

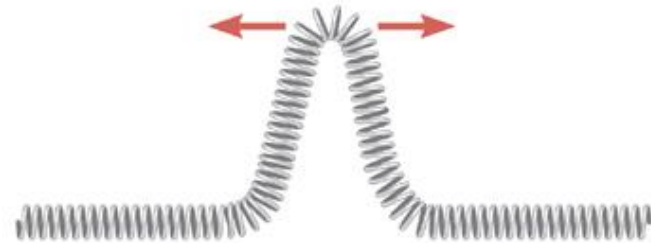
# *Chapter 17*

## ***The Principle of Linear Superposition and Interference Phenomena***

## 17.1 The Principle of Linear Superposition



(a) Overlap begins



(b) Total overlap; the Slinky has twice the height of either pulse

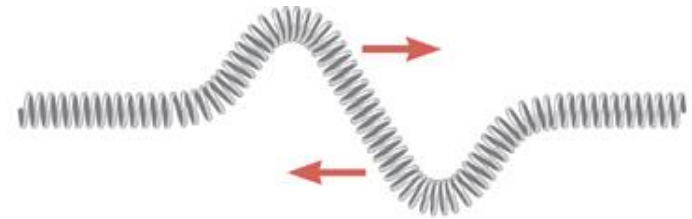


(c) The receding pulses

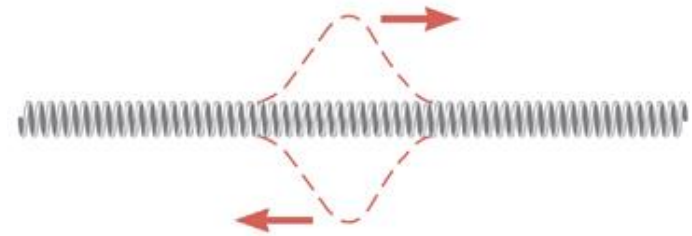
When the pulses merge, the Slinky assumes a shape that is the sum of the shapes of the individual pulses.

## 17.1 The Principle of Linear Superposition

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(c) The receding pulses

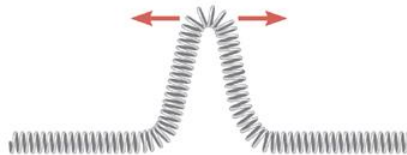
## 17.1 The Principle of Linear Superposition

### THE PRINCIPLE OF LINEAR SUPERPOSITION

When two or more waves are present simultaneously at the same place, the resultant disturbance is the sum of the disturbances from the individual waves.



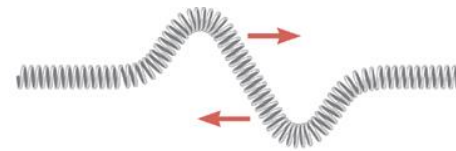
(a) Overlap begins



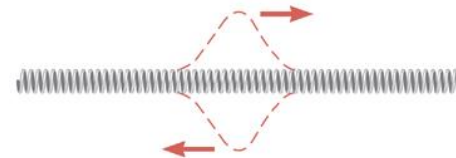
(b) Total overlap; the Slinky has twice the height of either pulse



(c) The receding pulses



(a) Overlap begins



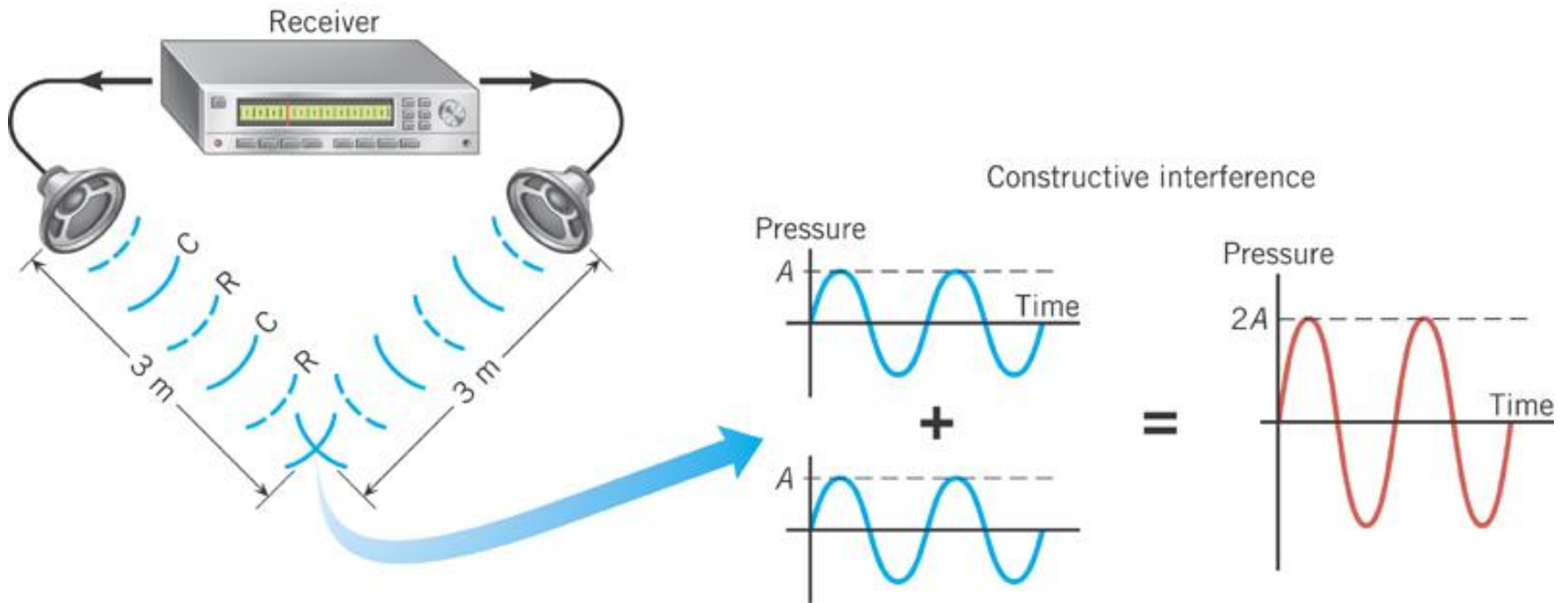
(b) Total overlap



(c) The receding pulses

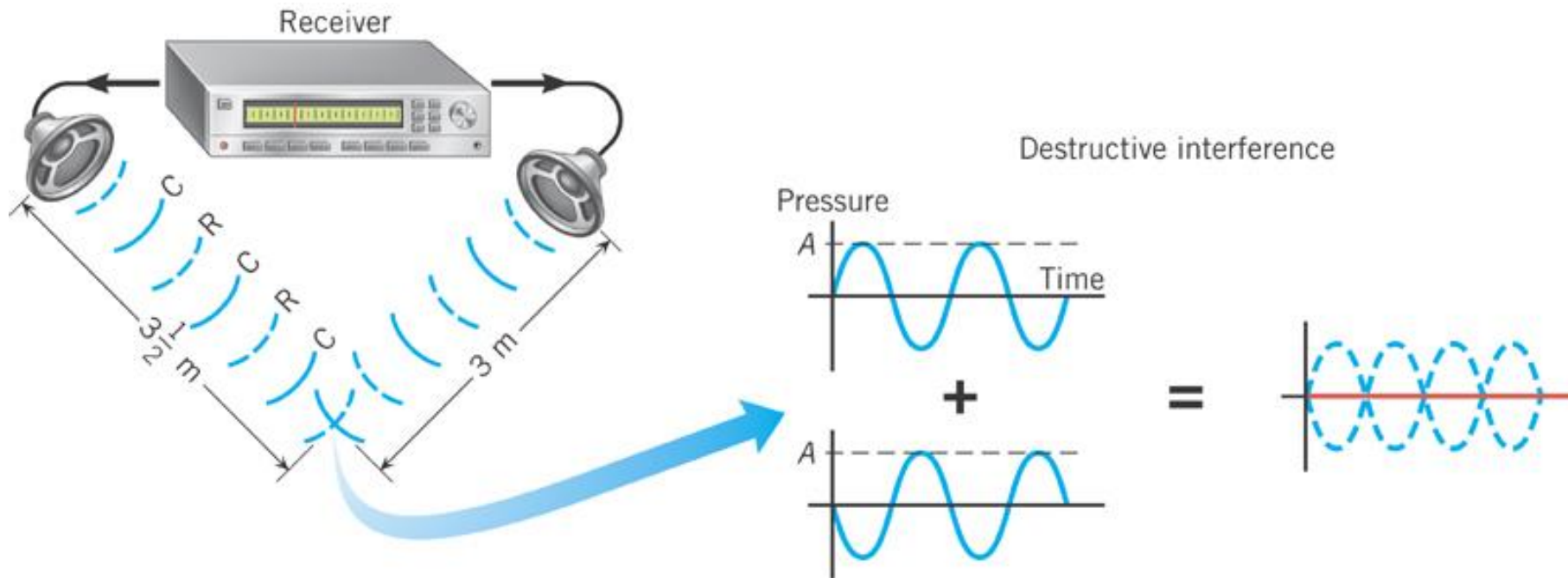
## 17.2 Constructive and Destructive Interference of Sound Waves

When two waves always meet condensation-to-condensation and rarefaction-to-rarefaction, they are said to be **exactly in phase** and to exhibit **constructive interference**.

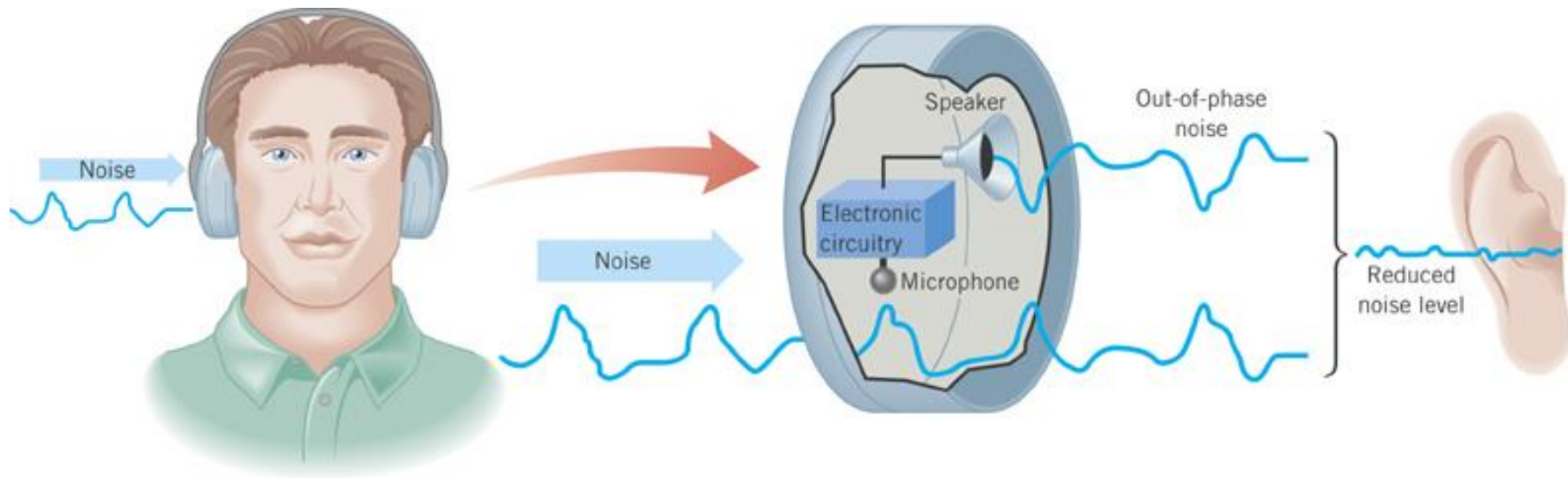


## 17.2 Constructive and Destructive Interference of Sound Waves

When two waves always meet condensation-to-rarefaction, they are said to be **exactly out of phase** and to exhibit **destructive interference**.



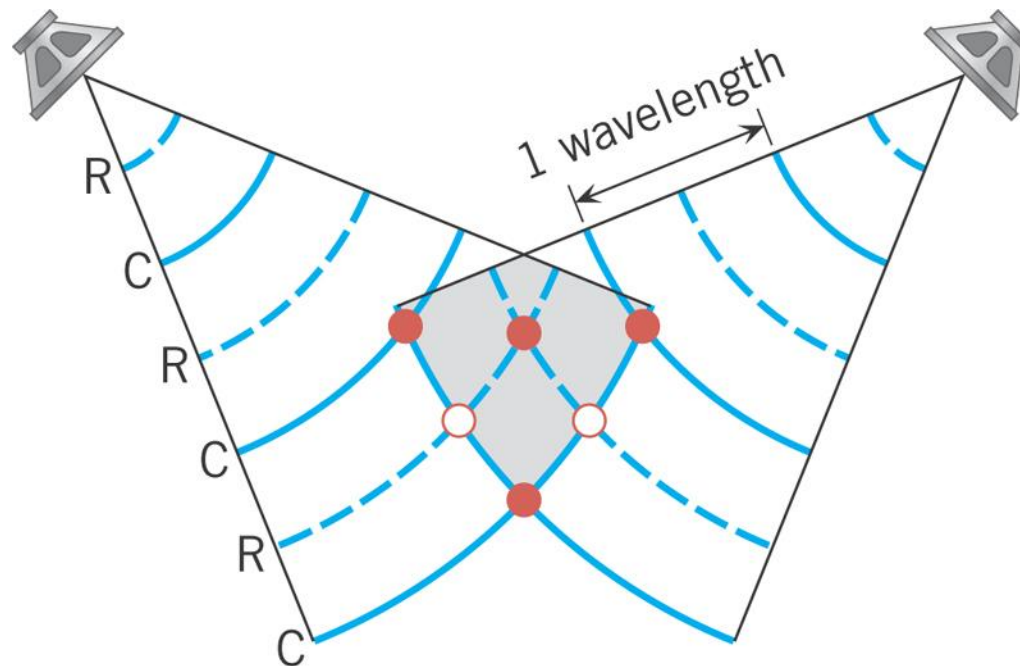
## 17.2 Constructive and Destructive Interference of Sound Waves



## 17.2 Constructive and Destructive Interference of Sound Waves

If the wave patterns do not shift relative to one another as time passes, the sources are said to be **coherent**.

