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Sound Propagation, Harmonic Motion, Frequency, and Wavelength

Definitions: Physical vs. Psycho-Acoustic

Definition of Sound: Physical

- American Heritage dictionary: "A vibratory disturbance in the pressure and density of a fluid, or in the elastic strain in a solid."

Definition of Sound: Psycho-Acoustic

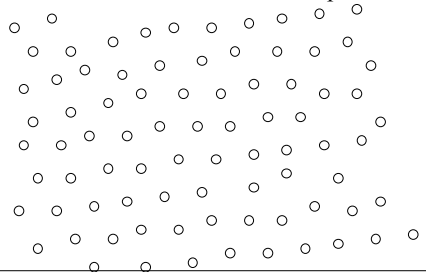
". . . and capable of being detected by the organs of hearing."

Sound Propagation

- Air particles in compression/rarefaction (when viewed from a single point of reference)

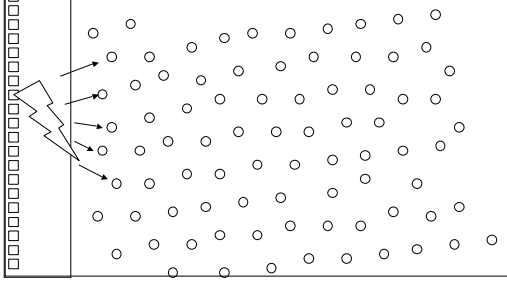
How sound propagates

- Air molecules with neutral displacement



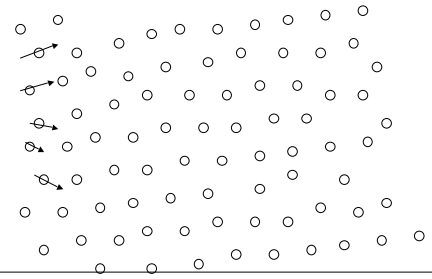
How sound propagates 2

- Energy is injected into the system



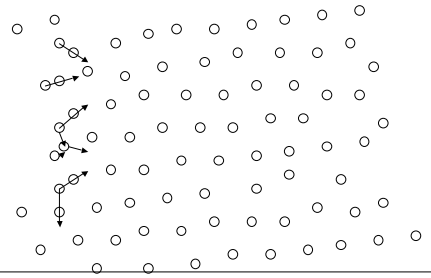
How sound propagates 3

- Energy is transferred to molecules



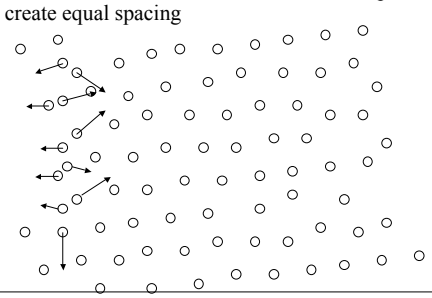
How sound propagates: Compression

- Energy is transferred as molecules attempt to maintain equal distance from each other



How sound propagates 4

- As energy is transferred, original molecules now are too close to other molecules, and attempt to create equal spacing



How sound propagates 5

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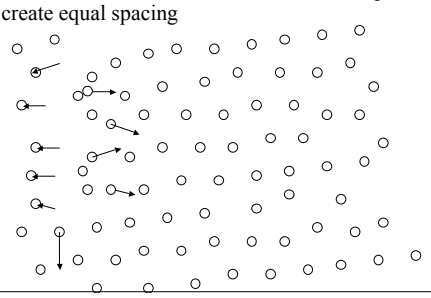
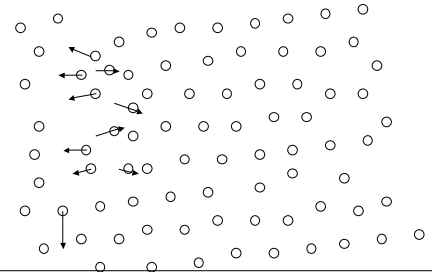
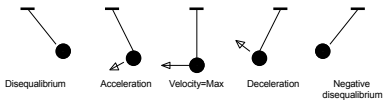


How sound propagates 6

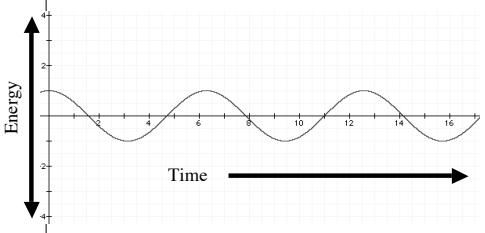
- This impulse continues to travel through the medium until all energy is dispersed.



