Chapter 12

Sound

12-1 Characteristics of Sound

Sound can travel through any kind of **matter**, but not through a **vacuum**.

TABLE 12–1 Speed of Sound in Various Materials (20°C and 1 atm)

Material	Speed (m/s)
Air	343
Air (0°C)	331
Helium	1005
Hydrogen	1300
Water	1440
Sea water	1560
Iron and steel	≈5000
Glass	≈4500
Aluminum	≈5100
Hardwood	≈4000
Concrete	≈3000

The **speed** of sound is different in different materials; in general, it is slowest in **gases**, faster in **liquids**, and fastest in **solids**.

The speed depends somewhat on **temperature**, especially for gases.

12-1 Characteristics of Sound

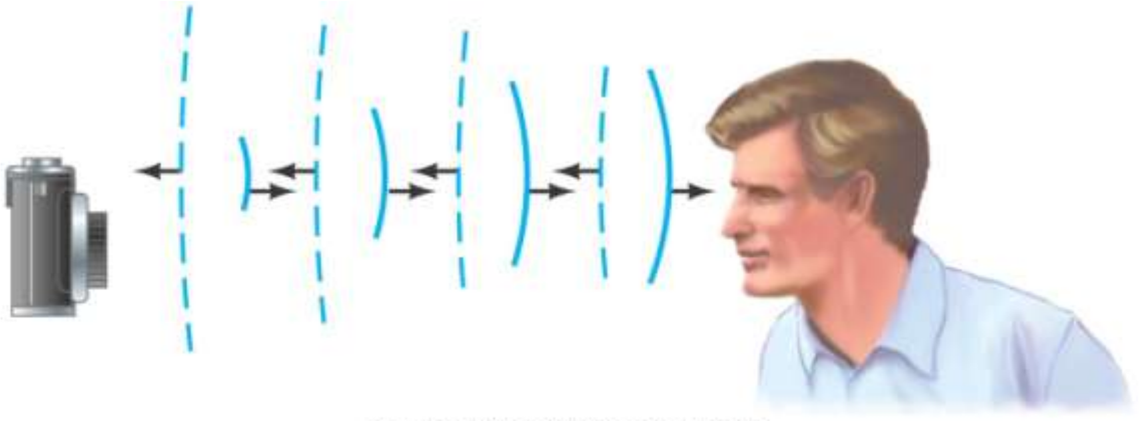
Loudness: related to **intensity** of the sound wave

Pitch: related to **frequency**.

Audible range: about **20** Hz to **20,000** Hz; upper limit decreases with age

Ultrasound: above **20,000** Hz; see ultrasonic camera focusing below

Infrasound:
below **20** Hz



12-1 Characteristics of Sound

Let’s test your hearing range.

Keep track of what letter sound you can hear.

a. 🔊

b. 🔊

c. 🔊

d. 🔊

e. 🔊

f. 🔊

g. 🔊

h. 🔊

i. 🔊

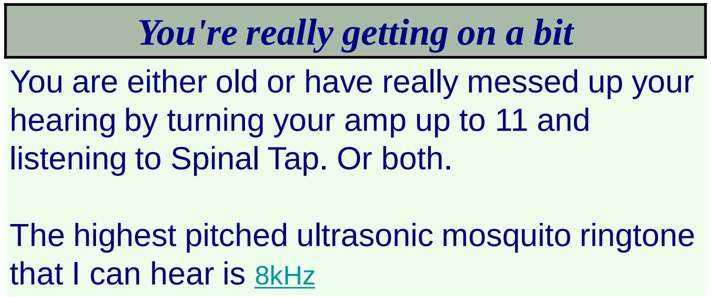
j. 🔊

k. 🔊

l. 🔊

12-1 Characteristics of Sound

a.

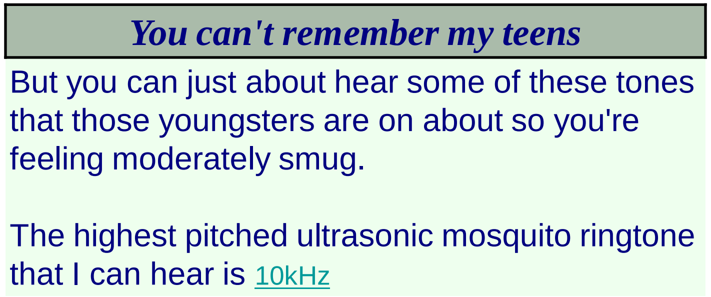


You're really getting on a bit

You are either old or have really messed up your hearing by turning your amp up to 11 and listening to Spinal Tap. Or both.

