
Sound and Vibrations

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Grade Level: 3

Benchmarks

P.EN.03.31 Relate sounds to their sources of vibrations (for example: a musical note produced by a vibrating guitar string, the sounds of a drum made by the vibrating drum head).

S.RS.03.11 Demonstrate scientific concepts through various illustrations, performances, models, exhibits, and activities.

Objectives

Upon completion of this lesson a student will be able to:

1. Build one or more instruments (guitar, drum, xylophone).
2. Play the instruments and demonstrate that vibrations are the source of sound.
3. Explain how sound travels in a report (paragraph written with drawing)

Misconceptions

Sound travels in one direction like a flash light beam. Sound is transmitted in all directions through particles (gas, liquid or solid) and vibrating objects create waves that move through a medium from one location to another (Edmondson). This misconception will be addressed in the elaborate portion of this lesson plan.

Materials and Setup

Engage:

The *Understanding Vibrations and Pitch* video.

<http://www.teachersdomain.org/resource/phy03.sci.phys.howmove.collage/>

Explore:

The class will be divided into thirds and assigned one of the following instruments to build in a group. Materials will be sectioned into three areas in the back of the classroom.

- For guitar
 - Empty Kleenex/tissue box
 - Elastic bands of different sizes and widths
- For drum
 - Empty soup cans
 - Balloons
 - Rubber bands
 - Wooden spoon
- For Xylophone
 - Different sizes of glass jars
 - Small spoon
 - Water

Safety: Clarify with students that balloons and rubber bands are to be carefully stretched over soup cans and not blown up/flung. Also, the cans may be sharp so make sure students are aware of this so they don't cut themselves.

Requisite Knowledge

Students should know that sound is produced by different things.

Engage: (10-15 minutes)

1. Show students the *Understanding Vibrations and Pitch* video. The video shows many different ways vibrations create different sounds like the vibrations of a cricket, bullfrog, opera singer, etc.
2. The following is adopted from teachersdomain.org, I didn't modify it because it gets at the heart of the idea of vibrations as sound and allows students to feel their own vibrations. "Ask students to think of other things that vibrate (washing machines, toys, pagers, car engines, and so on). Have them touch their throat with the tips of their fingers and hum (or sing a song together). Ask them if they can guess how the humming sound is made. They should be able to feel their larynx vibrating. Tell them that the vibrations are what make the sounds" (teachers domain).

Explore: (20-30 minutes)

1. Make sure each group of students is assigned an instrument (guitar, drum or Xylophone) and try to space out the amount of groups building each instrument evenly.
2. For the most part, let the groups explore and figure out themselves how to make the instruments with the materials provided. Give the students guidance in building their instruments when needed (provided at end of lesson).
3. Prompt the students to experiment in their groups the different sounds their instruments can make (high and low).

Explain: (10-15 minutes)

1. Challenge each group to make soft and loud sounds with their own instruments and then explain how they did it.
2. Then, have them make a sound and then stop it and ask them to explain how they did it.
3. Have groups walk around to all the instruments and make loud and soft sounds.
4. After the students have experimented with all the instruments gather them into discussion about what they observed.
5. Discuss with students how they demonstrated that vibrations are the source of sound, how they demonstrated a soft sound and a loud sound and how limiting vibrations limits sound.

Elaborate: (15-20 minutes)

1. The teacher will address the misconception here that sound travels in one direction like a flash light beam.
2. Have students spread out in a circle around the room, then shine a flashlight in such a way that only some students can see the beam, and ask who sees it.
3. Now do the same with the maraca and ask the students what this means about the sound waves.
4. This demonstration will help students understand that although light travels in once direction (only some of the students in the circle could see the light). While sound travels in all directions and is transmitted through particles in the air we cannot see through waves made by the vibrating object.
5. Each individual student will explain in a report how sound travels.

6. They will do this using their own words and draw a picture of how sound travels if we could see sound traveling through the particles in the air like a wave.
7. Provide them the analogy of a slinky for how the particles move in compressions and rarefactions so they have an accurate model to base their sound wave illustrations off of.

Evaluate:

ENGAGE: The teacher will assess group understanding by asking the class questions about the behavior of the sound producing animals and things in the video clip.

Sample Questions and Expected Answers:

1. What happens when the instruments are played in the video? Why?
The instruments produce sound because they make vibrations.
2. What is different about the sound the helicopter makes compared to the sound the clock makes? Why?
The clock makes a softer sound than the helicopter because the clock doesn't make as strong as vibrations as the helicopter.

EXPLORE: Students will be building three types of instruments and the teacher will help those that need assistance. Students should record their observations in the form of written question and response that will be given to them during the explore (a sample for a Xylophone is provided at end of lesson plan). The students will be evaluated based on the following rubric.

	Excellent	Good	Poor
Correct assembly of each instrument	None or minimal assistance was needed to construct the instruments, followed written directions (5)	Some assistance was needed to construct instruments or minor help needed to interpret written directions (3-4)	Much assistance was needed to construct instruments, written directions were not interpreted or used effectively (1-2)
Record of observations	All three questions are answered and are relevant to how an instrument produces a vibration when struck/hit/tapped (5)	At least two questions are answered and are somewhat related to how an instrument produces a vibration. (3-4)	One or no questions are answered and responses are unclear in relation to an instrument producing a vibration. (1-2)
Pair Interaction or Group Work	Group shared tasks for construction of instrument equally (5)	Group shared tasks for construction of instrument but not more or less equally (3-4)	One or two students did most of the work (1-2)

EXPLAIN: Class participation and students' involvement in the challenge of making virtually no sound will be assessed. The teacher will make sure all students stop the vibrations to accomplish the task of making virtually no sound with their instruments.

ELABORATE: This is where student's reports are evaluated by the following rubric. The rubric is set up as credit no-credit because students either do or do not understand the concept of how sound travels at this point.

Sample of student observations for explore for Xylophone:

1. How did you try changing the way you played your instrument?

	Acceptable	Not acceptable
Sound Travel	Student writes that sound travels in all directions (1)	Student doesn't write that sound travels in all directions or explanation is faulty (0)
Sound Waves	Student writes that sound travels through waves (1)	Student doesn't write that sound travels through waves or explanation is faulty (0)
Wave transfer	Student writes that the wave is transferred through particles in the air (1)	Student doesn't writes that the wave is transferred through particles in the air or explanation is faulty (0)
Sound Wave Picture	Student draws a picture of sound waves coming from a vibrating source and traveling in all directions (1)	Student doesn't draws a picture of sound waves coming from a vibrating source and traveling in all directions or picture is faulty (0)

We added different amounts of water to the glasses.

2. Did changing this affect the sound made?

Yes, an empty glass had a higher pitched sound than a glass with more water.

3. What other things did you observe about your instrument and the sounds it makes when played?

When we tapped harder on the glasses, the sound got louder and when we tapped softer on the glass, the sound got quieter.

Guidance for how to construct instruments:

Guitar:

Try wrapping the different bands around the box. What happens when you pluck the rubber bands?

Drum:

Put the balloon over the can and hold it in place with a rubber band. What happens when you tap the balloon?

Xylophone:

Put different amounts of water in the jars. Tap them with the spoon. What do you notice?

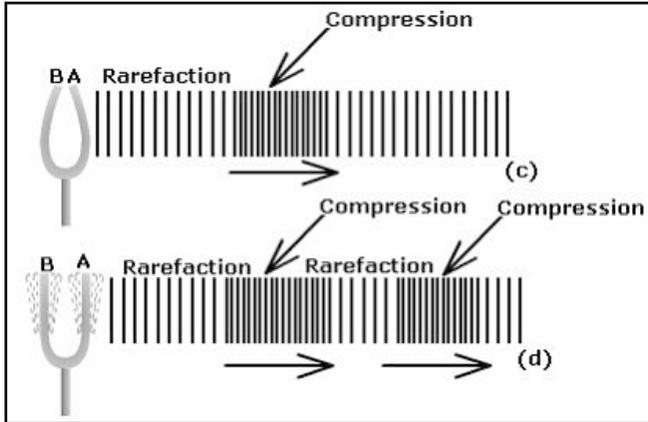
Scientific Background For Teacher:

Sound is an energy that acts like a wave. Like a wave, sound will move in pulse ripples.

