Physics
Chapter 11: Vibrations and Waves
Chapter 12: Sound

Section 12.2

Sound Intensity and Resonance

11/29/2007

Sound Intensity

--Work is done on air molecules when a vibrating object creates sound waves.

--Since work is done, energy is transferred to the molecules; the object eventually stops vibrating as its energy is transferred.

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

--Since <u>power</u> is the <u>rate</u> at which energy is transferred, the intensity of a sound wave can also be expressed in terms of power:

$$\text{intensity} = \frac{\Delta E / \Delta t}{area} = \frac{P}{area}$$

--The SI unit of power is the watt; thus intensity has units of:

$$\frac{\text{watts}}{\text{square meter}} = \frac{W}{m^2}$$

--For a spherical wave, the power is distributed over the surface area of sphere.

$$\text{area of a sphere} = 4\pi R^2$$

$$\text{intensity} = \frac{P}{4\pi r^2}$$

or

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

--The intensity decreases as the distance from the source increases because the same amount of energy is spread over a larger area.

Audible Sounds

--In addition to frequency, the <u>intensity</u> of sound also determines which sounds are audible.

--Sounds with either a high or low frequency must be relatively intense to be heard.

--Sounds with a medium frequency can be heard at lower intensities.

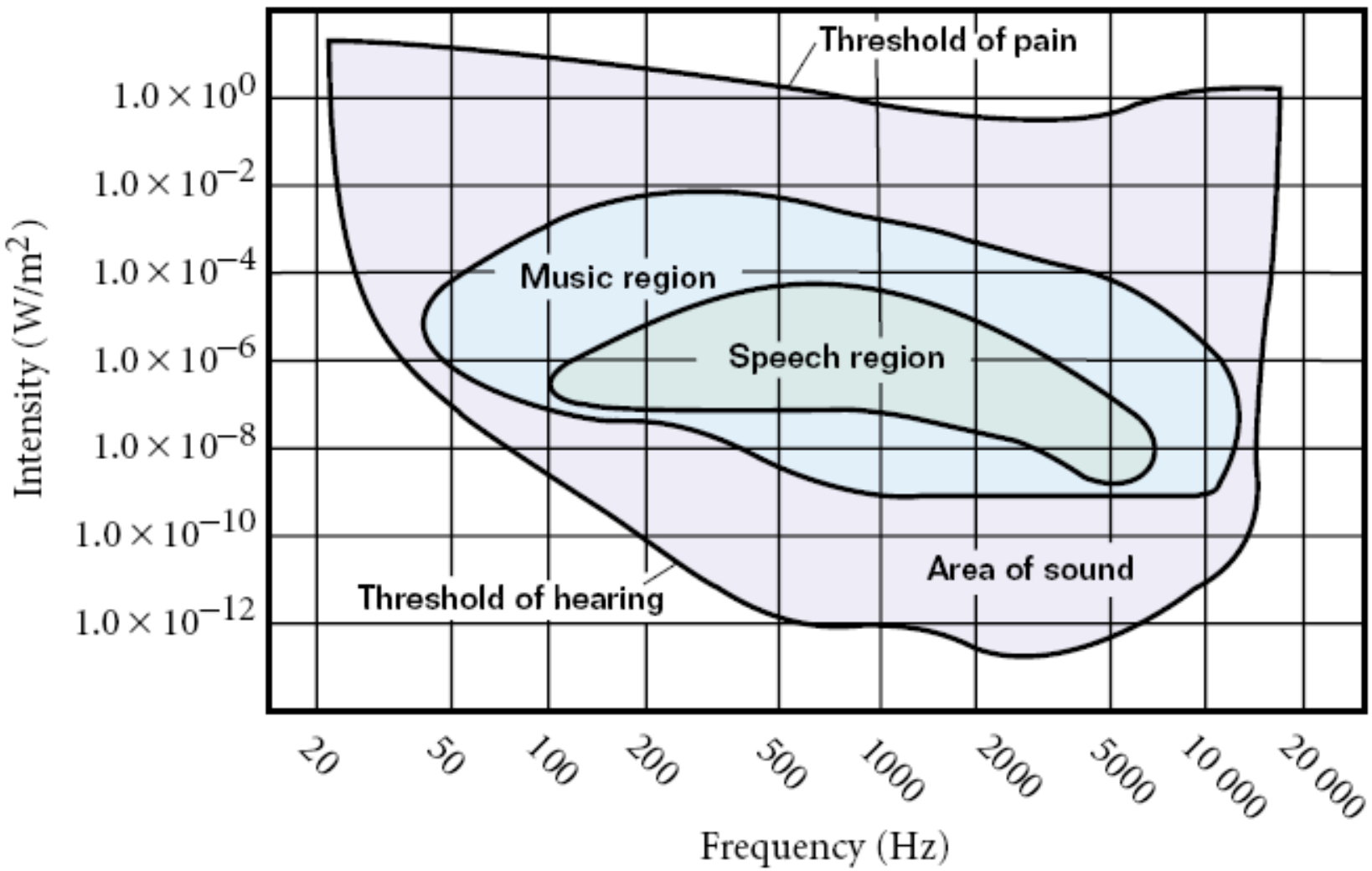

Figure 12-9, page 416

--The lowest intensity that the average human ear can detect is about 1.0 x 10-12 W/m^2 at 1000 Hz; this is known as the <u>threshold of hearing</u>.

--The loudest sound humans can tolerate has an intensity of 1.0 W/m^2; known as the <u>threshold of pain</u>.

Loudness

--The intensity of a sound wave determines the <u>loudness</u> or volume of the sound.

--The loudness is <u>not directly proportional</u> to the intensity; the sensation of sound is approximately <u>logarithmic</u> in the human ear.

--<u>Relative intensity</u>, which relates the intensity of a given sound to the intensity at the threshold of hearing, is more closely related to human perceptions of sound.

--Relative intensity is also called the <u>decibel level</u> because the unit of relative intensity is the <u>decibel (dB)</u>. (Note that the decibel is a dimensionless unit because it compares one sound intensity to another.)

Conversion of Intensity to Decibel Level

(Table 12-2, page 417)

