Lecture 26 Announcements

1. Results of the class votes
   a. Final replace a midterm score? **Yes**
      i. 26% for option A (regular final, safety net at 77%)
      ii. 74% for option B (final score will replace one midterm if it helps you, chosen to maximize your points; safety net moved to 73%)

      → Note: computer grading system does not (yet?) reflect this change in the "Your score on the final exam must be at least xx% to guarantee a final grade of X" statements.

2. Colton "class improvement survey" link sent out, 3 bonus points if you complete it by Thurs, Dec 10.

3. Online course evaluations due Dec 13
   http://studentratings.byu.edu
   → Please take both the ratings and the comments seriously. I read every single comment, as does the Physics Department promotion/tenure committee. (No extra credit)

4. TA-led final exam review—doodle.com survey again

5. Rate the TA-lab tutors! You should receive an email. The top tutor (tutors?) gets a cash prize.

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

Can you go over bulk modulus , that was rather confusing.

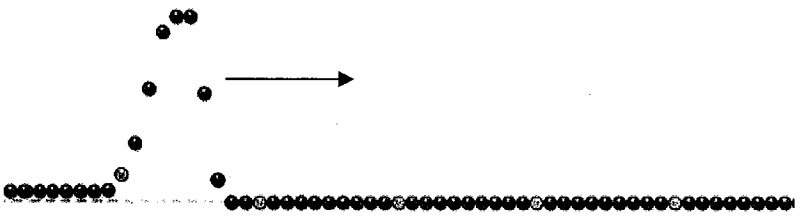
Skip it!

General comments:

how does pitch relate to everything. If someone has perfect pitch what does that mean?

↓ frequency of the sound wave

Reflections



Clicker quiz: What happens when an upward pulse hits the end and turns around?

a. the wave reflects back, upward
b. the wave reflects back, downward
c. it depends

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

Boundaries

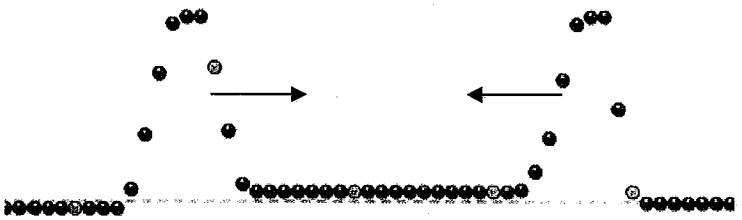
Rope: Light rope meets heavy rope
Light: Air meets glass

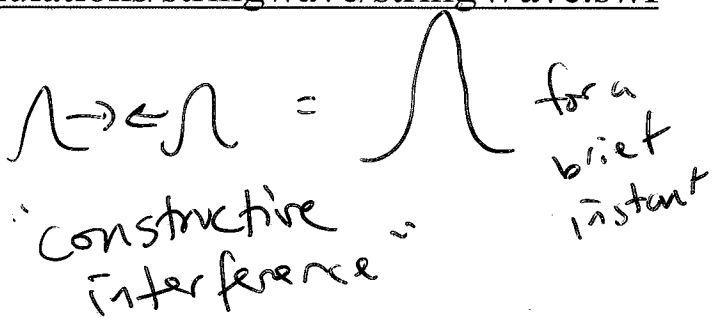
In both cases: transverse wave will flip, it's amplitude (typically)

Sound: Thin air meets dense air
→ Also can cause reflections

Superposition/Interference

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



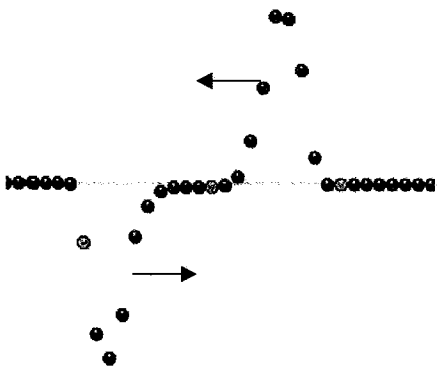


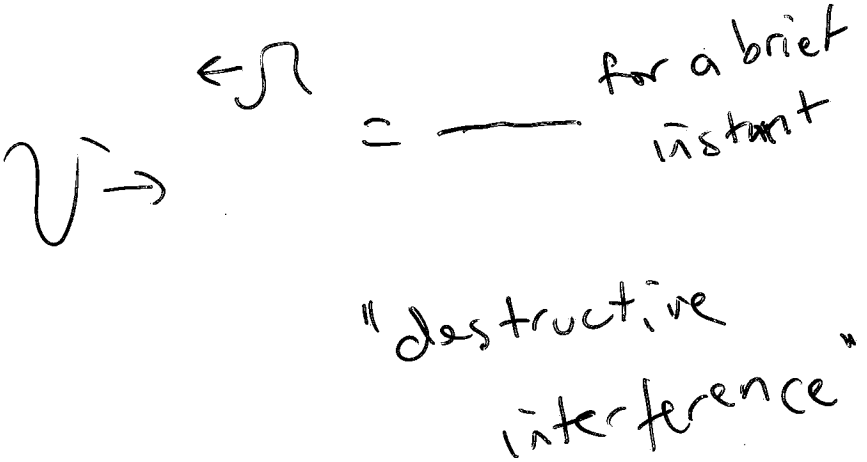
From warmup: What happens when two pulses on a string (one coming from each end) meet in the middle?

a. The pulses pass through each other
b. The pulses reflect off of each other

Demo: Shive wave machine

What about this case?





Review:

What gets transported by the wave? energy
What does the transporting? medium

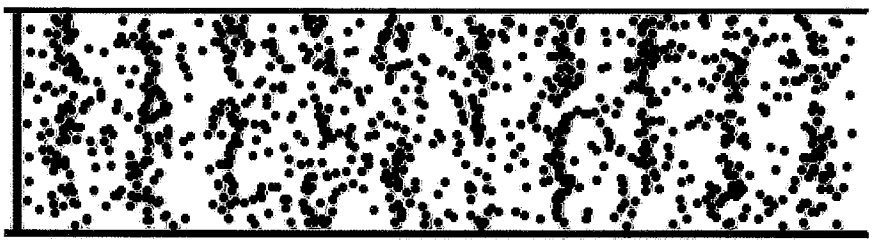
What was wrong with the Star Wars video?

What is sound?

Clicker quiz: What type of oscillation is a sound wave?

a. Longitudinal
b. Transverse
c. Neither

Kind of like this:



…but not entirely. **What** is oscillating like that? The molecules?

pressure or density

Demo: Vacuum jar

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

Demo: **Hearing test!** 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

Gases longitudinal

Air: v = 343 m/s at 20° C

To impress your date:
~1 km in 3 seconds

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

(you don't need to know this)

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

Solids

"Sound waves" in solids are like the P (longitudinal) and S (transverse) waves in earthquakes

Table in book:

Aluminum	5100 m/s
Copper	3560 m/s

} Almost certainly these speeds are for *longitudinal* waves

Liquids

Only longitudinal. (Why are transverse waves not possible?)

Table in book:

Water	1490 m/s
Methanol	1140 m/s

→ Why would solids be the fastest?

Intensity

→ How concentrated (or "focused") the wave is

Definition $I = \frac{Power}{Area}$ $\frac{W}{m^2}$

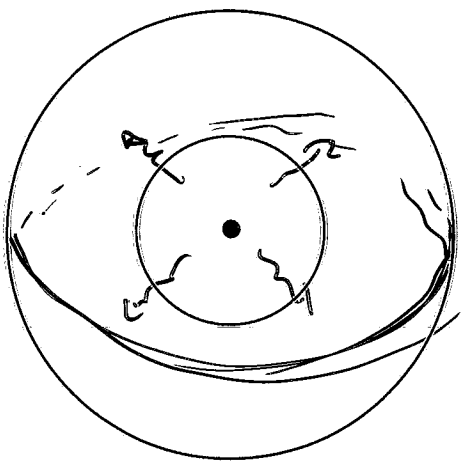
→ Not just for sound

Intensity vs distance?

For a *spherically* emitting source:

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$ area of a sphere

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



$I \sim \frac{1}{r^2}$

From warmup: If a loudspeaker emits spherical sound waves in all directions, what decreases as you go farther away from the loudspeaker?

a. frequency
(b) intensity
c. wavelength

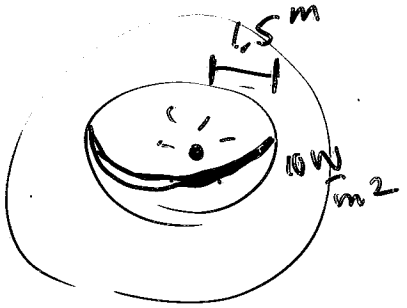
Clicker quiz: You measure the sound intensity produced by a spherically-emitting speaker to be 10 W/m^2 at a distance of 1.5 meters. What will be the intensity at 3 meters away?

_____ W/m^2

a. 2.5 b. 5 c. 10 d. 20 e. 40

double distance → $\frac{1}{4}$ the intensity

Problem: What is the total sound power (watts) being produced by the speaker?



