## Experiment 2: Standing Waves and the Speed of Sound

(If some of you do part two first, it's easier to hear your tuning fork if there aren't five others going at the same time.)

PART I: Standing Waves on a String.

You will calculate what theory predicts for the resonant frequencies of a "string," then observe the frequencies to see if they match. (A long spring is actually used because its mass makes the waves go slower.) The frequencies can be predicted from speed and wavelength. The speed is found from observing the time for a transverse pulse to cover a known distance. The wavelength is determined from the length of the spring. The observed frequencies come from setting up the standing waves, and counting the number of cycles in a certain number of seconds.

1. Find the waves' speed: Give one end of the spring a quick push to the side or hit it with your finger. Measure the time the pulse takes to go back and forth for as many times as you can make the pulse out, hopefully 8 or 10. You might be able to feel the pulse with a finger resting lightly on the spring more clearly than you can see it. Get the spring's length from the tape measure. The picture shows a common mistake. Another is recording, for example, 3.46 m as .46m: Notice where 1m, 2m and 3m are on the tape measure. The total distance covered divided by the time is the speed.
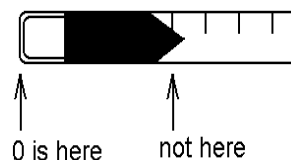
Most of the uncertainty in this experiment is due to your reaction time with the stopwatch, up to $\pm 1/2$ sec. Other uncertainties are small enough by comparison to call zero. Find the uncertainties in numbers you calculate from this. It's easiest to just leave them as percents until you get to the final answers for f_1, f_2 and f_3.

2. From the length of the spring and the wave speed, compute the three lowest resonant frequencies.

3. Set up each of the standing waves shown by shaking the spring at the appropriate frequency with your hand. Do not to cut off part of the vibrating length, like fingering a guitar string. Measure the frequency of each by measuring the time for some number of vibrations. (Cycles per second = cycles ÷ seconds.) Use a large enough number of vibrations so that the uncertainty is under 10%.
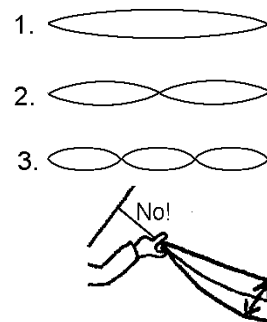
4. Compare the calculated to the actual resonant frequencies.

PART II: Sound Resonance.

Note: Once in a while, the apparatus gets tipped over, which is kind of messy. When not in use, please put it somewhere it's not likely to be bumped into.

You will use resonance to measure the speed of sound. The speed of a wave can be found from its frequency and wavelength. You get the frequency by simply reading it off the tuning fork making the sound. The wavelength can be determined from the length of a resonating air column.

Sound from the tuning fork goes down a plastic tube partly filled with water. The water is there so you can adjust the length of the air column; water is added or removed through a hose at the bottom, which leads to a cup. The sound reflects off the water and comes back up the tube; the waves going through each other in opposite directions make a standing wave. If the length of the air column is just right, this standing wave will resonate. Resonance means the buildup of a large amplitude, and the amplitude of a sound is its loudness, so you can hear when this happens because it gets louder. The resonating length is related to the wavelength, which in turn is related to the speed of sound.

Record the frequency stamped on the tuning fork.

Stand the apparatus on the floor and fill it to a few inches from the top with water. If you hold the cup on the hose in your hand, you can run the water level up and down in the tube by raising and lowering the cup. Use the large plastic beaker to add or remove water from the cup as necessary.

Strike the tuning fork with the rubber hammer. (Don't beat the daylights out of the poor tuning fork. You might try hitting it on your head once, instead of with the hammer, to see what it's supposed to sound like. Never strike it on anything hard, like the counter.) Hold it above the tube horizontally, close to the tube, with the vibrating ends going all the way across the tube but not much beyond. Strike it every ten seconds or so to keep it vibrating.

Lower the water level from near the top of the tube until you hear resonance. It should be no more than half way down the tube; resonances below this are from a different standing wave pattern. Put two rubber bands around the tube as close together as possible, so that you are sure that the correct level is somewhere between them. Run the water level past here a few times to be sure you've got it. Measure the length of the resonant air column, from the top of the water to the top of the tube. Its uncertainty is half of the distance between the rubber bands.

A more detailed analysis of resonating air columns shows that the antinode is not exactly at the open end, but .613 of the tube's inside radius beyond it. To obtain the correct wavelength of the sound, this "end correction" must be added to your measured air column length.

Compute the wavelength of the sound from the (corrected) length of the resonant air column. Compute the speed of sound from the wavelength and frequency of the sound produced by the tuning fork.
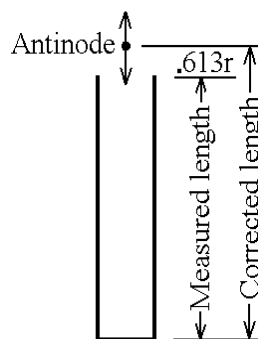
Compute a theoretical value for the speed of sound from the formula on your formula sheet. (Ask for a thermometer.)

Do the two values for the speed of sound agree within the uncertainty?

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PART I:

1. Find speed:

time = _____ $\pm .5$ s

length of spring = _____ ± 0

distance moved per round trip = _____ ± 0

number of round trips = _____

total distance = _____ ± 0

v = _____ $\pm$ _____

2. Predict frequencies from length and v:

$f_1 =$ _____ $\pm$ _____ $f_2 =$ _____ $\pm$ _____ $f_3 =$ _____ $\pm$ _____

Show all steps in how you obtained f_1, f_2 and f_3:

3. Observe frequencies. N = number of vibrations, t = corresponding time.

$N_1 =$ _____ $N_2 =$ _____ $N_3 =$ _____

$t_1 =$ _____ $\pm$ _____ $t_2 =$ _____ $\pm$ _____ $t_3 =$ _____ $\pm$ _____

$f_1 =$ _____ $\pm$ _____ $f_2 =$ _____ $\pm$ _____ $f_3 =$ _____ $\pm$ _____

PART II:

f = _____ $\pm$ 0

Measured length of air column = _____ $\pm$ _____

r = _____ $\pm$ 0

Correction to length = _____ $\pm$ 0

Corrected length = _____ $\pm$ _____
                                              (_____ %)

λ = _____ $\pm$ _____

Find v from f & observed λ:

Temperature = _____

Compute theoretical v from temperature: