

Have you ever been listening to music and found yourself tapping your foot to the rhythm, or beat, of the music? This type of beat is a rhythmic beat. In physics, there is another kind of beat called an acoustical beat. An acoustical **beat** is a periodic change in sound intensity caused by the interference between two nearly identical sound waves. Acoustical beats are formed when the frequencies of interfering waves are very close in value. You hear beats as a change in loudness, from soft to loud. 🌐

The two waves in **Figure 1(a)** have similar frequencies. If the waves occur in the same medium at the same time, they will interfere with each other according to the principle of superposition and produce acoustical beats. **Figure 1(b)** shows the waves added together according to the principle of superposition. At times, the waves are in phase and constructive interference occurs. At other times, the waves move out of phase with each other and destructive interference occurs. As time passes, the waves move out of phase, then into phase again, and so on. As a result, a listener at some location within the medium hears a change in loudness, which is the beat. The amplitude of a beat varies in a predictable way.

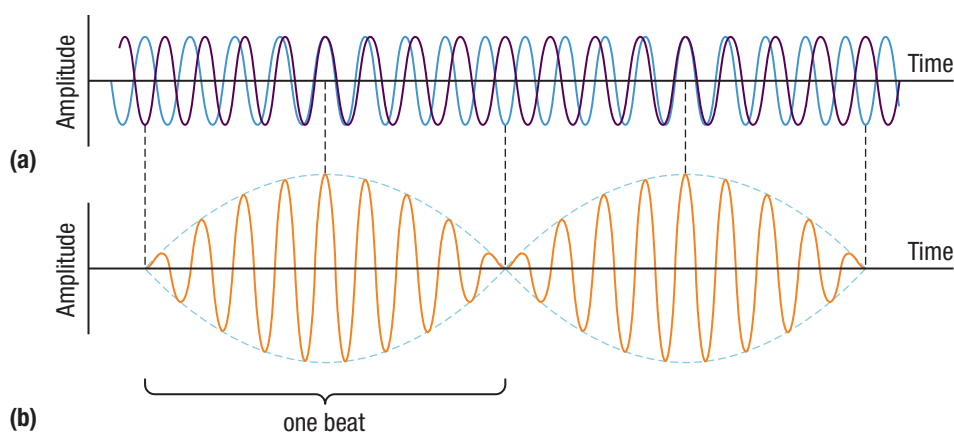


Figure 1 Beats are formed by the superposition of two waves with slightly different frequencies. (a) The individual sound waves are heard by an observer at some location within the medium. (b) The combined wave has an amplitude (blue dashed line) that varies in a regular manner.

Beats can be used to assess very small differences in frequency between two waves, because you can hear the change in loudness. Violinists and other musicians can use beats to tune their instruments by matching the musical notes with a standard note, perhaps from a piano or an oboe. A musical note refers to the specific frequency produced by a musical instrument, such as a piano, or other musical device, such as a tuning fork (**Figure 2**). By checking the frequency of the beats, musicians can determine how well the instrument is tuned. For example, when a piano tuner strikes a tuning fork of a given frequency and at the same time plays a piano key that is supposed to produce a note with the same frequency, she can determine the beat frequency by ear. The **beat frequency** is the frequency of the beats produced by the interference of two waves with slightly different frequencies. It is equal to the difference in frequencies of the two interfering waves. In this example, the beat frequency is the difference between the frequency of the tuning fork and the frequency of the piano key. The piano tuner can then tune the string to the desired frequency by adjusting the tension until she no longer hears any beats. 🌐

beat periodic change in sound intensity caused by the interference between two nearly identical sound waves

WEB LINK

To see an animation and hear acoustical beats,



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Figure 2 Tuning forks are available in different frequencies. A light tap to one tine (prong) of the fork sets both tines vibrating at a particular frequency.

beat frequency the frequency of beats produced by the interference of two waves with slightly different frequencies; equal to the difference in the frequencies of the interfering waves

CAREER LINK

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Mini Investigation

Wave Beat Demonstration

Skills: Performing, Communicating

A beat can be created by two waves whose ability to form beats is not immediately apparent. When a graph is displayed on a computer screen, the graphing program attempts to place a dot in a particular location. Across the screen there is a frequency at which the program attempts to place these dots. At the same time, the screen has a physical set of pixels appearing at a certain frequency across the screen. When the frequency of the plot and that of the screen get close, a beat pattern appears.

Equipment and Materials: computer with projection display or graphing calculator

1. Set up a graph on the screen using the equation $y = \sin 10x$.
2. Change the value of 10: start increasing the value and replot the graph each time until your graph appears similar to the graph shown in **Figure 3**.

