OPEN AND CLOSED TUBE RESONATORS (CYLINDERS)

By convention a rigid cylinder that is open at both ends is referred to as an "open" cylinder; whereas, a rigid cylinder that is open at one end and has a rigid surface at the other end is referred to as a "closed" cylinder.

The first three resonances in an open cylindrical tube. The horizontal axis is pressure.

The first three resonances in a closed cylindrical tube. The horizontal axis is pressure.

**Open**

Open cylindrical tubes resonate at the approximate frequencies

\[ f = \frac{nv}{2L} \]

where \( n \) is a positive integer (1, 2, 3...) representing the resonance node, \( L \) is the length of the tube and \( v \) is the speed of sound in air (which is approximately 343 meters per second at 20 °C and at sea level).

A more accurate equation considering an end correction is given below:

\[ f = \frac{nv}{2(L + 0.8d)} \]
where \( d \) is the diameter of the resonance tube. This equation compensates for the fact that the exact point at which a sound wave is reflecting at an open end is not perfectly at the end section of the tube, but a small distance outside the tube.

The reflection ratio is slightly less than 1; the open end does not behave like an infinitesimal acoustic impedance; rather, it has a finite value, called radiation impedance, which is dependent on the diameter of the tube, the wavelength, and the type of reflection board possibly present around the opening of the tube.

**Closed**

A closed cylinder will have approximate resonances of

\[
f = \frac{nv}{4L}
\]

where "\( n \)" here is an odd number (1, 3, 5...). This type of tube produces only odd harmonics and has its fundamental frequency an octave lower than that of an open cylinder (that is, half the frequency).

A more accurate equation is given below:

\[
f = \frac{nv}{4(L + 0.4d)}
\]