Lecture 27 Announcements

0. My voice is not fully functional. Might be "interesting" lecture...
1. Thursday lecture: Final exam review
2. Additional TA-led final exam review:
    a. Time/day still ~~TBA~~ 1. Thurs 7-9 pm 2. Friday 1-3 pm
3. Final exam
    a. Take in testing center anytime during finals week
4. Deadlines:
    a. All extra credit must be turned in to your regular HW box by midnight Thurs Dec 11 (last day of classes)
    b. Instructor/course ratings must be done by Sat Dec 13 http://studentratings.byu.edu "release name" to get extra credit
    c. All late homework must be turned in by midnight Fri Dec 19 (last day of finals)

Complete the following sentences with a short phrase. (a) Standing waves are caused by the interference of two waves which are... (b) Beats are caused by the interference of two waves which are...

a) in superposition with the same frequency but traveling in opposite directions.

b) in superposition with slightly different frequencies so that they are periodically both in and out of phase.

(2) travelling same direction

Any other comments:

Quick physics moment. I'm often annoyed because the shower curtain starts migrating towards me as i shower. I just realized that thats probably because I take hot showers and the air moves faster creating lower pressure, so the cooler, higher-pressure air on the opposite side pushes it towards me. I don't know if thats right, but it made me feel smart.

✓

why is it when two instruments aren't in tune with each other and they are playing next to each other does the sound sound as if it is vibrating? "beats"

In 7th grade I played the flute, and I remember while tuning our instruments, we were told that we'd be at the right key when the sound stopped pulsating and sounded uniform. I never knew how or why that worked until now! cool!

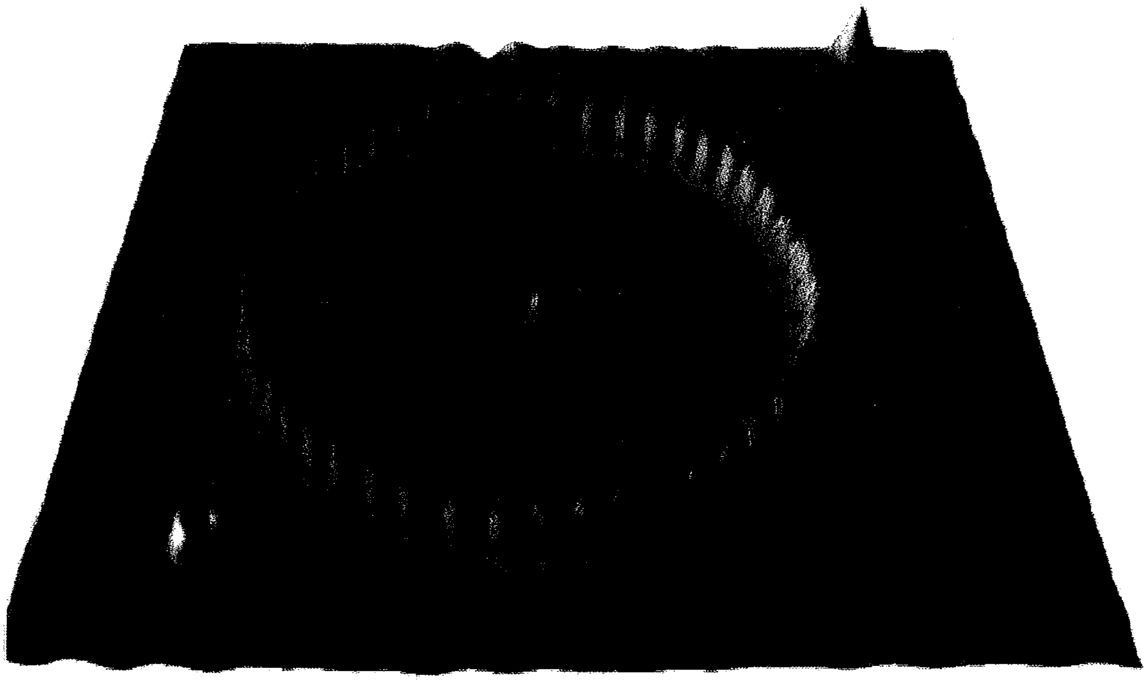
True!

Hang on...the book said that 'the number of beats, or beat frequency, equals the difference in frequency between the two sources.' But when I tune an instrument to another, if I remember correctly, the beats between the two seem to get faster and faster until they finally disappear and the instruments are in tune, not slower and slower and fade out. Am I right? Am I reading this right?

NO misremembering

Yes

Interference of waves



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

"Superposition": waves interfere by adding together

Demo: "Moire pattern" Transparencies

Path length $\Delta L = L_1 - L_2$

Path-length dependence

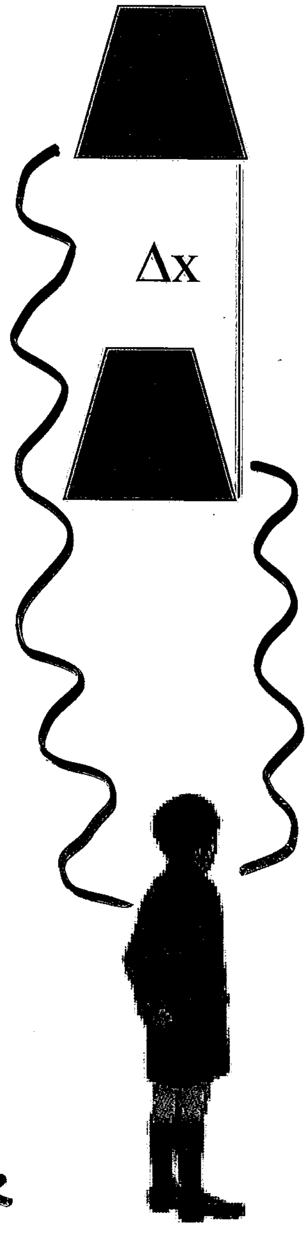
Constructive interference:

$\Delta L = n\lambda$ $\quad \lambda, 2\lambda, 3\lambda,$ etc.

Destructive interference

$\Delta L = (n + \frac{1}{2})\lambda$ $\quad \frac{1}{2}\lambda, \frac{3}{2}\lambda, \frac{5}{2}\lambda,$ etc

Worked Problem: Two speakers are on a line (not stereo). Both emit the same sound waves (v=343 m/s) at 500 Hz.



What is the wavelength?

$v = f\lambda$

$\lambda = v/f = \dfrac{343\ m/s}{500\ 1/s} = .686\ m$

How far back should one speaker be placed (Δx) to get a *minimum* where the boy is standing?

$\Delta L = \frac{\lambda}{2}$ $\Delta x = .343\ m$ or $\frac{3\lambda}{2}$, $\frac{5\lambda}{2}$, etc

How far back should one speaker be placed (Δx) to get a *maximum* where the boy is standing?

$\Delta L = \lambda$ or 2λ, 3λ, etc

$.686\ m$

Answers: 0.686 ; 0.343 m (or 1.029 m, 1.715 m, …); 0.686 m (or 1.372 m, 2.058 m, …)

8 m

$L_1 = \sqrt{8^2+4^2}$

L_2

4 m

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?

$\Delta L = \lambda \sim 2\lambda,\ 3\lambda,$ etc

$L_1 - L_2 = \lambda$

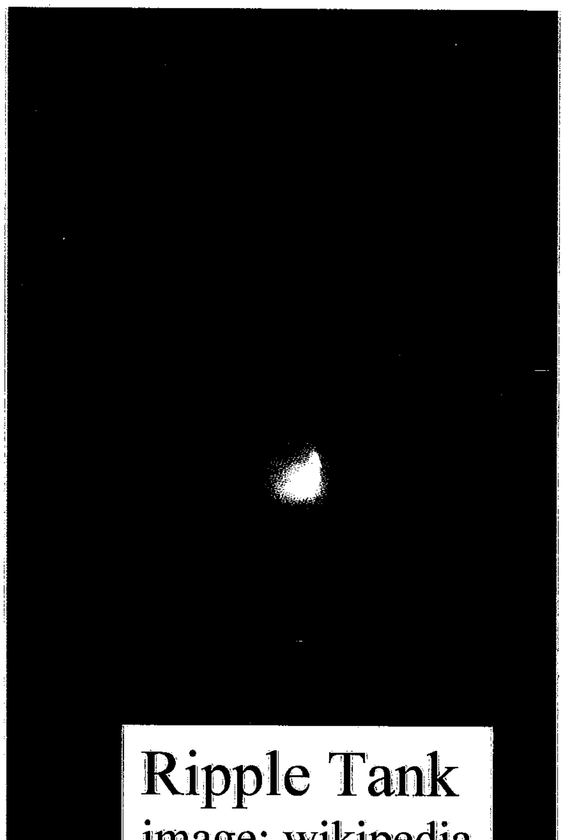
$\lambda = \sqrt{8^2+4^2} - 4$

$= \underline{4.94\text{ m}}$

Answers: 4.944 m, 2.472 m, 1.648 m, …

For a fixed position, many frequencies will work; for a fixed frequency, many positions will work.

Demo: two speaker interference



Ripple Tank
image: wikipedia

Standing waves:

- *Combination* of forward- and backwards-moving waves

Web demo: http://www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf

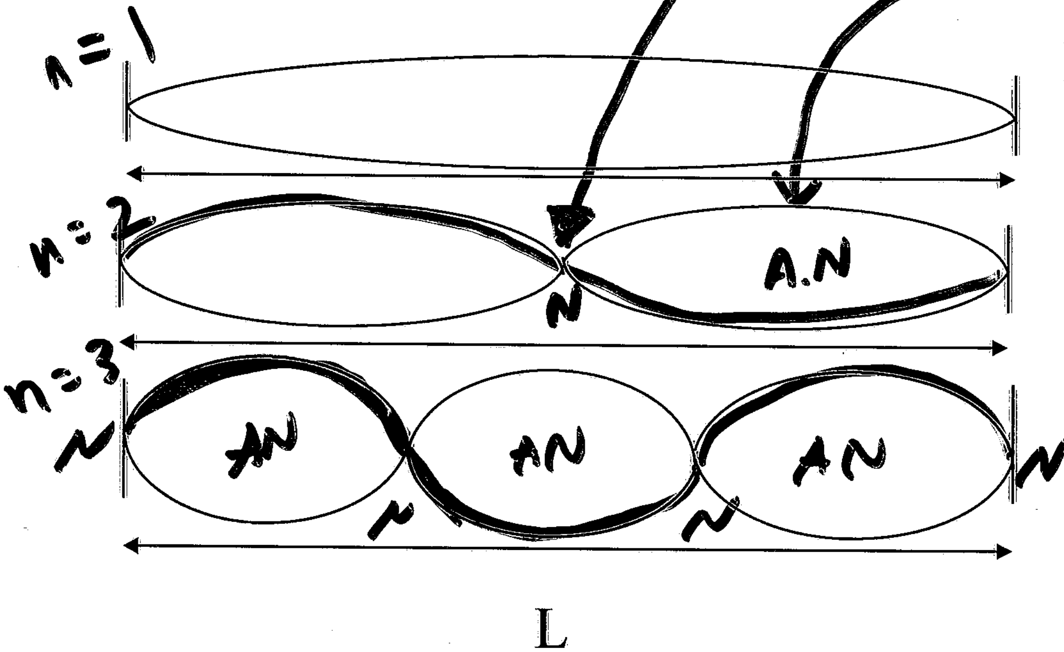
- *Boundary conditions* determine allowed vibration frequencies

Standing waves on "strings"

Demos: ¼ inch tubing, ladies belt

nodes vs. **antinodes**

Harmonics



L= $\frac{1}{2}\lambda$

L = $\frac{2}{2}\lambda$

L = $\frac{3}{2}\lambda$

$L = \frac{n}{2}\lambda$

Resonance condition:

"Integer number of half wavelengths fit into L."

λ_n = $2L/n$

f_n = v/λ

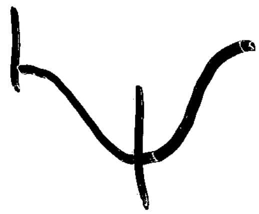
$= \frac{vn}{2L}$

n=1,2,3,... n = the harmonic number

Standing waves in air

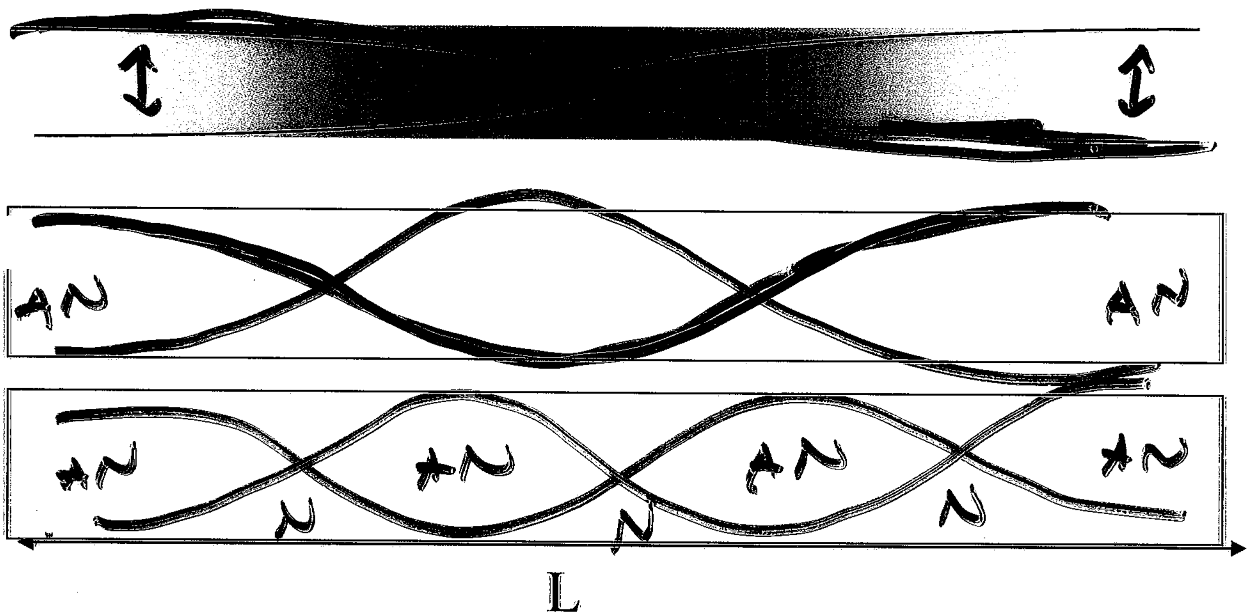
Demos: trumpet, organ pipe
Demo: gas lit tube

Open-open pipes



Pressure patterns:

Open end | Open end



$L = \frac{1}{2}\lambda$

$L = \frac{2}{2}\lambda$

$L = \frac{3}{2}\lambda$

$L = \frac{n}{2}\lambda$

Resonance condition:
"Integer number of half wavelengths fit into L."

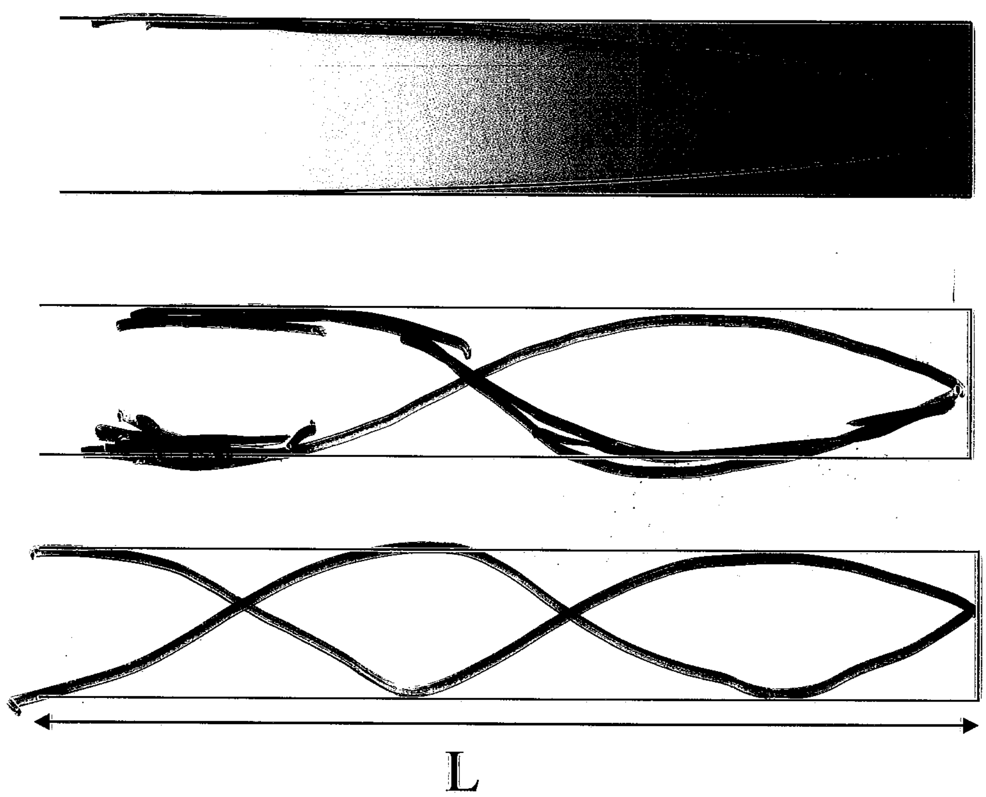
$\lambda_n = 2L/n$

$f_n = v/\lambda$ $\qquad n=1,2,3,\ldots$

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

Open-closed pipes

Pressure patterns:



L = $\frac{1}{4}\lambda$

L = $\frac{3}{4}\lambda$

L = $\frac{5}{4}\lambda$

$\frac{n}{4}\lambda$

"Odd integer number of quarter wavelengths fit into L."

$\lambda_n = 4L/n$

$f_n = v/\lambda$ n=1,3,5,... "f_n" = $n f_1$

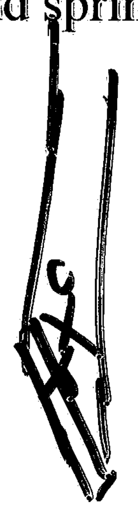
$f = \frac{vn}{4L}$ $f_1 = \frac{v}{4L}$

How does "fundamental" f_1 here compare to open-open case? different!

Demo: open-closed pipe

Resonance

Swings and springs



$$T = 2\pi\sqrt{\frac{L}{g}}$$

$$f = 1/T$$

pump your legs at just the right frequency

Videos: Bowling ball pendulum
Goblet shattering
Tacoma Narrows bridge

Demo: Tuning fork sympathetic vibrations

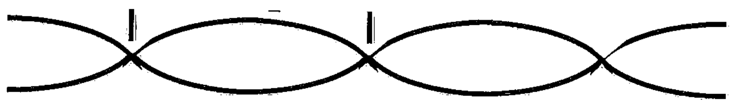
Demo: Trumpet, again

Demo: Chladni plates

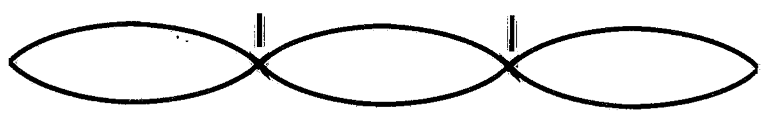
Web images: http://www.physics.utoronto.ca/nonlinear/chladni.html
(including violin shape)

Clicker quiz: Which of these pressure patterns could correspond to a closed-open pipe?

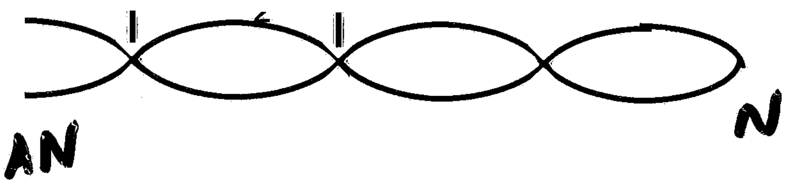
a



b



c



Clicker quiz: You change the frequency that you excite a pipe, and find some resonant frequencies at 600, 840, and 1080 Hz. (Others resonant frequencies exist, also.) What is the largest frequency possible for the fundamental? _____ Hz

a. 60 b. 120 c. 200 d. 300 e. 600

600
− 240
360
− 240
120

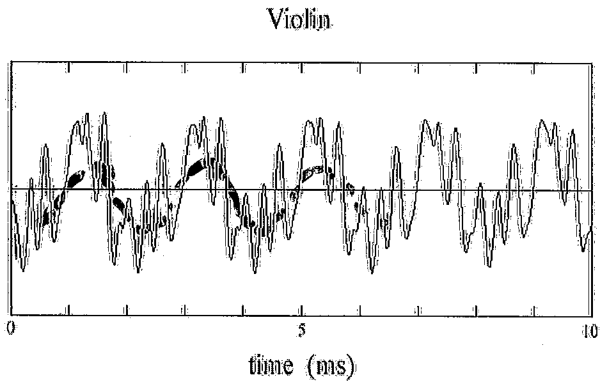
Clicker quiz: Is this an open-open pipe, or a closed-open pipe?

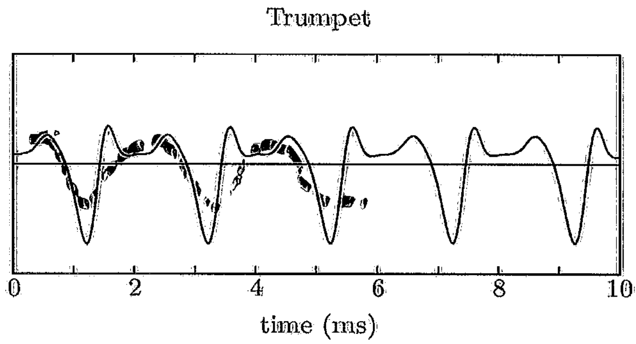
a. open-open
b. closed-open
c. could be either

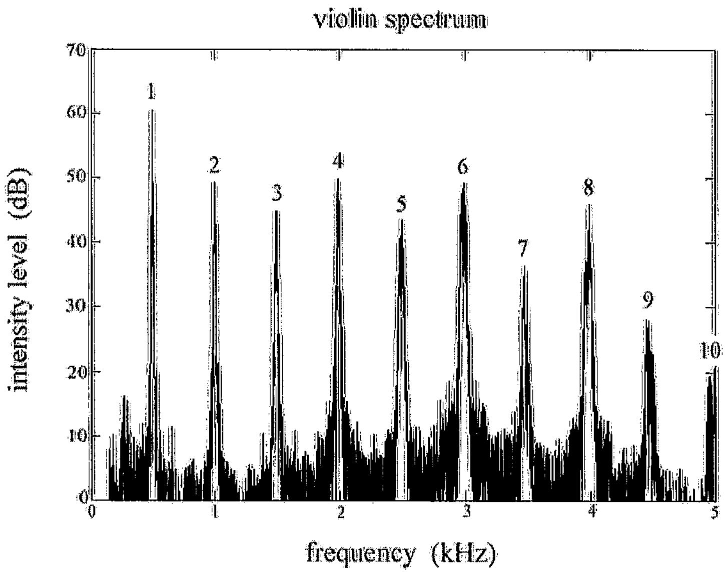
5th harmonic
7th
9th

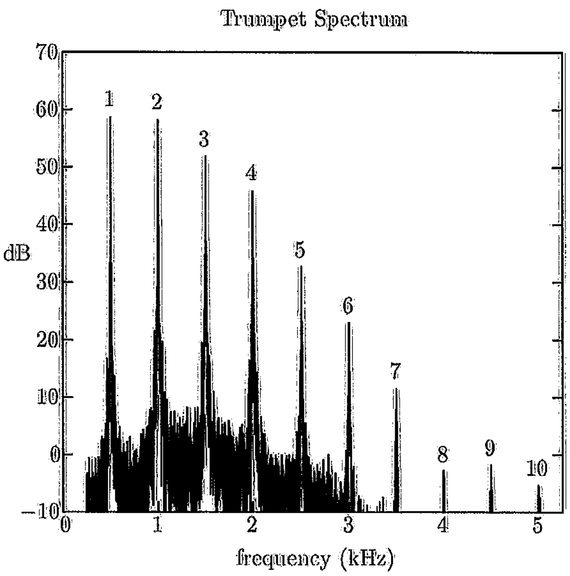
Tone *quality*: why do various instruments (and voices) sound different for the *same pitch?*

Answer: real sounds are not usually pure *sine waves*









→ using a frequency "spectrum analyzer"