Tool Kit IV

Amplification – Acoustic

Objective

Investigate how sound waves transfer energy or interact with different mediums, including resonators and dampeners, and how the transfer of sound energy between different mediums affects the characteristics of the sound.

Materials

- Music-box action*, tuning forks*, or other small source of sound (cell phone, etc.)
- Recycled materials: shoeboxes, cookie tins, plastic bins, string, wire, etc.
- Scissors or box cutters

**Available at the Museum Store at MIM*

Background Information for Educators

Review the basic characteristics of sound waves (**frequency**, **wavelength**, **amplitude**, and **speed**) in MIM's elementary curriculum for "STEM: How Science Brings Music to Life".

The loudness of a sound wave relates to its **amplitude**. Since a musical instrument is meant to be heard, its **vibrations** (or **sound-wave energy**) must disrupt a relatively large number of air molecules. For acoustic instruments, we can **increase the amplitude** by having a soundboard, or resonator, as part of the instrument design. The sound-wave energy of the initial sound source is **transferred** to a larger medium such as a soundboard or resonator, which itself begins to vibrate, transferring that sound-wave energy to an even larger number of air molecules. Conversely, if we wanted to **decrease the amplitude** of a musical instrument, we would direct its sound-wave energy into a medium that would absorb many of those vibrations without passing them on to the surrounding air molecules. In both cases, the vibrations (or energy) of the initial sound source are transferred from one medium to another.

Activity

What effects do different mediums (with which sound waves transfer energy) have on the sounds we ultimately hear?

Investigate

Present students with a sound source (small music-box action, tuning fork, or any electronic device with a small speaker such as a cell phone or MP3 player with earbud speakers).

A. ***How will we experience the amplitude of a sound source when it is played in the air?*** The amplitude is low; the sound is quiet.

B. ***How will we experience the amplitude of the sound source when it is placed against a hard surface, such as a table or desk?*** The amplitude is high; the sound is louder.

C. ***What will happen if the sound source is placed on a soft surface, such as a pillow or foam pad?*** The amplitude is low; the sound is quiet.

Students experiment with different resonating materials.

Create

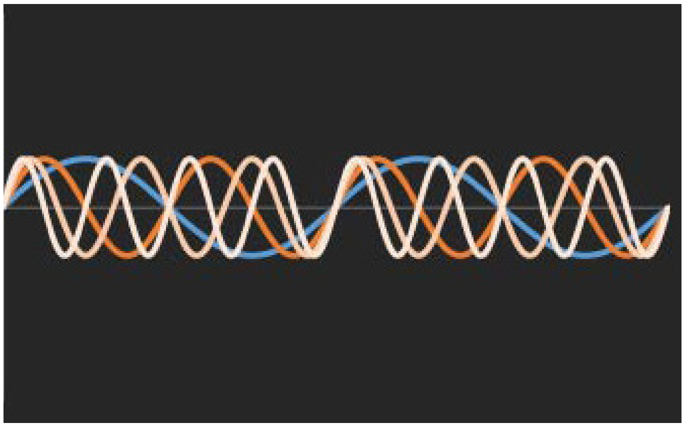
Experiment with different materials and construction techniques to make a resonator—something which will help amplify the vibrations of the small sound source.

D. ***What will happen to amplitude if the sound source is inside a cardboard box? Inside a metal tin?*** Resonance is directly related to both mass and stiffness or tension. Materials that are extremely stiff but of minimal mass, such as a tin can, a thin wooden box, or a hollowed-out gourd, all make highly effective resonators. This is because, due to their minimal mass, it takes a minimal amount of sound-wave energy to get them to vibrate. We sometimes call this "sympathetic vibration."

E. ***Does your instrument sound better if played at certain frequencies more than at others?*** Every material will have a "Helmholtz resonant frequency" at which it will amplify a specific frequency with the most efficiency. Herman von Helmholtz was the German scientist who first discovered how different materials could be used to amplify specific frequencies depending on their mass and density, among other things. Some materials resonate best at very low frequencies, and some resonate best at very high frequencies. This is called the "resonant frequency" of that material. Putting a material under tension (by stretching a drumhead or pulling a string tight) affects resonant frequency because it changes the physical properties of that material at a cellular level.

So-called f-holes on a violin improve its resonance at lower frequencies.

F. ***Will holes make a difference in the amplitude?*** The addition of holes lowers the mass of the resonator and changes the "Helmholtz resonant frequency" of the instrument. Exactly how a hole changes resonance is extremely complex and depends on its location, the source of vibrations, and the frequency of those vibrations. For example, studies have shown that the so-called f-holes on a violin improve its resonance at lower frequencies. It took hundreds of years of experimentation to settle on the placement and size of the f-holes on a violin.



This image is a representation of the type of "compound wave" that makes up sounds you hear. Each color represents a different frequency. The point where multiple waves come together at the same amplitude is called "node."

G. ***Will changing the resonator's structure with bracing or ribs make a difference in the loudness?*** Adding braces or ribs to the inside of the resonator will increase rigidity and mass at certain places on the instrument. Depending on where this rigidity and mass is added, both the resonance and resulting loudness can be affected. Every acoustic instrument resonates at multiple frequencies at once. These simultaneous frequencies are called overtones. Plucking a single string on an instrument creates sound waves at multiple frequencies. You hear the simultaneous frequencies as one note, but what you are in fact hearing is a "compound wave" made up of numerous overtones. Some overtone waves are very slow (low frequency) and some are very fast (high frequency). The point on the instrument where multiple waves come together at the same amplitude is called a node. Stiffening certain parts of your instrument with bracing will affect how these "nodes" behave. Calculating exactly where a node occurs on any given instrument is far too complex for this activity. However, you can experience how your bracing choices interact with these nodes by moving them around and noticing the subtle differences in the resulting sound.

H. ***Which resonator design provides the truest sound reproduction, as opposed to just the loudest?*** Regarding the overtones mentioned above, every instrument will emphasize certain overtones. Large resonators of minimal mass and rigidity can favor low overtones, while highly rigid resonators of added mass can favor higher overtones. Sometimes, a preference for one resonator design over another is a matter of personal taste.

Assessment

Formative

Students will demonstrate their understanding of wave energy exchange and resonance via the choices they make as they create different types of resonators or dampeners for their respective sound sources.

Summative

Students will explain the concept of acoustic resonance as a concept of vibrational (or wave energy) exchange.

Activity on your visit to MIM: Point out the different kinds of acoustic resonators.

Example: Acoustical Amplification – Thumb Pianos of Many Shapes and Sizes

What is a thumb piano?
The **thumb piano**, a generic term, is a musical instrument that consists of a wooden board to which staggered metal keys, or tongues, have been added. Another word for thumb piano is **lamellaphone**, which is a subcategory of an idiophone. Thumb pianos have been in use in Africa for thousands of years and are known by many different names, depending on the people who make and play them. There are many types of thumb pianos found within MIM's Africa Gallery, especially in the Zimbabwe exhibit. The mbira is played both in and out of a calabash gourd, which serves as an additional resonator.

First, a wooden soundboard is carved with an adze (like a small ax) and various knives. A hot iron poker is often used to burn/drill holes into it. In contemporary examples, keys/tongues as well as the pressure bars and bridges are manufactured from various recycled metals. The keys are cut to different lengths and shapes, depending on how the instrument is to be tuned. The handheld instrument is played by depressing or plucking the lamellae fixed to the soundboard.

How is a thumb piano's sound amplified?
The resonator can be made of many different materials, such as a solid wooden board, a hollow wooden box, a metal can, or a dried gourd. The shape of the resonator box or instrument body directly affects its sound. On a hollow-bodied resonator, there is often a sound hole to amplify the instrument's sound.

For centuries, the thumb piano has been a preferred instrument of storytellers, historians, and ritual experts throughout Africa. MIM's exhibit has over twenty-five thumb pianos from all over Africa made from diverse materials. Many of the instruments are carved into symbolic shapes or have patterns that carry culturally specific meaning.

Thumb pianos on display at MIM make use of a variety of different types of resonators.

C. F. Martin & Co. is an innovator in acoustic guitar design.

Example: Acoustical Amplification – Guitars

An important characteristic of acoustic guitars is found in the body: an acoustic guitar has a hollow body that acts as a resonator. The hollow body amplifies the vibrations of the strings. In contrast, the solid-wood body of an electric guitar does not have to resonate like an acoustic guitar because the sound waves primarily come from its connected amplifier and speaker, not from the guitar's body.

C. F. Martin & Co. continues to be an innovator and leader in acoustic guitar manufacturing. On display at MIM is a re-created Martin workshop, which prominently features X-bracing, one of the company's most successful innovations. X-bracing enhances the vibrational response of the guitar's resonating chamber (body) as it responds to and acoustically amplifies the vibrations of the guitar strings.

X-bracing improves the resonance of Martin acoustic guitars.

Additional Resources

Stradivarius at MIM: The Science of Stradivarius Violins

The Interconnected Nature of the Laws of Physics (Including Sound, Hearing, and Resonance)

Mathematics and Drumming: Analysis of Vibrating Nodes and Bessel Function Properties

Arizona State University's Consortium for Innovation and Transformation in Music Education (CITME) Curates Numerous STEM/STEAM Music Education Resources