SOUND WAVES

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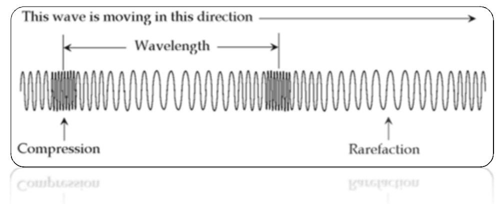
Sound

- A source, like a speaker, compresses air molecules at regular intervals, creating differences in pressure over time.
- This creates a longitudinal wave



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Speed of Sound

- The speed of a sound wave depends on the medium.

Speed of sound in various substances (CRC Handbook)

Gasses (*0°C*)	**Substance**	**Speed of Sound** (*m/s*)
	Carbon Dioxide	259
	Hydrogen	1284
	Helium	965
	Nitrogen	334
	Oxygen	316
	Air (21% Oxygen, 78% Nitrogen)	331
	Air (20°C)	344
Liquids (*25°C*)	Glycerol	1904
	Sea Water (3.5% salinity)	1535
	Water	1493
	Mercury	1450
	Kerosene	1324
	Methyl Alcohol	1103
	Carbon Tetrachloride	926
Solids	Diamond	12000
	Pyrex Glass	5640
	Iron	5960
	Granite	6000
	Aluminum	5100
	Brass	4700
	Copper (annealed)	4760
	Gold	3240
	Lead (annealed)	2160
	Rubber (gum)	1550

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Speed of Sound

- Speed of sound in air = 331 m/s @ 0^{o} C
- In air, speed increases 0.6 m/s for each 1^{o}C increases in temperature
- Velocity at any temperature can be found using: $v = 331 + 0.6T_c$
- Follows all properties of waves including:

$$v = \lambda f$$

- Wavelength, <u>not frequency</u>, changes when a wave changes speed

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The Sound Spectrum

- Humans can hear frequencies between 20 Hz and 20,000 Hz. These are called the audible sound waves.
- Sounds below 20 Hz are called infrasonic.
- Sounds above 20,000 Hz are called ultrasonic.
  - Used for medical imaging and echolocation

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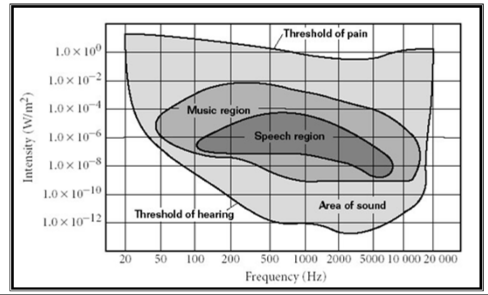
Audible Range

- Whether we can hear a sound or not depends on the frequency and intensity of the sound.



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Intensity

- Rate at which the energy of the sound wave strikes a unit area

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

Where P is the power in watts and $4\pi R^2$ is the area in square meters.

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Sample Problem

- Calculate the intensity of an electric guitar's amplifier at a distance of 5.0m if its power output is 100 W.

$$I = \frac{P}{[4\pi R^2]}$$

$$I = \frac{100}{[4\pi (5)^2]}$$

$$I = \frac{100}{314.15}$$

$$I = 0.318 \frac{W}{m^2}$$

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Intensity Level or Loudness

- Depends on the amplitude of the wave
- Measured in decibels (dB)
- 0 dB is the lowest level sound that people can hear 0 dB = $1x10^{-12}$ W/m^2. (I_o)
- Loudness is the relative intensity to this level.

$$\beta = 10\log\frac{I}{I_o}$$

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Sample Problem

- Calculate the decibel level of an electric guitar's amplifier at a distance of 5.0m if its power output is 100 W.

$$\beta = 10\log\left(\frac{0.318}{1x10^{-12}}\right)$$

$$\beta = 10\log(3.18x10^{11})$$

$$\beta = 115dB$$

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Decibel Level, Intensity, and Loudness

- Logarithmic relationship
- 10 Decibel increase - increases the intensity by 10 times, and the sound is approximately twice as loud
- 20 Decibel increase - increases the intensity by 100 times, and the sound is approximately 4 times as loud
- 30 Decibel increase - increases the intensity by 1000 times, and the sound is approximately 8 times as loud

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Decibel Level, Intensity, and Loudness

Decibel Increase	Intensity	Louder
10 dB	(10^1) = 10 times	(2^1) = 2 times
20 dB	(10^2) = 100 times	(2^2) = 4 times
30 dB	(10^3) = 1,000 times	(2^3) = 8 times
40 dB	(10^4) = 10,000 times	(2^4) = 16 times
50 dB	(10^5) = 100,000 times	(2^5) = 32 times

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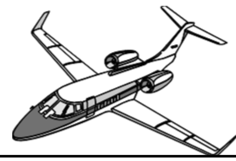
Doppler Shift

- Effect observed when a sound source moves toward you.
- Occurs with all wave motion
- Frequency gradually increases as the source approaches, then suddenly drops to a lower pitch as the source passes and moves away.



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Doppler Effect

- Here's why

- The source of the sound actually catches up to its own sound waves

•**Example**

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