatus as shown in diagram 17 using the plane wave dipper.
2. Tape a ruler to the underside of the ripple tank so that the ruler shows up on the viewing screen as shown in diagram 17.

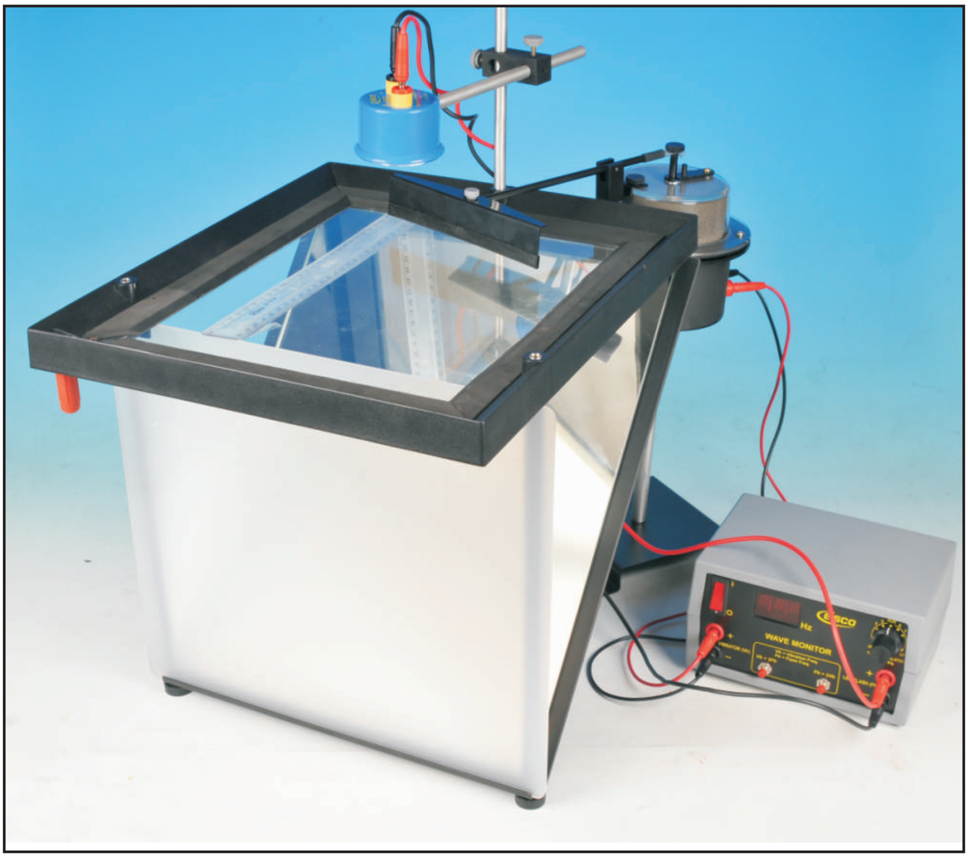


Diagram 17

3. Adjust your lamp so that the shadow of the dipper shows up on the viewing screen. If the lamp is down low, closer to the dipper, the magnification of the light source will be large, if the lamp is higher up, the magnification will be smaller. Also, it is possible to see a double image on the screen as shown in diagram 18. If this happens, tape a piece of paper around the strobe light to serve as a shade or move the lamp higher.

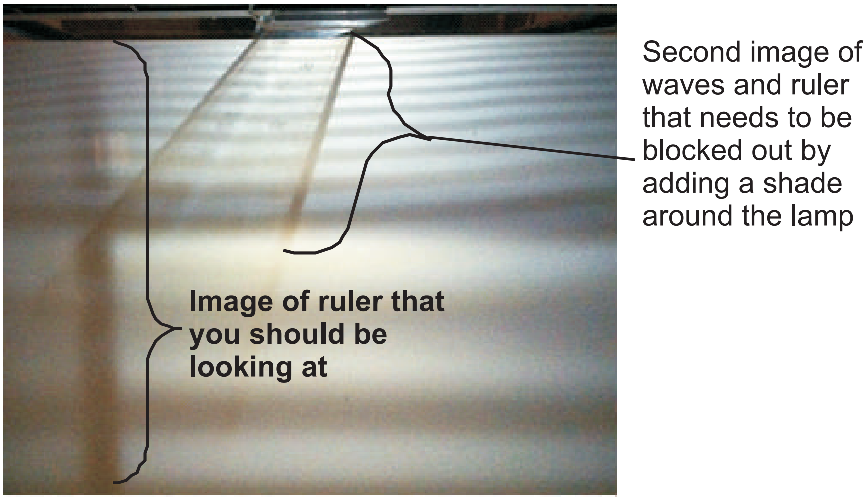


Diagram 18

4. It is very difficult to see the projected image of the ruler when the wavelength of the waves are small, so it is necessary to use a ruler taped to the projection screen to measure the wavelength of the waves.

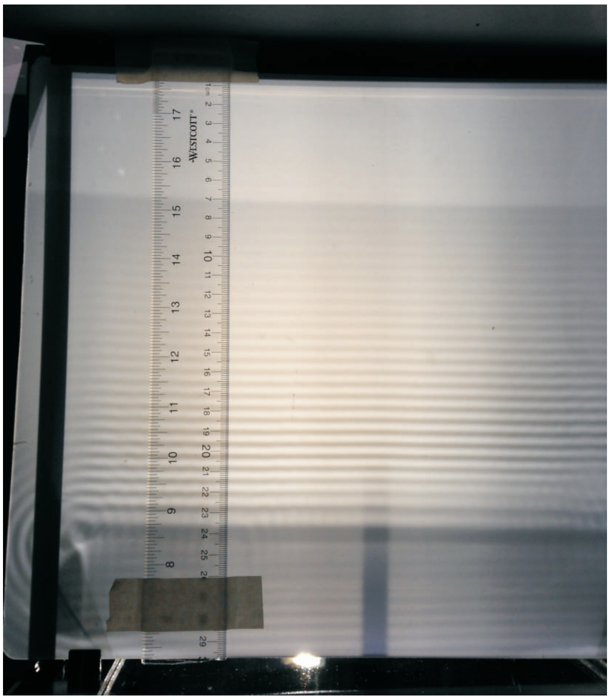


Diagram 19

5. Since the image of the waves is magnified, in order to get the actual wavelength of the waves, a magnification scale is needed. To obtain how much the measure of the wavelength should be multiplied by to get the actual wavelength tape a ruler next to the projected image of the ruler as shown in diagram 20.

6. Set the vibrator to 1.0 Hz, which will illuminate the screen long enough to get a ratio of cm of the projected image verses cm measured on the screen.

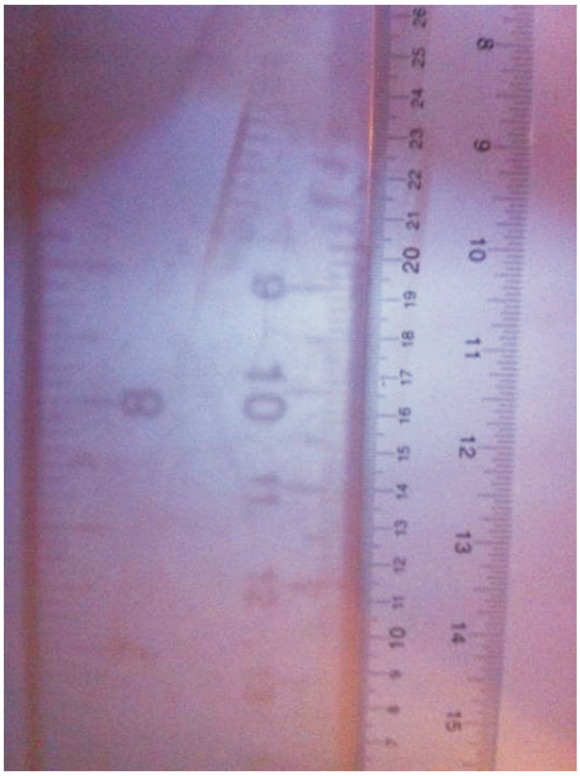


Diagram 20

7. Calculate the magnification ratio using the following method:

$$\frac{\text{Length of projected image}}{\text{Length of image on screen}} = \frac{\text{actual wavelength}}{\text{wavelength measured on screen}}$$

$$\frac{(13.0\text{cm} - 9.0\text{ cm})}{(19.3\text{cm} - 8.8\text{ cm})} = \frac{X}{\text{value measured during lab}}$$

0.381 * value measured during lab = X

Note: It is up to the teacher if they want the students to do the set up and calculation of the magnification for each wave table themselves, or if they want to have these values available to the students. The student instructions are written assuming that the students already have the magnification value. It is also important to note that changing the position of the lamp will change the magnification value.

INVESTIGATION PROCEDURE:

1. Turn the black plastic screw under the rippler motor clockwise or counterclockwise to adjust the height of the plane wave dipper so that it just barely touches the surface of the water.
2. Measure the depth of the water using a caliper and record this in your data table.
3. Find the magnification value and record this in your data table as well.

4. Turn the power supply on and turn the dial all the way to the right until the digital display reads 100 Hz.
5. Place a ruler perpendicular to the wave fronts on the screen and measure the distance of five wave fronts (six back to back dark spots).
6. Record your wavelength on your data table.
7. Adjust the frequency of the vibrator motor down about 10 Hz and repeat steps 5 & 6 until you have at least 6 data points.

DATA:

Teacher's Note: The best data is taken from the middle of the screen, directly under the stroboscope. The magnification changes from the middle of the screen to the outside of the screen because the distance the light travels is longer from the stroboscope to the edge of the ripple tank than it is from the stroboscope to the middle of the screen.

