Engineering with Sound Lesson Plan

Type of lesson: Challenge

<u>Teaching Plan</u>:

Goal
The goal of this lesson is to introduce the students to sound and its properties and have them apply what they learn to a sound-based challenge. At the end of the lesson, the students hopefully will understand how sound is amplified and how engineers use different materials to manipulate sound.

Lesson Agenda
(Note: all demos/activities described in later detail in Demos and Project.)

1. Introduction to Sound Waves: (~5 min)
    a. Go over the basics of sound and how sounds travel. The overview helps the global learners
        i. Slinky Demo accompany this instruction. This activity is to get the students moving and actively participating. Great for the hands-on learner.
2. Different Materials Affect Sound (~10 min)
    a. Perform the Differing Materials Activity. This will really help the visual and active learners. A way to help those who are more reflective is to ask questions while the students do this activity. After all, we want to get them thinking! At the end, ask them to explain what they have learned; great way to correct misconceptions.
    b. Perform the Hearing Through Your Bones activity (optional).
3. Resonance and What It Is (~15 min)
    a. Perform the Bottle Resonance Demo first by the mentors. Have one mentor explain what is going on while the other is performing it. This helps both visual and verbal learners. After this, let the students try it!
    b. Have a mentor do Tuning Fork Resonance Demo. If this takes a substantial amount of time to set up, ready this while they are doing the challenge and showcase it at the end.
4. Sound Challenge (40 min or more)
    a. Introduce the challenge of building the amplification system, set the constraints, tell them about the materials and get them going. Remember that they are following the 5-step Engineering Process.
        i. ASK and IMAGINE (5 min) - Help them out on what they are asking. Use questions like “What shapes best amplify sound?” Reference the previous activities.
        ii. PLAN (10 min) - Make sure they draw out their amplification system (room on worksheet). Do not let them have any materials until they show you the plan.
        iii. BUILD (25 min) - Help them with the cutting of the cardboard and make sure they are following the constraints. Ask them questions

as they progress, but try not to push them in any one direction. Really have them rely on their own ideas.

iv. IMPROVE (5 min) - Test each system. Have them discuss how they could improve their own system and their fellow mentees' amplification systems. The sound that is amplified the best wins the challenge.

REMEMBER: Do not downplay any of their ideas. Have them figure it out and if it does not work, that is a learning experience. It is a challenge, so too much outside help ruins the whole goal of the lesson.

Scientific Background

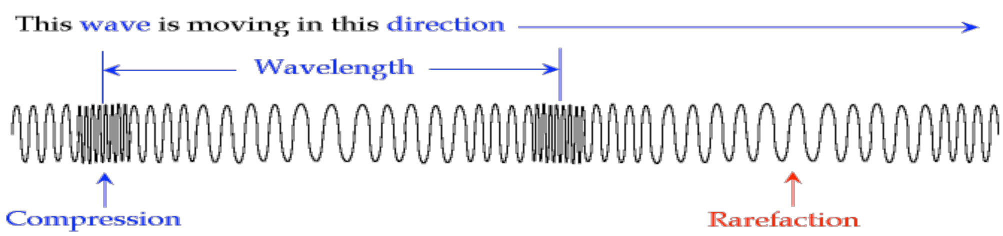
Sound in General

A sound wave can be described as a disturbance that travels through a medium transporting energy without transporting the medium itself. A sound wave has a wavelength, which is the distance from trough to trough, and a frequency. The speed of a sound wave is described by the equation:

velocity = wavelength x frequency

Remember that the velocity is dependent on the frequency, but the frequency is not dependent on the velocity.

Sound waves propagate through the material in a longitudinal wave. This is different from a transverse wave, where the direction of the wave propagation is perpendicular to the movement of the wave. A longitudinal wave is where the movement of the wave is parallel to the direction of propagation of the wave.