General Wave Motion

Sound waves are longitudinal, meaning the disturbance is parallel to the direction of travel (Griffith 310). The perfect example of this is a pulse ripple that can occur in a slinky. A disturbance on one end of the slinky will create a pulse traveling from one end to the other and back. The sound wave is able to travel and move due to air pressure variations (Griffith 318). Air particles travel randomly in all directions but with a sound wave, there are areas of higher and lower density that create an alternating back and forth motion throughout the air. Compressions appear where the slinky is close together and rarefactions appear where the particles are spread out (Griffith 321). This is shown in figure 1. The position of the overall slinky never changes however, demonstrating the energy transfer.

Figure 1:



Properties and Equations for Waves

Wavelength is the distance of two pulses, measured at the same point (Giffith p.330). If the time between each of the different wave lengths are consistant, then we can determine the amount of time it takes for one wave length to travel a distance, allowing us to show the velocity symbol.

$$v = \frac{\lambda}{T} = f \lambda$$

Knowing the fact that the speed of any given wavelength is directly dependent upon the acceleration given from the last wave length, then we can use the equation $a = F_{net} / m$. This equation gives us two specific factors that are beyond important in determining the speed of the wave. The first is the total tension given on the medium, and the second is the weight of the medium divided by its total length (μ).

However, for reasons unable to determine, it is found that the direct relation to this acceleration and speed is expressed as the square of the speed and is equal to the total tension force over the mass/length. Resulting in an equation of

$$v = \sqrt{\frac{F}{\mu}}$$

A key component of sound waves and waves in general is the period. The period is simply described as the time between pulses (Griffith 330). While the frequency is the number of pulses a section will experience durring a given time (Griffith 330). Frequency is measured in Hz. and is known to be the the reciprical of time.

$$f = \frac{1}{T}$$

Now getting into Pitch, which is nothing more than a term we use for how high and low a musical note sounds to us is, it seems to have direct relation to the occilation of frequency. So using our earlier equation, we can rearrange it to show that the frequency and pitch are therefore directly related to the wavelenth and the speed of occilation. In a simple wave called the *fundimental wave* (Grffith p. 316) we know that the wavelenth is always going to be twice the length, showing that we can change the equation again to be.

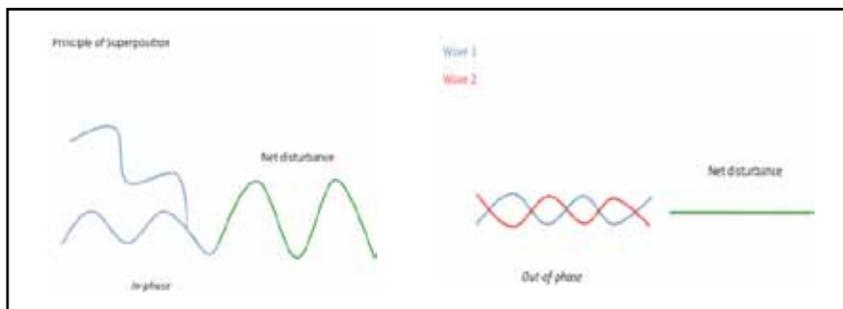
$$f = \frac{v}{2L}$$

Using this equation and assuming that the higher frequency means higher pich, we can see that the faster the occilation of the medium the higher the pitch. Whether that be a guitar string, a drum skin, or a piano wire. Two things will determine the speed, those being

the tension of the string and the mass. If you wanted to increase the pitch, it would be as simple as increasing the tension, which will result in a higher velocity. Increase the mass and it will drop the velocity, providing a much lower pitch.

