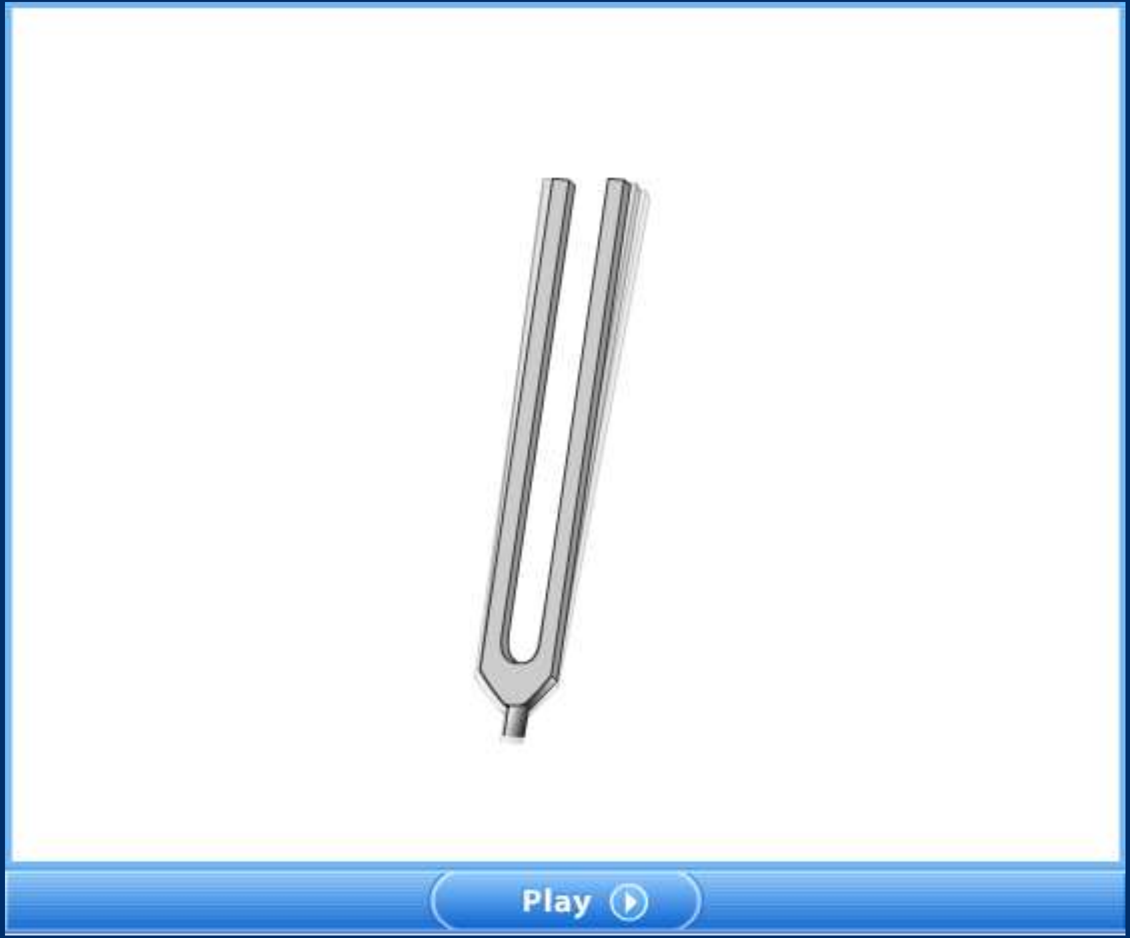
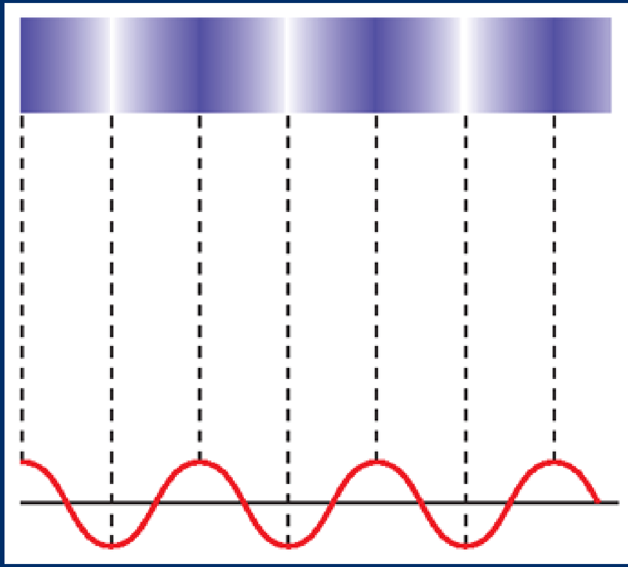
Sound Waves



The Production of Sound Waves, *continued*

- Sound waves are **longitudinal.**



Frequency and Pitch

- The **frequency** for sound is known as **pitch**.

End Of Slide

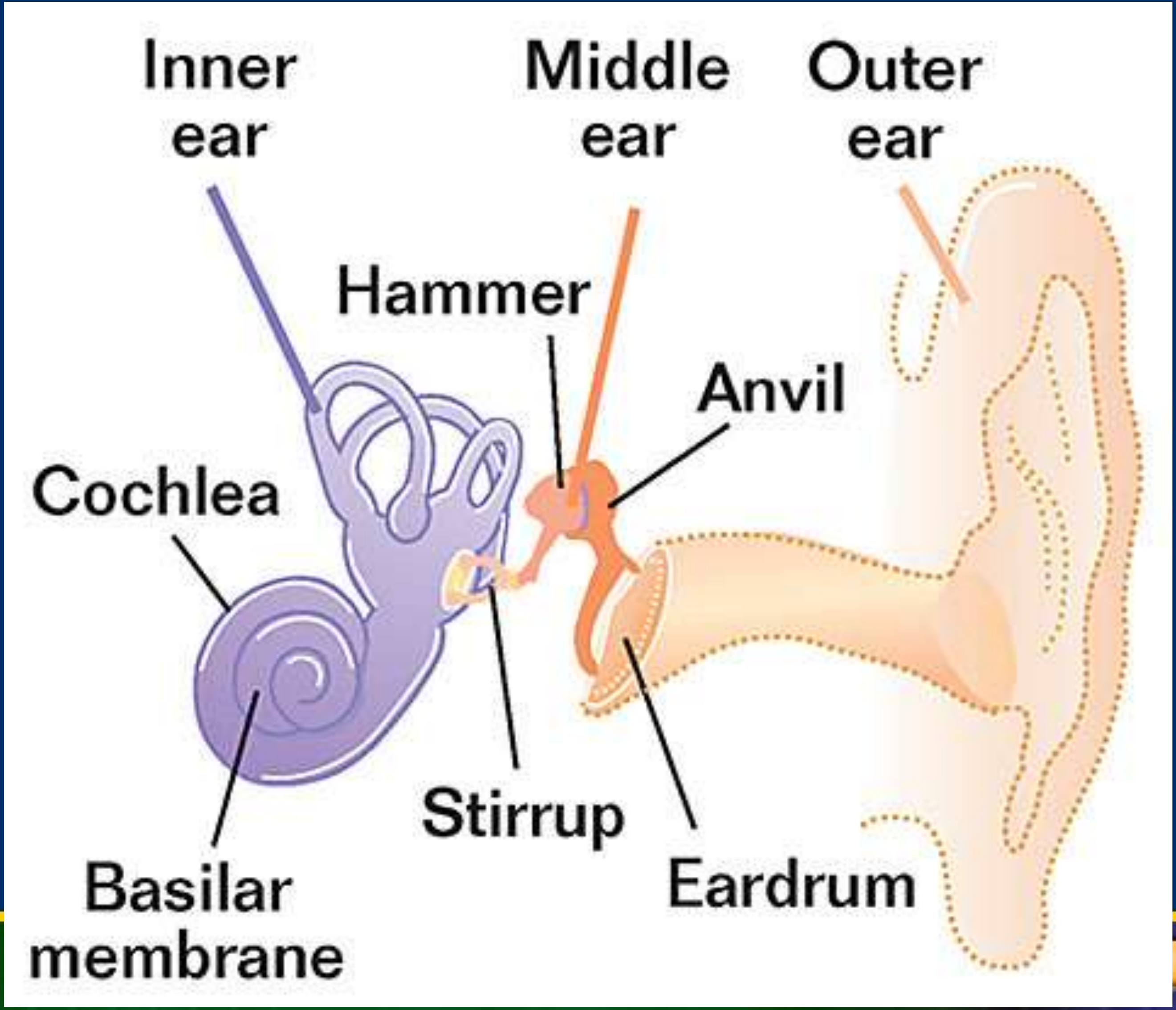
Frequency of Sound Waves

- , **frequency** =cycles per unit of time (s).
- **Audible** sound waves, frequencies are between **20 and 20 000 Hz.**
- **< than 20 Hz =infrasonic**.
- >**20 000 Hz =ultrasonic**.

