Summary of the *Speed of Sound in a Pure Gas* Experiment

This document is a companion to a web-based document on the *Speed of Sound in a Pure Gas* experiment in the Physics laboratories of the University of Toronto. The web-document may be accessed at:

http://www.upscale.utoronto.ca/IYearLab/Intros/SpeedPureGas/SpeedPureGas.html

Background Information

Standing Waves

It is vital to remember that although we analyze standing waves in terms of the *displacement* wave, the microphone you use measures the *pressure* wave. Nodes in the displacement wave correspond to antinodes in the pressure wave, and vice versa.

The accepted value of the speed of sound is:

$$v_{accepted} = 331.4 + 0.61t \tag{1}$$

When adjusted for a standing wave, the distance between the nodes d is:

$$\lambda = 2d \tag{2}$$

where λ is the wavelength. For a standing wave, the wavelength is:

$$\lambda = \frac{2L}{n}, n = 1,2,3,... \tag{3}$$

where L is the length of the tube and n is any positive integer.

For all waves, the relation between the wavelength, the frequency f, and the speed of the wave v is:

$$\lambda f = v \tag{4}$$

Specific Heats

The specific heat is approximately constant for a given material. When heat Q is transferred to a body of mass m, its temperature changes by ΔT. Then the specific heat c is:

$$c \equiv \frac{Q}{m\Delta T} \tag{5}$$

The ratio of specific heats γ is defined as:

$$\gamma \equiv \frac{c_p}{c_V} \tag{6}$$

where: c_p = specific heat at constant pressure
c_V = specific heat at constant volume

For an ideal gas this becomes Equation 10 in the full document on this experiment:

$$\gamma = \frac{Mv^2}{RT} \tag{10}$$

where: M = the molecular weight
v = the speed of sound in the gas
R = the gas constant
T = the temperature in Kelvin

Theoretical values are:

Value of γ	**Gas Type**
5/3	monatomic
7/5	diatomic gas of freely rotating molecules
9/7	diatomic gas of rotating and vibrating molecules

Adjusting for a Standing Wave

1. Place the microphone as close as possible to the loudspeaker.
2. Carefully adjust the frequency of the signal generator so the microphone measures a maximum in the pressure wave. This is a minimum in the displacement wave.
3. Place the microphone at a *node* in the pressure wave.
4. Slowly adjust the frequency to make the measured amplitude as small as possible. You will need to decrease the volts per division on the oscilloscope as you make these adjustments.

The Experiments

Do not attempt to change the pressure of the gas in the tube. If you suspect problems consult your Demonstrator or the Technologists.

Preliminaries

- Connect the signal generator to the oscilloscope, and adjust the voltage to a few hundred Hz and display the wave on the oscilloscope.
- Measure the frequency of the voltage using the oscilloscope and:
  $$f = 1/T \qquad (11)$$
  where f is the frequency and T is the period.
- Also connect the signal generator to the loudspeaker, and connect the microphone to the second beam of the oscilloscope. Adjust the display so that you can see the input voltage from the signal generator and the output of the microphone simultaneously.

The Experiment

- Adjust for a standing wave for a frequency between 200 Hz and 2 kHz.
- **Question**: how does the sound level that you hear with your ear close to the tube correlate with whether or not a standing wave exists in the tube? Can you think why this is so?
- From the positions of the nodes and/or antinodes, determine the wavelength of the standing wave. Calculate the speed of sound.
- Repeat for a few different frequencies.
- Give a final best value for the speed of sound and its error.
- Compare your result to the accepted value.
- Using Equation 10, calculate the ratio of specific heats and its error. Compare to the theoretical values.

Preparatory Questions

The questions should be answered and turned in to your Demonstrator *before* beginning the experiment.

1. From Equations 3 and 4, what are the *frequencies* of the possible standing waves in a tube closed at both ends?
2. Sound waves do not travel far through the air; eventually the waves "die out." What happens to the *energy* of the sound wave?
3. Values for the universal gas constant *R* are given in various references as web document. The units of the constant are give in units such as:
    a. Liter atmospheres per mole Kelvin
    b. Joules per mole Kelvin
    c. Meter cubed atmospheres per mole Kelvin
    d. Etc.

    What units should you use for this experiment?