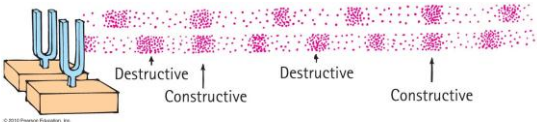
Note on Posted Slides

- These are the slides that I intended to show in class on Mon. Mar. 4, 2013.
- They contain important ideas and questions from your reading.
- Due to time constraints, I was probably not able to show all the slides during class.
- They are all posted here for completeness.

PHY205H1S
Physics of Everyday Life
Class 14: **Sound**

- Sound in Air
- Media That Transmit Sound
- Reflection of Sound
- Refraction of Sound
- Energy in Sound Waves
- Resonance
- Interference
- Beats



Nature of Sound

Sound is a form of energy that exists whether or not it is heard.

[image from http://thinkjustdoit.blogspot.ca/2012/04/phi-3000-if-tree-falls-in-forest.html]

Origin of Sound

Most sounds are waves produced by the vibrations of matter.

Examples:

- In a piano, a violin, and a guitar, the sound is produced by a vibrating string;

- in a saxophone, by a vibrating reed;
- in a flute, by a fluttering column of air at the mouthpiece;
- in your voice due to the vibration of your vocal chords.

[image from http://home.cc.umanitoba.ca/~krussll/phonetics/acoustic/harmonics.html]

Origin of Sound

- The original vibration stimulates the vibration of something larger or more massive, such as
  - the sounding board of a stringed instrument,
  - the air column within a reed or wind instrument, or
  - the air in the throat and mouth of a singer.
- This vibrating material then sends a disturbance through the surrounding medium, usually air, in the form of longitudinal sound waves.

[image from http://umanitoba.ca/outreach/evidencenetwork/archives/9635]

Frequency and Pitch

- The frequency of a sound wave is the same as the frequency of the vibrating source.
- The subjective impression about the frequency of sound is called **pitch.**

Lowest A: 27.5 Hz

Highest C: 4186 Hz

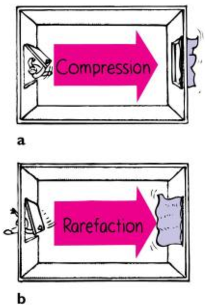
- The ear of a young person can normally hear pitches corresponding to the range of frequencies between about 20 and 20,000 Hertz.
- As we grow older, the limits of this human hearing range shrink, especially at the high-frequency end.

Infrasound and Ultrasound

- Sound waves with frequencies below 20 hertz are **infrasonic** (frequency too low for human hearing).
- Sound waves with frequencies above 20,000 hertz are called **ultrasonic** (frequency too high for human hearing).
- **We cannot hear infrasonic and ultrasonic sound.**

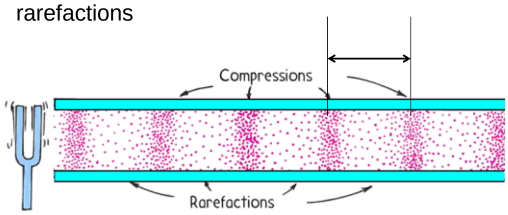

Compressions and Rarefactions

- Sound waves are vibrations made of compressions and rarefactions.
- In a **compression** region, the density and pressure are slightly **greater** than the average density and pressure
- In a **rarefaction** region, the density and pressure are slightly **lower** than the average density and pressure



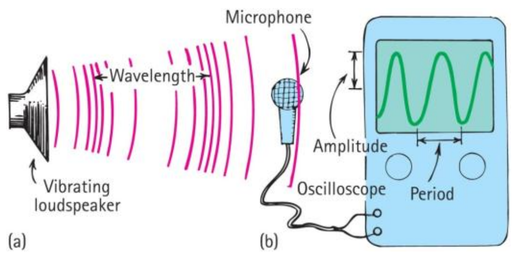
Wavelength of sound

- Distance between successive compressions or rarefactions



How sound is heard from a radio loudspeaker

- Radio loudspeaker is a paper cone that vibrates.
- Air molecules next to the loudspeaker set into vibration.
- Produces compressions and rarefactions traveling in air.
- Sound waves reach your ears, setting your eardrums into vibration. Or it reaches a microphone and sets up vibrations there, which are converted to an electric signal.



