Section 7.8 Questions

Understanding Concepts

1. Stereo speakers have colour-coded terminals (usually black and red) in the back that are hooked up to the wire from the amplifier in the stereo system. If the connections are reversed, the second speaker moves out when the first speaker moves in. Why is it important to wire both speakers so they move in and out together?
2. Distinguish between destructive and constructive interference.

Making Connections

3. Theatres and concert halls are designed to eliminate "dead spots." Research the answers to the following questions.
   (a) What are "dead spots?"
   (b) How do engineers eliminate the "dead spots" from these facilities?

7.9 Beat Frequency

We have been examining the interference of sound waves with identical frequencies and wavelengths. Now we will consider the interference of sound waves with slightly different frequencies and wavelengths. Consider a tuning fork that has one tine "loaded" with Plasticine or an elastic band wrapped around it. If this fork is struck at the same time as an "unloaded," but otherwise identical, tuning fork, the observed sound will alternate between loud and soft, indicating alternative constructive and destructive interference. Such periodic changes in sound intensity are called **beats**.

beats: periodic changes in sound intensity caused by interference between two nearly identical sound waves

Activity 7.9.1

Beats from Nearly Identical Tuning Forks

This activity will allow you to observe sound beats produced by two tuning forks of nearly identical frequencies.

Procedure

1. Place two mounted tuning forks close to and facing each other. Wrap an elastic band tightly around a prong on one of the tuning forks (**Figure 1**).
2. Sound the two forks together and describe the resulting sound.
3. Repeat the procedure using two elastic bands on the same prong.
4. Finally, remove the bands and repeat the process a third time.
5. Demonstrate beats with an oscilloscope and sound generator, if they are available, or use a computer program to demonstrate beats.

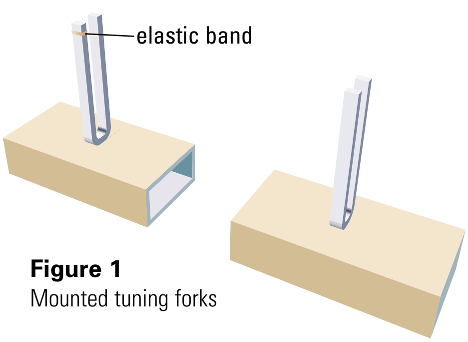

Figure 1
Mounted tuning forks

Analysis

(a) Did the frequency of a tuning fork increase or decrease when elastic bands were added to a prong? Explain your answer.
(b) Predict a relationship between the frequency of beats produced and the frequencies of the sources producing the beats.
(c) Explain how this activity demonstrates that sound energy travels by means of waves.

Interference Between Nearly Identical Sound Waves

The interference that occurs between two sources with slightly different frequencies is shown in **Figure 2**. The wavelengths are not equal and hence the distances between successive compressions and rarefactions are not the same. At certain points, a compression from one source coincides with a rarefaction from the other, producing destructive interference and minimum sound intensity. When compression and compression coincide and rarefaction and rarefaction coincide, constructive interference results and maximum sound intensity occurs. The number of maximum intensity points that occur per second is called the **beat frequency**.

beat frequency: the number of beats heard per second in hertz

To determine the beat frequency, the lower frequency is subtracted from the higher frequency. For example, if a tuning fork of 436 Hz is sounded with a 440-Hz tuning fork, the beat frequency will be 4 Hz.

