

# Physics of Sound

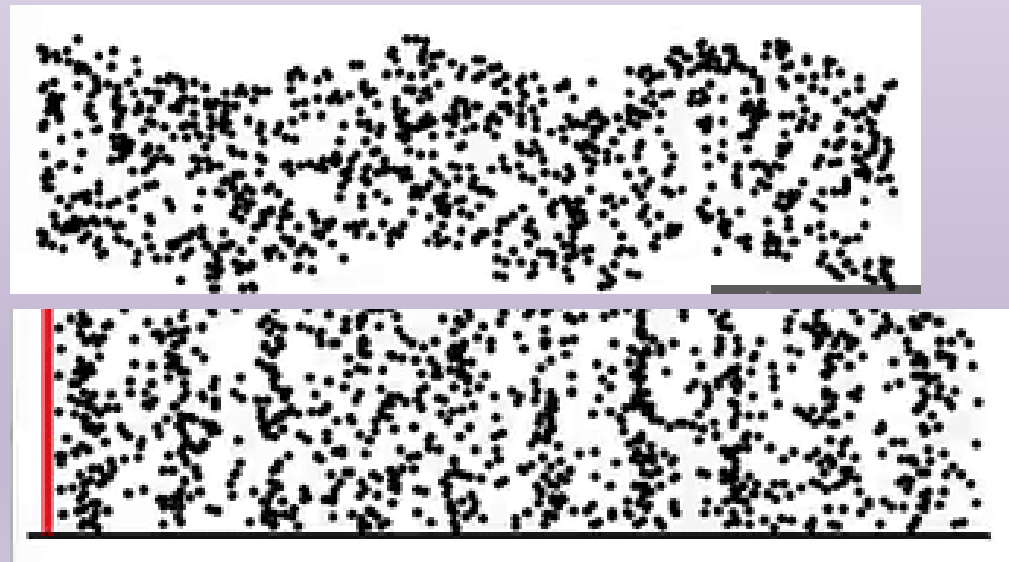
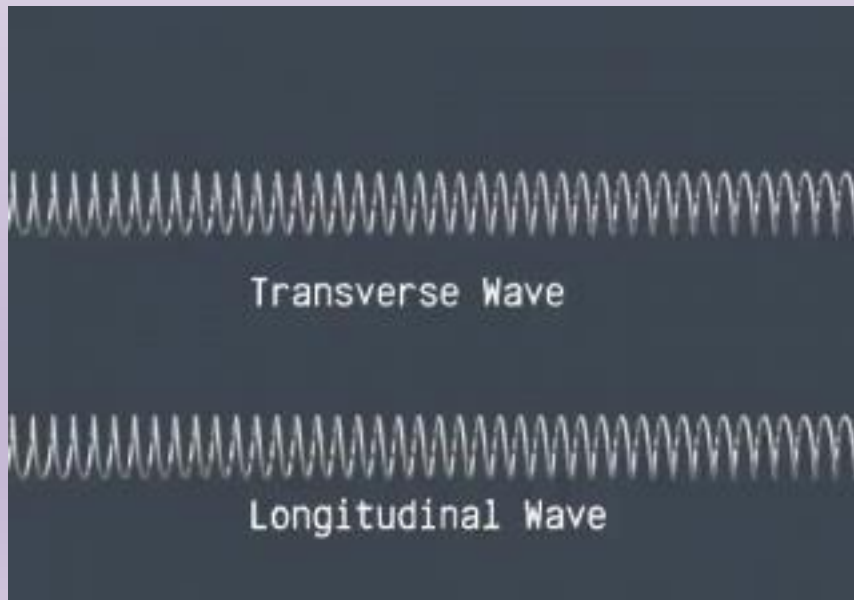
# What is sound?

