# Music Is Science

Lesson Sequence by William C Doublestein

## Concept #1- Vibration

- **YouTube video: "CYMATICS: Science Vs. Music - Nigel Stanford"**
  - All sound comes from vibration.
  - Examples include vibrating vocal cords, vibrating vibraslaps, and vibrating drumheads.
- **Demonstration: Vibrating speaker**
  - Show vibration using crumpled up paper inside a speaker.
  - Emphasize the difference in vibration between low and high pitches.
  - Use Oobleck to produce dancing figures with applied vibration.

## Concept #2- Traveling Sound

  - Sound travels by waves through air molecules bumping into each other.
  - Sound travels very quickly and bounces off objects.
  - The bounce of soundwaves over long distances creates echoes. You have to be at least 56 feet away from a solid object to hear an echo (at .1 second minimum time gap). You also have to produce a sound that's loud enough to cross that distance without being absorbed by the environment.
  - Your brain interprets sound after soundwaves vibrate your ear drums.
  - Diffusers and absorbers are sometimes placed in large rooms to decrease the effect of soundwaves. This allows for clearer sound.
- **Demonstration: Chrome Music Lab sound wave visualization**
  - Demonstrate air molecules bumping into each other.
  - Show that high pitches make shorter waves and low pitches make longer waves.

## Concept #3- Soundwave Properties

- **YouTube video: Physics applied on a guitar! Check out them standing waves.**
  - Sound waves show three important pieces of information: wavelength, frequency, and amplitude.
  - The wavelength is the length of a wave (pitch). The longer the wavelength, the lower the pitch. The shorter the wavelength, the higher the pitch.
  - The frequency is the speed of a wave (pitch). Frequency is measured in Hertz. Hertz measure the number of waves passing a point every second.
  - The amplitude is the height of a wave. (volume)
- **Demonstration: Function generator, speaker and Audio Visualizer app**
  - Change the frequency and amplitude knobs to show how sound waves are affected in real time.

## Concept #4- Hearing Ranges

  - The human hearing range is around 20-20,000 Hz, but it decreases as you get older. Hearing protection is important to keep your hearing healthy.
  - Certain animals, like moles and elephants, can hear below 20Hz. This is called the "infrasonic" hearing range.
  - Other animals, like bats, dogs, and dolphins, can hear above 20,000Hz. This is called the "ultrasonic" range.
  - In general (though there are exceptions), the larger the animal, the lower frequencies it can hear. The smaller the animal, the higher frequencies it can hear.
  - Bats "see" in the dark by bouncing soundwaves off insects. This is called "echolocation."
  - Submarines "see" underwater by bouncing soundwaves off underwater objects. This is called "sonar."
- **Demonstration: Hearing test via function generator, speaker**
  - Change the frequency to see the outer limits of students hearing ranges.

## Concept #5- Traveling vs. Standing Waves

- **YouTube video: Largest wave surfed - Guinness World Records**
    - Like a wave in the ocean, "traveling waves" move through space and carry energy. You can imagine a surfer gliding along a wave.
    - "Standing waves" on the other hand stay in one place and do not transfer energy.
    - Standing waves occur when a wave "reflects" off a fixed point. This happens because waves always flip over when they hit a stationary object.
- **Demonstration: Wave motion demonstrator**
    - Explain that all waves using this demonstrator are at a very low frequency (max motor frequency is 2hz).
    - Show traveling waves using water bobber.
    - Show standing waves using clamp.
    - Demonstrate wave reflection.

## Concept #6- Nodes vs. Antinodes

- The points at which two reflecting waves come together are called "nodes."
- The points at which two reflecting waves are furthest apart are called "antinodes."

- **Demonstration: String vibrator**
    - Explain that the string vibrator can function at much faster frequencies than the wave motion demonstrator.
    - The string vibrator allows us to SEE nodes and antinodes.
    - Change frequency in intervals of 10hz, from 10-150hz, adding a wave each time.
    - Identify the nodes and antinodes.
- **Demonstration: Resonance tube**
    - The resonance tube allows us to HEAR nodes and antinodes.
    - Use plunger to shorten the length of the tube. Listen for increased volume at the nodes and mark.

## Concept #7- Octaves

- **YouTube: You can't play 6 octaves in 9 bars.**
    - Pitches played by instruments or sung by singers each have their own specific frequency/wavelength.
    - There are only 12 pitches in all Western music, but those pitches can be higher or lower depending on their "octave."
    - Some eastern cultures divide frequencies into more than 12 pitches, but this is rare.
    - The lowest frequency of a particular note is called it's "fundamental frequency." The fundamental frequency of the pitch A (A0) is 27.5 Hz.
    - You get a new octave every time you double the frequency of a pitch. A0= 27.5 Hz, A1= 55Hz, A2= 110 Hz, A3= 220 Hz, A4= 440 Hz.
    - A4= 440 Hz is the pitch most used for tuning.
- **Demonstration: String vibrator**
    - Starting at 10 Hz, double frequency to show octave changes.

## Concept #8- Tuning

- **YouTube: the most out of tune piano**
    - For multiple instruments to sound good together, it's important that they are "in tune" with each other.
    - Tuning is the process of lining up frequencies/wavelengths between sources.
    - Instruments most often go out of tune due to humidity and temperature changes.
    - Some instruments stay in tune better than others. Oboes are used to tune an orchestra because their tuning is very consistent. String instruments have very inconsistent tuning and need retuned regularly.
    - When two instruments play slightly different frequencies, their sound waves collide and cancel each other out creating audible "beats."
    - Instruments are in tune with each other when there are no audible beats.
- **Demonstration: Beat creation with Tone Generator iPad app and function generator/speaker**
    - Play A= 440Hz on one speaker and A=439Hz on another. Point out the audible beats.
    - Continue to lower the frequency of the second speaker to change the speed of the beats.
    - Return the second speaker to A= 440 Hz to reestablish both pitches as in tune.

## Concept #9- The Speed of Sound

- **YouTube video: Coldplay - Speed Of Sound (Official Video)**
  - The speed of sound varies according to temperature (altitude) and medium (gas, liquid, solid).
  - Air Force pilots exclude these variables by referring to it as “Mach 1.”
  - A sonic boom is created whenever a source travels faster than its own soundwaves.
  - The speed of sound at 68 degrees Fahrenheit in dry air is 767 mph.
  - The speed of a car is approximately 60 mph, a commercial airplane 575 mph, a fighter jet 3,017 mph, the International Space Station 15,500 mph, and light 670,616,629 mph.
  - Sound travels at 767 mph through the air (gas), 3,355 mph through water (liquid), and 13,422 mph through metal (solid). This is due to the molecules being far apart in a gas and very close together in a solid (with liquid falling in the middle).
  - We see lightning before hearing its thunder because light travels so much faster than sound. It takes sound approximately 5 seconds to travel one mile, so thunder than takes 5 seconds to reach your ear after the lighting strike is about 1 mile away.
- **Demonstration: Chladni Plates**
  - Use sand on square and circle Chladni plates to show how nodes and antinodes can create art at different frequencies.

## Concept #10- Sound In Space

- **YouTube video: Falcon Heavy & Starman**
  - Because there is no air in space, there are no air molecules for vibrations to travel.
  - This means that there is no sound in space.
- **Demonstration: Glass chamber, bell, and vacuum pump**
  - Start the bell ringing and cover it with the glass chamber. Use the vacuum pump to remove the air and listen to the sound of the bell disappear. Then reintroduce air and listen as the sound returns.