The highest pitched ultrasonic mosquito ringtone that I can hear is 8kHz

b.

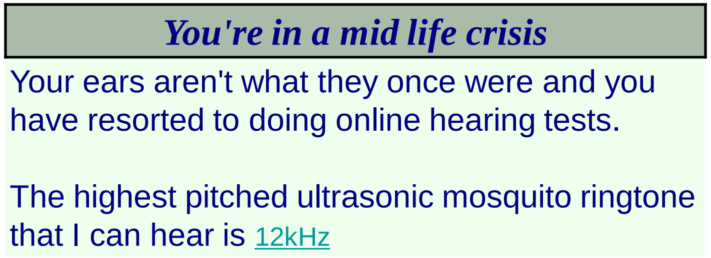


You can't remember my teens

But you can just about hear some of these tones that those youngsters are on about so you're feeling moderately smug.

The highest pitched ultrasonic mosquito ringtone that I can hear is 10kHz

c.



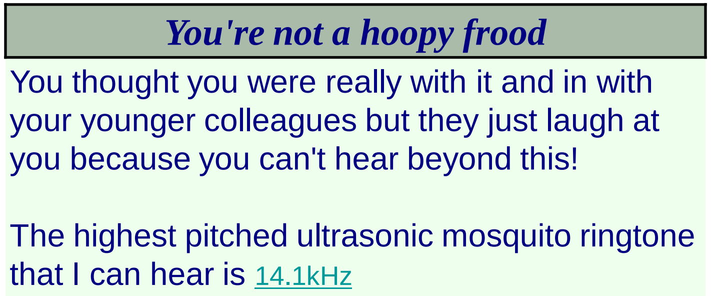
You're in a mid life crisis

Your ears aren't what they once were and you have resorted to doing online hearing tests.

The highest pitched ultrasonic mosquito ringtone that I can hear is 12kHz

12-1 Characteristics of Sound

d.

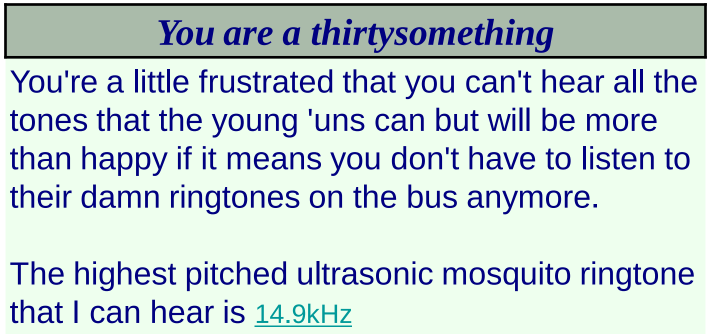


You're not a hoopy frood

You thought you were really with it and in with your younger colleagues but they just laugh at you because you can't hear beyond this!

The highest pitched ultrasonic mosquito ringtone that I can hear is 14.1kHz

e.

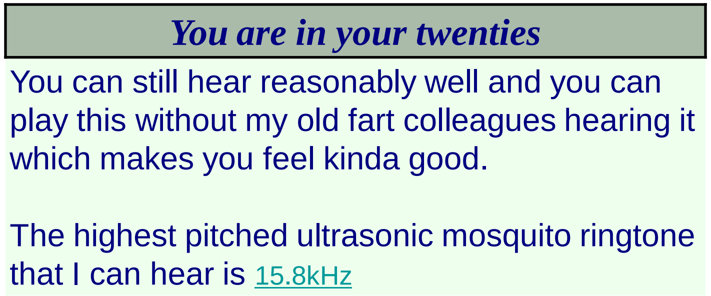


You are a thirtysomething

You're a little frustrated that you can't hear all the tones that the young 'uns can but will be more than happy if it means you don't have to listen to their damn ringtones on the bus anymore.

The highest pitched ultrasonic mosquito ringtone that I can hear is 14.9kHz

f.



You are in your twenties

You can still hear reasonably well and you can play this without my old fart colleagues hearing it which makes you feel kinda good.

The highest pitched ultrasonic mosquito ringtone that I can hear is 15.8kHz

12-1 Characteristics of Sound

g.

You are about 20 years old

The teen repellent will no longer foil you, but you can still hear some pretty high tones.

The highest pitched ultrasonic mosquito ringtone that I can hear is 16.7kHz

h.

You are the typical teenager

You can hear the frequency of the mosquito teen repellent - but probably not for much longer!

The highest pitched ultrasonic mosquito ringtone that I can hear is 17.7kHz

i.

You are an easily repelled teenager

The mosquito device was made for the likes of you. You are probably begging to make the noise stop!

The highest pitched ultrasonic mosquito ringtone that I can hear is 18.8kHz

12-1 Characteristics of Sound

j.

You aren't even a teenager yet!

Your hearing rules! You're either quite young or you've looked after your ears.

The highest pitched ultrasonic mosquito ringtone that I can hear is 19.9kHz

k.

You are a dog

Or maybe you are a mosquito, you certainly can't be human.

The highest pitched ultrasonic mosquito ringtone that I can hear is 21.1kHz

l.

You are a liar

You claimed to be able to hear a tone that contained absolutely no sound!

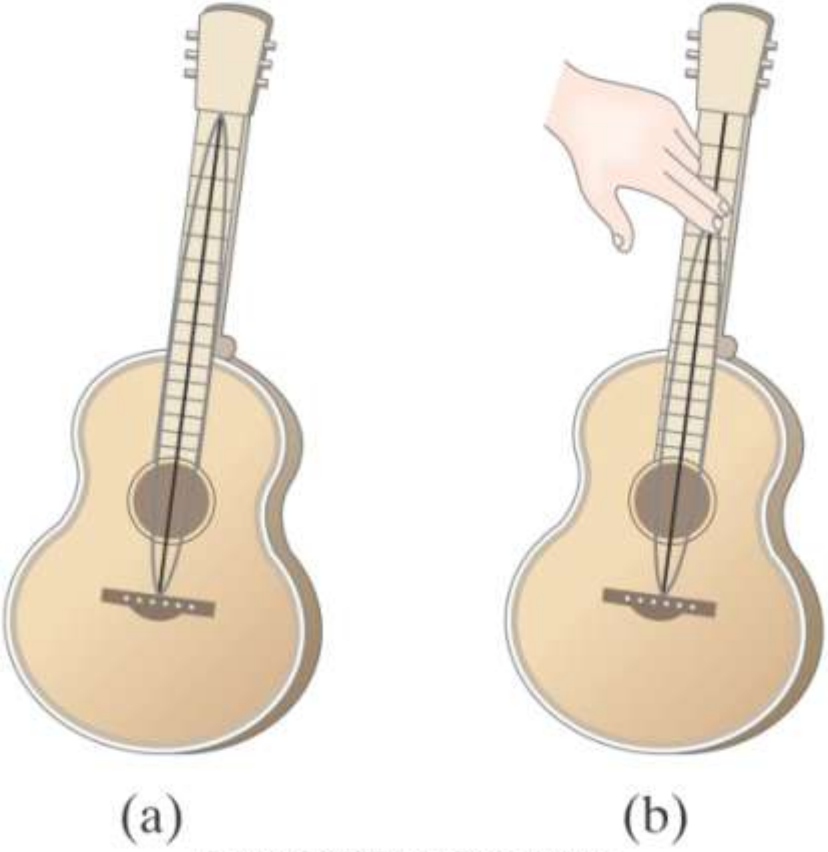
The highest pitched ultrasonic mosquito ringtone that I can hear is 22.4kHz

12-4 Sources of Sound: Vibrating Strings and Air Columns

Musical instruments produce sounds in various ways – vibrating strings, vibrating membranes, vibrating metal or wood shapes, vibrating air columns.

The vibration may be started by plucking, striking, bowing, or blowing. The vibrations are transmitted to the air and then to our ears.

12-4 Sources of Sound: Vibrating Strings and Air Columns



Copyright © 2005 Pearson Prentice Hall, Inc.

The strings on a guitar can be effectively **shortened** by fingering, raising the fundamental pitch.

The **pitch** of a string of a given length can also be altered by using a string of different **density**.

