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## What Effects Water Waves?

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# The Mathematics of Waves

**Name:** Mike Sicienski

**Grade level(s)/Subject taught:** 9<sup>th</sup> grade Physical Science (Or 11-12 grade regents physics for more advanced mathematical discussions (in green font))

## Objectives:

Students will discover that:

- Waves come in mainly two different types (transverse and longitudinal)
- How the type of wave, type of medium, wavelength, temperature, and depth effect the velocity of a wave
- This relationship can be used to determine the distances to stars and galaxies beyond 100pc.

Students will be able to define these terms:

- Luminosity, apparent brightness, inverse square law,

Students will be able to use these equations to find appropriate values:

$$v=f\lambda, \quad T=1/f, \quad c = \sqrt{\frac{g\lambda}{2\pi} \tanh\left(\frac{2\pi d}{\lambda}\right)}$$

where  $c$  = surface speed,  $d$  = depth,  $f$  = frequency,  $g = 9.81 \text{ m/s}^2$ ,  $T$  = period,  $v$  = velocity,  $\lambda$  = wavelength

...  
The Science Concept or “key idea” that modeling will be used to teach:

That the speed of a wave is affected by the type of medium it is traveling in, the depth, the temperature, and its wavelength. **This lesson will take two 40 minute periods.**

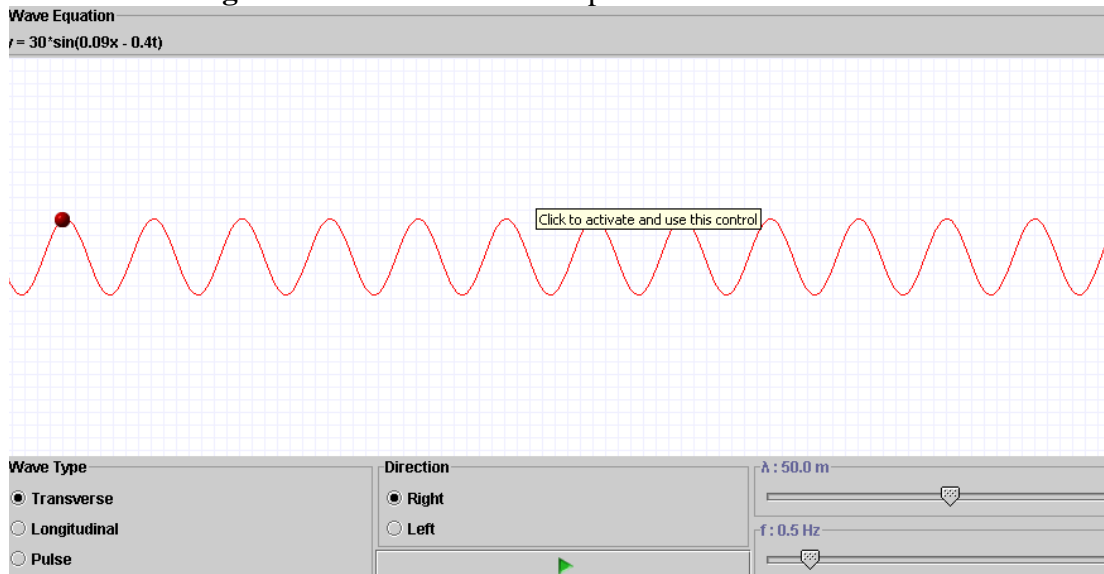
## Materials:

Computers with internet access, computer projector, student worksheet, calculators

## The Lesson:

### Types of Waves:

- Log onto the website [http://projects.cbe.ab.ca/sss/science/physics/map\\_north/](http://projects.cbe.ab.ca/sss/science/physics/map_north/) and scroll down to **Waves, Wave Motion, and Sound**. Click the first link called **Traveling Waves**. You should see a picture like this:



- Have students download the **Student Wave Worksheet 1** (at end of lesson) from the class website, get on the website, and have them answer the questions. After about 10 minutes, summarize and have them take these notes:

