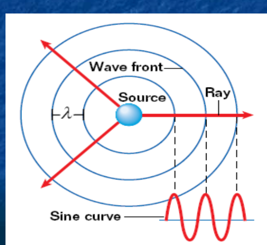
CHAPTER 13

Sound & Sound Properties

Hearing is believing

- How sound can be heard…



"Sound waves are longitudinal"

- Vibrating object
- Compression
- Rarefaction
- Tuning Fork

QuickTime™ and a decompressor are needed to see this picture.

Frequency of Sound Waves

- Definition - number of cycles per unit of time
- Audible Sound - (20 Hz < f < 20,000Hz)
- Inaudible Sound
  - Infrasonic - (f < 20 Hz)
  - Ultrasonic - (f > 20,000 Hz)
- Audible/ Inaudible

"Frequency determines pitch"

- High & Low Pitch
- What is the relationship between frequency & pitch?

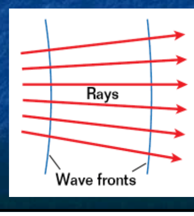
Speed of Sound

- SoS depends on…
  - Medium
    - Ex. Sound travels through solids faster than gases
  - Temperature
    - Most noticeable with gases

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

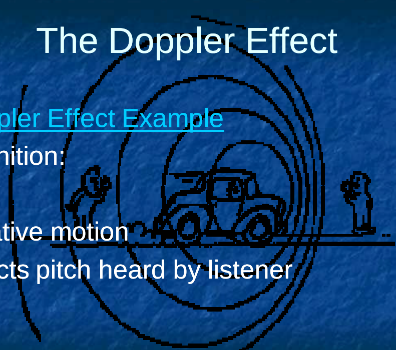
Sound Wave Propagation

- Can travel away from a source in all three dimensions
- Wave fronts
- Rays
- Plane waves
  - Treated as one-dimensional



The Doppler Effect

- Doppler Effect Example
- Definition:
- Relative motion
- Affects pitch heard by listener



Sound Intensity

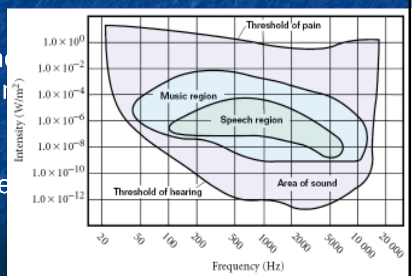
•As sound waves travel, energy is transferred from one molecule to the next. The rate at which this energy is transferred through a unit area of the plane wave is called the **intensity** of the wave.

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

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

Intensity

- UNIT = W / m^2
- Intensity & frequen determi which sounds are audible



Intensity (cont…)

- Sample:
  - What is the intensity of the sound waves produced by a trumpet at a distance of 3.2 m when the power output of the trumpet is 0.20 W? Assume that the sound waves are spherical.

More Intensity…

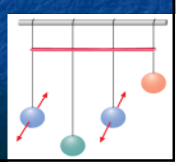
- Relative Intensity
- Decibel Level
  - UNIT = decibel (dB)

Conversion of Intensity to Decibel Level

Intensity (W/m²)	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

Forced Vibrations & Resonance

- A forced vibration at the natural frequency produces resonance
- Resonance - a condition that exists when the frequency of a force applied to a system matches the natural frequency of a vibrating object
  - Results in large amplitude of vib.
- Examples
  - Tacoma Narrows Bridge, 1940
  - Loma Pieta Earthquake, 1989
  - Pendulums -------------------------------->

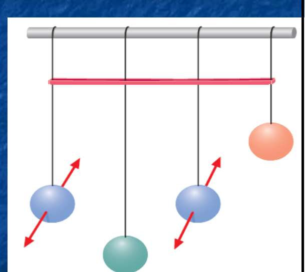


FV & R (Continued…)

•If a pendulum is set in motion, vibrations will be transferred from rubber band to the others (FORCED VIBRATION)

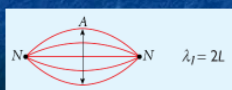
•Natural frequency is based on length

•Guitar



Standing Waves & Sound

- The greatest possible wavelength on a string of length L is $\lambda = 2L$.
- The **fundamental frequency,** which corresponds to this wavelength, is the lowest frequency of vibration.
- Violin
- Fundamental Frequency



$$f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$$

Standing Waves & Harmonics

- The **harmonic series** is a series of frequencies that includes the fundamental frequency and integral multiples of the fundamental frequency.

Harmonic Series of Standing Waves on a Vibrating String

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

Standing Waves in an Air Column

- If **both ends** of a pipe are **open,** there is an antinode at each end.
- In this case, **all harmonics are present,** and the earlier equation for the harmonic series of a vibrating string can be used.
- **Harmonic Series of Standing Waves on a Vibrating String**

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

Standing Waves in an Air Column, *continued*

- If **one end** of a pipe is **closed,** there is a node at that end.
- With an antinode at one end and a node at the other end, a different set of standing waves occurs.
- In this case, **only odd harmonics are present.**

Harmonic Series of a Pipe Closed at One End

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

Harmonics of Open and Closed Pipes