12-4 Sources of Sound: Vibrating Strings and Air Columns

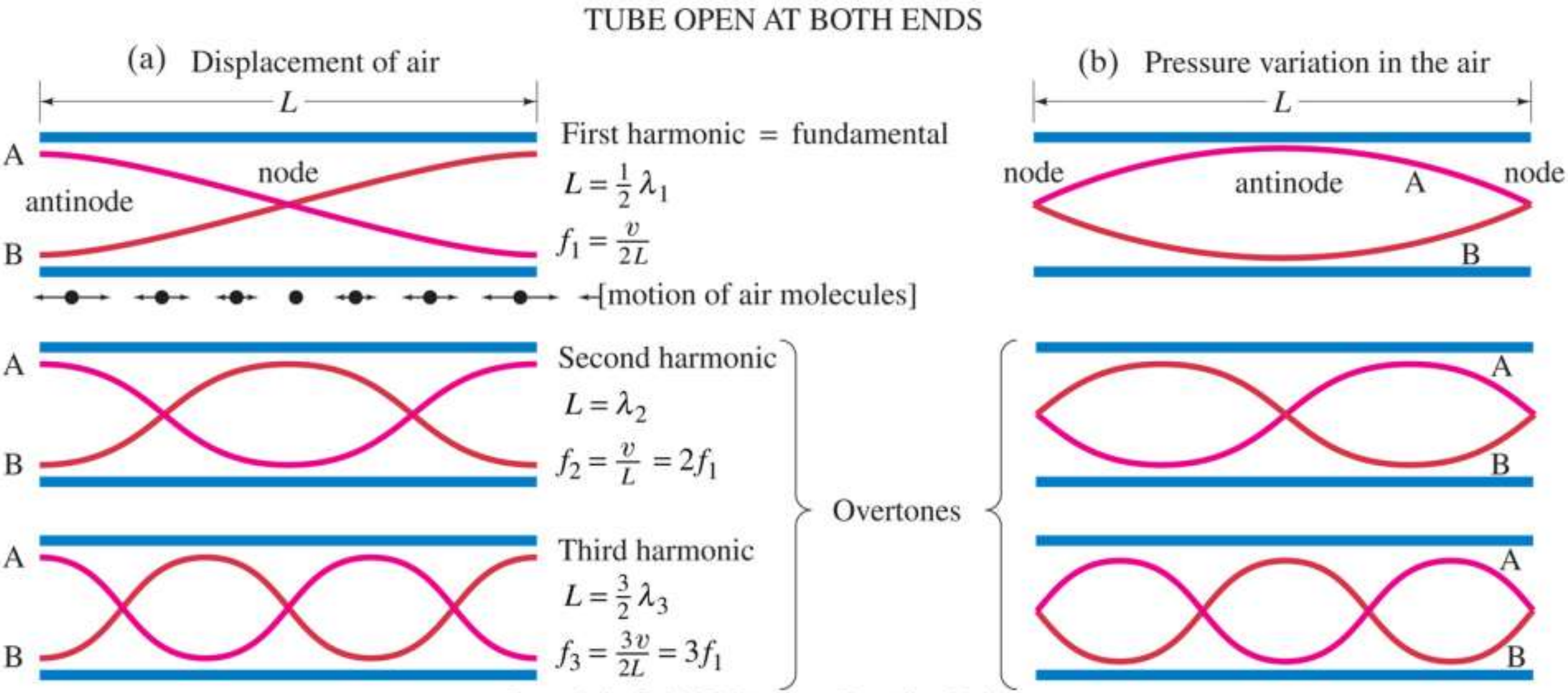
A piano uses both methods to cover its more than seven-octave range – the lower strings (at bottom) are both much **longer** and much **thicker** than the higher ones.

12-4 Sources of Sound: Vibrating Strings and Air Columns

Wind instruments create sound through standing waves in a column of **air**.

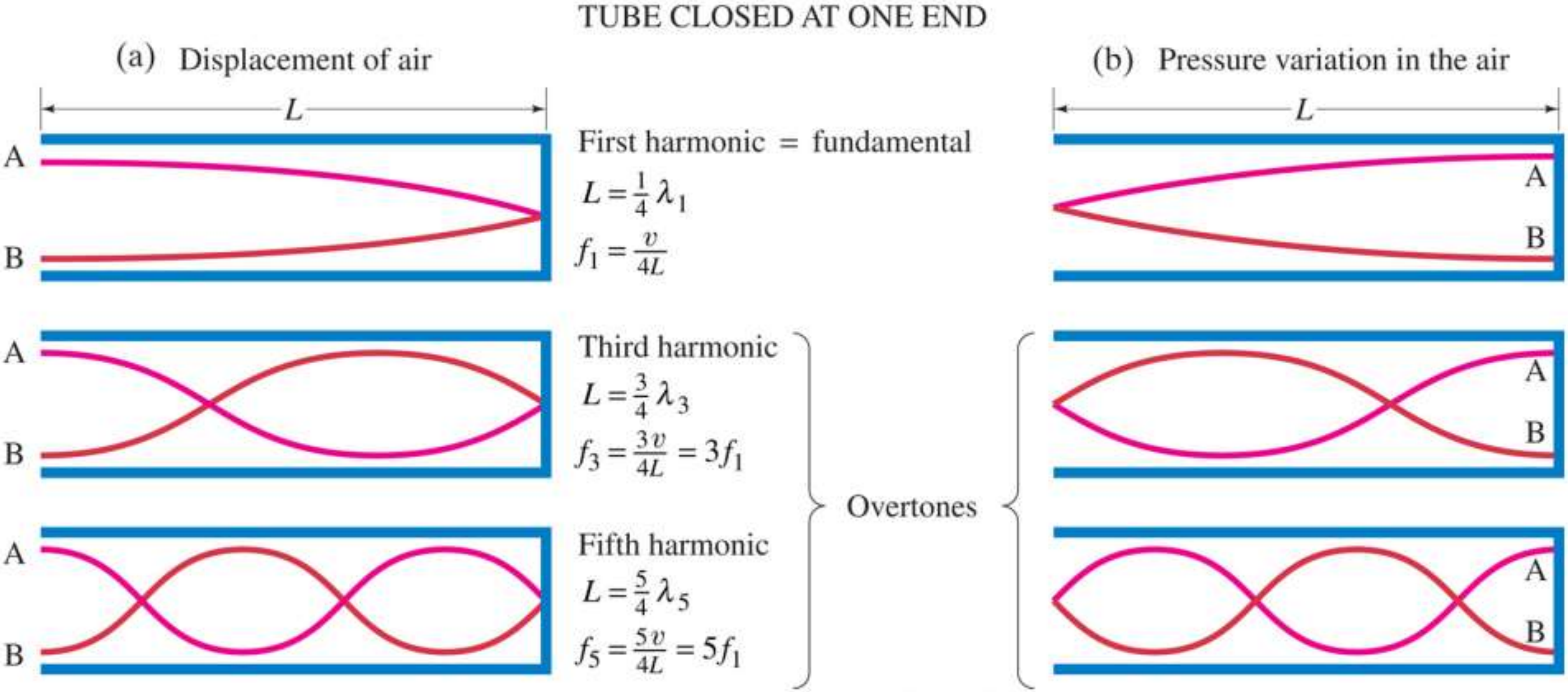
12-4 Sources of Sound: Vibrating Strings and Air Columns

A tube **open** at both ends (most wind instruments) has pressure **nodes**, and therefore displacement **antinodes**, at the ends.

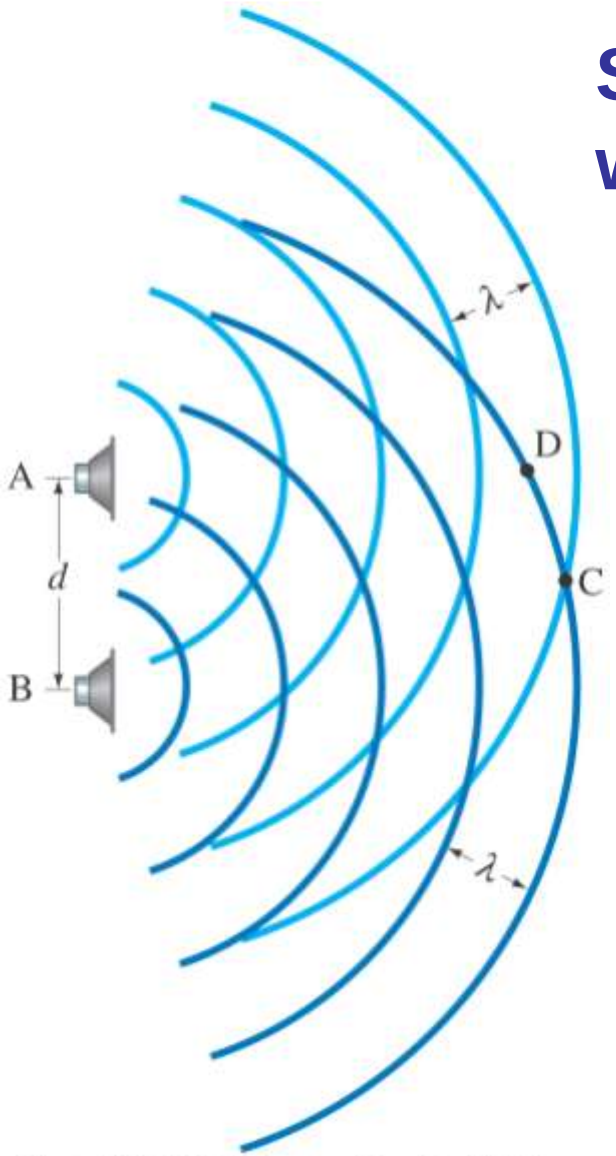


12-4 Sources of Sound: Vibrating Strings and Air Columns

A tube **closed** at one end (some organ pipes) has a displacement **node** (and pressure **antinode**) at the closed end.



