PowerPoint Lectures

Physical Science, 8e

Chapter 5
Wave Motions and Sound

New Symbols for this Chapter

T-Period
f-Frequency
v-Wave speed
λ-Wavelength
A-Amplitude

$$f = \frac{1}{T}$$

$$T = \frac{1}{f}$$

$$v = f\lambda$$

$$v = 331 + .6 \times T(in\ ^\circ C)$$

Core Concept

Sound is transmitted as increased and decreased pressure waves that carry energy.

Forces and Elastic Materials

Elastic material
- Capable of recovering shape after deformation
- Rubber ball versus lump of clay

Spring forces
1. Applied force proportional to distance spring is compressed or stretched
2. Internal restoring force arises, returning spring to original shape
3. Restoring force also proportional to stretched or compressed distance

Forces and Vibrations

- Vibration - repetitive back and forth motion
- Periodic motion - a motion that repeats itself
- When disturbed from equilibrium position, restoring force acts toward equilibrium
- Carried by inertia past equilibrium to other extreme
- Example of "simple harmonic motion"

Describing Vibrations

- Amplitude - maximum extent of displacement from equilibrium
- Cycle - one complete vibration
- Period - time for one cycle
- Frequency - number of cycles per second (units = hertz, Hz)
- Period and frequency inversely related

Waves

- Periodic disturbances transporting energy
- Causes
  - Period motion disturbing surroundings
  - Pulse disturbance of short duration
- Mechanical waves
  - Require medium for propagation
  - Waves move through medium
  - Medium remains in place

Kinds of Waves

Longitudinal waves

- Vibration direction parallel to wave propagation direction
- Particles in medium move closer together/farther apart

Transverse waves

- Vibration direction perpendicular to wave propagation direction

Longitudinal Waves

Compression

Expansion

In a **Longitudinal Wave**, the particles of the medium move parallel to the wave direction.

In a longitudinal waves can travel in solids, liquids or gasses.

Transverse Waves

In a **Transverse Wave**, the particles of the medium move at a right angle to the direction that the wave moves.

Transverse waves occur only in solids.

Transverse waves only occur in solids since in a transverse wave the particles must drag along the particles behind them.

Longitudinal waves can move through any type of matter since the particles only have to push the particles in front of them and in back of them.

Waves in Air

- Longitudinal waves only
- Large scale - swinging door creates macroscopic currents
- Small scale - tuning fork creates sound waves
- Series of condensations (overpressures) and rarefactions (underpressures)

Describing Waves

Graphical representation

- Pure harmonic waves = sines or cosines

Properties of Waves

Amplitude-The maximum displacement of any particle from its normal position. (*A* measured in units of length)

Wavelength- The distance from peak to peak or from one part of the wave to where that part shows up again. (λ in any length units)

Frequency-The number of waves that pass a given point per second. (*f* measured in s^{-1} or **Hertz** [**Hz**])

Period-The time needed for complete wavelength to pass a given point. (*T* measured in s)

Speed- The rate at which a wave will move through a substan
(*v* measured in m/s)

Relations Between Properties of Waves

The period of a wave is the inverse of the frequency.

$$T = \frac{1}{f}$$

$$v = \lambda f = \frac{\lambda}{T}$$

The speed of a wave is equal to the wavelength of the wave times the frequency.

Sound Waves

- Require medium for transmission
- Speed varies with
  - Inertia of molecules
  - Interaction strength
  - Temperature
- Various speeds of sound

Medium	m/s	ft/s
Air (0°C)	331	1087
Hydrogen (0°C)	1284	4213
Water (25°C)	1497	4911
Lead	1960	6430
Steel	5940	19488

Example 1 (Parallel Exercise Group B #19)

1) A 600 Hz sound has a velocity 0f 1,087 ft/s in the air and a velocity 0f 4,920 ft/s in water. Find the wavelength of this sound in
   a) Air and
   b) Water

Waves in Air and Hearing

Range of human hearing: 20-20,000 Hz

- Infrasonic
  - Below 20 Hz
  - Felt more than heard
- Ultrasonic
  - Dogs, cats, rats & bats
  - Used in imaging
- Mechanism in ear

Velocity of Sound in Air

- Varies with temperature
- Greater kinetic energy → sound impulse transmitted faster
- Increase factor (units!): 0.6 m/s/°C; 2.0 ft/s/°C

Visualization of Waves

- Sound = spherical wave moving out from source
- Each crest = wave front
- Wave motion traced with wave fronts
- Far from source, wave front becomes planar

Refraction and Reflection

- Boundary effects
  - Reflection - wave bounces off boundary
  - Refraction - direction of wave front changes
  - Absorption - wave energy dissipated
- Types of boundaries
  - Between different materials
  - Between regions of the same material under different conditions (temperature, pressure)

Refraction

- Bending of wave fronts upon encountering a boundary
  - Between two different media
  - Between different physical circumstances in the same medium
- Example - temperature gradient in air

Reflection

- Wave rebounding off boundary surface
- Reverberation - sound enhancement from mixing of original and reflected sound waves
- Echo
  - Can be distinguished by human ear if time delay between original and reflected sound is greater then 0.1 s
  - Used in sonar and ultrasonic imaging

Interference

- Two or more waves combine
- Constructive interference
  - Peaks aligned with peaks; troughs aligned with troughs
  - Total wave enhanced

Interference, cont.

- Destructive interference
  - Peaks aligned with troughs
  - Cancellation leads to diminished wave
- Beats
  - Overall modulation of sound from mixing of two frequencies
  - Beat frequency = difference in two frequencies

Sound Intensity

The intensity of a sound is defined as the rate of energy output of the sound source divided by the area over which that the sound is spread.

$$I = \frac{P}{A}$$

The scale used to measure the intensity (or loudness) of sound is the ***bel*** **(B)** scale named after Alexander Graham Bell. The more common unit is the ***decibel*** **(dB)** which is ***1/10*** of a ***bel (B).***

Example 2 (Parallel Exercise Group B #2)

1) The lower frequency limit for human hearing is usually considered to be 20 Hz. What is the corresponding wavelength for this frequency if the air temperature is 20°C?

Sources of Sound

- Vibrating objects are the source of all sounds.
- Irregular, chaotic vibrations produce noise.
- Regular, controlled vibration can produce music.
- All sound is a combination of pure frequencies.

Vibrating Strings

- Important concepts - strings with fixed ends
  - More than one wave can be present at the same time.
  - Waves reflected and inverted at end points
  - Interference occurs between incoming and reflected waves.

Standing Waves

If you shake a string tied down at one end at the proper frequency a constant pattern will emerge. This pattern is called a **Standing Wave**.

This pattern consists of regions of constructive interference called **Antinodes** and regions of destructive interference called **Nodes**.

The frequencies at which standing are formed are called the **Natural Frequencies**.

Resonant Frequencies of Strings

- Fundamental - lowest frequency
- Higher modes - overtones (first, second, ...)
- Mixture of fundamental and overtones produces “sound quality” of instrument

The Doppler Effect

When a source of sound is moving the sound’s frequency (or pitch) will be different when the sound is moving toward you then when it is moving away from you. This is the **Doppler Effect**.

When the source of the sound is moving toward you the waves are bunched together and you hear a higher pitch.

When the source of the sound is moving away from you the waves are spread out more and you hear a lower pitch.