Learning Science through the Sound of Music

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Contents:

Overview

The topic of this unit is “Learning Science through the Sound of Music”. Understanding sound is part of the School District of Philadelphia’s Core Curriculum for ninth grade students in Physical Science. This unit will help students understand the nature of waves, and the properties of sound waves. Properties such as frequency, amplitude, and their relation to human’s perception of sound will be covered. It will extend for two weeks with ten days of class periods of 58 minutes each. Classes will be conducted in the classroom, science lab, and music room and computer lab.

Rationale

In today’s society, sound is all around us. Sound is used to inform, entertain, and communicate. Students enthusiastically create, enjoy, and carry sound everywhere. They listen to music, dance to the rhythm or beat, enjoy movies and talk on cell phones. Sound is an important part of their lives. Understanding sound is part of the School District of Philadelphia’s Core Curriculum using the PA Standards 3.4 for Physical Science.

Students enthusiastically create, enjoy, and carry sound everywhere. In this unit students will learn the principles of sound and sound waves to get a better understanding of what sound is, how sound travels, and how it is affected by the medium through which it travels. Activity-based learning skills will be an important part of the unit to enrich the learning experience for students. The unit will incorporate different activities, such as teacher demonstrations, computer animations, students’ demonstrations, lab experiments with lab data sheets and identification of lab apparatus, scientific calculator for math skills, and online computer-based activities for animations and illustrations of concepts.

Background Information

Vibrations and Waves

To understand sound we need to investigate the physics of waves. Sound is a wave that results from vibrating objects. The vibrating object is the source of the disturbance that moves through the medium. These vibrations are transmitted through an elastic solid, liquid or gas medium. Steel, water and air are conductors of sound. Sound (like other waves) carries mechanical energy as it travels through matter. Sound is characterized by its wavelength, frequency, and amplitude.

There are two types of mechanical waves. One is a transverse wave; the other is a longitudinal wave. A transverse wave is defined as one in which the particles vibrate perpendicular to the direction of the wave propagation. A stretched wire or rope vibrating up and down is an example of a transverse wave. A longitudinal wave is one in which the particles vibrate parallel to the wave, motion. Compressing or stretching a spring is an example of longitudinal wave. It will helpful for students to view animations that provide a good visual understanding of the concept of sound as a longitudinal wave. These are available at the Physics Classroom Website.[1]

Frequency and Pitch

The frequency of a wave refers to how often the particles of the medium vibrate when a wave passes through the medium. The frequency is measured as the number of complete back-and-forth vibrations of a particle of the medium per unit of time. If a particle of air undergoes 500 longitudinal vibrations in 2 seconds, then the frequency of the wave would be 250 vibrations per second. A commonly used unit for frequency is the Hertz (Hz).[2] One Hertz equals one vibration per second. The formula that relates the frequency and the period is: f (frequency) = 1/T (time per vibration). Furthermore, the relationship between the velocity, wavelength and frequency is: velocity = frequency X wavelength. Since the velocity of sound is approximately the same for all wavelengths, frequency is used to better describe the effects of the different wavelengths.

The frequency of each vibrating particle is the same as the frequency of the original source of disturbance. The first particle of the medium begins vibrating and begins to set the second particle into vibration at the same frequency. The second particle then begins vibrating and sets the third particle of the medium into vibration. For example, a guitar string vibrating at 1000 HZ will cause the air particles to vibrate at the same frequency of 1000 HZ. This then carries the signal to the listener's ear with this same frequency.[3] Human hearing can detect sound waves with frequencies between 20 Hz and 20,000 Hz (20kHz).

The "pitch" of a sound (how high or low it is perceived to be) is determined by the frequency: the greater the frequency, the higher the pitch. For example, the note of "Middle A" has 440 vibrations per second. The next highest "A" has double the vibrations, which equals 880 vibrations per second. The "lower A" has half the vibrations of the "Middle A" which are 220 vibrations per second. The slow vibration produces low pitch and the fast vibrations produces the high pitch.[4]

Frequencies below 20Hz are called infrasonic. They are inaudible to human hearing. We can't hear them! Frequencies above 20,000Hz are called ultrasonic. They are also inaudible to human hearing. We can't hear them, but some animals can! Ranges of hearing for various mammal are: elephant (16Hz-12000Hz), human (20HZ-20000HZ), dog (40HZ-46000HZ0), and dolphin (70HZ-150000HZ).