**For two wave sources vibrating in phase, a difference in path lengths that is zero or an integer number (1, 2, 3, . . .) of wavelengths leads to constructive interference; a difference in path lengths that is a half-integer number ( $\frac{1}{2}$ ,  $1 \frac{1}{2}$ ,  $2 \frac{1}{2}$ , . . .) of wavelengths leads to destructive interference.**





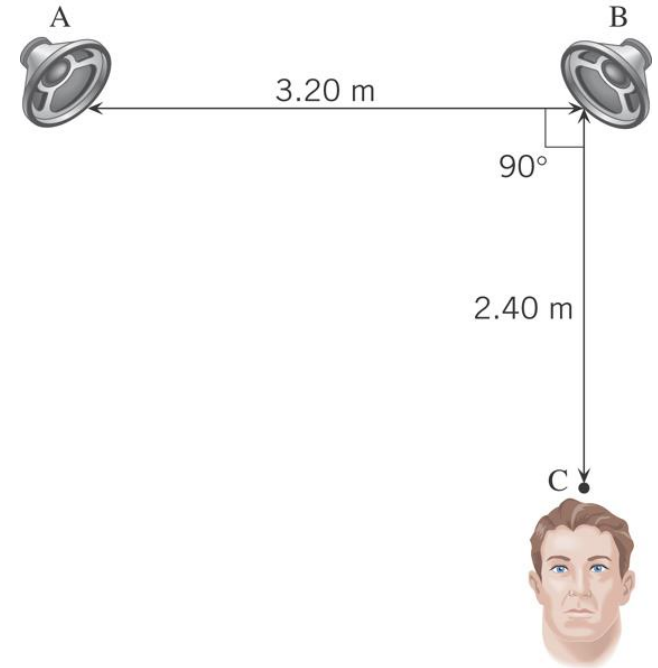
## 17.2 Constructive and Destructive Interference of Sound Waves

### Example 1 What Does a Listener Hear?

Two in-phase loudspeakers, A and B, are separated by 3.20 m. A listener is stationed at C, which is 2.40 m in front of speaker B.

Both speakers are playing identical 214-Hz tones, and the speed of sound is 343 m/s.

Does the listener hear a loud sound, or no sound?



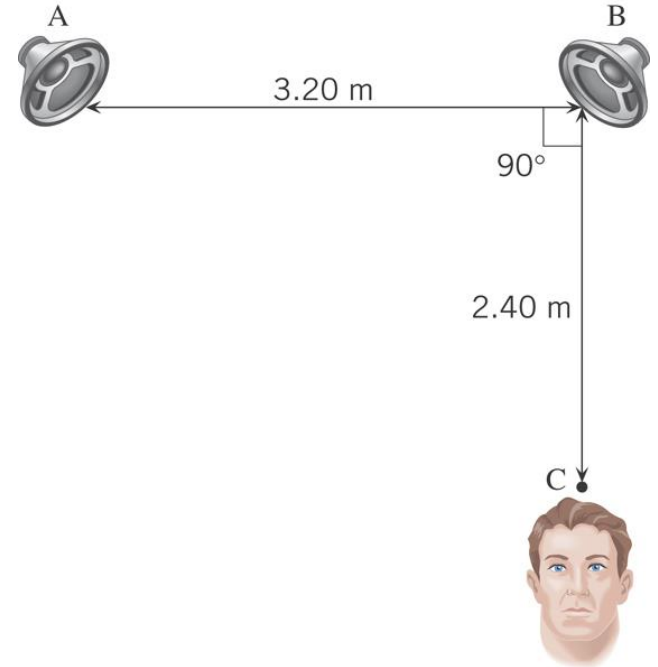
## 17.2 Constructive and Destructive Interference of Sound Waves

Calculate the path length difference.

$$\sqrt{(3.20 \text{ m})^2 + (2.40 \text{ m})^2} - 2.40 \text{ m} = 1.60 \text{ m}$$

Calculate the wavelength.

$$\lambda = \frac{v}{f} = \frac{343 \text{ m/s}}{214 \text{ Hz}} = 1.60 \text{ m}$$



Because the path length difference is equal to an integer (1) number of wavelengths, there is constructive interference, which means there is a loud sound.

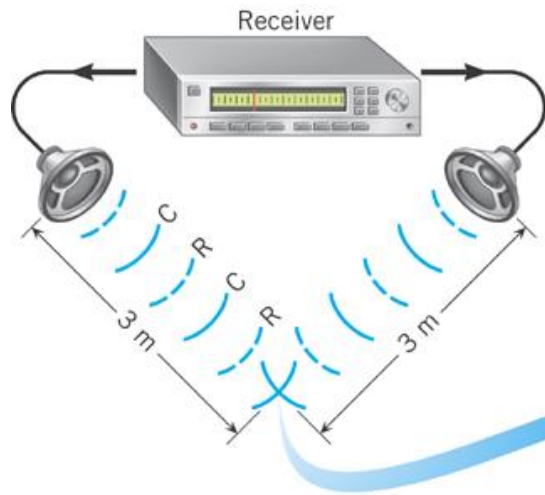
## 17.2 Constructive and Destructive Interference of Sound Waves

### Conceptual Example 2 Out-Of-Phase Speakers

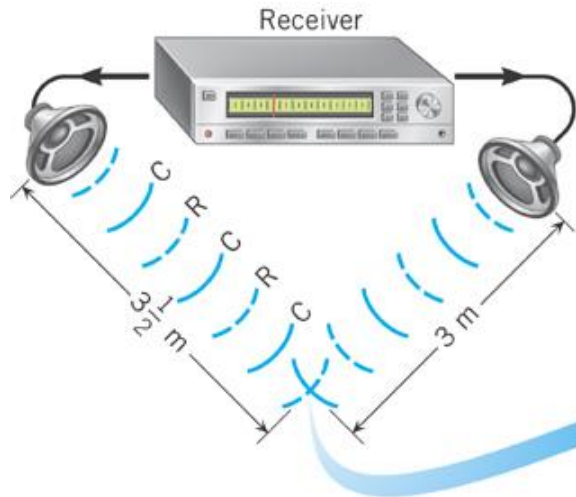
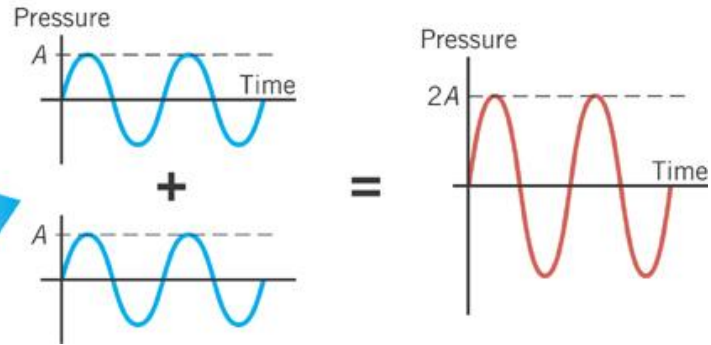
To make a speaker operate, two wires must be connected between the speaker and the amplifier. To ensure that the diaphragms of the two speakers vibrate in phase, it is necessary to make these connections in exactly the same way. If the wires for one speaker are not connected just as they are for the other, the diaphragms will vibrate out of phase. Suppose in the figures (next slide), the connections are made so that the speaker diaphragms vibrate out of phase, everything else remaining the same. In each case, what kind of interference would result in the overlap point?