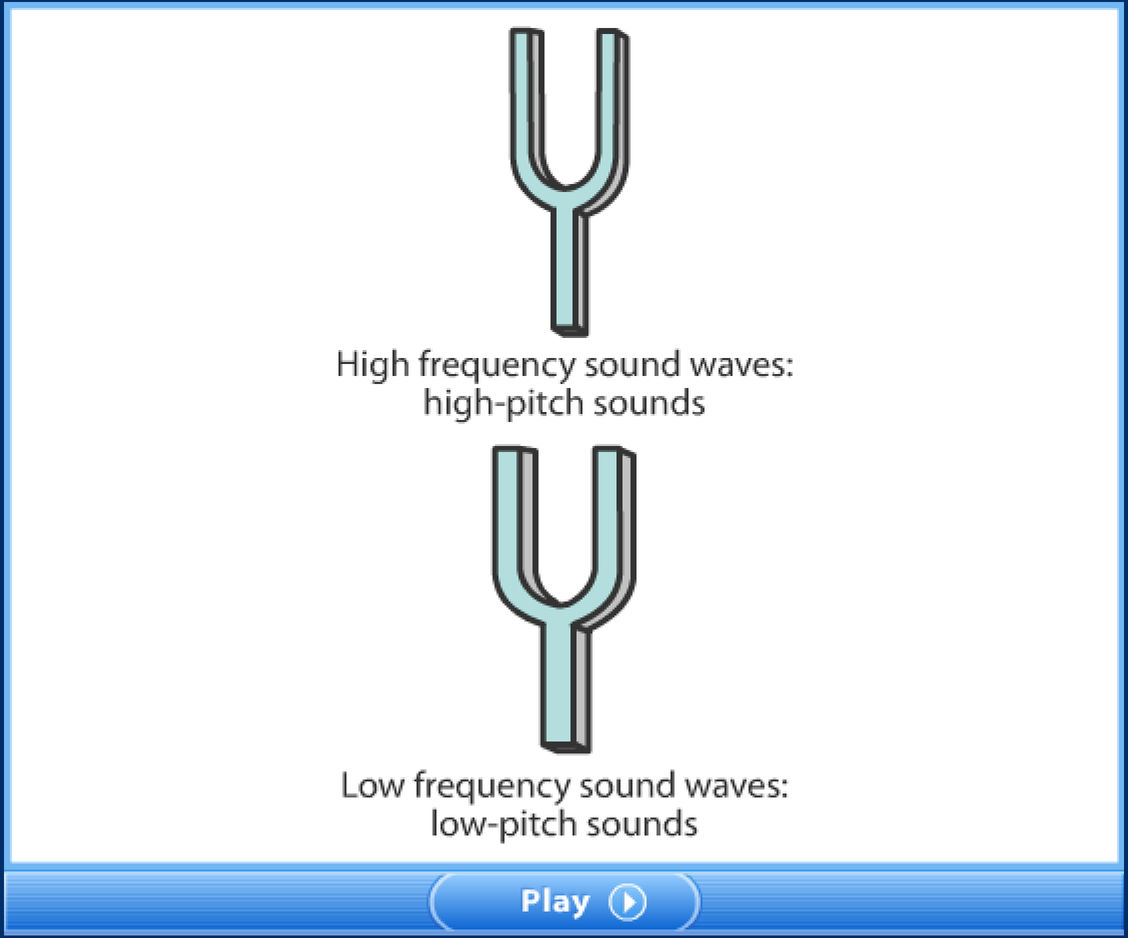
End Of Slide

The Human Ear

- .



Frequency and Pitch



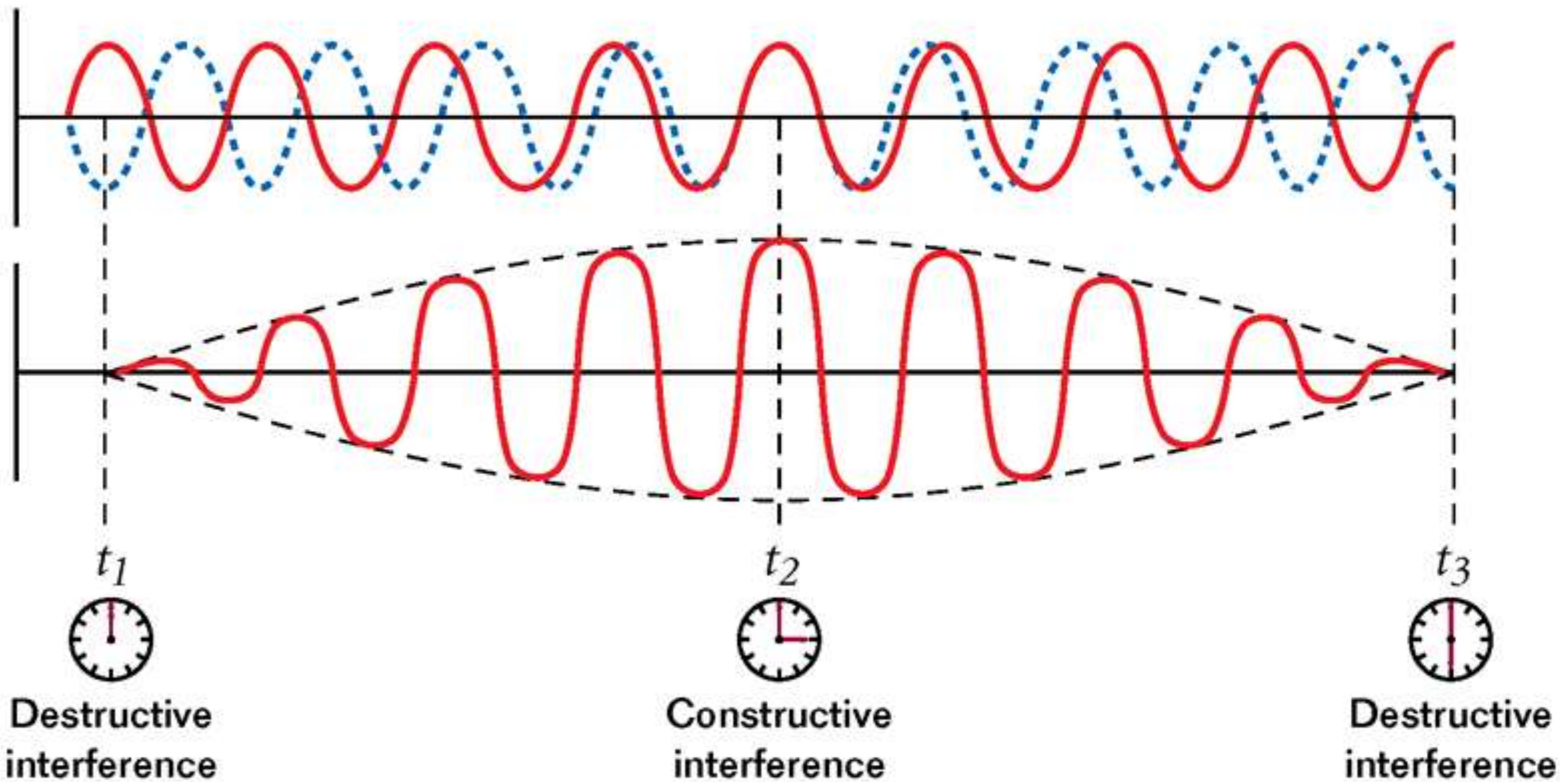
Beats Wave interaction

- **Beat =**When two waves of **slightly different frequencies** interfere, the interference pattern produces alternation between loudness and softness.

- $Beat_{f=} A_f - B_f$

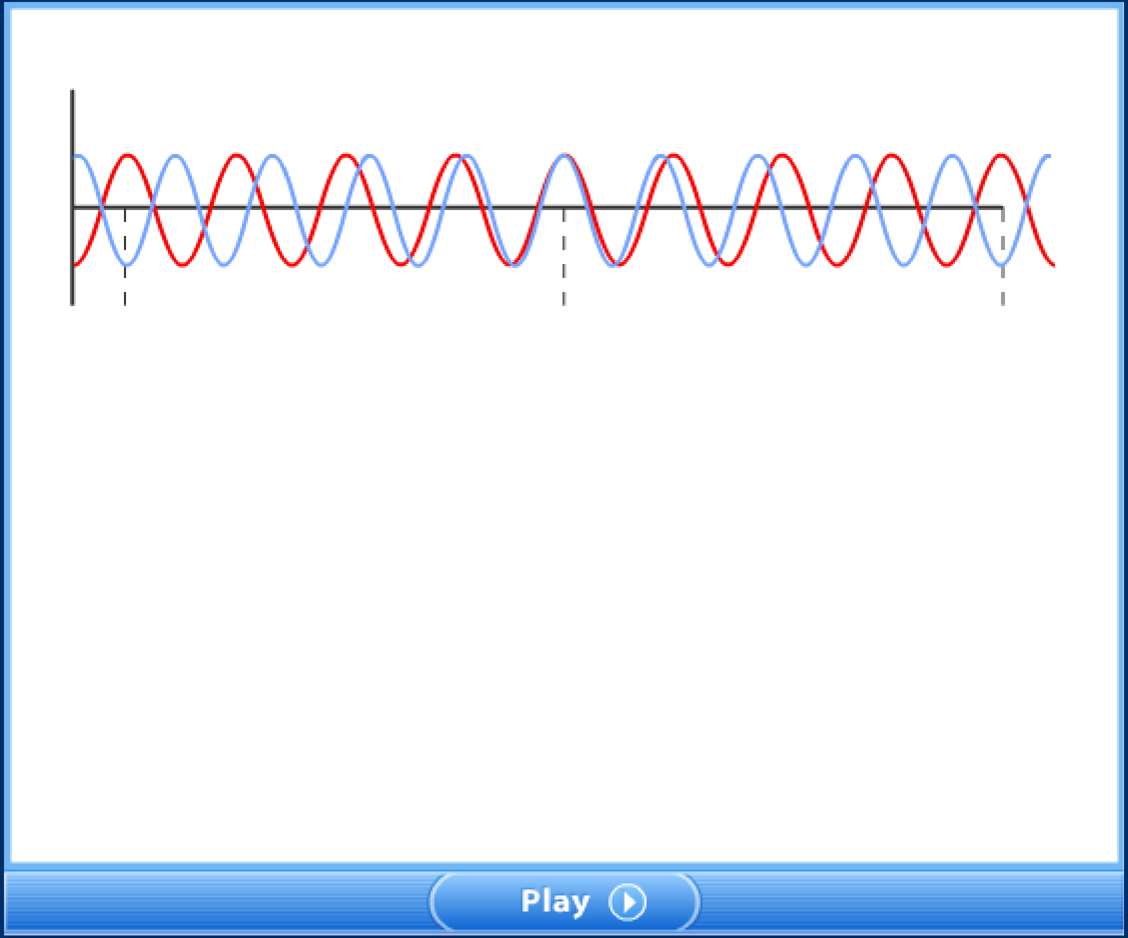
End Of Slide

Beats



t_1
t_2
t_3
Destructive interference
Constructive interference
Destructive interference

Beats



End Of Slide

The Speed of Sound

- The speed of sound depends on the **medium.**
- speed also depends on the **temperature** of the medium. Especially gases.
- Speed of sound in air is 331.5 @ 0 ^{o}C
- +/- (.6m/s)/ C
- @ 25 ^{o}C 346 m/s

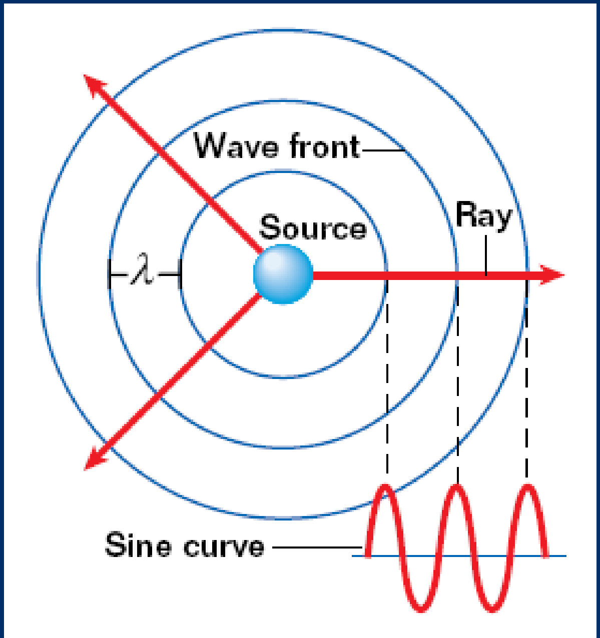
The Speed of Sound in Various Media

Medium	v (m/s)
Gases	
air (0°C)	331
air (25°C)	346
air (100°C)	366
helium (0°C)	972
hydrogen (0°C)	1290
oxygen (0°C)	317
Liquids at 25°C	
methyl alcohol	1140
sea water	1530
water	1490
Solids	
aluminum	5100
copper	3560
iron	5130
lead	1320
vulcanized rubber	54

