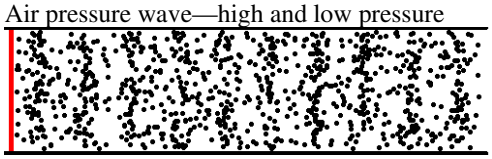
Announcements

1. Happy December!
2. Exam 4: starts Friday, goes through Monday
   a. Covers chapters 9-12
      i. Solids, fluids, gases
      ii. Thermodynamics
   b. Covers HW17-21
   c. Thursday's class will be exam review
   d. Equations should be posted on website
3. Late HW due on Friday for HW 17-20
4. Online course evaluations, do before Dec 13
   http://studentratings.byu.edu

What is sound?

Air pressure wave—high and low pressure

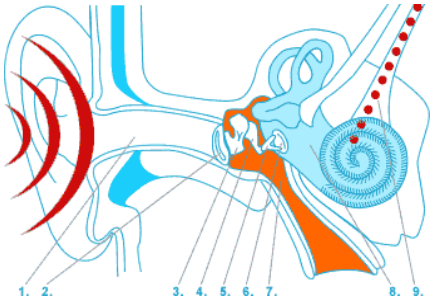


Longitudinal wave—air molecules move back and forth along the direction of wave travel.

Demo: siren disk, bucket call, tuning fork, vacuum jar
Video: Star Wars
http://www.youtube.com/watch?v=bqN-ybphzZc

Audible sound waves - 20 Hz to 20 kHz (varies in each person)

Hearing test! Demo: speaker, frequency source



2. Eardrum
3. Hammer
4. Anvil
5. Stirrup
6. Oval window
8. Cochlea
9. Nerve of hearing

Speed of sound in a gas/liquid:

$$v = \sqrt{\frac{B}{\rho}}$$

B is the bulk modulus (resistance to 3D "squeezing")

Air: v = 331 m/s at 0 °C

Other T's: $v = 331 \text{ m/s} \sqrt{\frac{T}{273K}}$

At 20°C: **v = 343 m/s**

Helium: 972 m/s at 0 °C

ρ_{He} compared to air?

Demo: frequency when speaking

Solids:

$$v = \sqrt{\frac{Y}{\rho}}$$ longitudinal waves

Y is Young's modulus: (resistance to 1D stress)

Air vs solids: solids are faster because_____

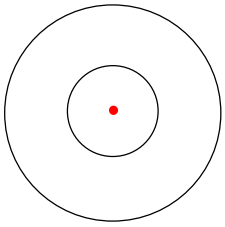
solids: water 1500 m/s
aluminum 5100 m/s

Intensity and power $I = \frac{P}{A}$

Intensity vs distance?
For a *spherically* emitting source:

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

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



A spherical speaker puts out an intensity of 10 W/m^2 at a distance of 1.5 meters.

Q4. The intensity at 3 meters away is _____W/m^2
a. 2.5 b. 5 c. 10 d. 20 e. 40

The total power the speaker puts out is _____ W

Decibel intensity scale

- We hear over a huge range of intensities
- So use *logarithmic scale*: decibel number β, (powers of 10)

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

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

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

		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

Intensity depends on distance from source!
Demo: sound meter
OSHA regulations: ≤ 90 dB averaged over 8 hour day.

Logarithms (base 10)

$\text{Log}_{10}(x)$ 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”:
1. log(ab) = log(a) + log(b)
2. log(a^n) = n log(a)

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

log(10^6) =

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

Decibels again

$$\beta = 10 \log \frac{I}{I_o} \qquad \beta = \text{“decibel number”}$$

$I_0 = 10^{-12}$ 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]

Q5. 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

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

Doppler Shift—“Race Car Effect”

Applications:
Doppler ultrasound: blood flow imaging in heart

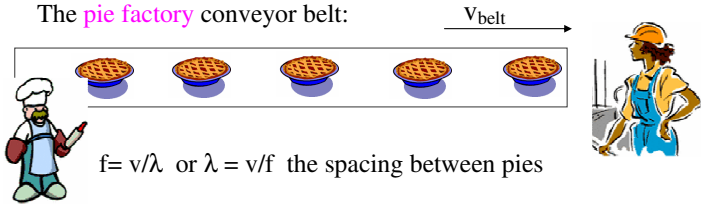

8 1/2 week embryo blood flow

Doppler radar

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

Demo: Doppler speaker

The pie factory conveyor belt: v_{belt}



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

v_s source speed
v_o observer speed
v speed of sound

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

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

Both source and observer could move:

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

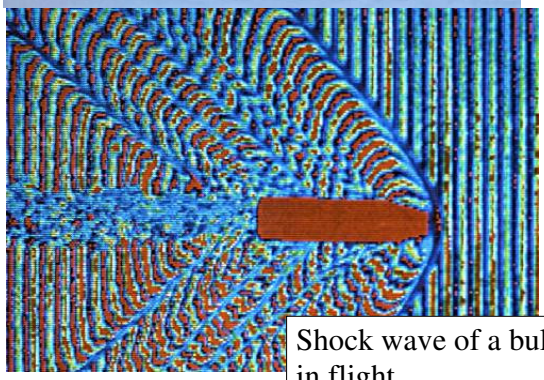
$$f' = f\left(\frac{v \pm v_o}{v \pm v_s}\right)$$

How to choose your signs?

Demo: tone change executable http://stokes.byu.edu/bells.wav

When the 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?

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!*

Spectral lines & big bang

Q6. 10^{-4} W/m^2 has a dB level of _____ dB.
a. 4 b. 8 c. 60 d. 80 e. 90

Q7. A siren emitting at 200 Hz is on a car going *very* fast toward you at ½ 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

Q8. Two plastics have the same density, but plastic A is 16 times as stiff as plastic B. Which has the *greatest speed* of sound?
a. A b. B

Q9. The factor by which it is greater is: _____
a. 2 b. 4 c. 8 d. 16 e. 32

Q10. Did you discuss at least half of the discussion quiz questions today with a neighbor?
a. Yes b. No