Intensity and the deciBel System

A source of sound 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/m²)
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/m². 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/m²)	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 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