- **Vibrations** that **travel** through the air (or another medium) that can be **heard** when they reach the ear
- Sound may be classified as **noise** based on its magnitude, characteristics, duration and time of occurrence

# Sound Waves

## Transverse vs. longitudinal

- **Transverse wave**: A wave vibrating at right angle to the direction of its propagation
- **Longitudinal wave**: A wave vibrating parallel to the direction of its propagation



Transverse vs. longitudinal; 2011 Dan Russell [2]

# Wave Properties

## Frequency (f)

- The number of waves passing a point in a certain time  
A sound wave consists of a repeating pattern of high-pressure and low-pressure regions moving through a medium
- Frequency units are hertz (Hz)  
1 hertz = 1 wave per second

$$f = 1/T$$

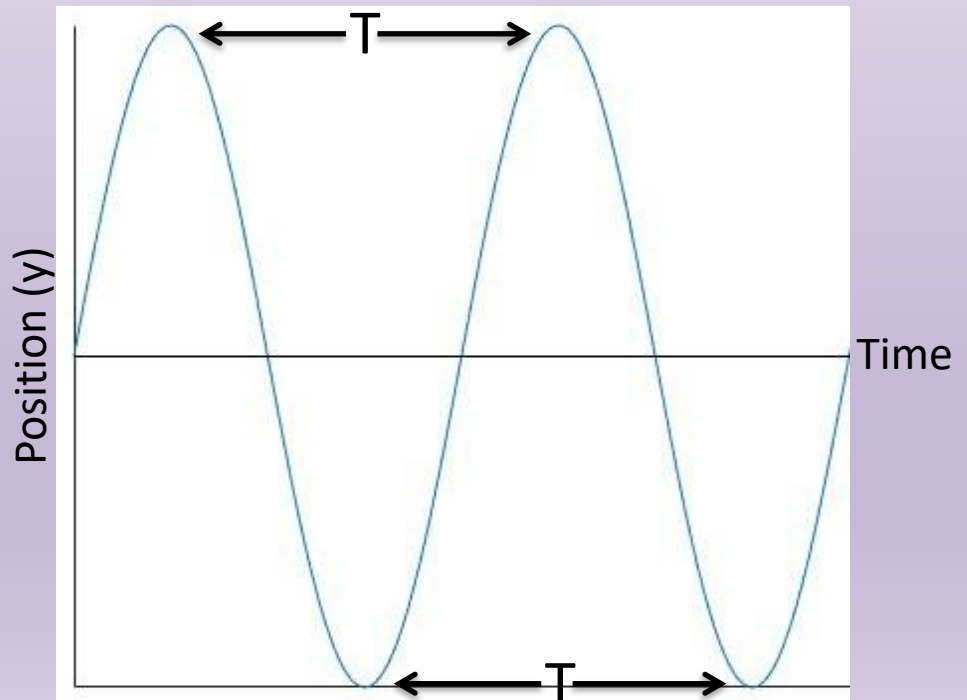
$$\text{OR } f = v/\lambda$$

f = frequency

v = wave velocity

$\lambda$  = wave length

T = time or period



# Frequency

- Sound is classified according to its frequency and pressure
- High and low hertz numbers characterize high and low tones, respectively
- Humans are able to perceive sounds in the range of  $\sim 20$  Hz to 20,000 Hz<sup>[3]</sup>

