Chapters 25: **Waves**

Text:
<u>*Chapter 25*</u>
Think and Explain: 1-10
Think and Solve: 1-4

Vocabulary:
wave, pulse, oscillation, amplitude, wavelength, wave speed, frequency, period, interference, constructive, destructive, node, anti-node, reflection, focal point, soft reflection, angle of incidence, hard reflection, crest, trough, compression, longitudinal, transverse, diffraction, standing wave, Doppler effect/shift, bow/shock waves, sonic boom

Equations:
$f = \frac{1}{T}$ $v = \lambda f$

Key Objectives:
Concepts
- ❑ identify, define, use and/or explain the vocabulary above. (This is HUGE.)
- ❑ compare and contrast longitudinal waves and transverse waves, with examples.
- ❑ explain how wave speed, amplitude, wavelength and frequency relate to each other and be able to state how the change in one variable effects the others.
- ❑ given two waves, draw how the waves will interfere with each other
- ❑ compare and contrast the two ways that waves reflect off a variety of surfaces and boundaries.
- ❑ explain how to change the speed of a wave traveling in a particular medium.
- ❑ explain, draw, identify how plane and circular waves reflect or pass by barriers. (i.e. Ripple Tank Lab.)
- ❑ identify where nodes and anti-nodes would exist, for both strings and circular waves.
- ❑ given a picture of a wave, be able to identify and measure the waves amplitude and wavelength, and the crest and trough of the wave.
- ❑ compare and contrast "wave motion" with "particle motion," e.g. how would you decide if something is a wave or a particle, what can a wave do that particles not do, etc.
- ❑ explain the Doppler effect, sonic booms and shock waves.
- ❑ for standing waves in a string, determine the wavelengths of the fundamental frequency and also of the harmonics

Problem Solving
- ❑ convert between frequency and period.
- ❑ convert between rpm and Hz.
- ❑ determine a wavelength based on a string length and the number of nodes/anti-nodes.
- ❑ calculate the missing variable in problems with wavespeed, wavelength and frequency.
- ❑ calculate speed, time or lengths with sound pulses in tubes (i.e. Reflections in a Tube lab)

Lab 7-1: **Slinkies**

Purpose: To make observations of wave phenomenon using a slinky.

NOTE: Be careful with the Slinky, as it easily becomes knotted and useless!

1. Stretch out the slinky between you and your partner. There are two types of waves you can create with the slinky: longitudinal and transverse.
   Transverse Pulse: Shake the slinky rapidly from side to side. Describe/draw what you see.

   Longitudinal Pulse: Give the slinky a quick push and then pull it back. Describe/draw what you see.

2. Keeping the slinky somewhat loose between you and your partner, send a wave **pulse** down to your partner by giving the slinky a very rapid side to side motion. Observe the following as the pulse travels to your partner:
   - Does the shape change?
   - Does the speed of pulse change?
   - Does the amplitude of the pulse change?

3. Repeat number 2 for a variety of pulses. Try long wavelengths vs. short wavelengths. Try large amplitudes vs. small amplitudes. What happens?

4. Does the speed of a wave depend on its amplitude or wavelength?

5. Now tighten the slinky between you and your partner. Send a pulse to your partner. What happens to the speed of the pulse? Tighten it more. What happens?

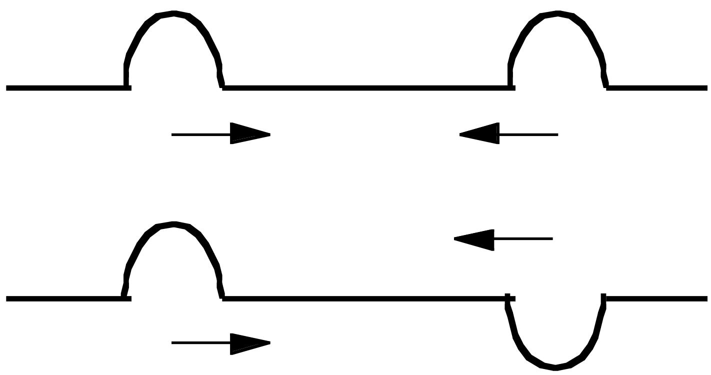
6. Have your partner hold their end of the slinky tightly to the floor. Send a wave pulse of large amplitude down and carefully observe the reflected wave that comes back to you. Look at the wavelength, shape, amplitude and which side of the slinky the wave is on when it reflects back as compared to when it came down. What happens?

Lab 7-1: **Slinkies**

7. Tie a string about 2 meters long to one end of the slinky. Have your partner hold the end of the string, so that the end of the slinky is free to move. Send a wave pulse of large amplitude down to your partner and again observe the wave that is reflected back to you. What happens. (Note: this can be tricky to see, so be careful.)

8. Now we want to look at how waves interfere with each other. Have your partner send a longitudinal pulse to you at the same time that you send a transverse pulse to your partner. What happens when the pulses hit each other?

