Quiz on Chapters 13-15

Chapter 16

Waves and Sound

continued

Final Exam, Thursday May 3, 8:00 – 10:00PM
ANH 1281 (Anthony Hall). Seat assignments TBD

RCPD students: Thursday May 3, 5:00 – 9:00PM, BPS 3239. Email will be sent.

Alternate Final Exam, Tuesday May 1, 10:00 – 12:00 PM, BPS 3239; BY APPOINTMENT ONLY, and deadline has past. Email will be sent.

16.8 Decibels

The ***decibel*** (dB) is a measurement unit used when comparing two sound Intensities.

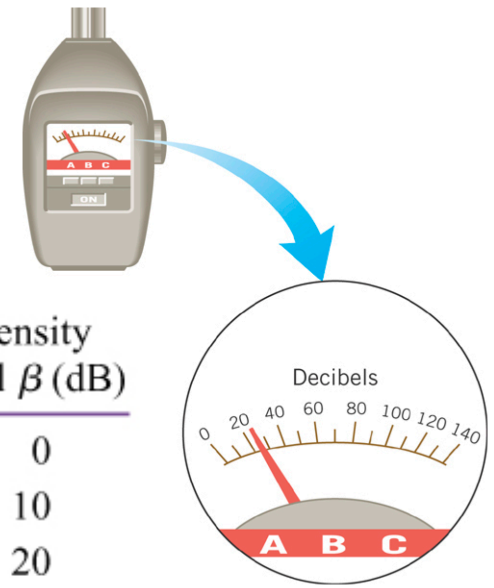
Human hearing mechanism responds to sound ***intensity level***, logarithmically.

$$\boxed{\beta = (10\ \mathrm{dB})\log\left(\frac{I}{I_o}\right)}$$

Note that log(1) = 0

$$\boxed{\mathrm{dB}\ \ (\mathrm{decibel})}$$

$$\boxed{I_o = 1.00\times10^{-12}\ \mathrm{W/m^2}}$$

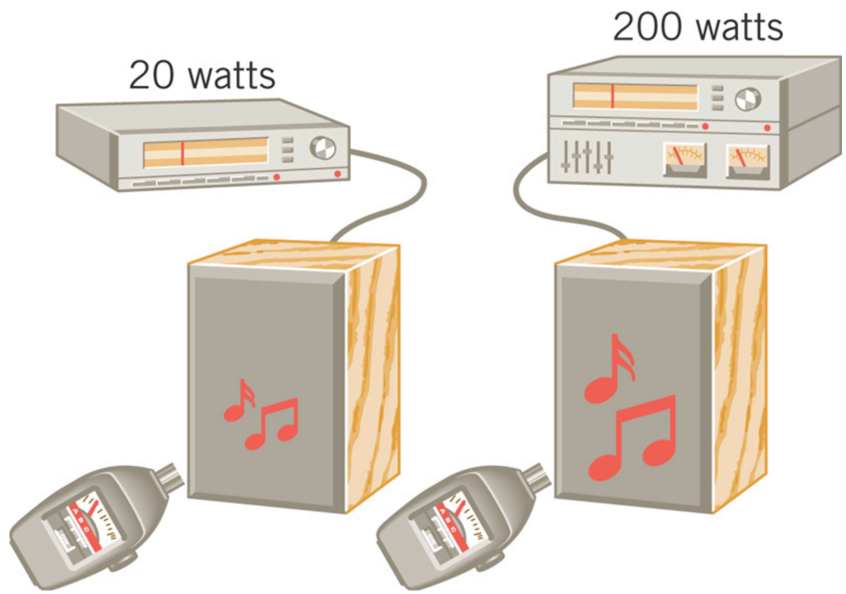


	Intensity I (W/m^2)	Intensity Level β (dB)
Threshold of hearing	1.0×10^{-12}	0
Rustling leaves	1.0×10^{-11}	10
Whisper	1.0×10^{-10}	20
Normal conversation (1 meter)	3.2×10^{-6}	65
Inside car in city traffic	1.0×10^{-4}	80
Car without muffler	1.0×10^{-2}	100
Live rock concert	1.0	120
Threshold of pain	10	130

Example 9 Comparing Sound Intensities

Audio system 1 produces a sound intensity level of 90.0 dB, and system 2 produces an intensity level of 93.0 dB. Determine the ratio of intensities.

$$\beta = (10\text{ dB})\log\left(\frac{I}{I_o}\right)$$



$$90\text{ dB} = (10\text{ dB})\log(I/I_o)$$
$$\log(I/I_o) = 9;$$
$$I = I_o \times 10^9 = (1\times10^{-12}\text{ W/m}^2)\times10^9$$
$$= 1\times10^{-3}\text{ W/m}^2$$

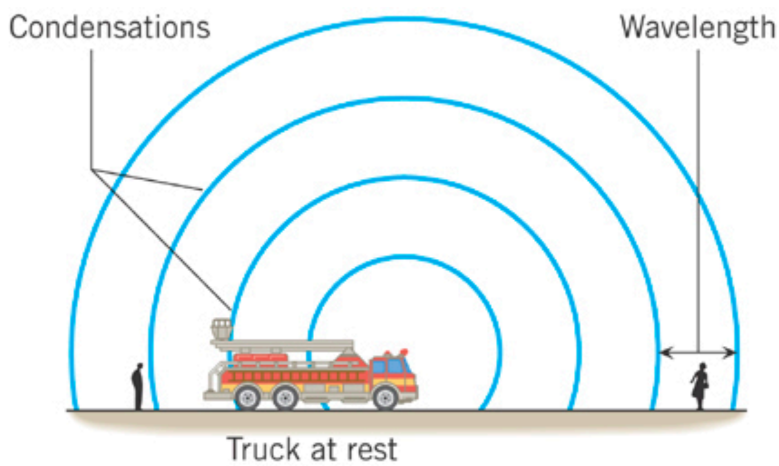
$$93\text{ dB} = (10\text{ dB})\log(I/I_o)$$
$$\log(I/I_o) = 9.3;$$
$$I = I_o \times 10^{9.3} = (1\times10^{-12}\text{ W/m}^2)\times10^{9.3}$$
$$= 1\times10^{-3.3}\text{ W/m}^2 = 1\times10^{-3}(10^{0.3})\text{W/m}^2$$
$$= 1\times10^{-3}(2)\text{W/m}^2 = 2\times10^{-3}\text{ W/m}^2$$

$$93\text{dB} = 90\text{dB} + 3\text{dB}$$

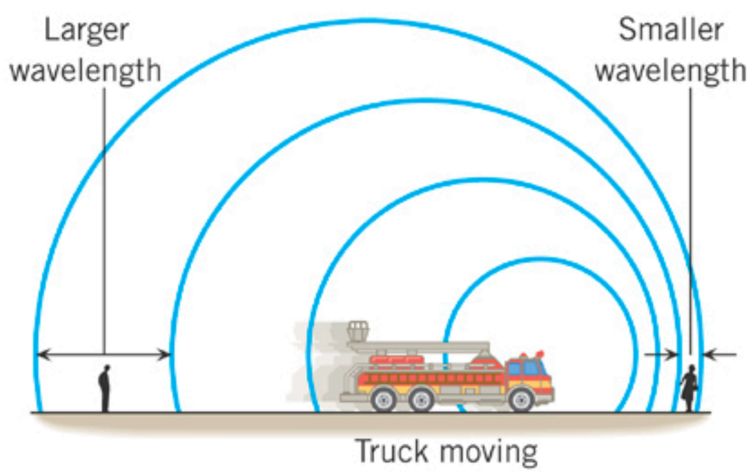
Adding 3dB results in a factor of 2 increase in the intensity.

$$3\text{ dB} = (10\text{dB})\log(I_2/I_1)$$
$$0.3 = \log(I_2/I_1);$$
$$I_2 = 10^{0.3} I_1 = 2I_1$$

16.9 ***The Doppler Effect***



(*a*)



(*b*)

The ***Doppler effect*** is the change in frequency or pitch of the sound detected by an observer because the sound source and the observer have different velocities with respect to the medium of sound propagation.

