SPEED OF SOUND

PURPOSE:

To determine the speed of sound in air using the concept of resonance and to compare it with its theoretical value.

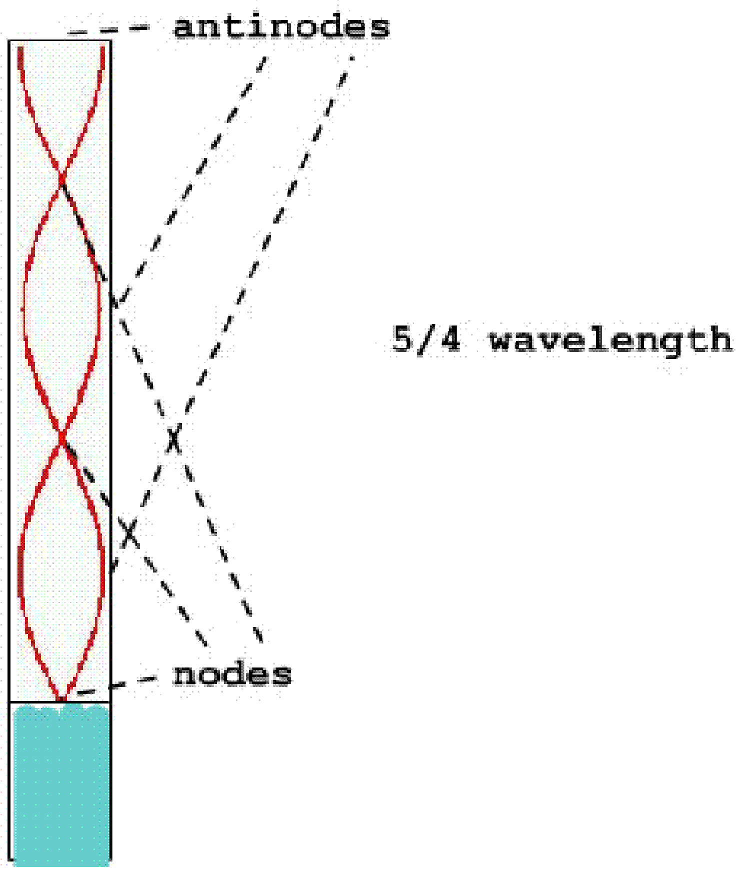
THEORY:

Sound is energy. It is the kinetic energy of atoms or molecules (particles) in motion in a periodic manner. All sound is produced by a vibrating membrane of some sort; for our purposes let's assume the source is a loudspeaker. When the electrical current in the coil of the loudspeaker forces it to move forward, the air load in front of it is compressed. Since the currents in a speaker are sinusoidal, the speaker will quickly be pulled back from its extended position. This creates a partial vacuum in the air load. The sinusoidal current usually carries interesting information (speech, music, etc.), and the motion of the speaker, and therefore the air load, tracks the current. The air load on the speaker forces the mass of air in front of it to move, and so the chain of compressions and rarefactions spreads out from the loudspeaker to the listener. This chain is called a longitudinal wave, and it is completely analogous to a sinusoidal (like a water) wave. The difference in pressure between the compressions and the rarefactions is the amplitude A (called loudness in music), and the number of waves produced each second is called the frequency f (pitch). The reciprocal of waves per second would therefore be seconds per wave; this is called period, T, obviously a specific time interval.

You perceive sound through a vibrating membrane in your ear called the tympanic membrane, or eardrum. Through a series of bones this vibration is conducted to sensors in your inner ear which send electrical impulses to your brain, and you ''hear''. The range of pitches you can detect is wide, from 20Hz (a hertz is a wave per second) to 20,000Hz, but you do not hear all frequencies at the same loudness. The ear discriminates against certain frequencies, depending on age, gender, and general wear and tear on your auditory system.

The speed v at which these or any longitudinal travels is dependent on the medium. Generally, waves travel faster in mediums that are less compressible and less dense. There is no exact correlation between compressibility and density, but many of the more incompressible materials are quite dense. Therefore, sound travels at about 1430m/s in water, but at 5000m/s in steel. Temperature affects the qualities of water and steel. The speed of sound in Sea water at 25 degrees Celsius is 1530 m/sec. The influence of temperature on gas is more dramatic. The speed of sound in air at 1ATM is 331m/s at 0 ^{o}C, but increases 0.606 m/s for every 1^{o}C increase in temperature.

We will be placing a sound source directly over a column of air and water in a glass tube. The height of the water column can be varied. The source of the sound is called an antinode, that is, where the amplitude of the wave is a maximum. At the air/water interface, the air is constrained, meaning it cannot move. This point is called a node, and any waves travelling down the tube are reflected at this interface. The distance from a node to an antinode is 25% of the wave's span, which is called its wavelength.
See picture below:



One complete wavelength will include two nodes and two antinodes. If the distance from the source to the interface is 1/4 of the wavelength, the wave will be reflected back on itself, adding to the incoming wave and increasing the amplitude, and therefore the loudness, of the sound. This is a condition of resonance in a single open-ended pipe. It is how certain organ pipes are made. If 1/4 of the wavelength is known, then the entire wavelength can be calculated, a necessary figure. Of course, when there are other points where an antinode exists at the pipe mouth, and a node exists at the water, and the wave fraction "just fits", the sound will be amplified as well. One of your procedures will be to draw a sinusoidal wave(s) and predict what fraction(s) of a wave will give you a node at one end and an antinode at the other. This way you can repeat the experiment to find the wavelength of the sound using a different length air column in order to corroborate your previous finding. Finally, with the frequency of the source known, and the wavelength calculated, the speed of sound in the tube can be easily deduced from the equation:

$$v = \lambda * f$$

PROCEDURE:

1. Setup the apparatus as the demo in the front of the class.
2. Start the capstone software software.
3. Click on the signal generator icon (the sine wave picture) on the left side of the screen.
4. You should get a signal generator window.

5. Select the **850 Output 1** from the signal generator list by clicking on it.
6. Set the frequency to one of the following values: 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300 Hz.
7. Set the Amplitude to **0.25 V**.
8. Let your instructor know which frequency you have chosen, **Each group must choose a different frequency.**
9. Click the "On" button to start the generator. You should hear sound coming of the speaker. If it is too loud reduce the value of the Amplitude.
10. Set the Sound meter to **70 or 60**. The meter should between **-6 and 0** with the speaker on.
11. Raise the metal can as high as possible.
12. Start filling the can with water. **<u>Do not overflow the can.</u>**
13. The water level on the tube should rise.
14. Put water until the level on the tube is about the **10 cm mark**.
15. Lower the aluminum can. The water level in the tube should be lowering at the same time.
16. Watch the sound meter. At the resonance level the meter reading will rise out of the scale. You will also hear a louder sound.
17. Read the scale on the side of the tube. Record the value in cm (you will later convert the value to meters) at which the resonance occurs.
18. Lower the can and record the location of the next resonance.
19. Close the software once you have all your data.
20. The distance between the two resonances is one half the wavelength of the sound.
21. Use the wavelength and the frequency to determine the speed of sound in air.
22. Find the value of the room temperature by reading your thermometer. Record the value of the temperature in degrees Celsius as part of your data.
23. Calculate the speed of sound from the formula: **v = (331 + 0.606T) m/sec**. Where T is the temperature in Celsius.
24. Calculate the percent difference **<u>The percent must be less than 5.</u>**