NAME_________________________________ DATE_______________

Lab 8: Waves and Sound

Pathway Essentials of Physics: PHYS 101

We are literally awash in waves every day. Standing in a crowded room, sound waves travel to our ears from many different sources, and many of those bounce off of the walls, ceiling and floor on the way. Standing alone in a field outdoors, electromagnetic waves in the form of sunlight, invisible infrared (IR), ultraviolet (uV), cosmic rays, radio and TV transmissions, and naturally-occurring very-low frequency (VLF) waves bombard us. But just what is a wave? Does it involve the transport of matter, or energy? How can information be carried in a wave? How fast can a wave (and its information) travel?

In Experiment One you will investigate some of the characteristics of waves—wavelength, period, frequency and velocity, and how they are related to one another. For Experiment Two you will also explore some of the peculiarities of sound waves.

Experiment One: ***Have a thinky about the slinky***

Part A Introduction:

All waves in nature travel at some speed. During a thunderstorm, the difference between seeing the flash of lightening and hearing it, in seconds, can be used to approximate how far away the lightening occurred (count the number of seconds between flash and thunder, divide by 3 to get distance away in km, divide by 5 to get miles). This is because sound waves travel at a much slower speed than do light waves emitted from lightening. The light waves tell us when to start counting and our knowledge of the speed of sound in air tells us the distant to the source.

A water wave travels at a different, but fixed speed. If you sit in one place in a boat after the neighborhood speedboat bully has zoomed by, you will bob up and down so many times in a minute, depending on the distance between successive waves. How many times you bob per second defines the wave's *frequency*.

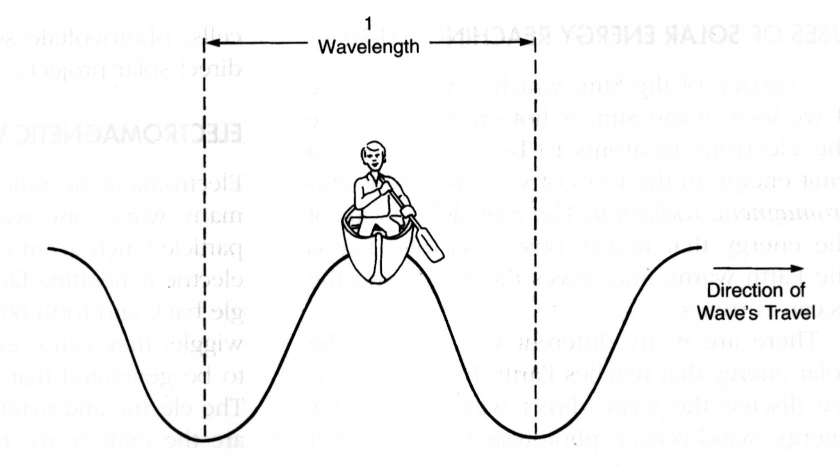

Figure 1: The wavelength is the distance between wave troughs (or peaks). Frequency is the number of bobs per second (looks like tough paddling!)

Question: Given a fixed *wave speed*, what would happen to your "bob frequency" if the distance between successive wave troughs (*wavelength,* see above) was doubled? Choose one of the three possibly correct hypotheses given below and indicate your reasons for choosing it below it.

Hypothesis One: The bob frequency would stay the same.

Hypothesis Two: The bob frequency would be doubled.

Hypothesis Three: The bob frequency" would be halved.

Checkpoint: Have a lab instructor check your hypothesis before proceeding with the lab.

For Part A of Experiment One you will be using a stretched slinky to model a water wave. You can time the speed of a slinky wave (exercise 1) and excite a *standing half wave* (one where half the wave just fits in the length of the slinky) to determine the frequency and wavelength (exercise 2).

Part A, Exercise 1 Procedure:

1. Attached to the leg of a lab table you will find a slinky and some pieces of tape on the floor (see Figure 2, below). The pieces of tape are positioned 0.5, 1, and 2 meters away from the table leg.
2. Stretch the loose end of the slinky so that the stretched slinky is 1m long. For this lab exercise, one group member can be responsible for wiggling the slinky, one can operate the stopwatch and one can record times.
3. The figure, below, shows how to initiate a *transverse wave pulse* (see definitions at end of lab) on the slinky. The "slinky operator" should displace the free end of the slinky as shown and be ready to quickly wiggle the slinky end back and forth, once, at the command of the timer.
4. The timer can say go, and start the stopwatch while the operator "pulses" the slinky. The pulse will travel **<u>to the table leg and back to the free end</u>**. The timer should record how long this takes.