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

$P = I \times \text{Area}$

$= 10 \frac{W}{m^2} \times (4\pi 1.5^2) m^2$

$= 283 W$

Decibel intensity scale

- We hear over a <u>huge</u> range of intensities
- So use a ***logarithmic scale***

(multiplied by 10, for no apparent reason)

"Decibel number" $\boxed{\beta = 10 \log \frac{I}{I_o} \quad \text{where } I_o = 10^{-12} \text{ W/m}^2}$ → minimum intensity we can hear

"log" = "logarithm, base 10"

→ adding ten to dB number = ×10 to the intensity

Answer: 282.7 W

From warmup: You go to a rock concert where the sound level where you are standing is 110 dB. How does the intensity (power/area) of sound waves compare to when you listen to the same music on your home stereo system, 90 dB at the spot you sit?

a. Concert intensity = Stereo intensity
b. Concert intensity = 1.20× stereo intensity
c. Concert intensity = 2× stereo intensity
d. Concert intensity = 10× stereo intensity
e. Concert intensity = 20× stereo intensity
f. Concert intensity = 100× stereo intensity

30% got right

From table in book:

		W/m^2	dB
Jet on a 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

"Jet on a runway?" → calling Mythbusters! ☺
http://www.youtube.com/watch?v=eTQh7D-nDNM start at 2:48

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

From warmup: Ralph is confused about Table 14.2 (8th edition), where the book lists different intensity levels for different sources. For example, the table says a vacuum cleaner has an intensity of 70 dB. What confuses Ralph, is that it seems like a vacuum cleaner should sound louder to someone who is pushing the vacuum cleaner than to someone who is a little farther away. How can the intensity level be 70 dB for both people? How should you answer Ralph's question?

Answer from the class:

Colton: For once in Ralph's life, he got something right!!

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The intensity does decrease as someone gets further away from the source.

Logarithm Review (base 10)

$\text{Log}_{10}(x)$ is the inverse of 10^y $\rightarrow$ if $x = 10^y$ then $y = \log_{10}(x)$

I.e. **"10 to the what equals 22?"** answer: 1.3424 (log(22))

$10^x = 22$ $\quad x = \log_{10}(22)$

$10^{1.3424} = 22$

Review of "Laws of Logs":

1. **log(ab) = log(a) + log(b)**
2. **log(a^n) = n log(a)**

1b. $\log(a/b) = \log a - \log b$

$\log_{10}(100) = ?$ Translation: 10 to what number equals 100? (2)

Test: $10^2 = 100$ ✓

$\ln(100) = ?$ ("ln" = $\log_e$ = $\log_{2.71828}$)

Translation: e to what number equals 100? (4.605)

Test with calculator: $2.71828^{4.605} = 99.983$

If the problem just says log(100)…could be either $\log_{10}$ or ln

For us: assume $\log_{10}$

Worked Problem: $\log_{10}(1{,}000{,}000) = \log_{10}(10^6)$

$= 6\log_{10}(10) = 6 \times 1 = \boxed{6}$

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

$\log(300) = \log(3) + \log(100)$

$= .477 + 2$

$= \boxed{2.477\ldots}$

Decibels again

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

β = "decibel number"

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

Compare two intensities:

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

If you increase I by a *factor* of 100, *add* +20 to β

If you increase I by a *factor* of 1000, *add* +30 to β

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

Worked problem: If you increase I by ×2, what do you add to β? (Given that log(2) = 0.301.)

$\beta_1 = 10 \log \frac{I_1}{I_0}$ $\quad$ $\beta_2 = 10 \log \frac{2I_1}{I_0}$

$\beta_2 - \beta_1 = ?$

$= 10 \log \frac{2I_1}{I_0} - 10 \log \frac{I_1}{I_0}$

$= 10 \left[\log \frac{2I_1}{I_0} - \log \frac{I_1}{I_0} \right]$

$= 10 \log \left[\frac{2I_1/I_0}{I_1/I_0} \right]$

$= 10 \log 2 = \boxed{3.01}$

You need to know this for final

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

→ each ×10 to the intensity means you add 10 dBs

→ each factor of 3 added to dB number = ×2 to the intensity

→ each ×2 to the intensity means you add 3 dBs

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

$8 = 2 \times 2 \times 2$

$I: \times 2 \times 2 \times 2$ ⇝ $dB: +3+3+3$

$= +9$

Worked problem: You hear an average of 82 dB in your workshop as three printing presses run. The next day you come in and find the sound level to be 88 dB. *How many* total printing presses are now running?

$6\ dB = +3+3$ ⇝ $\frac{I}{\times 2 \times 2} = \times 4$

3 printing presses × 4

= 12 presses

What if you need to solve for *I*?

$\beta = 10 \left(\log \frac{I}{I_0}\right)$ given

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

$10^{\beta/10} = 10^{\log(I/I_0)}$

$10^{\beta/10} = I/I_0$

(this is not given on final)

$$I = I_o \left(10^{\beta/10}\right)$$

Review quizzes

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

a. power
b. power/area
c. power × area

Clicker quiz 2: True/false: if you double the sound intensity, the decibel number also gets doubled.

a. true → add +3
b. false

Clicker quiz 3: 10^{-4} W/m^2 has a dB level of _____ dB.

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

$\beta = 10 \log \frac{I}{(10^{-12}\ W/m^2)}$

$= 10 \log \left(\frac{10^{-4}\ W/m^2}{10^{-12}\ W/m^2}\right) = 10 \log 10^8$

$= 10(8)\log 10$

$= 80$