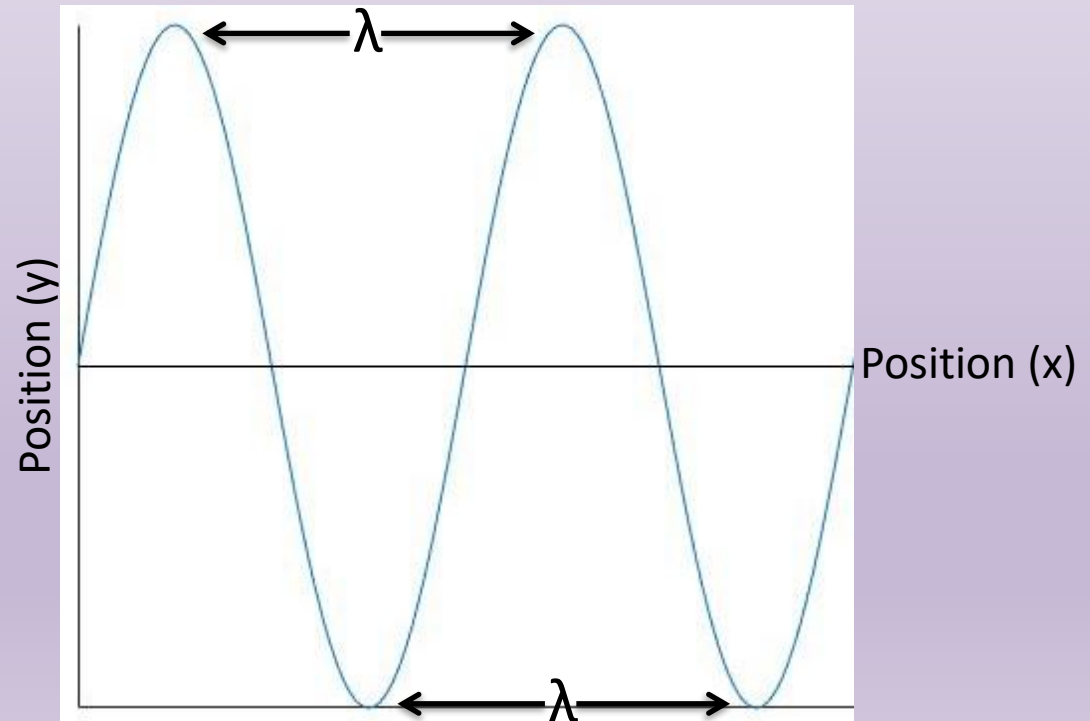
# Wave Properties

## Wavelength ( $\lambda$ )

- Distance from a particular point on a wave to the next point that is at the same height, going in the same direction
- Wavelength is measured in meters

Again  $f=v/\lambda$

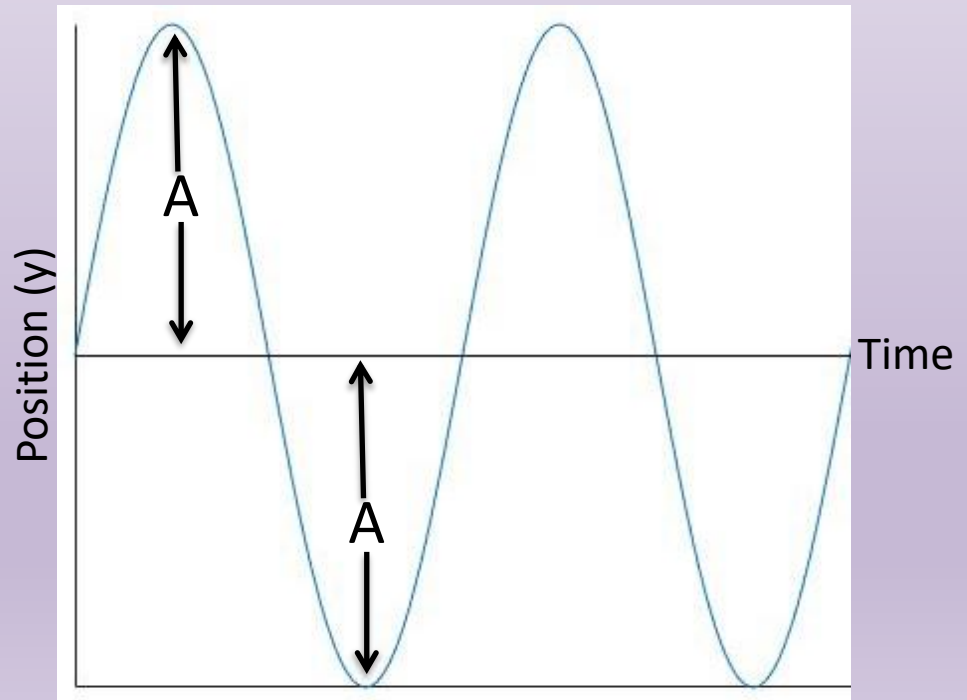
$$\rightarrow \lambda=v/f$$



# Wave Properties

## Amplitude (A)

- The distance from the center line to the top of a crest or to the bottom of a trough
- Measured in meters