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

--An increase of 10 times in the intensity adds 10 to the decibel level.

--An increase of of ten in the decibel level doubles the volume of the sound; the volume at the threshold of pain is 4096 times as loud as the volume at the threshold of hearing.

Forced Vibrations and Resonance

--When a guitar string makes the body of the guitar vibrate, the intensity of the sound increases; this is called a <u>forced vibration</u>. (Like the strings of a piano cause the sound board in a piano to vibrate)

--Forced vibrations are called <u>sympathetic vibrations</u>.

--The sympathetic vibrations of the guitar body transfers the energy of the vibrating string to the air much more quickly, increasing the intensity of the sound produced by the guitar.

--Every object has a natural frequency of vibration; for example, the natural frequency of a pendulum depends upon its string length.

--A pendulum that is vibrating will transfer its energy to another pendulum of the same length if they are connected, since they have the same natural frequency; this behavior is called <u>resonance</u>.

--Two tuning forks with the same frequency can also cause each other to start vibrating

--The Tacoma Narrows Bridge in Washington state collapsed in 1940 when the natural frequency of the wind produced sympathetic vibrations in the suspension bridge; as the vibrations became more violent the bridge eventually collapsed.

ISPS 07 Glass Breaking Video

Interference of Sound Waves

--Sound waves may interfere with each other, producing either constructive or destructive interference.

--If there is a regular pattern to the interference, the <u>beats</u> associated with music are produced.

--The interference of sound waves can be observed using a frequency oscillator/amplifier and two speakers emitting a sound of a single frequency.

Uses of Sound
(other than speech!)

--Sonar: uses ultrasonic waves to locate objects. (Example: bats)

--Ultrasonic cleaning: vibrations created by ultrasounds passing through a liquid vibrate dirt off objects placed in the liquid.

--<u>Ultrasound pictures</u>: Images of body tissues can be produced using ultrasonic waves, since the ultrasonic waves are partially reflected when they strike a boundary between material of different densities. Ultrasounds can be used to create images of internal organs or of a fetus.