SOURCE (*s*) MOVING AT v_s
TOWARD OBSERVER (*o*)

$$f_o = f_s\left(\frac{1}{1 - v_s/v}\right)$$

SOURCE (*s*) MOVING AT v_s
AWAY FROM OBSERVER (*o*)

$$f_o = f_s\left(\frac{1}{1 + v_s/v}\right)$$

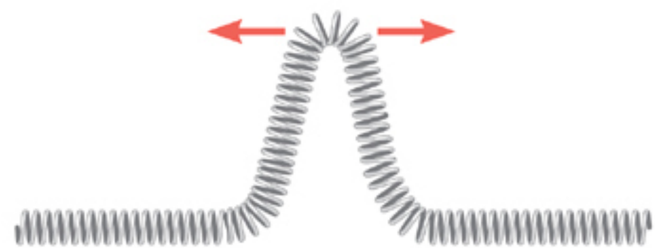
Chapter 17

The Principle of Linear Superposition and Interference Phenomena

17.1 The Principle of Linear Superposition

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

(*a*) Overlap begins

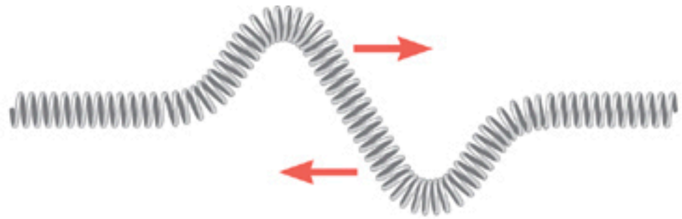


(*b*) Total overlap; the Slinky has twice the height of either pulse

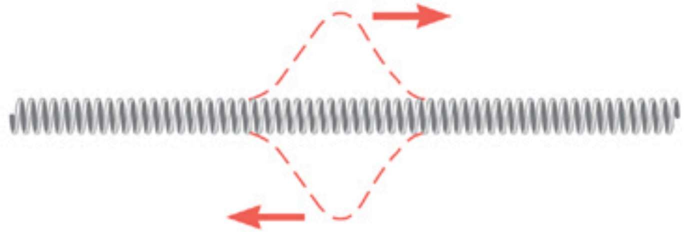
(*c*) The receding pulses

17.1 The Principle of Linear Superposition

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



(*a*) Overlap begins

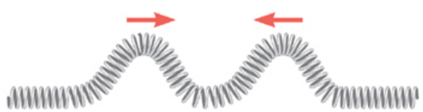


(*b*) Total overlap

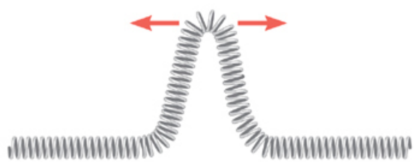
(*c*) The receding pulses

THE PRINCIPLE OF LINEAR SUPERPOSITION

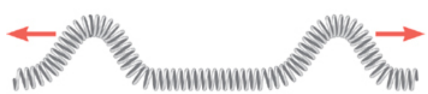
When two or more waves are present simultaneously at the same place, the resultant disturbance is the sum of the disturbances from the individual waves.



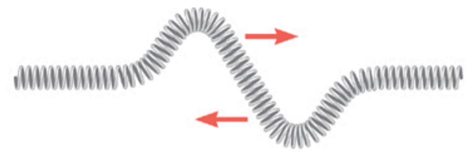
(*a*) Overlap begins



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



(*c*) The receding pulses



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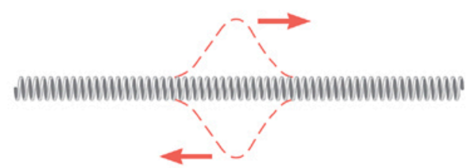
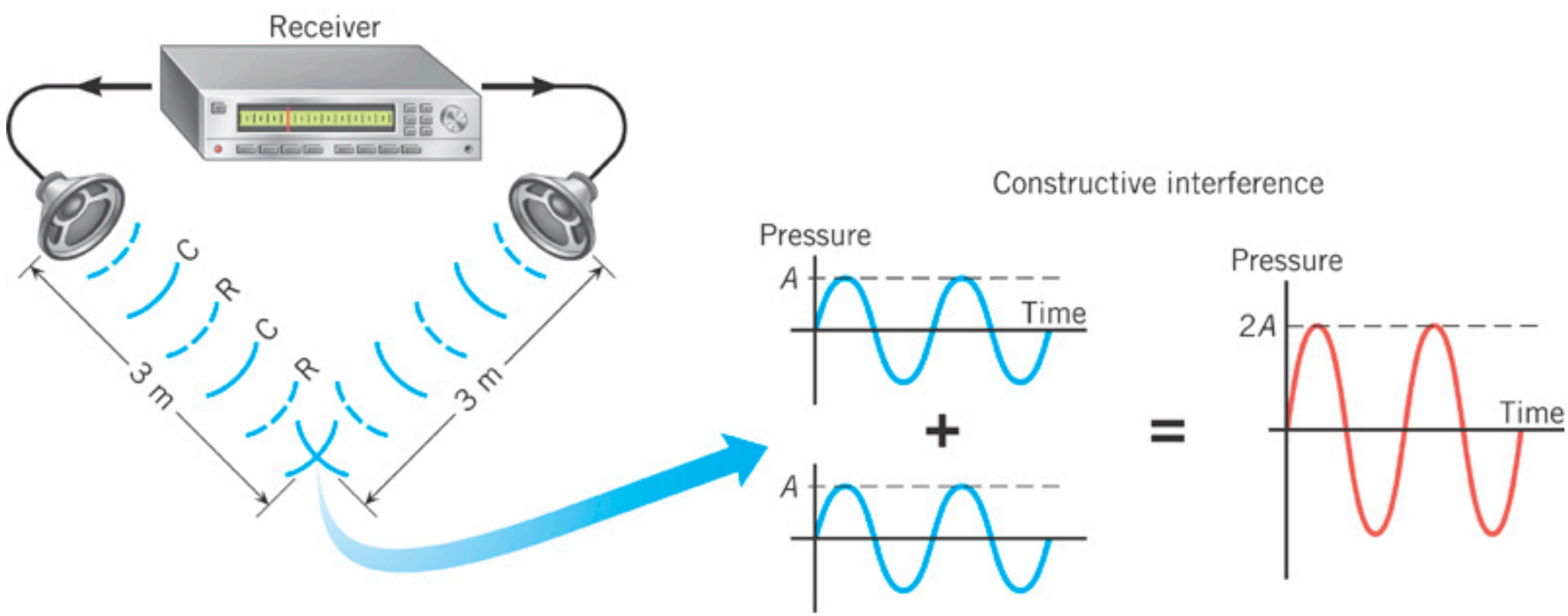


(*b*) Total overlap

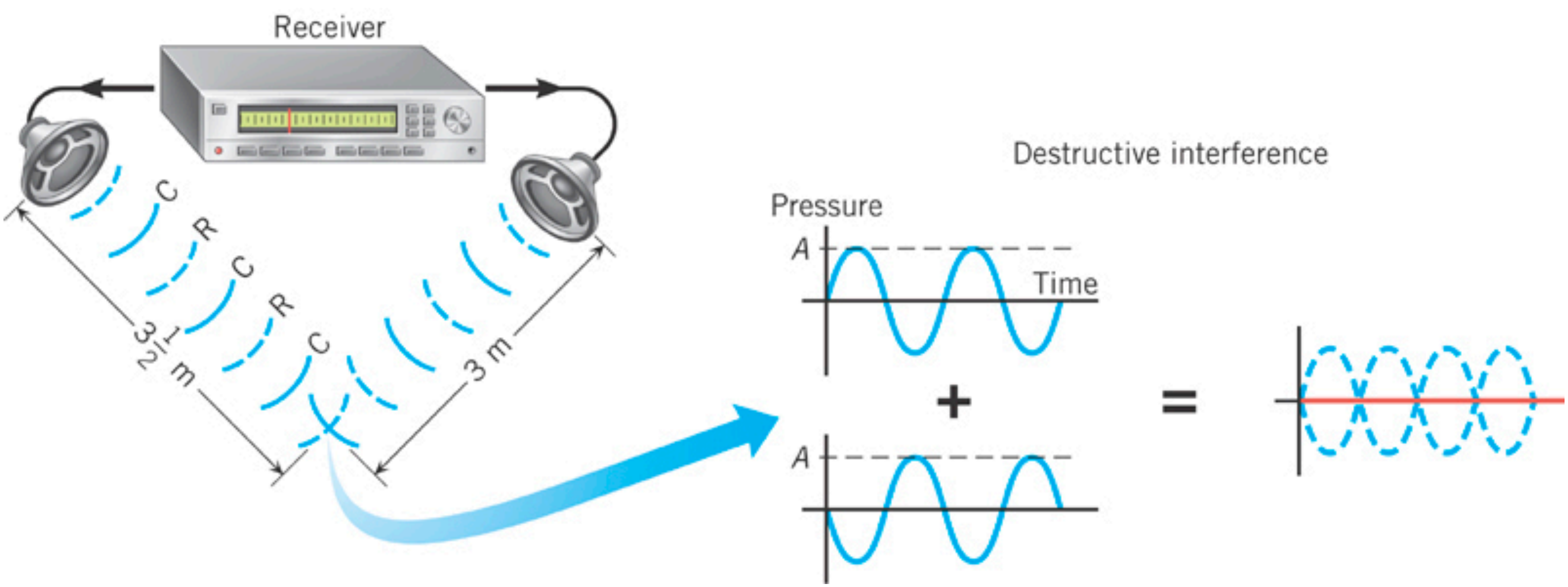
(*c*) The receding pulses

17.2 Constructive and Destructive Interference of Sound Waves

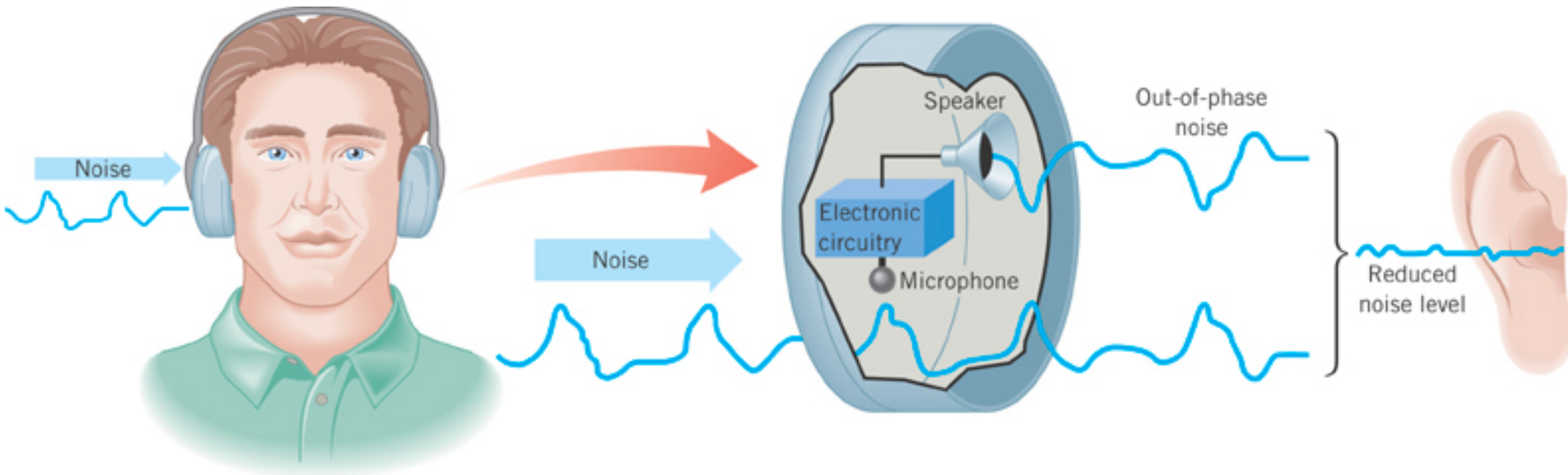
When two waves always meet condensation-to-condensation and rarefaction-to-rarefaction, they are said to be ***exactly in phase*** and to exhibit ***constructive interference.***



