Announcements – 2 Dec 2014

1. Prayer

2. Exam 3 going on
    a. Covers Ch 9-12, HW 18-24
    b. Late fee on Wed Dec 3, 3 pm
    c. Closes on Thursday Dec 4, 3 pm

3. Photo contest submissions due Friday Dec 5, midnight

4. Instructor/course ratings Nov 20 – Dec 14. Extra credit: 2 points
   http://studentratings.byu.edu

→ Please take the ratings and comments seriously!

“Which of the problems from last night's HW assignment would you most like me to discuss in class today?”

Waves on Ropes

$$w = \sqrt{\frac{k}{m}}$$

What will changing the **tension** do?

$$v = \sqrt{\frac{T}{\mu}}$$

For waves on a rope/string/etc

linear mass density, m/L

Note: the book uses symbol *F* for tension in this section
(I don't know why)

Demo: rubber tubing

From warmup (last time)

Two students play with an extra-long Slinky. The student on the left end sends waves to the other student by shaking her end back and forth. After the waves die down, both students take a step backwards and try it again. How will the speed of the waves now compare to the previous waves?

[✓ a.] They will be faster
b. They will be slower
c. They will go the same speed

Question

What happens when you increase the wave speed while keeping the wavelength constant?

$$\underset{\uparrow}{v} = \underset{\equiv}{\lambda} f$$

f goes up

Demo: violin

Clicker quiz

Two guitar strings of the same length have the same tension, but one has four times the mass of the other. The speed of a wave on the heavier guitar string is ___________ that of the lighter string.

a. ¼
[✓ b.] ½
c. the same as
d. 2×
e. 4×

$$v = \sqrt{\frac{T}{\mu}}$$

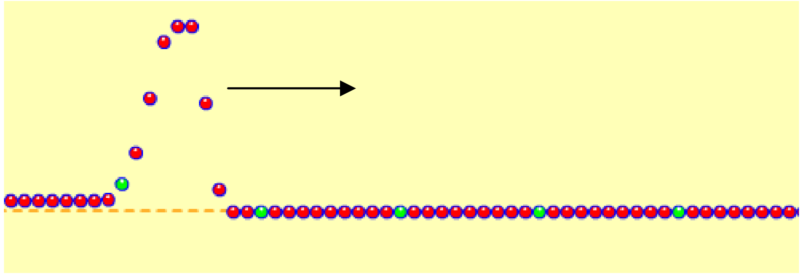
$$= \sqrt{\frac{T}{m/L}}$$

$$v \sim \frac{1}{\sqrt{m}}$$

$4\times$ m

$\rightarrow \frac{1}{2} v$

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]

Demo: rubber tubing

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

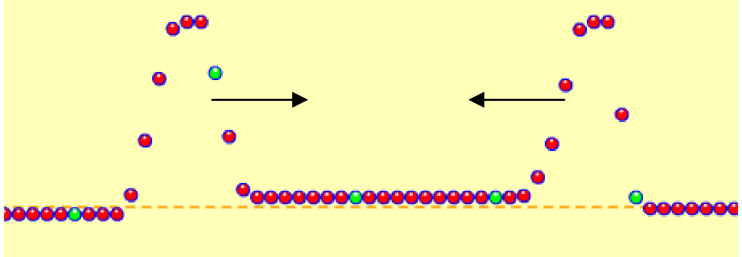
Boundaries

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

In both cases:
Part of wave reflects and part of wave transmits

Superposition/Interference

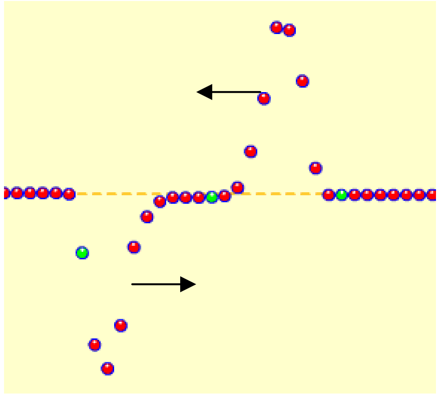
http://www.colorado.edu/physics/phet/simulations/stringwave/stringWave.swf



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

Demo: Shive wave machine

What about this case?



