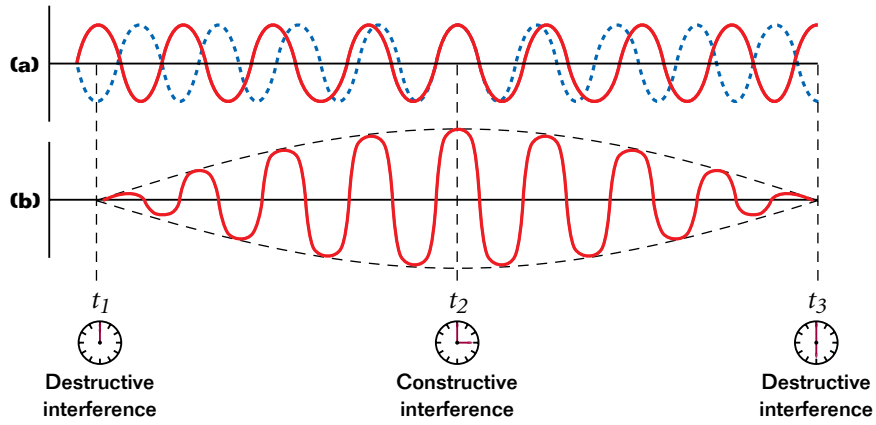

Figure 18
Beats are formed by the interference of two waves of slightly different frequencies traveling in the same direction. In this case, constructive interference is greatest at t_2, when the two waves are in phase.

BEATS

So far, we have considered the superposition of waves in a harmonic series, where each frequency is an integral multiple of the fundamental frequency. When two waves of *slightly* different frequencies interfere, the interference pattern varies in such a way that a listener hears an alternation between loudness and softness. The variation from soft to loud and back to soft is called a **beat.**

beat

the periodic variation in the amplitude of a wave that is the superposition of two waves of slightly different frequencies

Sound waves at slightly different frequencies produce beats

Figure 18 shows how beats occur. In **Figure 18(a),** the waves produced by two tuning forks of different frequencies start exactly opposite one another. These waves combine according to the superposition principle, as shown in **Figure 18(b).** When the two waves are exactly opposite one another, they are said to be *out of phase,* and complete destructive interference occurs. For this reason, no sound is heard at t_1.

Because these waves have different frequencies, after a few more cycles, the crest of the blue wave matches up with the crest of the red wave, as at t_2. At this

Why it Matters

Conceptual Challenge

1. Concert Violins Before a performance, musicians tune their instruments to match their fundamental frequencies. If a conductor hears the number of beats decreasing as two violin players are tuning, are the fundamental frequencies of these violins becoming closer together or farther apart? Explain.

2. Tuning Flutes How could two flute players use beats to ensure that their instruments are in tune with each other?

3. Sounds from a Guitar Will the speed of waves on a vibrating guitar string be the same as the speed of the sound waves in the air that are generated by this vibration? How will the frequency and wavelength of the waves on the string compare with the frequency and wavelength of the sound waves in the air?