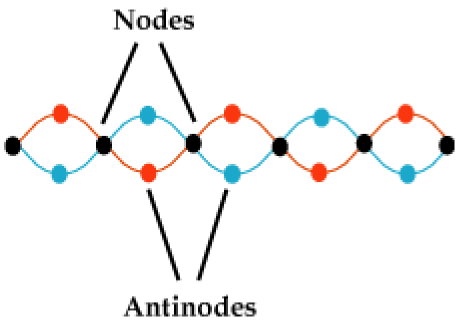
Measuring the Speed of Light

Objective: Calculate the speed of light.

Equipment: microwave, a ruler, chocolate chips, graham crackers, and marshmallows.

How it works: When you turn on your microwave oven, electrical circuits inside start generating microwaves – electromagnetic waves with frequencies around 2.5 gigahertz – 2500000000 Hz. These waves bounce back and forth between the walls of the oven, the size of which is chosen so that the peaks and troughs of the reflected waves line up with the incoming waves and form a “standing wave”. The vibrations are in “the electromagnetic field”. Where the vibrations are greatest (the anti nodes), you will see the greatest heating, but at the nodes, the chocolate will only melt slowly as heat diffuses into those areas. Thus, the distance between the melted regions (x) is equal to the distance between the antinodes of the standing wave, and equal to half the wavelength (λ)!



So, the detailed calculation to find the speed of light (c) is:

$c=\lambda*f$

Procedure:

1. Remove the turntable from the microwave. Place a single line of chocolate chips on graham crackers on a plate (so the plate does not rotate), and heat until chocolate chips just start to melt - about 20 seconds, depending on the power of the oven.
2. There will be some melted hot spots and some cold solid spots in the chocolate. Measure the distance between the melted spots (antinodes) and place in the table below.
3. Look up the frequency of the microwave on the back of the oven and put in the table below.
4. Make a delicious snack, don’t forget the marshmallows!
5. Perform the necessary calculations to fill out the results in the table below. Show all work!

Data and Results:

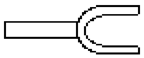
Distance between melted spots (m)	Wavelength (m)	Frequency of microwave (Hz)	Measured speed of microwave/light (m/s)	% error:

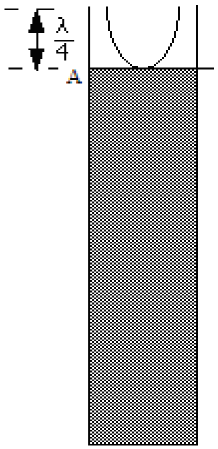
Velocity of Sound in Air

Purpose: To measure velocity of sound in air through resonance wavelength and frequency.

Materials: Water level adjustable resonance tube, 3 tuning forks with frequencies that vary by ~100 Hz

Background: The velocity of sound in air can be found by measuring the wavelength of the sound wave of a known frequency. Standing waves can be produced in a resonance tube. The tube is partially filled with water and is connected to a water reservoir. The water level can be raised or lowered by adjusting the height of the reservoir. Striking a tuning fork with a rubber hammer and placing it over the resonance tube while lowering the water level can determine wavelength.





1st. resonance condition

Procedure:

1. Fill the tube nearly full of water. Strike one of the tuning forks with the sole of your shoe and hold it above the water column. Caution: do not touch the tube with the tuning fork - the rapidly moving fork can break the plastic.

2. Test trial: Using the moveable water reservoir, lower the water surface slowly. Listen for amplification of the tone (a resonance is found, and a pronounced reinforcement of the sound is heard) and watch for the water level where the amplification occurs.

3. Repeat step 2, lowering the water even slower when approaching the resonance water level. Record ¼ λ (distance from top to water).

4. For each of the other 2 tuning forks, repeat steps 1-3.

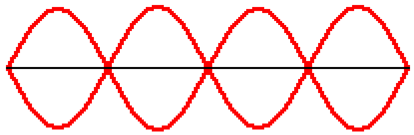
5. Calculate the wavelength, velocity of each wave, average velocity, and percent error and record in the table. Assume the correct value for the speed of sound is 340. m/s.

Tuning Fork Frequency (Hz)	**¼ λ**	**λ**	**v**
Average velocity:			
% Error:			

Determining the Speed of a Wave on a String

Introduction

In this lab you will determine the wave speed in a string by producing a standing wave pattern on a string and measuring the length between nodes and the frequency. After you determine the wavelength of the standing waves you will be able to determine the wave speed on the string.



A standing wave pattern for a string

Procedure

Do not touch the string or move the wave generator at any time during this lab! If you do your results will be wrong and you will fail!

1. Press the range button that says 10 and turn on the wave generator.
2. Find a frequency between 5-10 Hz that produces a clear standing wave pattern. Use the coarse adjust and then the fine adjust to get the best standing waves. Record the frequency in the data table for trial 1.
3. Measure the length from the node at the end of the string tied to the sink to the closest node on the string.
4. Press the range button that says 100.
5. Repeat steps 2-3 for a frequency between 10-20 Hz.
6. Repeat steps 2-3 for a frequency between 20-30 Hz.
7. Perform the necessary calculations to complete the table for all three trials. You must show all work!

Data

Trial	Frequency	Node Distance	Wavelength	Speed
1				
2				
3				

Waves Performance Assessment Questions

1. Define wave.

2. What were the three types of waves that you observed in the three lab activities you performed?
   a.
   b.
   c.

3. What type of energy was transferred in each wave type?

4. What formula did you use to calculate the speed of the wave in all three cases?

5. Should the frequency change the speed of each type of wave? Why or why not?

6. What (else?) would change the speed of each type of wave? Why?

Physics Unit Performance Assessment Rubric: Waves

Task	Points Earned	As Good As It Gets (3 pts)	Not Bad (2 pts)	Little Effort Exerted (1 pt)	Zero Effort Exerted (0 pts)
Velocity of Sound in Air		Measurements made using correct sig figs; less than 10% error for all 3 frequencies	Sig figs were not taken into account while measuring, OR error was greater than 10% for one frequency	Sig figs were not taken into account while measuring, and error was greater than 10% for one or more frequency	Values are missing from the table.
Determining the Speed of a Wave on a String		Measurements made using correct sig figs; λ correctly determined; wave speed correctly calculated	Sig figs were not taken into account while measuring, OR λ or wave speed calculations incorrectly calculated	Sig figs were not taken into account while measuring, and λ or wave speed calculations incorrectly calculated	Values are missing from the table.
Measuring the Speed of Light with Chocolate and a Microwave		Measurements made using correct sig figs; speed of light calculations correct; less than 10% error	Sig figs were not taken into account while measuring, OR calculations incorrect, OR error was greater than 10%	Sig figs were not taken into account while measuring, calculations incorrect, error was greater than 10%	Values are missing from the table.
Summative Questions		5-6 questions answered correctly	3-4 questions answered correctly	1-2 questions answered correctly	0 questions answered correctly
Work Shown		Givens labeled, formulas rearranged, values plugged in, and answers shown on separate paper for all three labs.	Majority of work is clearly shown on separate paper for all three labs.	Work was not turned in for one or two labs or work turned in was very sloppy or incomplete.	No work turned in on a separate page.

Total points earned __________ / 15 % earned __________

Contact Information:

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