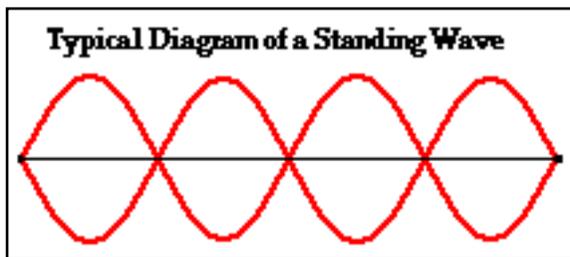
Multiple Waves

When two waves combine, their total amplitude is equal to the sum of each wave's individual amplitude, this is also known as the **principle of superposition** (Griffith 314). If two waves are *in-phase* they combine to make a wave with a larger amplitude and this is considered constructive interference. If two waves are *out-of-phase* they have destructive interference and cancel one another out.



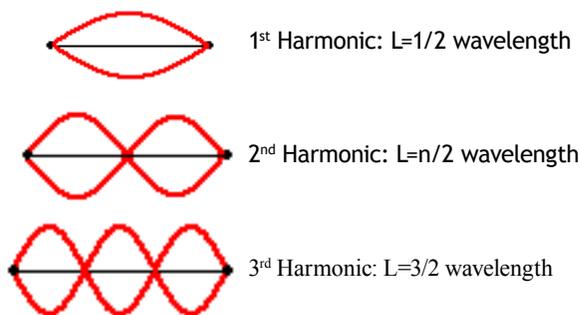
Standing Waves

The result of two waves traveling in opposite directions with the same frequency is called a *standing wave* (Griffith 315). Standing waves oscillate in such a way that they appear to be standing still. The points along a standing wave in which there is no motion are called nodes. Nodes are considered to have destructive interference because they cancel one another out. The points along a standing wave that have the largest amplitudes are antinodes. These are $\frac{1}{4}$ of a wavelength from a node and are considered to be constructive interferences. The points between nodes and antinodes are transitional points and have intermediate amplitude values (Griffith 315).



Harmonics

Standing waves are reflected back and forth on a string and can be plucked on guitar, piano or any instrument with fixed strings (Griffith 316). The first harmonic, also known as the fundamental wave, is the simplest standing wave. This first harmonic on a string is just half a wavelength although it is often mistaken to be a full wavelength. A full wavelength must contain three nodes and two antinodes so it would be twice that of a fundamental wave ($2L$). The second harmonic is half the wavelength of the first harmonic and twice the frequency. The third harmonic is a third the wavelength of the first harmonic and three times the frequency. The frequency of a fundamental wave is found by dividing wave speed by wavelength $F_0 = v/\lambda$. When a string is plucked, the air pulsates at different frequencies and the result is a wave with different harmonics. **Harmonic analysis** is used to determine all of the amplitudes of each of the frequencies in a sound.



By shortening the length of the string, you can increase the frequency of a string's sound as well as create a higher pitch. This makes sense in relation to a piano because longer strings produce the lower pitch sounds shorter strings produce the higher pitch sounds. Another way to change the sound of a guitar string would be to add more tension, which would increase the wave speed and frequency.

Musical Intervals

Earlier we noted that a higher frequency produces a change in pitch. When discussing music we call the doubling of frequency an **octave jump**, such as the jump from the first harmonic to the second (Griffith 322). Octave means eights and there are eight tones in the scale when singing, *do, re, mi, fa, sol, la, ti, and do*.

Nature of a Sound Wave

A sound wave is essentially pressure variation in the form of a longitudinal wave (Griffith 318). A longitudinal wave results when the disturbance is parallel to the line of travel, a transverse wave results when the disturbance is perpendicular to the direction of travel (Griffith 325). The longitudinal sound wave is analogous to a slinky moving back and forth. When a slinky pulses back and forth there are areas with more density and less density. Sound waves are regions of air pressure oscillating from areas of high pressure to areas of low pressure. The speed of the wave depends on the medium its' traveling through and how fast the molecules can transmit the change in air pressure. The spaces that are less dense in a sound wave are called rarefactions and the spaces that are denser are called compressions. Going back to the slinky analysis, the parts where the coils are closer together would be compressions and when the slinky gets spread apart those parts are rarefactions.

References

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