5. Do this 3 or 4 times and average the recorded times. Record the average time in the table on the next page.

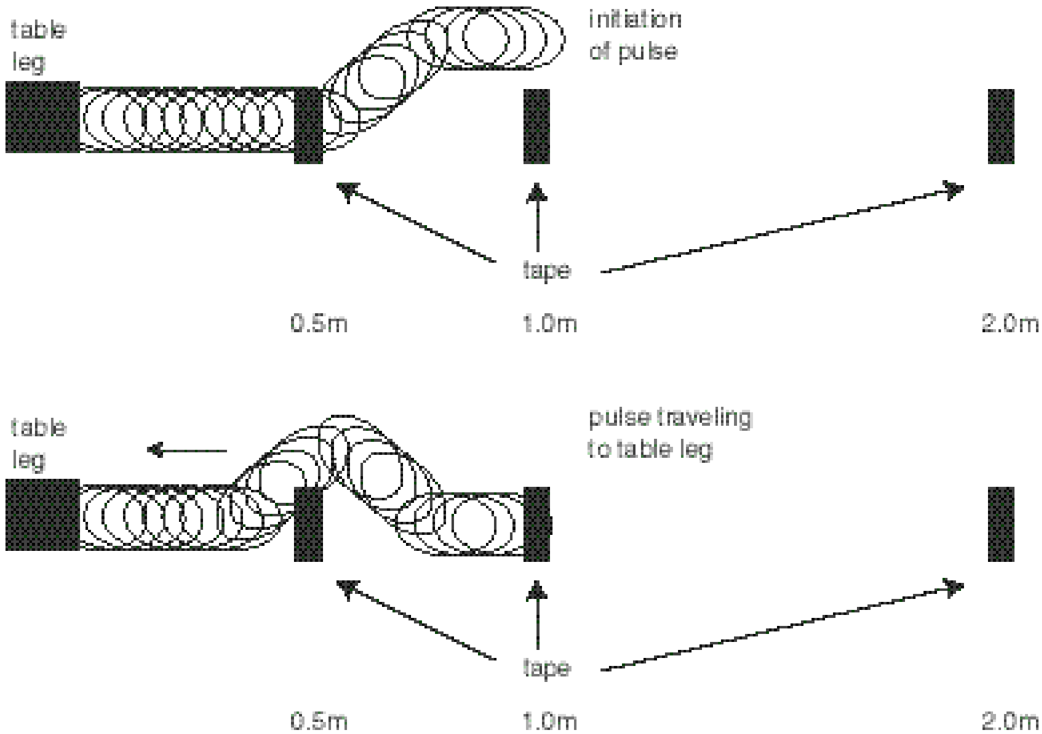

Figure 2

Part A, Exercise 1 Observations:

Data Table: Exercise 1, Part A, Experiment One

Average pulse travel time (s)	Distance pulse traveled (m)	Pulse speed (m/s)	Pulse reflection observations
	2 m (why?)		

Part A, Exercise 1 Questions/Calculations:

1. Use the formula for speed to calculate the wave (pulse) speed for the stretched slinky. Record your result in the table, above. Show your calculations below.

2. Pulse the slinky again and observe what happens to the pulse when it reflects off the table leg. Record your observations in the table above. If your initial pulse was to the right, what direction was the initial movement of the pulse <u>just after</u> it reflected?

3. Did the wave pulse travelling down the slinky involve transport of material down and up the slinky? Explain.

Part A, Exercise 2 Procedure:

1. Again stretch the slinky so that it is 1m long.
2. Have the "slinky operator" practice wiggling the slinky back and forth continuously. Wiggle the slinky mostly by bending your hand at the wrist, so the angle between the slinky where it meets your hand is continuously changing. The operator will need to adjust how fast they wiggle so that the following wave shape is achieved.