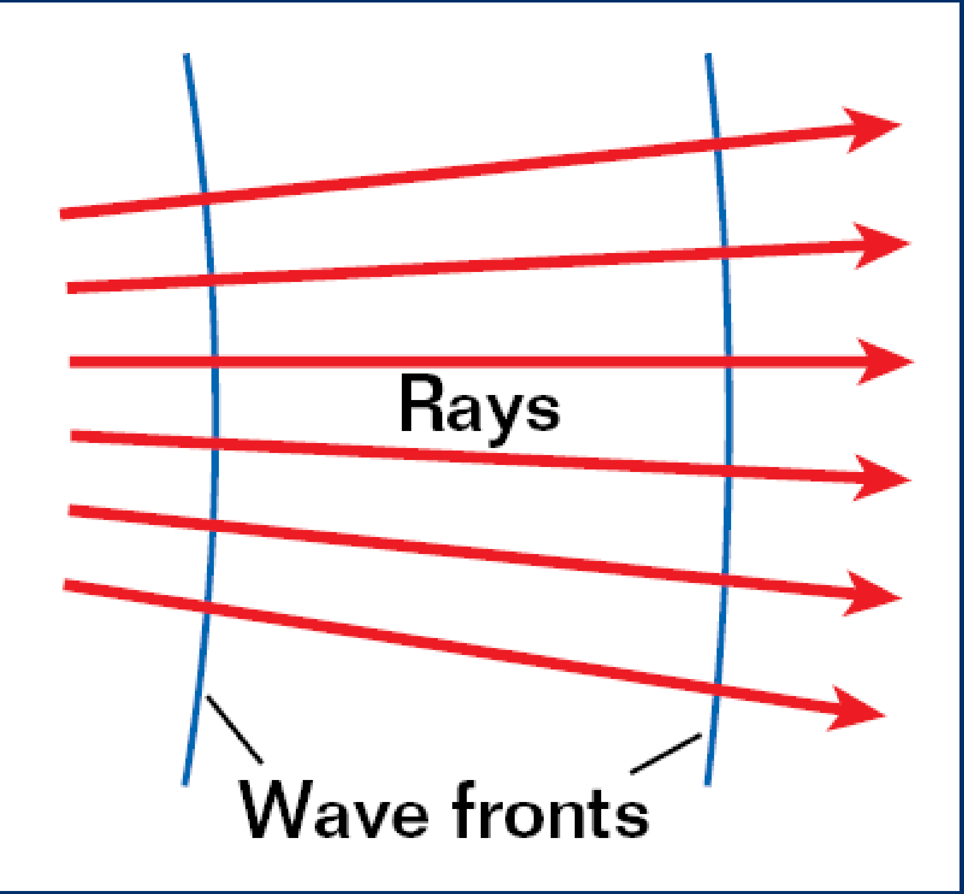
The Propagation of Sound Waves

- Spherical waves fronts

- The circles represent the centers of compressions, called **wave fronts.**



The Propagation of Sound Waves, *continued*



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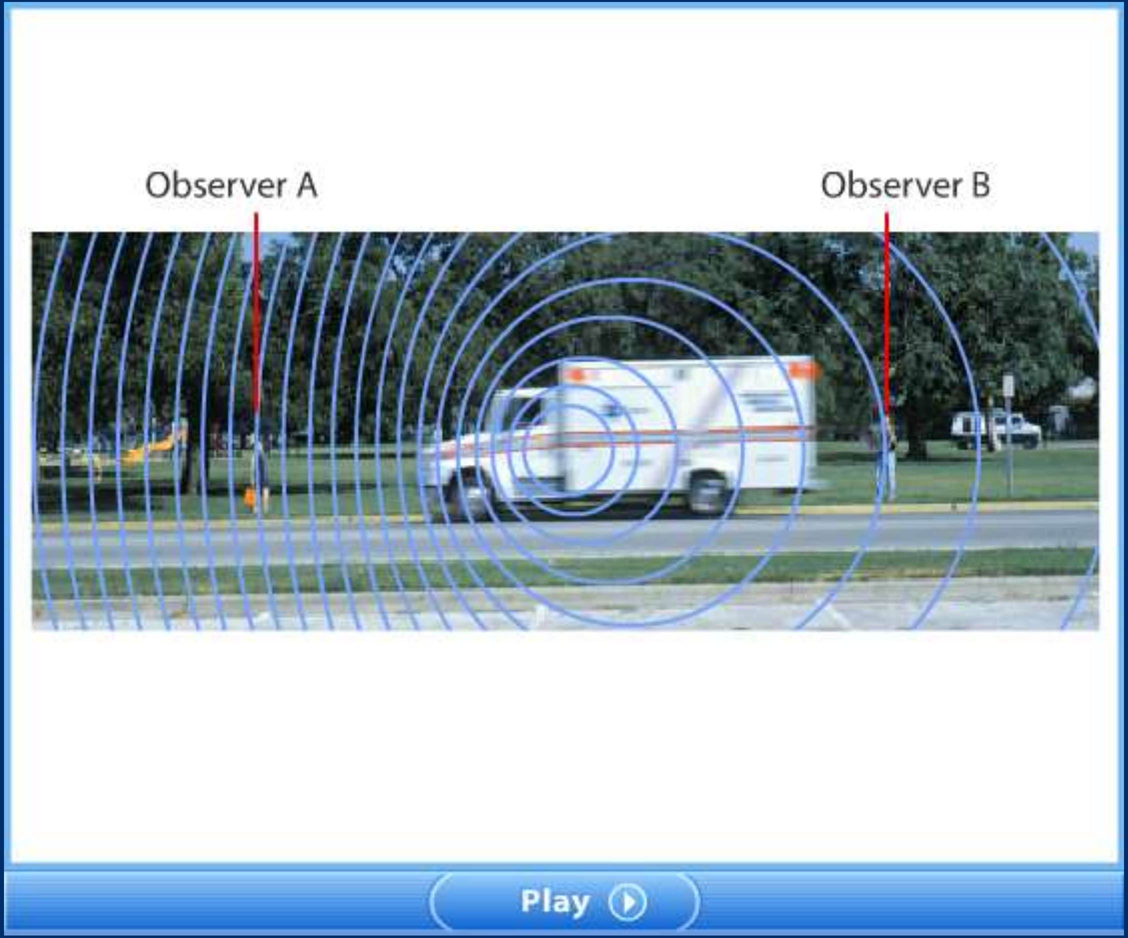
The Doppler Effect



The Doppler Effect

- The **Doppler effect** is an observed change in frequency due to **relative motion** between source and observer.
- Doppler, it is a phenomenon common to all waves, including, such as visible light.

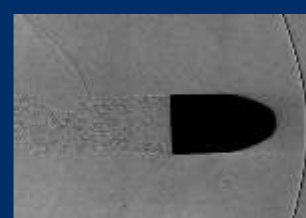
- $f_o = f_s((v+v_o)/(v-v_s))$
- fo= frequency of observer Vo= velocity of observer vs =velocity of source fs= frequency of source V=velocity of sound

End Of Slide

Mach 0 .7

Mach 1.4

Mach 1



Chapter menu

Resources

- An ambulance traveling down a highway at 75 m/s is emitting a sound of 400 Hz. What is the *f* heard by the passengers, and what is the *f* heard by an observer as it approaches on the road if the velocity of the sound is 340 m/s?

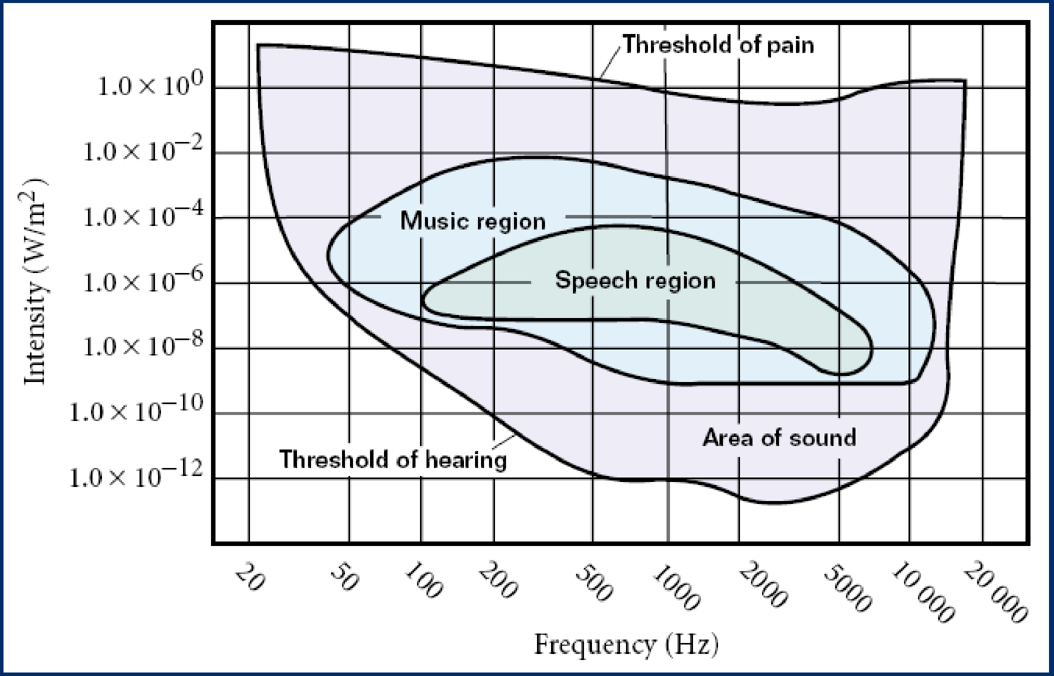
- =512Hz

Chapter menu

Resources

Sound Intensity, *continued*

- Human hearing depends on both the **frequency** and the **intensity** of sound waves.



