

point, the waves are said to be *in phase*. Now constructive interference occurs, and the sound is louder. Because the blue wave has a higher frequency than the red wave, the waves are out of phase again at t_3 , and no sound is heard.

As time passes, the waves continue to be in and out of phase, the interference constantly shifts between constructive interference and destructive interference, and the listener hears the sound getting softer and louder and then softer again. You may have noticed a similar phenomenon on a playground swing set. If two people are swinging next to one another at different frequencies, the two swings may alternate between being in phase and being out of phase.

The number of beats per second corresponds to the difference between frequencies

In our previous example, there is one beat, which occurs at t_2 . One beat corresponds to the blue wave gaining one entire cycle on the red wave. This is because to go from one destructive interference to the next, the red wave must lag one entire cycle behind the blue wave. If the time that lapses from t_1 to t_3 is one second, then the blue wave completes one more cycle per second than the red wave. In other words, its frequency is greater by 1 Hz. By generalizing this, you can see that the frequency difference between two sounds can be found by the number of beats heard per second.

SECTION REVIEW

1. On a piano, the note middle C has a fundamental frequency of 262 Hz. What is the second harmonic of this note?
2. If the piano wire in item 1 is 66.0 cm long, what is the speed of waves on this wire?
3. A piano tuner using a 392 Hz tuning fork to tune the wire for G-natural hears four beats per second. What are the two possible frequencies of vibration of this piano wire?
4. In a clarinet, the reed end of the instrument acts as a node and the first open hole acts as an antinode. Because the shape of the clarinet is nearly cylindrical, its harmonic series approximately follows that of a pipe closed at one end. What harmonic series is predominant in a clarinet?
5. **Critical Thinking** Which of the following are different for a trumpet and a banjo when both play notes at the same fundamental frequency?
 - a. wavelength in air of the first harmonic
 - b. which harmonics are present
 - c. intensity of each harmonic
 - d. speed of sound in air