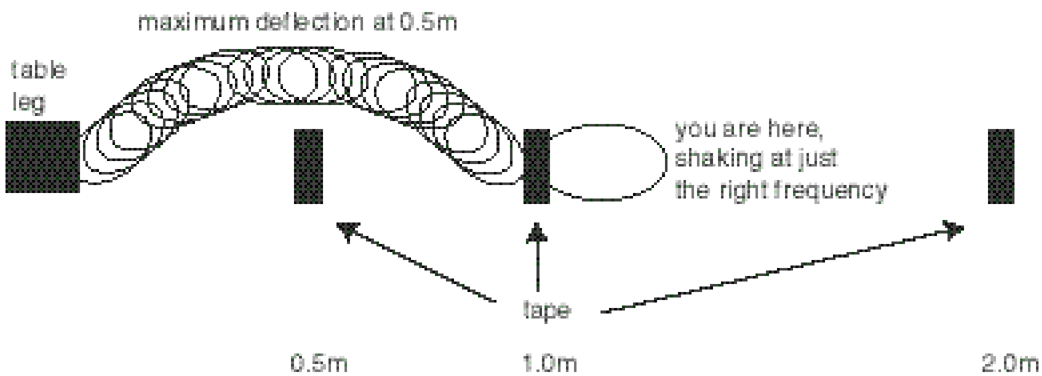

Figure 3

3. When wiggled appropriately, the slinky should maximally deflect at the 0.5m mark.
4. While the operator is wiggling, the timer should time how long it takes 10 complete wiggles (nearest 1/2 of slinky moves to right 10 times).
5. Timer and recorder repeat step 4) 3 or 4 times and average the recorded times. Divide the average time by 10 and record in the table, below.

Part A, Exercise 2 Observations:

Data Table: Exercise 2, Part A, Experiment One

Average time per one cycle (s)	Frequency of standing wave (Hz)	Wavelength of standing full wave (m)	Frequency • wavelength (m/s)	Wave speed (m/s) (from exercise 1)
		2 m*		

* *If you chose to excite a full wavelength standing wave as opposed to what's shown above (1/2 wavelength standing wave), your wavelength will be different.*

Part A, Exercise 2 Questions/Calculations:

1. The average time for the slinky wave to complete a cycle is called the *period*. The waves frequency is related to its period by the following formula:

Frequency = 1 / Period

Calculate the frequency of the standing full wave and record it in the table, above.

2. Multiply the frequency of the standing full wave by its wavelength and record above.
3. Fill in the wave speed from Exercise 1. Question: How do the wave speed and the frequency multiplied by the wavelength (last two columns) compare? Can you state in words a possible relationship between the slinky wave's speed, its frequency and its wavelength?

4. Use your rule (relationship) stated in 3, above, to predict what will happen to the frequency of a slinky wave when the wavelength is doubled while the wave speed is fixed. Does this prediction agree with the hypothesis you chose on page 2?

Part B Introduction:

What causes a wave to travel through air or water, even when the material itself is not transported along with the wave? Sound waves in air involve the compression and rarefaction of air molecules— the air molecules at one place are alternately pushed together and pulled apart as the air wave passes by. Waves travelling along a slinky are supported by the push and pull of the slinky acting as a spring. When the slinky is displaced, its "springiness" (called the *restoring force*) makes it want to return to normal. In addition, the *mass density* (mass per unit length) of the material supporting the wave is usually important. That is why sound waves travel slower in helium… and a person's voice sounds funny after breathing a lungfull of the stuff.

Question: If we stretch the slinky from 1m to 2m, we will undoubtedly affect the forces making the slinky want to return to normal. What about its mass density. Does it change? How do you think this will affect the speed of waves (pulses) travelling along the slinky? Select which hypothesis you agree with, below, and complete the hypothesis of choice:

Hypothesis One: The wave speed will decrease because …

Hypothesis Two: The wave speed will stay the same because…

Hypothesis Three: The wave speed will increase because…

The following two exercises are identical in nature to those followed in Part A, except the slinky is stretched to 2m total length for this part of the experiment.

Part B, Exercise 1 Procedure:

1. Stretch the loose end of the slinky so that the stretched slinky is 2m long. Again appoint a slinky operator, a timer and a recorder.
2. The timer can say go, and start the stopwatch while the operator "pulses" the slinky. The pulse will travel to the table leg and bounce back to the free end. See figure 2, above, for ideas. The timer should record how long this takes.
3. Again, do this 3 or 4 times and average the recorded times. Record the average time in the table, below.