Frequency (Hz)	Position of the first wave front (cm)	Position of the ending wave front (cm)	The no. of wave-lengths counted	The measured wave-length of one wave (cm)	The measured wave-length in (m)	The depth of the water (mm)	Velocity (m/s)	1/ frequency (1/Hz)	Actual wave-length (with magnifi-cation taken out)
99.7	18.4	14.8	5	0.72	0.0072	2.7	0.273	0.0100	0.00274
90.2	17.9	14.1	5	0.76	0.0076	2.7	0.261	0.0111	0.00290
82.7	16.7	12.7	5	0.80	0.0080	2.7	0.252	0.0121	0.00305
75.4	17.1	12.8	5	0.86	0.0086	2.7	0.247	0.0133	0.00328
66.3	15.5	10.8	5	0.94	0.0094	2.7	0.237	0.0151	0.00358
57.4	15.8	10.7	5	1.02	0.0102	2.7	0.223	0.0174	0.00389
48.3	14.8	9.2	5	1.12	0.0112	2.7	0.206	0.0207	0.00427

· *The magnification used for this experiment is the same as calculated in diagram 20 . The measured wavelength times 0.381 gives the actual wavelength*

DATA ANALYSIS:

1. Make a column on your data table and calculate the wavelength of the waves in meters, at each given frequency. Enter that value into your column on your data table.

2. Show how you calculated the measured wavelength of the wave with one example in the space provided below.

   For the 90.2 Hz trial, the first wave front was at 17.9cm on the ruler and the last wave front was at 14.1cm. 17.9cm-14.1cm = 3.8 cm. Since this was the length of five waves, I divided the 3.8cm/5 = 0.76 cm or 0.0076 m.

3. Make a column on you data table showing the actual wavelength of the waves by using your magnification constant specific to your lab set up. Show one example of how you got your actual wavelength below.

   *0.381 * measured wavelength = actual wavelength*

   For 90.2 Hz, my measured wavelength was 0.0076 m, therefore

   *0.381 * 0.0076 m = 0.00290 m*

4. Make a column on your data table showing the velocity of the wave at each given frequency. Show a sample calculation below showing formula used and substitution with units.

   *Velocity = frequency * wavelength*

   *Velocity = 90.2 Hz * 0.00290 m = 0.26 m/s*

5. Make a graph of frequency vs. wavelength and attach it to this lab where frequency is on your x-axis and wavelength is on your y-axis. Using your graph state the relationship between frequency and wavelength.

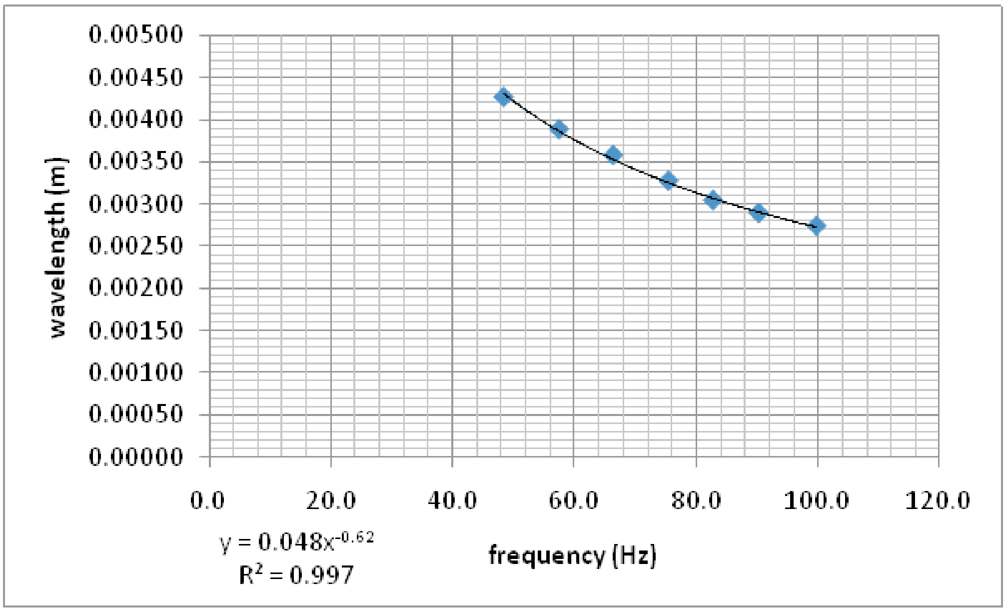


Diagram 21

*The frequency and wavelength are inversely proportional to one another. According to the formula velocity = frequency * wavelength, the best fit line should be in the form $y = m\,x^{-1}$, as you can see, the best fit line has a power of -0.6, nearly negative one.*

6. Plot 1/frequency vs. wavelength and find the best fit line and the slope of the line. Explain in the space provided below what the significance of the slope is.

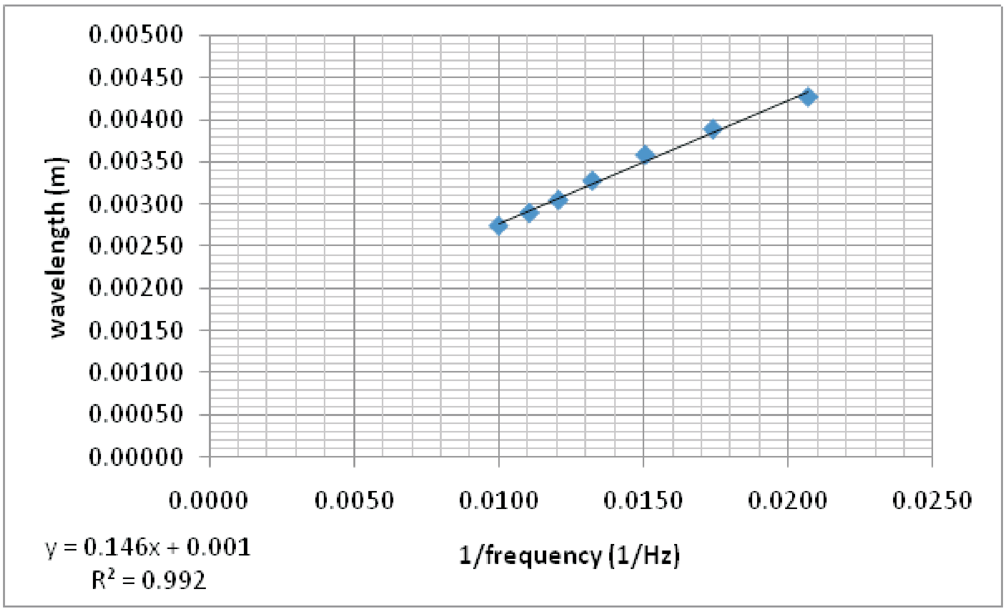


Diagram 22

*Since velocity equals frequency time wavelength, then rearranging the formula, wavelength = velocity * (1/frequency), y = m/x, therefore the slope "m" is the velocity. As you can see the slope is 0.146 m/s which is the speed of the wave.*

CONCLUSION:

Write a conclusion that answers your original question. Use data from your lab (the shape of your graph, numbers from your data table etc.) to justify your answer. Was your hypothesis correct or incorrect? What kinds of things happened during your lab that may have affected your results, what could you do next time in order to get better experimental results?

As the frequency decreases, the wavelength increases. They are inversely proportional to one another as shown in the graph of wavelength vs. frequency, the curved line indicates an inverse relationship. My original hypothesis was that they were directly proportional and that is incorrect. As the wavelength and the frequency change, the speed stays nearly constant. I noticed that the wavelength appears to get shorter further away from the center of the screen the waves get. This is due to the angle that the light source makes with the ripple tank. Some ways of minimizing this effect include placing the lamp up higher, so the angle is smaller and only taking values from the center of the screen. The position of my ruler did not change throughout the experiment, but the reading that I took moved further away from the center of the screen. For example, the first values that I took were between 18.4cm and 14.8cm, and the last values I took were between 14.8cm and 9.2cm on the ruler. This gradual shift of taking my readings further and further from the center resulted in my speed calculations to be gradually slower. It is important to note that frequency and wavelength are related by the equation velocity equals frequency times wavelength. As the frequency and wavelength change, the velocity of the wave should remain constant, as it nearly did.

Name:____ Date:________________

ACTIVITY 1: THE RELATIONSHIP OF PERIOD AND FREQUENCY

QUESTION: What is the relationship between frequency and wavelength of a wave train in a ripple tank?

HYPOTHESIS:

____

____

PROCEDURE:

1. Turn the black plastic screw under the rippler motor clockwise or counterclockwise to adjust the height of the plane wave dipper so that it just barely touches the surface of the water.
2. Measure the depth of the water using a caliper and record this in your data table.
3. Find the magnification value and record this in your data table as well.
4. Turn the power supply on and turn the dial all the way to the right until the digital display reads 100 Hz.
5. Place a ruler perpendicular to the wave fronts on the screen and measure the distance of five wave fronts (six back to back dark spots).
6. Record your wavelength on your data table.
7. Adjust the frequency of the vibrator motor down about 10 Hz and repeat steps 5 & 6 until you have at least 6 data points.

DATA: Magnification __________________

Frequency (Hz)	Position of the first wave front (cm)	Position of the ending wave front (cm)	The no. of wave-lengths counted	The measured wave-length of one wave (cm)	The measured wave-length in (m)	The depth of the water (mm)	Velocity (m/s)	1/ frequency (1/Hz)	Actual wave-length (with magnifi-cation taken out)

DATA ANALYSIS:

1. Make a column on your data table and calculate the wavelength of the waves in meters, at each given frequency. Enter that value into your column on your data table.

2. Show how you calculated the measured wavelength of the wave with one example in the space provided below.

3. Make a column on you data table showing the actual wavelength of the waves by using your magnification constant specific to your lab set up. Show one example of how you got your actual wavelength below.

4. Make a column on your data table showing the velocity of the wave at each given frequency. Show a sample calculation below showing formula used and substitution with units.

5. Make a graph of frequency vs. wavelength and attach it to this lab where frequency is on your x-axis and wavelength is on your y-axis. Using your graph state the relationship between frequency and wavelength.

6. Plot 1/frequency vs. wavelength and find the best fit line and the slope of the line. Explain in the space provided below what the significance of the slope is.

CONCLUSION:

Write a conclusion that answers your original question. Use data from your lab (the shape of your graph, numbers from your data table etc.) to justify your answer. Was your hypothesis correct or incorrect? What kinds of things happened during your lab that may have affected your results, what could you do next time in order to get better experimental results?