# Speed of Sound

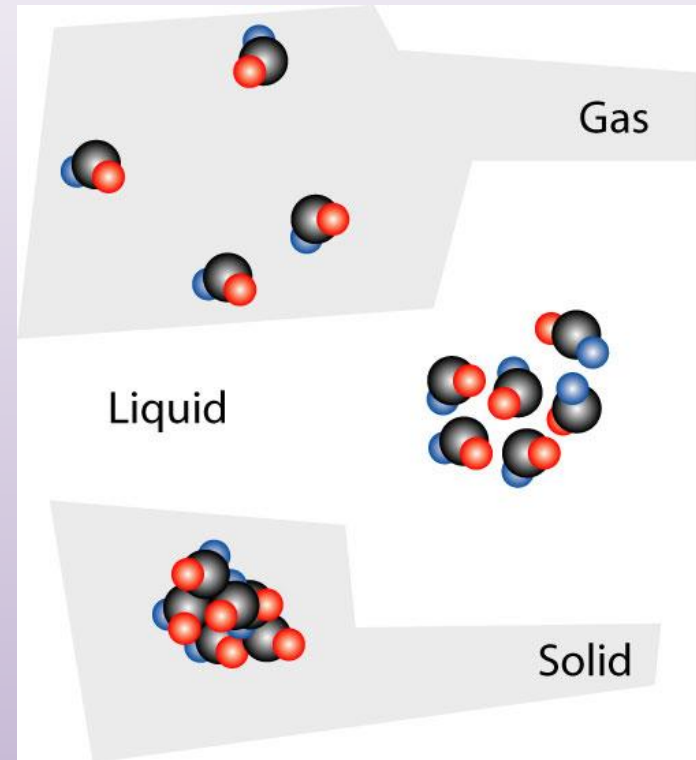
- Sound waves need to travel through a medium (for example, solids, liquids, gases)
- Sound waves move through various mediums by vibrating the molecules in the matter
- The speed of sound varies in different media (for example, solids, liquids, gases)
- Temperature also dictates how fast sound waves travel



# Sound Waves in Solids, Liquids and Gases

Molecules are:

- tightly packed **in rigid material**
- less tightly packed **in liquid**
- loosely packed **in gas**



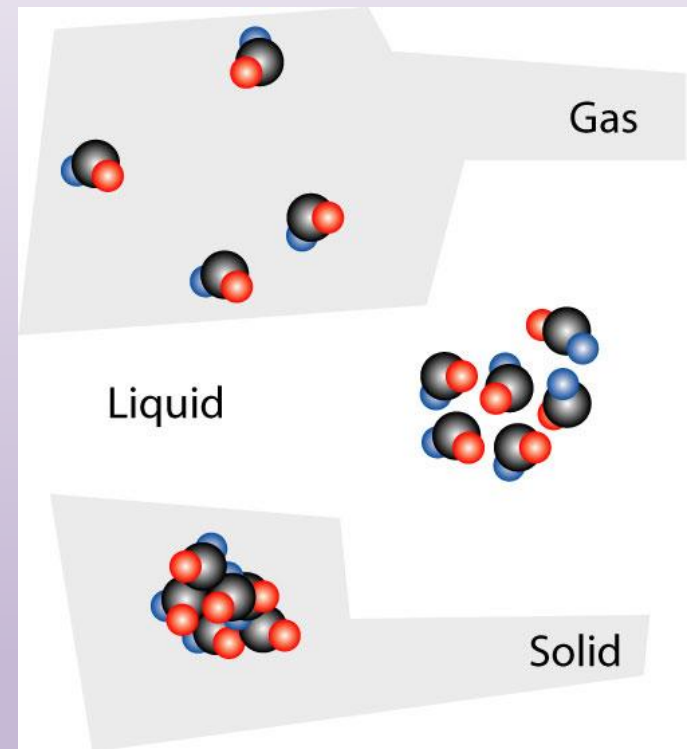
In close proximity, molecules collide with one another to propagate waves of vibrations

