Chromatic scale and frequencies

FizziQ activity · Middle school · 30 min

Scan to open in FizziQ

Using the FizziQ frequency meter on a smartphone or tablet, middle school students measure the twelve chromatic notes and show their geometric progression.

Learning objectives

- Measure the fundamental frequency of each note in a chromatic scale using FizziQ
- Discover that musical frequencies follow a geometric progression rather than an arithmetic one
- Calculate the frequency ratio between consecutive semitones and verify it equals $\sqrt[12]{2} \approx 1.05946$
- Verify that the frequency doubles with each octave (2:1 ratio)
- Understand the mathematical basis of equal temperament tuning

Instruments and sensors

Frequency meter (fundamental frequency) · Microphone

Materials

- Smartphone or tablet with the FizziQ app installed
- 'Range' and 'Octaves' recordings from the FizziQ sound library
- FizziQ experiment notebook to record and graph frequency data
- Calculator to analyze frequency ratios
- Note: the protocol remains adaptable to any comparable frequency/spectral analysis tool.

Protocol

1. Open FizziQ and navigate to the Sound Library. Load the 'Range' recording containing the twelve notes of the chromatic scale.
2. Select the Frequency Meter (fundamental frequency) tool in FizziQ.
3. Play the first note of the recording and record the measured frequency in a table. Note: the first note should be close to a known reference (e.g., C4 = 261.6 Hz or A4 = 440 Hz).
4. Proceed through all twelve notes of the chromatic scale, recording each frequency.
5. Create a table with columns: note number (1-12), note name, measured frequency (Hz).
6. Calculate the ratio between each consecutive pair of frequencies: f(n+1)/f(n).
7. Verify that this ratio is approximately constant and close to 1.0595 (the twelfth root of 2).
8. Now load the 'Octaves' recording from the sound library, which contains the same note played across several octaves.
9. Measure the frequency of the same note in each successive octave.
10. Verify the 2:1 ratio: the frequency should exactly double from one octave to the next.
11. Plot a graph of frequency versus note number for the chromatic scale. The curve should be exponential (geometric progression), not linear.
12. Plot log(frequency) versus note number. This graph should be a straight line, confirming the geometric progression.

Expected results

The twelve notes of the chromatic scale should show frequencies forming a clear geometric progression. Starting from A4 = 440 Hz, the sequence is approximately: 440, 466, 494, 523, 554, 587, 622, 659, 698, 740, 784, 831 Hz for the twelve semitones, with each ratio ≈ 1.0595. The octave recordings should show exact doubling: A3 ≈ 220 Hz, A4 ≈ 440 Hz, A5 ≈ 880 Hz. Measurement precision with FizziQ is typically ±1-2 Hz, sufficient to verify the geometric pattern. The plot of frequency versus note number shows the characteristic exponential curve, while log(frequency) versus note number yields a straight line with slope $\log(\sqrt[12]{2})$.

Questions

- Why do musical frequencies follow a geometric progression rather than an arithmetic one?
- What does it mean physically for two notes to be an octave apart?
- Why did musicians adopt equal temperament instead of the older Pythagorean tuning?
- What mathematical operation connects the frequency of a note to the frequency of the note n semitones higher?
- Why do some frequency ratios (like 3:2 for a perfect fifth) sound consonant while others sound dissonant?
- How many semitones are in a perfect fifth? What is the corresponding frequency ratio in equal temperament?

Going further

- Compare the frequencies of the chromatic scale with the theoretical values and calculate the deviation
- Investigate Pythagorean tuning by calculating frequencies based on ratios of 3:2 and compare with equal temperament
- Analyze the frequencies of a pentatonic scale and compare its mathematical structure with the chromatic scale
- Use FizziQ's synthesizer to generate two notes simultaneously and investigate which intervals sound consonant
- Record a real instrument playing a scale and compare its frequencies with the theoretical equal temperament values