- A. Most of the beats you will see with a computer are typically multiple beats. What might be causing this? [T/I](#)

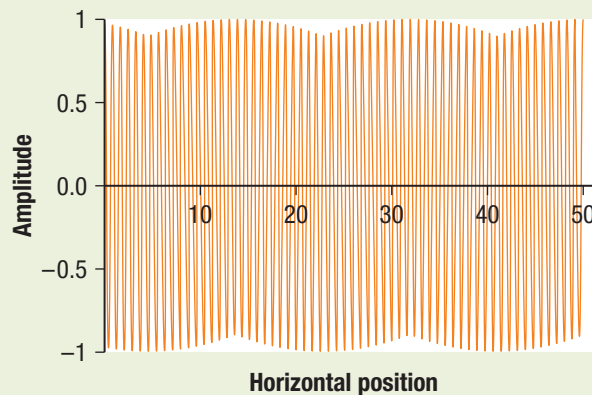


Figure 3

Mini Investigation

Creating Beats

Skills: Performing, Observing, Analyzing, Evaluating, Communicating

In this activity, you will produce audio beat patterns and view them on a computer.

Equipment and Materials: digital audio recording device, such as a personal music player or other device that produces audio computer files (for example, .wav or .mp3 type formats); digital audio editing software; pair of tuning forks that are close in frequency (about 5 Hz apart); rubber hammer; tuning fork whose frequency is about 40 Hz higher or lower than the frequency of one of the tuning forks in the pair; metre stick (optional)

1. Familiarize yourself with how to use the digital audio editing software. [G](#)
2. Familiarize yourself with the operation of your recording device. Consider, for example, the controls, the distance at which the sensor can detect sound, and for how long it can record a sound.
3. Take the pair of tuning forks, and gently tap them with a rubber hammer, one at a time. Record their sounds.
4. With your partner holding both tuning forks, gently tap them both at the same time with a rubber hammer. Listen for the slow changes in the amplitude as the sound changes between loud and soft. After practising, record the sounds.
5. Gently tap one of the tuning forks from Step 4 and the third tuning fork at the same time. Record the sounds.
6. Upload the files into the software, and display them.
7. The waveforms of the recordings from Step 5 should appear smooth and cyclic, as in Figure 1. If they are not, it is possible that your tuning fork tap was a double tap and there were two or more waves vibrating on the tuning fork at the same time. Repeat your recordings of the pairs of tuning forks until the waveforms look similar to Figure 1.
8. Now display the beat pattern. Using the mouse or a metre stick on the projection screen, determine if the beat pattern is indeed a sum of the two closely spaced waveforms.
9. Display the waveform of the recording from Step 5. Check whether the waveform is still an addition of the two waveforms.
 - A. Do you think that the waveform produced in Step 5 is a beat? Explain your answer. [T/I](#)
 - B. Do you think the beat pattern would change if you tapped the pair of tuning forks at different times? Explain. [K/U](#) [T/I](#)



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Research This

Humming Fish

Skills: Researching, Communicating

The midshipman fish lives off the western coast of Canada and the United States (**Figure 4**). At mating time the males prepare nests and start humming to attract females to lay their eggs in the males' nests. The males then fertilize the eggs.



Figure 4 The midshipman fish

1. Research the midshipman fish using Internet sources.
2. Find out how the females choose which male will fertilize her eggs.
 - A. At approximately what frequency do the males hum? **T/I**
 - B. When all the males are humming, what does it sound like? **T/I**
 - C. How do the females choose which male will fertilize her eggs? Explain your answer. **C A**



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9.3 Summary

- Acoustical beats are an interference pattern formed by two waves with nearly identical frequencies.
- You can hear an acoustical beat as a periodic change in sound intensity.
- Many musical instruments can be tuned by a musician or an instrument tuner by listening to the beats generated between a standard note and that of their instrument.

9.3 Questions

1. Explain how beats are created. Refer to the principle of superposition. **K/U**
2. You are tuning a guitar by comparing the sound produced by the string with the sound produced by a standard tuning fork. You notice a beat frequency of 5 Hz when both sounds are present. As you tighten the guitar string, the beat frequency rises steadily to 8 Hz. In order to tune the string exactly to the tuning fork, should you continue to tighten the string or loosen the string? Explain your answer. **K/U C**
3. An airplane mechanic notices that the sound from an aircraft with two engines varies rapidly in loudness when both engines are running. What could be causing this variation from loud to soft? **K/U**
4. The two waveforms in **Figure 5** have the same amplitude but different frequencies. They are interfering with each other. Copy the two waveforms into your notebook, and draw the resulting beat pattern. Mark the points of constructive interference and destructive interference. **K/U T/I C**

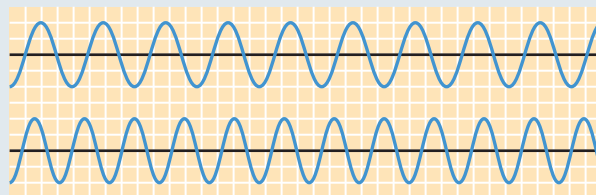


Figure 5