12-6 Interference of Sound Waves; Beats

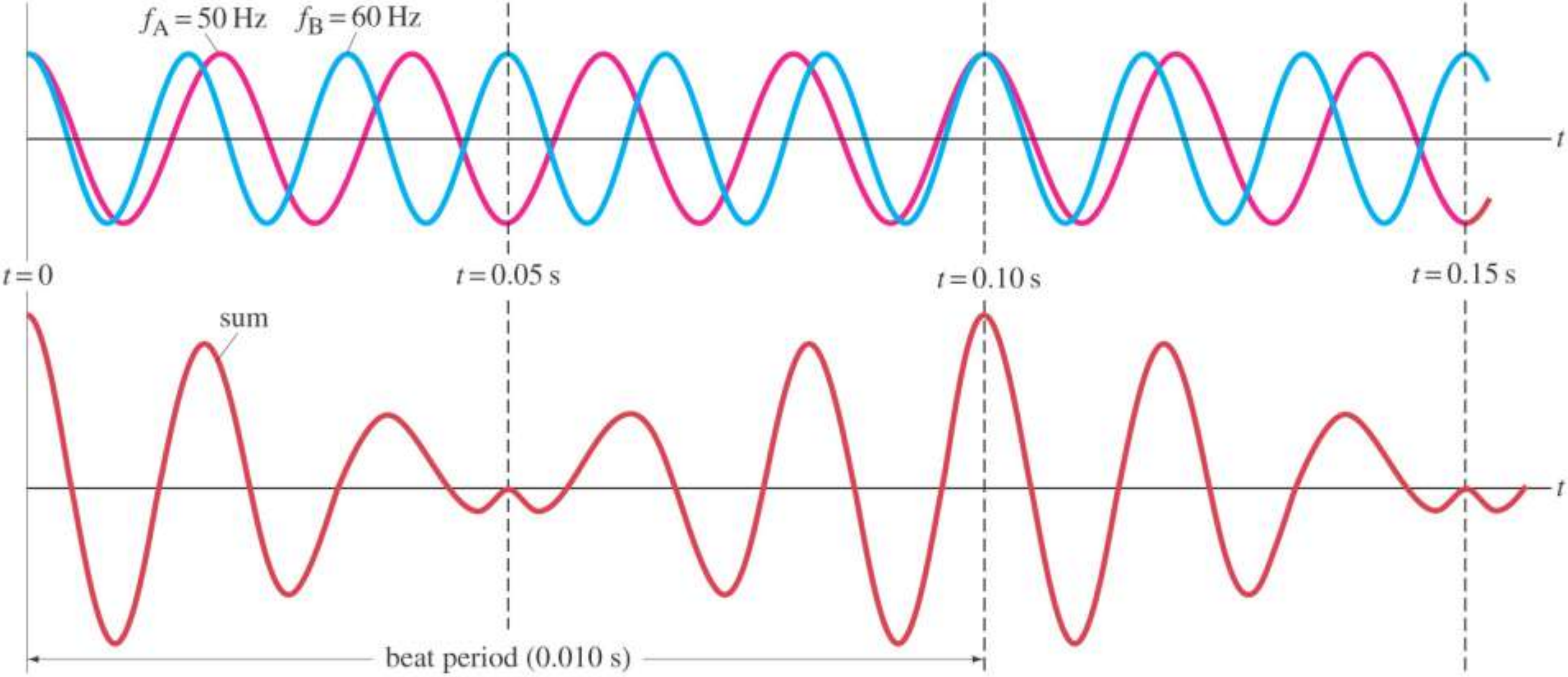


Copyright © 2005 Pearson Prentice Hall, Inc.

Sound waves **interfere** **in the same way that other waves do in space.**

12-6 Interference of Sound Waves; Beats

Waves can also interfere in time, causing a phenomenon called beats. Beats are the slow "envelope" around two waves that are relatively close in frequency.