Part B, Exercise 1 Observations:

Data Table: Exercise 1, Part B, Experiment One

Average pulse travel time (s)	Distance pulse traveled (m)	Pulse speed (m/s)	Pulse reflection observations
	4 m (why?)		

Part B, Exercise 1 Questions/Calculations:

1. Use the formula for speed to calculate the wave (pulse) speed for the stretched slinky. Record your result in the table, above. Show your calculations below.

2. Did the wave speed change? If so, how? Did this agree with the hypothesis you selected?

3. What do you think will happen to the frequency of a standing wave for the 2m long slinky? Will the frequency stay the same? Double? Halve? Why?

Part B, Exercise 2: You can wiggle the slinky, make a 2m long standing half-wave, and experimentally determine the frequency of the wave.

Part B, Exercise 2 Procedure:

1. Stretch the slinky so that it is 2m long.
2. Again, have the "slinky operator" practice wiggling the slinky back and forth continuously. The operator will need to adjust how fast they wiggle so that the wave shape used in Part A is, again, achieved.
3. When wiggled appropriately, the slinky should have a maximum deflection at the 1m mark.
4. While the operator is wiggling, the timer should time how long it takes 10 complete wiggles (nearest 1/2 of slinky moves to right 10 times). See figure 3, above, for ideas. Write down this time.
5. Timer and recorder repeat step 4) 3 or 4 times and average the recorded times. Divide the average time by 10 and record in the table, below.

Part B, Exercise 2 Observations:

Data Table: Exercise 2, Part B, Experiment One

Average time per one cycle (s)	Frequency of standing wave (Hz)	Wavelength of standing full wave (m)	Frequency • wavelength (m/s)	Wave speed (m/s) (from exercise 1)
		4 m*		

* *If you chose to excite a full wavelength standing wave as opposed to what's shown in Figure 3 (1/2 wavelength standing wave, but over 2m now), your wavelength will be different.*

Part B, Exercise 2 Questions/Calculations:

1. Calculate the frequency of the standing wave and record it in the table, above.
2. Multiply the frequency of the standing full wave by its wavelength and record above.
3. Did the observed frequency of the 2m standing wave agree with your answer to question 3, for Exercise 1 (page 6)? Explain.
4. How do the wave speed and the frequency multiplied by the wavelength (columns 4 & 5) for this exercise compare?
5. Compare wave speed to that from Exercise 1.

Part C Introduction:

For Part B you observed what happened to the wave speed and the frequency of a standing wave when the slinky was stretched to double in length. Stretching the slinky resulted in reducing its mass density and increasing its "springiness." Perhaps surprisingly, though, the frequency of the standing wave didn't change appreciably, even though the wave speed clearly increased. What would happen if, instead, you stretched the slinky without changing its length?

Question: We can stretch the slinky without changing its length by using only half the slinky. If we bunch half the slinky together and stretch the remaining half to 1m, we can approximately double the wave speed. What will happen to the frequency of a standing wave? Use the relationship you found in Part A, and any hypotheses confirmed in Part A and B to make a specific prediction.

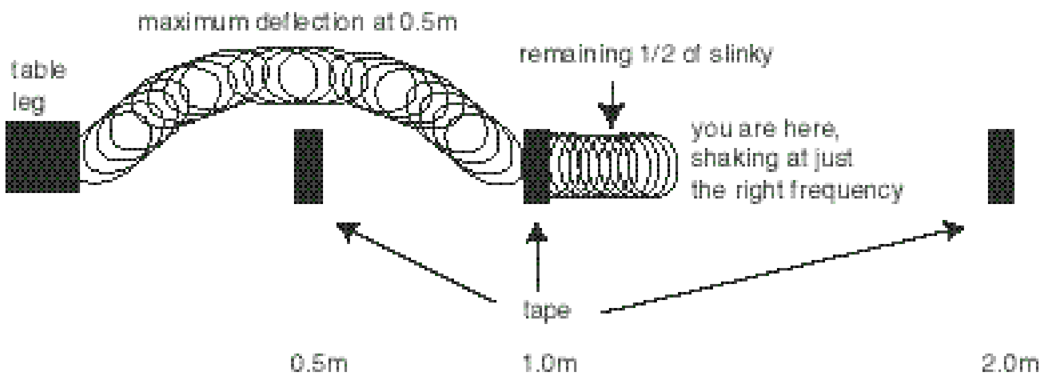

Figure 4

Prediction: If I double the wave speed while keeping the wavelength the same, the frequency of the standing wave will _____________. Explain your choice in terms of experiment results from Parts A & B, above.