Some sounds are pleasant and some are considered noise. A pleasant sound has a regular wave pattern. The pattern is repeated over and over. The waves of noise are irregular. They do not have a repeated pattern. Students can reflect on why some of their favorite music might be considered noise to others!

Wavelength

In a transverse wave, the wavelength is the distance between two crests or two troughs of the wave. In a longitudinal wave, such as sound, the wavelength is the distance between two compressions or rarefactions. A wavelength is represented symbolically by the Greek letter "lambda (λ).

Amplitude

The SI Base unit to measure energy is Joules. The amount of energy carried by a wave is related to the amplitude of the wave. A high-energy wave is characterized by high amplitude; a low energy wave is characterized by low amplitude. The amplitude measures the displacement of the vibrating particles from their resting position. The more energy the sound wave has the louder the sound seems. The intensity of a sound is the amount of energy it has. You hear intensity as loudness. The amplitude, or height of a sound wave is a measure of the amount of energy in the wave, so the greater the intensity of a sound, the greater the amplitude.

The energy transported by a wave is directly proportional to the square of the amplitude of the wave. Doubling the amplitude of a wave implies quadrupling its energy. For example, if a wave A has an amplitude of .1 cm. and wave B has an amplitude of .2 cm, the energy transported by Wave B must be four times the energy transported by wave A.[5]

The loudness of sound is measured in units called decibels (db). The loudness of a sound depends on intensity. Obviously, the higher the number means the louder the sound. If the decibels are too high, they can cause damage to the ear. Infrasound and ultrasound lie beyond the range of human hearing.

Speed of a Wave

The speed of a wave is defined as the distance traveled per unit of time. Speed equals distance over time. The speed of sound varies with the different media and with temperature. Sound travels faster in steel than in water, and faster in water than in air. Sound travels faster at a higher temperature. At 0 C sound travels at about 330 meters per second in air and at 2O C sound travels 340 meters per second. Students will find it interesting to compare speed of sound in various media.[6] Some typical values are:

Solids (in meters per second)

- Glass 5200
- Aluminum 5100
- Iron 4500
- Copper 3500
- Zinc 3200
- Polystyrene 1850

Liquids (in meters per second)

- Water 1500
- Mercury 1400
- Alcohol ethyl 1125

Gases (in meters per second)

- Hydrogen (0 C) 1284
- Helium (0 C) 965
- Air (100 C) 387
- Air (0 C) 331
- Oxygen (0 C) 316

A reflection occurs when a wave travels from the original position and reaches the end of a medium. The wave will reflect or bounce. Reflection of sound results in an echo. Sound reflects off of a smooth surface at the same angle at which it is incident. Smooth hard surfaces reflect best. Rough soft surfaces reflect poorly. Energy not reflected is absorbed or transmitted through the material.

Reflection of sound or ultra sound waves can be used to determine distances or to create sonograms. Reflected ultrasound can be used for range and direction finding. A boat on the sea can send a beam of ultrasound down to the sea floor where it is reflected back upwards to a detector on the boat. If both the speed of sound in the water and the time taken for the ultrasound echo to get back to the boat are known, then the depth of the sea water at that place can be calculated since distance = speed x time.[7] Also, fishing boats find fish between the boat and the sea floor with ultrasound, since the school of fish will return the echo more quickly. Bats use ultrasonic echolocation to fly safely and locate food in the dark. They build up an image of their environment in darkness and locate insects for food in the air. They accomplish this by analyzing the reflected sound.

Musical Instruments

Physics and music are closely related. Understanding the physics of sound provides a foundation for investigating the physics of musical instruments. A musical instrument is a device manufactured with the purpose of making music. Anything that produces sound and is controlled by a musician can serve as a musical instrument. The academic study of musical instruments is called organology.[8]

Percussion

Percussion instruments are played by being hit. These instruments rely on mechanical vibrations of the instrument or parts of the instrument; they are separated into instruments with a definite pitch, and those with indefinite pitch. Instruments with a definite pitch include the xylophone and the timpani drums. Those with an indefinite pitch include the snare drum and some of the smaller "auxiliary percussion" instruments, such as the tambourine and the triangle. Percussion instruments are all about vibration and resonance. In a drum set for example, there is a cylinder, which is the body of the drum with a piece of taut material at the top known as the drumhead. There may also be another head at the bottom of the drum. When you strike the drum, the head deforms, but the tension causes it to snap back into place, vibrating the air inside the drum. The body of the drum also begins to resonate, as well as the head on the bottom of the drum if it is there, causing a loud sound to come from the drum.

