What Is Sound?

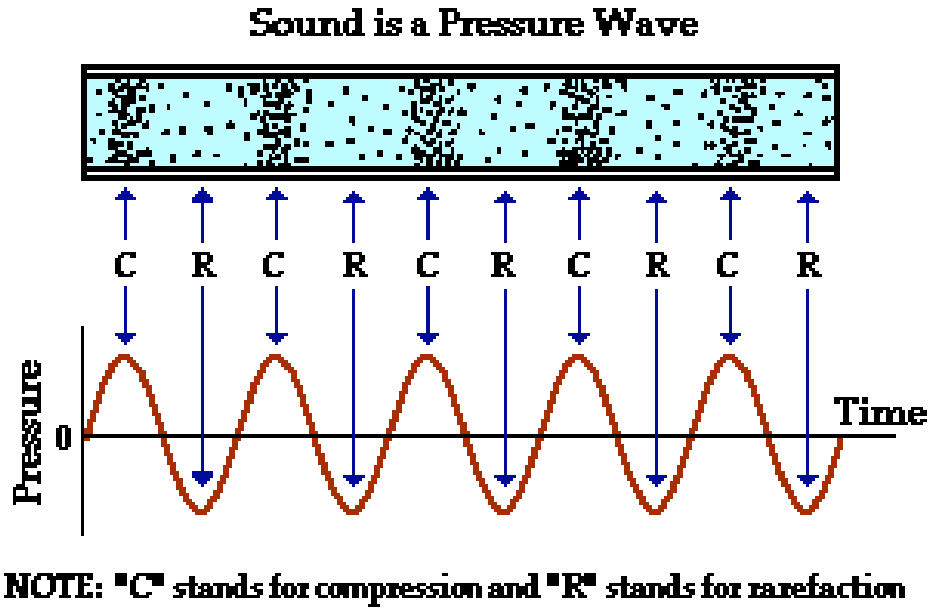
Sound is a pressure wave which is created by a vibrating object.

This vibrations set particles in the surrounding medium (typical air) in vibrational motion, thus **transporting energy** through the medium.

Since the particles are moving in parallel direction to the wave movement, the sound wave is referred to as a **longitudinal** wave.

The result of longitudinal waves is the creation of **compressions** and **rarefactions** within the air.

The alternating configuration of C and R of particles is described by the graph of a **sine wave** (C~crests, R~troughs)



The speed of a sound pressure wave in air is $331.5+0.6T_c$ m/s , T_c temperature in Celsius

The particles do not move down the way with the wave but **osciallate back and forth** about their individual equilibrium position.

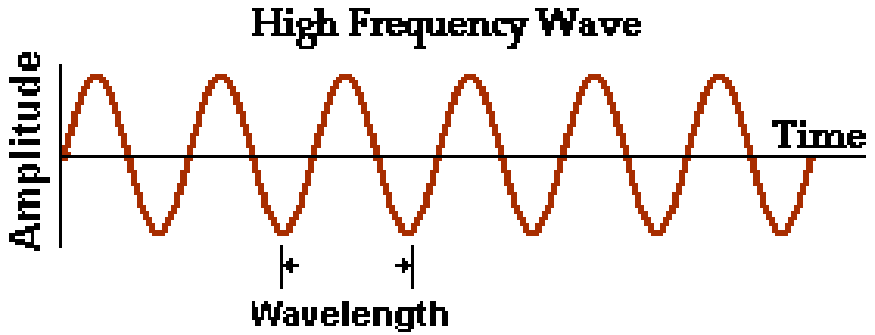
Wavelength, Amplitude, Frequency of a Wave

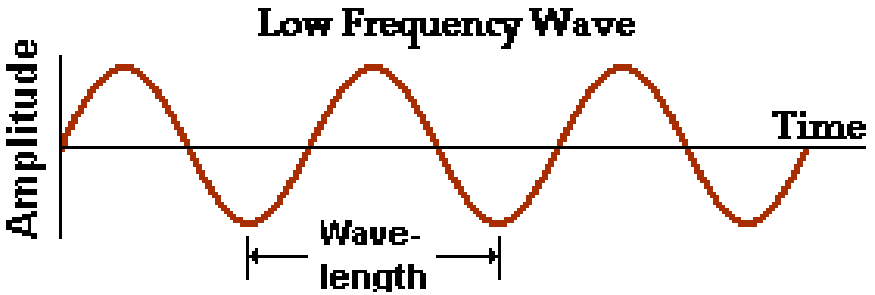
The amount of work done to generate the energy that sets the particles in motion is reflected in the degree of displacement which is measured as the **amplitude** of a sound.

The **frequency *f* of a wave** is measured as the number of complete back-and-forth vibrations of a particle of the medium per unit of time.

1 Hertz = 1 vibration/second

f = 1/Time





Depending on the medium, sound travels at some speed *c* which defines the **wavelength *l*: l = c/f**

Measuring the Intensity of Sound

- The softest audible sound modulates the air pressure by around 10^{-6} Pascal (Pa). The loudest (pain inflicting) audible sound does it by 10^2 Pa.
- Because of this wide range it is convenient to measure sound amplitude on a logarithmic scale in ***Decibel [dB]***.
- Decibel is not a physical unit - it expresses only a ratio for comparing the intensity of two sounds: $10 \log_{10} (I/I_o)$ where I and I_o are two intensity/power levels ($I \sim P^2$, P is sound pressure)
- One can say e.g. a channel is amplifying the sound by 3 dB, meaning the output is 3 dB louder than the input.
- In order to make it interpretable as a real unit, a fixed pressure $P_0 = 2*10^{-5}$ Pa is defined (the reference of 0db corresponds to the threshold of hearing) and the absolute sound pressure P in Decibel is defined as: $\mathbf{20 \log_{10} (P/P_0)}$
- Thus +20 dB means an increase in pressure by a factor of 10

Examples for Sound Levels in Decibel

Threshold of hearing	0 dB	softest audible 1000 Hz sound	6 dB
quiet living room	20 dB	soft whispering	25 dB
refrigerator	40 dB	soft talking	50 dB
normal conversation	60 dB	busy city street noise	70 dB
passing motorcycle	90 dB	somebody shouting	100 dB
pneumatic drill	100 dB	helicopter	110 dB
loud rock concert	110 dB	air raid siren	130 dB
pain threshold	120 dB	gunshot	140 dB
rocket launch	180 dB	Instant perforation of eardrum	160 dB

1) TOH: One-billionth of a centimeter of molecular motion
2) The most intense sound (without physical damage) is one trillion times more intense

Humans vs Machines on similar tasks (2001)

Tasks	Vocabulary	Humans	Machines
Connected digits	10	0.009%	0.72%
Alphabet letters	26	1%	5%
Spontaneous telephone task	2000	3.8%	36.7%
WSJ with clean speech	5000	0.9%	4.5%
WSJ with noisy speech (10db SNR)	5000	1.1%	8.6%
Clean speech based on trigram sentences	20000	7.6%	4.4%

- Humans are at least 5 times better than machines, and far more robust
- In the last experiment humans and machines have the same syntactic and semantic model > the difference disappears (Experiments by Microsoft, 2001)