Define the two types of waves:

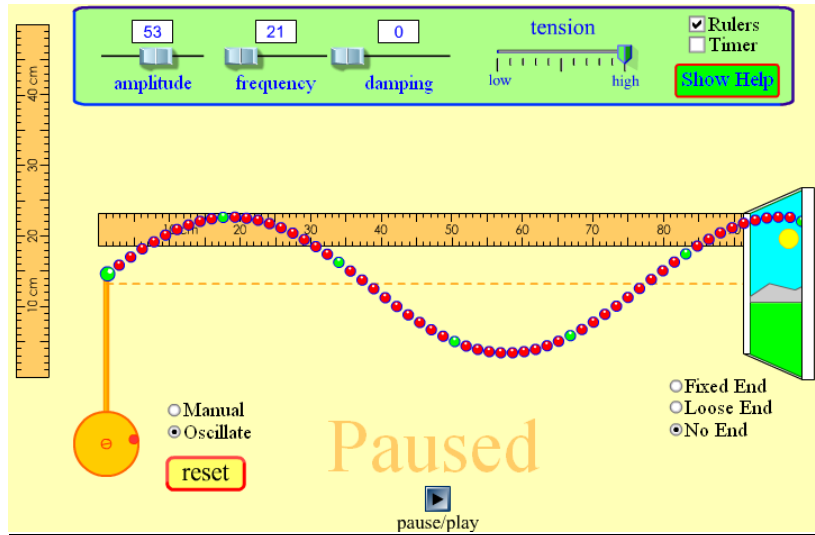
**Longitudinal-** (like a spring being stretched and compressed)

*Examples: Sound, Primary waves in an Earthquake.*

**Transverse-** The substance vibrates perpendicular to the direction the wave travels (for example, the substance vibrates up and down while the wave travels to the right.)

*Examples: Light, secondary earthquake waves, water*

- Next have them open up the applet at [www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf](http://www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf) , download **Student Wave Worksheet 2** (at end of lesson) from the class website, get on the website, and have them answer the questions. It should look like this:



- After about 10 minutes, summarize and have them take these notes:

### **Define these terms (relating to a transverse wave:)**

**Pulse:** One cycle of a wave

**Amplitude:** the maximum vertical displacement of a wave in one direction or half of the vertical displacement measured from the top of the wave (crest) to the bottom of the wave (trough)

**Wavelength ( $\lambda$ ):** the length of one cycle of a wave, or the distance between consecutive crests (or troughs)

**Frequency (f):** the amount of wave cycles per second (measured in Hertz)

**Period (T):** the amount of time it takes to complete one cycle of a wave

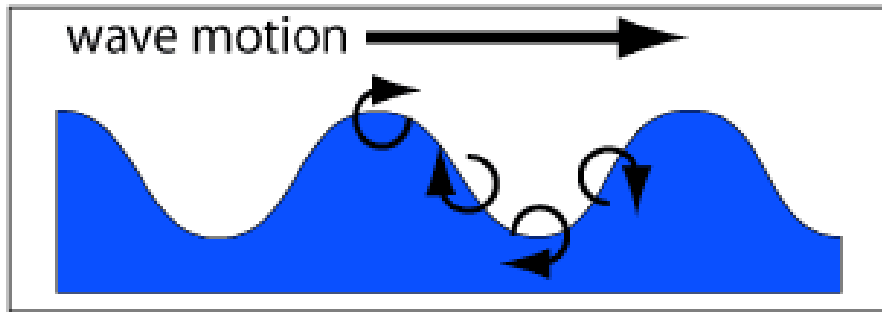
**Speed of a wave:** the product of the wavelength and the frequency of a wave

• There are three factors that influence the formation of waves in the water by wind:

- Wind speed
- Length of time the wind has blown over a given area
- Distance of open water that the wind has blown over (called the fetch)

Waves are measured by:

- Height -from trough to crest (amplitude is considered half of this distance)
- Wavelength -from crest to crest
- Steepness -angle between crest and trough
- Period -length of time between crests



