Acoustic beats at 440/441 Hz

FizziQ activity · High school · 35 min

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The FizziQ synthesizer plays 440 and 441 Hz tones on a smartphone; students record the pulsing sound level and verify the beat frequency equals the difference.

Learning objectives

- Generate acoustic beats by superposing two sounds of close frequencies using the FizziQ synthesizer
- Measure the beat frequency and verify that it equals the difference between the two source frequencies
- Visualize the amplitude modulation pattern on the FizziQ sound level graph
- Establish the general relationship between frequency difference and beat frequency
- Connect the mathematical model of wave superposition to auditory perception

Instruments and sensors

Synthesizer (dual-tone sound generator) · Sound level meter · Microphone

Materials

- Smartphone (or tablet) with the FizziQ application installed
- A quiet environment to minimize background noise
- Optionally, headphones for better perception of the beats
- Note: the protocol remains adaptable to any comparable sound level measurement tool.

Protocol

1. Open FizziQ and navigate to the Synthesizer tool. Set the first tone to 440 Hz (concert A).
2. Enable a second simultaneous tone and set it to 441 Hz, creating a frequency difference of 1 Hz.
3. Listen carefully. You should hear a single tone whose volume slowly pulses approximately once per second.
4. On a second device (or using FizziQ on the same device), open the Sound Level (dB) sensor and start recording.
5. Record for at least 15 seconds to capture multiple beat cycles. The graph should show regular oscillations in sound intensity.
6. Measure the period of the beats from the graph (time between consecutive maxima or minima). Verify that the beat frequency is approximately 1 Hz (period ≈ 1 second).
7. Now change the second frequency to 443 Hz (3 Hz difference). Listen to the faster pulsation and record again.
8. Measure the new beat period and verify that the beat frequency is now approximately 3 Hz.
9. Repeat with frequency differences of 5 Hz, 10 Hz, and 15 Hz, recording each time.
10. Create a table in your FizziQ notebook with columns: f_1, f_2, $\Delta f = |f_1 - f_2|$, measured beat frequency.
11. Plot a graph of measured beat frequency versus frequency difference (Δf). Verify that the relationship is linear with a slope of 1.
12. Finally, increase the difference to 20 Hz and then 30 Hz. Note at what point you stop perceiving discrete beats and begin hearing a rough or dissonant sound instead.

Expected results

For a 1 Hz frequency difference (440 Hz + 441 Hz), students should clearly hear a slow pulsation with a period of about 1 second and observe corresponding oscillations of 3-6 dB on the sound level graph. As the frequency difference increases, the beat rate increases proportionally: 3 Hz difference produces 3 beats per second, 5 Hz gives 5 per second, etc. The graph of beat frequency versus frequency difference should be approximately linear with slope 1. Beyond about 15-20 Hz, individual beats become too fast to distinguish as separate pulsations, and the perception transitions to a rough or buzzing quality. At 30 Hz difference, most listeners will hear two distinct tones rather than beats. Measurement precision is typically ±0.5 Hz due to noise and the difficulty of identifying exact maxima on the sound level graph.

Questions

- Why does the beat frequency equal the difference between the two source frequencies rather than their sum?
- At what frequency difference do beats become too fast to perceive individually? Why does this happen?
- How do piano tuners use beats to tune strings? What do they listen for?
- What would happen if the two sounds had different amplitudes? Would beats still occur?
- How is the beat phenomenon related to the LFO (Low Frequency Oscillation) effect in electronic music?
- Can beats occur with non-sinusoidal (complex) sounds? How would the perception differ?

Going further

- Use two smartphones emitting slightly different frequencies instead of the FizziQ dual synthesizer
- Try creating beats with higher base frequencies (880 Hz, 1760 Hz) and compare the perceived effect
- Record the phenomenon using the FizziQ oscilloscope to visualize the waveform envelope directly
- Investigate beats using two tuning forks of the same nominal frequency, with one slightly detuned by adding a small piece of tape
- Use the experiment to tune a musical instrument: adjust the frequency until the beats disappear