Many percussion instruments, in addition to having an indefinite pitch are mechanically complicated. Maracas, for example, are hollow instruments filled with beads that collide and resonate with each other and the body of the instrument. Snare drums don't have a definite pitch, either. These drums consist of a body of steel or wood, with a thick head at the top and a light plastic head at the bottom. Also on the bottom are the snares, taut chains usually made of metal, but sometimes plastic, which also vibrate when the drum is struck, producing its distinctive sound.[9] The percussion section of an orchestra provides a variety of rhythms, textures and tone colors.

Strings

Stringed instruments include the violin, guitar, banjo, harp, and sitar. All of these instruments use the same principles to produce sound. The way they are constructed and the materials used changes which overtones of the frequencies played will resonate, and therefore change what the instrument sounds like, even if all of the instruments are playing the same fundamental frequency. In all stringed instruments, the strings are fixed at both ends, and are plucked, bowed, hammered, or moved by some other means to produce a standing wave.[10]

Wind and Brass Instruments and the Human Voice

Wind and brass instruments are often grouped together because they use vibrating air passing through a column to produce sound. The material used to make the body of these instruments is not an accurate way to identify its family type. A more reliable way to determine whether an instrument is brass or woodwind is to examine how the player produces sound. Both wind and brass instruments use vibrations in pipes to create the sounds. The differences come from what is used to create the vibration. In brass instruments (horn, trumpet, tuba, cornet) the lips of the person playing create the vibration while a reed is used in most woodwind instruments (clarinets, oboes, recorders, and flutes). Shortening or lengthening the pipes creates the different notes. In wind instruments this is most commonly done by opening and closing holes on the pipe. In brass instruments valves and slides are used.

The human voice creates sound via air passing over the vocal chords causing them to vibrate. The pitch of the sounds change due to length and stress on the vocal chords. Women generally have shorter, thinner vocal chords than men. This is the reason for the higher pitch of women's voices.[11]

How The Ear Works

Our hearing is important to our daily lives, and our ears are the organs that pick up sounds and transmit the information to our brain. Amazingly, this is a mechanical process based solely on physical movement. We have previously discussed how sound travels through the air as vibrations. To hear the sounds, our ear has to do three things. First, it must direct the sound into the hearing part of the ear. Second, it must sense the fluctuations in the air pressure and finally, it must translate the fluctuations into an electrical signal that the brain can understand.[12]

The outer ear collects and channels sound to middle ear. The middle ear transforms the energy of a sound wave into the internal vibrations of the bone inner ear. Finally, the inner ear transforms the energy of a sound wave to electrical impulses, which are sent to the brain.

Objectives

Students will learn the key terms and definitions of vocabulary for waves, sound and musical instruments. They will learn the nature of sound, its properties, how it travels, and the relationship of frequency to pitch. They will recognize what factors affect the speed of sound. They will relate loudness and pitch to properties of sound waves. They will also learn how harmonics and resonance affect the sound from musical instruments. They will learn the composition and function of the ear in receiving sound waves. Students will discover how sonar and ultrasound imaging work.

Throughout the unit students will be developing math skills as well as reading and writing skills. They will have experience using tuning forks to identify resonance. Students will have opportunities to use the computer lab to view animations of concepts, conduct research, and learn the role technology plays for both the teaching and learning process.

Standards

The ideas presented in this unit provide a basic understanding of the physics of sound and will include real world applications. This unit will help students fulfill the Pennsylvania

Academic Standards for: Science and Technology, Mathematics and for Reading, Writing, Speaking and Listening. These standards are listed in the appendix.

Strategies

In using the Core Curriculum for ninth grade students. I will provide opportunities for demonstrations, group discussion and cooperative learning. Students will keep a glossary of terms and participate in constructing a word wall that will include key terms and definitions. Students will also develop illustrations for concepts learned and make connections to mathematical equations.

The lab periods will be structured for understanding the apparatus, performing experiments, and analyzing results. Students will visit the music room to learn the musical instruments. They will become familiar with categories of musical instruments. In the computer lab students will have opportunities to access various websites for online tutorials and animations. They will conduct research on one topic covered in this unit.

Lesson Plans/ Classroom Activities

Day 1

The objective of this lesson is for the students to learn that waves (e.g., sound, seismic, water, light) have energy and can transfer energy when they interact with matter.

