Decibels, Phons, and Sones

The rate at which sound energy reaches a given cross-sectional area is known as the **sound intensity**. There is a large range of intensities that humans can hear. Given the large range, it is common to express the sound intensity using a logarithmic scale known as the **decibel scale**. By measuring the intensity level of a given sound, the deciBel rating can be determined. **Table 1** lists intensity values and decibel ratings for several sound sources.

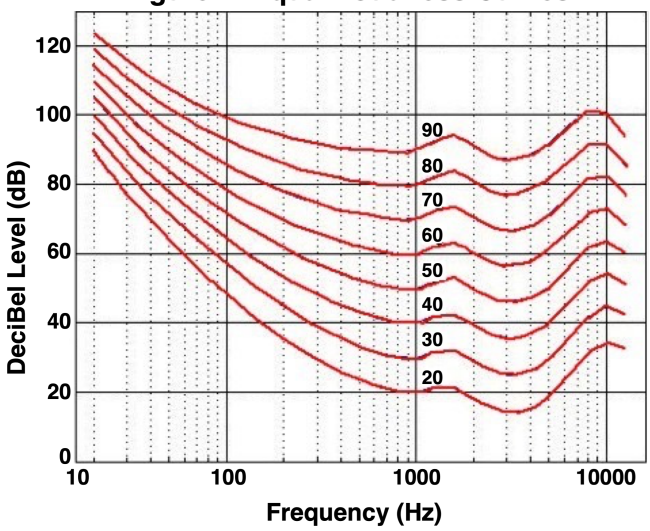
Table 1: deciBel Ratings of Several Sounds

Sound Source	Intensity	deciBel
Weakest Sound Heard	1×10^{-12} W/m^2	0.0
Rustling Leaves	1×10^{-11} W/m^2	10.0
Quiet Library	1×10^{-9} W/m^2	30.0
Average Home	1×10^{-7} W/m^2	50.0
Normal Conversation	1×10^{-6} W/m^2	60.0
Phone Dial Tone	1×10^{-4} W/m^2	80.0
Truck Traffic	1×10^{-3} W/m^2	90.0
Chainsaw, 1 m away	1×10^{-1} W/m^2	110.0

Intensity values and deciBel levels (dB) are objective measures of a sound. On the other hand, the loudness of a sound is subjective. Sound loudness varies from person to person. Furthermore, sounds with equal intensities but different frequencies are perceived by the same person to have unequal loudness. For instance, a 60 dB sound with a frequency of 1000 Hz sounds louder than a 60 dB sound with a frequency of 500 Hz. The unit **phon** is used to indicate an individual's perception of loudness. By definition, 1 phon is equivalent to 1 deciBel at 1000 Hz (1 kHz).

Figure 1 shows several experimentally-determined equal loudness curves. Volunteers were subjected to a 1 kHz sound at 60 dB; this is a *loudness* of 60 phon. Sounds with different frequencies were then played; the volunteer adjusted the decibel level until it was perceived to have the same loudness as it had at 1000 Hz. This was repeated for varying frequencies to generate the entire 60-phon curve. To create an 80-phon curve, subjects were exposed to 1 kHz sounds at 80 dB. For other frequencies, they adjusted the decibel level until it was perceived to be of equal loudness as the 1 kHz sound. **Figure 1** represents an average of the results for many individuals .

Figure 1: Equal Loudness Curves



The **sone scale** is a third scale associated with the loudness of a sound. According to the sone scale, a 1 sone sound is defined as a sound whose loudness is equal to 40 phons. A 10 phon increase in a sound level is most often perceived as a doubling of loudness and thus a doubling of the sone rating. **Figure 2** is generated based on these assumptions.

Figure 2: The Sone Scale