Design of music instruments for a rock band

SLED
Science Learning through Engineering Design

Grade Level:	**Total Time Required:**
3	~ 3 – 5 class sessions (30 minute each)

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Lesson Objectives:

In this lesson, Students will be able to:

1. Explain how vibrations in various materials create and transmit sounds.
2. Design and build a musical string instrument that is capable of producing a pattern of 3 different pitches.
3. Evaluate their team's results and present their findings to the class.
4. Learn about and apply the principles of the engineering design process.

Indiana Standards:

3.PS.3 Generate sound energy using a variety of materials and techniques, and recognize that it passes through solids, liquids, and gases (i.e. air).

3.PS.4 Investigate and recognize properties of sound that include pitch, loudness (amplitude), and vibration as determined by the physical properties of the object making the sound

3-5.E.1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.

Next Generation Science Standards:

3-5.ETS1-1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.

Science/Engineering Practices
1. Asking questions (for science) and defining problems (for engineering)
6. Constructing explanations (for science) and designing solutions (for engineering)

Crosscutting Concepts
2. Cause and effect: Mechanism and explanation.

Concepts and Vocabulary

Term	*Defined by a scientist or engineer*	*Defined by a student*
Acoustics	The interdisciplinary science that deals with the study of all mechanical waves in gases, liquids, and solids including vibration, sound, ultrasound and infrasound. [1]	Sound or the study of sound.
Decibel	The term used to identify ten times the common logarithm of the ratio of two like quantities proportional to power or energy. Thus, one decibel corresponds to a power ratio of 100.1.	Sound measurement unit; Sound level; A measure of how loud the sound is.
Frequency	The number of occurrences of a repeating event per unit time. The frequency of a pure tone is defined as the number of cycles per second at which ambient air pressure is fluctuating. The unit of frequency measurement is hertz (Hz). One Hz corresponds to 1 cycle per second. The human ear responds to a wide range of sound frequencies. A young person with excellent hearing may be able to discern sounds between 20 Hz and 20,000 Hz. As we get older, the audible range has a tendency to shrink at both the low and high frequency.[2]	Frequency is how often something happens. In a wave or ripple, it is how often the crests arrive.
Sound	When something causes sound to fluctuate rapidly above and below the local ambient air pressure and our eardrums respond similarly.[2]	Something we can hear.
Noise	Noise is unwanted sound – simple short duration annoyance or extended duration annoyance. Perceived negatively by the average human, community, etc. [2]	Unwanted sound or sounds that we do not like.
Beat	Interference between two sounds of slightly different frequencies.[1]	Thump; music pulse.
Volume	Subjective reaction to sound. Sensation related to amplitude of the pressure fluctuation above and below the existing ambient air pressure. The greater the amplitude of pressure fluctuation, the louder the sound is perceived to be. Function of amplitude and frequency of an air pressure fluctuation simultaneously. [2]	Loudness
Pitch	Subjectively, we react to the rate of pressure fluctuation by assigning a certain pitch to it. A low pitched sound (foghorn) is composed of relatively slow pressure fluctuations. A high pitched sound (police whistle) is composed of relatively fast pressure fluctuations. Low pitch sound has a long	High and low sounds

	wavelength and high pitch sound has a short wavelength. [2]	
Tone	Often people subjectively classify sounds as a function of their tonal quality. Examples of this are when we characterize sounds as hissing, rumbling, roaring or whistling. [2]	Quality of Sound
Wavelength	Wavelength is defined as the speed of sound (1120 ft/sec) divided by the frequency (Hz) reported in units of feet. For example, the wavelength of 63 Hz is 18 ft. and the wavelength of 4000 Hz is 0.28 ft. [2]	
Vibrations	A rapid linear motion of a particle or of an elastic solid about an equilibrium position.[3]	How anything shakes or moves from side to side.
Instrument	A device for recording, measuring, or controlling sound, especially such a device functioning as part of a control system.[3]	Something you use to create sound (music or noise).
Source	Sound radiates from a source. [2]	Item making the sound
Transmit	To send from one person, thing, or place to another; convey.[3]	Send from one place to another.
Sound wave	A longitudinal pressure wave of audible or inaudible sound.[3]	How sound travels through materials
Receiver	Consists of a person, neighbor or community that is being affected by the sound generated by the source and traveling across the path. [2]	What or who is hearing the sound – human ear or microphone.
Sources	1. http://en.wikipedia.org/wiki/Sound 2. http://www.sensidyne.com/sound-noise-vibration-measurement-svantek/sound-and-vibration-resources/resource-sound-and-vibration-related-terms.php 3. http://www.thefreedictionary.com	

Equipment, Materials, and Tools

Materials		
Boxes of various sizes	Glue	Scotch tape
Balloons	Duct tape	Cups (paper, plastic, foam)
Different kind of strings	Masking tape	Plastic Wrap
Rubber bands		

Tools/Equipment		
Rulers	Tuning forks	Phones made from plastic cups and different strings.
Scissors		

Safety Guidelines:

- Provide strict instructions on proper use of the rubber bands.

Science Content - Basics

What is Sound and How is it Produced

Sound is basically vibrations traveling through a medium such as air. All the sound we hear is actually movement of air particles as they swing back and forth, following the motion of the object producing the sound: the strings of your guitar, your voice, or a loudspeaker. The movements of the air particles determine the type and timbre (quality of tone) of the sound.

Speakers work by moving back and forth, manipulating the air around the speaker. Microphones record sound by means of a diaphragm whose motions are converted into electric currents, with variations in current corresponding to higher and lower compressions.

The ear works the same way, with the ear drum producing changes in current that go to the brain. The sounds we hear, even a steady pitch, are rapidly changing areas of pressure. A steady pressure would not produce any sound.

Sound Waves

Sound travels in the form of waves. The basic definition of wave motion is a transfer of energy, without transferring matter. Sound waves are Mechanical Longitudinal Waves. The mechanical part of the title means that the waves require a medium to travel through, such as the air when you are speaking. The longitudinal part describes the motion of the wave. It means that the motion of particles in the medium is parallel to the motion of the wave. The diagram below shows a simple wave. A longitudinal wave can be created in a slinky if the slinky is stretched out in a horizontal direction and the first coils of the slinky are vibrated horizontally. In such a case, each individual coil of the medium is set into vibrational motion in directions parallel to the direction that the energy is transported.

We will use a tuning fork as an example to explain how sound waves propagate. Sound waves consist of periodic fluctuations in air pressure called compressions and rarefactions. Vibrate the tuning fork and focus on the right prong. When the prong moves to the right, it compresses the air particles to form a compression. When the prong moves to the left, the air pressure to the right of the prong decreases to form a rarefaction. As the tuning fork continues to vibrate, the waves consist of alternating compressions and rarefactions. It is a longitudinal wave because the direction of the motion of the sound wave is the same as that of the air particles. The distance between consecutive compressions is the wavelength.

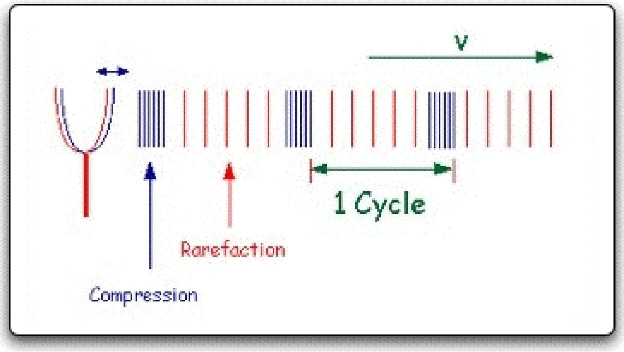
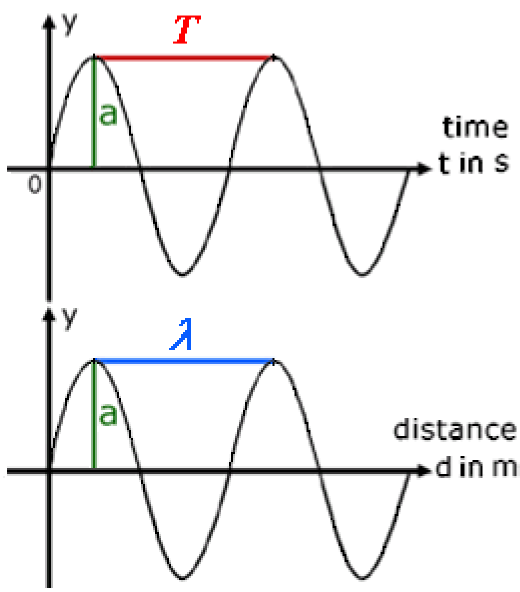


Image is from the Basic Physics of Nuclear Medicine/Sonography & Nuclear Medicine. (2014, January 31). *Wikibooks, The Free Textbook Project*. Retrieved February 21, 2017 from https://en.wikibooks.org/w/index.php?title=Basic_Physics_of_Nuclear_Medicine/Sonography_%26_Nuclear_Medicine&oldid=2605342.

Parts of a Sound Wave

A sound wave (or any wave) has four main parts: wavelength, period, amplitude, and frequency.

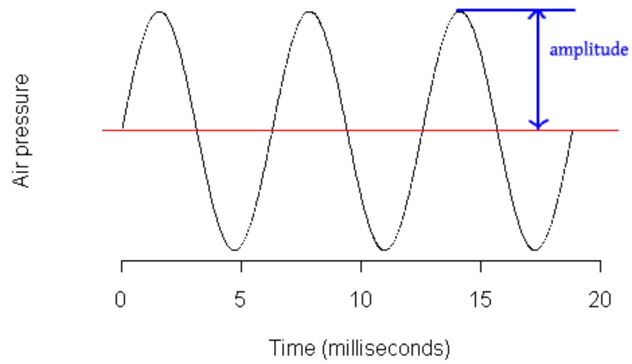
1. Wavelength
   The wavelength is the horizontal distance between any two successive equivalent points on the wave. That means that the wavelength is the horizontal length of one cycle of the wave. In the figure below, λ (*the greek letter lambda*), which represents the distance in meters, is the wavelength.



2. Period
   The period of a wave is the time required for one complete cycle of the wave to pass by a point. So, the period is the amount of time it takes for a wave to travel a distance of one wavelength. In the figure above, T, which represents time in seconds, is the period.

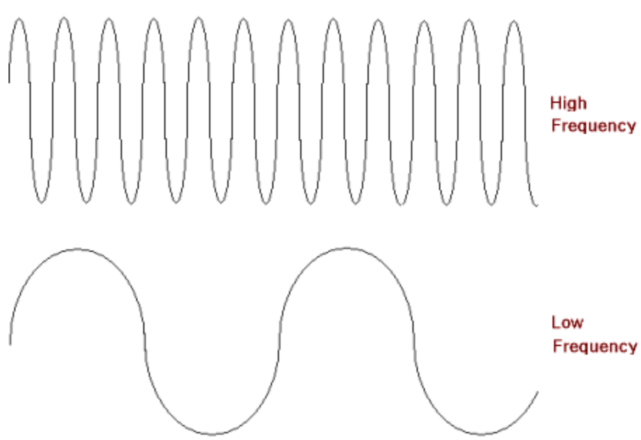
3. Amplitude

The amplitude of a sound is represented by the height of the wave. When there is a loud sound, the wave is high and the amplitude is large. Conversely, smaller amplitudes represent softer sounds. A decibel is a scientific unit that measures the intensity of sounds. The softest sound that a human can hear is the zero point. When the sound is twice as loud, the decibel level goes up by six. Humans speak normally at 60 decibels.



4. Frequency

Every cycle of sound has one condensation, a region of increased pressure, and one rarefaction, a region where air pressure is slightly less than normal. The frequency of a sound wave is measured in hertz. Hertz (Hz) indicate the number of cycles per second that pass a given location. If a speaker's diaphragm is vibrating back and forth at a frequency of 900 Hz, then 900 condensations are generated every second, each followed by a rarefaction, forming a sound wave whose frequency is 900 Hz. The following figure shows high and low frequency waves.



Properties of Sound Waves

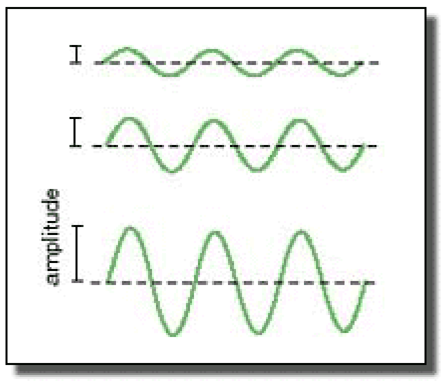
Sound waves have 3 main properties: speed, loudness and pitch. Each property is described in detail below.

1. <u>Speed</u>

   Speed describes how fast the sound wave moves in a medium. The speed of the sound depends on the medium. In gases, it is about 769 miles per hour, 1400 miles per hour in liquid and 5000 miles per hour in solids. Thus, the speed of sound increases as the medium gets denser.

2. <u>Loudness</u>

   Loudness describes how intense the sound is. The intensity of a sound is a measure of how much energy the sound wave has. The amplitude (height) of a sound wave shows its loudness. The following figure shows waves of three different amplitudes with the smallest amplitude on the top. Lower amplitude (low energy) will produces a softer sound and vice versa.



Loudness is measured in decibels (db). A zero db can barely be heard and a sound greater than 100 db can cause hearing loss. The following table shows the sound levels (db) for various types of activities in our life.

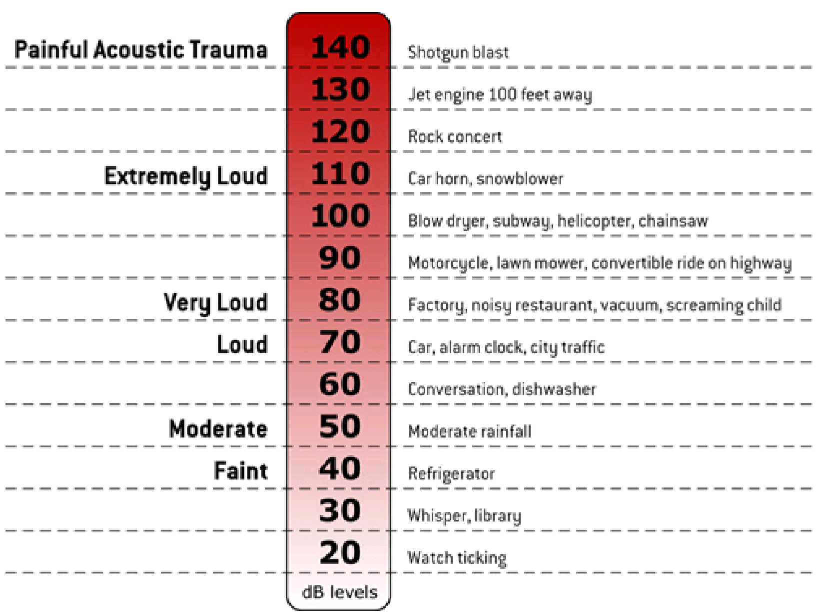


Image retrieved from http://staff.uow.edu.au/content/groups/public/@web/@ohs/documents/mm/uow140346.jpg.

3. <u>Pitch</u>

Pitch is the frequency of the sound wave. It describes how high or low a sound is perceived by the human ear. The wavelength of a sound wave describes its frequency. The following figure shows low and high frequency waves.

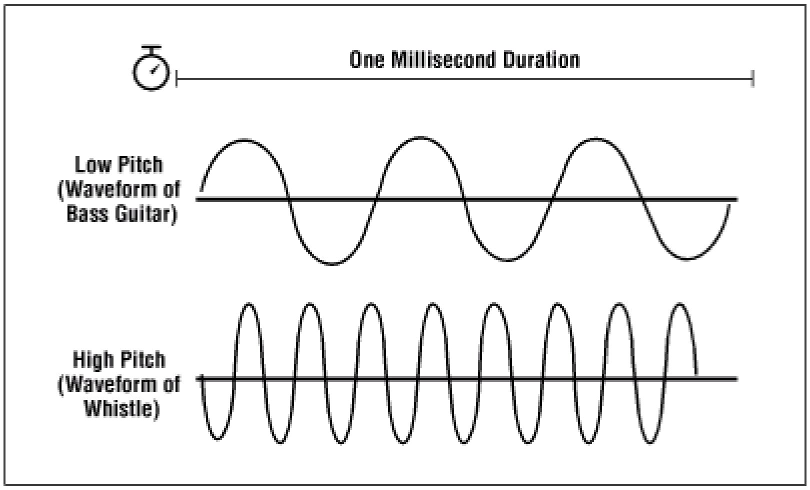


Image from Beggs, J. and D. Thede. (2001) *Designing Web Audio, First Edition*. Sebastopol, CA: O'Reilly & Associates, Inc. Retrieved December 2013 from http://docstore.mik.ua/orelly/web2/audio/ch02_01.htm.

Sources

http://www.physicsclassroom.com/class/sound/u11l1b.cfm

http://physics.tutorvista.com/waves/longitudinal-waves.html

http://www.mrenns.com/Docs/PowerpointsWeb/Ppoint-SoundandHearing.pdf

http://staff.uow.edu.au/content/groups/public/@web/@ohs/documents/mm/uow140346.jpg

http://docstore.mik.ua/orelly/web2/audio/ch02_01.htm

Engineering Design

Synopsis of the Design Activity:

Problem:	Your school is on a field trip to Indianapolis to listen to Indiana Rock Band. After reaching arriving at the concert, you were told that the band's instruments were damaged during travel.
Goal:	To create a musical instrument for a rock band to learn about sound
Who is the client:	Indiana Rock Band
End-User:	Indiana Rock Band
What is the design:	A simple string instrument.
Criteria:	Produce three different sounds or pitches and have at least one string.
Constraints:	Only available material should be used and the instrument should be no longer than 30 centimeters (one foot).

Lesson Plan #1
Guiding Question – How is sound created and transmitted?

Time: 30 minutes

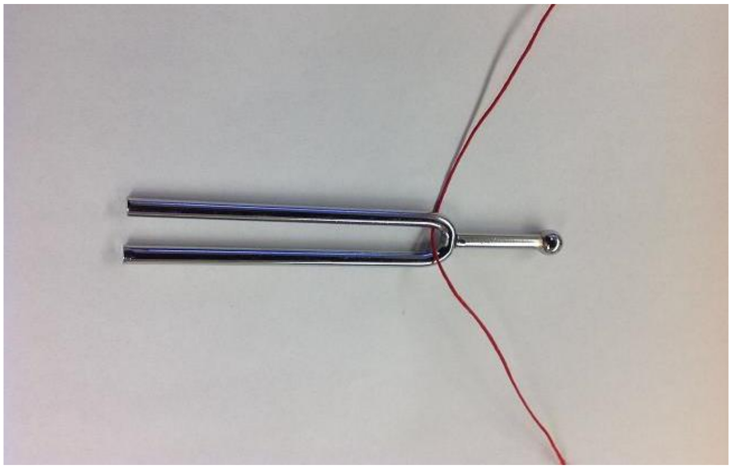
Note: In this lesson the teacher will guide the students to learn about sound by using tuning fork experiment and tin can phones.

Procedure:

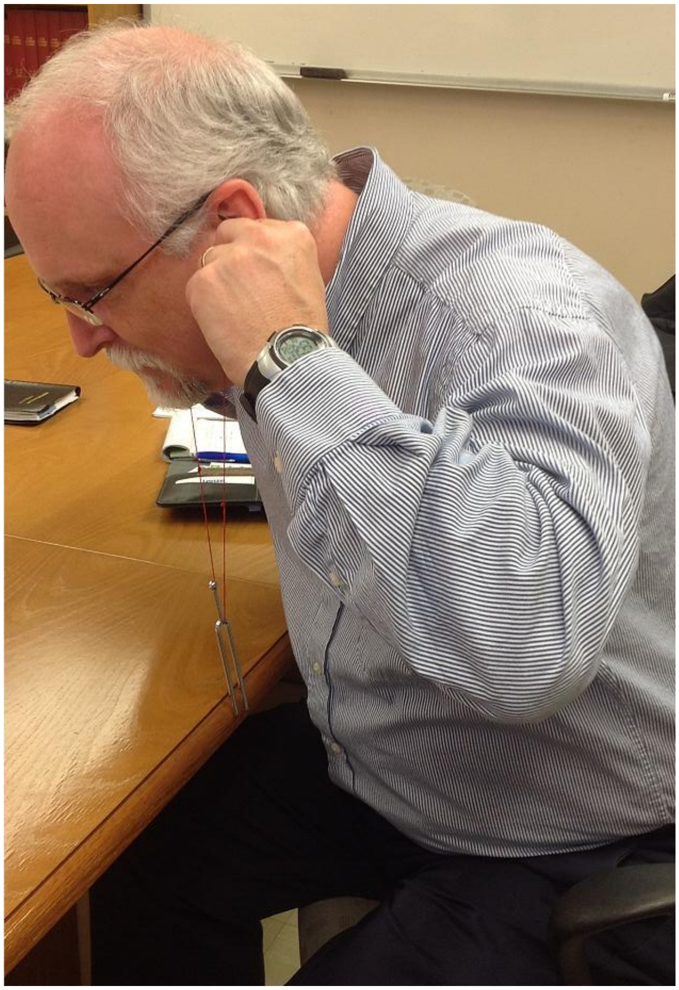
1. Before the class, make sure all phones are prepared for students to test in 3c. Students will investigate the effect of two variables in transmitting the sound: distance of travel (String length) and the material (type of string) for transmitting the sound. For testing string length, assemble four phones using string lengths of 1.5m, 2m, 3m and 4m. For testing the material for transmitting sound, assemble four phones using three different kinds of strings that are 2m long. Instructions for producing phones are provided in lesson extensions and resources.

2. Start a whole class discussion focusing around the following key questions:
   - *How is sound created?*
   - *What causes sound to travel?*
   - *How does sound travel?*
   - *What is needed for sound to travel?*
   - *What else do you know or want to know about sound?*

3. Divide the class into number of groups by having 2-3 students per group, and give one tuning fork to each group.
   a) Have each student tap the tuning fork on different surfaces and have them hear the sound by bringing the fork to their ear. Ask students what do they hear?
   b) Give approximately one meter string to each group, and have them pass the string through the fork as shown in the picture below.



Ask any student in the group to wrap each end onto his/her forefinger, and put the forefingers in the ears. Next ask the student to hit the tuning fork against a hard surface (e.g., table top as shown in the picture below.