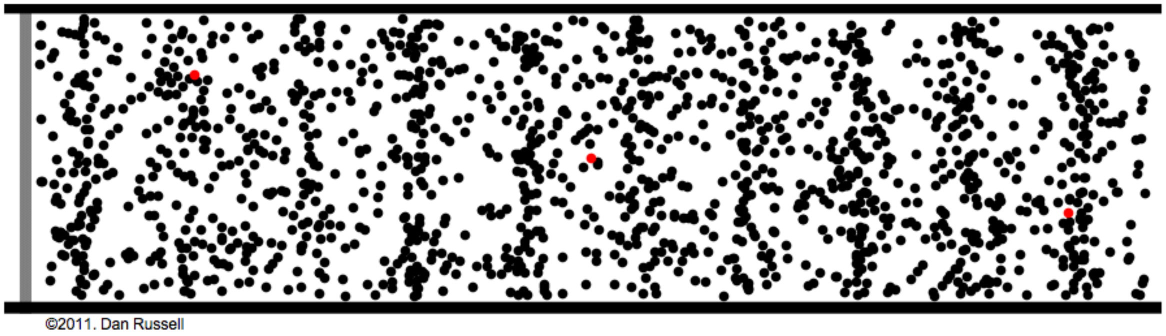
Sound

Demo: No sound in a vacuum

aka “What’s usually wrong with science ficition movies?”

What is Sound?

Kind of like this:
http://www.acs.psu.edu/drussell/demos/waves/wavemotion.html



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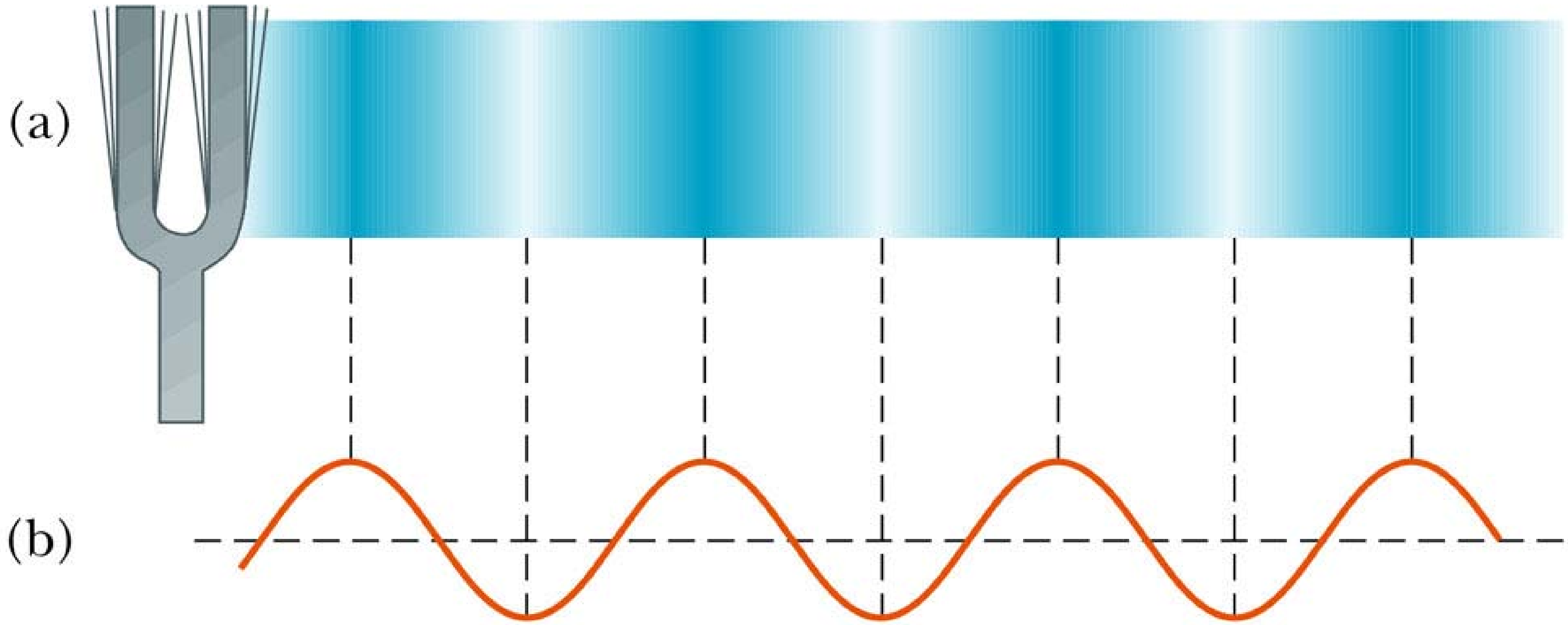
…but not entirely

Compressions & Rarefactions



Demo

Hearing test! Frequency source & speaker

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

How is sound produced?

