Objectives

- **Explain** how sound waves are produced.
- **Relate** frequency to pitch.
- **Compare** the speed of sound in various media.
- **Recognize** the Doppler effect, and **determine** the direction of a frequency shift when there is relative motion between a source and an observer.
The Production of Sound Waves

- Every sound wave begins with a _vibration_, such as the vibrating prong of a tuning fork.

- A _compression_ is the region of a longitudinal wave in which the density and pressure are at a maximum.

- A _rarefaction_ is the region of a longitudinal wave in which the density and pressure are at a minimum.
The Production of Sound Waves, continued

- Sound waves are __________.
- The simplest longitudinal wave produced by a vibrating object can be represented by a ______ __________
- In the diagram, the ______ of the sine curve correspond to __________, and the ________ correspond to __________.

Frequency of Sound Waves

- As discussed earlier, __________ is defined as the number of cycles per unit of time.
- Sound waves that the average human ear can hear, called ______ sound waves, have frequencies between ________________.
- Sound waves with frequencies __________ are called ________ waves.
- Sound waves with frequencies __________ are called ________ waves.
Chapter 12  Section 1  Sound Waves

Frequency of Sound Waves

- The \________\ of an audible sound wave determines how \________\ we perceive the sound to be, which is known as \________\.
- As the frequency of a sound wave \________\, the pitch \________\.
- The frequency of a wave is an objective quantity that can be measured, while pitch refers to how different frequencies are perceived by the human ear.

Chapter 12  Section 1  Sound Waves

Frequency and Pitch

- The \________\ of an audible sound wave determines how \________\ we perceive the sound to be, which is known as \________\.
- As the frequency of a sound wave \________\, the pitch \________\.
- The frequency of a wave is an objective quantity that can be measured, while pitch refers to how different frequencies are perceived by the human ear.
The speed of sound depends on the __________.
- Because waves consist of particle vibrations, the speed of a wave depends on how quickly one particle can transfer its motion to another particle.
- For example, sound waves generally travel faster through solids than through gases because the molecules of a solid are closer together than those of a gas are.

The speed of sound also depends on the ______________ of the medium. This is most noticeable with gases.
The Speed of Sound in Various Media

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

The Propagation of Sound Waves

- Sound waves propagate in three dimensions.
- Spherical waves can be represented graphically in two dimensions, as shown in the diagram.
- The circles represent the centers of compressions, called ____________.
- The radial lines perpendicular to the wave fronts are called ____________.
- The sine curve used in our previous representation corresponds to a single ray.
Chapter 12

Section 1 Sound Waves

The Propagation of Sound Waves, continued

- At distances from the source that are great relative to the wavelength, we can approximate _______ with _______.
- Such waves are called _______.
- Plane waves can be treated as one-dimensional waves all traveling in the same direction.

The Doppler Effect
Chapter 12

The Doppler Effect

- The _______________ is an observed change in frequency when there is _______________ between the source of waves and an observer.
- Because frequency determines pitch, the Doppler effect affects the ________ heard by each listener.
- Although the Doppler effect is most commonly experienced with sound waves, it is a phenomenon common to all waves, including electromagnetic waves, such as visible light.

Chapter 12

Section 2 Sound Intensity and Resonance

Objectives

- Relate intensity, decibel level, and perceived loudness with amplitude of the wave
- Explain why resonance occurs.
Sound Intensity

• As sound waves travel, energy is transferred from one molecule to the next. The rate at which this energy is transferred through a unit area of the plane wave is called the ________ of the wave.

Sound Intensity, continued

• Human hearing depends on both the ________ and the ________ of sound waves.
• Sounds in the middle of the spectrum of frequencies can be heard more easily (at lower intensities) than those at lower and higher frequencies.
Chapter 12

Sound Intensity, continued

• The _________ of a wave approximately determines its perceived _________ and _________ of the wave.

• However, loudness is not directly proportional to intensity. The reason is that the sensation of loudness is approximately logarithmic in the human ear.

• _________ is the ratio of the intensity of a given sound wave to the intensity at the threshold of hearing.