ACTIVITY 2A: 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 15, your teacher may have already done this for you.
2. Tape a clear ruler to the underside of the wave table so that the measuring side of the ruler goes through the point where the single point dipper touches the water as shown in diagram 14.
3. Tape a second ruler to the viewing screen so that the part of the ruler that measure cm is aligned on both sides as shown in diagram 20.
4. Use these two rulers to figure out the magnification of the waves on the viewing screen by recording two corresponding points the top and bottom of the viewing screen, and then using a ratio to figure out the magnification.
5. Add about 2 mm of water to the table.
6. Measure the depth with a caliper.
7. Record the depth of the water in your data table.
8. Turn the vibrator motor on to about 50 Hz. Record the frequency.
9. Measure the length between the first five waves emitted from the dipper and record this value in your data table.
10. Add one more mm of water to the table and repeat steps 4-7 until the depth of the water is about 8mm deep.

DATA:

Average Depth of water (mm)	Top wave at: (cm)	Bottom wave at: (cm)	# of wave-lengths	Fre-quency (Hz)	Measured wave-length (cm)	Magnifi-cation ratio	Actual wave-length (cm)	Speed (cm/s)
8.0	22.3	15.3	8.0	55.0	0.875	0.458716	0.401	22.1
7.0	22.6	15.7	8.0	55.0	0.863	0.458716	0.396	21.8
6.3	21.6	15.6	7.0	55.0	0.857	0.458716	0.393	21.6
5.5	22.7	15.0	9.0	55.0	0.856	0.458716	0.392	21.6
5.0	21.7	15.8	7.0	55.0	0.843	0.458716	0.387	21.3
4.1	22.6	15.8	8.0	55.0	0.850	0.458716	0.39	21.4
3.1	22.6	15.9	8.0	55.0	0.838	0.458716	0.384	21.1
2.1	22.7	15.4	9.0	55.0	0.811	0.458716	0.372	20.5

Magnification: 5.0cm to 10.0cm on the ripple tank = 23.7cm to 12.8cm on the viewing screen.

DATA ANALYSIS:

1. What is the magnification of your viewing screen? Show all work below including formula and substitution with units.

$$\frac{\text{distance from point A to B on projected ruler}}{\text{distance from point A to B on viewing screen}} = \frac{\text{actual wavelength}}{\text{measured wavelength}}$$

$$\frac{(10.0\text{ cm} - 5.0\text{ cm})}{(23.7\text{cm} - 12.8\text{ cm})} = \frac{\text{actual wavelength}}{\text{measured wavelength}}$$

$$\frac{5.0\text{cm* measured wavelength}}{10.9\text{cm}} = \text{actual wavelength}$$

0.459 * measured wavelength = actual wavelength

2. Show one sample calculation on how you can calculate the measured wavelength of the wave. Add a column titled "measured wavelength" to your data table and fill in those values.

$$\frac{\textit{(Position of first wave – position of second wave)}}{\textit{Number of wavelengths}} = \textit{measured wavelength}$$

$$\frac{(22.3cm - 15.3cm)}{8} = 0.875cm$$

3. Show one sample calculation of how you can get the actual wavelength from the measured wavelength. Add a column titled "actual wavelength" to your data table and fill in those values.

*Actual wavelength = 0.459 * measured wavelength =0.459 * 0.875cm = 0.401 cm*

4. Show one sample calculation of how you can get the speed of the wave. Show formula and substitution with units. Add a column titled "speed of the wave" to your data table and fill in those values.

*Velocity = frequency * wavelength = 55.0 Hz * 0.401 cm = 22.1 cm/s*

5. Make a graph of speed of the wave vs. depth of the water and attach that graph to this lab.

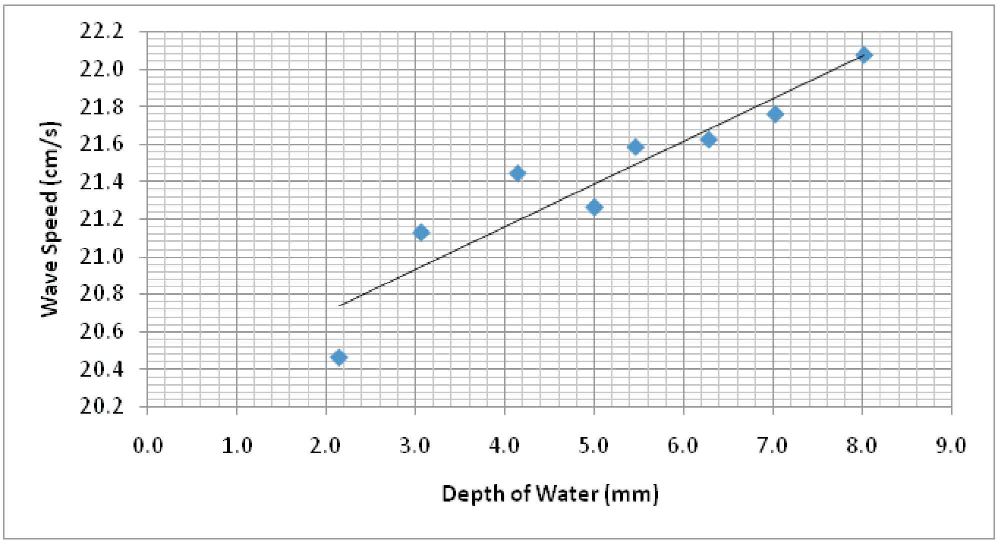


Diagram 23

CONCLUSION:

Answer your original question and support your answer with evidence from your experiment. Where you able to answer your question? Did anything happen during your experiment that may have affected your results?

As the depth of the water increases, the speed of the wave increases, but only very slightly. As you can see from my graph above, at a depth of 2.0mm, the speed of the wave is around 20.7 cm/s according to my best fit line. At around 7.0mm of water depth, the speed of the wave has only increased to around 21.8 cm/s. This value is just barely significant. The depth of my water was accurate to +/- 0.2mm, and the length of the wave was accurate to only two significant figures. This is why the data points on my graph are often far from my best fit line. If I were to round to the nearest 1's place for my speed and to plot those values, there is hardly a detectable increase in speed. Our lab group noticed that toward the end of our lab, it was difficult to drain the water out because the far back corner of the water table was lower than the right front corner where the drain was. This leads me to believe that the table was not level and therefore the depth of the water was not constant. This would change our results because the wave would travel faster toward the back of our wave table, and then slow down as the water became shallower towards the front of our wavetable.

Name:____ Date:______________

ACTIVITY 2A: 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 wave table as shown in diagram 15, your teacher may have already done this for you.

Diagram 15

2. Tape a clear ruler to the underside of the wave table so that the measuring side of the ruler goes through the point where the single point dipper touches the water as shown in diagram 14.

Diagram 14

3. Tape a second ruler to the viewing screen so that the part of the ruler that measure cm is aligned on both sides as shown in diagram 20.

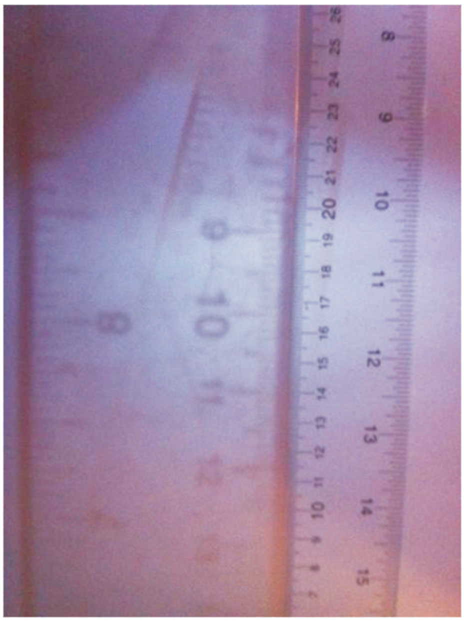


Diagram 20

4. Use these two rulers to figure out the magnification of the waves on the viewing screen by recording two corresponding points the top and bottom of the viewing screen, and then using a ratio to figure out the magnification.
5. Add about 2 mm of water to the table.
6. Measure the depth with a caliper.
7. Record the depth of the water in your data table.

8. Turn the vibrator motor on to about 50 Hz. Record the frequency.
9. Measure the length between the first and last of five waves emitted from the dipper and record this value in your data table. (The distance between six consecutive dark or bright spots.)
10. Add one more mm of water to the table and repeat steps 4-7 until the depth of the water is about 8mm deep.

DATA:

Average Depth of water (mm)	Top wave at: (cm)	Bottom wave at: (cm)	# of wave-lengths	Fre-quen-cy (Hz)	Measured wave-length (cm)	Magnifi-cation ratio	Actual wave-length (cm)	Speed (cm/s)

MAGNIFICATION:

DATA ANALYSIS:

1. What is the magnification of your viewing screen? Show all work below including formula and substitution with units.

2. Show one sample calculation on how you can calculate the measured wavelength of the wave. Add a column titled “measured wavelength” to your data table and fill in those values.

3. Show one sample calculation of how you can get the actual wavelength from the measured wavelength. Add a column titled “actual wavelength” to your data table and fill in those values.

4. Show one sample calculation of how you can get the speed of the wave. Show formula and substitution with units. Add a column titled “speed of the wave” to your data table and fill in those values.

5. Make a graph of speed of the wave vs. depth of the water and attach that graph to this lab.

CONCLUSION:

Answer your original question and support your answer with evidence from your experiment. Where you able to answer your question? Did anything happen during your experiment that may have affected your results?

ACTIVITY 2B: HOW DOES WATER DEPTH CHANGE WAVE SPEED?

TEACHER ANSWERS:

Requires a video camera and a lamp that can be turned on without a strobe effect.

1. Set up your wave table as shown in diagram 15a on page 34. Diagram 15a is the same diagram 15 except that the strobe lamp is replaced with a constant light source. Your teacher may have already done this for you.
2. Tape a clear ruler to the underside of the wave table so that the measuring side of the ruler goes through the point where the single point dipper touches the water as shown in diagram 14.
3. Set up a video camera to record the view screen. The camera should be held in place by a clamp and ring stand or other immovable object, and it should be perpendicular to the viewing screen, focused on the exact center.
4. Add about 2 mm of water to the table.
5. Measure the depth with a caliper.
6. Write the depth of the water on a piece of masking tape, and tape this to the opaque viewing screen so that the video camera can record this value, but so that the tape is not obscuring the view of the wave train. This is shown in diagram 14 as well.
7. Turn the vibrator motor on to 1.0 Hz.
8. Start the video and record three pulses traveling across the tank.
9. Add one more mm of water to the table.
10. Repeat steps 5-9 until the depth of the water is about 8mm deep.

