Physics of Sound

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Duration: Four sessions of 30 minutes each

Introduction

This lesson is a free resource for teachers and students and is part of the Callysto project, a federally-funded initiative to foster computational thinking and data literacy in Canadian Grade 5-12 classrooms.

Sound is simply the mechanical transmission of energy through the air via vibrations of the air molecules, specifically through rapid variations in the air pressure that our ears perceive as sound. Some of the key ideas we wish to explore in the science and music curriculum include:

- how vibrations produce sound
- the three main characteristics of a sound: pitch/frequency, loudness/amplitude, and timbre
- periodic waveforms, and discuss those aspects of the waveform that define pitch, amplitude and timbre
- frequency, and describe its relationship to pitch
- harmonics, their relationship to fundamental pitch, and their effect on timbre and wave shape.

This lesson focuses on using the computer to create sounds with specific characteristics and to understand visual representations of the sounds. We will work with Jupyter notebooks on the Callysto hub.

To complete this lesson, you will need:

- A desktop computer or laptop with a working sound system
- A web browser on your computer
- Access to the Callysto hub at https://hub.callysto.ca
- Some simple musical instruments to make sounds

To log in to the Callysto Hub you and your students will need a Google or Microsoft account. This can be a school division-provided account or a personal account. Callysto does not collect any personal information about accounts.

Grade Level and Audience

Grades 8 through 12

Necessary Background Knowledge

1. Teachers and/or students should have some basic knowledge about sounds, and the difference between a musical tone and other random sounds.
2. Students should know how to log in to the Callysto Hub as well as run a notebook prior to interacting with it. Teachers, to get started with Callysto notebooks and running material on the Callysto Hub, see our Starter Kit.
3. It would be important to remind the students to protect their ears when working with sound on the computer. The sounds can be loud and piercing, so keep the volume settings low to begin.

Learning Outcomes

- Understanding the basic characteristics of sound
    - The properties of pitch, amplitude and timbre
    - Using the computer to create sounds with different pitch, amplitude and timbre
    - Hearing the difference between various sounds, and seeing them graphically
    - Testing the range of sounds that an individual person can hear with their ears
    - Observing the spectral characteristics of various sounds
- Understanding the properties of musical sounds
    - Periodic waveforms, how they sound and how they are represented graphically
    - Musical pitch, frequency, and connection to wavelength
    - Harmonics as a key property of musical sounds
- Understanding sound waves as a physical phenomenon
    - Sound waves are generated by vibrating material objects: tuning forks, vocal chords, etc.
    - Sound waves are variations in air pressure that our ears can hear.
    - A microphone can capture these variations, and plot it as a curve on the computer screen.
    - Simple harmonic motion appears as sine waves; more complex sounds have more complicated graphical representations

Required Materials

Required materials

1. A charged computer, with built-in speaker(s) and microphone.
2. Access to the internet.
3. An installed internet browser.
4. A Google or an Outlook email account.
5. A quiet place to create and observe sound
6. A few musical instruments to generate sounds for viewing.

Modifications

While the notebooks can be completed by individual students, it is very interesting to present the content to a group of students, perhaps of different ages, genders, and backgrounds. The sounds being generated are sometimes perceived differently by different people, and it is interesting to see their reactions. In particular, the very high frequency tones can be heard by young students and often not by adults. Also, females often hear high frequency sounds better than males do. Musically-trained students often have more acute hearing skills. It is interesting to see how students react to this difference as many are surprised by the phenomena.

Preparation

It is important to verify in advance that the sound system on your computer(s) is working properly. The software tools here will use both the computer's microphone to record sound, and the computer's speaker to play sounds out loud. Also, the sound may be very loud and irritating to some people, so check that the volume setting on the computer is set to a lower value for initial tests. Headphones can hurt the ears if the sound volume is too high.

It would be useful to have on hand a variety of musical instruments to use in the activities, as we can record the sounds and view them on the computer. These can include simple items like a penny whistle, a woodwind recorder, a tuning fork, a ukulele or guitar, perhaps a violin. A drum or bell is interesting as well. If you can whistle with your lips, that works too.

In-Class Activities

Activity 1: Pitch, Amplitude and Timbre (30 minutes)

- Notebook: physics-of-sound_1.ipynb
- Observing sounds of different pitches, amplitudes, timbres
- Using the computer to create a variety of sounds.
- Testing the limits of human hearing.
- Creating pleasing musical tones, and annoying sounds

Activity 2: Visualizing sound (30 minutes)

- Notebook: physic-of-sound_2.ipynb
- Software oscilloscope to view sounds as a graph, amplitude versus time
- Pitch, amplitude and timbre and their effect on the visualization of a sound
- Connection between pitch/frequency and the wavelength on screen

Activity 3: Energy spectrum of sounds (30 minutes)

- Notebook: physics-of-sound_3.ipynb
- Software spectrogram to view sounds as a graph, energy content versus frequency
- Pitch, amplitude and timbre and their effect on the visualization of a sound
- Presence of harmonic frequencies in natural sounds

Activity 4: Music and periodic waves (30 minutes)

- Notebook: physics-of-sound_4.ipynb
- Periodic waveforms as musical tones, fundamental with harmonics
- Periodic waveforms as a mathematical sum of sinusoids at multiple frequencies
- Generating complex waveforms by adjusting weights of harmonics

Reflections

Some suggested questions:

- *What went well? Why?*
- *What was tricky? How did you overcome it?*
- *What would you do differently? What would you do the same? Why?*
- *What connections can you make between what you learned from this lesson and your other coursework, lessons, or experiences?*

Next Steps

For more information, you can check out our YouTube videos, online courses, or callysto.ca for learning modules, tutorials, lesson plans, exercises and events.

Contact

If you encounter any issues or have any suggestions, please get in touch with us at contact@callysto.ca or twitter.com/callysto_canada.