MATERIALS™ EXPLORERS

SCIENCE OF SOUND

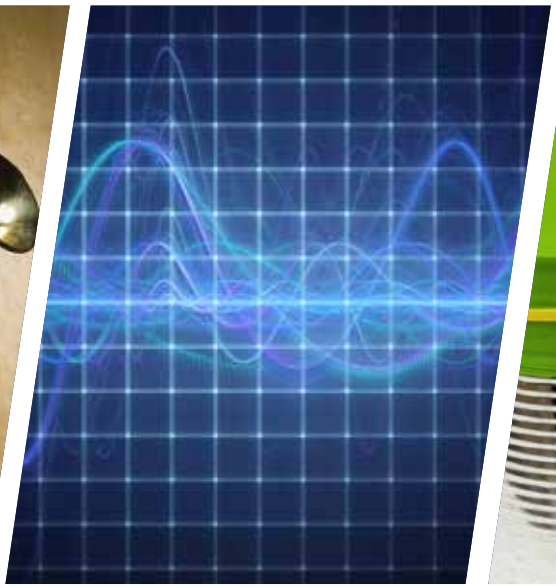
Ever wonder how music is made? In this chapter, you'll learn about the connection between waves and music by exploring how musical instruments produce sound. You'll also learn more about how musical instruments can be affected by the materials they are made from.

In this module students will be able to:

- Explain how pitch and amplitude can be adjusted for string and wind instruments
- Construct a prototype of an instrument which can be adjusted for pitch and amplitude
- Demonstrate the prototype and discuss challenges encountered
- Explore how various materials are used in the manufacturing of musical instruments
- Interpret graphs displaying sound waves, comparing pitch and loudness

Class Activity

ACOUSTIC AUDITION


Background:
When you hear your favorite song play on the radio or listen to a band play at a concert, what you're really experiencing are a series of waves, causing vibrations within your ear. These vibrations cause signals to be sent to your brain which, in turn, translates those signals into the amazing variety of noises you hear every day.

Sound is simply energy that moves through a medium, usually air, in a wave pattern. The **frequency** of a sound is directly related to its **pitch**. The more waves per second that hit your ear, the higher in pitch the tone is and the smaller the wavelength. Instruments can have high or low frequencies and some instruments sound louder than others. Louder sounding instruments have higher **amplitudes,** meaning they can compress air to a greater extent.

When a musical instrument produces a note, what it's really doing is creating a sound wave with a unique frequency, pitch, and amplitude. However, not all musical instruments do this in the same way. One of the most common ways to organize musical instruments is by classifying them into families based on the materials used in their construction and the method by which they produce sounds. The most common families are percussion, string, brass, and woodwind. In percussion instruments, sound generating vibrations are caused by a striking action, such as when drums are hit or when piano strings are struck by the piano's hammer. String instruments, such as guitars, cause vibrations in a slightly different way. The string of the instrument is pulled or plucked and the sound occurs as the string returns to its original position. Finally, the sound produced by brass and woodwind instruments is created by forced air interacting with the instrument. Think of how air is pushed through a recorder or trumpet.

Class Activity

Problem

An award-winning school marching band has decided to audition for a televised talent competition. The band members are very excited about this opportunity and know they need to deliver a unique performance in order to qualify. The students have decided to design, create, and play their own musical instruments instead of traditional instruments to make them stand out. Since you have exceptional knowledge of waves, pitch, and amplitude, they have enlisted your help to make the endeavor a success.

Task:
You are tasked with applying what you have learned about the properties of sound and acoustics as you design and create a musical instrument to present to your class.

Requirements:

1. The instrument must be a string, percussion or wind instrument.
2. The instrument cannot contain parts taken from other musical instruments.
3. The instrument must be capable of playing the following eight notes in order of increasing pitch: C, D, E, F, G, A, B, C.
4. The song you play for the class must consist of at least six different musical notes.
5. The class presentation you deliver must include a discussion of the following:
   a. How pitch and amplitude can be adjusted on your instrument.
   b. Problems you encountered while building and tuning the instrument.
   c. The inspiration behind the design of your instrument.

Definitions

Frequency
Frequency refers to the rate at which a wave is repeated over a specific period of time. It is typically measured in Hertz (which is calculated as the number of cycles per second).

Pitch
Pitch is related to frequency. The more waves per second hitting your ear, the higher in pitch the tone seems.

Amplitude
Amplitude is a measure of how “loud” a sound is. The greater the amplitude of the wave, the louder you perceive the sound.

Class Activity

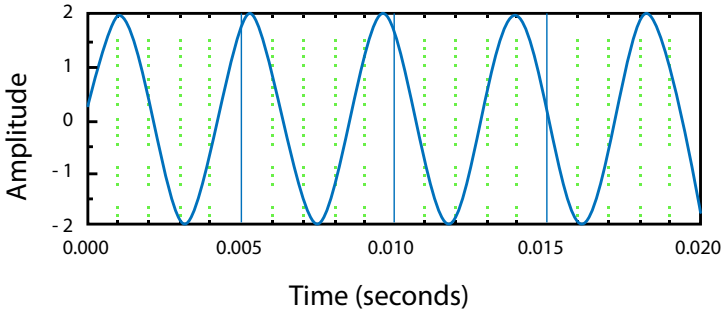
Questions

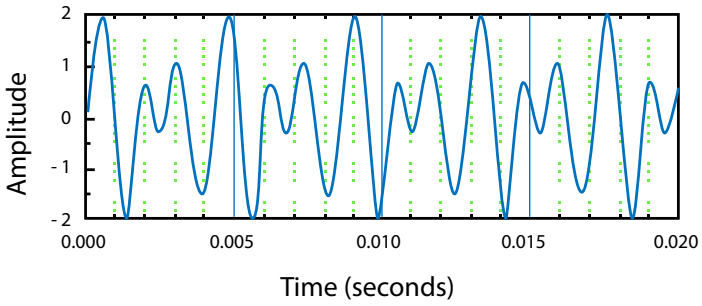
1. **Does frequency change based on the material used to create the instrument?**

2. **Do higher pitched sounds have a higher or lower frequency? Do they have a greater or shorter wavelength?**

3. **How can pitch and amplitude be adjusted for the following:**
   - **i.** A string instrument?
   - **ii.** A wind instrument?

4. **If the two waves below represent sound waves, how do the pitch and loudness compare?**





5. **What kind of work might an acoustical engineer do?**

Extension Activity

DO MATERIALS MATTER TO MUSIC?

When it comes to creating a musical instrument, one thing is certain. Materials matter. Instrument makers may use a signature material to differentiate their works from others, a rare material to add to the prestige of an instrument, or a pliable material to make production of the instrument easier. The choice of materials can also affect the sound an instrument creates and even traditional craftspeople have been known to tinker with advanced materials for better sound quality.

However, the influence of material choice on sound quality can vary vastly from one musical instrument to another. Take, for instance, the debate around brass instruments.

The prices of brass instruments can vary widely based on the type of material used to produce them, but players and manufacturers alike are divided on whether this makes any difference at all to the final sound. Researchers have set out to find an answer.

At the Institute für Wiener Klangstil (IWK) in Austria, researchers tested seven identical flutes made out of silver, various degrees of gold, and platinum, as well as coated instruments, to determine if the sound quality from the different flutes was affected by the choice of material. (Photo courtesy of the IWK)

Testing Precious-Metal Flutes

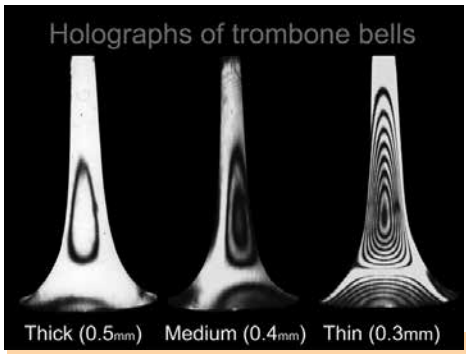
Gregor Widholm, who established the Institut für Wiener Klangstil (IWK) at the University of Music and Performing Arts in Vienna in 1980, conducts applied research in the field of musical acoustics. The institute credits Widholm with founding the scientific research field of musical acoustics in Austria by adapting scientific physical measuring methods to the investigation of the functionality of musical instruments.

Widholm and his colleagues set out to learn the effect of different metals on the sound of flutes. They chose seven identical flutes made by a single manufacturer, Muramatsu, in seven different materials: silver coated, full silver, 9 kt gold, 14 kt gold, 24 kt gold, platinum coated, and all-platinum. Seven professional flute players from Viennese orchestras were recruited to test the flutes by playing short solo pieces and individual notes on each of the seven flutes. These results were recorded and analyzed by IWK researchers, and the professionals listened to the results. What they found was that the instrument being played had little effect on the sound being produced.

“Silver, 24 kt gold, and platinum all have different vibrating properties,

Extension Activity

of course, but the musician can mask all these properties by generating the sound," said Widholm. "That's the reason why there's really no difference between the $3,500 flute and the $150,000 flute. We conducted these tests with professional flute players, and when they heard the samples recorded, they heard no difference." These tests also measured the dynamic range of the instrument—that is, how loud or soft the musician can play. The platinum flute provided a slightly higher dynamic range, but, while measurable, it was not significant. The difference between musicians varied more than between instruments.



This image shows holographic measurements of vibrations in trombone bells of various thicknesses. Though there is a measurable difference in vibration, instrument players were able to detect little difference in sound quality among the three.
(Photo courtesy of Richard Smith)

An Experiment in Brass

Unlike many instrument makers, who start out as musicians, Richard Smith began as a scientist, receiving master's and Ph.D. degrees in acoustics. His doctoral research dealt with the application of quantum physics to musical instruments.

Now, Smith uses his scientific background to manufacture brass instruments with high sound quality at his own company, SmithWatkins, where he designs instruments with trumpet player Derek Watkins.

Like Widholm, Smith has also put instruments to scientific tests–this time, to determine if varying the material of a trombone will change its sound. Smith conducted an experiment using several trombone bells of various materials and thicknesses. Although holographic measurements show differences in the vibration for the various thicknesses of material, Smith found that not one of the professional trombone players in his study was able to tell the difference either between different types of material or different thicknesses of material in the bell of the trombone.

Internal shape is important to the sound, bell shape is important, and the lead pipes are important, according to Smith. "Materials are

Instrument manufacturers are always experimenting with alternative materials. Ted Brewer's Vivo² electric violins deviate from traditional violins in both material and shape. (Photo courtesy of Ted Brewer Violins)

really just the icing on top," he said.

However, sound quality isn't the only factor determining material choices and, for Smith, brass is still best. "It's all about what material is easiest to work with," said Smith. "Brass is ideal because it's malleable."

While the body material will likely stay the same, there is room for materials innovations in some of the instrument's smaller pieces. For example, Smith would like to see a materials redesign of trumpet valves to make them faster. Using lighter weight materials in the valves, such as magnesium or titanium, could be the solution, he suggested.

Extension Activity

Instruments are Like Golf Clubs...

If specific metals have not proven to make much difference in the sound of metallic instruments, why select one material over another? Some manufacturers use materials as a marketing device to differentiate themselves from competitors. For others, it is simply a way to offer musicians more choice.

Elizabeth Holm, a materials scientist and amateur musician, notes that another factor driving material choice is likely psychological. She compares it to the golf club industry, where new clubs made of "better materials" are introduced every year, claiming to improve your game. "There's a strong placebo effect. If you have more confidence in your clubs, doesn't it make you play a little better, at least for a while?" she said. "I don't know; I've never measured it. But it's the same with music."

Elizabeth Holm (right), a materials scientist, plays violin with her friend Jude Rowe, as members of a band that performs primarily for Celtic dance groups and festivals. (JOM: December 2013)

This article is excerpted from "The Science of Sound: Examining the Role of Materials in Musical Instruments" by Kelly Roncone Zappas, published in JOM, August 2007, Volume 59, Issue 8, pp 13-17.

Questions

Whether the choice of material affects the sound, appearance or cost of an instrument, craftspeople give serious thought to the types of materials they use. While Widholm and Smith found that the choice of material did not affect the sound quality for their flutes or trombones, it has a major influence on the sound produced by a violin.

1. **How is sound produced in a traditional violin and why might the choice of materials be important to this?**

2. **What materials are violin bows traditionally made of and what challenges to this material have caused violin makers to explore new materials?**

3. **What alternative material is currently in use for bows? What are the pros and cons of using this material?**

4. **Kevlar, a material often used in bullet-proof vests, is also used in violins. What part of the violin is composed of Kevlar and what is the advantage of using this material?**

5. **While there are no restrictions on materials that can be used to make electric violins, what are some factors manufacturers should consider when selecting materials?**

Materials Explorers™ is a STEM educational outreach initiative of The Minerals, Metals & Materials Society (TMS). TMS is non-profit, international professional society with a mission to promote the global science and engineering professions concerned with minerals, metals, and materials.

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