Intensity and the decibel System

A source of sound, such as an audio speaker, produces sound energy that propagates outward from the source in roughly all directions. The rate at which this sound energy is produced is known as the **power**. A 300 Watt speaker (operating at 100% efficiency) produces 300 Joules of sound energy every second. The rate at which this sound energy reaches a given cross-sectional area is known as the **sound intensity**. Sound intensity is measured in units of power per area - for example, Watts per meter squared. The intensity of sound from a source varies with the distance from the source. **Table 1** portrays the relationship between sound intensity and the distance from a 300-Watt audio speaker.

Table 1

distance (m)	Intensity (W/m^2)
1	23.873
2	5.968
3	2.653
4	1.492
5	0.955
6	0.663
7	0.487
8	0.373

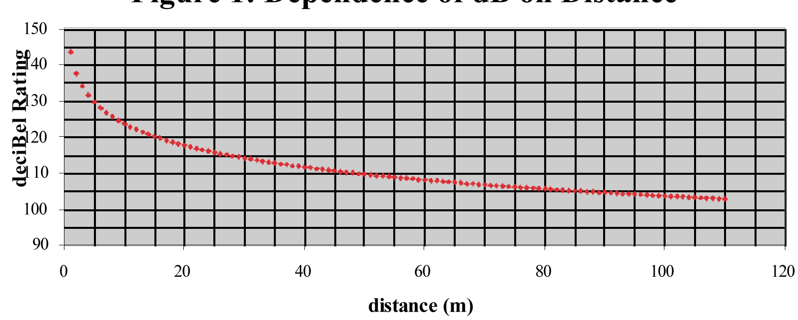
Humans are able to detect sound with an intensity as low as 1.0×10^{-12} W/m^2. This particular intensity level is known as the **threshold of hearing** (TOH). Many humans can hear sounds that are 10 trillion times more intense than the TOH without exhibiting signs of pain. Given the large range of intensities that humans are sensitive too, it is common to express the sound intensity using a logarithmic scale known as the **decibel scale**. A *decibel* is one-tenth of a Bel and a Bel is the logarithm of the ratio of two sound intensity values. In acoustics, the decibel rating assigned to a sound is the logarithm of the ratio of the intensity of that sound to the intensity of the threshold of hearing. This logarithmic relationship is illustrated in **Table 2**.

Table 2

Intensity (W/m^2)	deciBel Rating
1.0×10^{-12}	0.0
1.0×10^{-11}	10.0
1.0×10^{-10}	20.0
1.0×10^{-9}	30.0
1.0×10^{-8}	40.0
1.0×10^{-7}	50.0
1.0×10^{-6}	60.0
1.0×10^{-5}	70.0
1.0×10^{-4}	80.0
1.0×10^{-3}	90.0
1.0×10^{-2}	100.0
1.0×10^{-1}	110.0
1.0×10^{0}	120.0

High intensity sounds can cause permanent damage to the human ear. Decibel levels of 120 dB can cause pain to the ears of some humans. Researchers studying hearing loss claim that prolonged exposure to sound levels of 85 dB can lead to hearing loss. They suggest limiting exposure to sound levels that exceed 100 dB to no more than 15 minutes. Exposure to sound levels of 110 dB should be restricted to 1-minute duration. Teenagers are most susceptible to damage by exposure to loud music emanating from the earbuds of mp3 players or exposure to loud sounds at concerts. **Figure 1** shows the dependence of the decibel level upon the distance from the 3000-Watt super-speakers used at a concert.

Figure 1: Dependence of dB on Distance



Questions:

1. What effect does an increase in distance from the source have upon the decibel level of a sound?
   a. Increasing the distance causes the decibel level to increase.
   b. Increasing the distance causes the decibel level to decrease.
   c. Increasing the distance has no effect upon the decibel level.
   d. Increasing the distance decreases the decibel level at first and then increases it

2. According to **Table 1**, what effect does the doubling of the distance have upon the intensity level of the sound?
   a. As the distance is doubled, the intensity level doubles.
   b. As the distance is doubled, the intensity level quadruples.
   c. As the distance is doubled, the intensity level becomes one-half as intense.
   d. As the distance is doubled, the intensity level becomes one-fourth as intense.

3. What effect does increasing the power of the source of sound have upon the intensity of a sound and the decibel rating of a sound as perceived at a particular location?
   a. Increasing the power causes the intensity and the decibel rating to both increase.
   b. Increasing the power causes the intensity to increase the decibel rating to decrease.
   c. Increasing the power causes the intensity to increase but does not effect the decibel rating.
   d. Increasing the power causes the intensity to increase but does not effect the decibel rating.

4. What effect does an increase in the intensity of a sound have upon the decibel rating of the sound?
   a. Increasing the intensity of a sound decreases the decibel rating.
   b. Increasing the intensity of a sound increases the decibel rating.
   c. Increasing the intensity of a sound does not affect the decibel rating of the sound.
   d. The effect that intensity has upon the decibel rating varies, depending upon the distance.

5. The intensity of a sound source becomes 1000 times greater. What effect does this have upon the decibel rating (dB) of the sound?
   a. The decibel rating will increase by 3 dB.
   b. The decibel rating will increase by 30 dB.
   c. The decibel rating will become 30 times greater.
   d. The decibel rating will become 1000 times greater.

6. How many times greater is the intensity of an 80 decibel sound than that of a 60 decibel sound?
   a. 1.3 times b. 2 times
   c. 20 times d. 100 times

7. How many times greater is the intensity of a 100 decibel sound than that of a 66 decibel sound?
   a. 1.5 times b. 3.4 times
   c. 34 times d. 2500 times

8. Sound A is 10 000 times more intense than Sound B. How do the decibel ratings of the two sounds compare?
   a. The decibel rating of Sound A is 4 dB higher than the decibel rating of Sound B.
   b. The decibel rating of Sound A is 40 dB higher than the decibel rating of Sound B.
   c. The decibel rating of Sound A is 1000 dB higher than the decibel rating of Sound B.
   d. The decibel rating of Sound A is 4 times greater than the decibel rating of Sound B.

9. Sound A is 500 times more intense than Sound B. How do the decibel ratings of the two sounds compare?
   a. The decibel rating of Sound A is 5 dB higher than the decibel rating of Sound B.
   b. The decibel rating of Sound A is 27 dB higher than the decibel rating of Sound B.
   c. The decibel rating of Sound A is 25 times greater than the decibel rating of Sound B.
   d. The decibel rating of Sound A is 50 times greater than the decibel rating of Sound B.

10. Audio speakers that are rated at 300 Watts are very powerful speakers. If placed in your room and operating at 100% efficiency, what would be the decibel rating you would be exposed to at a distance of 2 meters from the speakers?
   a. The decibel rating would be approximately 6 dB.
   b. The decibel rating would be approximately 6 dB.
   c. The decibel rating would be between 120 db and 130 dB.
   d. The decibel rating would be approximately 10^6 dB.

11. A rock band is holding a concert in the local park and using three 1000-Watt speakers (totaling 3000 Watts) to project the sound. You visit the concert and consider two seats. Seat A is an average distance of 20 meters from the speakers. Seat B is an average distance of 50 meters from the speakers. How does the decibel rating of the two seats compare when the speakers are blasting at 100% efficiency?
   a. The sound at Seat A is 2 dB higher than the sound at Seat B.
   b. The sound at Seat A is 2.5 dB higher than the sound at Seat B.
   c. The sound at Seat A is 3 dB higher than the sound at Seat B.
   d. The sound at Seat A is 8 dB higher than the sound at Seat B.