Section 2  Sound Intensity and Resonance

• Because of the logarithmic dependence of perceived loudness on intensity, using a number equal to 10 times the logarithm of the relative intensity provides a good indicator for human perceptions of loudness.

• This is referred to as the _________.

• A dimensionless unit called the _________ is used for values on this scale.
Section 2 Sound Intensity and Resonance

Conversion of Intensity to Decibel Level

<table>
<thead>
<tr>
<th>Intensity (W/m²)</th>
<th>Decibel level (dB)</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 × 10⁻¹²</td>
<td>0</td>
<td>threshold of hearing</td>
</tr>
<tr>
<td>1.0 × 10⁻¹¹</td>
<td>10</td>
<td>rustling leaves</td>
</tr>
<tr>
<td>1.0 × 10⁻¹⁰</td>
<td>20</td>
<td>quiet whisper</td>
</tr>
<tr>
<td>1.0 × 10⁻⁹</td>
<td>30</td>
<td>whisper</td>
</tr>
<tr>
<td>1.0 × 10⁻⁸</td>
<td>40</td>
<td>mosquito buzzing</td>
</tr>
<tr>
<td>1.0 × 10⁻⁷</td>
<td>50</td>
<td>normal conversation</td>
</tr>
<tr>
<td>1.0 × 10⁻⁶</td>
<td>60</td>
<td>air conditioning at 6 m</td>
</tr>
<tr>
<td>1.0 × 10⁻⁵</td>
<td>70</td>
<td>vacuum cleaner</td>
</tr>
<tr>
<td>1.0 × 10⁻⁴</td>
<td>80</td>
<td>busy traffic, alarm clock</td>
</tr>
<tr>
<td>1.0 × 10⁻³</td>
<td>90</td>
<td>lawn mower</td>
</tr>
<tr>
<td>1.0 × 10⁻²</td>
<td>100</td>
<td>subway, power mower</td>
</tr>
<tr>
<td>1.0 × 10⁻¹</td>
<td>110</td>
<td>auto horn at 1 m</td>
</tr>
<tr>
<td>1.0 × 10⁰</td>
<td>120</td>
<td>threshold of pain</td>
</tr>
<tr>
<td>1.0 × 10¹</td>
<td>130</td>
<td>thunderclap, machine gun</td>
</tr>
<tr>
<td>1.0 × 10²</td>
<td>150</td>
<td>nearby jet airplane</td>
</tr>
</tbody>
</table>

Forced Vibrations and Resonance

- If one of the pendulums is set in motion, its vibrations are transferred by the rubber band to the other pendulums, which will also begin vibrating. This is called a ______________.
- Each pendulum has a ______________ based on its length.
Forced Vibrations and Resonance, continued

- __________ is a phenomenon that occurs when the frequency of a force applied to a system matches the __________ of vibration of the system, resulting in a __________ __________.

- If one blue pendulum is set in motion, only the other blue pendulum, whose length is the same, will eventually resonate.

Resonance

One object can cause another object to vibrate through resonance.
The Human Ear

• The human ear is divided into three sections—outer, middle, and inner.

• Sound waves travel through the three regions of the ear and are then transmitted to the brain as impulses through nerve endings on the basilar membrane.
Extra Material

- Non-Regents Concepts
- Practice Questions for Section 12.1 – 12.2 Follow
Timbre is 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.
Chapter 12

Section 3 Harmonics

Harmonics of Musical Instruments

- Tuning fork
- Clarinet
- Viola

Beats

End of slide.
Beats

- When two waves of *slightly different frequencies* interfere, the interference pattern varies in such a way that a listener hears an alternation between loudness and softness.
- The variation from soft to loud and back to soft is called a *beat*.
- In other words, a *beat* is the periodic variation in the amplitude of a wave that is the superposition of two waves of slightly different frequencies.
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

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

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

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

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.

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

F. $5.0 \times 10^{-6}$ m
G. $5.0 \times 10^{-7}$ m
H. $2.0 \times 10^6$ m
J. $2.0 \times 10^{14}$ m
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.

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?