Ask what is happening and why he/she is hearing the sound, and why it is different than the sound you get just by hitting the fork without any string.

c) Divide students into groups of four and have each group investigate the effect of either the string length or the material on transmission of sound.

4. Ask students to write few bullet points about what they have learned about sound through this exercise?
   - *Which string worked the best?*
   - *Is longer string better or worse compared to a shorter string?*
   - *Question related to fork?*

Lesson Plan #2
Guiding Question – How to design a musical instrument?

Time: one 30 minute class session

Procedure:

1. "Your school is on a field trip to Indianapolis to listen to a rock band called "The Indiana Band." After arriving at the concert, you were told that the band's instruments were damaged during travel. As future engineers, you are asked to come up with a design for a string instrument by using the materials available to you.

2. Guide students through the design activity student resource with students.
   - *What is the problem?*
   - *What is the goal?*
   - *Who is the client?*
   - *Are there any criteria? What are they?*
   - *Are there any constraints? What are they?*

3. Form teams of 2 to 3 students. Review team rules and expectations (see examples below)
   a) Everyone contributes with all tasks
   b) Professional behavior
   c) Safety

4. Have each group work on a design of a string instrument. Their design must include a sketch and the materials needed to build the design.

Lesson Plan #3
Guiding Question – How to build a musical instrument?

Time: one 30 minute class session

Procedure:

1. Students will begin by reviewing and presenting their design sketch for their string instrument.

2. Based on their design sketch, have each group gather the needed materials.

3. Have each group build their instrument. Ask them to write down any changes they made to their original design during the actual building. Also list any new material that was used.

4. After the design ask each group to demonstrate their instrument and create three different pitch or notes.

Assessment/Wrap-up

Check if the students understand pitch by asking them to produce high/low pitch from their instrument.

Wrap up the activity by discussing the following:

- *Have students comment on different designs*
- *Why some instruments one produced better sound than others*
- *What is the effect of materials used in the design,*
- *What kind of changes they would make to the design to improve the quality of their instrument.*
- *Can student produce different volume and pitch without changing their design? Teacher can show this to students by shortening the length of the string by putting pressure, etc.*

Lesson Extensions and Resources

Activity Extensions: Lesson 2 and 3 can be extended to design and build a drum or any other instrument by providing appropriate materials.

Resources:

How to build a plastic cup phone (modified version of text from ehow.com)

a) Take two identical plastic cups. One cup will act as a transmitter and other will act as a receiver.
b) Turn one cup upside-down, so that its intact end is facing up.
c) Drive a hole through the center of the intact end using a nail or a pin. The nail should make a neat hole in the end of the can. Repeat with the other can.
d) Thread one end of the string through one of the nail holes. Make a knot in the string on the inside of the cup, so that the string remains attached to the cup. Repeat with the other cup and the other end of string. The cups should now be tied to either end of the string.
e) Hold one cup, and give the other cup to someone else. Walk away from each other until the string between the caps is taut.
f) Speak into the open end of one cup while your partner listens to the open end of the other cup. Switch roles, and listen through the open end of your cup can while your partner speaks into the open end of the other cup.

Read more:
http://www.ehow.com/how_2067160_make-tin-can-phone.html#ixzz2DYYuHVpb

Web Links:
http://www.teachersdomain.org/resource/phy03.sci.phys.howmove.lp_sound/
http://tryengineering.org/lesson-plans/engineered-music

Designing Musical Instruments for a Rock Band

Source: http://www.littlekidsrock.org/

Your school is on a field trip to Indianapolis to listen to Indiana Rock Band. After arriving at the concert, you were told that the band's instruments were damaged during travel. The band needs your help to design and build a string instrument with the available materials. Your design must satisfy the following criteria and constraints.

<u>Criteria:</u>
Produce three different sounds (pitch)
Your instrument must include at least one string

<u>Constraints:</u>
Only available material should be used
The instrument cannot be longer than 30 centimeters (or one foot)