A longitudinal sound wave is also called a compression wave. Whenever an object vibrates, it creates a compression wave in the air and this produces sound. This is how stereo systems work by having a sheet of material moves (more like vibrates) back and forth in a certain way to create a specific compression wave. Our eardrums perceive these sound waves by vibrating in unison with the sound wave. This vibration is detected by the nerve cells, which transmit it back to the brain.

Differing Mediums

The velocities of sound waves are affected by the materials that they propagate through. The argument that density of the medium affects the speed of sound is true, but not in the way that people usually think about it. Sound travels through solids the fastest, liquids the second fastest, and gases the least fast. This is due to the bulk modulus elasticity constant for each medium. The bulk modulus measures the medium's resistance to uniform compression. Solids have a high bulk modulus, while gases do not.

The equation for the speed of sound through different mediums can be expressed with Hook's Law:

$$\mathbf{c = (E/\rho)^{1/2}}$$

where

c = speed of sound
E= bulk modulus elasticity
ρ= density of the medium

From this equation, a greater density actually means a slower speed. Thus, the speed is increased by lower density and/or high bulk modulus of the medium.

Resonance

Resonance is an important concept of sound because it is important in the production of sound in musical instruments. Resonance is when the sound wave created by one object matches the natural frequency of another object. The natural frequency is the frequency at which an object tends to vibrate when disturbed. When this matching occurs, the amplification of this particular sound wave reaches the maximum of a peak. The best way to describe this to the students is with this analogy: You know exactly how to taunt your sibling, especially how to annoy them in the best possible way. Just think of yourself as one object and your brother the other object. You emit a sound wave (tease him) and this gets a huge response from him because that sound wave (or taunt) is exactly what he would get really mad at.

The equations for resonance differ with each object, since resonance has as much to do with the medium as with the geometric orientation of the medium (aka shape).

Introduction to the Mentees

First, start off asking questions. Does anyone know how sound travels? What shape is it? Can someone show me the movement of a sound wave? The answers to these questions will help you gauge what they know. If you are noticing a student that is not answering any of these questions, make sure to go up to them separately to see what they know. Then, introduce the worksheet and tell them they can fill it out at their own speed as you will go through it in the end or during the challenge.

Second, bring the idea of sound to their lives. Ask if any play any instruments. If they do, have them explain to their classmates what they do to make the instrument create sound (i.e. placement of fingers, hitting of certain mediums, etc.)

Third, the demos (which are described in the next section in detail) are very much a moment for active participation. With the Slinky Demo, have everyone try it and have them work in pairs. With the Materials Activity, have them go around the room and try and test different materials. Make sure everyone is actively participating. During the activities, make sure to ask the mentees questions. Often times the student will superficially understand and an extra question will lead them to complete understanding.

Fourth, for the challenge, the key is to not give too much guidance. To have the mentees think on their own to address the problem is the best possible method. At the end is the best time for kind, constructive criticism of their projects. That being said, if they ask for help along the way, a little tip here or there is always acceptable.

<u>Demos and Project</u>

1. Slinky Demo
    a. Materials: slinky, two people
    b. Instructions:
        i. Have two people hold the slinky between them somewhat taunt
        ii. One person should create a disturbance on their end. Watch as the wave travels back and forth.
    c. Understanding: It represents a longitudinal wave and describe this is how sound travels through the air.
2. Differing Materials Activity
    a. Materials: a room of different materials, a tone creator
    b. Instructions:
        i. Have the mentees traipse around their room and see what materials transmit the sound the best. Make sure they see the difference between metal and wood materials.
    c. Understanding: the speed of the sound wave is reliant on the medium through which it is propagated.
3. Hearing Through Bones: (optional)
    a. Materials: a tuning fork, a person
    b. Instructions:
        i. Have mentee hit the tuning fork on a hard surface then hold it close to their elbow.
    c. Understanding: This is how we hear our own voice--transmission through our own bones.

