10.3.4: Volume or Helmholtz Resonance

Rooms, containers and many instruments have a confined volume of air of a certain size. If a small opening is made in a container or a window opened in a room the air can oscillate with a frequency that depends on the size of the container or room. The fundamental frequency produced is referred to as ***Helmholtz resonance***, as mentioned in Chapter 4. If you have ever blown across the top of a soft drink bottle to get a note you have excited a Helmholtz resonance. Another example is when you drive your car at just the right speed with one window partly opened and you hear a low frequency sound.

For a rectangular container the walls are parallel to each other and we can describe the higher frequency modes of the container as standing waves in three dimensions, much like the standing waves on a guitar string. As shown above, for a string the overtones are given by $f_n = v/2((n/L)^2)^{1/2}$ where L is the length of the string, v is the speed of a wave on the string and n is the mode number. Extending this to three dimensions, the equation for frequency modes inside a rectangular container with height H, length L and width W is $f_{n,l,m} = v/2((n/L)^2 + (l/H)^2 + (m/W)^2)^{1/2}$. Now there are three different mode numbers since sound can travel in three directions. You can explore these modes in this box modes simulation Applet by Paul Falstad (notice you can grab and rotate the box to see different modes from different angles).

Acoustic stringed instruments have a body that contains a volume of air and air holes in the body so that this air can resonate. The shapes are much more complicated than a rectangular box but there are still resonance modes. Along with the surface resonances these volume resonances modify the string harmonics to give an instrument its unique timbre.