

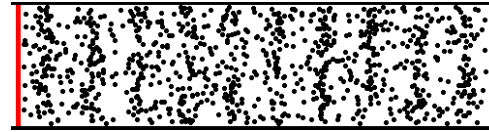
Lecture 26 Announcements

- Happy December!
- Results of the class survey about the final—61% in favor of “plan b”, 39% against. So we’ll do it:
 - Final will replace your worst midterm (unless final is lower than all midterms)
 - Final will be a little harder than last year
 - I’ll shoot for median ≈ 73 (last year had median = 76)
 - If median is below 70, I’ll curve it up to 70
 - Computer grading system may or may not be able to reflect this change in the “Your score on the final exam must be at least xx% to guarantee a final grade of A” statements. I’ll let you know.
- Online course evaluations due Dec 13
<http://studentratings.byu.edu>
 Please take evaluations seriously—I think other students can now see your ratings; promotion/tenure committees definitely look at both the ratings and the comments.
 → 3 pts of extra credit

What’s wrong with this video? Star Wars, Battle of Yavin

What is sound?

Kind of like this:



...but not really. **What** is oscillating? (not exactly the molecules)

What type of oscillation is it?

Demo: Vacuum jar

Audible sound waves: ~20 Hz to ~20 kHz (different for everyone)

Hearing test! Demo: frequency source & speaker

How is sound produced?

- Speaker cutaway
- Tuning fork demo
- Air jet and spinning disk demo
- Vocal folds (“cords”) demo
- “singing rod” demo

Speed of sound

Solids

Recall for strings, $v = \sqrt{\frac{T}{\mu}}$ (transverse waves)

Longitudinal waves in a thin rod: $v = \sqrt{\frac{Y}{\rho}}$ Y is Young’s modulus, related to a 1D stress

Longitudinal waves in general: $v = \sqrt{\frac{B}{\rho}}$ B is the bulk modulus (resistance to 3D “squeezing”)

Solids vs liquids: sound is faster in _____ because _____

Aluminum 5100 m/s
 Water 1500 m/s

Gases: Air: $v = 343$ m/s at 20° C

Other temps: $v = 331$ m/s $\sqrt{\frac{T}{273K}}$

Helium: 972 m/s (at 0° C) Why so much faster?

Intensity

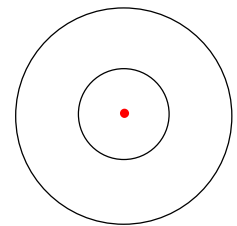
Definition $I = \frac{P}{A}$

Intensity vs distance?

For a *spherically* emitting source:

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

$$\text{so } \frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$$



Clicker quiz: You measure the sound intensity produced by a spherical speaker to be 10 W/m² at a distance of 1.5 meters. What will be the intensity at 3 meters away? _____ W/m²
 a. 2.5 b. 5 c. 10 d. 20 e. 40

What is the total sound power being produced by the speaker?

Decibel intensity scale

- We hear over a huge range of intensities
- So use *base 10 logarithmic scale*: decibel number β
 → **adding ten to dB number = ×10 to the intensity**

$$\text{decibel number} = \beta = 10 \log \frac{I}{I_0} \quad \text{where } I_0 = 10^{-12} \text{ W / m}^2$$

$$\text{solving for I: } I = I_0 \left(10^{\beta/10} \right)$$

		W/m ²	dB
Jet on runway	Instant pain, damage	1000	150
Machine gun	damage	10	130
Rock concert (best seats)	pain, damage	1	120
Power mower	damage (if all day)	10 ⁻²	100
Vacuum cleaner	safe all day	10 ⁻⁵	70
Conversation		10 ⁻⁷	50
Whisper		10 ⁻⁹	30
Rub fingers by ear	Threshold	10 ⁻¹²	0

Mythbusters: jet on a runway

<http://www.youtube.com/watch?v=eTQh7D-nDNM> start at 2:48

...of course, the intensity also depends on the distance away...

OSHA regulations: ≤ 90 dB averaged over 8 hour day.

Logarithm Review (base 10)

$\log_{10}(x)$ is the inverse of 10^y → if $x = 10^y$ then $y = \log_{10}(x)$

I.e. “10 to the what equals 22?” answer: 1.3424 ($\log(22)$)

Review of “Laws of Logs”:

- $\log(ab) = \log(a) + \log(b)$
- $\log(a^n) = n \log(a)$

$\log(100) = ?$ Translation: 10 to what number equals 100?

