3.11.1.2: Standing Wave Simulation

The following simulation compares the fundamental, second, third and forth harmonics of standing waves on a string with standing waves in a tube. Notice that for a tube open on both ends the displacement nodes occur where the string has nodes and the displacement anti-nodes in the tube occur where the string has displacement nodes. The *pressure* nodes in a tube open at both ends occur in the same place as the string nodes.

For a tube closed at one end (as is the case for most musical instruments based on vibrating columns of air) the even harmonics cannot exist. A tube closed on one end has a different timbre because the even harmonics are missing.

Simulation Questions:

1. Play the standing wave simulation for the case of the fundamental. The length of the string is 3.14 m. What is the wavelength of the fundamental?
2. Describe the fundamental of the tube simulation (bottom). Where do the dots (representing air molecules) move the most? Where do they form a displacement node? Assuming the tube is the same length as the string, what is the fundamental wavelength of the tube open at both ends?
3. Use the time in the simulations to find the period and calculate the frequency of the fundamental for both simulations. For a musical instrument this would be the frequency of the tone being sounded by the instrument when it plays its lowest note.
4. What is the wave speed of each of the component waves making up the fundamental (the speed determined by $v = f\lambda$)?
5. Now click the box for a tube closed at one end. What is the wavelength of the fundamental for a tube closed at one end? How is this different for the case of the tube open at both ends?
6. Reset the simulation and look at the second harmonic for the string and tube open at both ends. What is the wavelength and frequency of the second harmonic/first overtone for the string and tube open on both ends? What is the speed of the component waves?
7. Try the third and fourth harmonics for the string and tube open at both ends. What are the wavelengths and frequencies of these waves? What are the speeds of the component waves?
8. The formula for the wavelength as a function of the length of the string or open tube is given by $\lambda = 2L/n$ where n is a whole number and L is the length of the string. Verify this relationship with the numbers you got in the previous questions.
9. Now check the box for a pipe with closed end simulation and examine the harmonics. Describe the difference in the node and anti-node pattern. What are the wavelengths for these cases? The formula for the frequencies of a tube closed at one end are given by $\lambda = 4L/n$ where n is an odd whole number. Verify this relationship with the numbers you got in the previous questions.
10. Flutes are basically pipes with openings at both ends but clarinets, trumpets and trombones are basically tubes that are closed at one end. Why does this make a difference in the frequencies each instrument plays?
11. Pressure anti-nodes occur at places where the air is not moving (displacement nodes). What would be the effect of cutting a hole in the tube at the location of a pressure anti-node? Would the standing wavelength be affected? (This is the basis behind using finger holes in wind instruments to play different frequencies.)