Checkpoint: Have a lab instructor check your prediction and reasoning before proceeding.

Procedure:

1. Stretch the slinky so that it is 1m long, with 1/2 the slinky held together as a bunch.
2. Again, have the "slinky operator" practice wiggling the slinky back and forth continuously. The operator will need to adjust how fast they wiggle so that the wave shape used in Part A is, again, achieved.
3. When wiggled appropriately, the slinky should remain fairly still at the 0.5m mark.
4. While the operator is wiggling, the timer should time how long it takes 10 complete wiggles (nearest 1/2 of slinky moves to right 10 times). Write down this time.
5. Timer and recorder repeat step 4) 3 or 4 times and average the recorded times. Divide the average time by 10 and record in the table, below.

Observations:

Data Table: Exercise 2, Part C

Average time per one cycle (s)	Frequency of standing wave (Hz)	Wavelength of standing full wave (m)	Frequency • wavelength (m/s)	Wave speed (m/s) (from exercise 1)
		2 m *		

* *If you chose to excite a full wavelength standing wave as opposed to what's shown in Figure 4 (1/2 wavelength standing wave), your wavelength will be different.*

Questions/Calculations:

6. Calculate the frequency of the standing wave and record it in the table, above.
7. Multiply the frequency of the standing full wave by its wavelength and record above.
8. Did the observed frequency match your prediction, above? If so, how? If not, why not?

9. A guitar string is tuned by stretching or unstretching it. In tuning the string, which characteristics (velocity, wavelength, frequency, period) are changed and which are not? Explain how you know this.

Experiment 2: *The sound of muzak!*

Introduction:

In Part B of experiment 1 it was stated that sound waves in air involve the compression and rarefaction of air molecules— the air molecules at one place are alternately pushed together and pulled apart as the air wave passes by.

If we could somehow see the individual air molecules in an otherwise quiet room as a sound wave traveled from a sound source, this is what they might look like at two different instances in time.

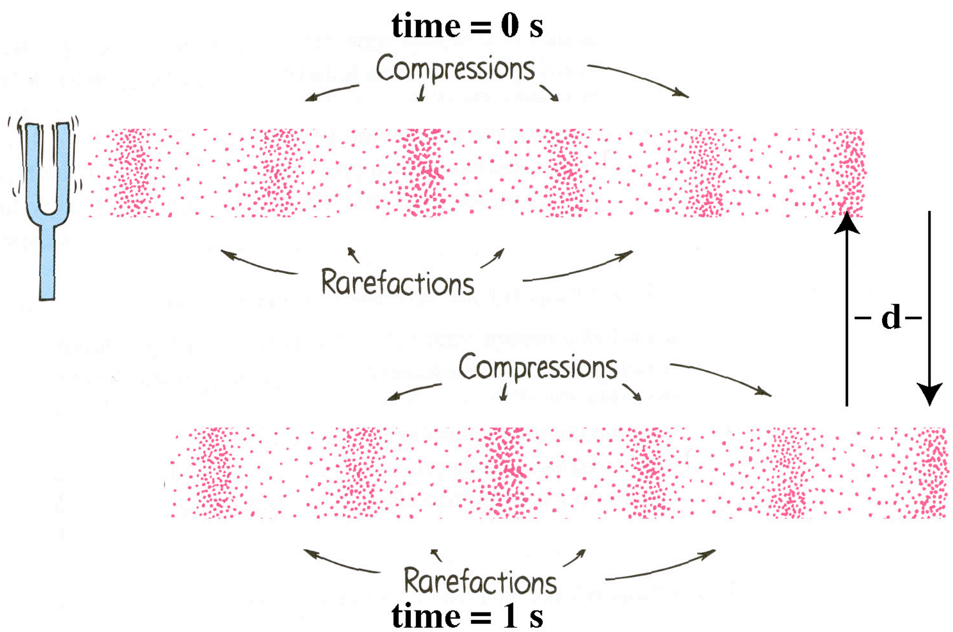

Figure 5

The distance that a group of compressed air molecules (a particular compression) travels in time, d in the above figure, divided by the time it took to travel (noted as 1s, above), would give the speed of this particular sound wave.

