

Intensity and the DeciBel Scale

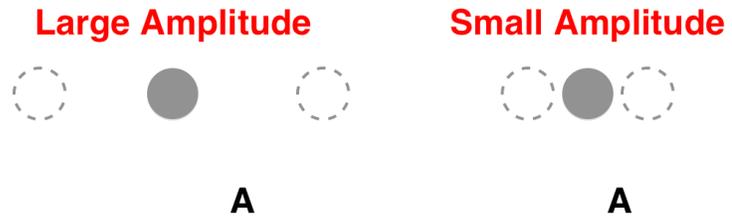
Lesson Notes

Learning Outcomes

- What is the relationship between the intensity of sound and distance from the source?
- How does the deciBel system work?

Energy and Amplitude

- As a sound wave travels through air, air particles vibrate about a fixed position.
- Amplitude is the maximum amount of displacement a particle experiences relative to its resting position.
- High amplitude sounds transport more energy than low amplitude sounds. They are perceived as louder sounds.



Intensity, Power, and Distance

Intensity (I) refers to the amount of sound energy that reaches a given surface area per time. Units on intensity are **Watts/meter²** (abbrev. **W/m²**).

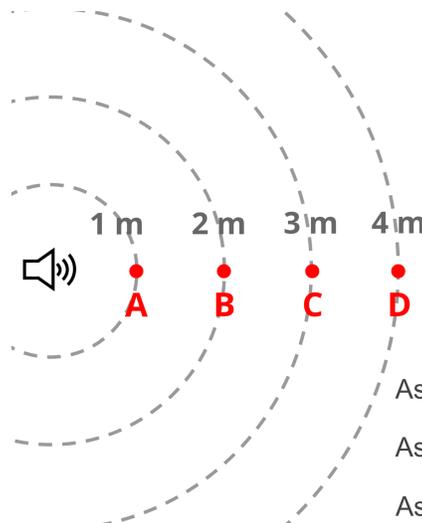
Power (P) is a property of the sound source.

The energy emitted by a source travels into the surroundings and spreads over a spherical surface area with radius **R**.

$$\text{Intensity} = \frac{\text{Energy}}{\text{Time} \cdot \text{Area}} \rightarrow \text{Intensity} = \frac{\text{Power}}{\text{Area}} \rightarrow \boxed{I = \frac{P}{4 \cdot \pi \cdot R^2}}$$

Inverse Square Law

The **intensity** of a sound at any given location is **inversely proportional** to the **square of the distance** from the source.



$$I \propto \frac{1}{R^2}$$

Location	Distance	Intensity
A	1 m	160 units
B	2 m	40 units
C	3 m	17.8 units
D	4 m	10 units

As R doubles, I becomes 1/4-th the value

As R triples, I becomes 1/9-th the value

As R quadruples, I becomes 1/16-th the value

The deciBel Scale

Sound Source	Intensity (W/m ²)	#times more intense than TOH	Bel Rating	deciBel Rating
Threshold of Hearing	1 x 10 ⁻¹²	--	0	0
Rustling Leaves	1 x 10 ⁻¹¹	10 ¹	1	10
Whisper	1 x 10 ⁻¹⁰	10 ²	2	20
Normal Conversation	1 x 10 ⁻⁶	10 ⁶	6	60
Busy Street Traffic	1 x 10 ⁻⁵	10 ⁷	7	70
Vacuum Cleaner	1 x 10 ⁻⁴	10 ⁸	8	80
Rock Concert (1 st Row)	1 x 10 ⁻¹	10 ¹¹	11	110
Threshold of Pain	1 x 10 ¹	10 ¹³	13	130
Military Jet Takeoff	1 x 10 ²	10 ¹⁴	14	140

Thinking in Powers of 10

Example 1: How many times more intense is an 80 dB sound than a 40 dB sound?

40 dB ⇒ 4 Bel } The 80 dB sound is 4 Bels higher ...
 80 dB ⇒ 8 Bel } So 80 dB is **10⁴ X more intense.**

Example 2: How many times more intense is an 90 dB sound than a 30 dB sound?

30 dB ⇒ 3 Bel } The 90 dB sound is 6 Bels higher ...
 90 dB ⇒ 9 Bel } So 90 dB is **10⁶ X more intense.**

The deciBel Equation

What do you do when the intensity is something like 6.27 x 10⁻⁵ W/m²? How do you find its deciBel rating?

$$dB = 10 \cdot \log(I / I_0) \quad \text{where } I = \text{intensity of sound}$$

$$I_0 = 1.0 \times 10^{-12} \text{ W/m}^2$$

Suggestion:

- Determine I / I_0 ratio. $\rightarrow 6.27 \times 10^{-5} / 1.0 \times 10^{-12} = 6.27 \times 10^7$
- Determine the **log** of this ratio. $\rightarrow \log(6.27 \times 10^7) = 7.80$
- Multiple by 10. $\rightarrow 10 \cdot 7.80 = \mathbf{78.0 \text{ dB}}$

Loudness

- An intense sound is perceived as a loud sound ... but not equally loud to all individuals.
- Loudness is a subjective quality, dependent upon the hearing ability of the observer and the sound's frequency.