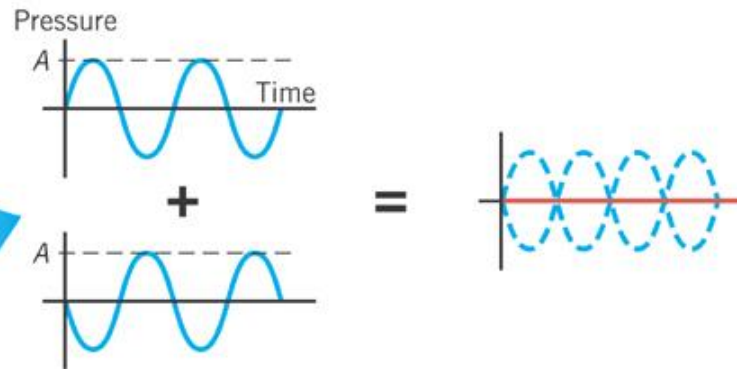
## 17.2 Constructive and Destructive Interference of Sound Waves



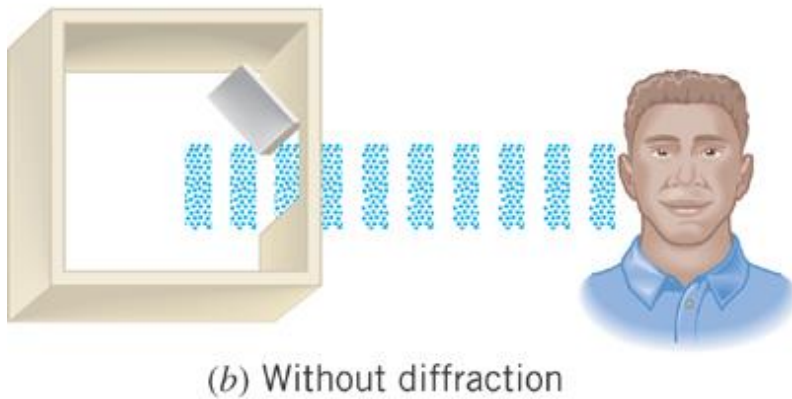
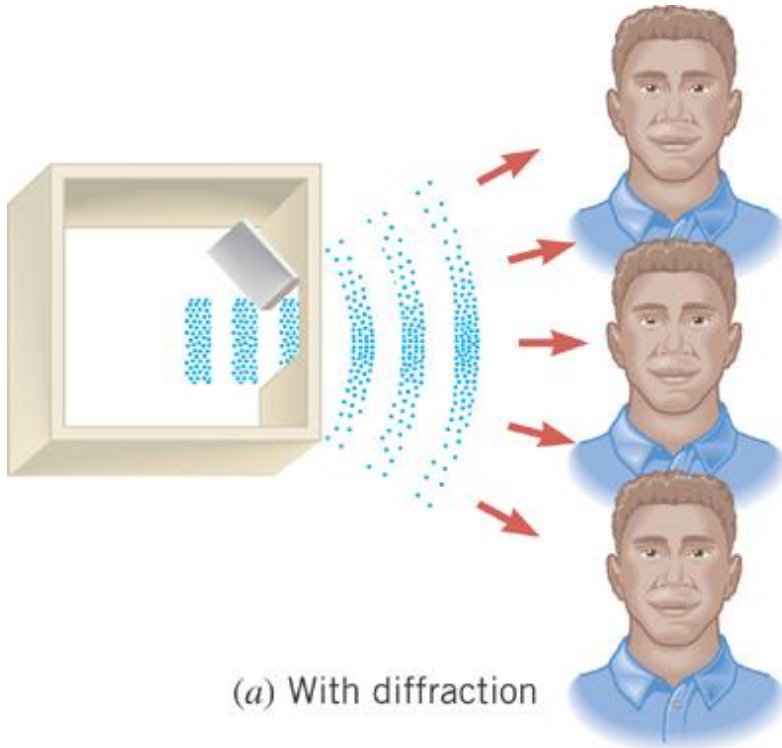
Constructive interference



Destructive interference

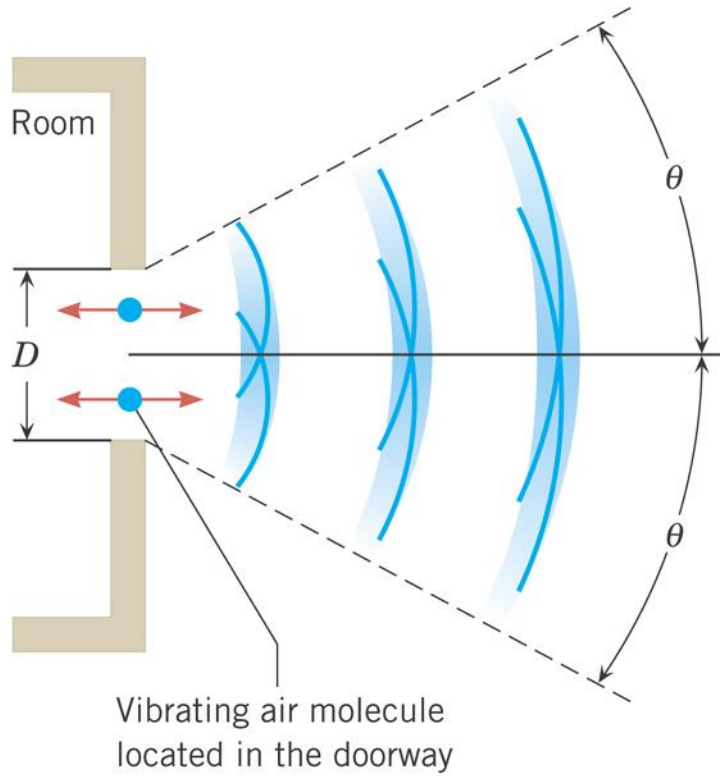


## 17.3 Diffraction



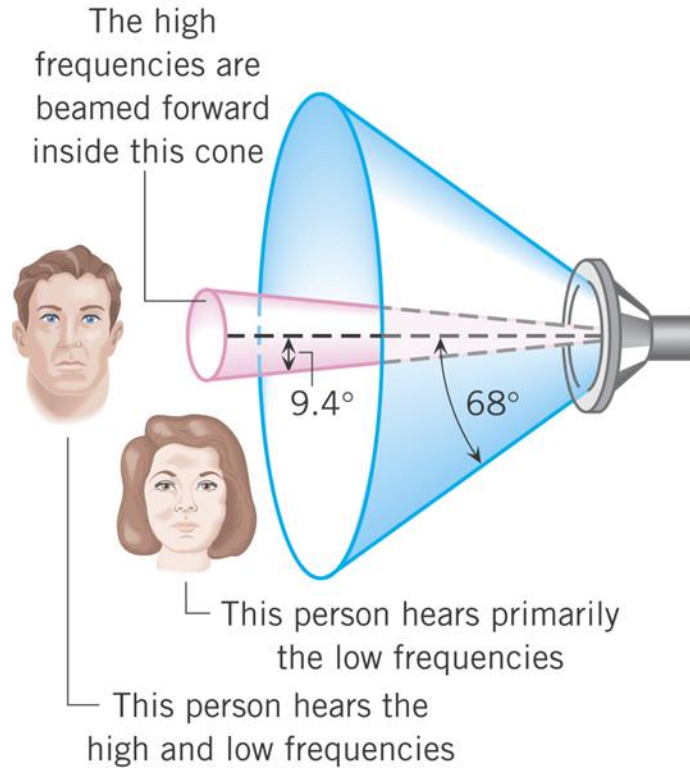
The bending of a wave around an obstacle or the edges of an opening is called ***diffraction***.

