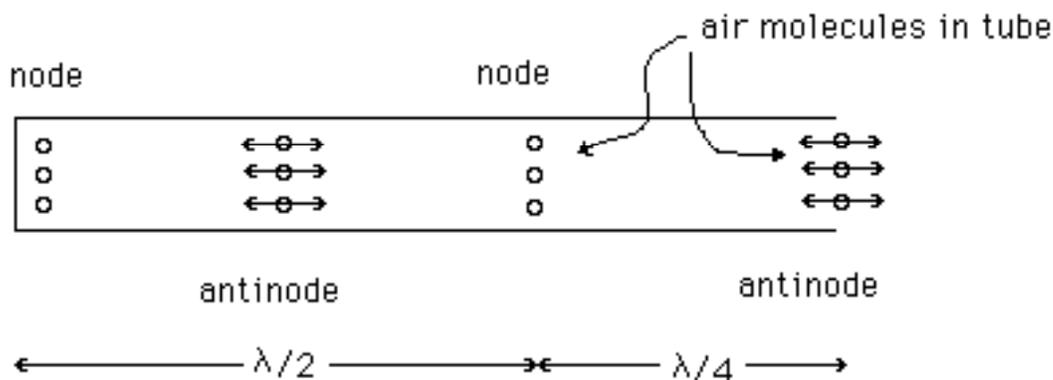


Measuring the speed of sound from standing waves

In class you will see a simulation of transverse standing waves that are made of two identical waves traveling in opposite direction. Since these were transverse, you may wonder if you can have standing waves for longitudinal waves such as sound wave. It turns out this is possible by sending a wave down a tube and having it reflect off the other end. This creates two identical waves traveling in opposite directions and will cause nodes (where the pressure is constant) and anti nodes (where there is a large fluctuation of pressure) in the tube. At nodes the tube the air will be motionless. In other regions (anti-nodes) there will be a back and forth (longitudinal) motion of air at the same frequency of the original wave source. As was the case for transverse standing waves on a string, the distance between one node and the next is half a wavelength; $\lambda/2$. In the figure below the 2nd harmonic is shown (other harmonics are shown in the class notes online). If we excite a pipe at one of its natural frequencies (wavelengths) we have resonance and this phenomenon is used in designing pipe organs, flutes, and other wind instruments.



Just like for a string, the length of the tube, L , determines what fundamental wavelength will fit in the tube. But this time, since one end of the tube is open and the other closed, one end is a node and the other end an antinode (recall that for a string both ends are nodes because they are fixed). This means the fundamental wavelength is $\lambda/4 = L$ instead of $\lambda/2 = L$ as it was for the string.

If we excite the air in the tube using a tuning fork with a wavelength equal to $4L$ (so that one quarter of a wavelength will fit in the tube) we have resonance. You can hear this resonance but only when the length of the tube is just the right size; one fourth the wavelength.

If we lengthen the tube to where we can get one half of the wavelength into the tube we do *not* get resonance because that would require a node at the open end, but the open end has to be an antinode. We could keep lengthening the tube until we have $3/4\lambda$ inside the tube in which case we will have resonance again since there is an antinode at the open end (this is the case shown above, $L = 3/4\lambda$). The next length for which resonance occurs is $5/4\lambda$. In this lab you will change the length of the tube by changing the water level. As you add water you will only hear resonance if the length of the open part is some fraction ($1/4, 3/4, 5/4$, etc.) of the tuning fork wavelength.

Do not lift the apparatus by grabbing the tube- it will slip out and break.

Note: If you don't have the apparatus described here you can make your own. You will need about five feet of clear PVC pipe (2 inch diameter is perfect), a cap to seal one end, a watering can with a narrow spout and a tuning fork with a frequency of 512 Hz. To change the level of water in the tube, place the pipe upright at a slight angle so the water will run smoothly down the sides and quickly pour the water in using the watering can.

Hold a vibrating tuning fork of frequency 512 Hz over the open end of the tube and vary the water level in the

tube by raising and lowering the water reservoir. When you hear a loud re-enforcing of the sound you have resonance; record the water level when you hear the resonance. (It helps to vary the water level quickly and to have more than one person listening and keep track of the water level.) You should hear a resonance at several different water levels, L_1 , L_2 and L_3 . The distance between resonance points, $L_1 - L_2$ and $L_3 - L_2$ is equal to $1/2\lambda$ since each time we add enough tube length for resonance we have added enough room for one half a wavelength.

- 1) What values do you get for λ ?
- 2) The frequency of your tuning fork is 512 Hz. Multiply frequency times the average wavelength you measured to get the speed of the waves (speed = λf).
- 3) How does this number for speed compare with the known value of 344 m/s for the speed of sound at room temperature?
- 4) The density of air changes with temperature. Considering that the velocity of waves on a string depends on density, do you think the velocity of sound will change depending on the temperature? Explain.