→ Speaker cutaway
→ Demo: Tuning fork
→ Demo: “singing rod”
→ Demo: Air jet and spinning disk

Speed of sound

Gases longitudinal

Air: v = 343 m/s at 20° C

To impress your date:
~1 km in 3 seconds

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

(You need that for one or two HW problems.)

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

Solids

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

Speed of sound, cont.

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

$$\frac{\text{power}}{\text{area}} \quad \left(\frac{\text{energy}}{\text{time}}\right)$$

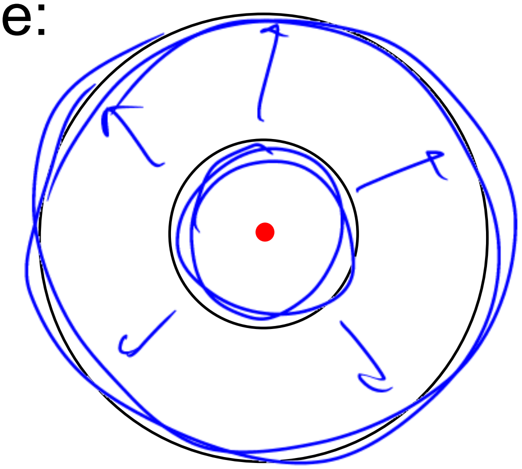
(not just for sound)

Intensity vs distance

watts/m^2

$A_{sphere} = 4\pi r^2$

For a *spherically* emitting source:



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

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

inverse square law!

True also for most sound waves, even if not spherical, since $A \sim r^2$ for other shapes as well.

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. speed
d. wavelength

$$\lambda = \frac{v}{f}$$

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?

- [✓ a. 2.5 W/m^2]
- b. 5
- c. 10
- d. 20
- e. 40 W/m^2

inverse square!