Procedure:

The teacher will begin by mimicking the sound of a train whistle and train motion ranging from slower to faster frequency. Students will mimic the same sound of train. Along with this, two students will demonstrate tapping with fingers, pencils and rulers on desk. This will motivate students to begin discussing the concept of sound. They will brainstorm sounds they hear and categorize them as sounds from: weather, animals, environment, music, humans, etc.

The students will begin to develop a glossary of terms for a science of sound word wall. They will be responsible for defining and illustrating terms: acoustic, compression wave, echo, energy, medium, sound, vibrate, and wave.

Day 2

The objective of this lesson is for the students to observe the resonance phenomenon in an open ended cylindrical tube and then to use the resonance to determine the velocity of sound in air at ordinary temperatures.

Procedure: The teacher will introduce the concept that the velocity with which sound travels in any medium may be determined if the frequency and the wavelength are known. The relationship between these quantities is: Velocity = frequency X wavelength.

The teacher will explain that all objects have a frequency that they vibrate at naturally. A vibrating tuning fork held over an open tube can cause the air column to vibrate at a natural frequency that matches the frequency in the tuning fork. This is resonance. The length of the air column can be shortened by adding water to the tube. The sound is loudest when the natural vibration frequency of the air column is the same as (resonates with) the frequency of the tuning fork.

The students will use a lab session to calculate the velocity of sound using a resonance tube. They will need tuning forks, graduated cylinder, and the resonance tube apparatus Students will use data sheet to apply formulas. We will use the set a directions and data sheet found online.[13]

Day 4

The objective of this lesson is for the students to use computer animations to observe how sound travels in different states of mater: solid, liquids and gases

Procedure: The students will be taken to computer lab for an online animated activity-based experiment. They will begin with an interactive animation demonstrating the different speed of sound in air, water and steel.[14] This will be followed by interactive animations demonstrating the effect a change in frequency has on the passage of sound waves through a solid, [15] and animations of sound waves traveling in a gas allowing changes to be made to the frequency and amplitude.[16] As they make changes and observe how sound travels in different media, they will identify if sound is longitudinal or transverse in each of these states of matter.

Day 5

The objective of this lesson is for the students to use hand-on lessons and demonstrations to determine the factors influencing sounds that drums make.

Procedure: The students will be taken to the music room to observe the music teacher playing drums. After the demonstration we will discuss the concept of drumbeat and the factors that influence the sound of the drum.

When a drummer hits a drum, the head of the drum vibrates up and down. Each time the drumhead moves upward, it compresses the air above it. As the head moves back down again it leaves a small region of air that has a lower pressure. This happens over and over the drumhead creates a series of compressions and rarefactions in the air, in given figure of drumbeat.

The students will be given an opportunity to beat the drum to observe the difference between a low pitch and a high pitch. They will have question and answer session with the music teacher. The key concepts of this lesson are[17]:

- Deciding which factors influencing the type of sound a drum makes

- The tension of the drumhead is determined by its thickness and tightness
- The greater the tension of the drumhead, the faster it vibrates when struck.
- The faster the drumhead vibrates, the shorter the wavelength and the higher the frequency of the sound waves produced.
- The shorter the wavelength, the higher the frequency and the higher the pitch
- A tight, or high-tension, drumhead, therefore, produces higher-pitched sounds, while a lower-tension head produces lower-pitched sounds.

Day 6

The objective of this lesson is for the students to use a computer lab to learn about the relationship between intensities of different sounds

Procedure: The students will use a tutorial to observe the intensity measured in decibels of common sounds from barely audible to a rocket. Some examples are: whispers (0 dB), normal conversation (30dB), vacuum cleaner (50dB), lawnmower (70dB), threshold of pain (90 dB), nearby jet (120 dB) airplane (150dB), and rocket launching (180dB).

Next they will select combinations of medium, frequency, and amplitude to observe their effects on intensity decibel levels. They will enjoy determining what combinations produce intensities great enough to shatter a wine glass.[18]

Day 7

The objective of this lesson is for the students to will use reading, writing and listening skills to make judgments about sound and music. They will begin a research project on careers in physics.

Procedure: We will begin by brainstorming words and phrases that apply to the words “sound” and “music.” Then they will use a Venn diagram to list words that apply to both terms and list those that are exclusive to one term or the other. Students generally conclude that musical sounds have organized or regular properties, such as pitch and quality, that other sounds do not have.