Media That Transmit Sound

- Any elastic substance — solid, liquid, gas, or plasma — can transmit sound.
- In liquids and solids, the atoms are relatively close together, respond quickly to one another's motions, and transmit energy with little loss.
- Sound travels about 4 times faster in water than in air and about 15 times faster in steel than in air.


Speed of Sound in Air

- Depends temperature, pressure and humidity
- Speed in 0°C dry air at sea level is about 330 m/s.
- In warm air faster than cold air.
  - Each degree rise in temperature above 0°C, speed of sound in air increases by 0.6 m/s

Speed of Sound in Air
CHECK YOUR NEIGHBOR

You hear thunder 3 seconds after you see a lightning flash. How far away is the lightning?

A. About 340 m
B. About 660 m
C. About 1 km
D. More than 2 km
D. There's no way to tell.

[image from http://www.forodecostarica.com/solaz/42155-el-jueguito-de-la-foto-13.html]

Speed of Sound in Air

- Note that light travels almost instantaneously (300,000 km/s) and sound travels about 1/3 km/s.
- So if you count the number of seconds between seeing a flash and hearing the thunder, you can divide by 3 and get the distance to the storm in kilometres.

[image from http://www.forodecostarica.com/solaz/42155-el-jueguito-de-la-foto-13.html]

Speed of Sound vs Speed of Light
A situation to ponder…

- Consider a person attending a concert that is being broadcast over the radio.
- The person sits about 45 m from the stage and listens to the radio broadcast with a transistor radio over one ear and a nonbroadcast sound signal with the other ear.
- Further suppose that the radio signal must travel all the way around the world (40,000 km!) before reaching the ear.

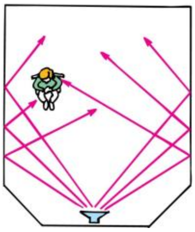
A situation to ponder…
CHECK YOUR NEIGHBOR

Which signal will be heard first?

A. Radio signal
B. Nonbroadcast sound signal
C. Both at the same time.
D. None of the above.

Reflection of Sound

- Process in which sound encountering a surface is returned
- Often called an echo
- Multiple reflections—called reverberations



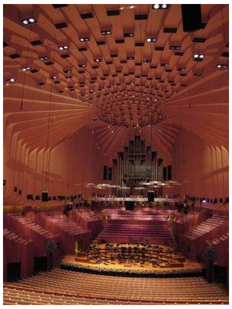
Reflection of Sound
CHECK YOUR NEIGHBOR

Reverberations are best heard when you sing in a room with

A. carpeted walls.
B. hard-surfaced walls.
C. open windows.
D. None of the above.

Reflection of Sound

- Acoustics is the study of sound and architecture
- A concert hall aims for a balance between reverberation and absorption.
- Some have reflectors to direct sound



[images of the Sydney Opera House from http://shedexpedition.com/sydney-opera-house/]

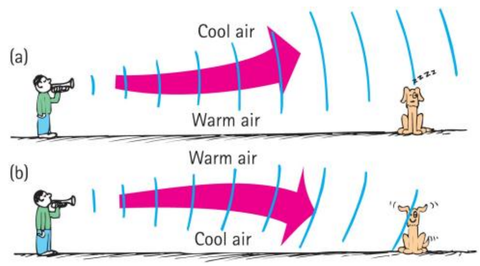
Test on Wednesday during class time

- **Location:** EX100, which is 255 McCaul St.
- Test will begin promptly at 10 minutes after the hour and will be 50 minutes long – if you can be there a bit early that would be great.
- Please bring a calculator, and, if you wish, a 3x5 notecard upon which you may write anything you wish on both sides
- Test will cover Hewitt chapters 12-16, 19 and 20, and will include:
- 3 short-answer problems for which you must show your reasoning (4 points each)
- 12 multiple choice questions (2 points each) – you fill in a bubble sheet
- Questions will be similar in style and level to the Exercises and Problems at the end of the chapters in Hewitt

