PHSX 1010 **Experiment 12** **Name:**____________________

Title: Standing Waves in Pipes

Object: (1) To observe standing waves in pipes, and (2) To measure the speed of sound.

Theory: When a wave is produced in a medium that has a well-defined boundary that wave will be reflected at the boundary and create a situation in which waves will be traveling in both directions through the same medium. If the dimensions of the medium fulfill certain conditions, the wave will reflect back on itself so as to create a stationary or *standing* wave with nodes and anti-nodes.

In the case of a pipe that is open on both ends, if it is to resonate with an external sound source, the fixed length L of the pipe must be equal to a whole number n of half-wavelengths of the incoming sound wave:

$$L = n\lambda_n/2 \qquad n = 1, 2, 3, \ldots \tag{1}$$

where λ_n is the wavelength. Since $\lambda_n = v/f_n$ then $L = nv/2f_n$.

Thus we see that a pipe has a series of "resonant frequencies" which can be found by solving the above equation for f_n:

$$f_n = \frac{v}{2L}n \qquad n = 1, 2, 3, \ldots \tag{2}$$

The slope of a graph of f_n vs. n is therefore $v/2L$. If we wish to determine the speed of sound in air v, it should be the *slope* $\times$ $2L$. See pages 112 and 113 in *Physics: A Numerical World View.*

In the case of a pipe that is open on one end and closed on the other the length must be equal to an odd number $(2n-1)$ of quarter wavelengths of the incoming sound wave for resonance to occur:

$$L = (2n-1)\lambda_n/4. \qquad n = 1, 2, 3, \ldots \tag{3}$$

Again, since $\lambda_n = v/f_n$ then $L = (2n-1)v/4f_n$, which gives resonant frequencies of

$$f_n = \frac{(2n-1)v}{4L} \qquad n = 1, 2, 3, \ldots. \tag{4}$$

You should verify that this is equivalent to the last equation on page 113 of *Physics: A Numerical World View.* Put equation 4 in $y = mx + b$ form and see that the speed of sound is still *slope* $\times$ $2L$.

Apparatus: Draw a diagram of the standing wave patterns for the first two harmonics ($n = 1, 2$) of both the pipe open on both ends and the pipe open on one end and closed on the other.

Pipe open on both ends: Pipe open on one end:

Procedure:

1. Connect the speaker to a variable frequency oscillator and the microphone to an oscilloscope. Keep the amplitude low enough to avoid blowing the speaker (about 1/3 of maximum). Measure room temperature in kelvins and compute the expected value of v from $v = 20\sqrt{T}$.

2. Starting at a low frequency, slowly increase it until a resonance is observed. Continue in this manner, recording the frequency for each resonance ($n = 1, 2, 3, \ldots$).

3. Plot the resonances on a graph of frequency vs. n. Compare the measured slope of the best-fit straight line multiplied by $2L$ to the expected value for v. (See equation 2.)

4. Now repeat the steps 2 and 3 for the open-closed pipe. The best-fit straight line will not go through the origin in this case. (See equation 4; in fact, put it in the form $y = mx + b$.)

5. Remove the plunger and set the oscillator to one of the resonance frequencies (say $n = 4$) for the open-open pipe and move the microphone along the tube from node to node to measure the wavelength directly. (You must skip one node to get a full wavelength.) Use $v = \lambda f$ to compute the speed of sound measured in this manner and compare with the expected value.

Results:

1. Room temperature in kelvins: ______________; Expected value of v: ______________

2. Record the resonance frequencies and lengths of the pipe for the two cases:

open-open

n	Frequency (Hz)
1	
2	
3	
4	
5	
6	

L = __________

open-closed

n	Frequency (Hz)
1	
2	
3	
4	
5	
6	

L = __________

Compare the $slope \times 2L$ with the expected value of v.

3. For open-open pipe: $slope \times 2L =$ ______________ % diff = ______________

4. For open-closed pipe: $slope \times 2L =$ ______________ % diff = ______________

5. Compute the speed of sound from procedure 5 and compare to the expected value.

$\lambda =$ ____________ $f =$ ____________ $v =$ ____________ % diff = ______________

Conclusions: