Lecture 27 Announcements

1. Thursday lecture: Some new stuff, ~~mostly~~ half final exam review. Coolest demo of the semester!!

2. TA-led final exam review(s):
   a. Time/date(s): Thurs 7-9 pm place: ? 256 CB
      Sat ? 2:30-4 place: ?

3. Rate the TA-lab tutors. Email sent out yet?
   Fri 3-5 pm

4. Deadlines:
   a. Colton "class improvement survey" must be done by Thurs, **Dec 10**, to get extra credit
   b. All extra credit papers and late FBDs must be turned in by midnight Sat, **Dec 12**
   c. BYU Instructor/course ratings must be done by ~~Sat~~ Sun Dec 13. http://studentratings.byu.edu
   d. Final exam in Testing Center anytime during finals week (last day: Fri, **Dec 18**)
   e. All computer-graded homework must be turned in by midnight Fri, **Dec 18** (last day of finals)

Which part of today's assignment was particularly hard or confusing?

May we go over Mach numbers again? The book explains it in only one brief, confusing sentence! Like: "accel was 3 g's" → $a = 3 \times 9.8 \frac{m}{s^2}$

"Mach 3" → v = 3 x speed of sound

Doppler effect

General comments:

last warm-up quiz of the semester! Hooray! No it's not

Are our extra credit papers supposed to be double-spaced? I could not find any clarification in the syllabus. Thanks! Either way.

I got my free body diagrams back from exam 3, but they aren't entered into the computer yet. Should I be concerned? Yes.

I don't understand logarithms and how we compute them or use them to solve equations. They seem really confusing to me so it is hard for me to start on the assignment.

You need to learn them!

Doppler Shift—"Race Car Effect"

Applications:

Radar guns
Doppler weather radar
Astronomy "red shifts" and "blue shifts"
Doppler ultrasound: blood flow imaging in heart

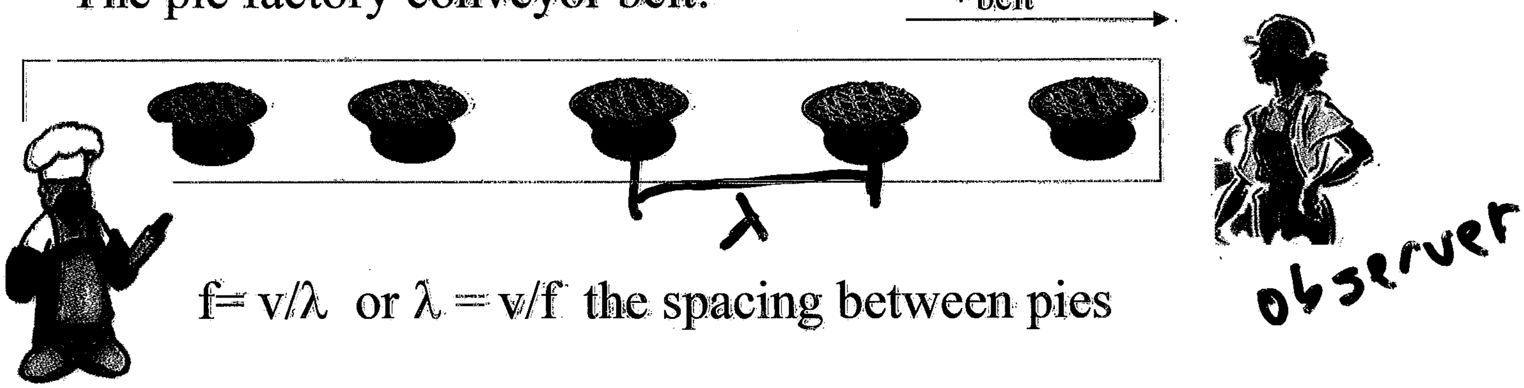
8 1/2 week embryo blood flow

Key point: Frequency is increased when the source and observer approach each other, decreased when they go away from each other.

Demo: Doppler speaker

Demo: Come, Come, Ye Saints http://stokes.byu.edu/bells.wav

The pie factory conveyor belt:



$f = v/\lambda$ or $\lambda = v/f$ the spacing between pies

v_s source speed
v_o observer speed
v speed of sound (pies)

If **observer moves** toward source (pie maker), she would measure the same λ but the pies are coming at her at a faster frequency

If **source moves** toward observer, the λ shrinks, but the pie v doesn't change

$v = \lambda f$
→ f increases

Both source and observer can move
http://stokes.byu.edu/doppler_script_flash.html

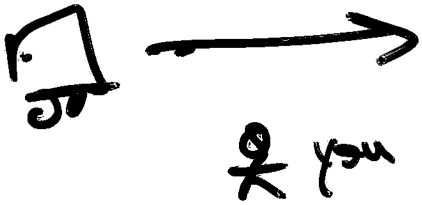
Equation: $f' = f\left(\frac{v \pm v_o}{v \pm v_s}\right)$

what you hear; source freq.; speed of sound; speed of observer; speed of source

Choose your signs **carefully**!!
→ + in numerator when observer is moving towards source
→ – in denominator when source is moving towards observer
Otherwise, reversed!

Worked problem: An ambulance siren emits a 500 Hz tone as it approaches you at 25 m/s, and continues to emit the tone as it goes away from you (still at 25 m/s). What two pitches do you hear? (v_{sound} = 343 m/s.)

(a) towards (b) away

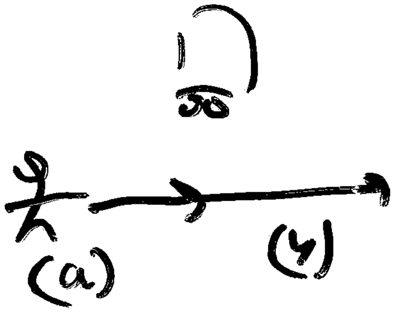


(a) $f' = f \dfrac{v \pm v_o}{v \pm v_s} = 500\text{Hz} \dfrac{343 + 0}{343 - 25}$

$= \boxed{539 \text{ Hz}}$

(b) $f' = 500 \left(\dfrac{343 + 0}{343 + 25} \right) = \boxed{466 \text{ Hz}}$

What if ambulance were stationary and you were moving at 25 m/s?



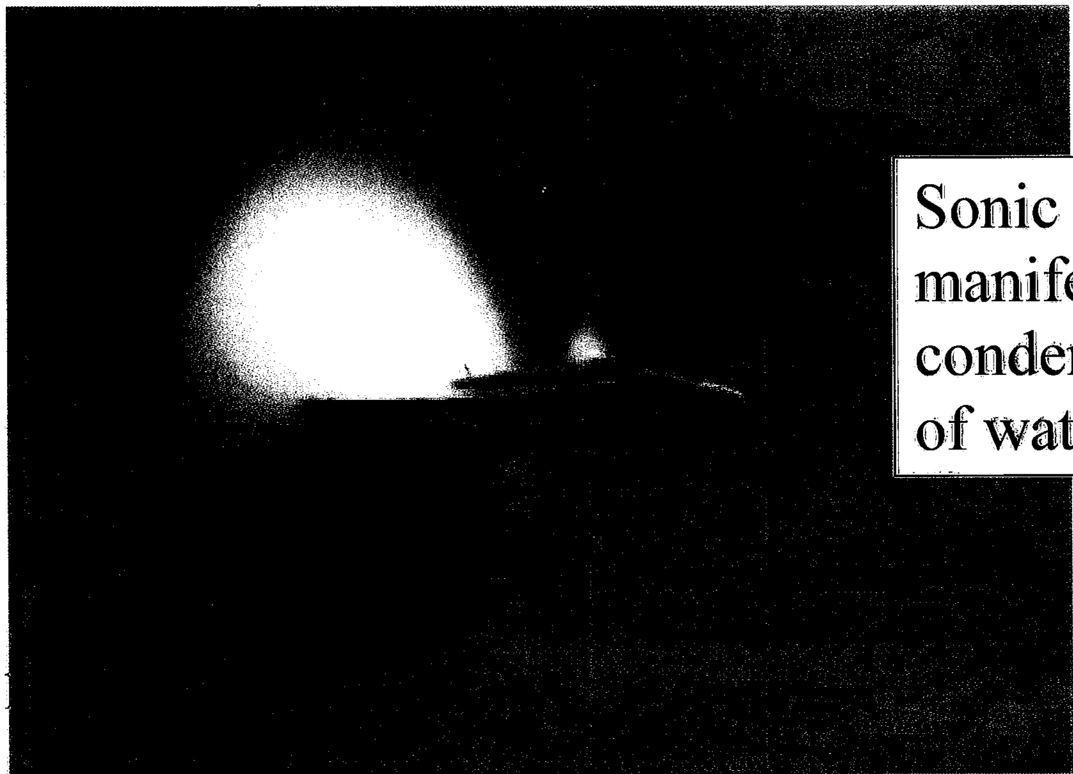
(a) $f' = 500 \left(\dfrac{343 + 25}{343 + 0} \right)$

(b) $f' = 500 \left(\dfrac{343 - 25}{343} \right)$

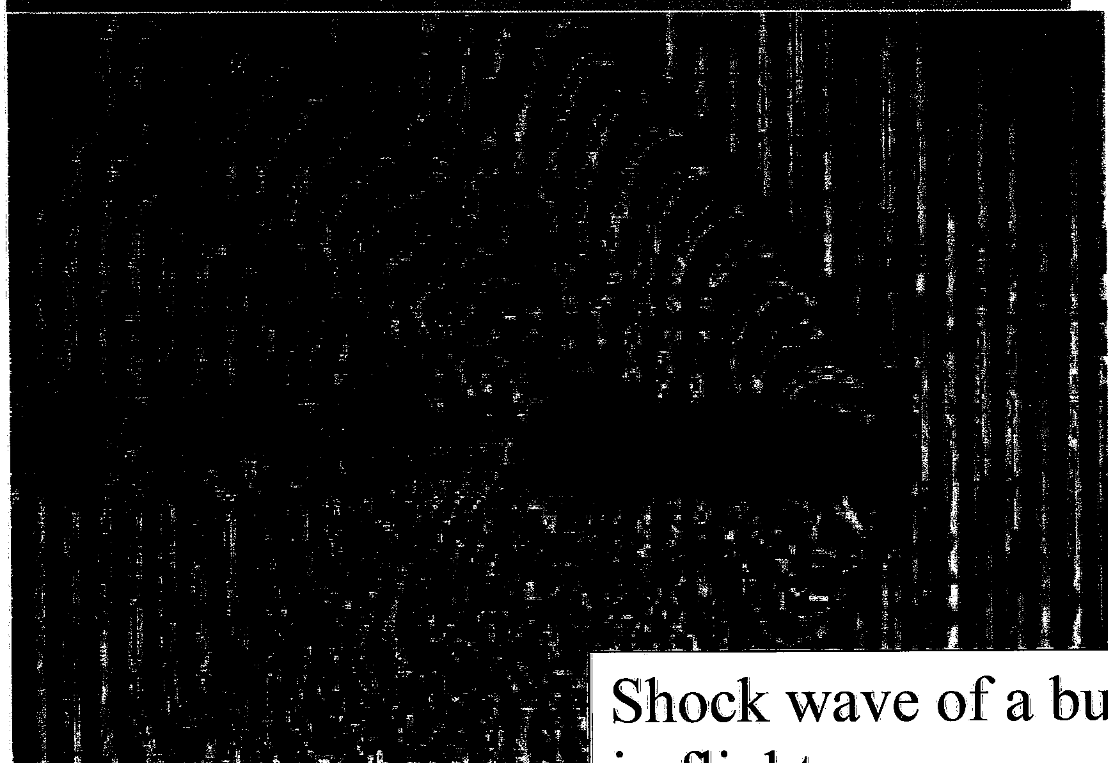
Answers: 539.3 Hz, 466.0 Hz

If source moves at or above the speed of the waves…

($v_{source} > v_{wave}$) http://stokes.byu.edu/boom_flash.html



Sonic boom manifested by condensation of water in air



Shock wave of a bullet in flight

Doppler Shift of light

From warmup: Ralph wants to know why this is funny.

Answer from the class:

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In theory, Ralph, if you approach a light-emitting source, blue shift occurs because the wavelengths are squished together, making the frequency higher and the wavelengths shorter.

shift to higher freqs.

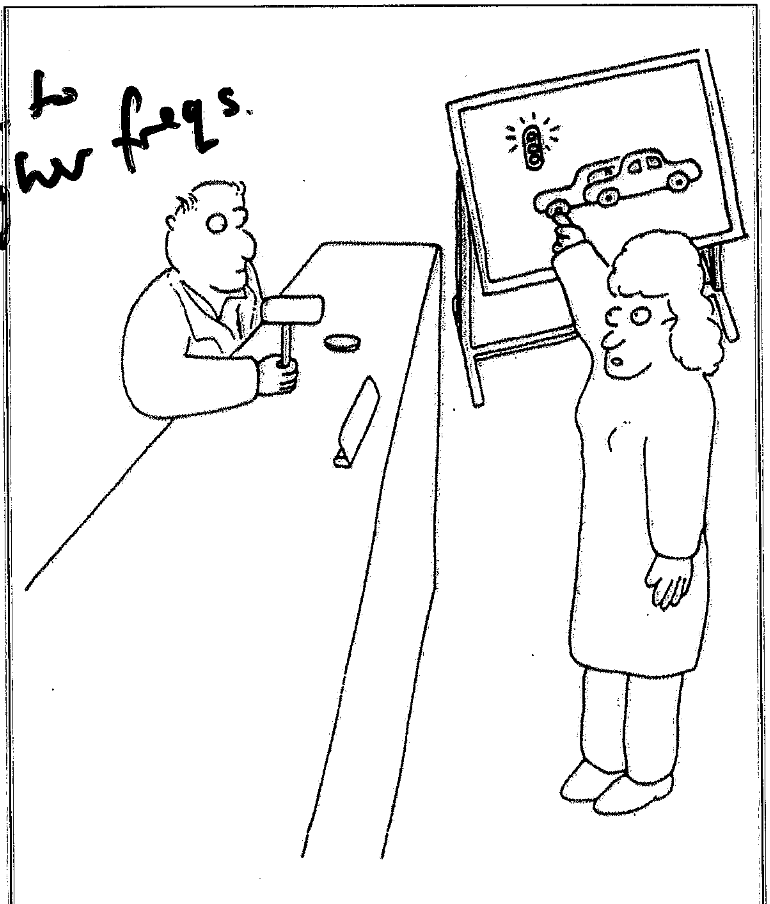


FIGURE 60. *Based on her successful Doppler effect defense, Carla was found not guilty of running a red light and instead was found guilty of speeding and fined eight trillion dollars!*

→ How fast would you need to go?

close to the speed of light $3 \cdot 10^8 \frac{m}{s}$

What use is it?

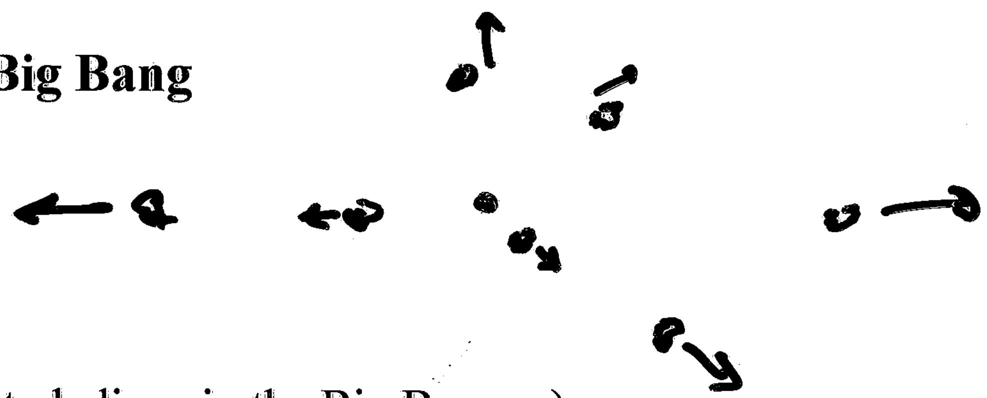
One answer: **Astronomy**
How far away is a star/galaxy? Hard question

Edwin Hubble, 1929: Distance away proportional to speed

→ How did he measure speed?
Doppler shift of spectral lines!

That's now a standard technique for today's astronomers when they want to measure distances… just measure Doppler shift.

Hubble's Law and the Big Bang



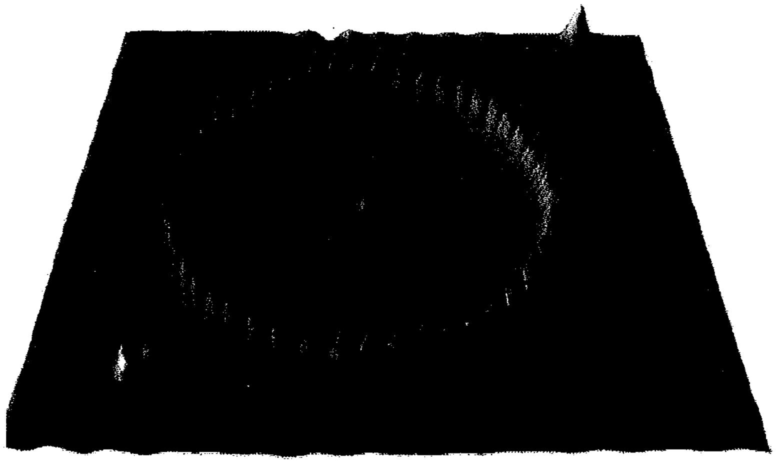
(Yes, it's OK for LDS to believe in the Big Bang…)

Clicker quiz: Take the speed of sound to be 300 m/s for convenience. A 200 Hz siren is coming towards you on a fast car going 150 m/s. You're driving away from that car at 100 m/s. What frequency do you hear (in Hz)?

a. 150 b. 200 c. 250 d. 267 e. 330

$$f' = f_s \frac{v \pm v_o}{v \pm v_s} = 200\text{Hz}\left(\frac{300-100}{300-150}\right) = 200\left(\frac{200}{150}\right) = \boxed{267\text{ Hz}}$$

Interference/superposition: waves add together



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

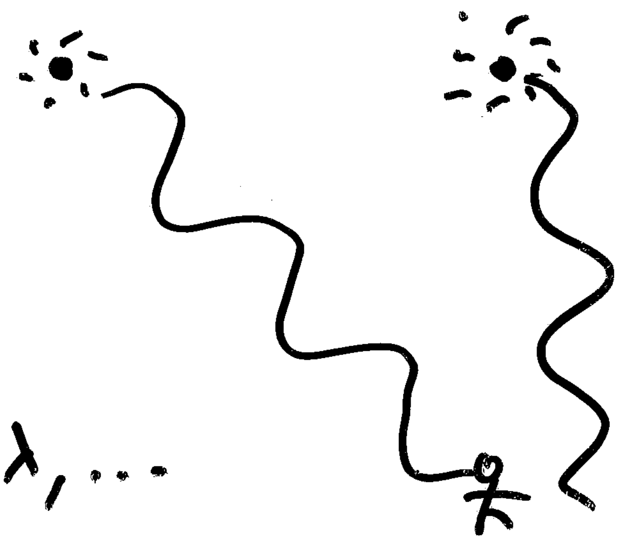
"Path length"

→ waves coming at you from different sources can be shifted from each other

Demo: "Moire pattern" transparencies

From warmup: If two waves are shifted by ________, completely destructive interference will occur.

a. $\lambda/2$
b. $2\lambda/3$
c. λ
d. 2λ



Path-length dependence

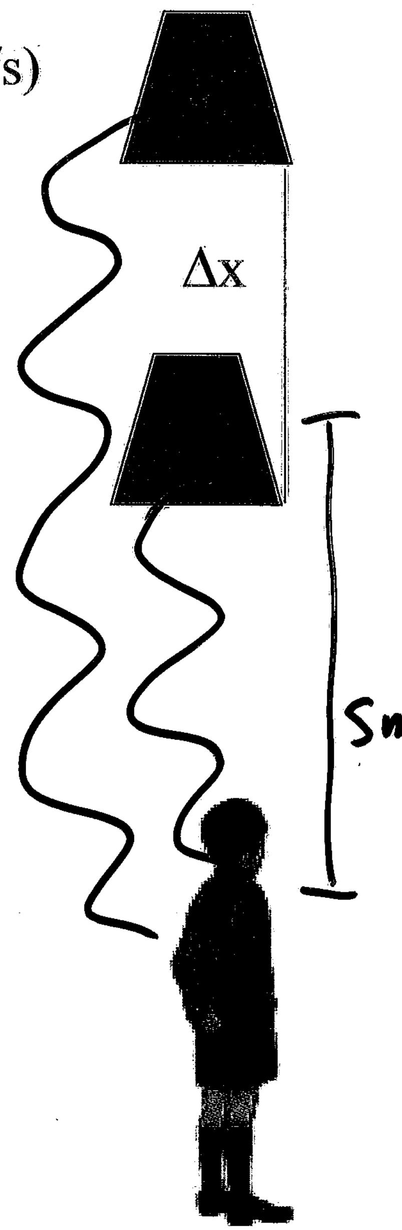
Constructive interference:

$$\Delta L = \lambda, 2\lambda, 3\lambda, \ldots$$

Destructive interference

$$\Delta L = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \ldots$$

Worked Problem: Two speakers are in-line as shown. Both emit the same sound waves (v=343 m/s) at 500 Hz. A boy is standing 5 m away from the nearest speaker.



What is the wavelength?

$$v = \lambda f$$

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

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

dest. interference

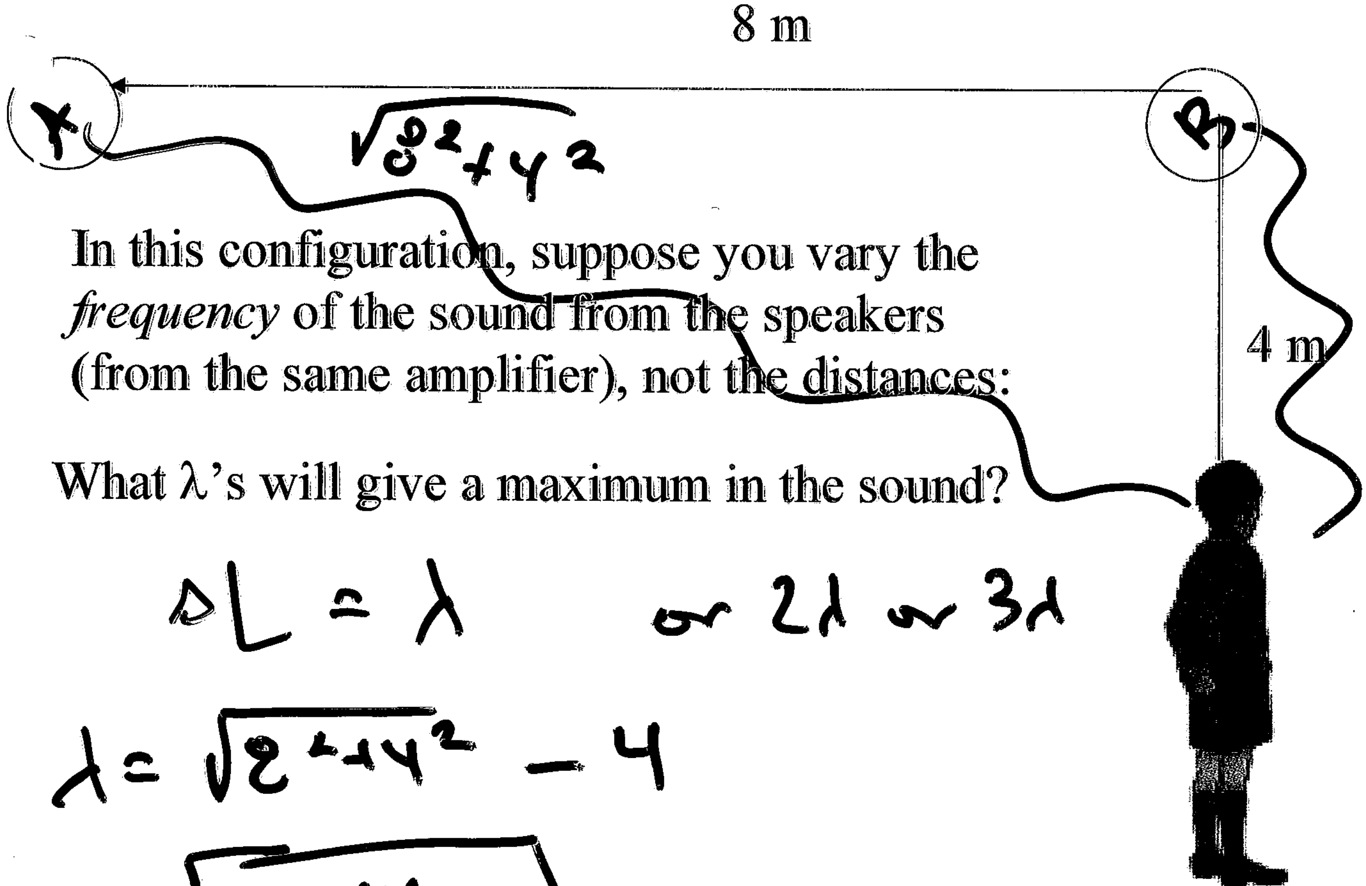
.343m or $\frac{3}{2}\lambda$ or $\frac{5}{2}\lambda$

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

const. interference

.686m or 2λ or 3λ

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



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

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?

$\Delta L = \lambda$ or 2λ or 3λ

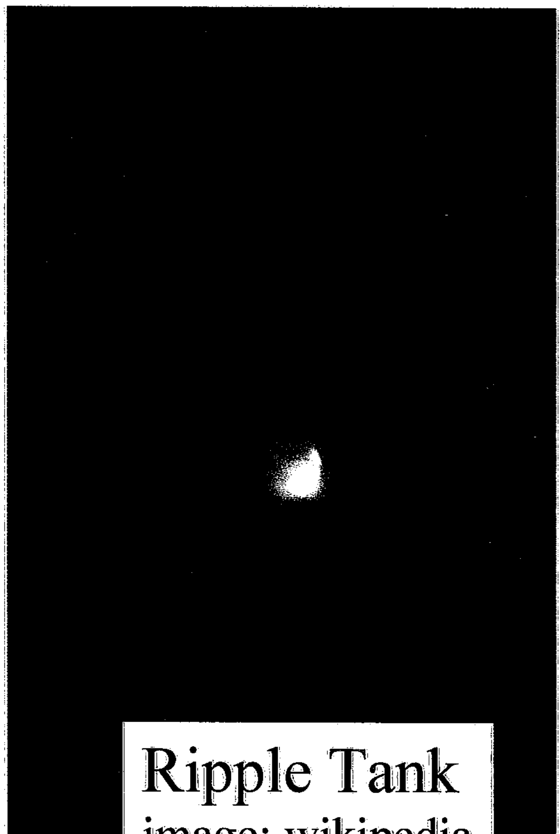
$\lambda = \sqrt{8^2+4^2} - 4$

$= \boxed{4.944\text{m}}$

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

Demo: two speaker interference

Answers: 4.944 m, 2.472 m, 1.648 m, …



Ripple Tank
image: wikipedia

Standing waves:

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

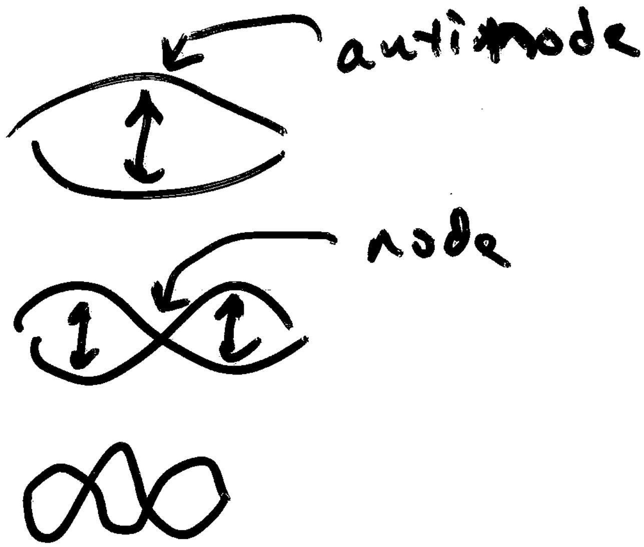
Web demo: http://www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf

- Only certain vibration frequencies give you a stable pattern.

Standing waves on "strings"

Demos: ¼ inch tubing, "ladies belt"

What kinds of patterns can you get?



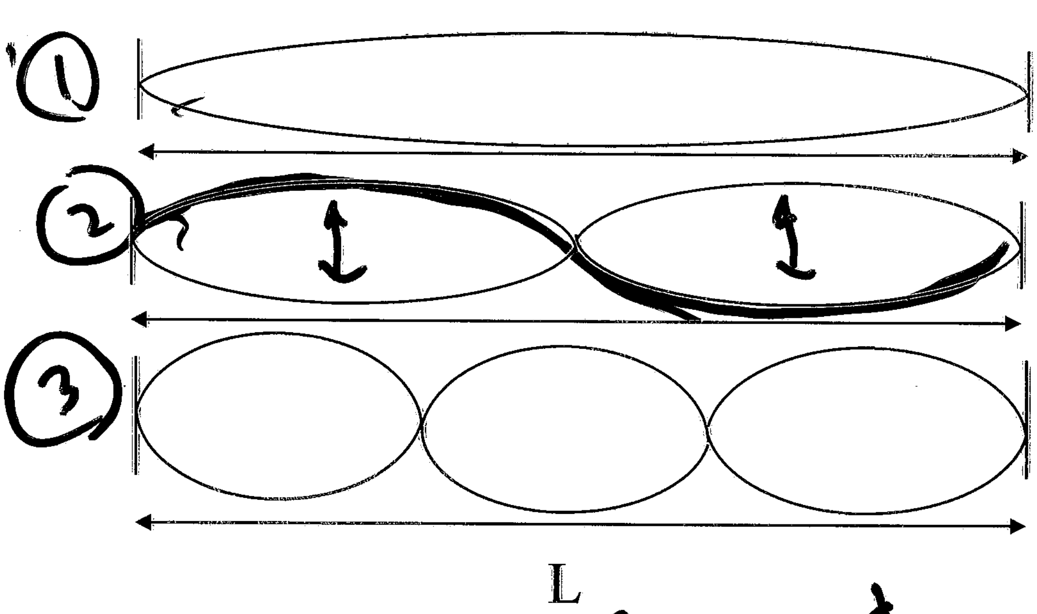
From warmup: In a standing wave, the points that have the maximum vibration are called:

a. nodes
b. anti-nodes

Different stable frequencies called: Harmonics

Harmonics of string, both ends fixed

→ How many wavelengths fit into the length, L?



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

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

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

For stable patterns: $n \times \frac{\lambda}{2}$

What are the frequencies of these harmonics? $v = \lambda \cdot f$

1. $L = \frac{1}{2}\lambda = \frac{1}{2}\left(\frac{v}{f}\right)$

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

2. $f_2 = 2\frac{v}{2L}$

3. $f_3 = 3\frac{v}{2L}$

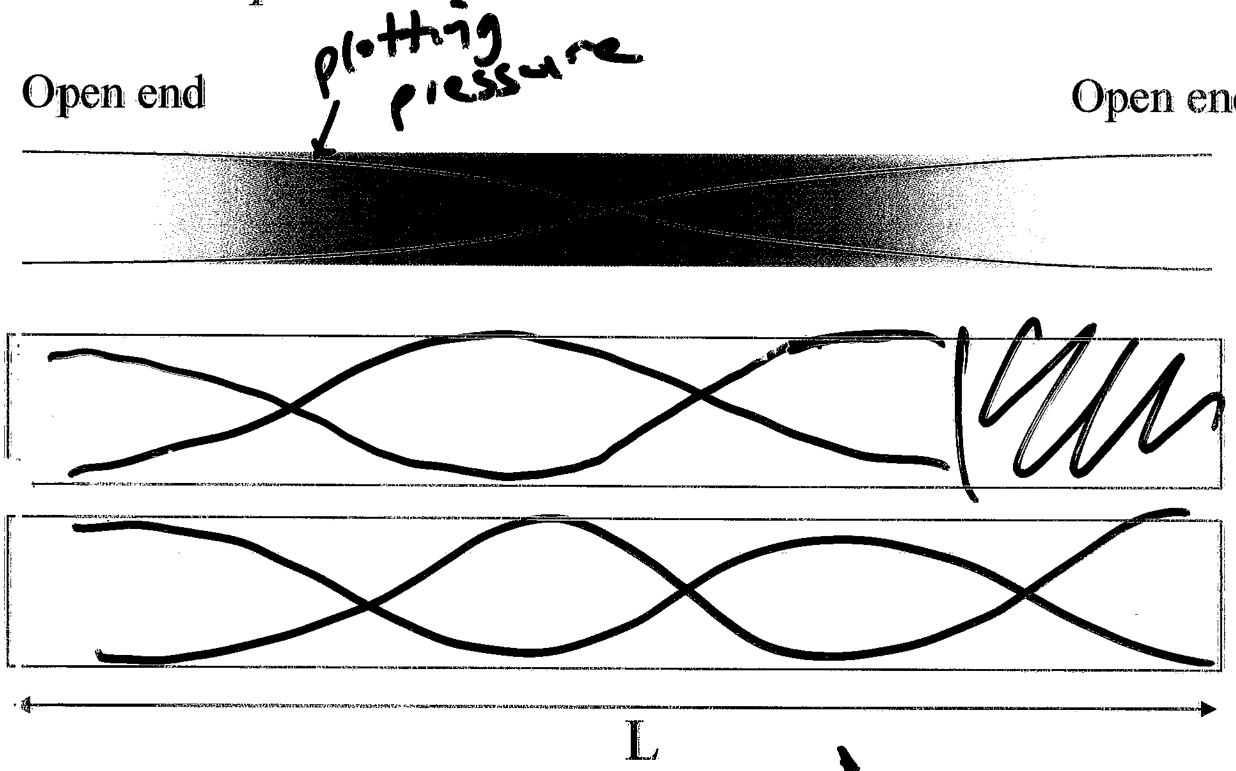
The pattern: $f_n = n \times f_1$; n = 1, 2, 3, …

Standing waves in air

Demos: trumpet, organ pipe

"Open-open" pipes

Pressure patterns:



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

L = λ

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

For stable patterns: $L = n\frac{\lambda}{2}$

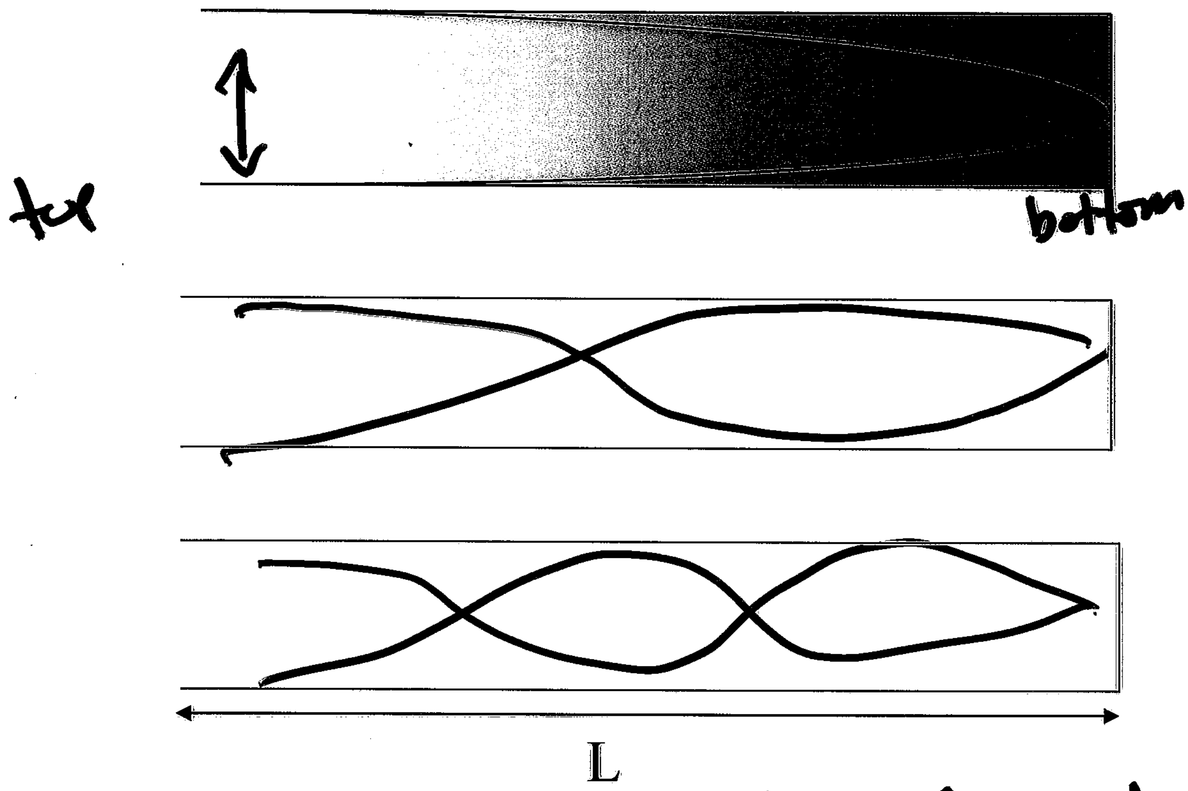
What is the fundamental frequency? (First harmonic)

$f_1 =$ $L = \frac{1}{2}\left(\frac{v}{f}\right) \rightarrow f = \frac{v}{2L}$

Same pattern as before: $f_n = n \times f_1$; n = 1, 2, 3, …

"Open-closed" pipes

Pressure patterns:



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

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

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

For stable patterns: $n \times \frac{1}{4}\lambda$ (odd n)

What are the frequencies of these harmonics?

1. $L = \frac{1}{4}\left(\frac{v}{f}\right) \rightarrow f_1 = \frac{v}{4L}$

2.

3.

The pattern: $f_n = n \times f_1$; n = 1, 3, 5, …

(skipped this page)

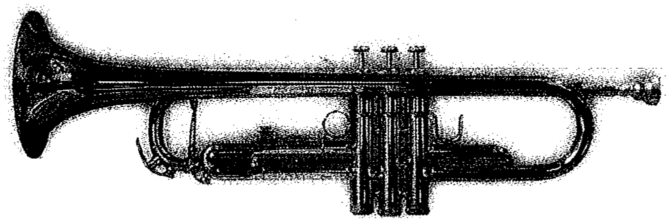
From warmup: You have two pipes which produce sound: one is open at both ends (like an organ pipe) and the other is open at only one end (like a panpipe). If the two pipes have the same length, the fundamental resonant frequency will be ___________ for the two.

a. the same
b. different

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.) T/F: The fundamental frequency could be 240 Hz?

a. True
b. False

Music (if we have time)



Trumpet (Let's suppose a "C trumpet" instead of a regular trumpet, so we don't have to worry about the shift between trumpet & piano scales)

The notes you can play with no valves pushed in:

Note	**Frequency**	**Ratio to Fundamental**
1st harmonic: Low C (with difficulty)	130.8 Hz (fundamental)	1:1
2nd harm: Middle C	261.6	2:1
3rd harm: G	392.4	3:1
4th harm: C above middle C	523.3	4:1
5th harm: E	654.1	5:1
6th harm: G	784.9	6:1
7th harm: B-flat??	915.7	7:1
8th harm: High C	1046.5 Hz	8:1

Common chords: Typically have integer ratio relationships

C-E-G (major) → ratios 4:5:6 (can see from table)

C-E-G-B_{flat} (dominant 7th) → ratios 4:5:6:7

C-E-G-B (major 7th) → ratios 8:10:12:15

C-E_{flat}-G (minor) → ratios 10:12:15

C-E_{flat}-G-B_{flat} (minor 7th) → ratios 10:12:15:18

"One of these things is not like the other"

→ B-flat on piano = 932.3 Hz …why? **To be cont.**