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.

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).

Sound

- 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 vibrating objects, propagated through a medium from one location to another.
Two Tables

- Two tables are depicted as if in different orientations in space.

![Two tables](image1)

Figure 2: Two tables (from Cook, Chapt. 3).

- Stating they are tables is a cognitive interpretation:
  - patterns of lines are interpreted as 3-D objects.

Removing Cognitive Interpretation

- Turning off the interpretation of “tables in space”, we see two parallelograms of identical size and shape.

![Parallelograms](image2)

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.

  
  ![Image](https://example.com/courtesy_dr_dan_russell_kettering_university)

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

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

  
  ![Image](https://example.com/courtesy_dr_dan_russell_kettering_university)

  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).

![Figure 3: Sinewave.](https://example.com/courtesy_dr_dan_russell_kettering_university)

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.
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/m²
  - Threshold of feeling (or pain!): 200 N/m²
- 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 = 17 m

Hot chocolate effect (Frank Crawford 1982)

- Check out the Allassonic Effect:
  - frequency heard from tapping the bottom of a cup of hot cocoa is a function of
    1. speed of sound;
    2. wavelength.
  - upon initial stirring of cocoa, gas transported by the liquid reduces the speed of sound through the liquid, lowering the frequency.
  - as bubbles clear, sound travels faster in the liquid and the frequency increases.
  - try also by adding salt to cold beer.

Example of Sound Sources

- Vibrating bodies: drumhead, piano soundboard, ...
- Changing airflow:
  - vibrating vocal folds open and close changing rate of airflow from lungs to vocal tract;
  - holes in a rotating siren alternately periodically stop the flow of air;
- Time-dependent heat sources:
  - electrical spark producing a crackle;
  - explosion producing a bang due to rapid heating causing air to expand;
  - thunder results from rapid heating of air by a bolt of lightning.
- Supersonic flow: shock waves result when air flows faster than the speed of sound:
  - supersonic airplane,
  - speeding rifle bullet,
  - shock waves have been also known to occur in brass instruments (trumpet).

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 through a medium, away from the source, before reaching our ears.