9. Now you and your partner must send transverse wave pulses to one another. Each of the diagrams below represents the pulses to be sent. Draw what happens the *instant* the two waves are on top of each other and then what happens after the waves have interfered with each other.



10. Now send continuous waves down the slinky by shaking your hand back and forth.
    a. If you shake your hand with a higher frequency, what happens to the wavelength?

    b. If you shake your hand with a lower frequency, what happens to the wavelength?

    c. If you keep the frequency of your shaking constant, but make the amplitude bigger, what happens to the wavelength?

    d. If you keep the frequency of your shaking constant, but make the amplitude smaller, what happens to the wavelength?

Post-Lab 7-1 Worksheet

Define each of the following terms:

1. Wave:

2. Crest

3. Trough:

4. Wavelength:

5. Frequency:

6. Amplitude:

7. Period:

8. Hertz:

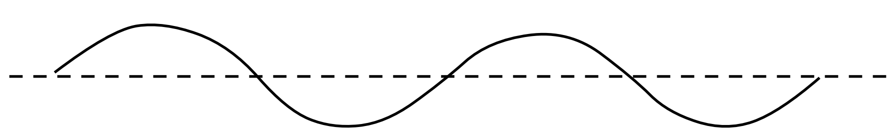
9. Transverse Wave:

10. Longitudinal Wave:

11. Pulse vs a Continuous Wave:

12. How does a wave's wavelength depend on its frequency?

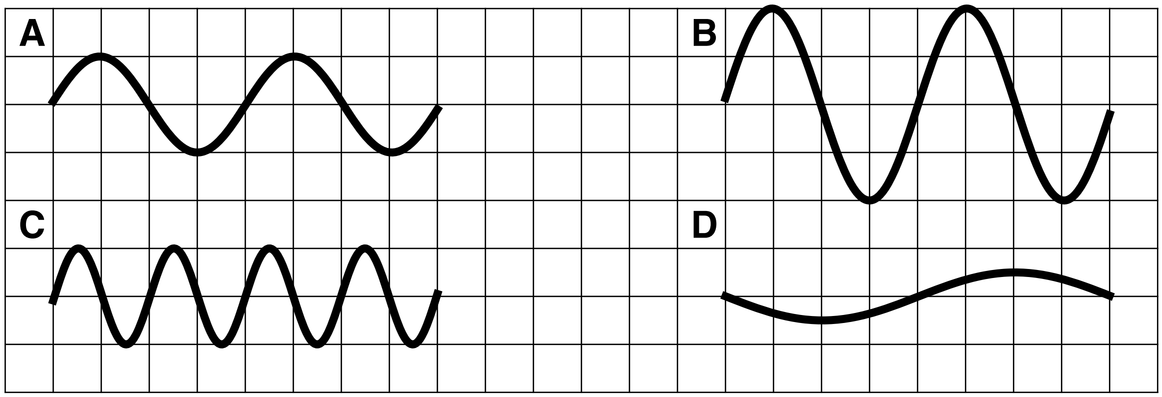
13. On the diagram below, label the following points: (a) crest (b) trough (c) wavelength and (d) amplitude. Also, is the wave pictured a transverse wave or a longitudinal wave?



NAME: ___________________

Wave Diagrams

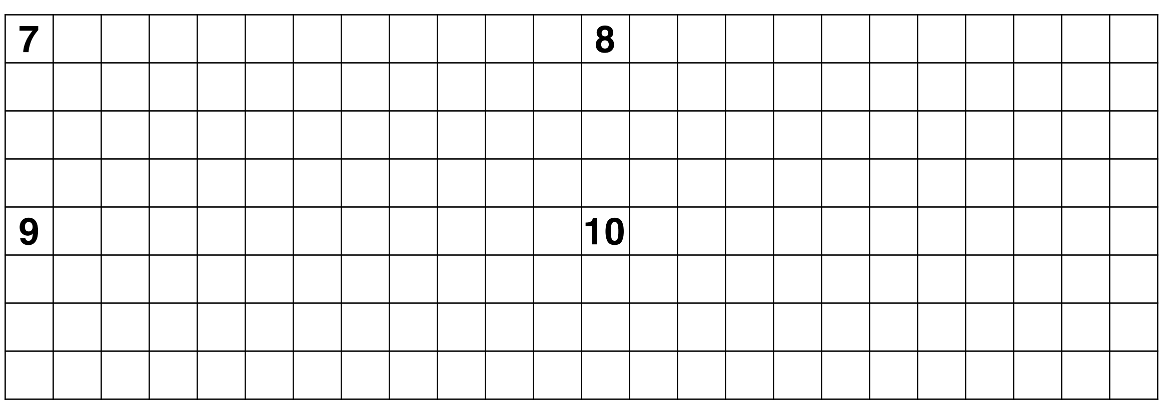
Questions 1 to 10 refer to the following waves. The scale is 1/4" per square.



