Music 175: What is Sound?

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What is Sound?

If a tree falls in a forest and no one is there to hear it, does it make sound?

Figure 1: A mime in the forest.
Sound and Vibration

• The word *sound* is used to describe both:

1. an auditory sensation in the ear
2. the disturbance in a medium that causes an auditory sensation

• Nearly all objects will vibrate when disturbed.
• Sound is the result of a *wave* created by a disturbance, that propagates through a medium from one location to another.
The Science of Sound

• **Acoustics** is the science that deals with the quantifiable measure of the *production, control, transmission* and *reception* of sound.
  
  – encompasses disciplines such as physics, engineering, psychology, audiology, speech, architecture, neuroscience, music and more!

• **Psychoacoustics** is the study of the way humans perceive sounds.
  
  – things are sometimes different than they sound or appear.
  
  – internal representation can be quite different from the physical stimulus on the ear (or the retina).
  
  – consider a visual example of two tables (on the next slide).
Two Tables

- Describe the image below; are the tables different?

Figure 2: From Cook, Chapt. 3.

- Stating there are two tables is a cognitive interpretation:
  - patterns of lines are interpreted as 3-D objects;
  - tables are depicted as if in different orientations in space.
Removing Cognitive Interpretation

• Turning off the interpretation of “tables in space”, we see two parallelograms of identical size and shape.
What is a wave?

- A wave is a disturbance or oscillation that travels from one location to another over a period of time.

  Waves carry information/energy from one point to another—the medium in which they propagate is not transported!

- There are two main types of waves:
  1. **Mechanical**: waves propagate through a *medium*.
  2. **Electromagnetic**: wave propagation does not require a medium (they can travel in a vacuum).

- Which kind of wave is sound?
Direction of particle displacement

- Depending on the direction of its oscillations, a mechanical wave can be:

1. **Longitudinal**: Particle displacement is parallel to the direction of wave propagation.

   ![Longitudinal Wave Animation]

   Click image for animation: (Courtesy of Dr. Dan Russell, Kettering University)

2. **Transverse**: Particle displacement is perpendicular to the direction of wave propagation.

   ![Transverse Wave Animation]

   Click image for animation: (Courtesy of Dr. Dan Russell, Kettering University)
Waveform

- The waveform of the sound shows the time evolution of the variations, illustrating:
  - **amplitude**: maximum particle displacement from rest position (Pa or N/m²),
  - **period**: time to complete one cycle (s),
  - **frequency**: number of cycles per second (Hz),
  - **wavelength**: length of one complete cycle (m).

![Sinewave](image-url)
Sound Waves

- Sound waves are **mechanical waves**:  
  - a disturbance travelling through a *medium*  
  - transports energy from one location to another
- Sound waves travel in solids, liquid, or gas.
- In fluids (liquid or gas), sound waves are longitudinal (compression) waves.
- **No material is transported as a result of mechanical waves.**
Speed of Sound

• What is the approximate speed of sound in
  1. air? approx. 340 m/s.
  2. water? approx. 1,484 m/s.
  3. vacuum?

• Speed of sound is dependent on medium’s
  1. density / compressibility (inversely related)
  2. stiffness (solids)
  3. temperature (fluids)

• Sound will travel faster in
  – solids than in liquids because solids are more
difficult to compress;
  – liquids than gases because liquids are more difficult
to compress.
Hot chocolate effect (Frank Crawford 1982)

• Click on youtube video: the Allassonic Effect
  – frequency of sound heard from tapping the bottom of the cup of hot cocoa is a function of
    1. speed of sound;
    2. wavelength.
  – upon initial stirring of cocoa, sound is transported via bubbles (gas) in the liquie, thus reducing the speed of sound and lowering the frequency;
  – as bubbles clear, sound travels faster in the liquid and the frequency increases.
Properties of Sound Waves

• Speed of sound
  – in air: 340 m/s
  – in water: 1480 m/s

• Amplitude range of hearing (humans)
  – Threshold of audibility: 0.00002 N/m$^2$
  – Threshold of feeling (or pain!): 200 N/m$^2$

• Frequency range of hearing
  – humans: 20 - 20 000 Hz
  – dogs: 20 - 45 000 Hz
  – beluga whale: 1000 - 123 000 Hz

• Period of lowest and highest audible frequencies
  – $1/20$ Hz = 0.05 s  $1/20 000$ Hz = 0.05 ms

• Shortest audible wave
  – $340/20000$=1.7cm

• Longest audible wave
  – $340/20$=17m
Sound Summary

- Sound waves are mechanical longitudinal (compression) waves.
- A disturbance of a source (such as vibrating objects) creates an initial region of compression or high pressure.
- When the source vibrates, alternating regions of low and high pressure are produced in the surrounding air, called rarefactions and compressions respectively.
- The alternating pressure propagates from the source, through a medium, before reaching our ears.