Tips for the 50 minute Test

- No phones / ipods etc allowed. You will need a regular calculator, and a watch could be handy as well!
- Time Management:
  - Skim over the entire test from front to back **before** you begin. Look for problems that you have confidence to solve first.
  - If you start a problem but can't finish it, leave it, make a mark on the edge of the paper beside it, and come back to it after you have solved all the easy problems.
- Bring your T-card or other photo ID, as we will be collecting signatures

Refraction of Sound



- Bending of waves—caused by changes in speed affected by temperature variations.

Refraction of Sound
CHECK YOUR NEIGHBOR

When air near the ground on a warm day is warmed more than the air above, sound tends to bend

A. upward.
B. downward.
C. at right angles to the ground.
D. None of the above.

Refraction of Sound
CHECK YOUR NEIGHBOR

In the evening, when air directly above a pond is cooler than air above, sound across a pond tends to bend

A. upward.
B. downward.
C. at right angles to the ground.
D. None of the above.

Natural Vibrations

- Every object has its own unique frequency that it naturally tends to vibrate at.
- Dependent on
  – Elasticity
  – Mass of object
  – Shape of object
  – Size of object

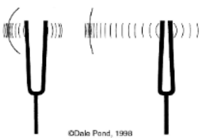
[image from http://www.haines.com.au/index.php/physics/heat-light-sound/tuning-fork-e-320-hz.html]

Forced Vibrations

- Setting up of vibrations in an object by a vibrating force
- Examples:
- factory floor vibration caused by running of heavy machinery
- Table vibration from paint shaker

[image from http://www.harborfreight.com/pneumatic-paint-shaker-94605.html]

Resonance



A phenomenon in which the frequency of forced vibrations on an object matches the object's natural frequency

Examples:

- Swinging in rhythm with the natural frequency of a swing
- Tuning a radio station to the "carrier frequency" of the radio station
- Troops marching in rhythm with the natural frequency of a bridge (a no-no!)

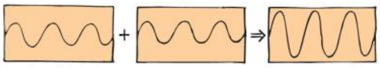
[image from http://pondscienceinstitute.on-rev.com/svpwiki/tiki-index.php?page=sympathetic+vibration]

Tacoma Narrows Bridge Collapse 1940

Dramatic example of wind-generated resonance!

[left image from http://www.stkate.edu/physics/phys111/index.html]

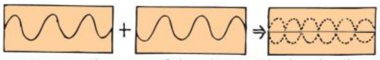
Interference


(a)

The superposition of two identical transverse waves in phase produces a wave of increased amplitude.


(b)

The superposition of two identical longitudinal waves in phase produces a wave of increased intensity.

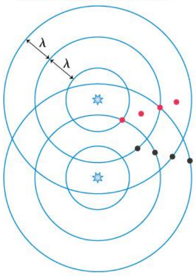

(c)

Two identical transverse waves that are out of phase destroy each other when they are superimposed.


(d)

Two identical longitudina waves that are out of phase destroy each other when they are superimposed.

Two in-phase sources emit circular or spherical waves.

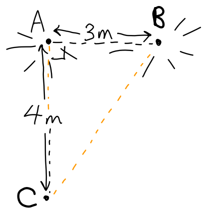


- Points of constructive interference. A crest is aligned with a crest, or a trough with a trough.
- Points of destructive interference. A crest is aligned with a trough of another wave.

Example

Two speakers, A and B, are “in phase” and emit a pure note with a wavelength 2 m. The speakers are side-by-side, 3 m apart. Point C is 4 m directly in front of speaker A.

Will a listener at point C hear constructive or destructive interference?

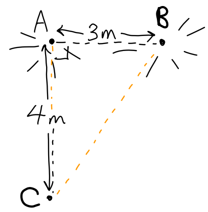


In Class Discussion Question

Two speakers, A and B, are “in phase” and emit a pure note with a wavelength 2 m. The speakers are side-by-side, 3 m apart. Point C is 4 m directly in front of speaker A.

How many wavelengths are between Speaker A and Point C?

A. 0.5
B. 1.0
C. 1.5
D. 2.0
E. 2.5

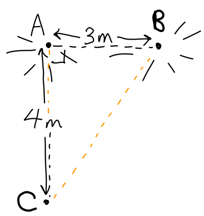


In Class Discussion Question

Two speakers, A and B, are “in phase” and emit a pure note with a wavelength 2 m. The speakers are side-by-side, 3 m apart. Point C is 4 m directly in front of speaker A.

How many wavelengths are between Speaker B and Point C?

A. 0.5
B. 1.0
C. 1.5
D. 2.0
E. 2.5

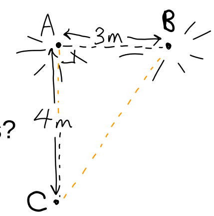


In Class Discussion Question

Two speakers, A and B, are “in phase” and emit a pure note with a wavelength 2 m. The speakers are side-by-side, 3 m apart. Point C is 4 m directly in front of speaker A.

At point C, what is the path difference between the sounds received from speakers A and B, as measured in wavelengths?

A. 0.5 B. 1.0 C. 1.5
D. 2.0 E. 2.5

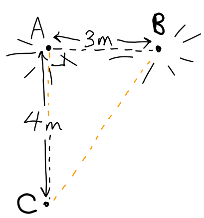


In Class Discussion Question

Two speakers, A and B, are “in phase” and emit a pure note with a wavelength 2 m. The speakers are side-by-side, 3 m apart. Point C is 4 m directly in front of speaker A.

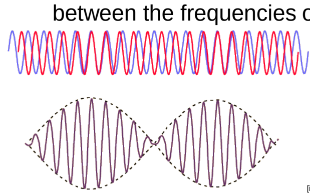
At point C, there will be

A. Constructive interference (Amplitude at C =2A)
B. Destructive interference (Amplitude at C =zero)



Beats

- Periodic variations in the loudness of sound due to interference
- Occur when two waves of similar, but not equal frequencies are superposed.
- Provide a comparison of frequencies
- Frequency of beats is equal to the **difference** between the frequencies of the two waves.



[image from http://hyperphysics.phy-astr.gsu.edu/hbase/sound/beat.html]

Beats

- Applications
  - Piano tuning by listening to the disappearance of beats from a known frequency and a piano key
  - Tuning instruments in an orchestra by listening for beats between instruments and piano tone

Refraction of Sound
CHECK YOUR NEIGHBOR

Suppose you sound a 1056-hertz tuning fork at the same time you strike a note on the piano and hear 2 beats/second. What is the frequency of the piano string?

A. 1054 Hz
B. 1056 Hz
C. 1058 Hz
D. Either A or C
E. Either A, B or C

Refraction of Sound
CHECK YOUR NEIGHBOR

Suppose you sound a 1056-hertz tuning fork at the same time you strike a note on the piano and hear 2 beats/second. You tighten the piano string very slightly and now hear 3 beats/second. What is the frequency of the piano string?

A. 1053 Hz
B. 1056 Hz
C. 1059 Hz
D. Either A or C
E. Either A, B or C

Before class on Monday…

- Please read Chapter 21, or at least watch the 10-minute pre-class video for class 15.
  - Something to think about:
  - When you record the sound of music or a voice, what data is actually being stored in your computer? What is it about the sound that is being recorded?