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.

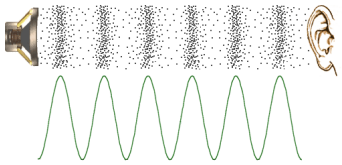
Sound and Vibration

- 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.
  - emcompasses 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?

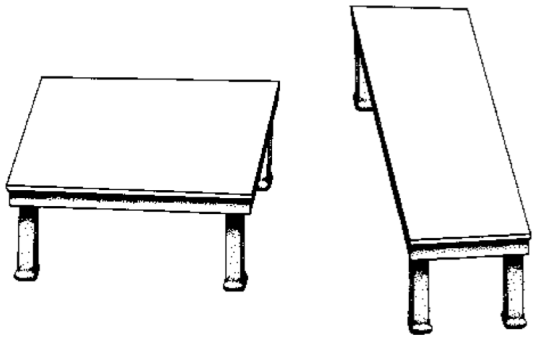
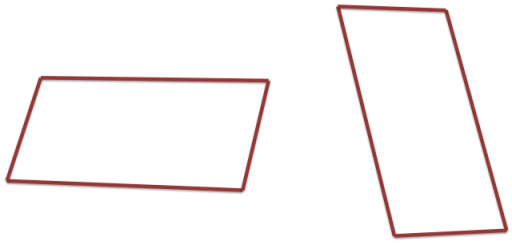


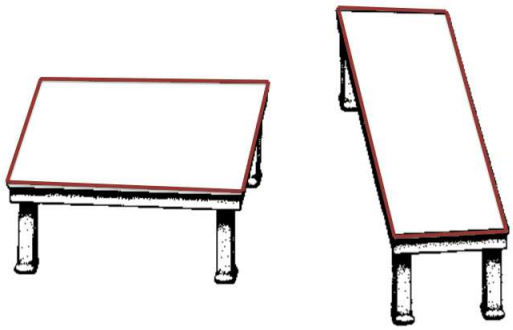
Figure 2: From Cook, Chapt. 3.

- 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?

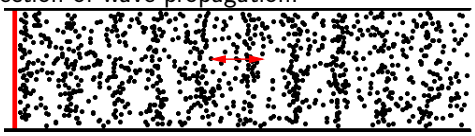
- A wave is a disturbance or oscillation that travels from one location to another over a period of time.

> 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?

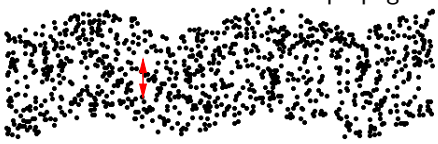
Direction of particle displacement

- Depending on the direction of its oscillations, a mechanical wave can be:
  1. **Longitudinal**: Particle displacement is parallel to the direction of wave propagation.



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

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



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/m^2),
  - **period**: time to complete one cycle (s),
  - **frequency**: number of cycles per second (Hz),
  - **wavelength**: length of one complete cylce (m).

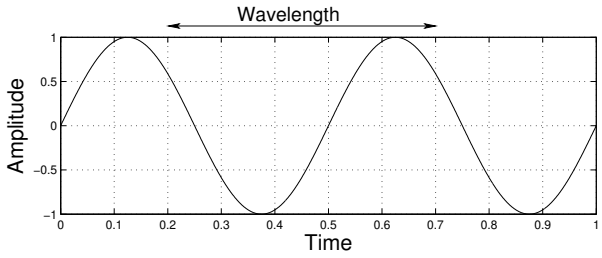


Figure 3: Sinewave.

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 cocao, 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.