1. Determine the wavelength of each of the waves:

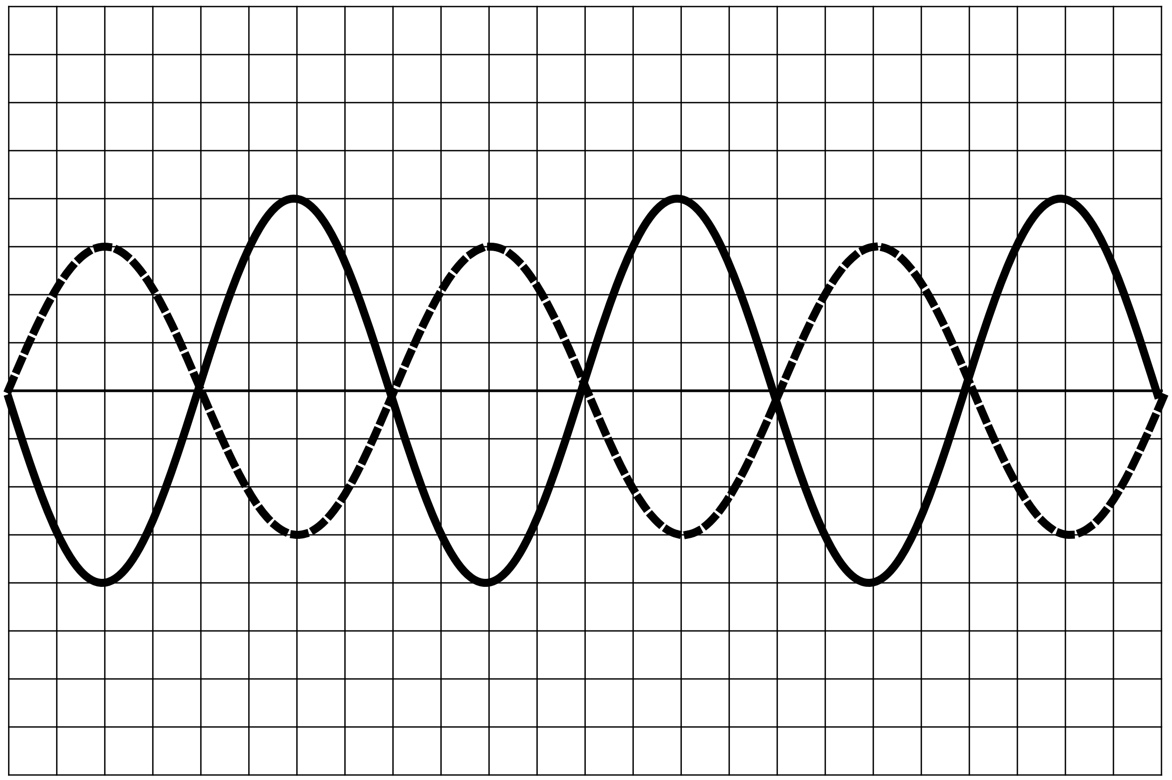
   A: ____________ B: ____________ C: ____________ D: ____________

2. Which wave has the greatest amplitude?
3. Which wave has the highest frequency?
4. Which wave has the lowest amount of energy?
5. Which wave has the lowest frequency?
6. Which two waves have the same frequency?
7. Below, draw a wave that has the same amplitude and twice the frequency of wave A.
8. Below, draw a wave that has the same frequency and half the amplitude of wave B.
9. Below, draw a wave that has twice the wavelength and half the amplitude of wave C.
10. Below, draw a wave that has four times the frequency and twice the amplitude of wave D.

