12.4 - Sound Intensity & Sound Intensity Level

Stop Yelling!

No!

Sound Intensity

If anyone here has heard gunshots up close or a jackhammer, you know sound gets pretty loud.

Wave motion involves the propagation of energy.

Has anyone heard a loose window vibrate when a passing car goes by, or felt a piece of paper vibrating near a speaker?

Intensity Dynamics

Intensity depends on the distance from a source.

A sound wave propagating from a point source has a spherical shape, and the surface of that enlarging sphere has greater area the farther away one is.

Energy transmitted spreads out over a greater area, and drops off at a rate inversely proportional to the square of the distance from the source.

Intensity Calculations

Let's talk spheres!   No, that's Spears!

Since intensity spreads   over the surface of an expanding sphere,   can anyone give the equation for the surface area of a sphere?

It's: $4\pi r^2$

Sonic power distribution, intensity is governed by:

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

I = Intensity (W/m²)
P = Power of Source (W)
A = Area (m²)
r = radius (m)

Comparing Intensity

When comparing two sound-measuring points, use the ratio:

$$\frac{I_2}{I_1} = \left(\frac{R_1}{R_2}\right)^2$$

I_1 R_1 = Intensity, radius at close point
I_2 R_2 = Intensity, radius at far point

1. What's the intensity at a point 45 m away from a sound source if it's 3.4 W/m² 8.0 m away?

$$\frac{I_2}{I_1} = \left(\frac{R_1}{R_2}\right)^2$$

$$I_2 = I_1\left(\frac{R_1}{R_2}\right)^2 = 3.4\frac{W}{m^2}\left(\frac{8.0\,m}{45\,m}\right)^2 = 0.11W$$

8.0 m
3.4 W/m²

45 m
?? W/m²

Loudness

Sound needs enough intensity for our ears to hear it.

The Threshold of Hearing, I_o, is the lowest intensity we can hear, and is about 1.0 E -12 W/m².

The Threshold of Pain, I_p, occurs at 1.0 W/m², and is the point when sound is uncomfortably loud and may be painful.

The threshold of pain is one trillion times greater than that of hearing!

You may need these.

Intensity Level: The decibel (dB)

Intensity **level** differs from sound intensity.

It is convenient to compare a range of intensities by using a base 10 logarithmic scale.

To determine intensity level, log intensity ratio:

$Intensity\ Level\ (dB) = 10 \bullet \log\left(\dfrac{I}{I_o}\right)$	I = Signal Intensity (W/m^2) I$_o$ = Threshold of hearing (1 E -12 W/m^2)

This relation is used for <u>any</u> comparison:

$Intensity\ Level\ (dB) = 10 \bullet \log\left(\dfrac{I_2}{I_1}\right)$	I$_2$ = Final Intensity (W/m^2) I$_1$ = Initial Intensity (W/m^2)

Decibels to Intensity:
Reversing the log Function

To go from dB to I, use this mathematical sequence:

$$dB = 10 \bullet \log\left(\frac{I}{I_o}\right)$$

I = sound intensity of signal (W/m^2)
I$_o$ = threshold of hearing (1 E -12 W/m^2)

$$\frac{dB}{10} = \log\left(\frac{I}{I_0}\right)$$

$$10^{\frac{dB}{10}} = \frac{I}{I_0}$$

Calculator Tutorial

$$I_0 \bullet 10^{\frac{dB}{10}} = I$$

2. Intensity Example A

What is the intensity level of a sound with intensity of 5.0 E -6 W/m^2?

$$Intensity\ Level\ (dB) = 10 \bullet \log\left(\frac{I}{I_o}\right)$$

$$= 10 \bullet \log\left(\frac{5.0E - 6W/m^2}{1E - 12W/m^2}\right) = 67\,dB$$

3. Intensity Example B

An observer is 5.0 m from a sound source. By how much will the sound level decrease (in dB) if the observer moves out to 25 m?

$$\frac{I_2}{I_1} = \left(\frac{R_1}{R_2}\right)^2 = \left(\frac{5}{25}\right)^2 = \frac{25}{625}$$
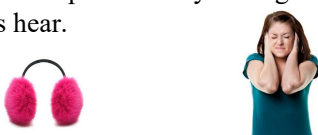
$$Intensity\ Level\ (dB) = 10 \bullet \log\left(\frac{I_2}{I_1}\right)$$

$$= 10 \bullet \log\left(\frac{25}{625}\right) = -14\,dB$$

Hearing Damage

An abundance of sound can permanently damage the nerve cells that help us hear.

Wear your earmuffs!

How To Look At Noise

Intensity comparisons with NIOSH recommended permissible exposure time.

For every 3 dB, the energy doubles.

Source	Pressure rms (Pa)	Sound Intensity level SIL (dB)	Intensity (W/m^2)
Jet engine at 10 m		150	10^3
Jet engine	200	140	100
Jack hammer	60	130	10
Car horn	20	120 (pain threshold)	1
Rock band	6	110	0.1
Machine shop	2	100	0.01
Train	0.6	90	10^{-3}
Vacuum cleaner	0.2	80	10^{-4}
TV	0.06	70	10^{-5}
Conversation	0.02	60	10^{-6}
Office	0.006	50	10^{-7}
Library	0.002	40	10^{-8}
Hospital	0.0006	30	10^{-9}
Broadcast studio	0.0002	20	10^{-10}
Rustle of leaves	0.00006	10	10^{-11}
Threshold of hearing	0.00002	0	10^{-12}

Noise Intensity	Unprotected Exposure Limit
85 dBA	8 hours
88 dBA	4 hours
91 dBA	2 hours
94 dBA	1 hour
97 dBA	30 minutes
100 dBA	15 minutes
103 dBA	7 1/2 minutes
106 dBA	3 3/4 minutes

Homework

12.4 Problems.

Due: Next Class.