4. Bottle Resonance Demo:
    a. Materials: four glass bottles, water
    b. Instructions:
        i. Fill the bottles up with differing amounts of water.
        ii. Have a mentee blow across the top of each bottle and compare the sounds produced.
    c. Understanding: The sound produced is the resonant sound of that particular object, which is the certain amount of water in that bottle. The more water there is, the wavelength that can resonate in that bottle has to be shorter.
5. Tuning Fork Resonance Demo:
    a. Materials: tuning fork, bottle, water
    b. Instructions:
        i. Fill the bottle with a small amount of water and have the fork sound over the bottle. Now add more water and sound the fork again. Compare these two different sounds, as in loudness.
        ii. Keep differing the water amounts until you have the loudest sound. This bottle with the specific water combo has a natural frequency that matches the frequency the tuning fork is creating.
6. Amplification Challenge:
    a. Materials: cardboard (differing thicknesses), plastic containers (like to-go containers), paper, tin foil, music box
    b. Constraints:
        i. No bigger than a 9 x 11 piece of paper
        ii. No taller than 8 inches
        iii. Must fit the music box.
        iv. Must follow 5-step Engineering Process! (Look at lesson agenda)
    c. Instructions:
        i. Using the ideas of resonance and differing materials, create an amplification device that will amplify the song created by a music box.
            1. Ideas: one can model it after musical instruments, like the piano, which has a soundboard, or after an old-fashioned hearing aid, which applies a conical shape. Or both!
        ii. Work in pairs or alone.
        iii. Equal division of materials. If large group, also put a constraint on materials. One can instate a certain currency system, but since it is a shorter challenge, we decided not to do that.
    d. The winner of the challenge gets a prize (TBD).

<u>Conclusion:</u>

Have the mentees test each of their amplifications systems. Improvements for each should be discussed.

Now, sum up the whole lesson by bringing it back to the real world. Here are some articles that discuss how sound and sound engineering are shaping the world:

~Using Tuning Forks in Fracture Diagnostics
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2681212/

~Tacoma Narrows Bridge: The Power of Resonance
Video:
http://paws.kettering.edu/~drussell/Demos/TacomaNarrowsBridge.mpg
Explanation:
http://en.wikipedia.org/wiki/Tacoma_Narrows_Bridge

~Acoustics of an Opera House: cool pictures of sound intensity
http://www.google.com/url?sa=t&source=web&cd=2&sqi=2&ved=0CCAQFjAB&url=http://www.acousticdimensions.com/Downloads/tech_papers/Acoustics_Baroque_Opera_House.pdf&rct=j&q=opera%20house%20acoustics&ei=Ok_zTLufEI70tgOztOWkCw&usg=AFQjCNEM8k0wgUSxihrgM4AGPpyNorUq7Q&sig2=GTzz7StlW4QRTGr68-DwxA

~A long article of Musical Instrument Engineering
http://uconngalileo.engr.uconn.edu/upload/module/updated%20EMI.doc

Look over these to get more ideas at how you can make it more relevant to the students. Concluding with an idea like this will make the ideas more understandable to them.

Materials

- Tuning fork (1 or 2)
- Music box or some other object that produces consistent sound. (1)
- Four glass bottles, same size
- Water
- Cardboard (varying thickness)*
- Plastic containers (medium size)*
- Paper (varying thickness)*
- Tin foil*

*Quantity varies on group size. Each person should have one plastic container, three pieces of different thickness cardboard, several sheaves of paper, and one medium length of tin foil.

References and Citations

-If having trouble understanding, check out some of these websites. Very helpful!

"Acoustic Resonance." *Wikipedia, the Free Encyclopedia*. 26 Nov. 2010. Web. <http://en.wikipedia.org/wiki/Acoustic_resonance>.

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"Overview of Sound Waves - Succeed in Understanding Physics: School for Champions." *School for Champions: Online Lessons for Those Seeking Success*. Web. <http://www.school-for-champions.com/science/sound.htm>.

Schmidt-Jones, Catherine. "Sound and Music Activities." 12 Apr. 2010. Web. <http://cnx.org/content/m11063/latest/>.

"Sound Waves and Music." *The Physics Classroom*. Web. <http://www.physicsclassroom.com/class/sound/>.