We can “look” at sound waves by observing their effect upon a microphone hooked up to an oscilloscope. When a compression or rarefaction passes by, a voltage difference is created by the microphone, and we can use the oscilloscope or computer to observe this AC voltage.

Part A Question: Given a microphone and a source for sound waves, what can you directly characterize (frequency, wavelength, wave speed, period, amplitude) about the sounds you record?

Checkpoint: Have a lab instructor ask you about your answers before proceeding.

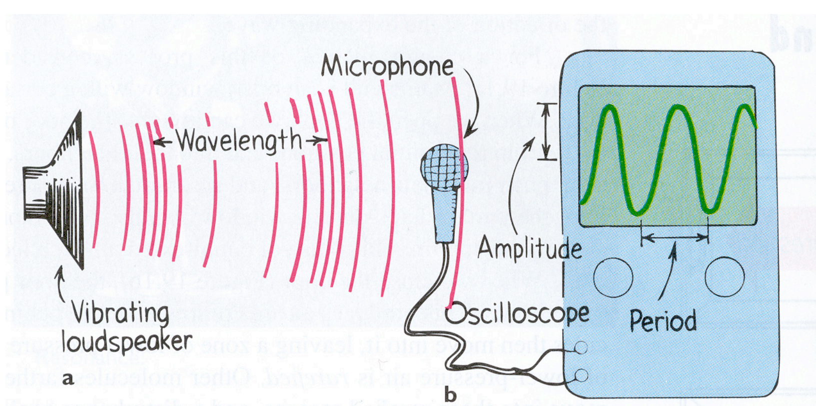

Figure 6

Part A Procedure:

You have at your disposal a Casio keyboard (sound source), a microphone, and an computer set up to monitor the signal from the microphone. After examining these apparatus, design an experiment to characterize sounds you make (using the keyboard or with your voice). In particular, plan to characterize the choices you made under Part A Question, above (e.g., frequency, wavelength, wave speed, period, amplitude).

Summarize the procedures you will follow below. For each procedure make sure to describe which variable you are characterizing and make clear how you will keep all other variables as constant as possible. Draw your experimental setup and, if needed, what you think the oscilloscope display will look like for each procedure.

For each procedure you design, then, record your observations below your description of the procedure. Draw pictures representing the oscilloscope display for each procedure.

Conclude with a short analysis of the results of the procedure. <u>Describe in words and with pictures (or labels) what you observed, whether and how the variable(s) in question were characterized, and what findings from Experiment 1 support your analysis.</u>

Procedure 1: variable examined_____________________

Observations 1:

Analysis 1:

Procedure 2: (as needed) variable examined_____________________

Observations 2:

Analysis 2:

Procedure 3: (as needed) variable examined______________________

Observations 3:

Analysis 3:

Definitions:

Name	**Symbol**	**Definition**	**Formula**
wavelength	λ (m)	Distance between successive peaks or troughs of a wave at a given instant in time.	
period	T (s)	Time between successive peaks or troughs of a wave at a given position.	

frequency	f (Hz)	Number of waves passing a given position each second.	$f = 1 / T$
wave speed	v (m/s)	Speed at which waves travel.	$v = f \cdot \lambda$
Transport media		Medium (air, water, string, slinky) that supports waves. Note that electromagnetic waves (light, radio waves, uV, IR, etc) don't require a transport media.	
Transverse wave		A wave that looks like the wave in Figure 2. The displacement of the media (e.g., slinky) is perpendicular to the direction the wave travels	
Longitudinal wave		A wave that looks like Figure 5. The short-range motion of the media (e.g., compression of air) is in the direction the wave is traveling.	
Restoring force	F_R (Newtons)	The force that acts to restore the transport media to its original state. Example: Tension on a stretched slinky	
mass density	μ (kg/m), ρ (kg/m^3)	For strings, slinkys, etc., the mass per unit length. For air, the density (mass per unit volume)..In general, that which opposes displacement when waves are passing through.	