Next we will brainstorm a list of jobs or careers associated with the science of sound (acoustics) and music (musical acoustics). Acoustics is the science of sound related to speech and hearing, recorded music, to the behavior of sound in concert halls and buildings, and to noise in our environment. Sound waves are used in medical diagnosis, for testing critical materials, and for locating fish in the ocean or oil-bearing rock formations underground. Musical acoustics deals with the way in which we hear and perceive musical sound, the instruments that produce it, and even the structure of melody and harmony. It combines elements of both the arts and science. [19]

Students will work independently to choose a career to research. Some possibilities are acoustical engineer, acoustical consultant, audiologist, architectural acoustics, building professional, musical engineer, noise specialist, and marine mammal biologist. Other careers involve working with communication systems, microphones, loudspeakers, and medical diagnosis, seismic surveying, recording and reproducing speech and music.

The teacher will ask students to read want ads to identify other careers related to the physics of sound and music. They will then research the education or training needed, the starting salary, where the jobs are available (private sector, government, academia, laboratories or military) and any interesting facts.

Day 8

The objective of this lesson is for the students to engage in real world activities to think critically about sound in our everyday life.

Procedure: The first project will be to find a cross walk with a crossing signal. The students will watch as the signal changes from "walk" to "don't walk" and back again. Does the cross signal ever produce a sound? If so, why? If not, why would it be a good idea for the signal to produce a sound?

For the second project I plan to contact the Overbrook School for the Blind to invite teachers as well as blind students to talk about the experiences in their life. Do they have crossing signal for blind pedestrians, near their school? How useful is sound in their daily life? What are their difficulties of being blind and how does the concept of sound play an important role in their life as well as everyone's life? I would invite my students to imagine ways that sound concepts can improve life for he blind and other handicapped persons.

Additionally, students will read from a selected book list related to topics on the science of sound. They will write writing the synopsis of each of the books. They are listed in the Student Resources.

Day 9

The objective of this lesson is for the students to learn about the different families and different types of musical instruments.

Procedure: The will introduce the lesson with an outline of the sections of the orchestra and a brief introduction to the instruments. She will ask students who play instruments to share their experiences (and if possible to bring in the instrument). Next, students will go to the computer to use an online tutorial to become familiar with the sections and instruments.[20] They will read a brief description of the instrument and hear the instrument being played.

For an assignment they will select a section of the orchestra and list the instruments and their salient features. The teacher will direct them to several web sites that have information and audio. One such site is a Web Quest called "Energy in the Air" and was created by students for students. They listen to each instrument, learn how each makes its unique sound, and even find directions for making some of the instruments.[21]

Day 10

The objective of this lesson is for the students to learn about workings of the ear.

Procedure: The students will use their textbook and other print and online resources to study how the ear works. The will be required to know the functions of each part of the ear and to draw and label the parts using the following steps:

- The outer ear catches and directs sound waves into the ear canal.
- The ear canal carries the sound waves to the eardrum.
- Sound waves cause the eardrum to vibrate.
- The bones in the middle ear pick up these vibrations.
- Vibrations pass through to the cochlea, setting the fluid inside this structure into motion.
- Special hair cells in the cochlea turn the sound waves into electrical impulses.
- The auditory nerve sends these electrical impulses to the brain where they are heard as sound.
- The outer ear catches and directs sound waves into the ear canal.
- The ear canal carries the sound waves to the eardrum.
- Sound waves cause the eardrum to vibrate.
- The bones in the middle ear pick up these vibrations.
- Vibrations pass through to the cochlea, setting the fluid inside this structure into motion. Special hair cells in the cochlea turn the sound waves into electrical impulses.
- The auditory nerve sends these electrical impulses to the brain where they are heard as sound.[22]

Teacher Resources

Backus, John. *The Acoustical Foundations of Music*. New York: W.W. Norton, 1969. The book gives a good understanding of acoustics and the physics of sound and the physics of musical Instruments.

Wilson, J.D., and Buffa, A.J. *Physics*. New Jersey: Prentice-Hall, 1997. This teacher's edition of the student text includes extensive background information, and an online companion for additional resources.

Student Resources

Crickmore, Paul F. *Lockheed Blackbird: Beyond the Secret Missions.* London: Osprey Publishing, 2004 This photo-essay about the SR-71 Blackbird includes a pictographic tour of the plane to explain its capabilities, as well as a demonstration of the ground and air support it requires to fly its missions.

Lampton, Christopher F. *Sound: More Than What You Hear*. New Jersey: Enslow Publishing, 1992. This book explores what sound is, how we perceive it, how it's recorded, and how it's used to transmit information. The natural sonar of bats and dolphins and the man-made sonar used underwater by the Navy are discussed in one section.