# Sound Waves in Solids, Liquids and Gases

- Sound travels faster in solids than in gases

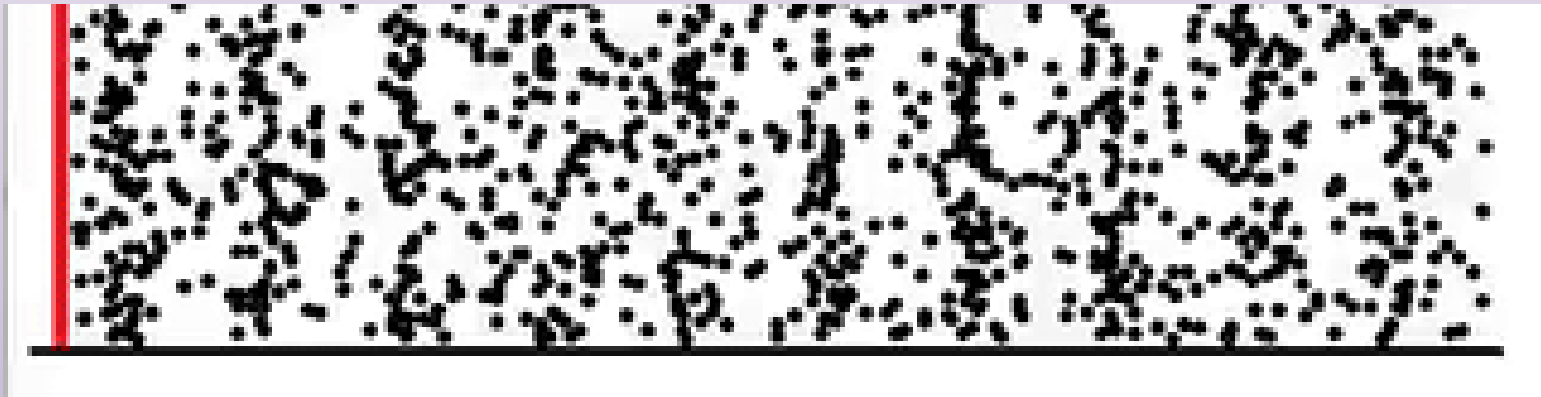
For example, sound waves move  
~13 times faster in wood than in air<sup>[4]</sup>

- Sound travels faster in liquids than in gases
- Loosely packed molecules have further to travel and take longer to collide with one another



# Sound Waves in Media

Recall the longitudinal wave:



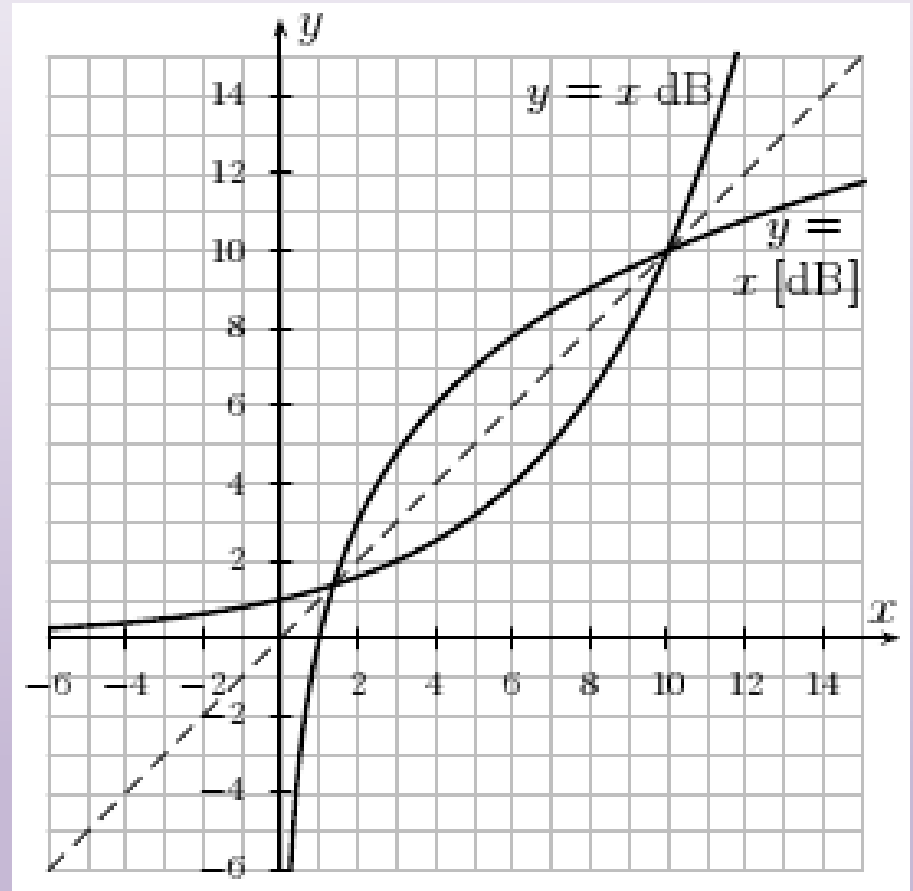
# Sound Measurement

- The scale for measurement of sound pressure is called decibels (dBs)
- Decibels are measured on a logarithmic scale
  - A small change in the number of decibels results in a huge change in the amount of noise and the potential damage to a person's hearing<sup>[5]</sup>

# Decibel

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

- When a sound increases by 10 units on the decibel scale, its loudness becomes 10 times more powerful
- $\beta$  represents sound intensity level measured in dB



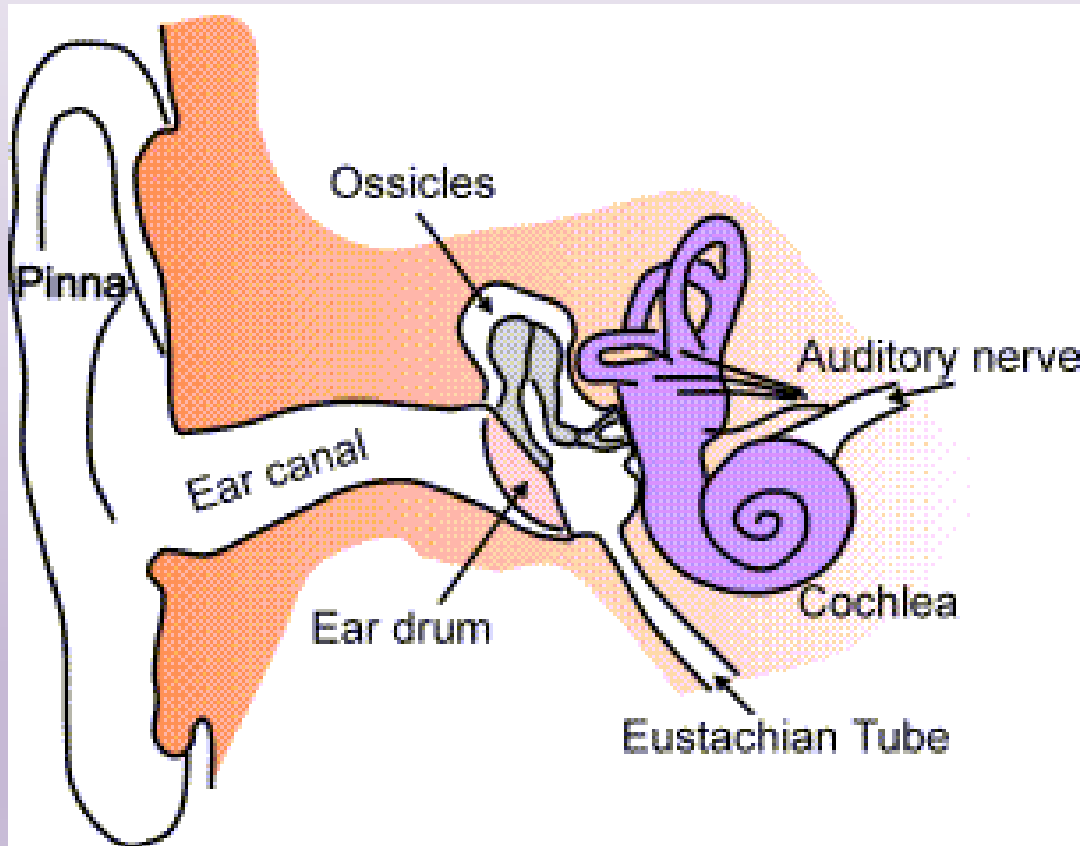
Graph of the decibel function and its inverse