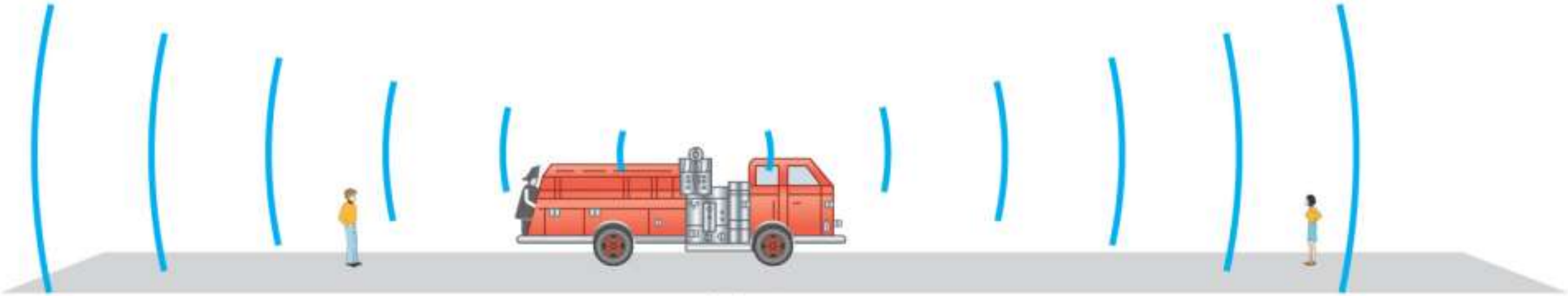


12-6 Interference of Sound Waves; Beats

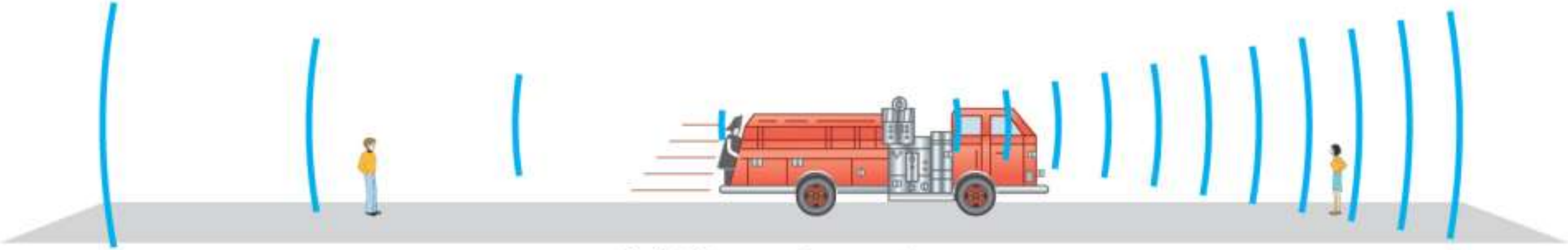
Time for a Gizmo!

12-7 Doppler Effect

The **Doppler effect** occurs when a **source** of sound is **moving** with respect to an **observer**.