Penny, Malcolm. *How Bats "See" in the Dark.* New York: Benchmark Books, 1997. Here, readers will find a brief but thorough explanation of how bats use ultrasonic echolocation to fly safely and locate food in the dark. Many photographs and drawings illustrate the way that bats, as well as other animals and humans using technology, use sound to "see" their world.

Wilson, J.D., and Buffa, A.J. *Physics*. New Jersey: Prentice-Hall, 1997. The student edition of this book is used in my school district as the physics text.

Web Resources

5-14 Curriculum (http://www.ltscotland.org.uk/5to14/resources/science/sound/solid.asp) on June 10, 2007. This is a service of the Learning and Teaching Scotland Website. It offers resources for a Curriculum of Excellence including interactive science animations.

Acoustical Society of America (http://asa.aip.org/acou_and_you.html) on June 10, 2007. This site has a vast amount of information including information on careers, sound recording of animals, instruments and sounds in the atmosphere.

Music Teachers Resource site (http://www.ltscotland.org.uk/5to14/resources/science/sound/solid.asp) on June 10, 2007. The site makes resources available for listening projects related to science of music and musical instruments.

The Physics Classroom. (http://www.physicsclassroom.com) on June 10, 2007. This is a good website for teacher recourses and student understanding. It includes quizzes and animations.

Physical Education Library (http://www.sv.vt.edu/classes/ESM4714/Student_Proj/class95/physics/physics.html on June 10, 2007. The Physics Education Laboratory is an instructional physics site that allows high school students to experiment with fundamental physics laws and concepts. It includes a section on sound waves, speed of sound, intensity, and Doppler effect.

The Physics of Musical Instruments (http://www.mrfizzix.com/instruments/) on June 10, 2007. The site explains the basics of sound and waves, and working of different types of instruments.

Think Quest Library (http://thinkquest.org/library/search.html) on June 10, 2007. The Think Quest Library provides innovative learning resources for students of all ages on a wide range of educational topics. This is a link to science of sound activities for students.

Appendices

This unit will incorporate the following standards that are embedded in the School District of Philadelphia's Core Curriculum

Academic Standards for Science and Technology

3.1 Unifying themes of science
3.2 Inquiry and Design
3.6 Technology Education
3.7 Technological Devices
3.8 Science, Technology, and Human Endeavors

Academic Standards for Mathematics

2.1 Numbers, Number Systems and Number Relationships
2.3 Measurement and estimation
2.5 Mathematical Problem Solving and Computation
2.6 Statistics and Data Analysis.

Academic Standards for Reading, Writing, Speaking and Listening

1.2.11 Reading Critically in All Content Areas
1.3.11B Types of Writing- Research Papers
1/6/11 Speaking and Listening

Endnotes

[1] http://www.physicsclassroom.com/mmedia/waves/lw.html
[2] http://www.physicsclassroom.com/Class/sound/U11L2a.html
[3] http://www.physicsclassroom.com/Class/sound/U11L2a.html
[4] http://www.mtrs.co.uk/Y7_lessons/2_1/2_1.htm
[5] http://www.physicsclassroom.com/Class/waves/U10L2c.html
[6] Wilson and Buffa. *Physics*. New Jersey: Holt Rinehart, 1997, Table14.1, p 482.
[7] http://gcsephysics.com/pwav15.htm
[8] http://en.wikipedia.org/wiki/Organology
[9] http://www.mrfizzix.com/instruments/percussion.html
[10] http://www.mrfizzix.com/instruments/stringed.html
[11] http://www.mrfizzix.com/instruments/wind.html
[12] http://www.howstuffworks.com/hEnterearing.htm

[13] http://www.hse.k12.in.us Enter the term “resonance” in the search field at bottom of page and then download the data sheet.
[14] http://www.ltscotland.org.uk/5to14/resources/science/speedofsound.asp
[15] http://www.ltscotland.org.uk/5to14/resources/science/sound/solid.asp
[16] http://www.ltscotland.org.uk/5to14/resources/science/soundingas.asp
[17] http://www.teachersdomain.org/resources/phy03/sci/phys/mfe/zsuperdrums/index.html
[18] http://www.sv.vt.edu/classes/ESM4714/Student_Proj/class95/physics/intensity.html
[19] http://asa.aip.org/acou_and_you.html
[20] http://datadragon.com/education/instruments/
[21] http://library.thinkquest.org/5116/
[22] http://www.stronghealth.com/services/Audiology/hearing/index.cfm