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



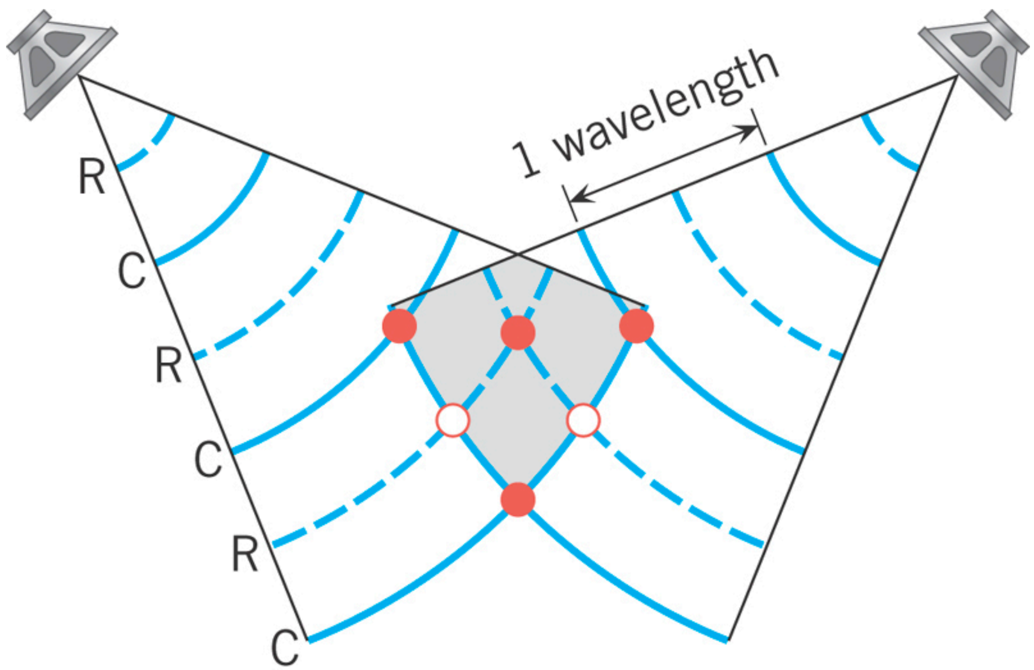
17.2 Constructive and Destructive Interference of Sound Waves



17.2 Constructive and Destructive Interference of Sound Waves

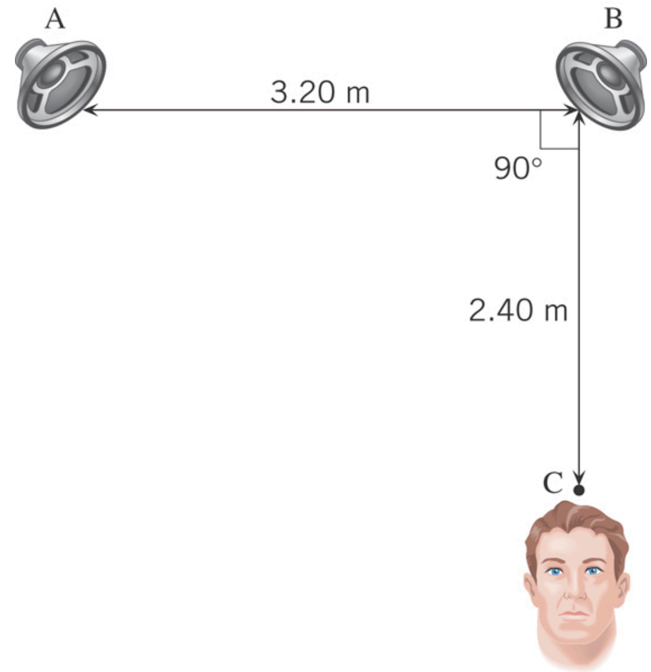
If the wave patters do not shift relative to one another as time passes, the sources are said to be ***coherent***.

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 (½ , 1 ½, 2 ½, . .) 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?

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.

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

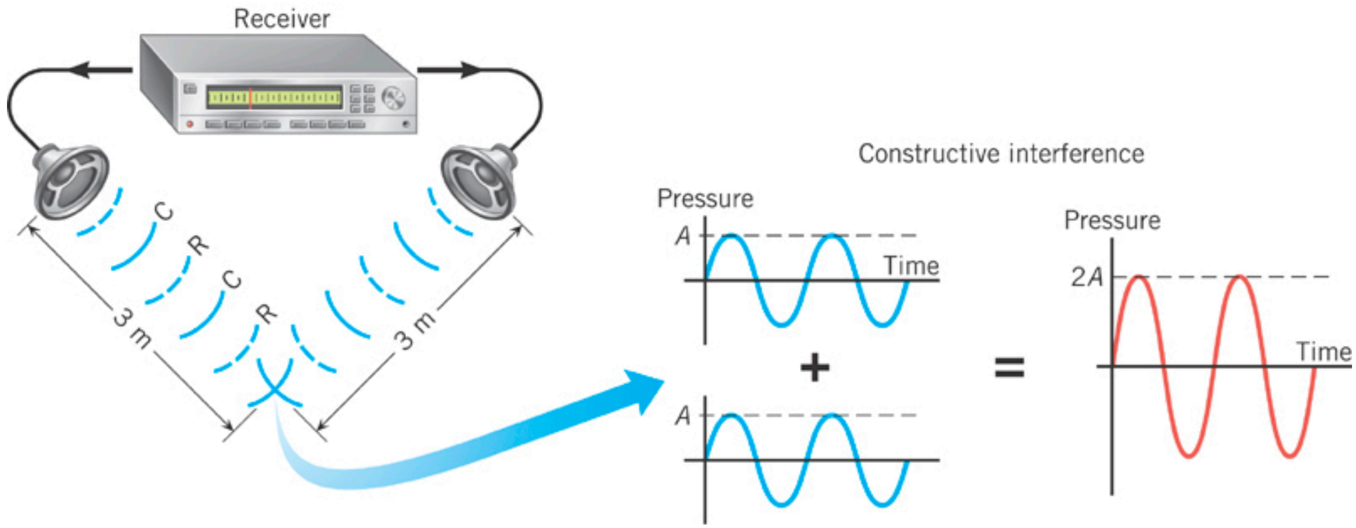
Because the path length difference is equal to an integer (1) number of wavelengths, there is constructive interference, which means there is a loud sound.

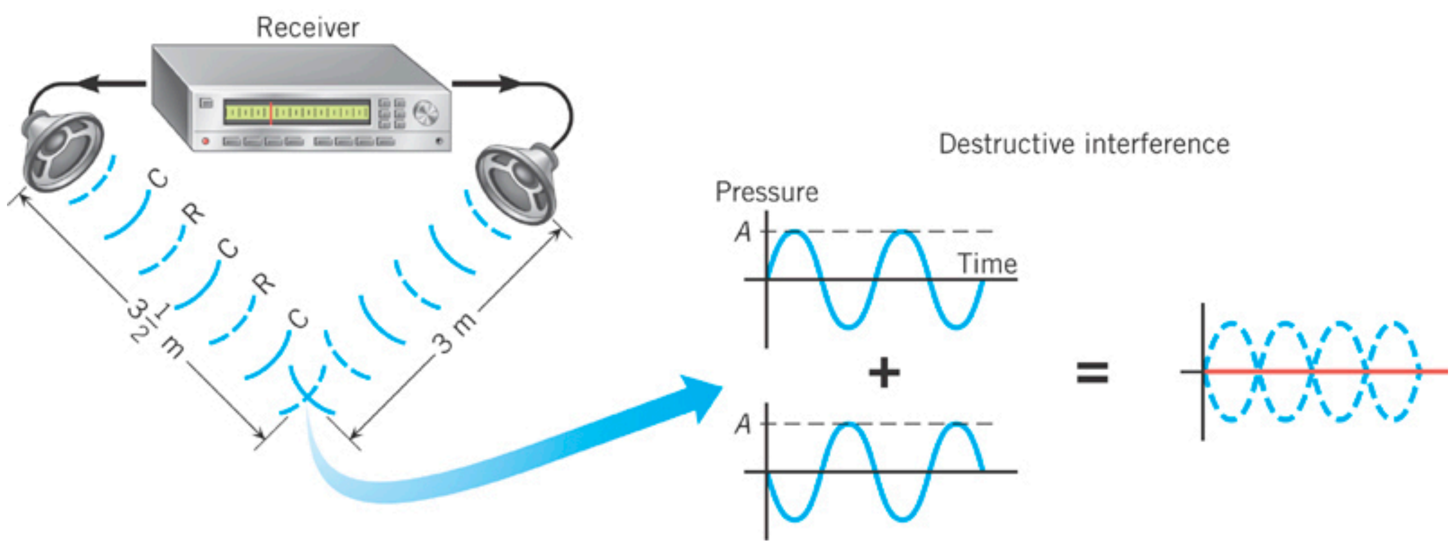
17.2 Constructive and Destructive Interference of Sound Waves