DATA ANALYSIS:

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

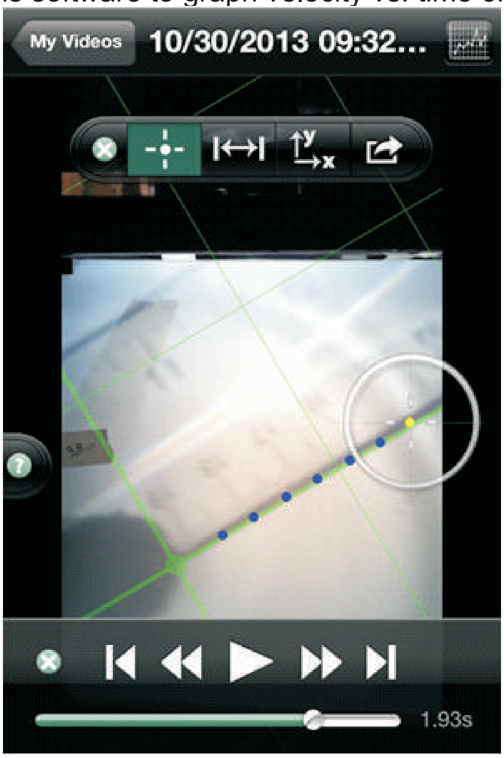
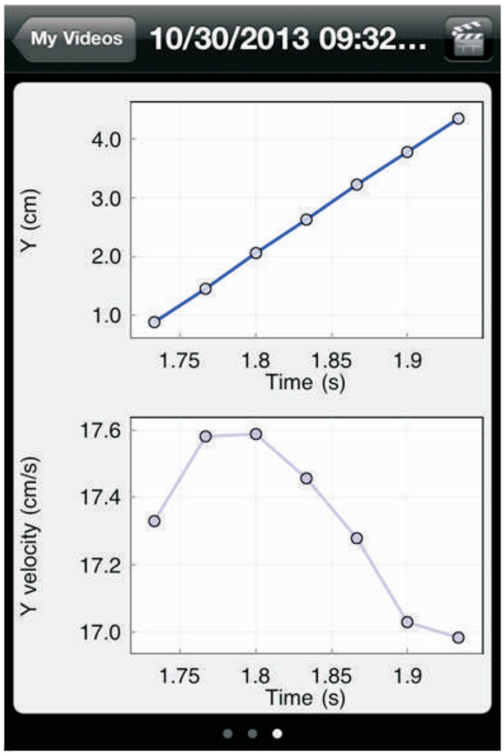


Diagram 24



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

Diagram 25

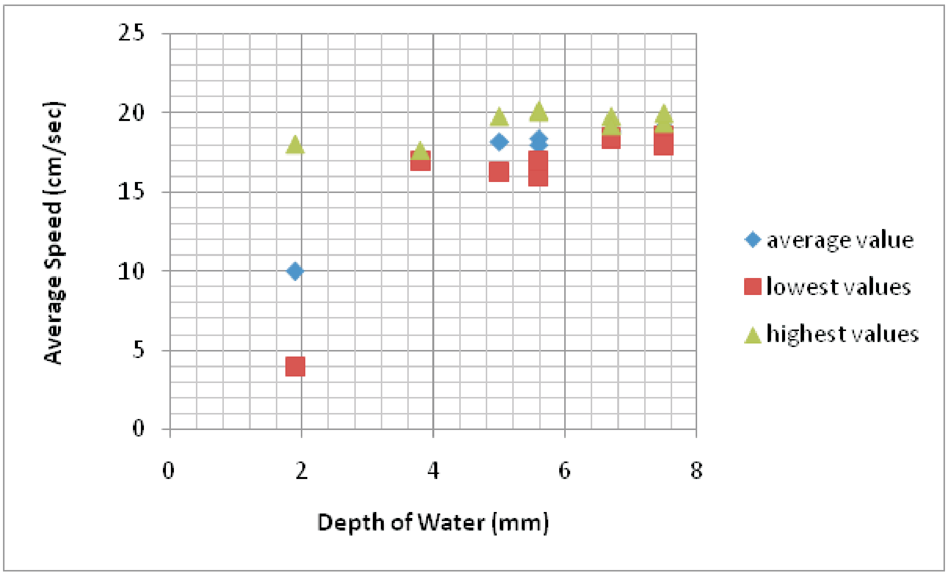
Diagram 25: Actual data using Vernier's "Video Physics" app on a smart phone for a depth of 3.8 mm (shown in diagram 24).

I estimated the velocity to be about 17.3 cm/s from the velocity vs. time graph shown in diagram 21.

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

Depth of Water (mm)	***Average speed (cm/sec)***
1.9	10
3.8	17.3
5	18.2
5.6	18.4
5.6	18
6.7	18.8
6.7	18.9
7.5	19.1
7.5	19.1

4. Make a graph of average wave speed vs depth of water and attach it to this lab. 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.

Diagram 26

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 2B: HOW DOES WATER DEPTH CHANGE WAVE SPEED?

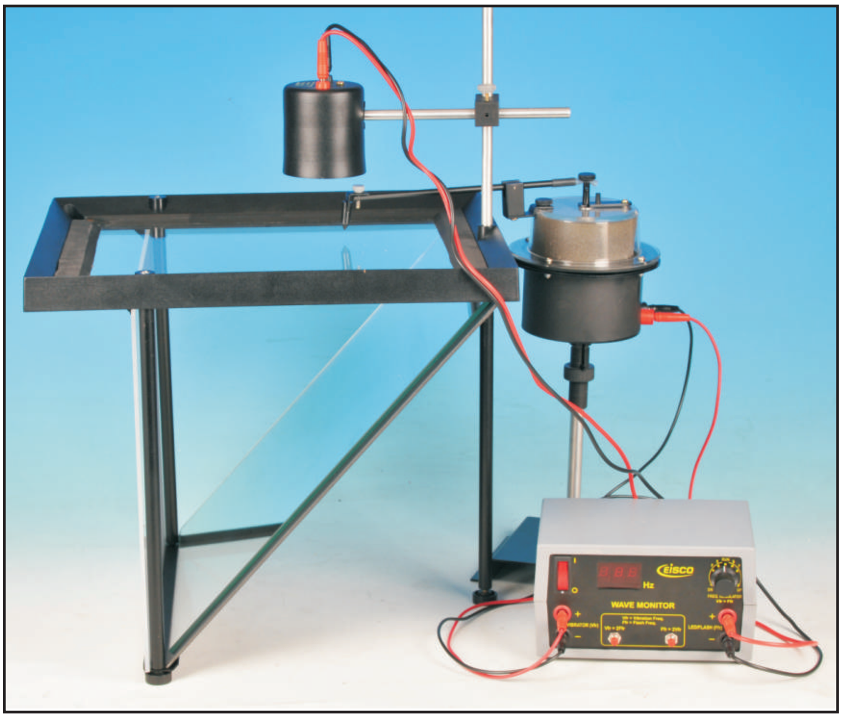


Diagram 15a

Diagram 14

1. Set up your wave table as shown in diagram 15a, your teacher may have already done this for you.

2. Tape a clear ruler to the underside of the wave table so that the measuring side of the ruler goes through the point where the single point dipper touches the water as shown in diagram 14.

3. Set up a video camera to record the view screen. The camera should be held in place by a clamp and ring stand or other immovable object, and it should be perpendicular to the viewing screen, focused on the exact center.

4. Add about 2 mm of water to the table.

5. Measure the depth with a caliper.

6. Write the depth of the water on a piece of masking tape, and tape this to the opaque viewing screen so that the video camera can record this value, but so that the tape is not obscuring the view of the wave train. This is shown in diagram 14 as well.

7. Turn the vibrator motor on to 1.0 Hz.
8. Start the video and record three pulses traveling across the tank.
9. Add one more mm of water to the table.
10. Repeat steps 5-9 until the depth of the water is about 8mm 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.

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

4. Make a graph of average wave speed vs. depth of water and attach it to this lab. What is the relationship between velocity and depth? Explain how you reached this conclusion.

CONCLUSION:

What is the relationship between velocity and depth? Explain how you reached this conclusion. 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 3: DIFFRACTION

TEACHER INSTRUCTIONS

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

HYPOTHESIS: Draw what you think the plane waves will look like as they move around each of the following barriers. Then perform the experiment by using the plane dipper to make plane waves. 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:

Situation 1: Actual Data

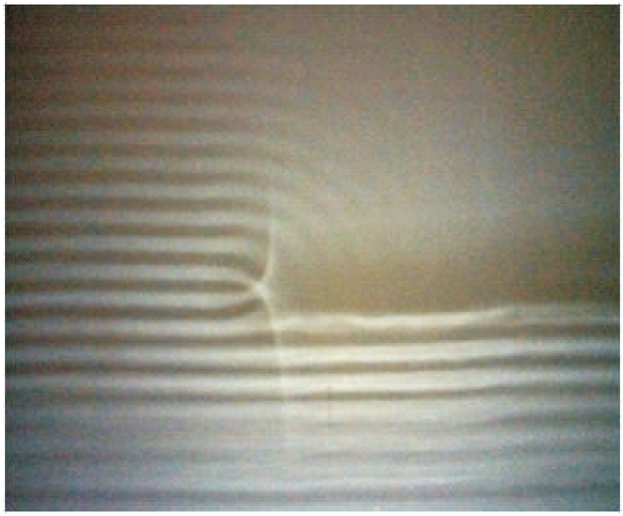


Diagram 27

Situation 2: waves around one small barrier

Hypothesis:

Situation 2: Actual Data

Diagram 28

Situation 3: narrow slit between two barriers
Hypothesis:

Situation 3: Actual Data

Diagram 29

Situation 4: medium slit between two barriers
Hypothesis:

Situation 4: Actual Data

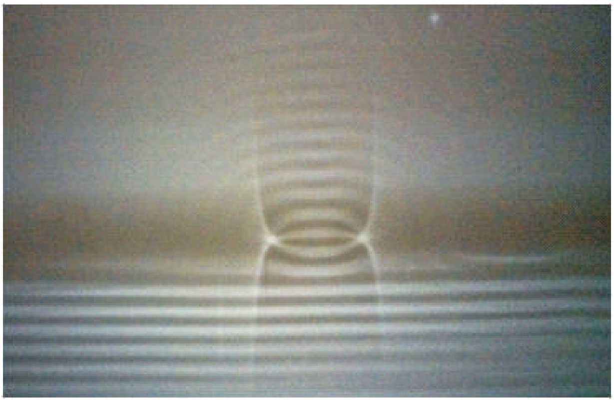


Diagram 30

Situation 5: large slit between two barriers
Hypothesis:

Situation 5: Actual Data

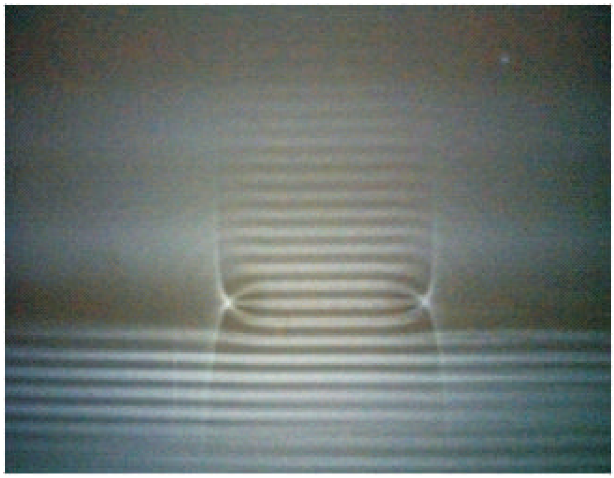


Diagram 31

Name:____ Date:_____________

ACTIVITY 3: DIFFRACTION

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

HYPOTHESIS: Draw what you think the plane waves will look like as they move around each of the following barrier. Then perform the experiment by using your plane dipper 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:

Situation 1: Actual Data

Situation 2: waves around one small barrier

Hypothesis:

Situation 2: Actual Data

Situation 3: narrow slit between two barriers
Hypothesis:

Situation 3: Actual Data

Situation 4: medium slit between two barriers
Hypothesis:

Situation 4: Actual Data

Situation 5: large slit between two barriers
Hypothesis:

Situation 5: Actual Data

ACTIVITY 4: ANGLE OF REFLECTION USING A BARRIER

TEACHER INSTRUCTIONS

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

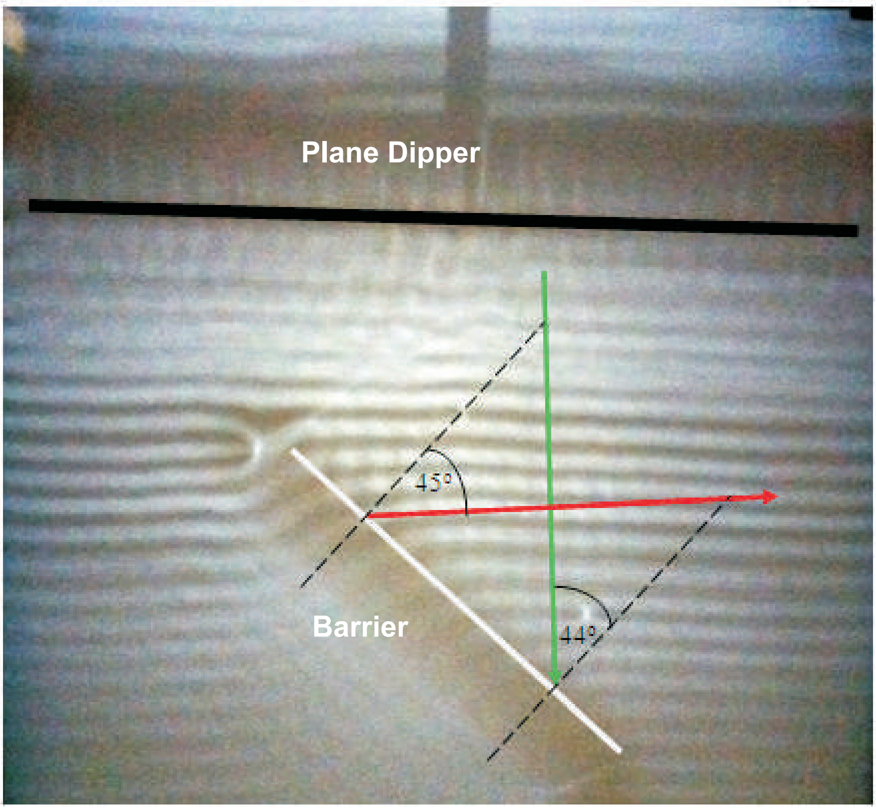


Diagram 32 : Picture of a wave reflecting off of a barrier. The green arrow shows the direction of the incident wave. The black dashed lines show the normal lines. And the red arrow shows the direction of the reflected wave front.

1. Set up apparatus as shown in diagram 17 and add the large barrier at some angle to the wave front.
2. Set the frequency of the plane wave dipper at any frequency that gives a good clear picture. Around 50-60 Hz works well.
3. Use a video recorder or camera to capture the wave reflecting off of the larger barrier. Make sure the shadow of the barrier can be clearly seen on your 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 barrier. 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:

Print out a picture of each of your six different angles of reflection.

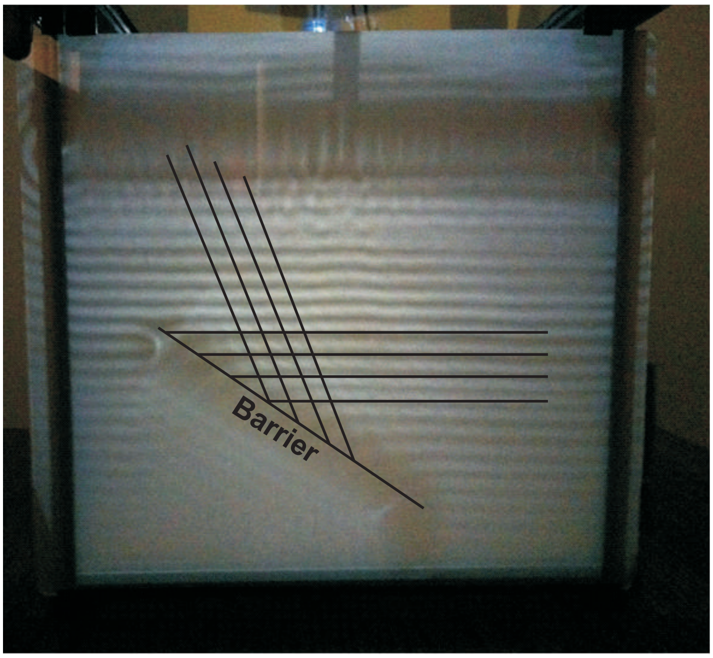


Diagram 33 Example of student work

DATA ANALYSIS:

1. There is a diamond shaped pattern that should immerge in the picture. Use your pencil to place a dot in the center of each diamond.
2. Use a straight edge to connect the dots and draw the wave fronts for the reflected waves as well as the incident waves.
3. Measure the angle of incidence for at least three wave fronts to get an average. This angle is the same angle that the wave front makes with the reflecting surface. Record your measurements in the data table.
4. Measure the angle of reflection for at least three waves fronts and take the average. Record your measurements in the data table.

DATA TABLE:

Angle of Incidence (degrees)	*Angle of Reflection (degrees)*
0	0
19	16
20	21
33	33
35	35
43	43
62	60

CONCLUSION :

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 4: ANGLE OF REFLECTION USING A BARRIER

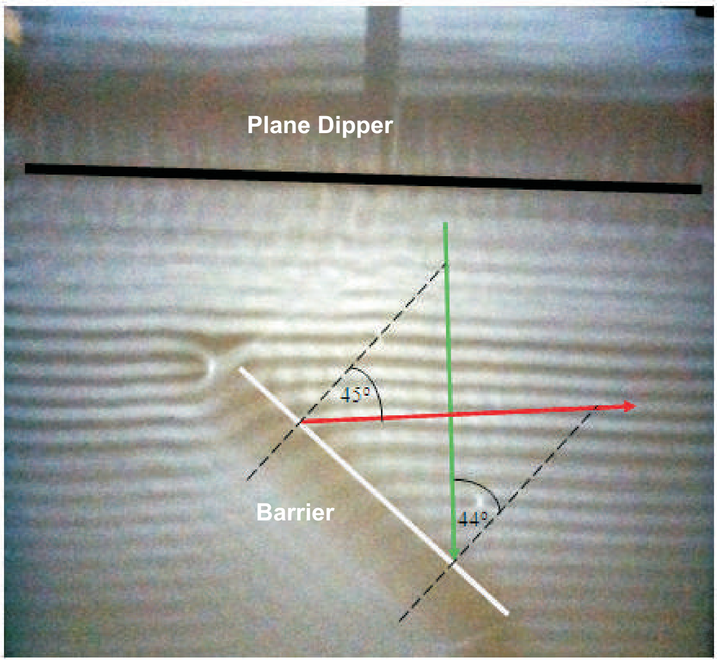


Diagram 32

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 wave front. 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 from 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. In diagram 32, the red arrow 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.

1. Set up apparatus as shown in diagram 17 and add the large barrier at some angle to the wave front.
2. Set the frequency of the plane wave dipper at any frequency that gives a good clear picture. Around 50-60 hz works well.
3. Use a video recorder or camera to capture the wave reflecting off of the larger barrier. Take a picture of viewing screen. Make sure the shadow of the barrier can be clearly seen on your viewing screen.

