Decibels, Phons, and Sones

The rate at which sound energy reaches a given cross-sectional area is known as the **sound intensity**. There is an abnormally large range of intensities over which 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 with a meter, the deciBel rating can be determined. Intensity values and decibel ratings for several sound sources listed in **Table 1**.

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

The decibel scale and the intensity values it is based on is an objective measure of a sound. While intensities and deciBels (dB) are measurable, 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).

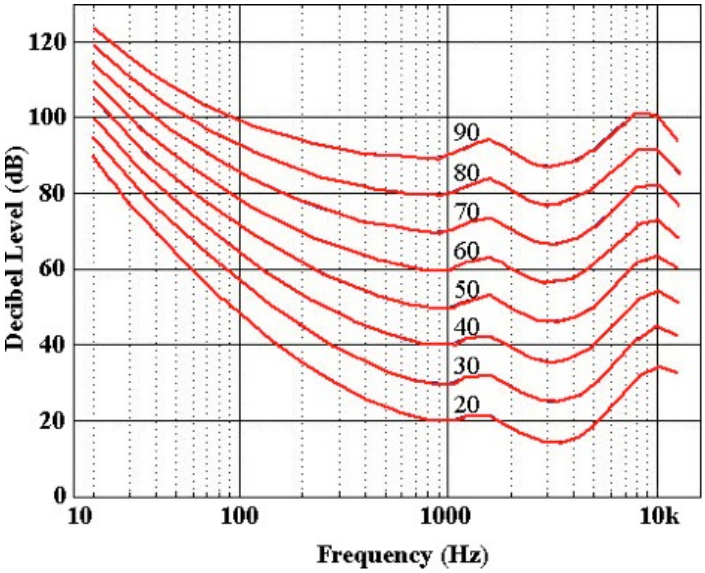
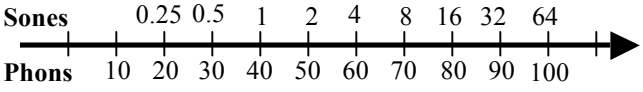


Figure 1 shows several equal loudness curves. The curves were determined experimentally. Volunteers were subjected to a 1 kHz sound at 60 dB; this is a *loudness* of 60 phon. Sounds with different frequencies were then played; the volunteer adjusted the decibel level until it was perceived to have the 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.

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

Figure 2: The Sone Scale



Questions:

1. How many times more intense is the sound of an average home than the sound of a quiet library?
   a. 2 times
   b. 20 times
   c. 60 times
   d. 100 times

2. The sound of a vacuum cleaner from 1 meter away is rated at 70 decibels. What is the intensity of such a sound?
   a. 1×10^{-7} W/m^2
   b. 5×10^{-5} W/m^2
   c. 1×10^{-5} W/m^2
   d. 5×10^{-4} W/m^2

3. The sound in Mr. G's chemistry lab during lab day is 10 times more intense than the sound of normal conversation. What is the decibel rating in this lab?
   a. 50 dB
   b. 61 dB
   c. 70 dB
   d. 600 dB

4. Which statement describes the relationship between the intensity of a sound and the decibel rating?
   a. The decibel rating increases as the intensity increases.
   b. The decibel rating decreases as the intensity increases.
   c. The decibel rating remains constant even as intensity increases.
   d. There seems to be no pattern relating the intensity and the decibel rating.

5. Consider the following two sounds:

   Sound A: 70 dB, 100 Hz
   Sound B: 50 dB, 500 Hz

   Which statement accurately compares the perceived loudness of these two sounds?
   a. Most people will perceive Sound A to be louder than Sound B by about 20 phons.
   b. Most people will perceive Sound B to be louder than Sound A by about 20 phons.
   c. Most people will perceive these two sounds to be of approximately equal loudness.
   d. There is no way to compare the loudness since they have unequal frequency and unequal decibel rating.

6. Which one of the following 80-decibel sounds would be perceived to be loudest?
   a. 100 Hz
   b. 400 Hz
   c. 2000 Hz
   d. 7000 Hz

7. What would be the phon rating of a 400 Hz sound that has a decibel rating of 70 dB?
   a. 60 phons
   b. 66 phons
   c. 70 phons
   d. 75 phons

8. Which one of the following sounds would seem as loud as a 60-decibel sound having a frequency of 1000 Hz?
   a. A 20-decibel sound with a frequency of 60 Hz
   b. A 50-decibel sound with a frequency of 220 Hz
   c. A 60-decibel sound with a frequency of 60 Hz
   d. A 60-decibel sound with a frequency of 1100 Hz

9. The conversational voice of a typical adult female ranges in frequency between 165 Hz and 255 Hz. Use **Table 1** and **Figure 1** to determine the phon range for the normal conversation of a typical adult female.
   a. From 45 to 52 phon
   b. From 45 to 70 phon
   c. From 50 to 70 phon
   d. From 68 to 72 phon

10. What is the sone value of a 10 phon sound?
   a. 0.125 sones
   b. 0.250 sones
   c. 1 sones
   d. 64 sones

11. Based on the information in **Figure 2**, how many times louder would a typical person perceive a 60 phon sound to be compared to a 40 phon sound?
   a. 0.25 times louder
   b. 2 times louder
   c. 4 times louder
   d. 20 times louder

12. Based on the information in **Figure 2**, how many times louder would a typical person perceive a 60 phon sound to be compared to a 30 phon sound?
   a. 2 times louder
   b. 4 times louder
   c. 4.5 times louder
   d. 8 times louder

13. A sound has a decibel level of 40 dB and a frequency of 200 Hz. Use **Figure 1** and **Figure 2** to determine its rating on the Sone Scale.
   a. Approximately 0.4 sones
   b. Approximately 1 sones
   c. Approximately 2.5 sones
   d. Approximately 25 sones

14. A sound has an intensity level of 1×10^{-6} W/m^2 and a frequency of 200 Hz. Use **Table 1**, **Figure 1**, and **Figure 2** to determine its rating on the Sone Scale.
   a. Approximately 1.7 sones
   b. Approximately 4 sones
   c. Approximately 60 sones
   d. Approximately 95 sones