Simple Harmonic Motion

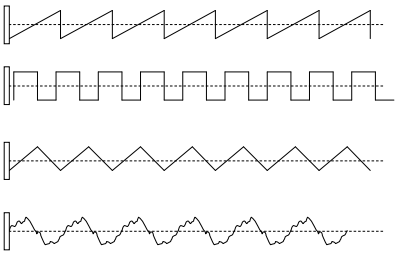


Representation 1: Time/Energy Chart

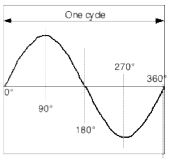


Periodic Waveform

Any waveform which repeats itself exactly



Definitions: Cycle

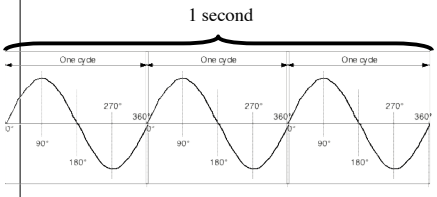


Definitions: Frequency

$$Frequency = \frac{Cycles}{Second}$$

- Sound is a cyclic phenomenon
- Frequency is the number of cycles occurring in one second.
- Measured in Hertz (after Mr. Hertz)
- Also known as Pitch

Definitions: Frequency



The number of cycles performed per time.

Frequency is measured in Cycles per Second (cps) or hertz (Hz)

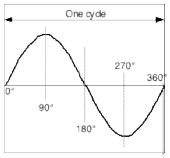
Getting to know Frequency

- Listen to different frequencies
- View frequencies on screen

Speed of Sound

- Speed 1130 ft/sec at 59°F, or "Standard Temperature"
- Travels roughly 1 ms/Foot
- Remember this number!!!

Definitions: Wavelength



The distance that a single cycle travels

Wavelength is measured in feet or meters (any unit of distance)

Wavelength

$$Wavelength = \frac{Speed}{Frequency}$$

- Length of one cycle is the distance per second divided by the frequency in cycles per second
- Speed of sound changes with air temperature

What is the wavelength of a 1000Hz sound wave?

$$Wavelength = \frac{Speed}{Frequency}$$

$$Wavelength = \frac{1130\,ft/s}{1000 cycles/s(Hz)}$$

What is the wavelength of a 1000Hz sound wave?

$$Wavelength = \frac{1130\,ft/s}{1000 cycles/s(Hz)}$$

$$1.13 = \frac{ft}{cycle}$$

What is the wavelength of a 60Hz sound wave?

$$Wavelength = \frac{1130\,ft/s}{60\,Hz}$$

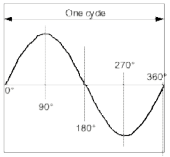
$18.83\,ft$

What is the wavelength of a 6000Hz sound wave?

$$Wavelength = \frac{1130\,ft/s}{6000\,Hz}$$

$.19\,ft$

Definitions: Period



The length in time that it takes one cycle to complete

Period is measured in SECONDS (s)

Period

$$Period = \frac{1}{Frequency}$$

- Frequency is Cycles per Second
- Period is time one cycle takes
- Period is inverse of frequency

What is the period of a 1000Hz sound wave?

$$Period = \frac{1s}{1000\,cycles/s}$$

$.001s$

$1ms$

Period/frequency relationship

Frequency is the INVERSE of period

$$Frequency = \frac{1}{Period}$$

Thus, FLIP f to get p,
and FLIP p to get f

Period/Wavelength Relationship

Period times the speed of sound = Wavelength

$$Wavelength = Period \leftrightarrow SpeedofSound$$

Hearing Frequency Range

- 20 Hz - 20,000 Hz
- Remember this!

Octave

- A 2:1 relationship of frequency
- Thus 200 Hz is 1 octave higher than 100 Hz
- Also referred to as 8va

Math: How many Octaves in the human range of hearing?

- 20
- 40
- 80
- Etc….

Note about linear vs. exponential

- Half of the frequency range is in the last (top) octave.

JND for frequency

- Psychoacoustical term
- "Just noticable difference"
- Is about 3 Hz.
- However, the ear can hear transitions better than steady states.
- So it is possible to hear an abrupt transition from 300 Hz - 202 Hz.

What is the implication of JND in terms of the frequency range?

What is the implication of JND in terms of the frequency range?

- Hint: compare octave ranges an frequency range as we move through the human range of hearing.

Some Pitch to Frequency Relationships

- Middle C = 256 Hz
- A for tuning = 440 Hz.
- Note that each orchestra can tune to a different “A”.