

The Sound of Music

The sound of many musical instruments is the result of vibrations resonating within a column of air. There are two types of air columns – referred to as **closed-end** and **open-end air columns**. The difference depends on whether one or both ends of the column are open to the surroundings.

Any column of air has a set of frequencies at which its particles naturally vibrate. These frequencies are called **harmonics**; their values depend on the length of the air column. The lowest frequency in the set is known as the **first harmonic**. Other frequencies in the set are whole number multiples of the lowest frequency. The mathematical relationship between the wavelength (λ), frequency (f), and speed (v) for the various harmonics is very predictable. **Table 1** illustrates these relationships for a 60-cm long closed-end air column. **Table 2** illustrates these same relationships for a 60-cm long open-end air column.

Table 1: Closed-End Air Columns

Harmonic	f (Hz)	λ (m)	v (m/s)
1 st	142	2.40	340
3 rd	425	0.80	340
5 th	708	0.48	340
7 th	992	0.34	340

Table 2: Open-End Air Columns

Harmonic	f (Hz)	λ (m)	v (m/s)
1 st	283	1.20	340
2 nd	567	0.60	340
3 rd	850	0.40	340
4 th	1133	0.30	340
5 th	1417	0.24	340

When a musical instrument is played, air particles immediately begin to vibrate with a set of many frequencies. These frequencies combine to produce the sound that we hear. Some of the frequencies within the set quickly dissipate and do not affect the overall sound. Others are sustained over time and become the prominent frequencies that affect the sound. These *enduring* frequencies are the harmonic frequencies. Two different instruments can play the same note yet sound quite different. A computer analysis of the sound reveals that instruments differ in terms of the relative strength of the various harmonics. A **frequency spectrum** shows the specific frequencies within the sound and their relative intensity or amplitude. Frequency spectra for a clarinet and a flute playing the note C₄ are shown in **Figure 1**.

Figure 1