17.3 Diffraction



*single slit – first minimum*       $\sin \theta = \frac{\lambda}{D}$

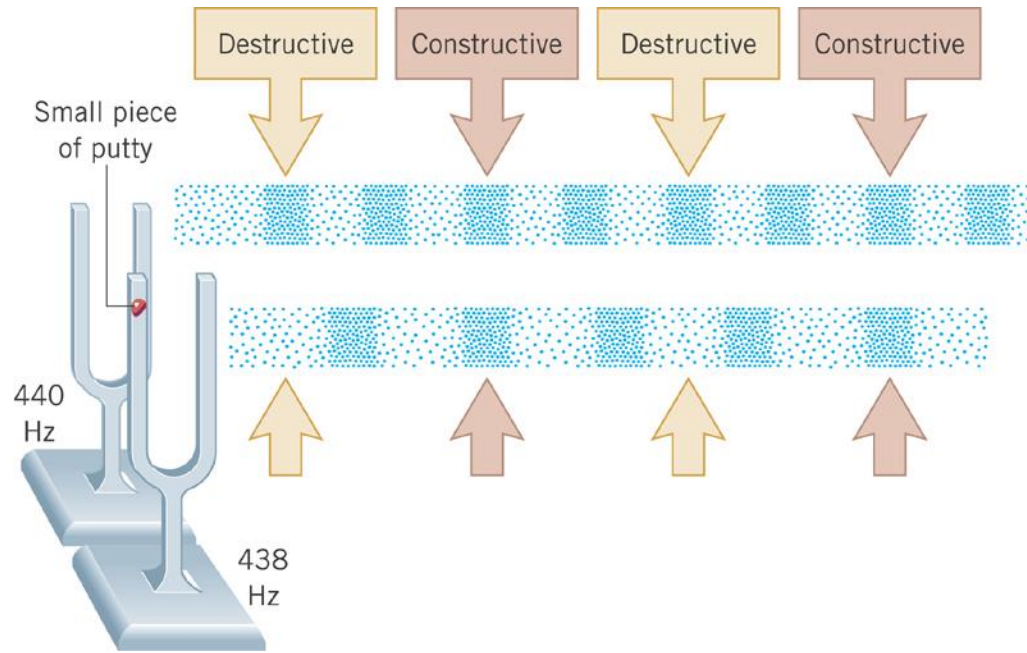
## 17.3 Diffraction



***Circular opening – first minimum***

$$\sin \theta = 1.22 \frac{\lambda}{D}$$

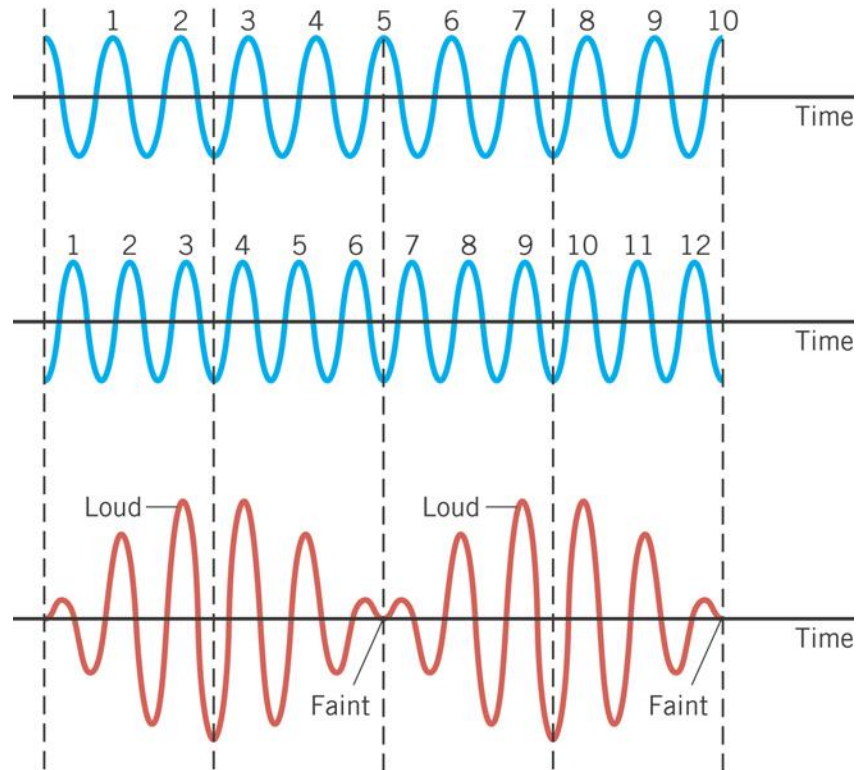
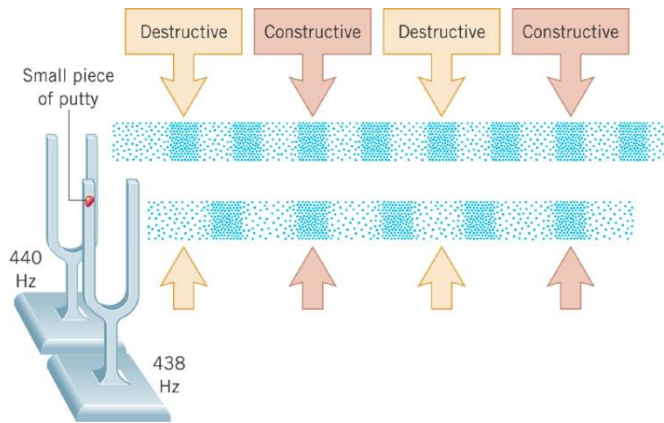
## 17.4 Beats



Two overlapping waves with *slightly different frequencies* gives rise to the phenomena of beats.



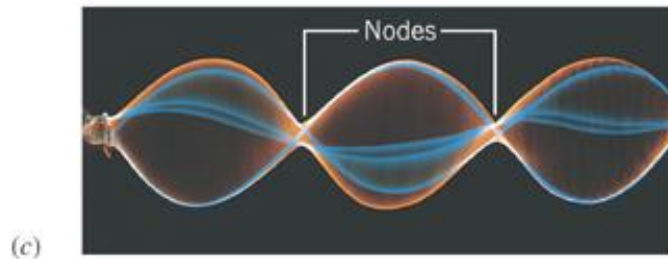
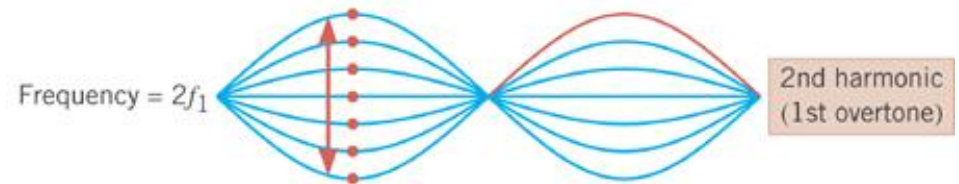
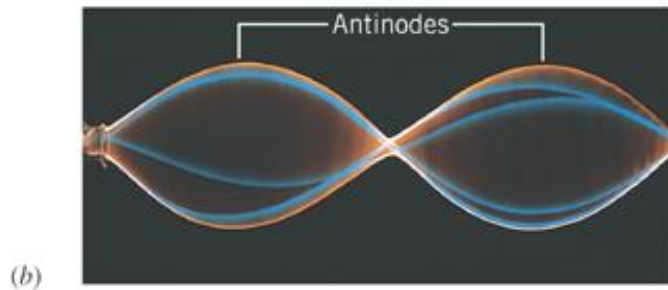
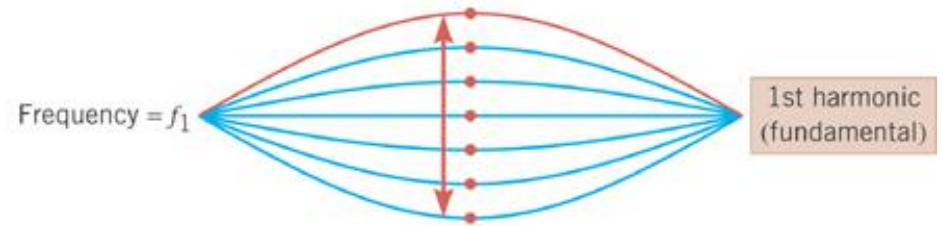
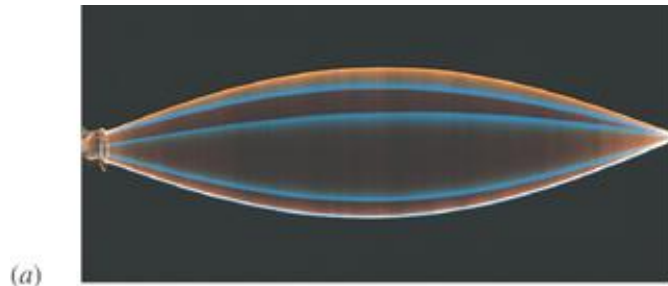
## 17.4 Beats



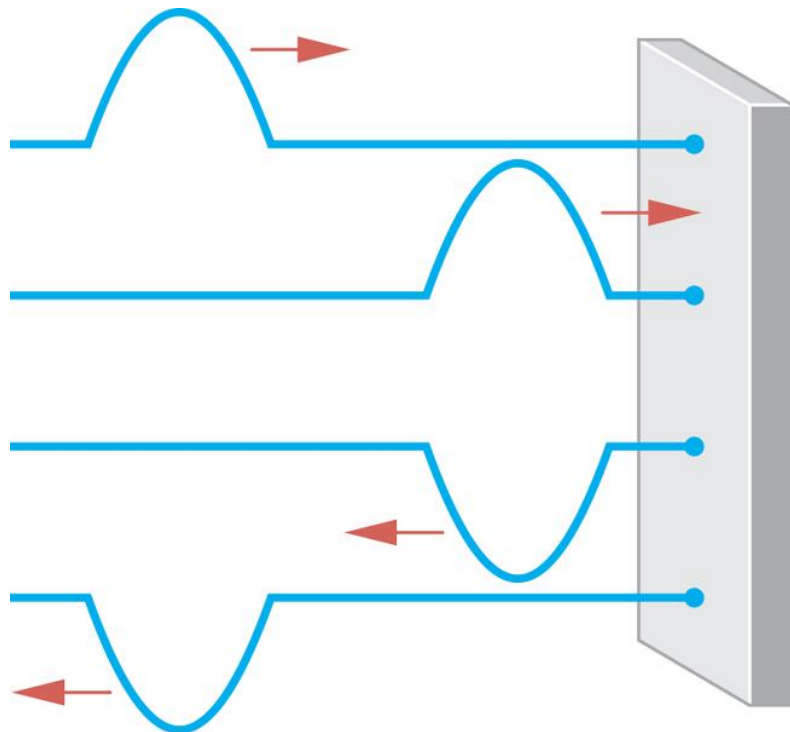
The **beat frequency** is the **difference** between the two sound frequencies.

## 17.5 Transverse Standing Waves

Transverse standing wave patterns.



## 17.5 Transverse Standing Waves

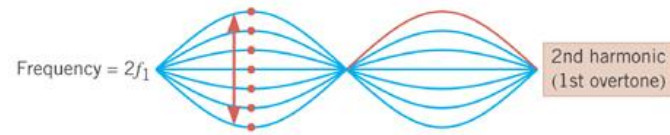
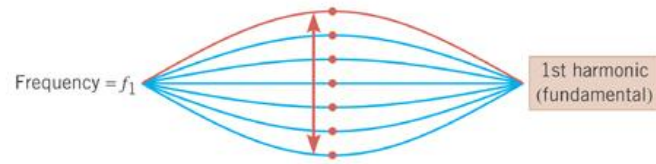
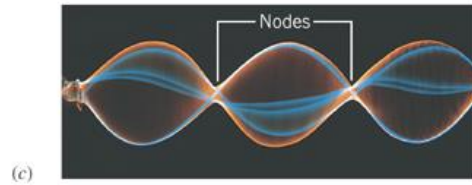
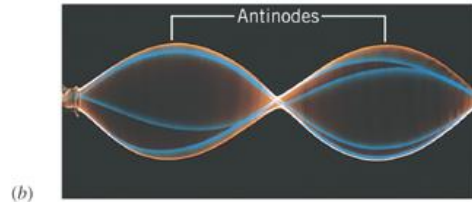
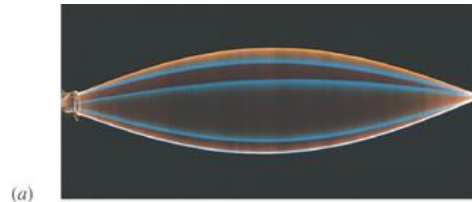


In reflecting from the wall, a forward-traveling half-cycle becomes a backward-traveling half-cycle that is inverted.

Unless the timing is right, the newly formed and reflected cycles tend to offset one another.

Repeated reinforcement between newly created and reflected cycles causes a large amplitude standing wave to develop.

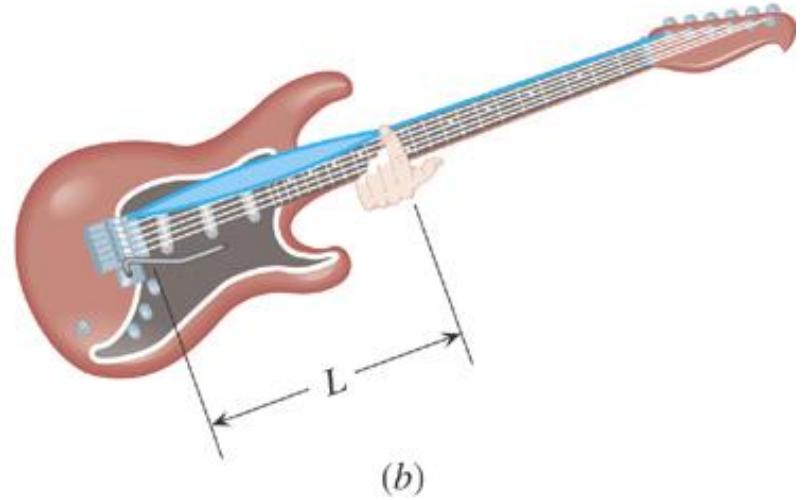
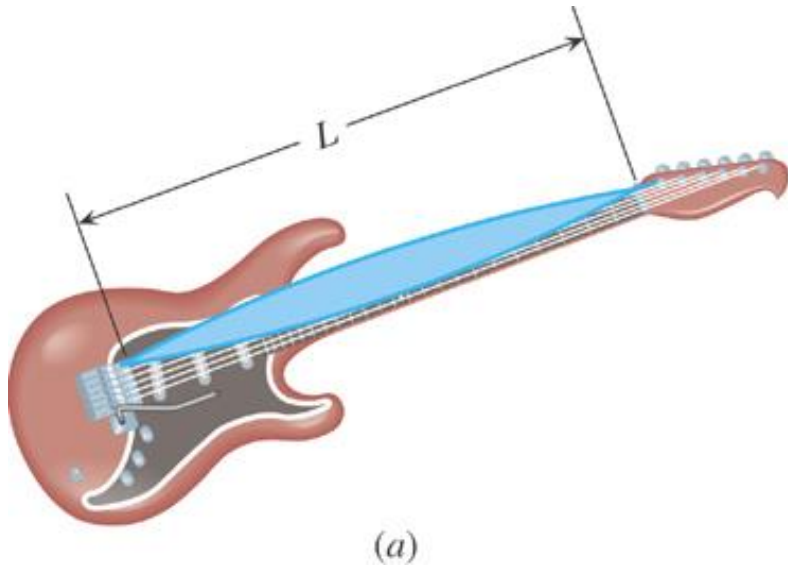
## 17.5 Transverse Standing Waves