Conceptual Example 2 Out-Of-Phase Speakers

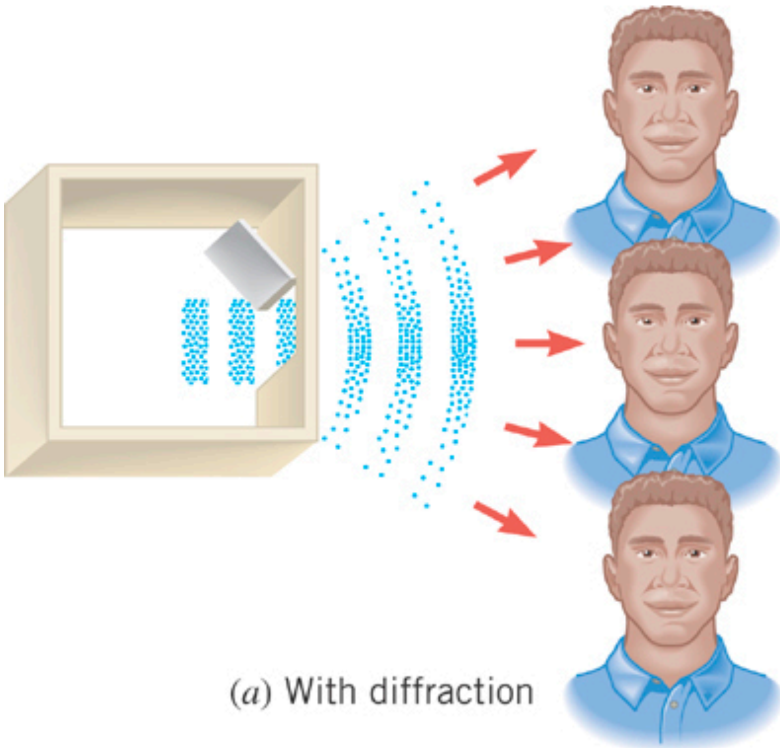
To make a speaker operate, two wires must be connected between the speaker and the amplifier. To ensure that the diaphragms of the two speakers vibrate in phase, it is necessary to make these connections in exactly the same way. If the wires for one speaker are not connected just as they are for the 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

