Name: Dr. William Tireman **Lab Day:** Tuesday **Time:** 10 AM

Lab Partner(s): Mr. Johnny Cash

Date of Lab Exercise: January 8, 2013 **Lab Title***: Determination of the Speed of sound in air using a resonance tube*

Introduction: The objective of this laboratory was to determine the speed of sound in air using a resonance tube experiment. The tools for the experiment were twelve tuning forks with a frequency range of 250.0 Hz to 4000.0 Hz, an open end glass resonance tube with plunger, and meter stick attached to the resonance tube. The principle behind this laboratory was to measure the speed of sound using the relationship between frequency and wavelength of the sound wave. The equation is

$$\boldsymbol{v = f\lambda}$$

where *v* is the speed of sound, *f* is the frequency of the wave, and *λ* is the wavelength of the wave. This expression can be converted into a period depended equation by substituting for the frequency the relationship

$$f = \frac{1}{T}$$

And this results in the this final expression.

$$\lambda = vT$$

The frequency (period) of the wave is known by our choice of the tuning fork frequencies and the wavelength could be measured using the principle of resonance. In this experiment, resonance occurs when a standing wave is setup in the open tube by holding a vibrating tuning fork in front of the opening of the resonance tube. The plunger in the tube is then moved back and forth until the sound from the tube is heard to be the loudest which indicates the air column in the tube is at one of the resonance lengths. In an open tube system the resonance occurs at ¼ wavelength intervals or in other words at ½ λ, ¾ λ, etc. To find the wavelength of the wave, we needed to find two resonance lengths and then subtract the two lengths and multiply by two.

$$\lambda = 2(L_2 - L_1)$$

The speed of sound can then be found by plotting the measured wavelength of the tuning forks in the resonance tubes versus the period of the tuning forks. The slope of the best linear fit is the speed of sound in air at the temperature and pressure for that location and day. A correction factor for temperature can be applied to make a final comparison. The formula for the approximate speed of sound in air is as follows. This will serve as our expected value.

$$\boldsymbol{v_{air} = 331.3\frac{m}{s} + 0.606\frac{m}{s\cdot ℃} \times Temp}$$

The Key Results: The key result of this experiment is the measured speed of sound in air which is found from the slope of the wavelength versus period graph. For our measurements, the speed of sound was found to be 333.0 m/s.

Compare the results with theory or expectation: Using the temperature correction formula from the introduction section, we found the expected speed of sound to be 344.3 m/s given a measured room temperature of $21.5^{o}C$. Using a simple percent difference comparison yields a difference of 3.3%. This is a good percent difference. The R^2 value was 0.98 so I am very confident the choice of a linear fit is very good. Our theory predicted a linear correlation and this R^2 value gives support to the theory.

Reasonable Sources of Errors/Improvements to the Experiment: In this laboratory there were several sources of uncertainty. Most notable is the determination of the resonance in the resonance tube. The determination of when the plunger was at the correct position was done by ear. We moved to a “quiet” place in the hallway but we still had difficulty in finding the best position for the plunger. This introduces a significant uncertainty in our measurement of the wavelength of the sound wave but given our results I am confident we minimized it. If a sound sensor could be used to pick up the resonance wave and display it on an oscilloscope or computer screen then a more precise positioning of the plunger could be made.

Another possible area for significant uncertainty is the tuning forks themselves. We had to “trust” the stamp on the side of the tuning fork to be a precise value since we didn’t have a way to independently measure the frequency of each tuning fork. If a way to measure the tuning fork frequency to at least three significant figures we could be more confident in our assumption. However, given the results I am confident our trust was not misplaced.

Lastly, the comparison with the temperature corrected theoretical result could be flawed and possibly in our favor. This corrected theoretical value comes from an approximation given in our textbook that assumes dry air (0% relative humidity) and standard air pressure. These conditions were probably not meet. A more sophisticated analysis of the speed of sound data would be necessary to correct this portion of the experiment. However, this is outside the scope of this particular experiment.