<http://www.owrc.com/waves/waves.html>

### **Tsunamis**

- Occur when the sea floor is abruptly deformed which causes the water above it to be vertically displaced.
- They are hard to detect because compared to regular waves, Tsunamis have small amplitudes (which makes them hard to see) and have long wavelengths (they travel extremely fast.)
- As the wave nears the shore, its velocity decreases, and its amplitude grows

### **Specific Formula for wave speed:**

$$c = \sqrt{\frac{g\lambda}{2\pi} \tanh\left(\frac{2\pi d}{\lambda}\right)}$$

**where**  
 $c$  = phase ( surface) speed ;  
 $\lambda$  = wavelength;  
 $d$  = water depth;  
 $g$  = acceleration due to gravity;

In deep water, where  $d > 1/2\lambda$  , the hyperbolic tangent approaches 1, and the formula for  $c$  ( in m/s) approximates to  $1.25\sqrt{\lambda}$  , when  $\lambda$  is measured in meters.

- \*Tsunamis are deadly because they have long wavelengths ( $> 100$  km) and therefore travel very fast (up to 500mph or 800km/hr.  $v = (gd)^{0.5}$  )
- \*Energy loss is inversely proportional to the wavelength, so they lose very little energy as they travel.
- \*They are capable of flooding hundreds of meters inland.
- \*They may reach a maximum vertical height onshore above sea level of 30 meters

Tsunami applet <http://chair.pa.msu.edu/applets/tsunami/tsunami.html>

### **QUIZ:**

Students will go back on the second website

[www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf](http://www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf)

and determine the wavelength, amplitude, period, and speed of a wave that has an **amplitude setting of 70 and a frequency of 40 Hz.**

**Answers: wavelength: 41 cm; amplitude: 13cm; period: 0.025 sec; speed: 1640 cm/sec**

## Student Wave Worksheet 1

Log onto the website [http://projects.cbe.ab.ca/sss/science/physics/map\\_north/](http://projects.cbe.ab.ca/sss/science/physics/map_north/) and scroll down to **Waves, Wave Motion, and Sound**. Click the first link called **Traveling Waves**.

### **Push play and answer these questions:**

1. With the wave type selected as **transverse** (in bottom left), what do you notice about vertical and horizontal movements of the red sphere on the wave?

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2. Adjust the  $f$  (which means frequency) setting in the bottom right corner to a larger value. What do you notice?

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3. Adjust the  $\lambda$  (which means wavelength) setting in the bottom right corner to a larger value. What do you notice?

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### **Now switch the wave type to LONGITUDINAL and answer these questions**

4. What do you notice about vertical and horizontal movements of the red sphere on the wave?

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5. Adjust the  $f$  (which means frequency) setting in the bottom right corner to a larger value. What changes?

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6. Adjust the  $\lambda$  (which means wavelength) setting in the bottom right corner to a larger value. What changes?

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## Student Wave Worksheet 1 **ANSWERS**

Log onto the website [http://projects.cbe.ab.ca/sss/science/physics/map\\_north/](http://projects.cbe.ab.ca/sss/science/physics/map_north/) and scroll down to **Waves, Wave Motion, and Sound**. Click the first link called **Traveling Waves**.

### **Push play and answer these questions:**

1. With the wave type selected as **transverse** (in bottom left), what do you notice about the vertical and horizontal movements of the red sphere on the wave?

**IT MOVES UP AND DOWN BUT DOESN'T MOVE HORIZONTALLY**

2. Adjust the  $f$  (which means frequency) setting in the bottom right corner to a larger value. What do you notice?

**THERE ARE MORE WAVES, THE WAVES MOVE QUICKER**

3. Adjust the  $\lambda$  (which means wavelength) setting in the bottom right corner to a larger value. What do you notice?

**THERE ARE LESS WAVES, THE WAVES MOVE SLOWER**

### **Now switch the wave type to LONGITUDINAL and answer these questions**

4. What do you notice about the vertical and horizontal movements of the red sphere on the wave?

**IT MOVES BACK AND FORTH HORIZONTALLY BUT DOESN'T MOVE VERTICALLY**

5. Adjust the  $f$  (which means frequency) setting in the bottom right corner to a larger value. What changes?

**THE BALL SHAKES BACK AND FORTH MORE QUICKLY, THE WAVES MOVE FASTER**

6. Adjust the  $\lambda$  (which means wavelength) setting in the bottom right corner to a larger value. What changes?

**THE WAVES ARE MORE SPREAD OUT**

## Student Wave Worksheet 2

Open up the applet at

[www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf](http://www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf)

Adjust the **damping to 0** and select the rulers (you will see a vertical and horizontal ruler.) Also, make sure the Tension is on **high** and select **No End** at the lower right. You will see a line of beads going out the door. Then do the following and answer the questions.

1. Click **oscillate** and observe the wave. Increase the amplitude. What do you notice?

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2. **a) Pause** the applet, adjust the **amplitude to 50**, and click **reset**. Let it run for a few seconds and pause it again. Drag the vertical ruler so that the bottom (0 cm) touches the dotted line and so that you can measure the highest point on the wave. This is known as the amplitude. What is it? \_\_\_\_\_

**b)** Next, take the horizontal ruler and measure the length from the top of one of the waves to the top of the next wave. This is known as the wavelength. What is it? \_\_\_\_\_

3. Repeat step 2 so that you can measure the amplitudes and wavelengths of the waves at these settings:

Amplitude setting	Amplitude (cm)	Wavelength (cm)
25		
60		
85		
100		

4. The speed of a wave is the product of its frequency and wavelength. Set the frequency to the following values, measure the wavelength, and calculate the speed. (**Show your work!**)

Frequency (per second)	Wavelength (cm)	Speed (cm/sec)
25		
60		
85		
100		

5. **Challenge:** The period of a wave is the time it takes to make one cycle of a wave. Using the timer button, see if you can time how long it takes to make one wave with these frequencies:

Frequency (per second)	Period (sec)
5	
10	
15	
20	



## Student Wave Worksheet 2 **ANSWERS**

Open up the applet at

[www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf](http://www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf)

Adjust the **damping to 0** and select the rulers (you will see a vertical and horizontal ruler.) Also, make sure the Tension is on **high** and select **No End** at the lower right. You will see a line of beads going out the door. Then do the following and answer the questions.

1. Click **oscillate** and observe the wave. Increase the amplitude. What do you notice?  
**THE HEIGHT OF THE WAVES GETS LARGER**

2. **a) Pause** the applet, adjust the **amplitude to 50**, and click **reset**. Let it run for a few seconds and pause it again. Drag the vertical ruler so that the bottom (0 cm) touches the dotted line and so that you can measure the highest point on the wave. This is known as the amplitude. What is it? **9-10 cm**

**b)** Next, take the horizontal ruler and measure the length from the top of one of the waves to the top of the next wave. This is known as the wavelength. What is it? **ABOUT 70 cm**

3. Repeat step 2 so that you can measure the amplitudes and wavelengths of the waves at these settings:

Amplitude setting	Amplitude (cm)	Wavelength (cm)
25	4-5	70
60	11	70
85	16	70
100	19	70

4. The speed of a wave is the product of its frequency and wavelength. Set the **amplitude to 50**, and adjusting the frequency to the following values, measure the wavelength, and calculate the speed. (**Show your work!**)

Frequency (per second)	Wavelength (cm)	Speed (cm/sec)
25	65	1625
50	33	1650
75	22	1650
105	16	1680

**NOTICE SPEEDS ARE CLOSE TO SAME VALUE- IN SAME MEDIUM**

5. **Challenge:** The period of a wave is the time it takes to make one cycle of a wave. Using the timer button, see if you can time how long it takes to make one wave with these frequencies:

Frequency (per second)	Period (sec)
1	1.0
2	0.5
3	0.33
4	0.25