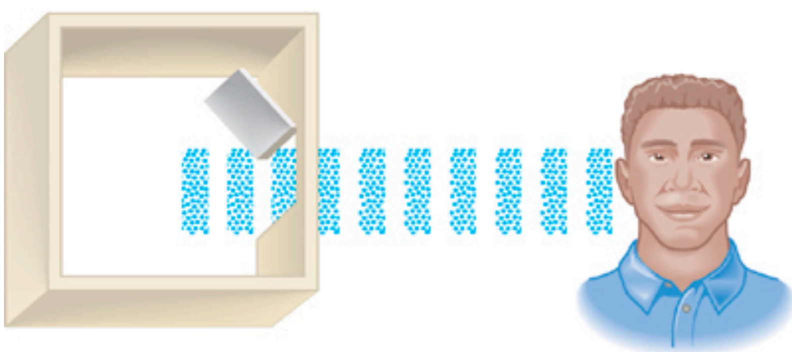




17.3 Diffraction



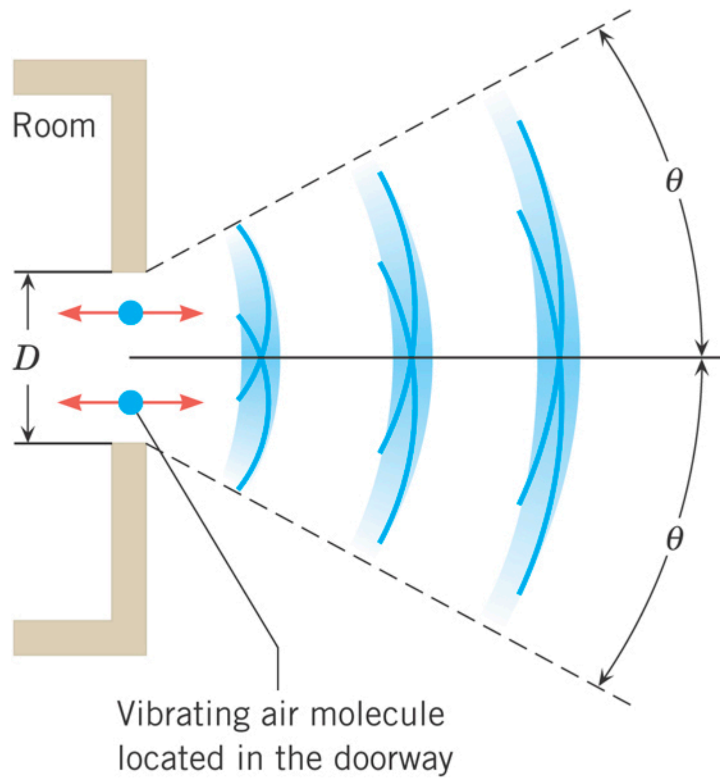
(a) With diffraction



(b) Without diffraction

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

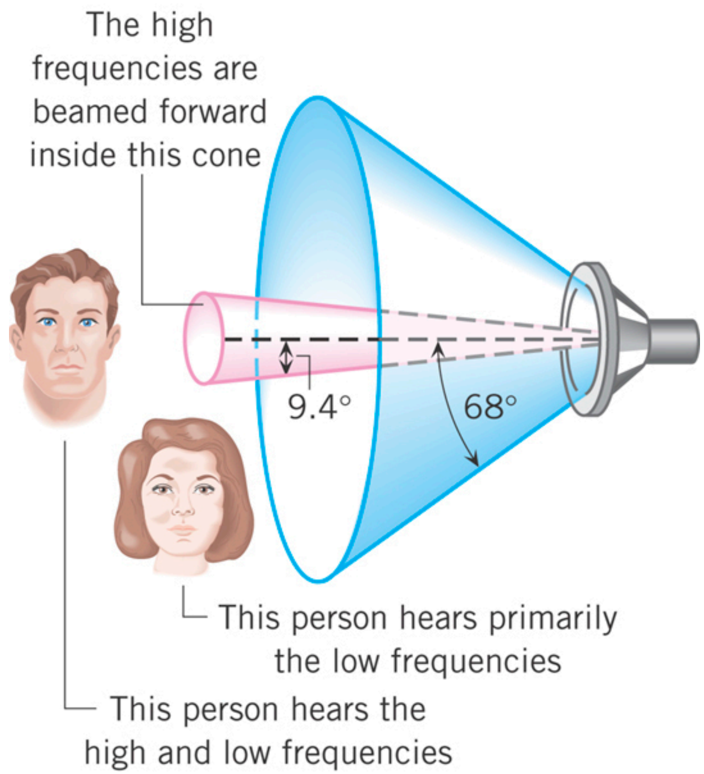
17.3 Diffraction



single slit – first minimum

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

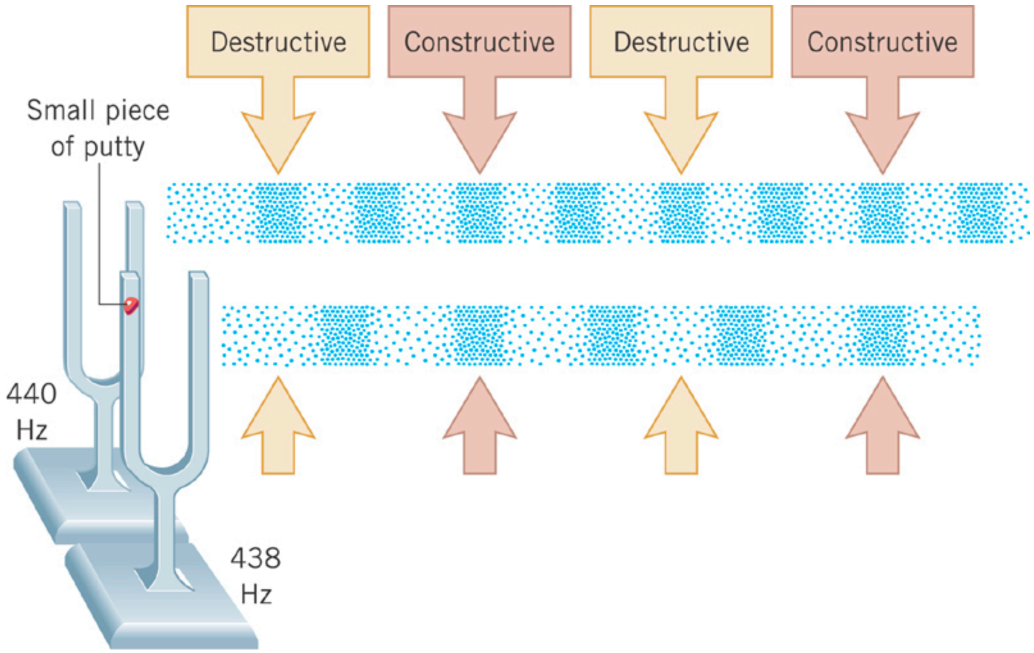
17.3 Diffraction



Circular opening – first minimum

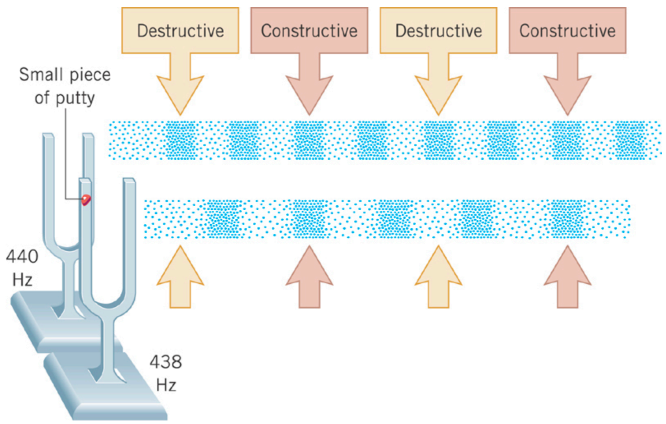
$$\sin\theta = 1.22\frac{\lambda}{D}$$