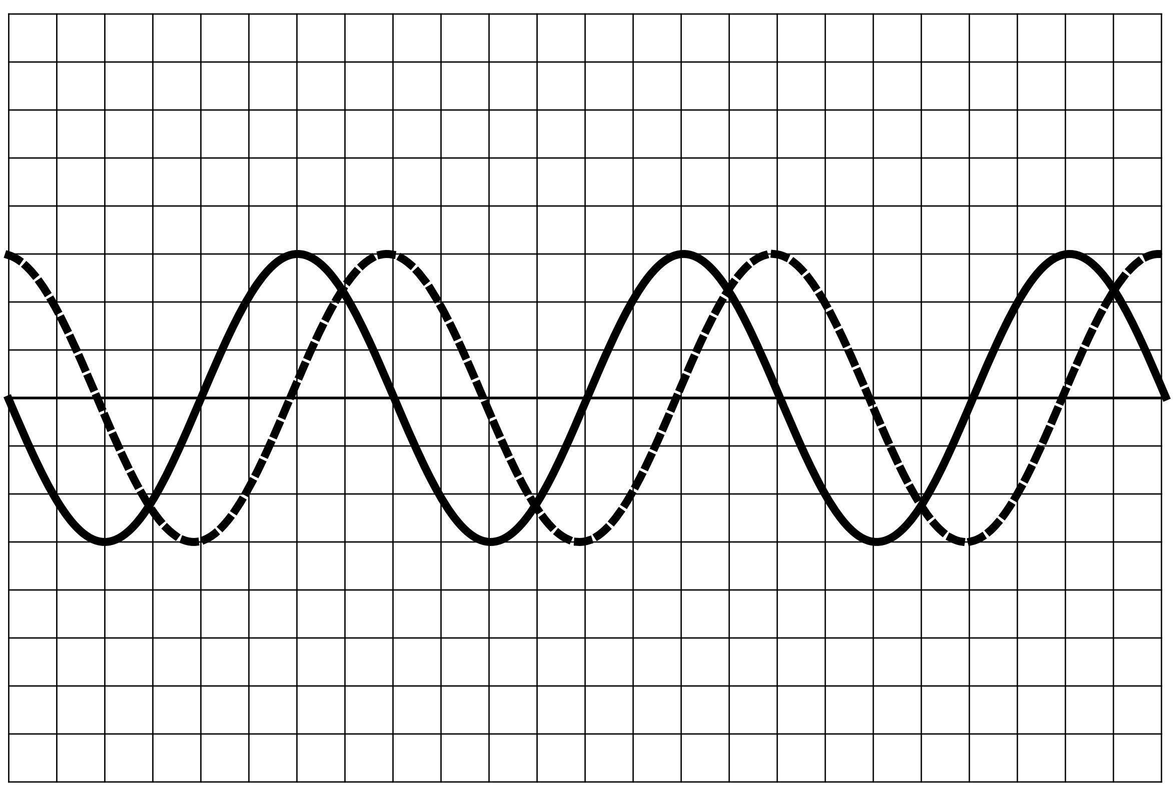


Wave Addition

1. Find the sum of the two waves shown.

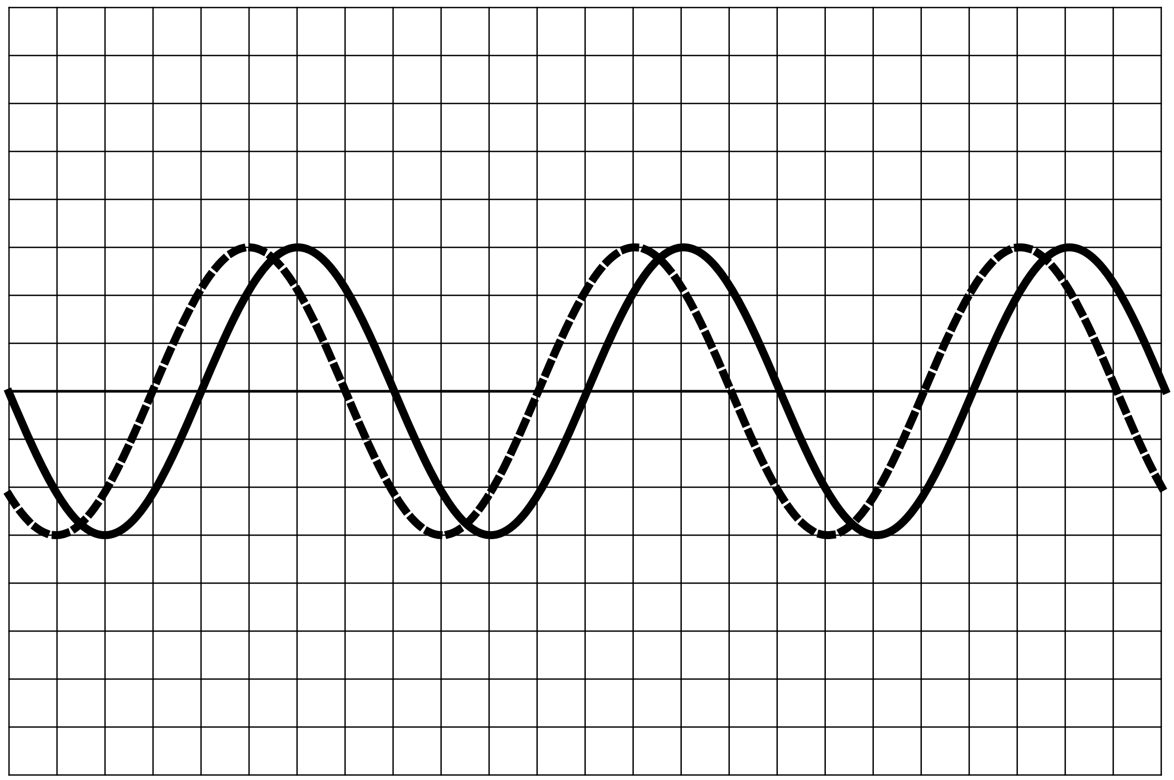


2. Find the sum of the two waves shown.

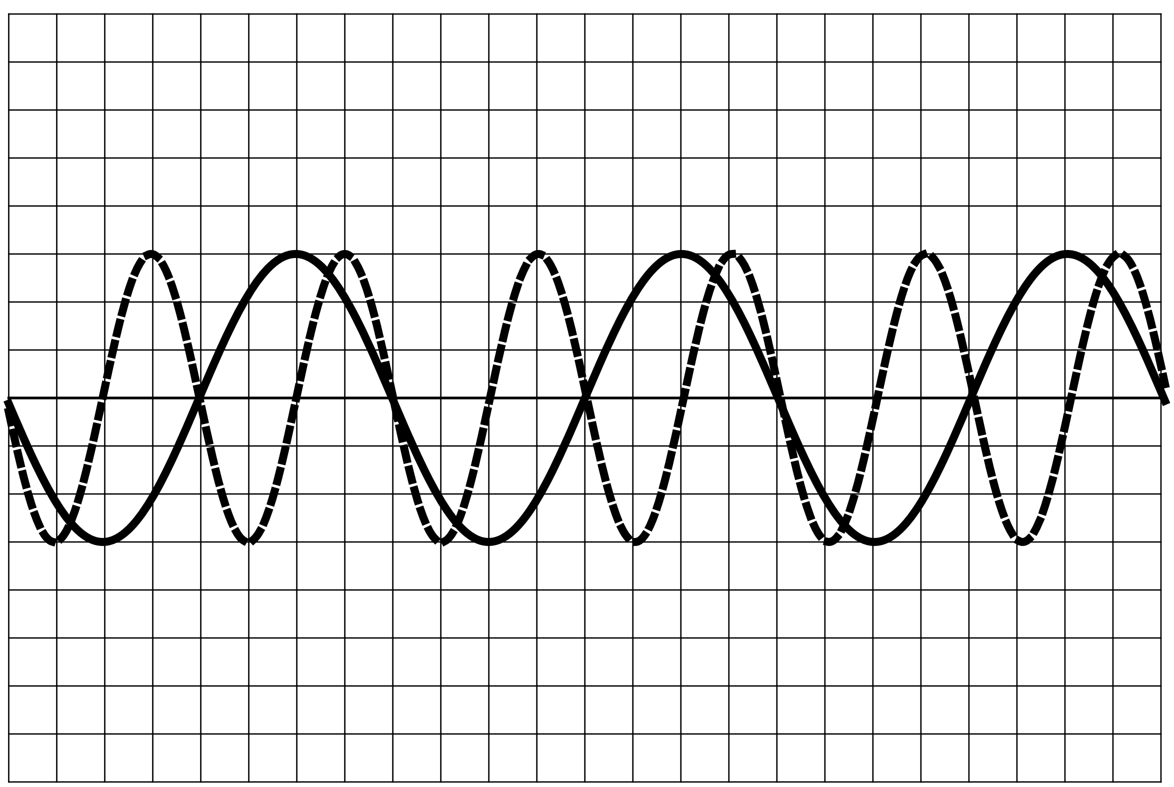


Wave Addition

3. Find the sum of the two waves shown.



4. Find the sum of the two waves shown.



Wave Problems I

What is the equation that relates *frequency* (f) and *period* (T) for a wave?

What is the equation that relates the *speed* of a wave (v) to its *wavelength* (λ) and *frequency* (f) ?

Frequency and Period

1. A certain wave has a period of 3 seconds. What is its frequency?

2. A wave has a frequency of 10 Hertz. What is its period?

3. A mass on a spring is going up and down with a frequency of 0.5 Hertz. How long does it take to go up and down once?

4. A mass on a spring goes up and down 4 times every second.
   a. How long does it take the mass to go up an down once?

   b. What is the frequency of the mass going up and down?

5. You are sitting in a boat while waves go by. You bob up and down once every 5 seconds.
   a. What is the period of the waves?

   b. What is the frequency of the waves?

Speed, Wavelength & Frequency

6. Two students are shaking a rubber hose with a frequency of 2 Hertz (cycles per second). The speed of a wave in the hose is 3 m/s. What is the wavelength of the resulting wave?

7. Some students are shaking a slinky. The waves they are making are 2.5 meters long and the speed of the wave is 4 m/s. What is the frequency of the waves?

Wave Problems I

8. An ocean wave has a wavelength of 6 meters and a frequency of 1/2 Hertz. How fast is the wave traveling?

9. The speed of sound is 340 m/s. If someone were to play a C note (f = 261 Hz.) on a guitar, how long a sound wave would be created?

10. Someone is doing an experiment sending waves in a tube filled with some gas. They send waves with a frequency of 200 Hz, and measure the wavelengths to be 12 meters long. How fast do the waves travel in the gas?

11. Waves travel in a steel pipe at about 5000 m/s.
    a. How long would a wave be if it had a frequency of 300 Hz?

    b. What frequency would a wave have if it had a wavelength of 3.2 meters?

Everything

12. You are on a boat in the ocean during a wicked storm. There are huge waves rolling under the boat, and you are going up and down once every 7 seconds. You notice that the waves are 25 meters from crest to crest. How fast are the waves traveling in the water?

