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?

\[ f \]

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
   ☐ 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?

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 \( \text{longitudinal} \)
Air: \( v = 343 \text{ m/s at } 20^\circ \text{ C} \)

To impress your date:
\(~1 \text{ km in } 3 \text{ seconds}\)

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 \text{longitudinal waves} \}

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

Table in book:
- Water 1490 m/s
- Methanol 1140 m/s

\( \rightarrow \) Why would solids be the fastest?
Intensity

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

Definition \[ I = \frac{P_{\text{ower}}}{A_{\text{rea}}} \quad \frac{\text{W}}{\text{m}^2} \]

→ Not just for sound

Intensity vs distance?
For a spherically emitting source:

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

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/m² at a distance of 1.5 meters. What will be the intensity at 3 meters away?

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

\[ \text{Intensity at 3 meters} = \frac{1}{4} \text{ of the intensity at 1.5 meters} \]

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

\[ P = I \times \text{Area} = 10 \text{ W/m}^2 \times \left(4\pi \times 1.5^2 \right) \text{ m}^2 = 283 \text{ W} \]

**Decibel intensity scale**
- We hear over a huge range of intensities
- So use a logarithmic scale (multiplied by 10, for no apparent reason)

**“Decibel number”**

\[ \beta = 10 \log \left( \frac{I}{I_o} \right) \quad \text{where} \quad I_o = 10^{-12} \text{ W/m}^2 \]

“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

From table in book:

<table>
<thead>
<tr>
<th></th>
<th>W/m²</th>
<th>dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet on a runway</td>
<td>1000</td>
<td>150</td>
</tr>
<tr>
<td>Machine gun</td>
<td>10</td>
<td>130</td>
</tr>
<tr>
<td>Rock concert (best seats)</td>
<td>1</td>
<td>120</td>
</tr>
<tr>
<td>Power mower</td>
<td>10⁻²</td>
<td>100</td>
</tr>
<tr>
<td>Vacuum cleaner</td>
<td>10⁻⁵</td>
<td>70</td>
</tr>
<tr>
<td>Conversation</td>
<td>10⁻⁷</td>
<td>50</td>
</tr>
<tr>
<td>Whisper</td>
<td>10⁻⁹</td>
<td>30</td>
</tr>
<tr>
<td>Rub fingers by ear</td>
<td>10⁻¹²</td>
<td>0</td>
</tr>
</tbody>
</table>

"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)

Log_{10}(x) is the inverse of 10^y \quad \rightarrow \quad \text{if } x = 10^y \text{ then } y = \log_{10}(x)

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

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

Review of "Laws of Logs":

1. \log(ab) = \log(a) + \log(b)
2. \log(a^n) = n \log(a)
3. \log\left(\frac{a}{b}\right) = \log(a) - \log(b)

\log_{10}(100) = ? \quad \text{Translation: 10 to what number equals 100? (2)}
\quad \text{Test: } 10^2 = 100 \checkmark

\ln(100) = ? \quad (\ln = \log_e = \log_{2.71828})
\quad \text{Translation: e to what number equals 100? (4.605)}
\quad \text{Test with calculator: } 2.71828^{4.605} = 99.983

If the problem just says \log(100)\ldots \text{could be either } \log_{10} \text{ or } \ln
\quad \text{For us: assume } \log_{10}

**Worked Problem:** \log_{10}(1,000,000) = \log_{10}(10^6)
\quad = 6 \log_{10}(10) = 6 \times 1
\quad = \boxed{6}

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

\[ \log(300) = \log(3) + \log(100) \]
\quad = 0.477 + 2
\quad = \boxed{2.477\ldots}
Decibels again

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

Compare two intensities:
- If you increase I by a factor of 10, add \( +10 \) to \( \beta \)
- If you increase I by a factor of 100, add \( +20 \) to \( \beta \)
- If you increase I by a factor of 1000, add \( +30 \) to \( \beta \)

→ each factor of ten added to dB number = \( \times 10 \) to the intensity

**Worked problem:** If you increase \( I \) by \( \times 2 \), what do you add to \( \beta \)?
(Given that \( \log(2) = 0.301 \).)

\[ \beta_1 = 10 \log \frac{I_1}{I_0} \]
\[ \beta_2 = 10 \log \frac{2I_1}{I_0} \]

\[ \beta_2 - \beta_1 = ? \]
\[ = 10 \log \frac{2I_1}{I_0} - 10 \log \frac{I_1}{I_0} \]
\[ = 10 \left[ \log \frac{2I_1}{I_0} - \log \frac{I_1}{I_0} \right] \]
\[ = 10 \log \left[ \frac{2I_1}{I_0} \right] \]
\[ = 10 \log 2 = [3.01] \]

Colton - Lecture 26 - pg 11
You need to know this for final

→ each factor of ten added to dB number = $\times 10$ to the intensity
→ each $\times 10$ to the intensity means you add 10 dBs

→ each factor of 3 added to dB number = $\times 2$ to the intensity
→ each $\times 2$ 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 = $2 \times 2 \times 2$

$I \times 2 \times 2 \times 2 = 3$ 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?

$6 \text{ dB} = +3 + 3 \leq \frac{I}{x2 \times 2 = x4}$

$3 \text{ printing presses} \times 4 = 12 \text{ presses}$
What if you need to solve for $I$?

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

Given

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

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

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

(this is not given on final)

**Review quizzes**

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

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

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

- a. true
- 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

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

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

$$= 80$$