***String fixed at both ends***

$$f_n = n \left( \frac{v}{2L} \right) \quad n = 1, 2, 3, 4, \dots$$

## 17.5 Transverse Standing Waves



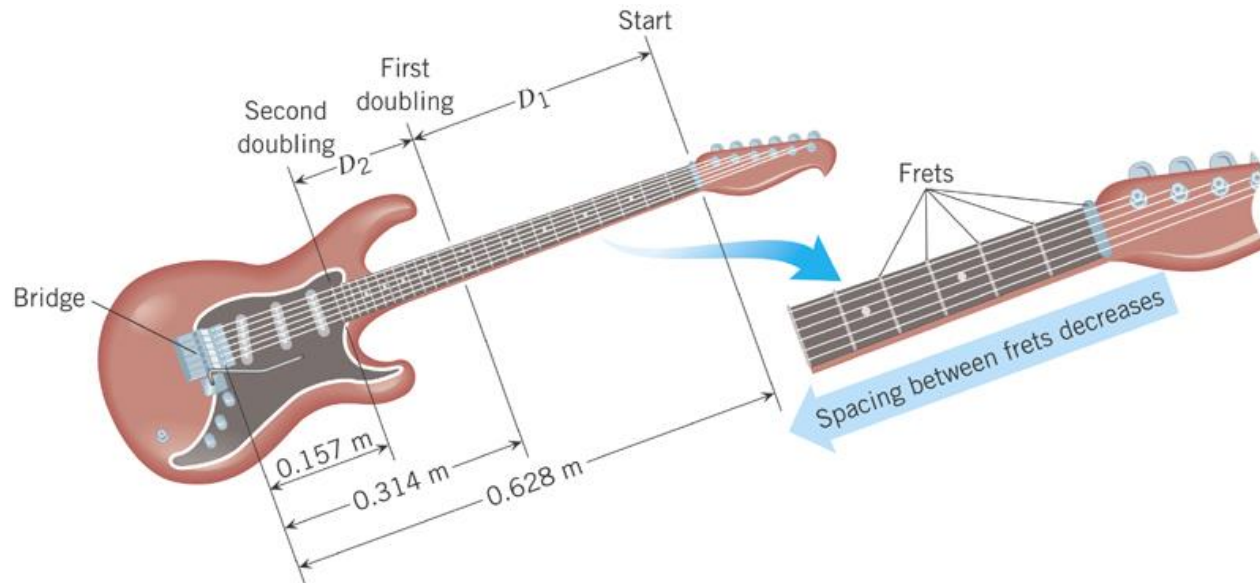
$$f_n = n \left( \frac{v}{2L} \right)$$

$$n = 1, 2, 3, 4, \dots$$

## 17.5 Transverse Standing Waves

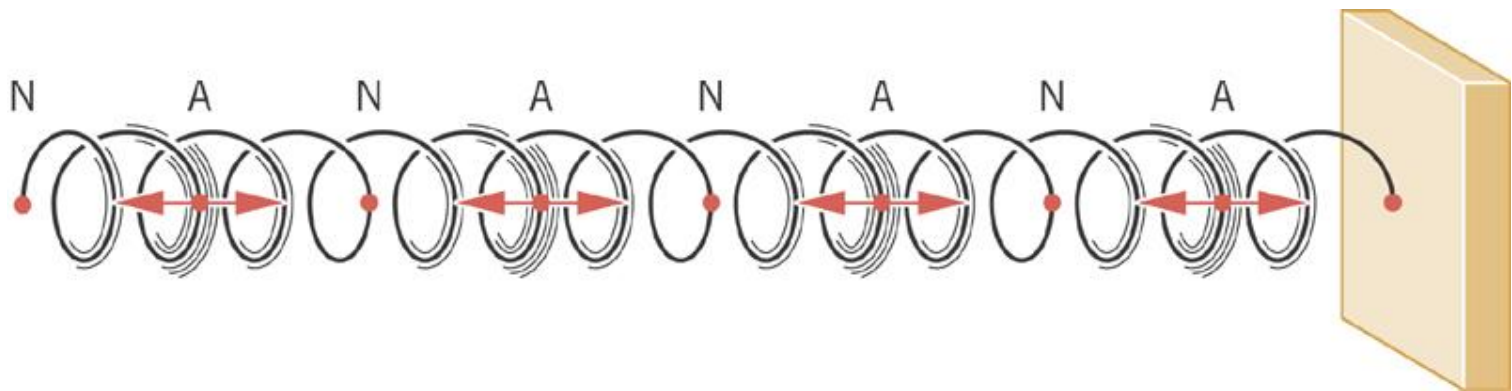
### Conceptual Example 5 The Frets on a Guitar

Frets allow a the player to produce a complete sequence of musical notes on a single string. Starting with the fret at the top of the neck, each successive fret shows where the player should press to get the next note in the sequence. Musicians call the sequence the chromatic scale, and every thirteenth note in it corresponds to one octave, or a doubling of the sound frequency. The spacing between the frets is greatest at the top of the neck and decreases with each additional fret further on down. Why does the spacing decrease going down the neck?



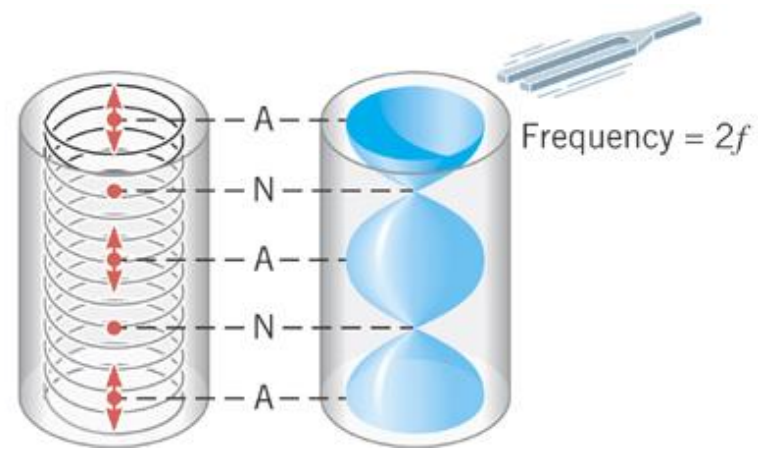
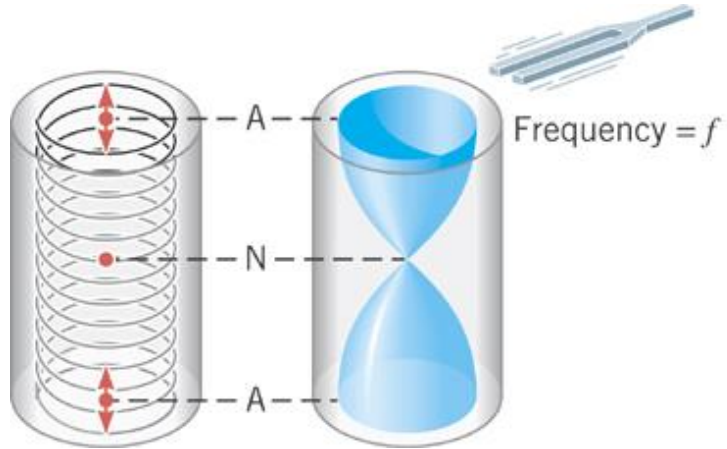
## 17.6 Longitudinal Standing Waves

A longitudinal standing wave pattern on a slinky.





