Harmonic and inharmonic sounds

FizziQ activity · Middle school · 30 min

Scan to open in FizziQ

Compare bell and oboe spectra with FizziQ's spectrum analyzer on smartphone or tablet: oboe overtones are integer multiples, bell overtones are not. Middle school.

Learning objectives

- Analyze and compare the frequency spectra of a bell and an oboe using FizziQ
- Identify the fundamental frequency and overtones in each spectrum
- Determine whether the overtones are harmonic (integer multiples) or inharmonic (non-integer multiples)
- Understand the concept of musical timbre and its relationship to spectral content
- Classify everyday sounds as harmonic or inharmonic based on spectral analysis

Instruments and sensors

Sound spectrum analyzer (FFT) · Microphone

Materials

- Smartphone or tablet with FizziQ installed
- Bell and oboe sound recordings from the FizziQ Sound Library
- Optional: various everyday sound objects (glass, metal pot, wooden table)
- Note: the protocol remains adaptable to any comparable spectral analysis tool.

Protocol

1. Open the app and load the oboe recording from the Sound Library.
2. Play the recording and open the Spectrum Analyzer. Observe the spectrum: you should see a series of distinct peaks.
3. Record the frequencies of all visible peaks in a table. Label them as f_1 (fundamental), f_2, f_3, f_4, etc.
4. Calculate the ratio of each overtone to the fundamental: f_2/f_1, f_3/f_1, f_4/f_1, etc. For the oboe, these should be approximately 2, 3, 4, 5... (integer multiples).
5. Now load the bell recording from the Sound Library.
6. Play it and observe the spectrum. Again record the frequencies of all visible peaks.
7. Calculate the ratios of the bell overtones to its fundamental. These should NOT be simple integers.
8. Create a comparison table with columns: peak number, oboe frequency, oboe ratio, bell frequency, bell ratio.
9. Highlight the contrast: the oboe ratios are approximately 1, 2, 3, 4... while the bell ratios are irregular (e.g., 1, 2.0, 2.5, 3.0, 3.7...).
10. Listen to both sounds again. Can you now hear the difference in quality that corresponds to the harmonic versus inharmonic spectra?
11. Test other sounds from everyday objects: tap a glass, a metal pot, a wooden table. Classify each as harmonic or inharmonic.
12. Discuss why harmonic sounds are perceived as musical notes while inharmonic sounds are perceived as metallic or noisy.

Expected results

The oboe spectrum should show clearly harmonic overtones: if the fundamental is at approximately 440 Hz

(A4), the overtones should appear near 880, 1320, 1760, 2200 Hz, etc. (ratios of 2, 3, 4, 5). The bell spectrum should show overtones at non-integer ratios, typically: 1, ~2.0 (octave, roughly tuned), ~2.4 (minor third above the octave), ~3.0, ~3.7, etc. The exact ratios depend on the specific bell. Students should observe that the bell's overtone pattern is distinctly different from the oboe's, explaining the qualitative difference in sound character. Everyday objects like glasses and metal pots typically produce inharmonic spectra, while wind and string instruments produce harmonic spectra.

Questions

- Why do string and wind instruments produce harmonic overtones while bells and drums do not?
- What physical property of a vibrating string ensures that its overtones are exact integer multiples?
- How do bell founders attempt to make bells sound more musical despite their inharmonic nature?
- What is the relationship between harmonic content and the perception of a clear musical pitch?
- Why do some instruments (like the piano) have slightly inharmonic overtones at very high frequencies?
- Can a sound be both inharmonic and still perceived as having a definite pitch?

Going further

- Compare the spectra of different types of bells (church bell, hand bell, tubular bell) and rank them by harmonicity
- Analyze a gong or cymbal and compare its spectrum with the bell
- Investigate how the point where you strike a bell affects which overtones are most prominent
- Create a synthetic harmonic sound and a synthetic inharmonic sound using the FizziQ synthesizer and compare
- Record and analyze the sound of a singing bowl, which has a distinctive inharmonic spectrum