13. Two students are standing exactly 7 meters apart and they are each shaking a slinky. There are exactly 4 whole waves between the two students. They are shaking the slinky with a frequency of 3 Hz. How fast are the waves traveling in the slinky?

14. The speed of wave in a slinky is 1.75 m/s. The slinky is stretched between two students so that it is 5 meters long. At what frequency should the slinky be shaken, so that there is exactly two whole wave between the students?

Answers: 1) 1/3 Hz 2) 1/10 s 3) 2 s 4. a) 0.25 s b) 4 Hz 5. a) 5 s b) 0.2 Hz 6) 1.5 m 7) 1.6 Hz 8) 3 m/s 9) 1.3 m 10) 2400 m/s 11. a) 16.7 m b) 1563 Hz 12) 3.57 m/s 13) 5.25 m/s 14) 0.70 Hz

Lab 7-2: Ripple Tank Observations

Purpose: To make observations of wave phenomenon in a ripple tank.

Procedure: The ripple tank is already set up; just turn on the light. There should be nothing in the water at the start of the lab. You will be asked to make a series of observations. **Do your best to describe what you see and use diagrams.** It will generally be much easier to make observations by looking at the white paper underneath the ripple tank than by looking at the water directly. (Note: Whenever the water above the paper forms a crest**,** it will act like a magnifying glass and create a bright spot on the paper underneath. Conversely, wherever the water forms a trough**,** it will act like a diverging lens and create a dark spot on the paper underneath.)

I. Wave Pulses

1. Create a wave pulse by briefly touching the surface of the water with your finger. Describe what you see. (Note the speed and shape of the pulse as it travels.)

2. Place a wooden dowel in the water. Create a wave pulse by lightly tapping the dowel. Describe what you see. (Note the speed and shape of the pulse as it travels.)

II. Reflections

3. Using the wooden blocks, make a barrier in the ripple tank so that you can see its shadow on the paper below. Send a straight wave pulse into the barrier head-on. Describe what you see. (Note the speed, shape and direction of the pulse as it travels and reflects.)

4. Repeat step 3 several times. In each case, change the angle at which the pulse strikes the barrier. How does the ***angle of incidence*** compare to the ***angle of reflection****?* Describe what you see. (Also note the speed and shape of the pulse as it travels and reflects.)

5. Create a circular wave pulse with your finger and observe the reflections**.** Describe what you see. (Note the speed, shape and direction of the pulse as it travels and reflects. From where does the reflected wave seem to be originating?)

6. Remove the wooden blocks from the water. Create a straight wave pulse and observe its reflection off the edge of the ripple tank. Describe what you see. (Note the speed and shape of the pulse after it reflects off the side of the tank.)

7. Find the point where the reflected waves from step 6 meet. (This is the ***focus*.**) Create a circular wave at this point. Describe what you see. (Note the speed and shape of the pulse after it reflects.)

Lab 7-2: **Ripple Tank Observations**

III. Continuous Waves

For these observations, turn on the wave generator by plugging it in. You get pretty decent results by keeping the frequency between 10 and 20, and keeping the amplitude pretty small. Start off with the plane wave generator, which has the plastic bar attached to it. You may have to adjust the height of the wave generator so that the it does not touch the glass bottom of the ripple tank.

8. Adjust the frequency of the motor. What effect does increasing the ***frequency*** of the waves have on the ***wavelength*** of the wave? How about the ***speed*** of the wave?

9. Place some wooden blocks a few centimeters from the wave generator. Adjust the frequency so that you create ***standing waves*** in between the generator and the block. (Standing waves do not seem to be moving. Standing waves are created when a continuous stream of waves is traveling in one direction, while at the same time, there is another stream of waves traveling in the opposite direction. Two waves that are in the same place at the same time are said to ***interfere*** with each other. If they are out of phase, they will ***destructively interfere***. If they are in phase, they will ***constructively interfere***.) How does the wavelength of the standing wave compare with the wavelength of the wave traveling past the barrier?

10. Using the same set up as in step 9, note what happens to the wave fronts as they go past the blocks. Look behind the blocks. Describe what you see. (It is called ***diffraction.***)

11. Place wooden blocks across the tank until they reach from side to side with a small opening (about 1 to 2 cm) in the middle. Using the wave generator, send straight waves into the barrier. How does the straight wave pattern change as it passes through the opening? What phenomenon is occurring?

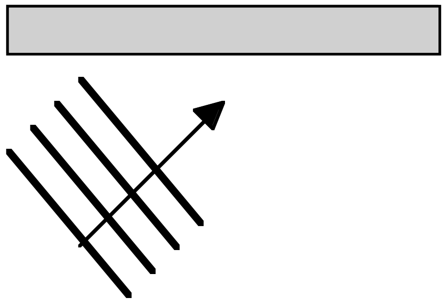
12. Modify your barrier so that there are two openings separated from each other by about 4 cm near the center and repeat what you did in step 11. Describe and draw what you see. What two phenomenon are occurring?