## 17.6 Longitudinal Standing Waves



***Tube open at both ends***

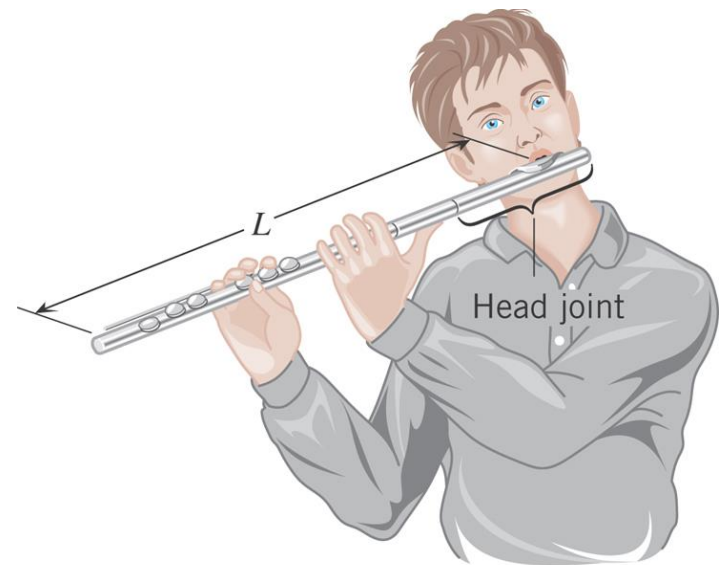
$$f_n = n \left( \frac{v}{2L} \right) \quad n = 1, 2, 3, 4, \dots$$



## 17.6 Longitudinal Standing Waves

### **Example 6** Playing a Flute

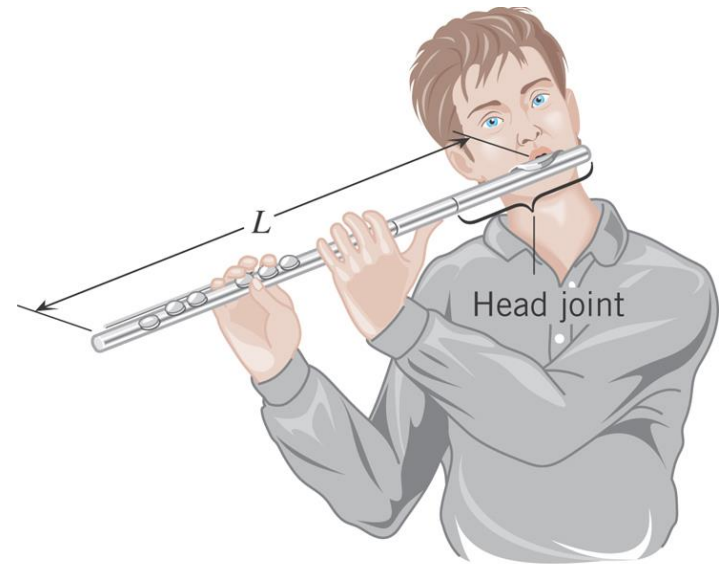
When all the holes are closed on one type of flute, the lowest note it can sound is middle C (261.6 Hz). If the speed of sound is 343 m/s, and the flute is assumed to be a cylinder open at both ends, determine the distance  $L$ .



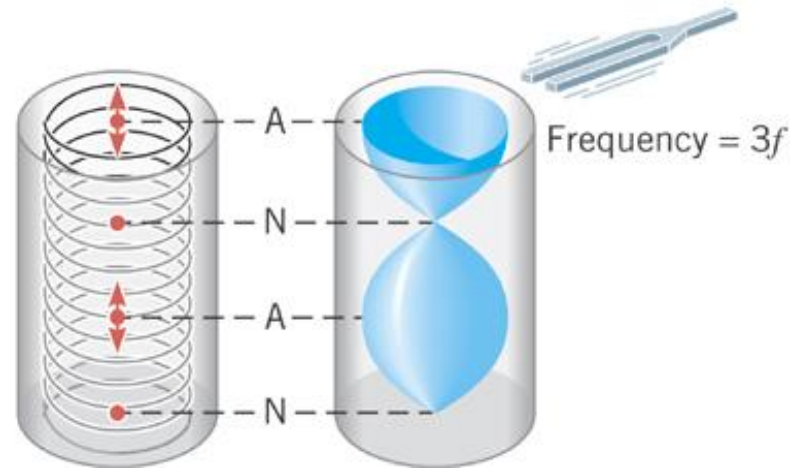
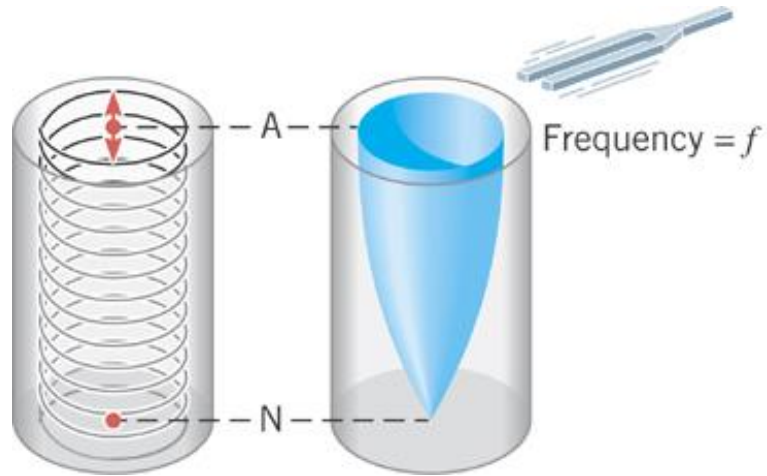
## 17.6 Longitudinal Standing Waves

$$f_n = n \left( \frac{v}{2L} \right) \quad n = 1, 2, 3, 4, \dots$$

$$L = \frac{nv}{2f_n} = \frac{1(343 \text{ m/s})}{2(261.6 \text{ Hz})} = 0.656 \text{ m}$$



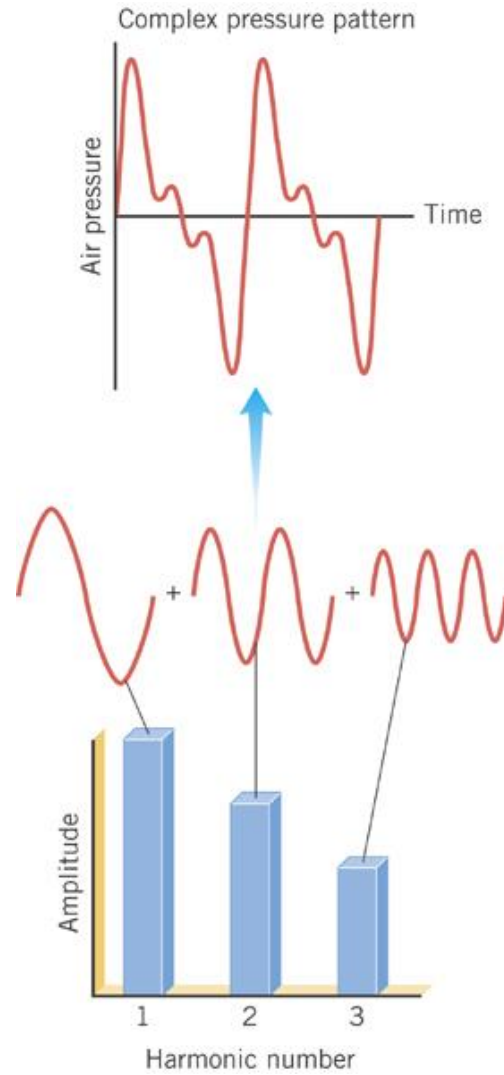
## 17.6 Longitudinal Standing Waves



***Tube open at one end***

$$f_n = n \left( \frac{v}{4L} \right) \quad n = 1, 3, 5, \dots$$

## 17.7 Complex Sound Waves



## 17.7 Complex Sound Waves