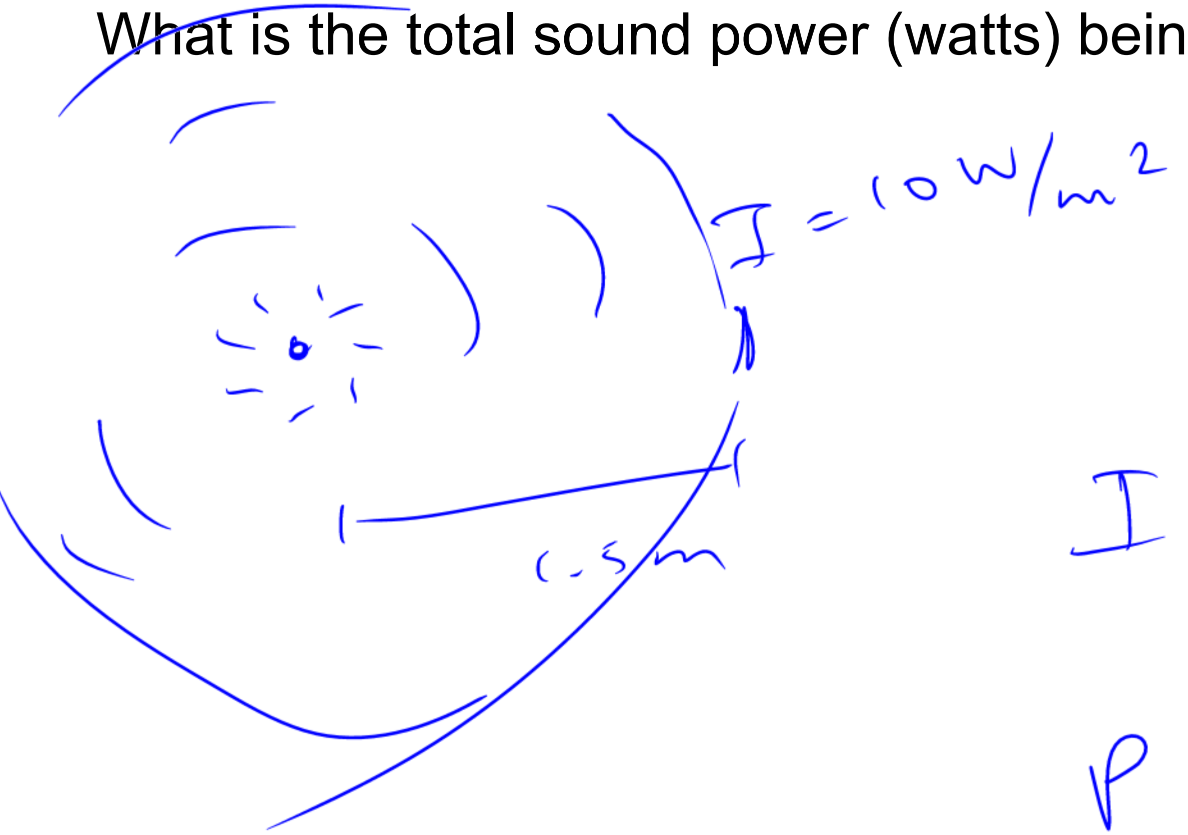
$$I \sim \frac{1}{r^2}$$

$$r \times 2$$

$$\rightarrow I \div 4$$

Worked Problem

Same situation (spherically emitting speaker, 10 W/m^2 at 1.5 meters). What is the total sound power (watts) being produced by the speaker?



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

$$P = I \cdot A$$

$$= \left(10\,\frac{W}{m^2}\right)\left(4\pi \cdot (1.5\,m)^2\right)$$

$$= \boxed{282.7\,W}$$

Answer: 282.7 W

Clicker quiz

An earthquake that has a Richter scale magnitude of 8 is how much more "powerful" (in some sense) than one that has a magnitude of 7?

Earthquake 1 = ______ × Earthquake 2.

a. 1.1
b. 1.1429
c. 2
d. 8
[✓ e.] 10

Richter Scale: “Logarithmic”

→ **adding one to Richter scale number = ×10 to the intensity**

Decibels

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

→ multiplied by 10, for no apparent reason

beta

"Decibel number" $\beta = 10\log\frac{I}{I_o}$ where $I_o = 10^{-12}\ \text{W/m}^2$

"log" = "logarithm, base 10"

→ **0 dB = 10^{-12} W/m^2 reference**

→ **adding <u>ten</u> to dB number = ×10 to the intensity**

β	I
0 dB	$10^{-12}\ \frac{W}{m^2}$
10 dB	10^{-11}
20	10^{-10}
30	10^{-9}
40	10^{-8}

if $I = 10^{-12}$

then $\beta = 10 \times \log\left(\frac{10^{-12}}{10^{-12}}\right)$

$\beta = 0$

From warmup

How much more intensity (power per area) does a 100 dB sound have compared to an 80 dB sound?

a. 2x more intensity
b. 10x
c. 20x
d. 50x
[✓ e. 100x]
f. 200x

+20 dB = × 100

Decibels, cont.

From table in book:

I β

		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

OSHA

TABLE D-2 - PERMISSIBLE NOISE EXPOSURES

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4 or less	115

https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10625

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?

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

Logarithm Review (base 10)

"10 to the what equals 22?" answer: $\log_{10}(22)$ $= 1.3424\ldots$

$10^{1.3424\ldots} = 22$

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

$\log x = \log(10^y) = y$

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

$\log_{10}(235) =$? Translation: 10 to what number equals 235? (2.3711…)
Test with calculator: $10^{2.3711} = 235.017\ldots$

Natural Logs? Looking at powers of 2.171828…, called "e"

Clicker quiz

What is $\log_{10}(1{,}000{,}000)$?

a. 1
[✓ b.] 6
c. 7.5
d. 10
e. 93

$10^x = 1000000$?

$10^6 = 1000000$

$\log a/b = \log a - \log b$

"Laws of Logs" Review

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

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

$= \log 3 + 2$

$\log(\underset{3^3}{27}) = 3 \log 3$

Worked problem: Given $\log_{10}(3) = 0.477$, what is $\log_{10}(300)$?

$\boxed{2.477\ldots}$

Decibels, revisited

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

β = "decibel number"

$I_0 = 10^{-12}$ 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

$\beta = +3$

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

$I_2 = 2 I_1$

$\beta_2 = \beta_1 + ?$

$\beta_2 = 10 \log \frac{I_2}{I_0}$

$\beta_1 = 10 \log I_1/I_0$

$\beta_2 - \beta_1 = 10 \log I_2/I_0 - 10 \log I_1/I_0$

$10\left(\log I_2 - \cancel{\log I_0}\right) - 10\left(\log I_1 - \cancel{\log I_0}\right)$

$10\left(\log I_2/I_1\right) = 10 \log(2)$

You may 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

I	dB
×2	+3
×2	+3
×2	+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?

What if you need to solve for *I*?

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

Answer: $I = I_0 \cdot 10^{\beta/10}$

Review quizzes

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

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

Clicker quiz 2: T/F: 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