13. Remove the blocks and put the two point sources on the wave generator (about 4 cm apart, if you have a choice.) Turn on the wave generator. Circular waves from these two point sources will move out in all directions. You will see on the white paper only the circles moving in one direction because of the way it is illuminated. Watch them constructively interfere and destructively interfere. Describe and draw what you see. Mark the sites where ***nodes*** and ***antinodes*** exist.

Ripple Tank Observation Notes

Part II: Reflections

3 & 4.



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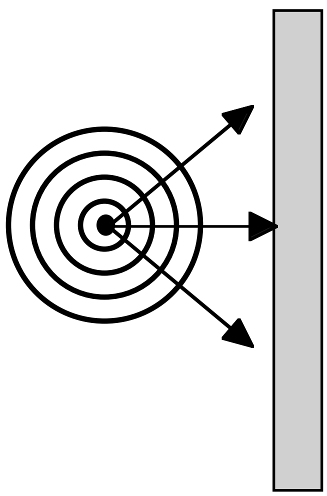

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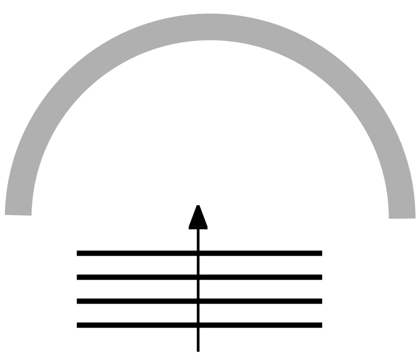

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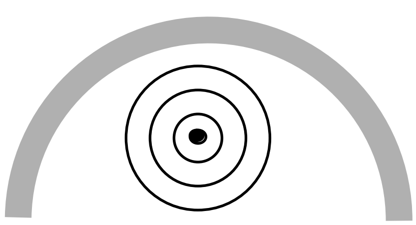
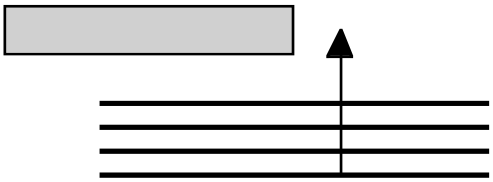


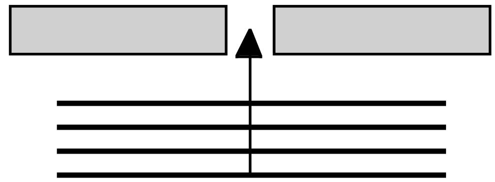
Ripple Tank Observation Notes

Part III: Continuous Waves

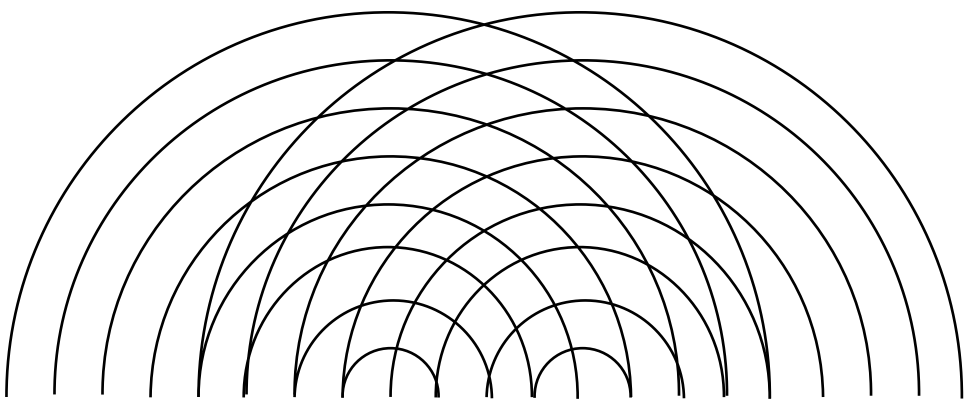
10.



11.



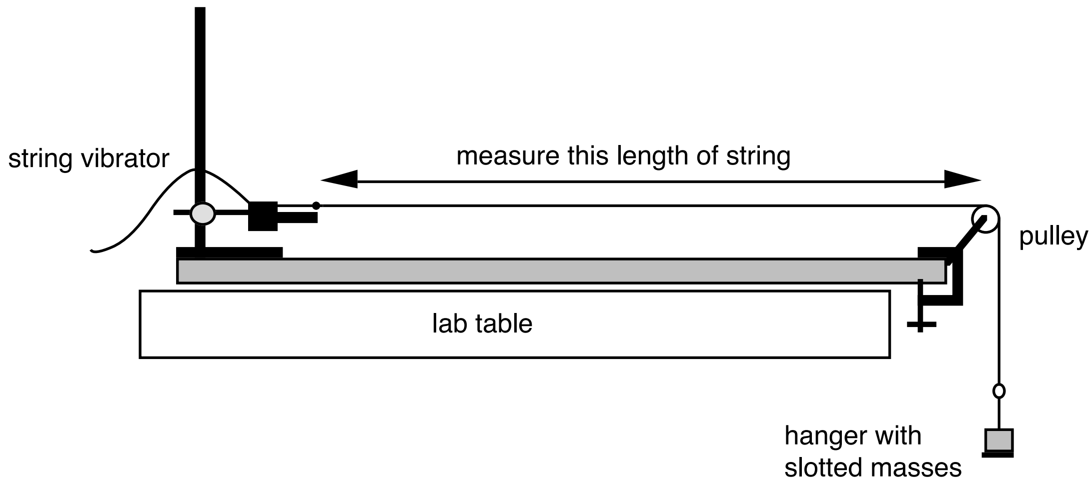
12 & 13.