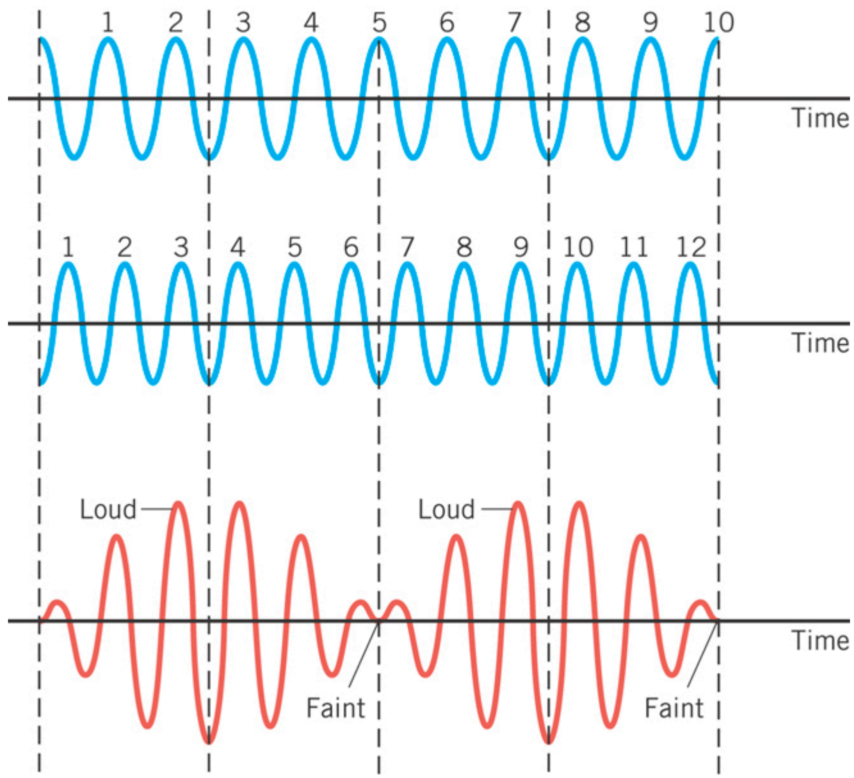
17.4 Beats



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

17.4 Beats

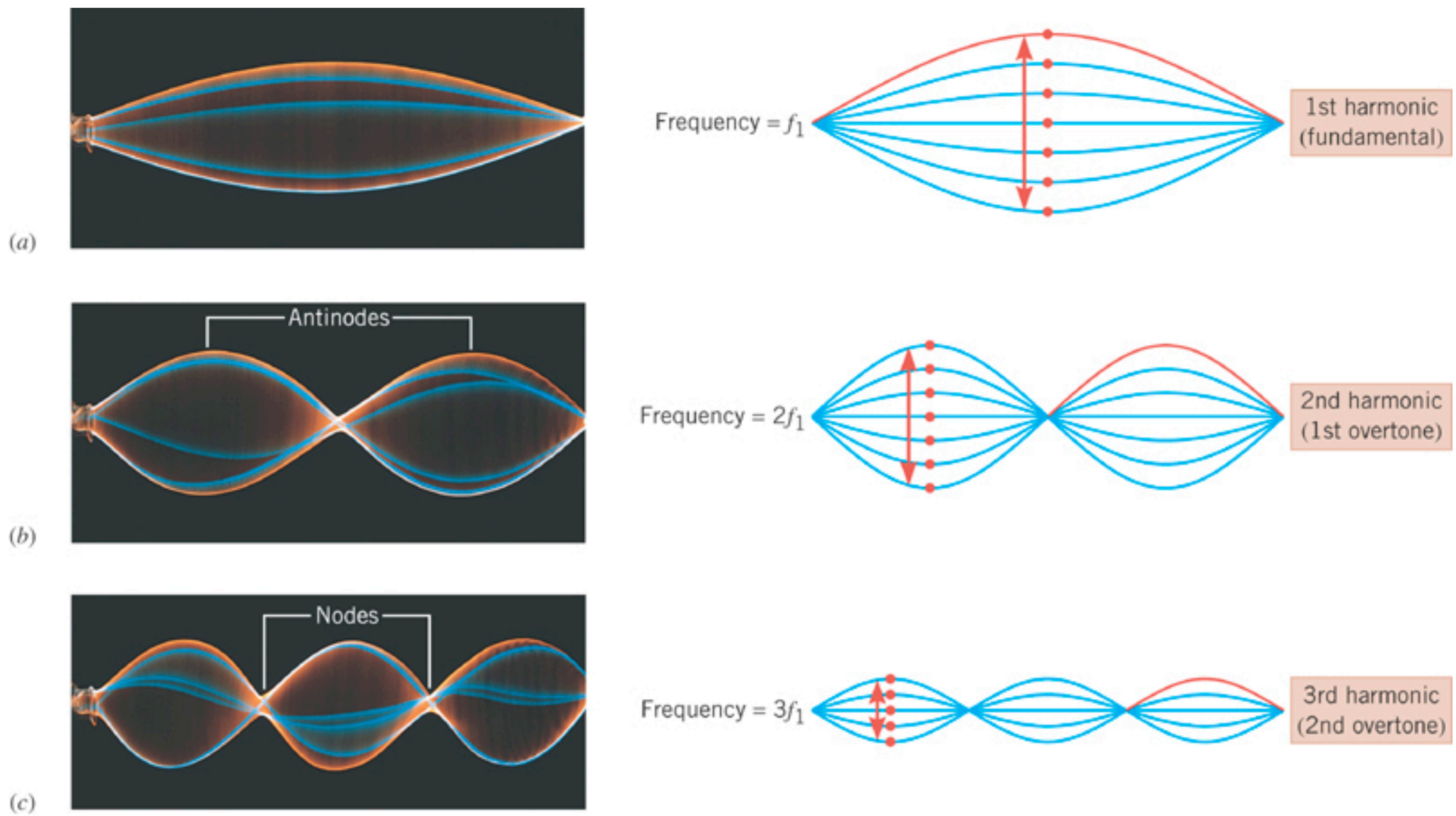




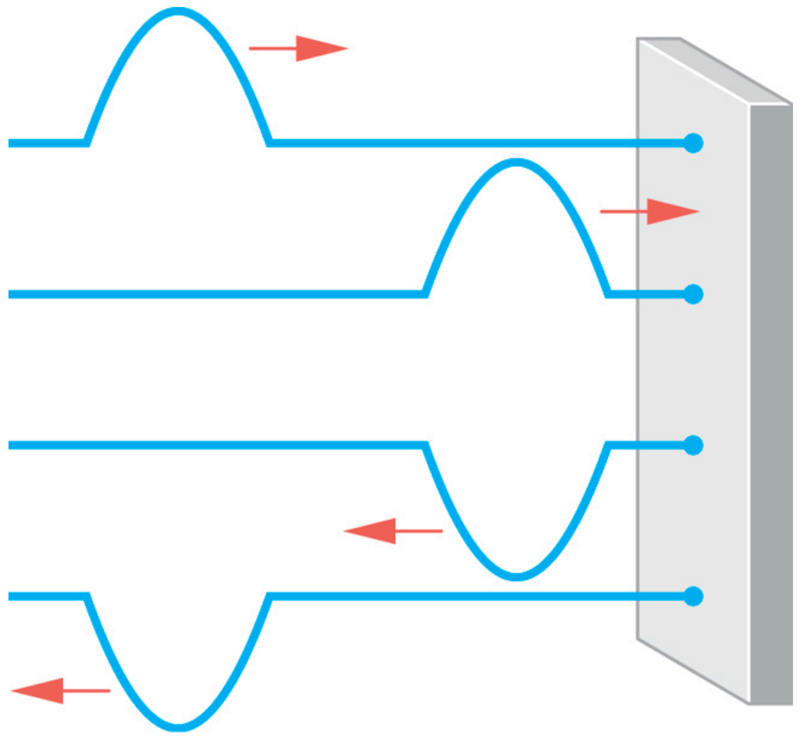
The ***beat frequency*** is the ***difference*** between the two sound frequencies.

17.5 Transverse Standing Waves

Transverse standing wave patters.



17.5 Transverse Standing Waves

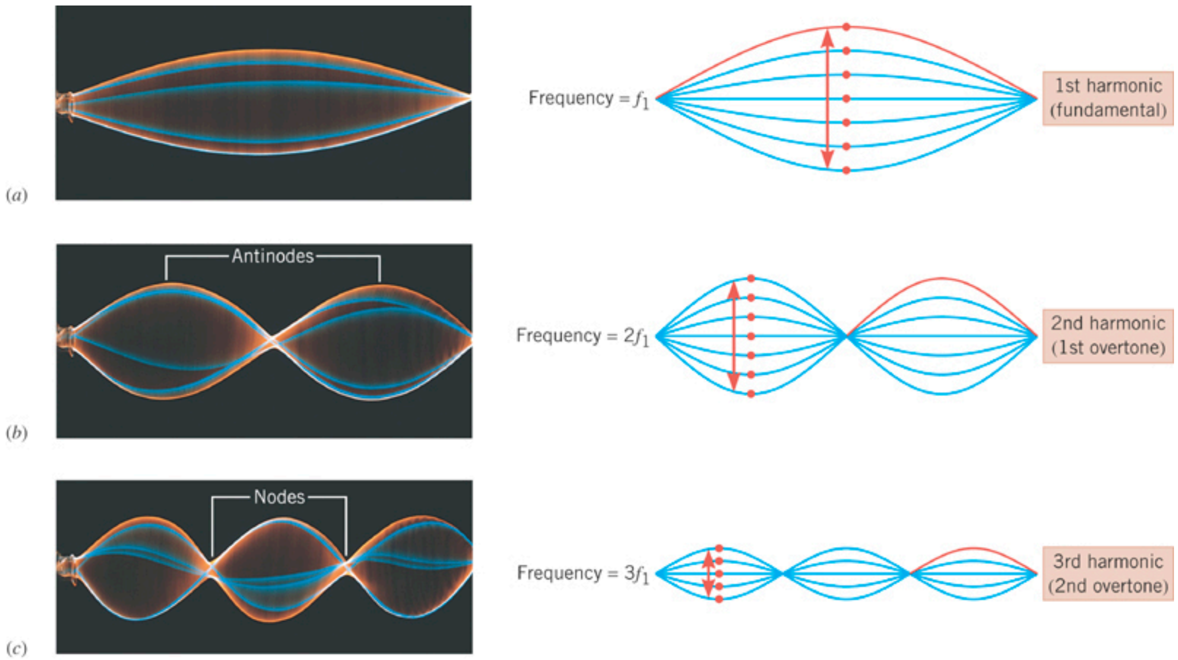


In reflecting from the wall, a forward-traveling half-cycle becomes a backward-traveling half-cycle that is inverted.