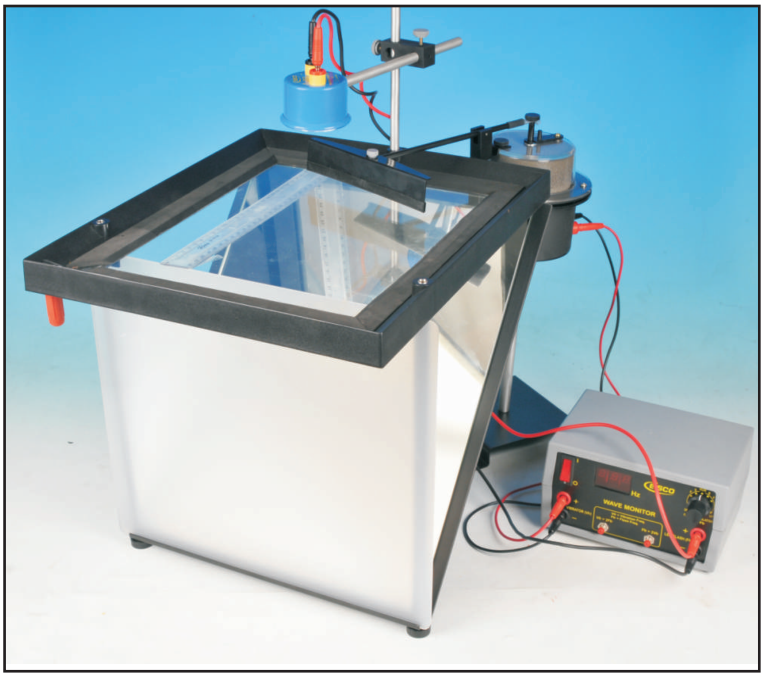


Diagram 17

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 barrier. 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. There is a diamond shaped pattern that should immerge in the picture. Use your pencil to place a dot in the center of each diamond.

3. Use a straight edge to connect the dots and draw the wave fronts for the reflected waves as well as the incident waves.

4. Measure the angle of incidence for at least three wave fronts to get an average. This angle is the same angle that the wave front makes with the reflecting surface. Record your measurements in the data table.

5. Measure the angle of reflection for at least three waves fronts and take the average. Record your measurements in the data table.

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 5: REFRACTION

TEACHER INSTRUCTIONS

As shown in activity 2a & 2b, 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 5-6 mm. 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 prism and set up the ripple tank as shown in the diagram 34.

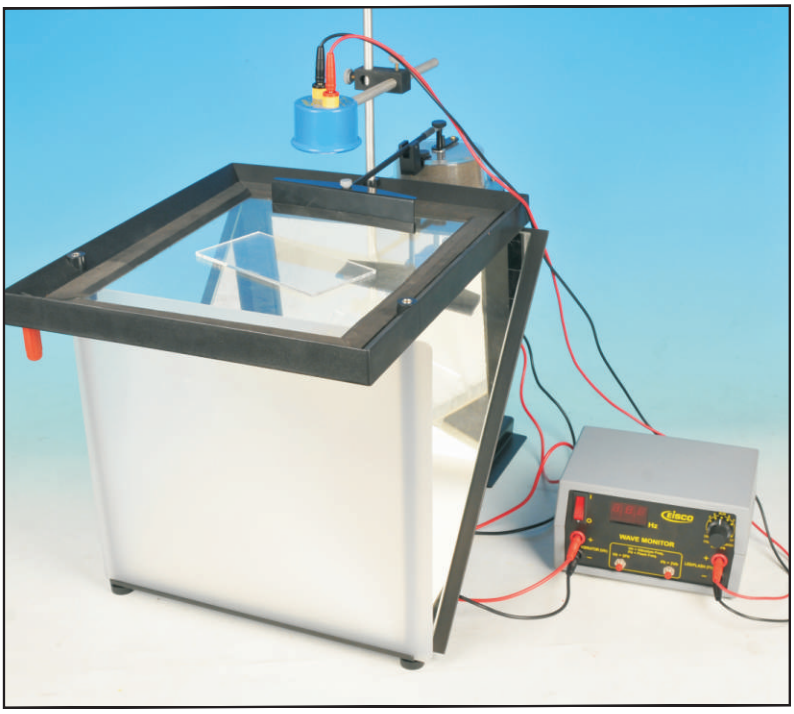


Diagram 34

2. Set up a camera to capture the image of a plane wave moving across the prism.
3. Make a plane wave by using the plane wave dipper set at a frequency of 50-70Hz.
4. First align the rectangular prism so that the long side is parallel with the plane wave fronts.
5. Tape a ruler to the viewing screen parallel to the direction of the wave fronts are traveling in *(as shown in diagram 35a.)*

6. Measure and record the wavelength of the waves before they reach the rectangular prism and then measure and record the wavelength of the waves while they are traveling over the barrier. *(It may be helpful to measure the length of 4-5 waves and then divide by the number of waves to get the wavelength.)*

7. Next turn the prism so that the wave fronts hit the prism at some angle. You should be able to clearly see a change in direction of the waves. Rotate the prism until you do. *(If the water is too deep, there will be no noticeable difference. You may have to drain the water until the waves can no longer be seen over the barrier and then slowly add water to the ripple tank until the waves are visible again.)*

8. 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 ANALYSIS FOR WAVES HITTING THE PRISM STRAIGHT ON:

1. What is the wavelength of the waves before they reach the prism? Show or explain how you got your answer.

   Using diagram 35a, I found that there were five consecutive waves from 21.7cm-16.9cm. Finding the difference between those two numbers and dividing by five gave me 0.96cm or about 1.0cm for the wavelength.

2. What is the wavelength of the waves while they were traveling on top of the prism? Show or explain how you got your answer.

   Using diagram 35a, I found that there were four consecutive waves from 14.3cm – 10.8cm. Finding the difference between those two numbers and dividing by four gave me 0.88cm or about 0.9cm for the wavelength using the right number of significant digits.

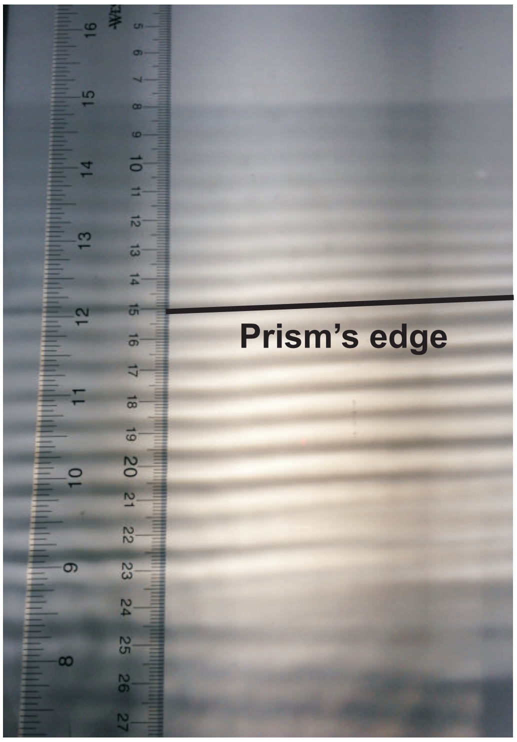


Diagram 35a

3. Compare the wavelength of the waves before and after they reached the prism. Using the formula speed = frequency x wavelength, explain what happens to the speed of the wave as it travels from deeper to shallower water.

   The wave length got shorter when traveling from deeper water to shallower water. I know this because the wavelength went from 1.0cm in the deep water to 0.9cm traveling over the prism in the shallow water. The formula that relates frequency and wavelength is speed = frequency x wavelength. Since the frequency stays the same and the wavelength decreases, the speed must also decrease.

4. In activity 2, how does the speed of the wave change with depth? Is this consistent with your findings in this activity?

In this activity, the waves moved slower through the shallow water. This is consistent with my findings in activity 2 because as the depth of the water increased, the speed of the waves increased as well.

DATA ANALYSIS FOR WAVES HITTING THE PRISM AT AN ANGLE :

1. 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 slow down.)

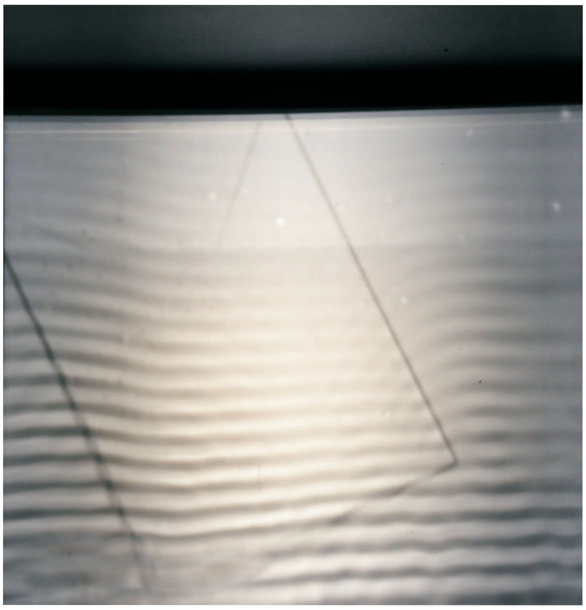


Diagram 35b

2. 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.)

3. 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.)

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

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 5: REFRACTION

TEACHER INSTRUCTIONS

As shown in activity 2a & 2b, 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 5-6 mm. 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 prism and set up the ripple tank as shown in the diagram 34.

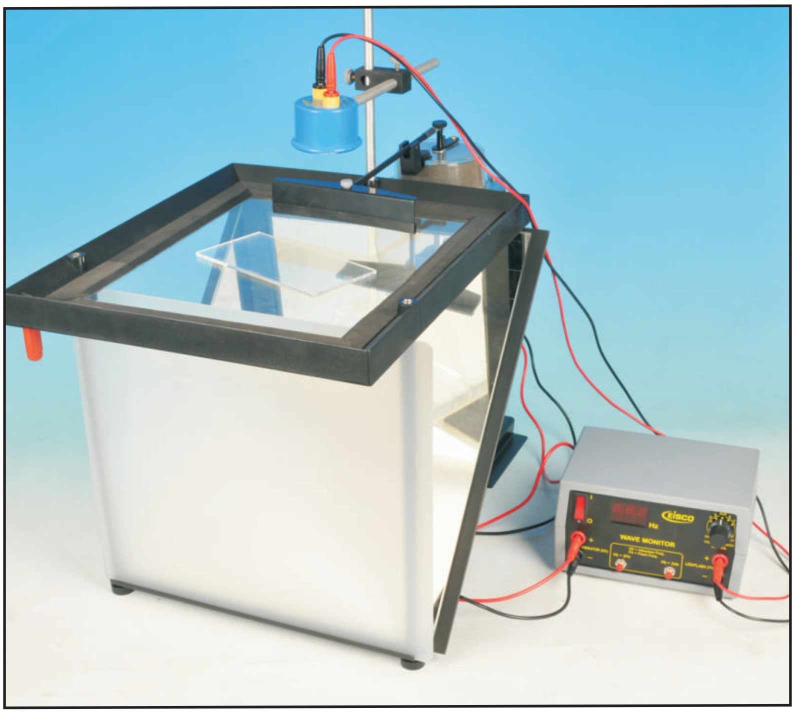


Diagram 34

2. Set up a camera to capture the image of a plane wave moving across the prism.
3. Make a plane wave by using the plane wave dipper set at a frequency of 50-70Hz.
4. First align the rectangular prism so that the long side is parallel with the plane wave fronts.
5. Tape a ruler to the viewing screen parallel to the direction of the wave fronts are traveling in *(as shown in diagram 35a.)*

6. Measure and record the wavelength of the waves before they reach the rectangular prism and then measure and record the wavelength of the waves while they are traveling over the barrier. *(It may be helpful to measure the length of 4-5 waves and then divide by the number of waves to get the wavelength.)*

7. Next turn the prism so that the wave fronts hit the prism at some angle. You should be able to clearly see a change in direction of the waves. Rotate the prism until you do. *(If the water is too deep, there will be no noticeable difference. You may have to drain the water until the waves can no longer be seen over the barrier and then slowly add water to the ripple tank until the waves are visible again.)*

8. 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 ANALYSIS FOR WAVES HITTING THE PRISM STRAIGHT ON:

1. What is the wavelength of the waves before they reach the prism? Show or explain how you got your answer.

____

____

____

2. What is the wavelength of the waves while they were traveling on top of the prism? Show or explain how you got your answer.

____

____

____

3. Compare the wavelength of the waves before and after they reached the prism. Using the formula speed = frequency x wavelength, explain what happens to the speed of the wave as it travels from deeper to shallower water.

____

____

____

4. In activity 2, how does the speed of the wave change with depth? Is this consistent with your findings in this activity?

____

____

____

DATA ANALYSIS FOR WAVES HITTING AT AN ANGLE :

1. 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?

2. 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?

3. 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?

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

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

ACTIVITY 6: CONCAVE AND CONVEX LENSES AND MIRRORS
TEACHER INSTRUCTIONS

To make each of these images, set up your ripple tank as shown in diagram 17 and make a single parallel wave using plane wave dipper and a frequency of 40-60 Hz.

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 11.

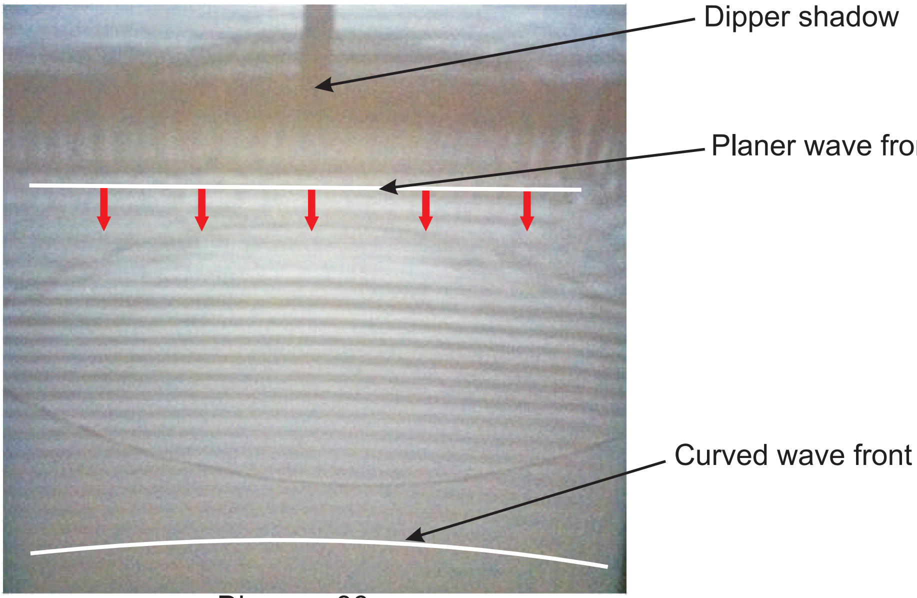


Diagram 36

Diagram 36: Here you can see one parallel wave front striking the convex prism on the top of the lens, and on the bottom you can see the curve of the wave front focusing towards one point. The red arrows show the direction of the wave front. As you can see the arrows are pointing towards each other after being refracted.

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 37 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.

Diagram 37 The shape of the concave lens is outlined in yellow. The plane wave is a straight line and the line coming out of the bottom end of the screen is slightly bowed. It is difficult to tell with the naked eye that there is a curve to the wave front, however using a straight edge or printing out a picture and drawing a straight line will reveal the curvature of the wave front.

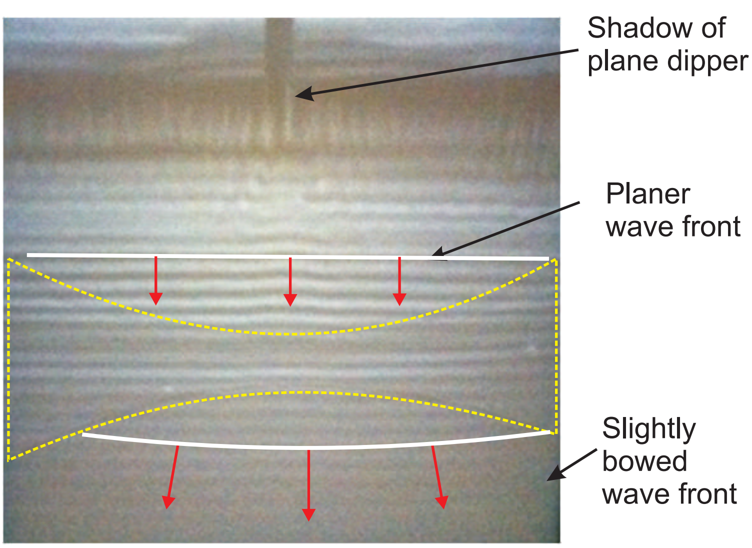


Diagram 37

A sample of ray diagrams of the concave lenses is shown in diagram 38

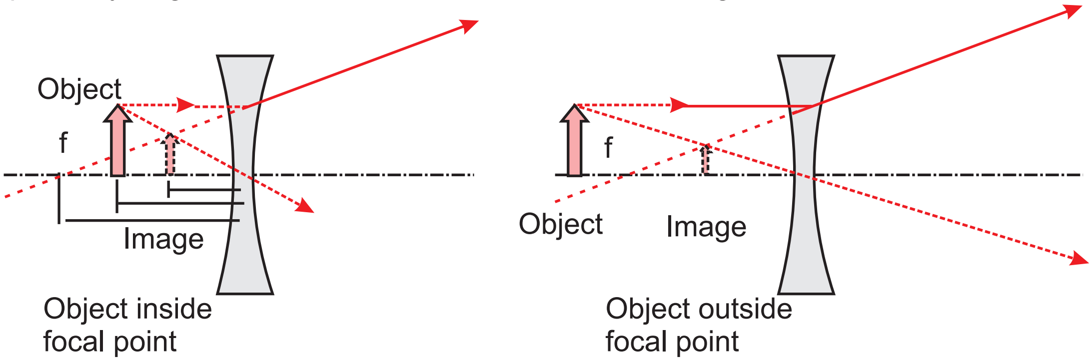


Diagram 38 See how the direction of the parallel water wave front diverges as does a light wave traveling through a concave lens.

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 39.

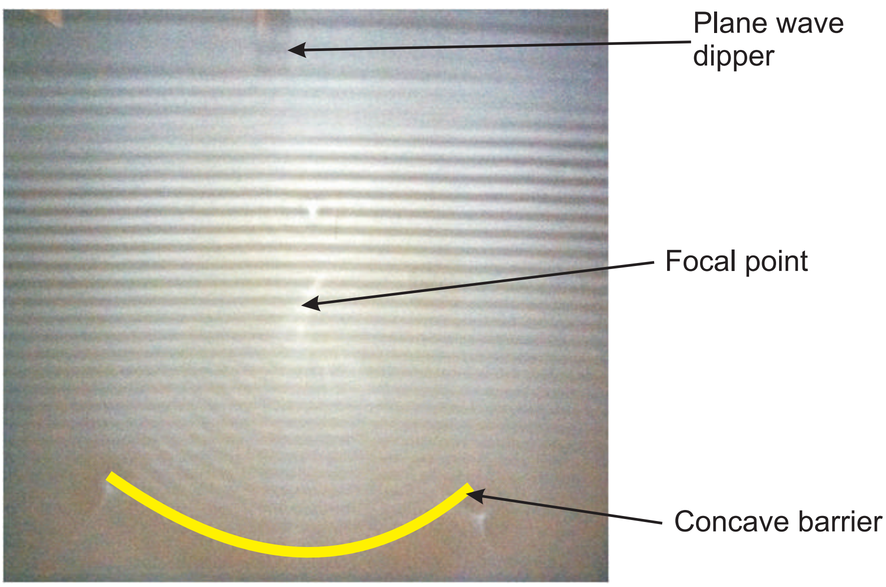


Diagram 39 This diagram shows a concave barrier (highlighted in yellow) with plane waves reflecting off the surface and converging into one point.

A convex barrier will also behave like a convex mirror when a parallel wave front reflects off the barrier. This is shown in diagram 40.

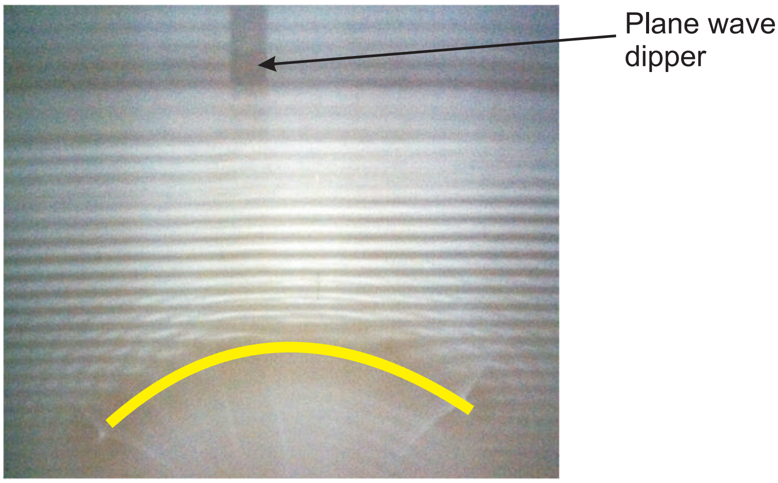


Diagram 40 This diagram shows a parallel wave front indecent on a convex barrier. The waves reflect off the barrier and all diverge away from the barrier.

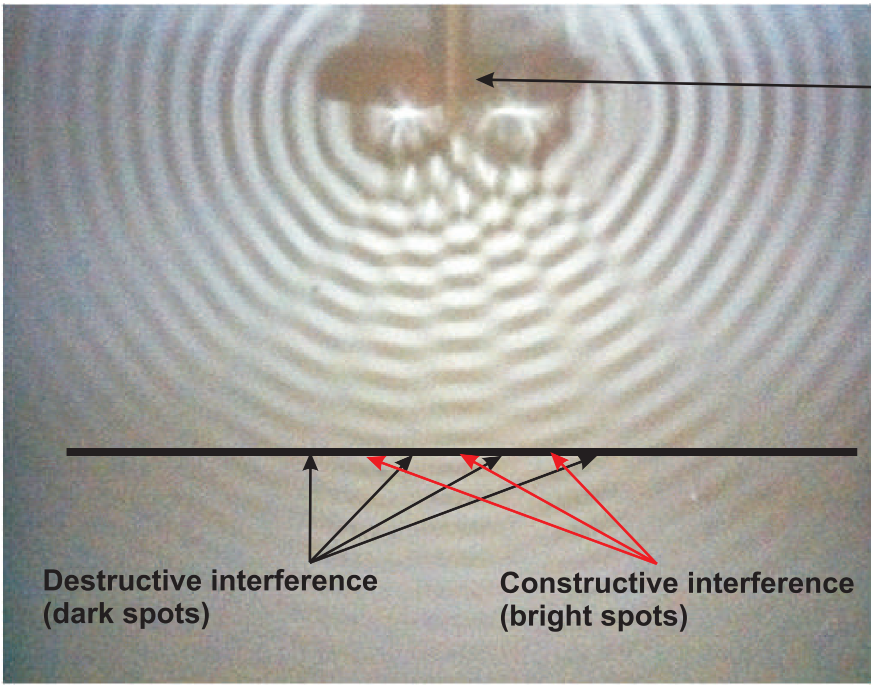
ACTIVITY 7: YOUNG'S DOUBLE SLIT EXPERIMENT

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 waves from point sources interfere with one another. In Young's experiment, one can only see a one-dimensional image on the screen. A series of bright and dark spots. 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 41. Increasing the frequency of the wave generator will decrease the wavelength of the waves.



Shadow of dipper with two point sources hooked up.

Diagram 41 You can see the wave pattern nicely portrayed here. The dippers are set at a frequency of about 60 Hz. A line is drawn in to simulate the screen in Young's double slit experiment.

Alternatively, you can get a similar pattern by arranging the two large barriers and one small barrier as shown in diagram 43.

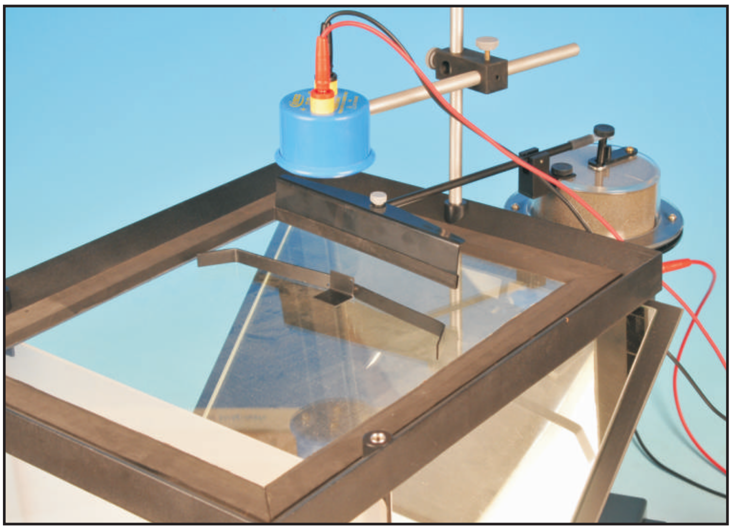
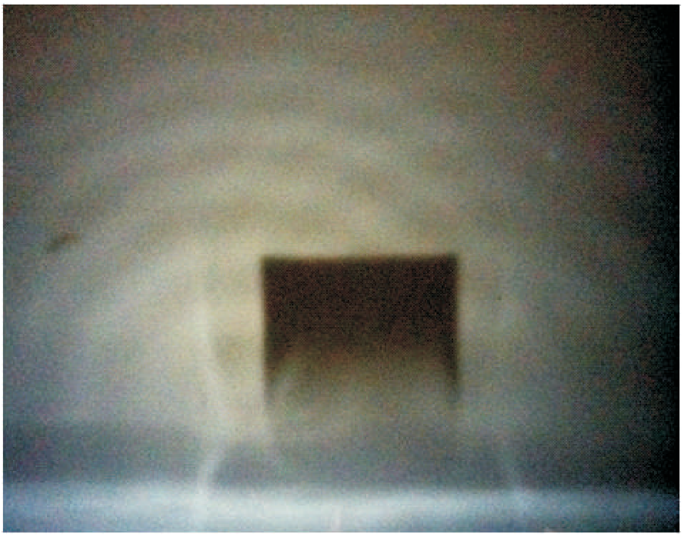


Diagram 42 Shows how to set up your ripple tank to model Young's double slit experiment.



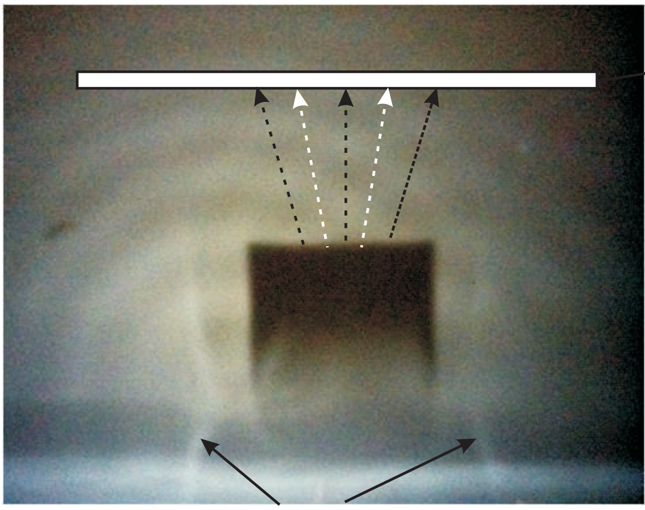


Diagram 43 This shows a coherent wave source (produced by a plane wave) incident on a double slit formed by three barriers. As you can see there is a nice diamond pattern show the constructive and destructive interference pattern that can be seen with a double point source. This experiment works best with a lower frequency, around 10-30 Hz. You may need to slowly adjust the frequency to get the wave pattern to show clearly.

ACTIVITY 8: CHRISTIAAN HUYGENS

Christiaan Huygens' wave theory is explained in more detail in the background section of this manual, but the main idea of his theory is that all waves can be assumed to originate from infinitely many point sources, and that the pattern we see as waves travel through a medium is the constructive and destructive interference of the waves at a given time “t” after the waves have propagated from that every single point on the original wave front. Therefore a plane wave, and infinitely many point sources originating at the same time in a line will look exactly the same.

For this demonstration set up your apparatus as shown in diagram 17. Attach the multi-point source to the vibrator and turn the frequency up to about 50-60 Hz. The pattern that immerges will look like diagram 44 below. As you can see the interference pattern is beginning to look more like a straight line. In theory, adding more points closer and closer together, will yield a pattern closer and closer to a plane wave front. A plane wave front is the product of infinitely many point sources originating in a straight line.

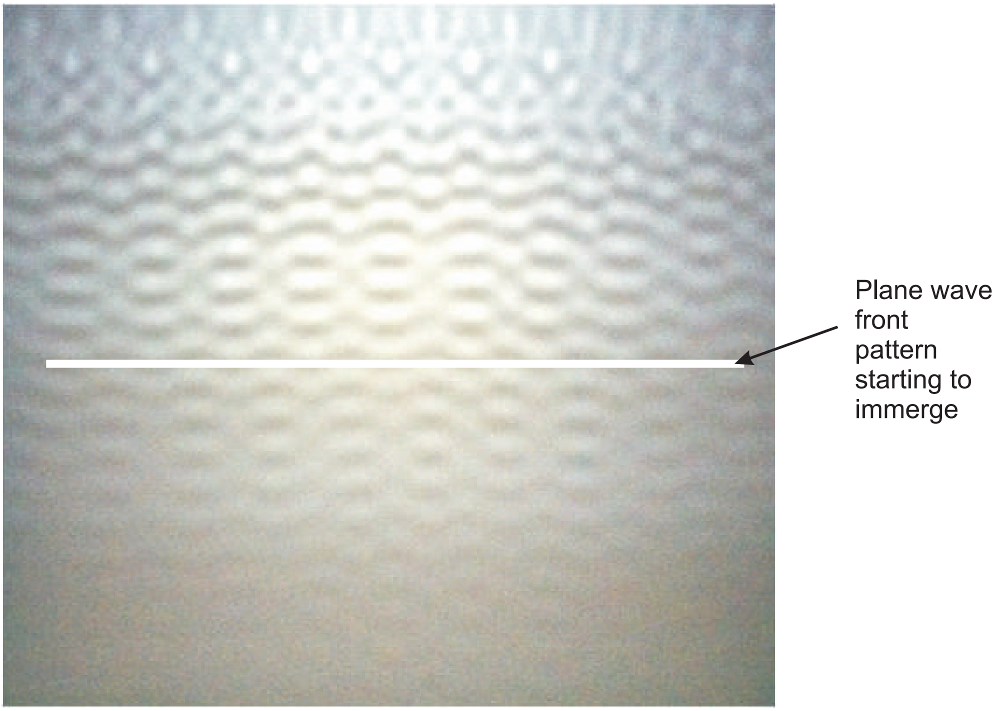


Diagram 44: Multi-point source wave front. Compare this to the double point wave pattern and notice how the waves and getting closer to looking like a plane wave.

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