Lab 7-3: Standing Waves in a String

Purpose: 1. To examine standing waves created in a string as waves interfere with each other as they **reflect** back and forth. (You have seen a standing wave generated in a slinky.) Identify nodes and antinodes
2. To determine the relationship between the tension in a string and the speed of a wave in that string.

Diagram:



Procedure:

1. Set up the apparatus as shown in the diagram. Adjust everything so that there is 1 meter of string from the vibrator to the pulley. **Your teacher will tell you how much mass to hang at the start.**

2. Turn on the string vibrator. You will hear it making some noise. It will be forcing the string to vibrate at 60 Hertz.

3. Increase the tension in the string by adding masses to the those already on the hanger until you get a standing wave in the string *without* a node in the middle. You should see exactly half a wave in the string; the ends of the string are nodes and the middle of the string will be an anti node. Record the total mass suspended. (Remember to include the mass of the hanger.)

4. Decrease the tension in the string by removing some of the suspended mass until you get a node in the middle of the string. You should then see a standing wave with a whole wave fitting in the string. Record the total mass suspended.

5. Decrease the tension until there are two and then finally three nodes in the string. Each time, record the total mass that is suspended.

6. Adjust the tension to get *one* node in the middle again. Carefully unclamp the stand holding the string vibrator. Slowly slide the stand towards the pulley. The standing wave will disappear, and then reappear. When a standing wave reappears in the string, record the number of nodes you see, and also the length of the string.

Data:

Trial	*# Nodes*	*Frequency (Hz)*	*Total Mass (kg)*	*String Length (m)*
1	0	60		1
2	1	60		1
3	2	60		1
4	3	60		1
5		60		

Lab 7-3: **Standing Waves in a String**

Results:

Trial	*# Waves*	*Frequency (Hz)*	*Tension (N)*	*Wave Length (m)*	*Wave Speed (m/s)*
1		60			
2		60			
3		60			
4		60			
5		60			

Calculations:

1. For each trial, calculate the **tension** in the string. Show your calculations here and record your results in the Results table.

2. For each trial, draw a picture of the standing wave.
   a. 0 nodes
   b. 1 node
   c. 2 nodes
   d. 3 nodes

3. For each trial, calculate the **wavelength** of the standing wave. Show your calculations here and record your results in the Results table.

4. For each trial, calculate the **speed** of the wave in the string. Show your calculations here and record your results in the Results table.

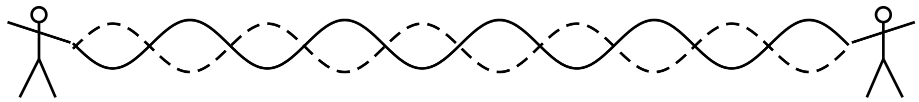
Conclusion:

1. What is the relationship between the *speed* of a wave in a string and the *tension* in the string?

2. For the last trial, what happened when you shortened the length of the string? Why?

3. Suppose you had an identical string *2* meters long. You adjust the tension in the string until it equals the tension you had in your first trial. What would be the speed of the wave? Draw what the string would look like, clearly indicating where nodes would exist.

Standing Wave Problems



1. Two students are 10 meters apart and shaking a slinky between them. They create a standing wave with a frequency of 3 Hz, as shown in the picture above.
   a. How many nodes are in the standing wave? (Don't include the ends.)

   b. What is the wavelength of the wave?

   c. How fast is the wave traveling?

   d. If they wanted to have fewer nodes in the slinky, what are three things they could do?

   e. If they wanted to have more nodes in the slinky, what are three things they could do?

2. There is a standing wave in a string that is 1 meter long. There are exactly 3 nodes in the string. The waves travel with a speed of 45 m/s.
   a. Draw a picture of the string.

   b. What is the wavelength of the wave?

   c. What is the frequency of the wave?

3. There is a standing wave between two people. The wave has a speed of 340 m/s, a frequency of 800 Hz and there are 5 nodes between the two people.
   a. What is the wavelength of the wave?

   b. How many waves are between the two people?

   c. How far apart are the two people?

Answers: *1. a) 9 b) 2 m c) 6 m/s d) Increase tension, decrease frequency, stand closer*
2. a) 2 b) 1/2 m c) 90 Hz 3. a) 0.425 m b) 3 c) 1.275 m