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.

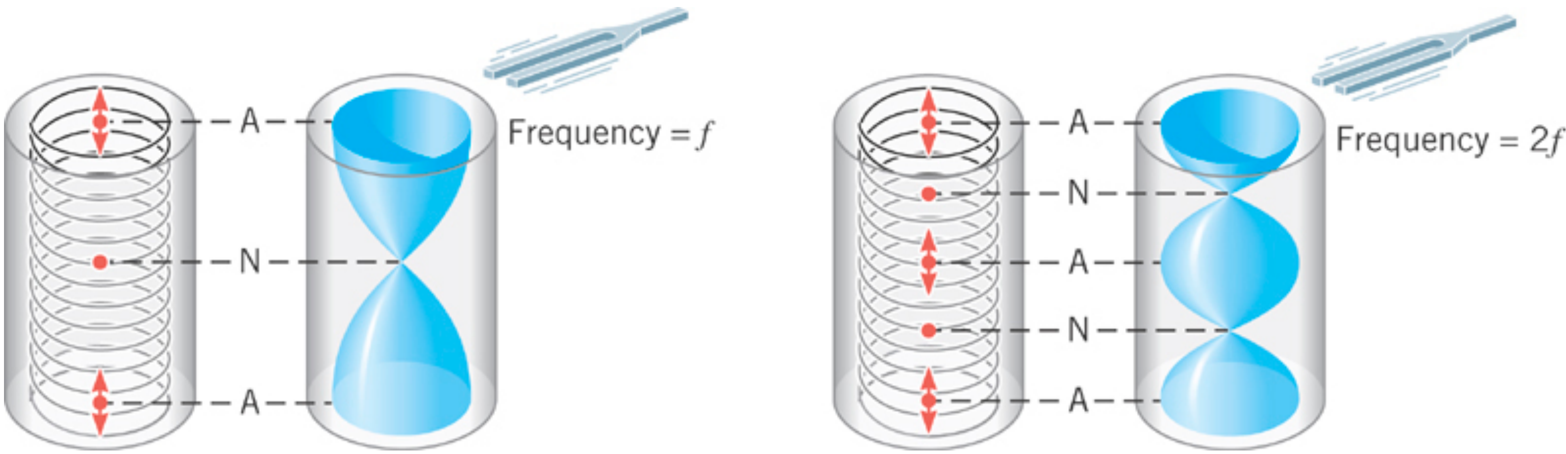
17.5 Transverse Standing Waves



String fixed at both ends

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

17.6 Longitudinal Standing Waves



Tube open at both ends

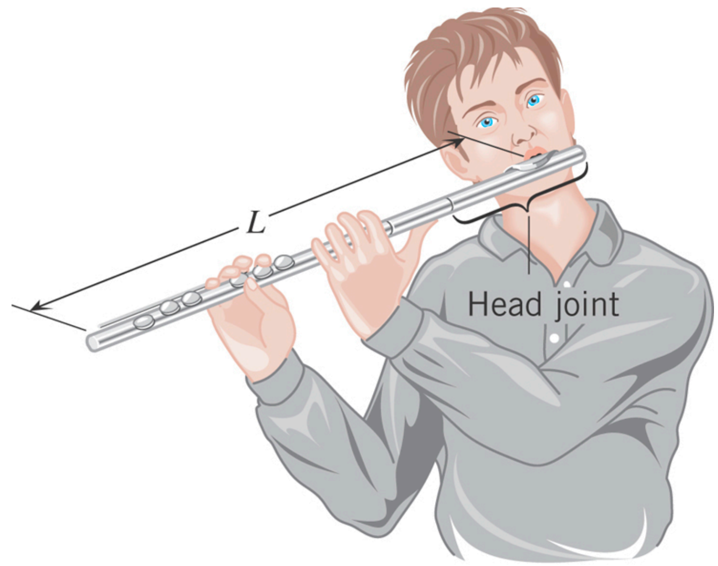
$$f_n = n\left(\frac{v}{2L}\right) \qquad n = 1, 2, 3, 4, \ldots$$

Example 6 Playing a Flute

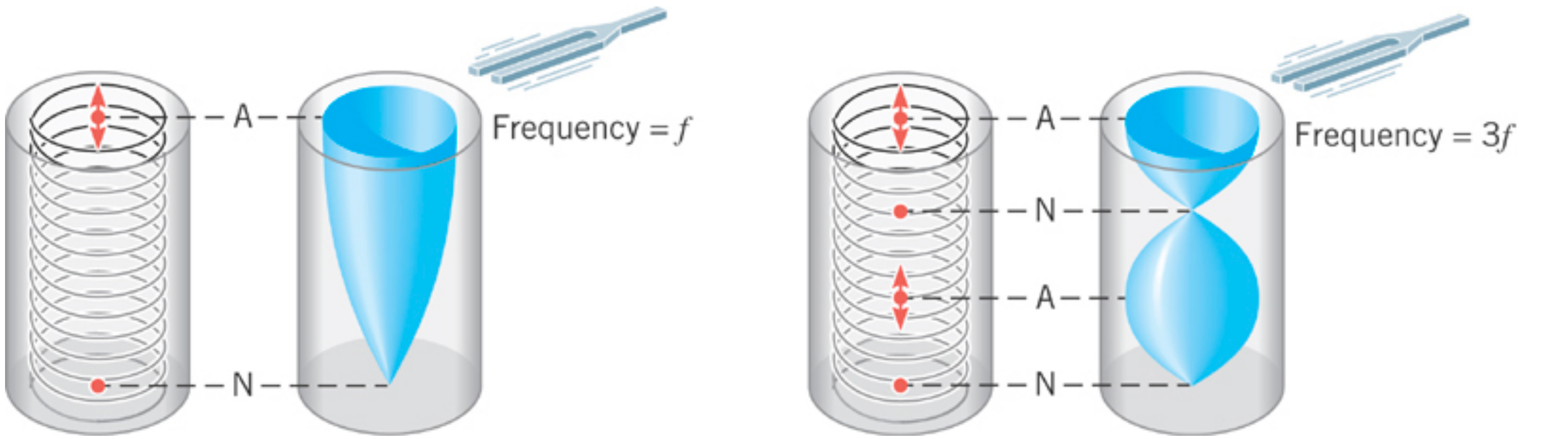
When all the holes are closed on one type of flute, the lowest note it can sound is middle C (261.6 Hz). If the speed of sound is 343 m/s, and the flute is assumed to be a cylinder open at both ends, determine the distance L.

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

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



17.6 Longitudinal Standing Waves



Tube open at one end

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

17.7 Complex Sound Waves