$\log(10^6) =$

Worked problem: If $\log(3) = 0.477$, what is $\log(300)$?

Decibels again

$$\beta = 10 \log \frac{I}{I_0}$$

β = “decibel number”

$I_0 = 10^{-12} \text{ W/m}^2$

Compare two intensities:

If you increase I by a *factor* of 10, add _____ to β

If you increase I by a *factor* of 100, add _____ to β

If you increase I by a *factor* of 1000, add _____ to β

→ **each factor of ten added to dB number = ×10 to the intensity**

If you increase I by a *factor* of 2, add _____ to β
 [$\log(2) = 0.301$]

Clicker quiz: If you increase I by a *factor* of 8, add _____ to the decibel level (Hint: do it with 2’s)

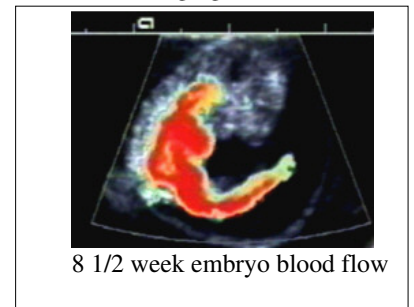
- a. 4 b. 6 c. 8 d. 9 e. 12

Worked problem: You hear an average of 82 dB in your workshop as one printing press runs. The next day you come in and find the sound level to be 88 dB. *How many* total printing presses are now running? (Hint: what happens to β as you double the number of presses?)

Doppler Shift—“Race Car Effect”

Applications:

Doppler ultrasound: blood flow imaging in heart



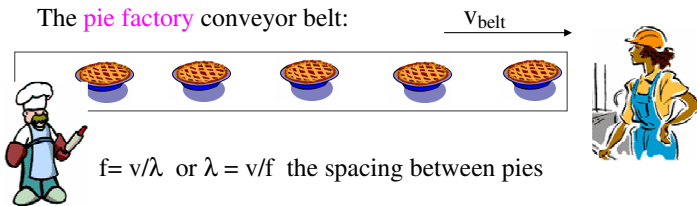
Doppler radar

Frequency is _____ when the source and observer approach each other, _____ when they go away from each other.

Demo: Doppler speaker

Demo: Come, Come, Ye Saints <http://stokes.byu.edu/bells.way>

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 _____ but the pies are coming at her at _____

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

Both source and observer can move

http://stokes.byu.edu/doppler_script_flash.html

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

Choose your signs **carefully!!**

→ Make sure new $f >$ old f when:

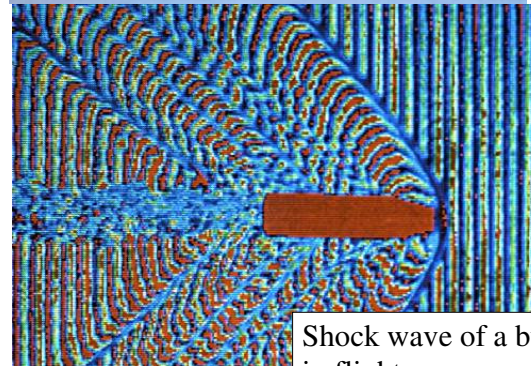
If source moves at or above the speed of the waves...

($v_{source} > v_{wave}$)

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

Bumper sticker:

If this sticker is blue, you're driving too fast.

How fast would you need to go?



Spectral lines & big bang

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!

Review quizzes

Clicker quiz 1: The *intensity* of a wave is its

- a. power
- b. power/area
- c. power \times area
- d. area/power

Clicker quiz 2: If a loudspeaker emits spherical sound waves in all directions, what *decreases* as you go farther away from the loudspeaker?

- a. wavelength
- b. intensity
- c. frequency

Clicker quiz 3: True/false: if you double the sound intensity, the decibel number also gets doubled.

- a. true
- b. false

Clicker quiz 1: 10^{-4} W/m^2 has a dB level of _____ dB.

- a. 4 b. 8 c. 60 d. 80 e. 90

Clicker quiz 2: Two plastics (A and B) have the same density, but plastic A is 16 times harder to compress; that is, it compresses 1/16 as much for the same applied pressure. Which has the *greatest speed* of sound?

- a. A b. B

Clicker quiz 3: A siren emitting at 200 Hz is on a car going *very* fast toward you at 1/2 the speed of sound (take the speed of sound to be 300 m/s here). You travel away from the car on your bike at 1/3 the speed of sound. The frequency you hear is _____ Hz

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