(a) At rest



(b) Firetruck moving

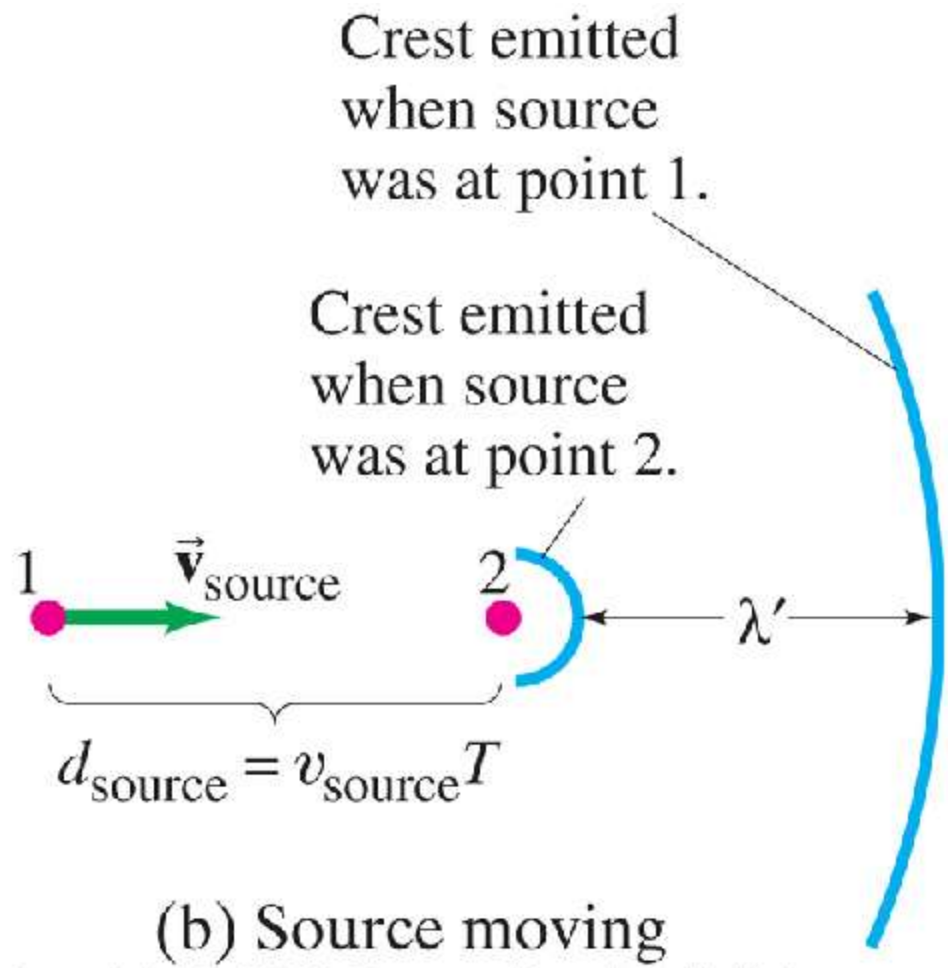
12-7 Doppler Effect

As can be seen in the previous image, a source moving **toward** an observer has a **higher** frequency and **shorter** wavelength; the opposite is true when a source is moving **away** from an observer.

12-7 Doppler Effect

Time for a Gizmo!

12-7 Doppler Effect

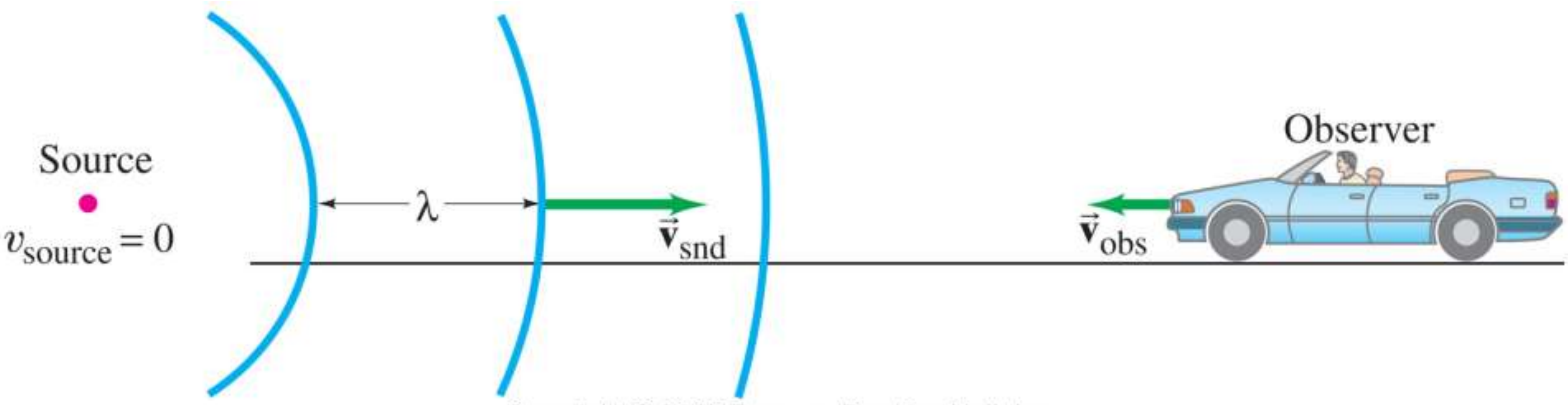


(b) Source moving

If we can figure out what the **change** in the **wavelength** is, we also know the change in the **frequency**.

12-7 Doppler Effect

If the **observer** is moving with respect to the source, things are a bit different. The **wavelength** remains the same, but the wave **speed** is different for the observer.



12-7 Doppler Effect

For convenience, we have a single equation that covers all cases of both a source and observer in motion.

$$f' = f\left(\frac{v_{snd} \pm v_{obs}}{v_{snd} \mp v_{source}}\right) \qquad \textbf{(12-4)}$$