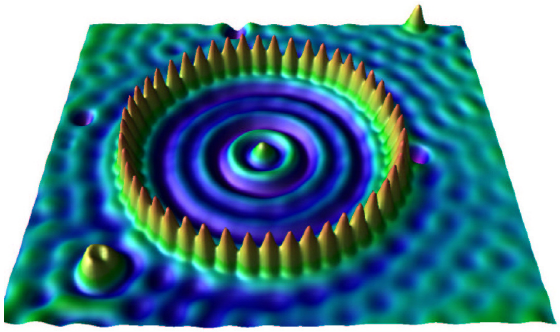
Announcements

1. Exam 4
   a. median was 74 (as of 2:30 pm Monday)
   b. Exams will be returned Thursday
2. Thursday lecture: Final exam review
   a. Demos or not?
   b. Do your online course evaluations before class!
3. Final exam
   a. Take in testing center anytime during finals week
   b. Review sessions led by TAs: Friday Dec 14 & Sat Dec 15, 11-1 in room C215 ESC.
4. Late homework deadline for HW 21-24: Friday Dec 21 (last day of finals)

Interference of waves



Electron waves on a copper surface with iron atoms added, viewed by scanning tunneling microscope.

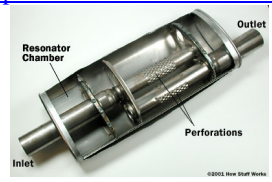
Principle of **superposition** (addition)
Video: Wave Superposition
Demo: Transparencies

Path-length dependence
Constructive

Destructive

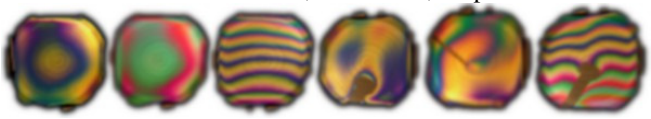
Applications of interference

Car mufflers http://auto.howstuffworks.com/muffler4.htm

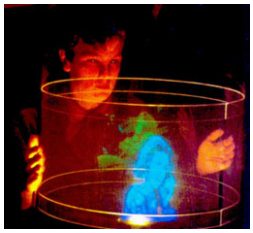


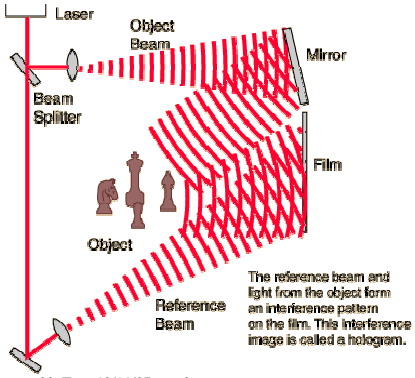
Noise canceling headphones

Measurements of motion, distortions, shapes



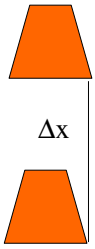
Holograms





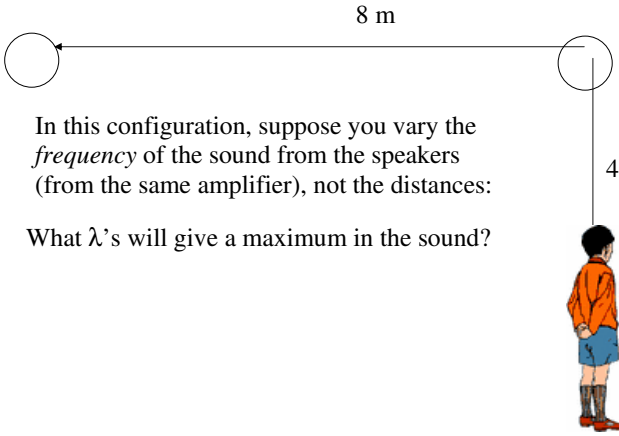
Worked Problem: Two speakers are on a line (not stereo). Both emit the same sound waves (v=340 m/s) at 500 Hz.

What is the wavelength?



How far back should one speaker be placed (Δx) to get a *minimum* along the line?

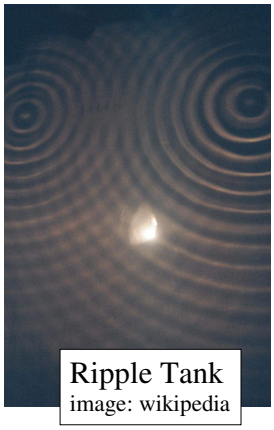
How far back should one speaker be placed (Δx) to get a *maximum* along the line?



In this configuration, suppose you vary the *frequency* of the sound from the speakers (from the same amplifier), not the distances:

What λ's will give a maximum in the sound?

Demo: two speakers



Ripple Tank
image: wikipedia

Standing waves:

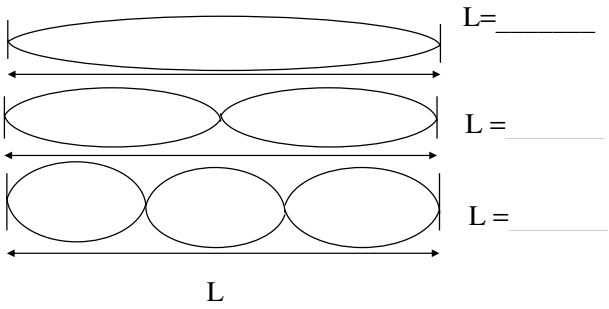
Boundary conditions determine allowed vibration frequencies

Stringed instruments

Demo: ¼ inch tubing, ladies belt, violin

nodes vs. antinodes

Harmonics



Resonance condition:
"Integer number of _____ fit into L."

$f_n = \frac{nv}{2L}$ n=1,2,3,... the *resonant* f's.

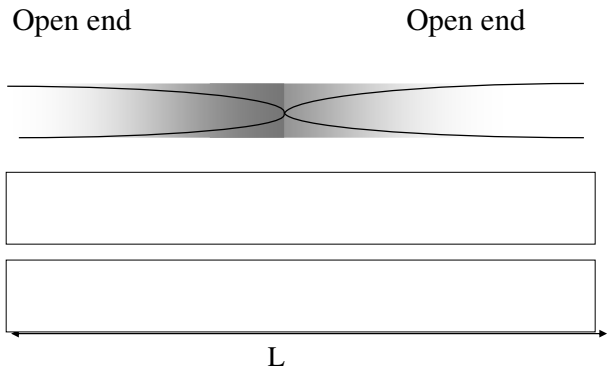
Harmonic number n: the # of _____

Standing waves in air

Demo: gas light tube
Demo: open pipe

Open-open pipes

Molecular displacement patterns:

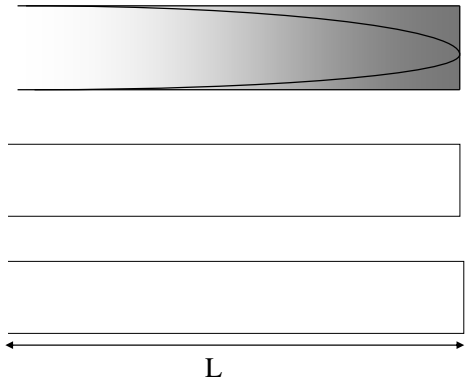


"Integer number of _____ fit into L."

$f_n = \frac{nv}{2L}$ n= 1,2,3,4,...

Open-closed pipes

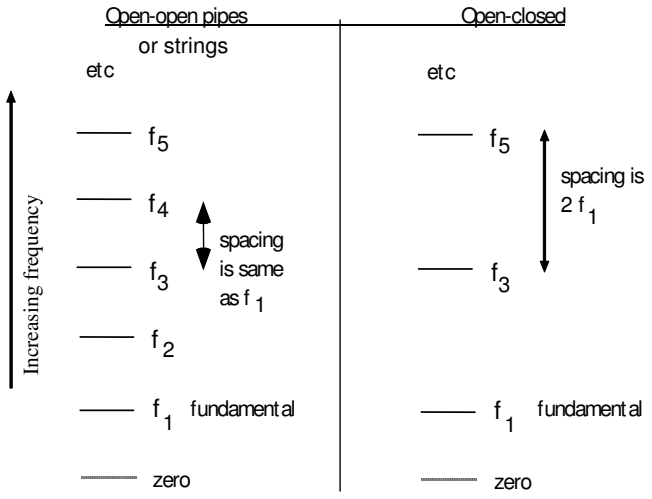
Molecular displacement patterns:



"Odd integer number of _____ fit into L."

$f_n = \frac{nv}{4L}$ n= 1,3,5,7,...

Demo: open-closed pipe



Resonance!

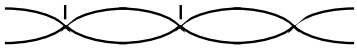
Swings and springs

Trumpet

Video: VE 9-1: Bowling ball pendulum
VE 9-6: goblet shattering
MU 17: Tacoma Narrows bridge

Demo: Singing rods, Chladni plate, holography of instruments

Q4. Which of these could correspond to a closed-open pipe?

a 

b 

c 

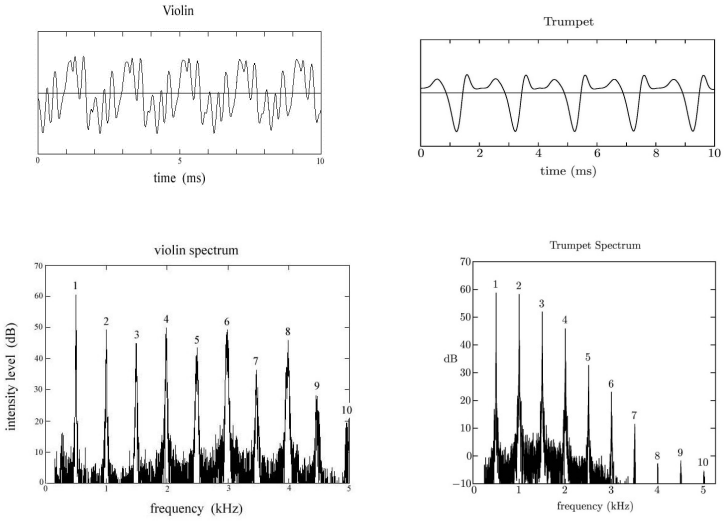
You change the frequency that you excite a tube, and find some resonant frequencies at 600, 840, and 1080 Hz.

Q5. What is the largest frequency possible for the fundamental?
_____ Hz (these are all integer multiples of the same fundamental)
a. 60 b. 120 c. 200 d. 300 e. 600

Is this an open-open pipe, or a closed-open pipe?

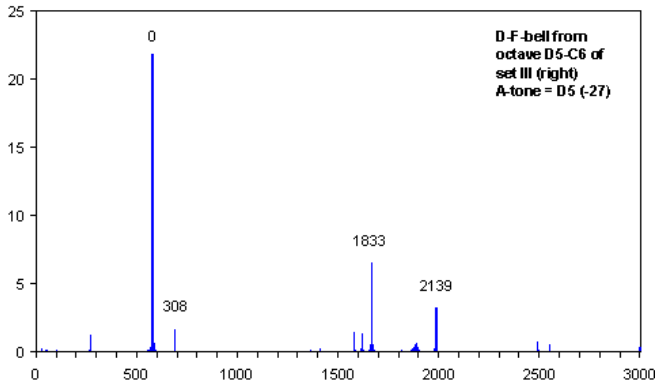
The harmonic n for 1080 Hz is _____

Why do various instruments (and voices) sound different for the *same pitch?*



→ using a "spectrum analyzer"

"Strange" instruments: bells, blocks
http://web.telia.com/~u57011259/Bellspectra.htm



Beats

Animation: http://stokes.byu.edu/computer_resources.html

Demo: Tuning forks

beat frequency: $f_{beat} = |f_1 - f_2|$

Applications of beats:

Tuning

Measuring Doppler shifts in radar, ultrasound

Chords in music

Consonant chords: simple frequency ratios… harmonics of each note overlap well.

Dissonance: not many harmonics match!

Chord	Freq. Ratios
Octave	2:1
Major	4:5:6
Minor	10:12:15
Diminished	160:192:231 (approx. 20:24:29)
7th	20:25:30:36
Min. 7th	10:12:15:18
Maj. 7th	8:10:12:15