2010 Name, Wikimedia Commons CC BY-SA 3.0

[https://commons.wikimedia.org/wiki/File:Plot\\_of\\_decibel\\_and\\_inverse.png](https://commons.wikimedia.org/wiki/File:Plot_of_decibel_and_inverse.png)

# How do people hear?

The human ear translates the energy from sound waves into neurologic impulses that are heard as sound<sup>[5]</sup>



Cutaway diagram of human ear anatomy

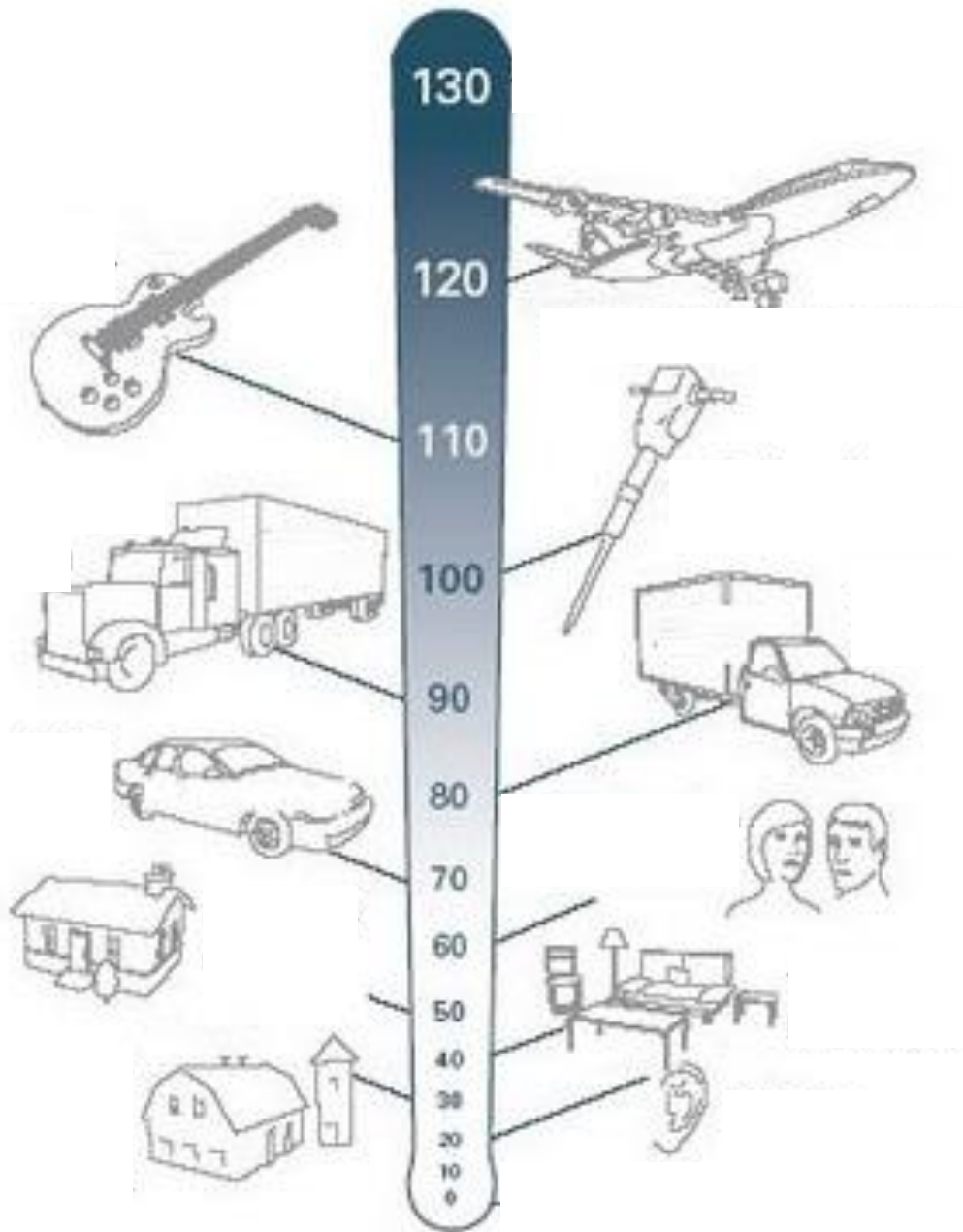
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<https://commons.wikimedia.org/wiki/File:Ear-anatomy-text-small-en.png>

