Sound Propagation through Media

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Overview

- What is a wave?
- What is sound?
- Types of sound waves
- Nature of sound

What is a Wave?

- A wave is a disturbance that travels in time as well as space.

- An example of a simple harmonic wave function is: $\psi(x, t) = A \sin(\omega t \pm kx)$. Here
  - $\psi(x, t)$ = is the wave function
  - A = wave amplitude
  - ω = angular frequency
  - k = wave number = $2\pi/\lambda$
  - λ = wavelength

What is a Wave?

- There are several types of waves. Some waves require presence of a material medium, while others do not.
  - Electromagnetic waves do not require presence of a material medium for propagation. Examples: light, and electricity.
  - Mechanical waves require presence of a material medium for propagation. Examples: water waves, sound, waves in a vibrating string, etc.

What is Sound?

- Sound is a mechanical wave which travels through media (solids, liquids, or gas).
- In fluids, sound travels as a pressure wave.
- In solids, mechanical waves can travel in several modes (shear, bending, pressure, etc.).
- Sound can also propagate through plasma.
- In air, sound is perceptible by the human ear, if its frequencies lie between 20 and 20,000 Hz.
- The matter that supports travel of sound is called ***medium***. Sound cannot travel through vacuum.

Types of Sound Waves?

- Sound waves are associated with two types of velocities. These are:
  - Particle velocity: It is the velocity of particles which constitute the wave
  - Wave velocity: It is the velocity of the disturbance which propagates through the medium.

- For sound waves, particle and wave velocity need not be the same. We will learn more about this distinction later.

- Sound waves can be broadly characterized as:
  - Longitudinal waves: Here, particle velocity and wave velocity are in the same direction.
  - Transverse waves: Such waves travel in direction normal to that of particle velocity.

Some Application Areas & Technologies

- Personal
  - Entertainment, noise cancellation
- Industrial
  - Transportation
  - Production machinery
  - Appliances and consumer goods
- Service
  - Medicine (diagnostics and procedures)
  - Entertainment (virtual reality, auditoriums)
- Defence
  - Silent subs
- Microgravity
  - Acoustic levitation

- Generation
- Reproduction & amplification
- Propagation & radiation
- Reception
- Attenuation and control

Acoustics and Its Applications

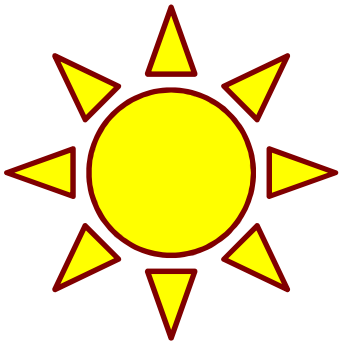
- Acoustics: *Science of sound and also of its accompanying auditory events*
  - Electro-mechanical acoustics
    - Transformation of electrical/mechanical energy into sound and vice-versa
  - Physical acoustics
    - Radiation, propagation, and reception
  - Psycho-acoustics
    - Brain-sound interactions

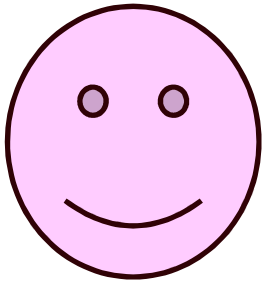
Understanding Sound

Sound Generation

Sound Propagation

Sound Perception





Electro-Mechanical Acoustics

Physical Acoustics

Psycho Acoustics

Nature of Sound

- Sound waves in air correspond to “small” fluctuations in ambient air pressure.
- When we say that “sound is travelling in air”, it implies these pressure fluctuations in air travel over distances over a certain period.
- The propagation velocity of these “fluctuations” corresponds to velocity of sound in air.
- If ambient air pressure is P_o, and pressure fluctuation in air due to sound is $p(x, t)$, then overall pressure in air P_{total} can be expressed as P_o, a sum of and $p(x, t)$. This is shown in the next slide.

Nature of Sound

$$P_{total}\,(x,t) = P_o + p(x,t)$$

P_o = 1,01,325 Pa
(at standard atmospheric conditions)

Typical values for p are shown in the next slide.

Typical Sound Pressures

Source	Pressure (Pa)
Krakatoa explosion at 160 km	20,000 Pa (RMS)
.30-06 rifle -1 m to shooter's side	7,265
Jet engine at 30 m	632
Threshold of pain	63.2
Hearing damage possible	20
Jet at 100 m	6.32 – 200
Hearing damage (long-term exposure)	0.356
Passenger car at 10 m	0.02 – 0.20
TV (set at home level) at 1 m	0.02
Normal talking at 1 m	0.002 – 0.02
Very calm room	6.32×10^{-4}
Leaves rustling, calm breathing	6.32×10^{-5}
Auditory threshold at 1 kHz	2×10^{-5}

Source
Wikipedia

Nature of Sound

- Like other waves, sound waves can:
  - Travel in one, two or three dimensions.
  - Reflect: Examples of sound reflections include echoes.
  - Refract: This happens especially when sound passes through a layered media, i.e. one with varying density.
  - Diffract: Sound bends around corners while travelling. This effect is more pronounced for waves with longer wavelengths.
  - Interfere: Beats are a commonly heard phenomenon and can be explained as an interference phenomenon.

References

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- Sound and Structural Vibration, Fahy Frank, et al, 2nd ed., Academic Press 2007.