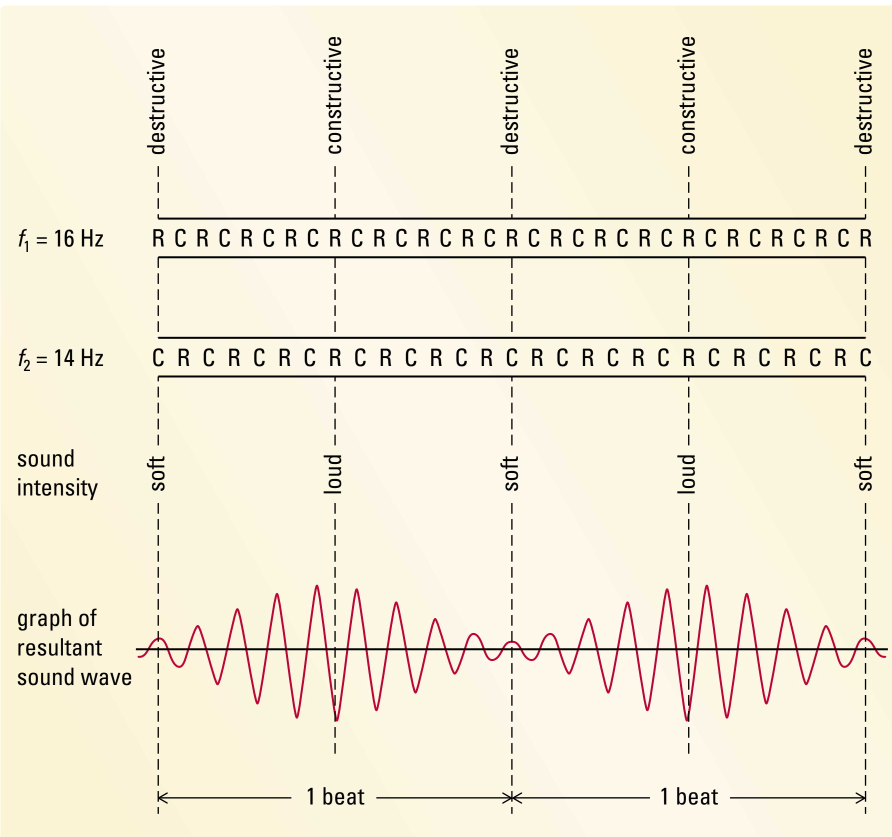

Figure 2
A source of sound with a frequency of 16 Hz interferes with a source with a frequency of 14 Hz to produce two beats in one second. The difference in frequency between the two sources is equal to the beat frequency.

DID YOU KNOW ?

Human Detection of Beat Frequencies

In practice, the human ear can only detect beat frequencies less than 7 Hz.

Sample Problem

A tuning fork with a frequency of 256 Hz is sounded together with a note played on a piano. Nine beats are heard in 3 s. What is the frequency of the piano note?

Solution

$$\text{beat frequency} = \frac{\text{number of beats}}{\text{total time}}$$

$$= \frac{9 \text{ beats}}{3 \text{ s}}$$

$$\text{beat frequency} = 3 \text{ Hz}$$

$$\text{beat frequency} = |f_1 - f_2|$$

$$3 \text{ Hz} = |256 \text{ Hz} - f_2|$$

$$f_2 = 253 \text{ Hz} \quad \text{or} \quad 259 \text{ Hz}$$

Note that there are two possible answers. Without more information, there is no way of knowing which is correct.

Practice

Understanding Concepts

1. What is the beat frequency when a 512-Hz and a 514-Hz tuning fork are sounded together?
2. Two tuning forks are sounded together. One tuning fork has a frequency of 200 Hz. An observer hears 21 beats in 3.0 s. What are the possible frequencies of the other tuning fork?

Making Connections

3. Explain in your own words how beats can be used to tune a guitar.

Answers

1. 2 Hz
2. 193 Hz, 207 Hz

SUMMARY Beat Frequency

- Interference between two nearly identical sources of sound results in periodic changes in intensity called beats.
- Beat frequency is the difference between the frequencies of two sound sources.

Section 7.9 Questions

Understanding Concepts

1. You sound two tuning forks together. One has a frequency of 300 Hz, the other a frequency of 302 Hz. What do you hear?
2. When a tuning fork with a frequency of 256 Hz is sounded at the same time as a second tuning fork, 20 beats are heard in 4.0 s. What are the possible frequencies of the second fork?

3. State the beat frequency when the following pairs of frequencies are heard together:
   (a) 202 Hz, 200 Hz (b) 341 Hz, 347 Hz (c) 1003 Hz, 998 Hz
4. Use the principle of superposition to "add" these two sound waves together on a piece of graph paper turned sideways:

   Wave A: λ = 4.0 cm; A = 1.0 cm; 5 wavelengths
   Wave B: λ = 5.0 cm; A = 1.0 cm; 4 wavelengths

   Describe how the resulting pattern relates to the production of beats.
5. A tuning fork with a frequency of 4.0×10^2 Hz is struck with a second fork, and 20 beats are counted in 5.0 s. What are the possible frequencies of the second fork?
6. A third fork with a frequency of 410 Hz is struck with the second fork in question 5, and 18 beats are counted in 3.0 s. What is the frequency of the second fork?
7. A 440-Hz tuning fork is sounded together with a guitar string, and a beat frequency of 3 Hz is heard. When an elastic band is wrapped tightly around one prong of the tuning fork, a new beat frequency of 2 Hz is heard. Determine the frequency of the guitar string.

Making Connections

8. How would a piano tuner use a tuning fork or pitch pipe to tune a piano by adjusting the tension of the strings?

7.10 The Doppler Effect and Supersonic Travel

If you've ever been to an automobile race, you probably noticed that when a racing car streaks past you, you can detect a change in frequency of the sound from the car. As the car approaches, the sound becomes higher in frequency. At the instant the car passes you, the frequency drops noticeably. The apparent changing frequency of sound in relation to an object's motion is called the **Doppler effect**, named after Christian Doppler (1803–53), an Austrian physicist and mathematician who first analyzed the phenomenon. You've probably heard this effect from train whistles, car horns, or sirens on fire trucks, ambulances, or police cruisers.

Doppler effect: when a source of sound approaches an observer, the observed frequency increases; when the source moves away from an observer, the observed frequency decreases

To understand why the Doppler effect occurs, look at **Figure 1**. **Figure 1(a)** shows sound waves travelling outward from a stationary source. **Figure 1(b)** shows the source of sound waves travelling to the left. As the waves approach observer A, they are closer together than they would be if the source were not moving. Thus, observer A hears a sound of higher frequency. Observer B, however, hears a sound of lower frequency because the source is travelling away, producing sounds of longer wavelength. A similar effect occurs when the source of sound is stationary and the observer is moving toward or away from it.