# Sound vs. Noise

**Noise** is unwanted or unpleasant sound

- One person may hear something as sound, while another person considers it noise
- Sound may be classified as noise based on its magnitude, characteristics, duration and time of occurrence<sup>[6]</sup>



The A-weighted sound levels closely match the perception of loudness by the human ear



# Health Hazards/Impacts

- Exposure to loud noises can cause a temporary threshold shift (TTS) in hearing sensitivity or a permanent threshold shift (PTS)<sup>[5]</sup>
- A noise-induced permanent threshold shift (NIPTS) is a permanent threshold shift that can be attributable to noise exposure

# Health Hazards/Impacts to Students

High noise levels may obstruct students' recognition of teachers' speech

- The extra effort required to identify and remember the words may result in fewer resources available for understanding<sup>[7]</sup>

# Sound Measurement

## Sound level meter:

- Commonly, a **handheld** instrument with a microphone
- The **microphone diaphragm** responds to air pressure changes caused by sound waves<sup>[5]</sup>
- Smart phones now have sound monitor **apps**



# Sound Measurements

- **Dosimetry:** The use of body-worn instruments to monitor people's noise exposure<sup>[5]</sup>
- **Engineering surveys:** Noise exposure monitoring



Pocket dosimeter; a NMR monitoring device with three Hall-effect sensors  
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[https://commons.wikimedia.org/wiki/File:Pocket\\_Dosimeter.jpg](https://commons.wikimedia.org/wiki/File:Pocket_Dosimeter.jpg)

# References

- [1] “Transverse wave and longitudinal Wave.” (6-second video) YouTube. Physics007animations, Sept. 2, 2011. <https://www.youtube.com/watch?v=2Wlh3M2a10U>
- [2] Russell, Dan. “Acoustics and Vibration Animations.” Longitudinal and Transverse Wave Motion. Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License
- [3] Serway, Raymond A, and John W. Jewett, Jr. *Physics for Scientists & Engineers with Modern Physics*. 8th edition. Belmont: Brooks/Cole Cengage Learning, 2010. Print.
- [4] Hall, Debra, and Crystal Patillo. “2.7 How does sound travel in different environments?” Kenan Fellows Program, BioMusic, Learn NC, School of Education, University of North Carolina. <http://www.learnnc.org/lp/editions/biomusic/6517>
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- [6] “Perception of Sound - Human Ear.” Sound and Noise - Perception of Sound - Human Ear. Web. [http://www.epd.gov.hk/epd/noise\\_education/web/text/ENG\\_EPD\\_HTML/m1/intro\\_1.html](http://www.epd.gov.hk/epd/noise_education/web/text/ENG_EPD_HTML/m1/intro_1.html)
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