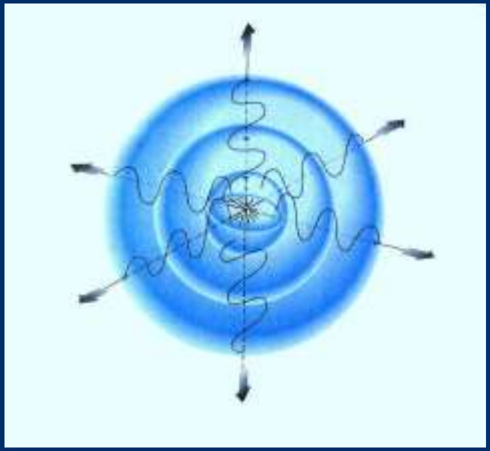
Sound Intensity, *continued*

- The **intensity** sound = **loudness.**
- loudness is approximately **logarithmic** in the human ear.
- **Relative intensity** is the ratio of the intensity of a given sound wave to the intensity at the threshold of hearing.

End Of Slide

Sound Intensity

- Intensity has units of **watt per square meter (W/m^2).**
- The intensity equation shows that the **intensity decreases** as the **distance (*r*) increases.** $1/r^2$



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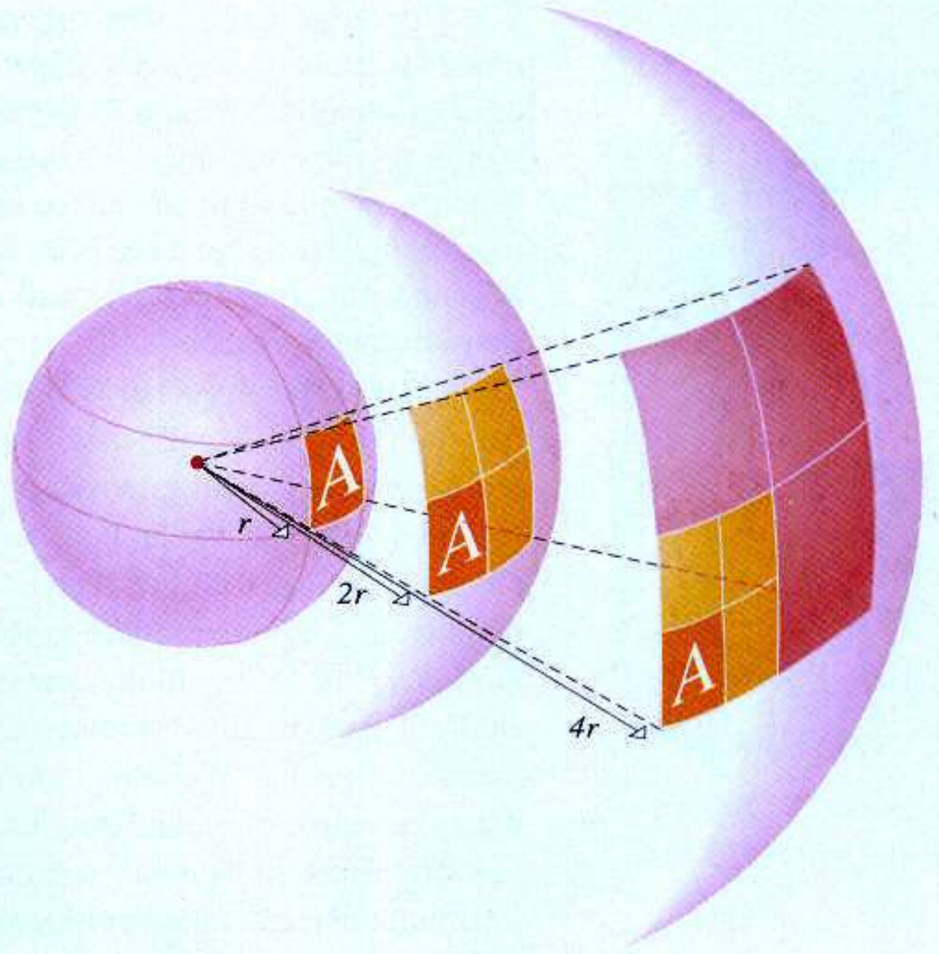

Figure 5.8

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Sound Intensity

- The rate at which this energy is transferred through a unit area of the plane wave is called the **intensity** of the wave.

$$\text{intensity} = \frac{\Delta E / \Delta t}{\text{area}} = \frac{P}{4\pi r^2}$$

$$\text{intensity} = \frac{\text{power}}{(4\pi)(\text{distance from the source})^2}$$

Sound Intensity, *continued*

- **decibel level.** A dimensionless unit called the **decibel (dB)** is used for values on this scale.
  - dβ=10log(I/I_o) dB=decible level
    - I=intensity in W/m^2
  - Io=Constant 1.0 X10^{-12} W/m^2

End Of Slide

Conversion of Intensity to Decibel Level

Intensity (W/m^2)	Decibel level (dB)	Examples
1.0×10^{-12}	0	threshold of hearing
1.0×10^{-11}	10	rustling leaves
1.0×10^{-10}	20	quiet whisper
1.0×10^{-9}	30	whisper
1.0×10^{-8}	40	mosquito buzzing
1.0×10^{-7}	50	normal conversation
1.0×10^{-6}	60	air conditioning at 6 m
1.0×10^{-5}	70	vacuum cleaner
1.0×10^{-4}	80	busy traffic, alarm clock
1.0×10^{-3}	90	lawn mower
1.0×10^{-2}	100	subway, power motor
1.0×10^{-1}	110	auto horn at 1 m
1.0×10^{0}	120	threshold of pain
1.0×10^{1}	130	thunderclap, machine gun
1.0×10^{3}	150	nearby jet airplane

Practice problem

- What is the sound intensity of a 70 dB noise made by a truck?
- dB=10log (I/Io)
- I=Io $\log^{-1}$ (dB/10)
- I= 10^{6} (10^{-12} W/m^2)= 10^{-6} W/m^2
- What is the power if you are 5 m away?
- I(4πr^2)= power= 3.1 10^{-3} W

Chapter menu | Resources

Objectives

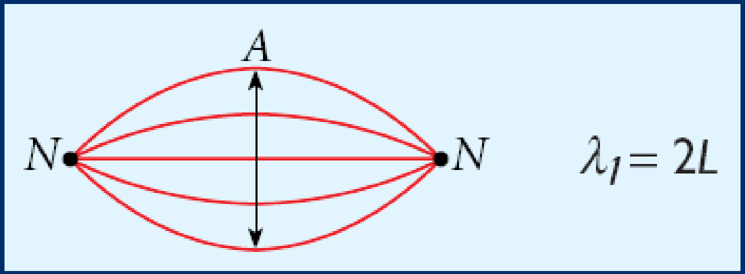
- **Differentiate** between the harmonic series of open and closed pipes.
- **Calculate** the harmonics of a vibrating string and of open and closed pipes.
- **Relate** harmonics and timbre.
- **Relate** the frequency difference between two waves to the number of beats heard per second.

Resonance

- A property in which the natural vibrational frequency of a material matches the frequency of the wave energy being added. This will increase the amplitude over time.

Standing Waves on a Vibrating String

- The vibrations on the string of a musical instrument usually consist of many standing waves.
- The greatest possible wavelength on a string of length *L* is **$\lambda = 2L$**.
- **fundamental frequency,**,



Standing Waves on a Vibrating String, *and open end pipe*

- Each harmonic is an **integral multiple** of the fundamental frequency.

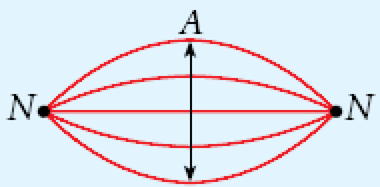
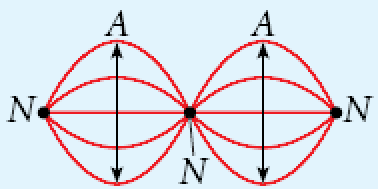
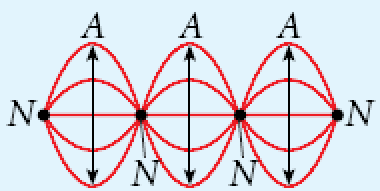
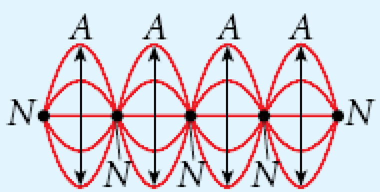
Harmonic Series of Standing Waves on a Vibrating String and open end pipe

$$f_n = n\frac{v}{2L} \qquad n = 1, 2, 3, \ldots$$

$$\text{frequency} = \text{harmonic number} \times \frac{\text{(speed of waves on the string)}}{\text{(2)(length of the vibrating string)}}$$

End Of Slide

The Harmonic Series

	$\lambda_1 = 2L$	f_1	fundamental frequency, or first harmonic
	$\lambda_2 = L$	$f_2 = 2f_1$	second harmonic
	$\lambda_3 = \frac{2}{3}L$	$f_3 = 3f_1$	third harmonic
	$\lambda_4 = \frac{1}{2}L$	$f_4 = 4f_1$	fourth harmonic

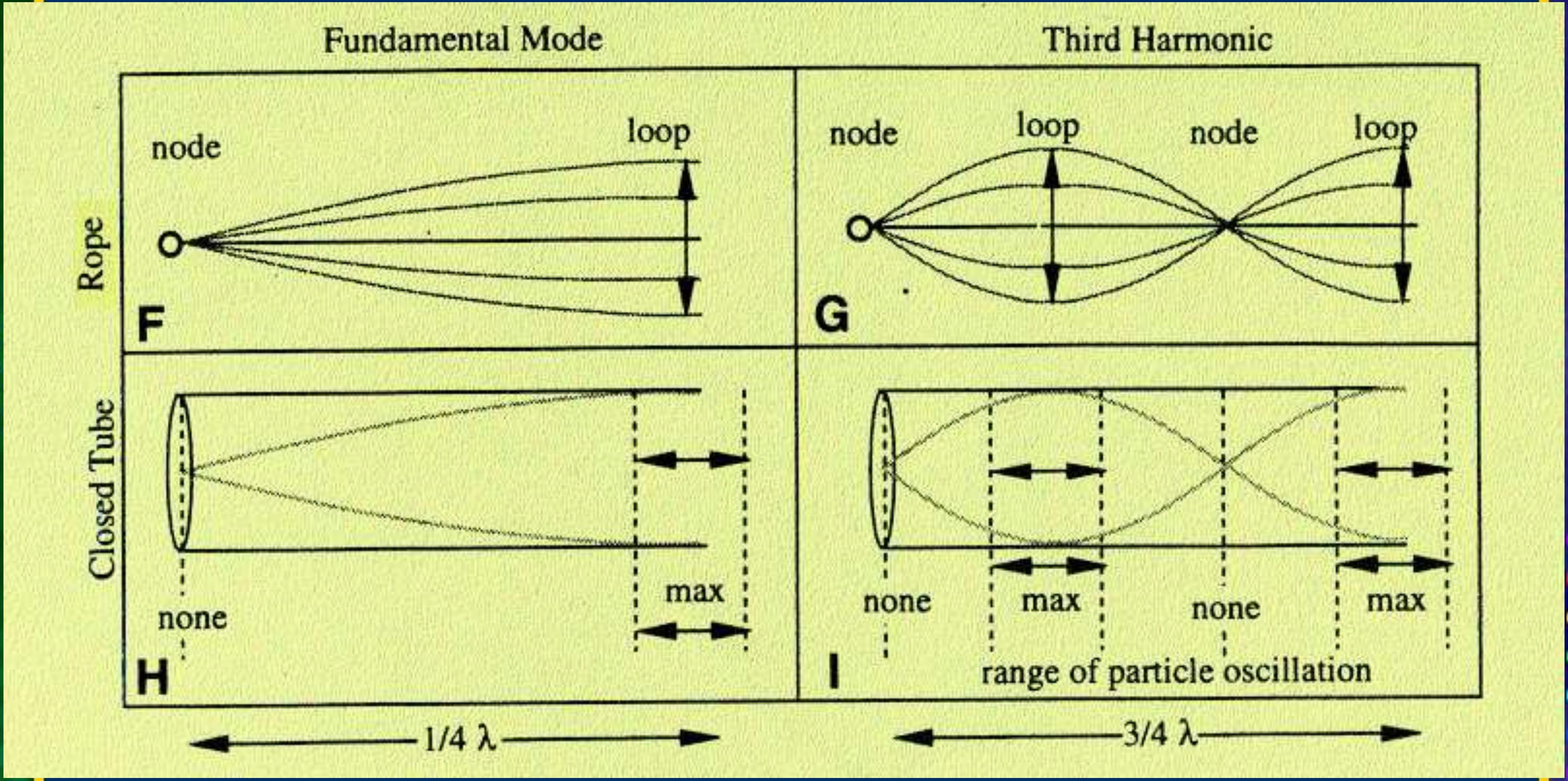
Standing Waves in an Air Column, *continued*

- If **one end** of a pipe is **closed,** there is a node at that end.
- **only odd harmonics are present.**

Harmonic Series of a Pipe Closed at One End

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

$$\text{frequency} = \text{harmonic number} \times \frac{\text{(speed of sound in the pipe)}}{\text{(4)(length of vibrating air column)}}$$



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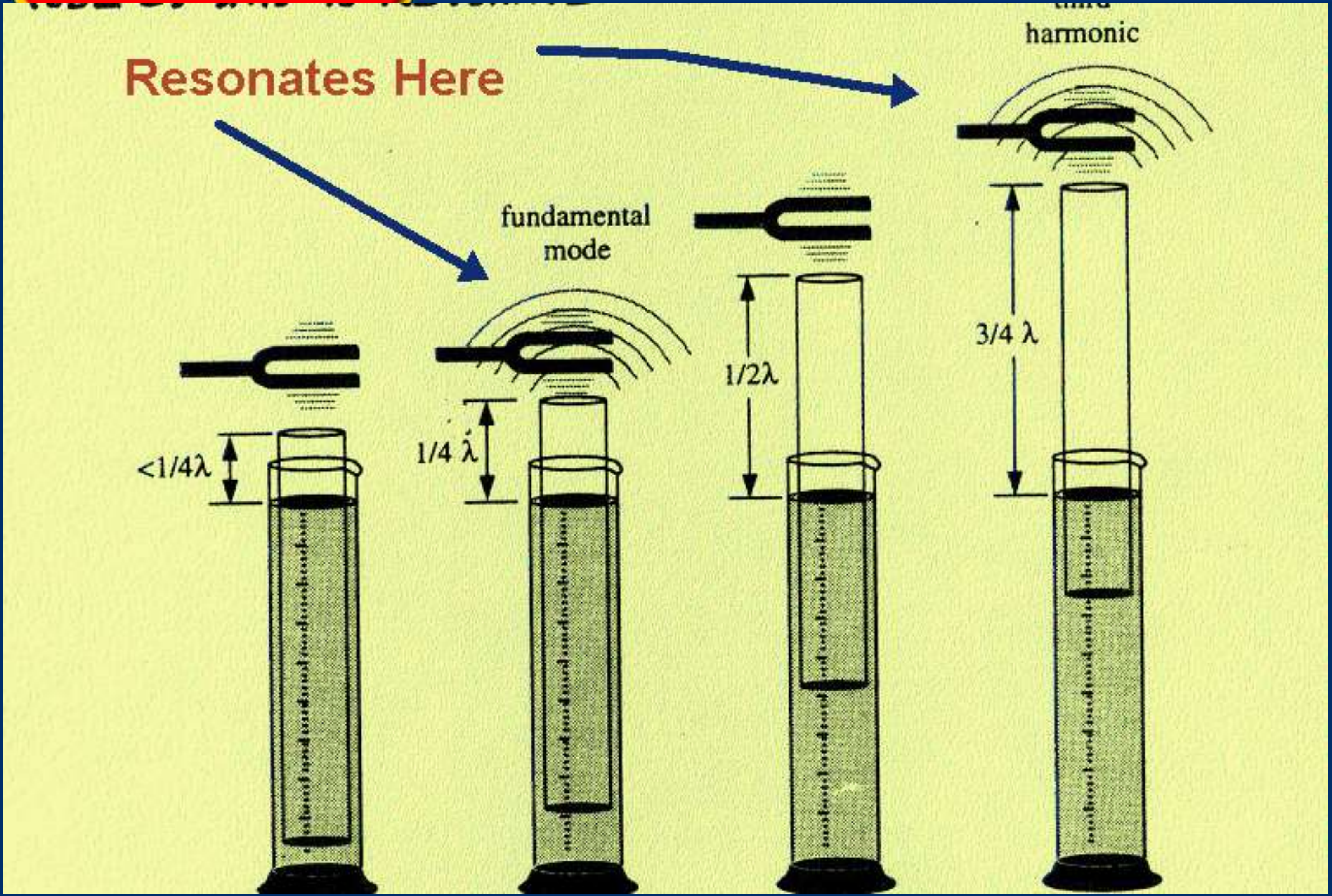

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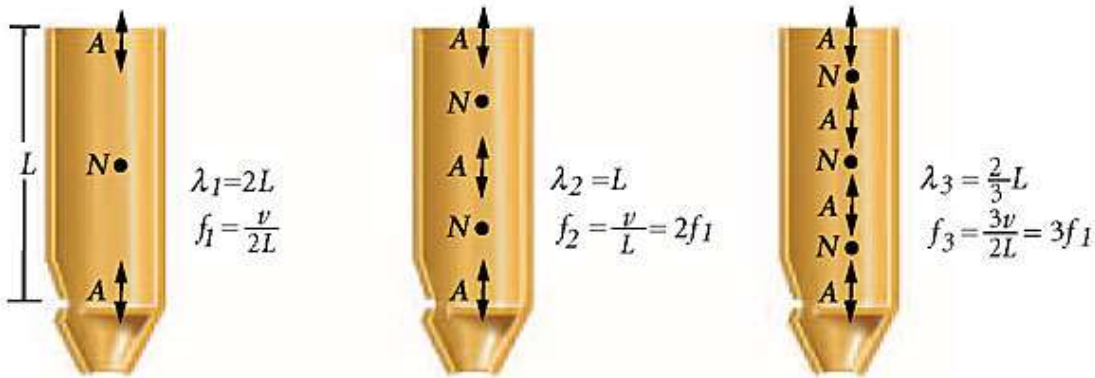
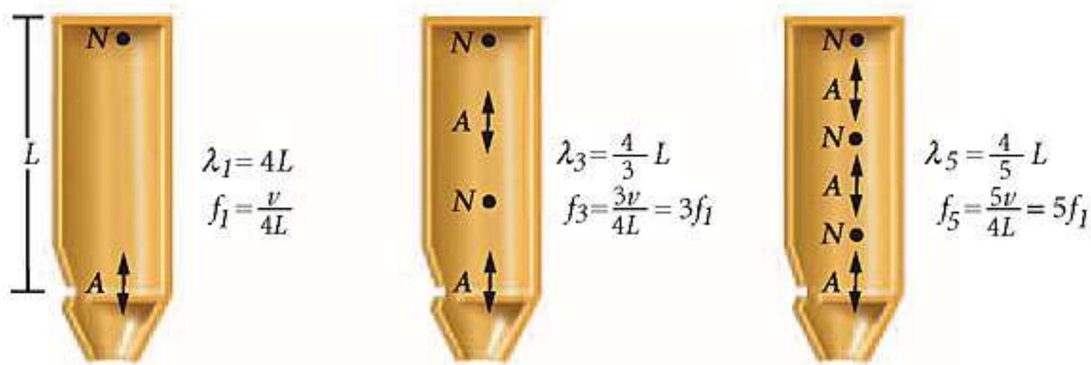
Harmonics of Open and Closed Pipes

Harmonics in an open-ended pipe



Harmonics in a pipe closed at one end



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Sample Problem

Harmonics

What are the first three harmonics in a 2.45 m long pipe that is open at both ends? What are the first three harmonics when one end of the pipe is closed? Assume that the speed of sound in air is 345 m/s.

1. **Define**

Given:

L = 2.45 m v = 345 m/s

Unknown:

Case 1: f_1, f_2, f_3 Case 2: f_1, f_3, f_5

End of Slide

Chapter menu Resources

Sample Problem

2. Plan

Choose an equation or situation:

Case 1:

$$f_n = n\frac{v}{2L} \qquad n = 1, 2, 3, \ldots$$

Case 2:

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

In both cases, the second two harmonics can be found by multiplying the harmonic numbers by the fundamental frequency.

Sample Problem

3. Calculate

Substitute the values into the equation and solve:

Case 1:

$$f_1 = n\frac{v}{2L} = (1)\left(\frac{(345\ \text{m/s})}{(2)(2.45\ \text{m})}\right) = \boxed{70.4\ \text{Hz}}$$

The next two harmonics are the second and third:

$$f_2 = 2f_1 = (2)(70.4\ \text{Hz}) = \boxed{141\ \text{Hz}}$$

$$f_3 = 3f_1 = (3)(70.4\ \text{Hz}) = \boxed{211\ \text{Hz}}$$

Sample Problem

3. Calculate, *continued*

Case 2:

$$f_1 = n\frac{v}{4L} = (1)\left(\frac{(345 \text{ m/s})}{(4)(2.45 \text{ m})}\right) = \boxed{35.2 \text{ Hz}}$$

The next two harmonics are the third and the fifth:

$$f_3 = 3f_1 = (3)(35.2 \text{ Hz}) = \boxed{106 \text{ Hz}}$$

$$f_5 = 5f_1 = (5)(35.2 \text{ Hz}) = \boxed{176 \text{ Hz}}$$

Tip: *Use the correct harmonic numbers for each situation. For a pipe open at both ends, n = 1, 2, 3, etc. For a pipe closed at one end, only odd harmonics are present, so n = 1, 3, 5, etc.*

Sample Problem

4. Evaluate

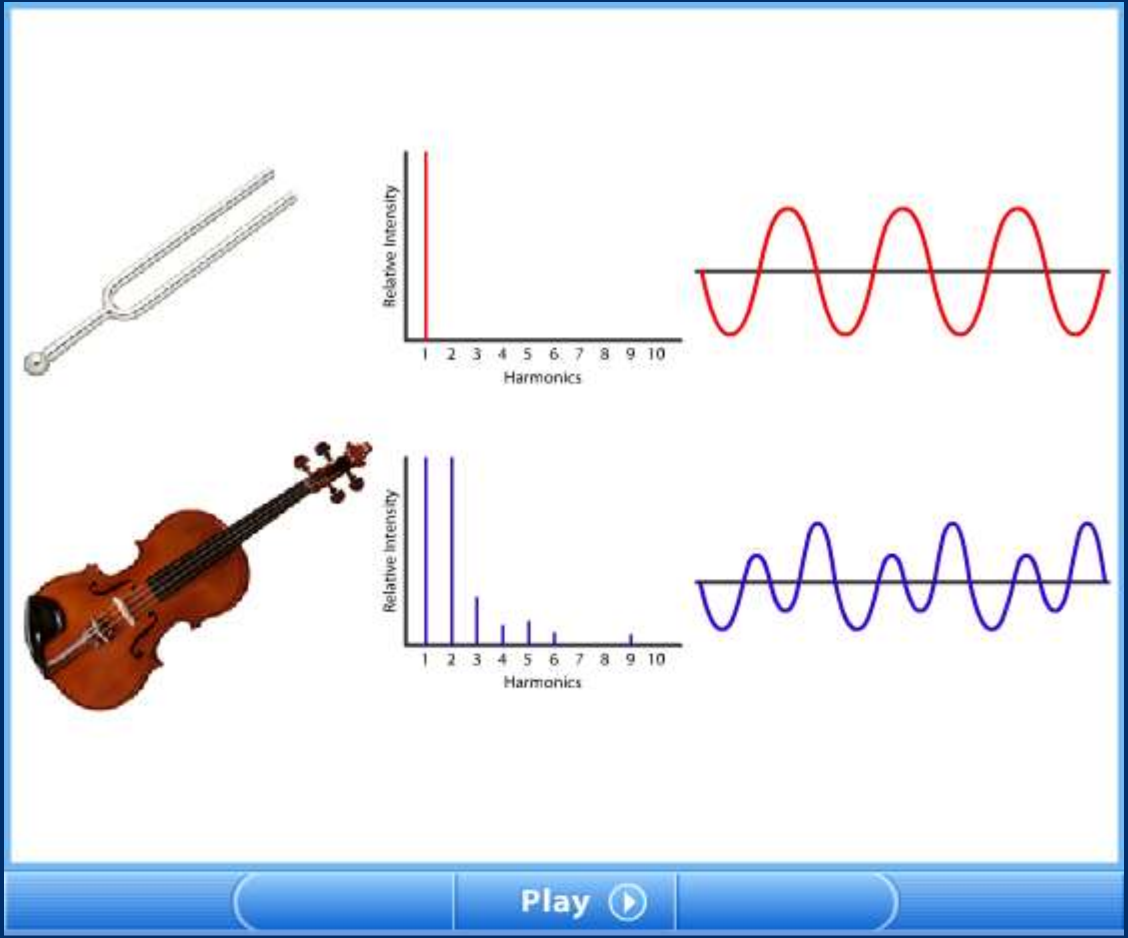
In a pipe open at both ends, the first possible wavelength is $2L$; in a pipe closed at one end, the first possible wavelength is $4L$. Because frequency and wavelength are inversely proportional, the fundamental frequency of the open pipe should be twice that of the closed pipe, that is, 70.4 = (2)(35.2).

End Of Slide

Objectives

- **Calculate** the intensity of sound waves.
- **Relate** intensity, decibel level, and perceived loudness.
- **Explain** why resonance occurs.

Timbre



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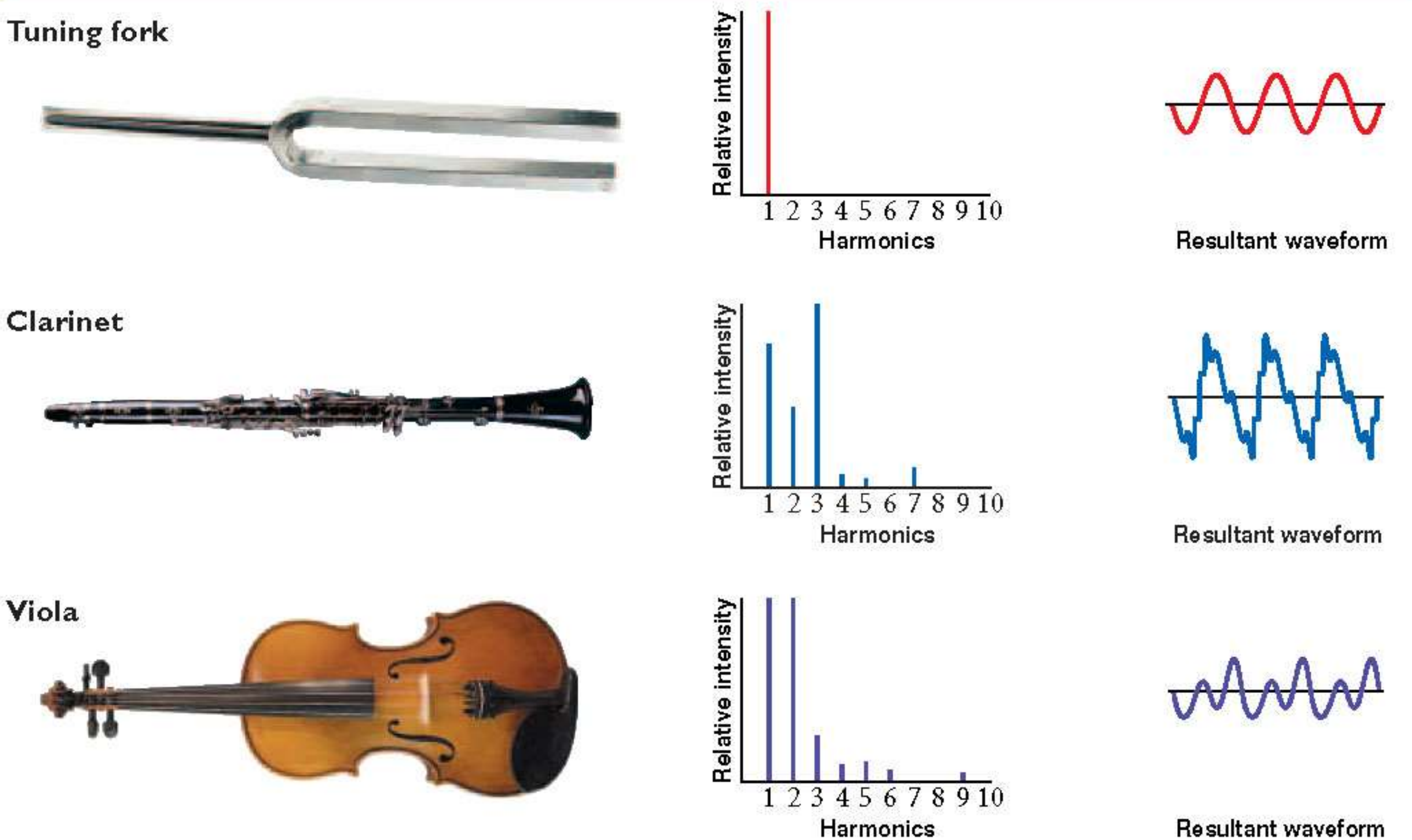
Timbre

- **Timbre** is the the musical quality of a tone resulting from the combination of harmonics present at different intensities.
- A clarinet sounds different from a viola because of **differences in timbre,** even when both instruments are sounding the same note at the same volume.
- The rich harmonics of most instruments provide a much fuller sound than that of a tuning fork.

End Of Slide

Harmonics of Musical Instruments



Multiple Choice

1. When a part of a sound wave travels from air into water, which property of the wave remains unchanged?

   A. speed

   B. frequency

   C. wavelength

   D. amplitude

Multiple Choice

1. When a part of a sound wave travels from air into water, which property of the wave remains unchanged?

A. speed

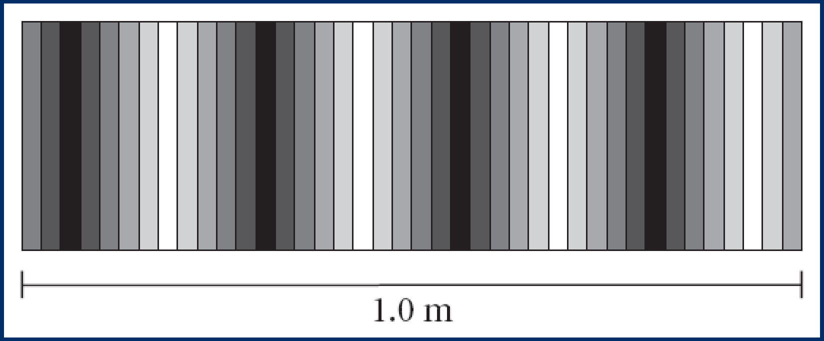
B. frequency

C. wavelength

D. amplitude

Multiple Choice, *continued*

2. What is the wavelength of the sound wave shown in the figure?



F. 1.00 m

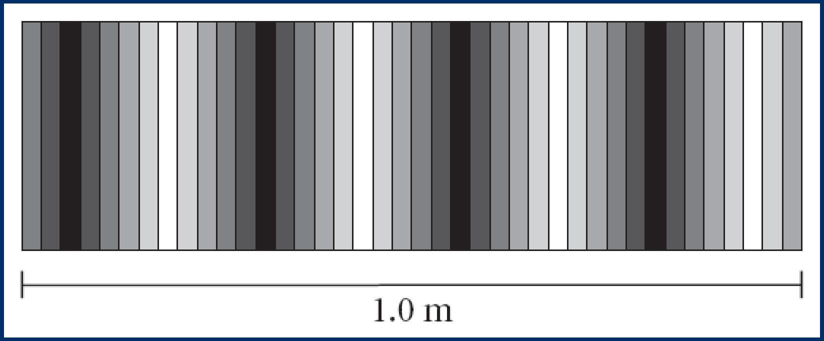
G. 0.75 m

H. 0.50 m

J. 0.25 m

Multiple Choice, *continued*

2. What is the wavelength of the sound wave shown in the figure?



F. 1.00 m

G. 0.75 m

H. 0.50 m

J. 0.25 m

End of Slide

Multiple Choice, *continued*

3. If a sound seems to be getting louder, which of the following is probably increasing?

A. speed of sound

B. frequency

C. wavelength

D. intensity

Multiple Choice, *continued*

3. If a sound seems to be getting louder, which of the following is probably increasing?

A. speed of sound

B. frequency

C. wavelength

D. intensity

Multiple Choice, *continued*

4. The intensity of a sound wave increases by 1000 W/m^2. What is this increase equal to in decibels?

F. 10

G. 20

H. 30

J. 40

End Of Slide

Multiple Choice, *continued*

4. The intensity of a sound wave increases by 1000 W/m^2. What is this increase equal to in decibels?

F. 10

G. 20

H. 30

J. 40

End of Slide

Multiple Choice, *continued*

5. The Doppler effect occurs in all but which of the following situations?

A. A source of sound moves toward a listener.

B. A listener moves toward a source of sound.

C. A listener and a source of sound remain at rest with respect to each other.

D. A listener and a source of sound move toward or away from each other.

Multiple Choice, *continued*

5. The Doppler effect occurs in all but which of the following situations?

A. A source of sound moves toward a listener.

B. A listener moves toward a source of sound.

C. A listener and a source of sound remain at rest with respect to each other.

D. A listener and a source of sound move toward or away from each other.

Multiple Choice, *continued*

6. If the distance from a point source of sound is tripled, by what factor is the sound intensity changed?

F. 1/9

G. 1/3

H. 3

J. 9

Multiple Choice, *continued*

6. If the distance from a point source of sound is tripled, by what factor is the sound intensity changed?

F. 1/9

G. 1/3

H. 3

J. 9

Multiple Choice, *continued*

7. Why can a dog hear a sound produced by a dog whistle, but its owner cannot?

A. Dogs detect sounds of less intensity than do humans.

B. Dogs detect sounds of higher frequency than do humans.

C. Dogs detect sounds of lower frequency than do humans.

D. Dogs detect sounds of higher speed than do humans.

End of Slide

Multiple Choice, *continued*

7. Why can a dog hear a sound produced by a dog whistle, but its owner cannot?

A. Dogs detect sounds of less intensity than do humans.

B. Dogs detect sounds of higher frequency than do humans.

C. Dogs detect sounds of lower frequency than do humans.

D. Dogs detect sounds of higher speed than do humans.

Multiple Choice, *continued*

8. The greatest value ever achieved for the speed of sound in air is about 1.0×10^{4} m/s, and the highest frequency ever produced is about 2.0×10^{10} Hz. If a single sound wave with this speed and frequency were produced, what would its wavelength be?

F. 5.0×10^{-6} m

G. 5.0×10^{-7} m

H. 2.0×10^{6} m

J. 2.0×10^{14} m

End of Slide

Multiple Choice, *continued*

8. The greatest value ever achieved for the speed of sound in air is about 1.0×10^4 m/s, and the highest frequency ever produced is about 2.0×10^{10} Hz. If a single sound wave with this speed and frequency were produced, what would its wavelength be?

F. 5.0×10^{-6} m

G. 5.0×10^{-7} m

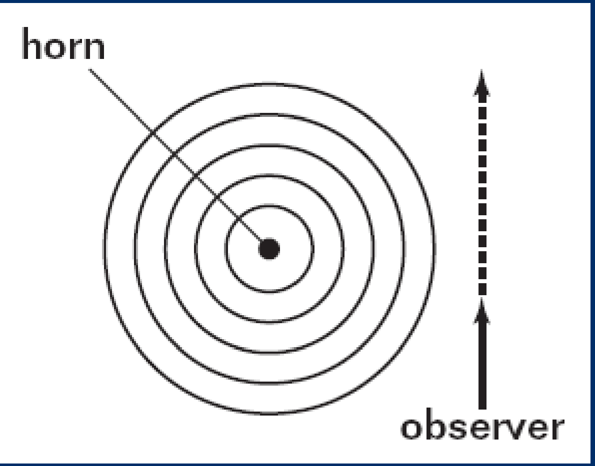
H. 2.0×10^{6} m

J. 2.0×10^{14} m

End of Slide

Multiple Choice, *continued*

9. The horn of a parked automobile is stuck. If you are in a vehicle that passes the automobile, as shown in the diagram, what is the nature of the sound that you hear?



A. The original sound of the horn rises in pitch

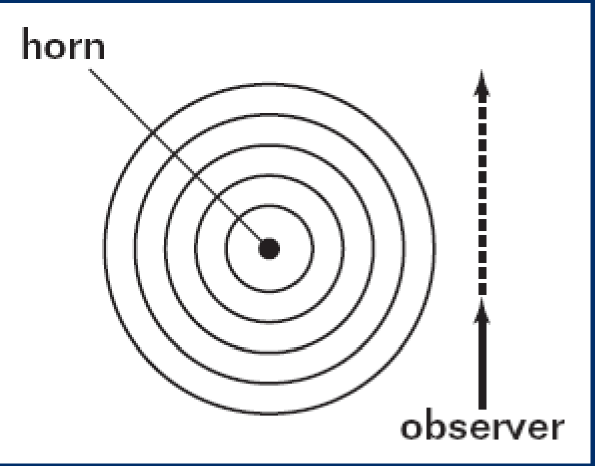
B. The original sound of the horn drops in pitch.

C. A lower pitch is heard rising to a higher pitch.

D. A higher pitch is heard dropping to a lower pitch.

Multiple Choice, *continued*

9. The horn of a parked automobile is stuck. If you are in a vehicle that passes the automobile, as shown in the diagram, what is the nature of the sound that you hear?



A. The original sound of the horn rises in pitch

B. The original sound of the horn drops in pitch.

C. A lower pitch is heard rising to a higher pitch.

D. A higher pitch is heard dropping to a lower pitch.

End of Slide

Multiple Choice, *continued*

10. The second harmonic of a guitar string has a frequency of 165 Hz. If the speed of waves on the string is 120 m/s, what is the string's length?

F. 0.36 m

G. 0.73 m

H. 1.1 m

J. 1.4 m

Multiple Choice, *continued*

10. The second harmonic of a guitar string has a frequency of 165 Hz. If the speed of waves on the string is 120 m/s, what is the string's length?

F. 0.36 m

G. 0.73 m

H. 1.1 m

J. 1.4 m

Short Response

11. Two wind instruments produce sound waves with frequencies of 440 Hz and 447 Hz, respectively. How many beats per second are heard from the superposition of the two waves?

Short Response

11. Two wind instruments produce sound waves with frequencies of 440 Hz and 447 Hz, respectively. How many beats per second are heard from the superposition of the two waves?

Answer: 7 beats per second (7 Hz)

End of Slide

Short Response, *continued*

12. If you blow across the open end of a soda bottle and produce a tone of 250 Hz, what will be the frequency of the next harmonic heard if you blow much harder?

Short Response, *continued*

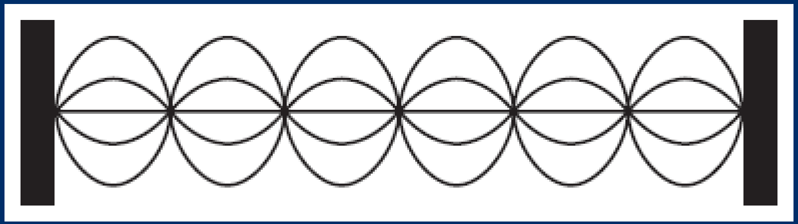
12. If you blow across the open end of a soda bottle and produce a tone of 250 Hz, what will be the frequency of the next harmonic heard if you blow much harder?

Answer: 750 Hz

End of Slide

Short Response, *continued*

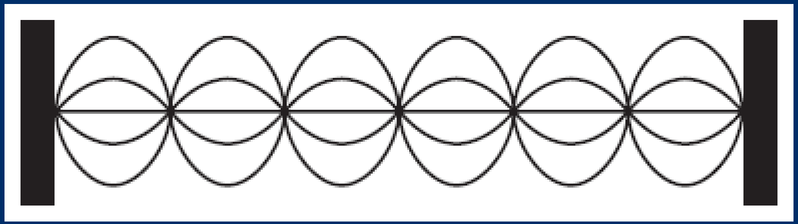
13. The figure shows a string vibrating in the sixth harmonic. The length of the string is 1.0 m. What is the wavelength of the wave on the string?



End of Slide

Short Response, *continued*

13. The figure shows a string vibrating in the sixth harmonic. The length of the string is 1.0 m. What is the wavelength of the wave on the string?



Answer: 0.33 m

Short Response, *continued*

14. The power output of a certain loudspeaker is 250.0 W. If a person listening to the sound produced by the speaker is sitting 6.5 m away, what is the intensity of the sound?

End of Slide

Short Response, *continued*

14. The power output of a certain loudspeaker is 250.0 W. If a person listening to the sound produced by the speaker is sitting 6.5 m away, what is the intensity of the sound?

Answer: 0.47 W/m^2

End of Slide

Extended Response

Use the following information to solve problems 15–16. Be sure to show all of your work.

The area of a typical eardrum is approximately equal to 5.0×10^{-5} m^2.

15. What is the sound power (the energy per second) incident on the eardrum at the threshold of pain (1.0 W/m^2)?

End Of Slide

Extended Response

Use the following information to solve problems 15–16. Be sure to show all of your work.

The area of a typical eardrum is approximately equal to 5.0×10^{-5} m^2.

15. What is the sound power (the energy per second) incident on the eardrum at the threshold of pain (1.0 W/m^2)?

Answer: 5.0×10^{-5} W

End of Slide

Extended Response, *continued*

Use the following information to solve problems 15–16. Be sure to show all of your work.

The area of a typical eardrum is approximately equal to 5.0×10^{-5} m^2.

16. What is the sound power (the energy per second) incident on the eardrum at the threshold of hearing (1.0×10^{-12} W/m^2)?

End of Slide

Extended Response, *continued*

Use the following information to solve problems 15–16. Be sure to show all of your work.

The area of a typical eardrum is approximately equal to 5.0×10^{-5} m^2.

16. What is the sound power (the energy per second) incident on the eardrum at the threshold of hearing (1.0×10^{-12} W/m^2)?

Answer: 5.0×10^{-17} W

End Of Slide

Extended Response, *continued*

Use the following information to solve problems 17–19. Be sure to show all of your work.

A pipe that is open at both ends has a fundamental frequency of 456 Hz when the speed of sound in air is 331 m/s.

17. How long is the pipe?

Extended Response, *continued*

Use the following information to solve problems 17–19. Be sure to show all of your work.

A pipe that is open at both ends has a fundamental frequency of 456 Hz when the speed of sound in air is 331 m/s.

17. How long is the pipe?

Answer: 0.363 m

End of Slide

Extended Response, *continued*

Use the following information to solve problems 17–19. Be sure to show all of your work.

A pipe that is open at both ends has a fundamental frequency of 456 Hz when the speed of sound in air is 331 m/s.

18. What is the frequency of the pipe's second harmonic?

End of Slide

Extended Response, *continued*

Use the following information to solve problems 17–19. Be sure to show all of your work.

A pipe that is open at both ends has a fundamental frequency of 456 Hz when the speed of sound in air is 331 m/s.

18. What is the frequency of the pipe's second harmonic?

Answer: 912 Hz

End Of Slide

Extended Response, *continued*

Use the following information to solve problems 17–19. Be sure to show all of your work.

A pipe that is open at both ends has a fundamental frequency of 456 Hz when the speed of sound in air is 331 m/s.

19. What is the fundamental frequency of this pipe when the speed of sound in air is increased to 367 m/s as a result of a rise in the temperature of the air?

End of Slide

Extended Response, *continued*

Use the following information to solve problems 17–19. Be sure to show all of your work.

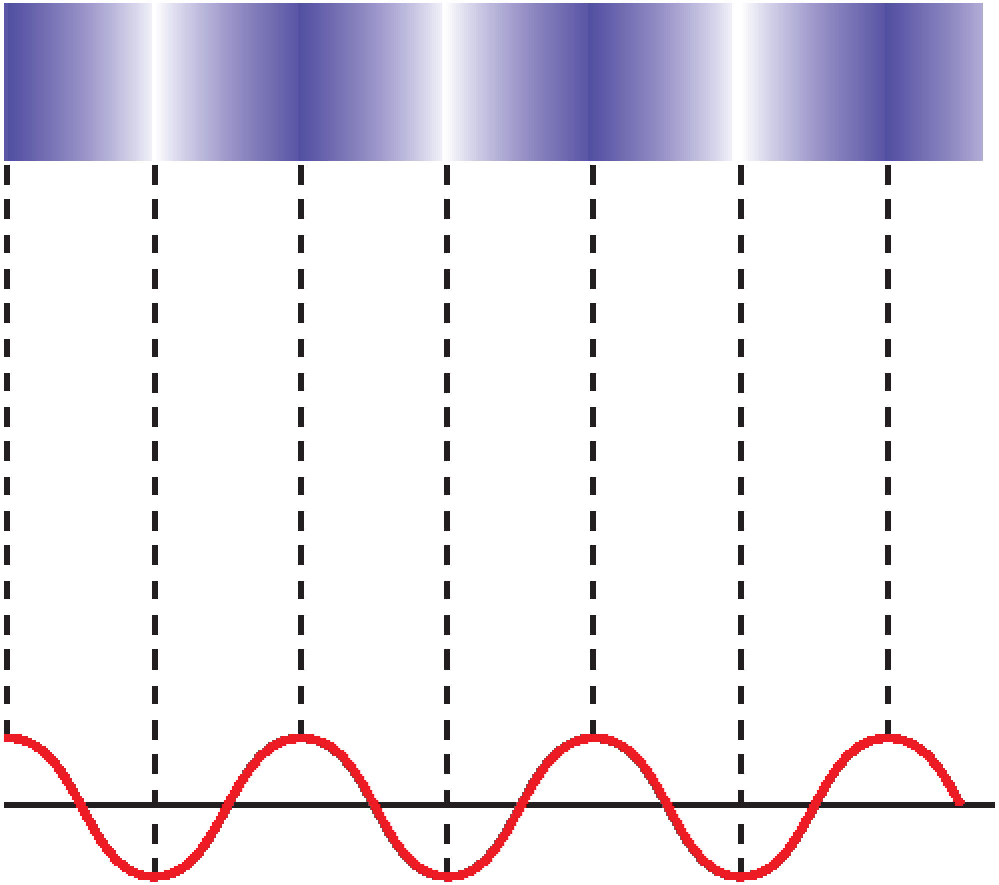
A pipe that is open at both ends has a fundamental frequency of 456 Hz when the speed of sound in air is 331 m/s.

19. What is the fundamental frequency of this pipe when the speed of sound in air is increased to 367 m/s as a result of a rise in the temperature of the air?

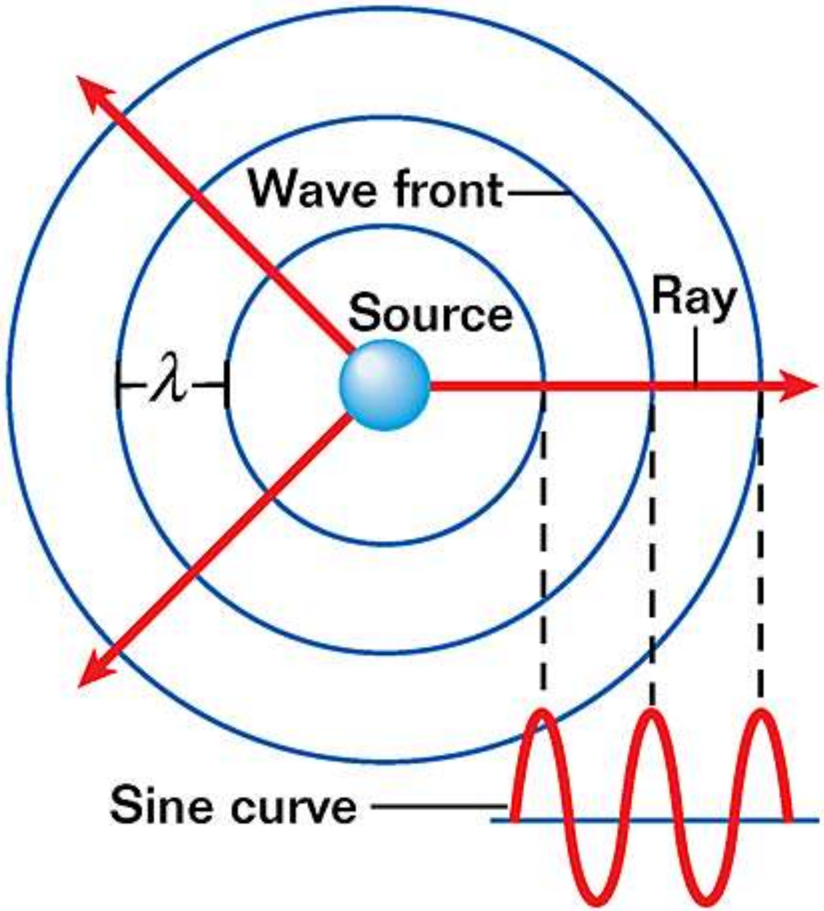
Answer: 506 Hz

End of Slide

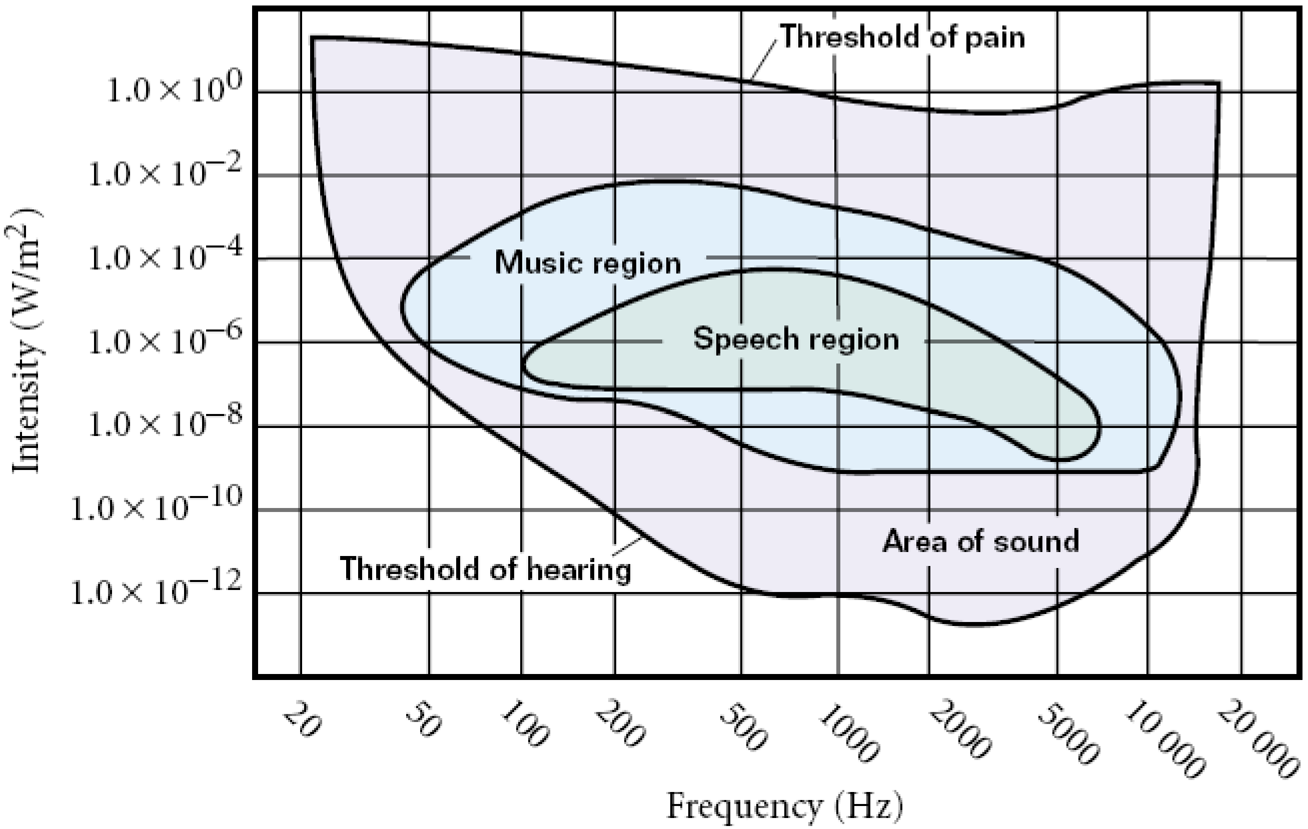
The Production of Sound Waves



The Propagation of Sound Waves



Sound Intensity



The Human Ear