Announcements 8 May 09

- Homework #13
  - Written homework due in class on Monday
  - Online homework due on Tuesday by 8 am
    - Problem 15.35: use v_{sound} = 343 m/s
- Final exam
  - Thu May 14 from 1:30 to 3:30 pm (see info on blog)
  - Boyden gym
  - Basic info and sample exam are on blog

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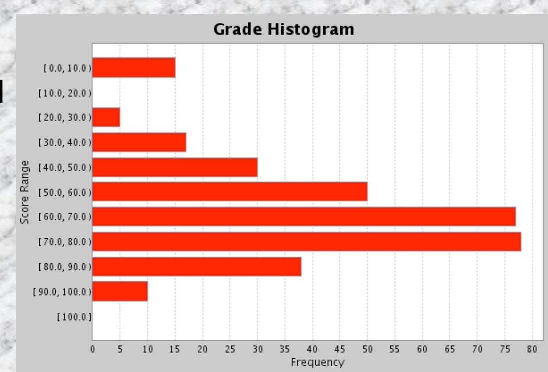
Announcements 8 May 09

- Exam 3
  - Answer keys posted
  - Multiple choice results in SPARK
  - 5 points added to all scores
  - Written question yet to be added



- Grade
  - Current letter grade posted in SPARK
  - Grade can only get better
  - Still need to scale PRS/WH category up slighly

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Chapter 16
Superposition and Standing Waves

Topics:

- Superposition
- Constructive and destructive interference
- Standing waves
- Resonant modes of systems
- Beats

Sample question:

How does a player get such a wide range of sounds from an instrument as simple as the didgeridoo?

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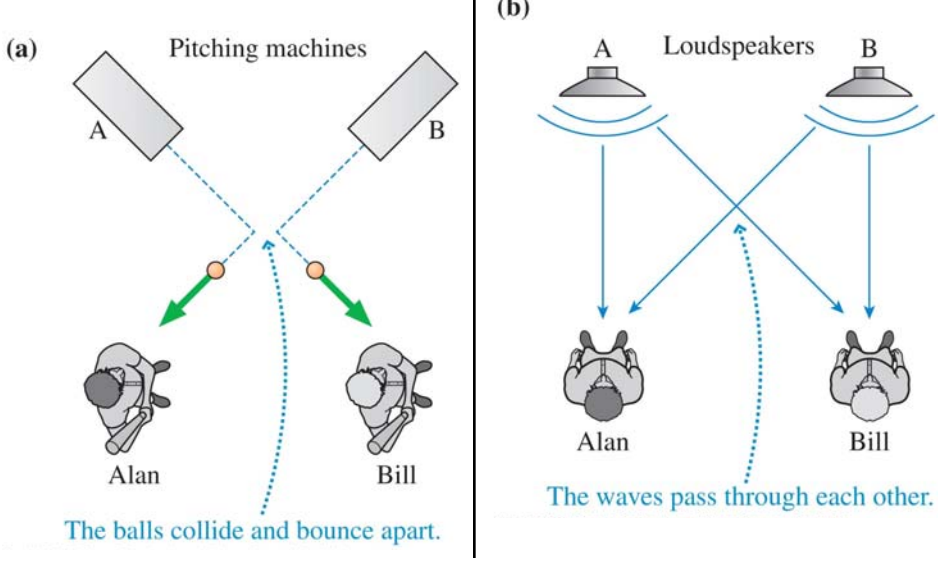
What happens when 2 waves meet at the same point?

2 particles

2 waves



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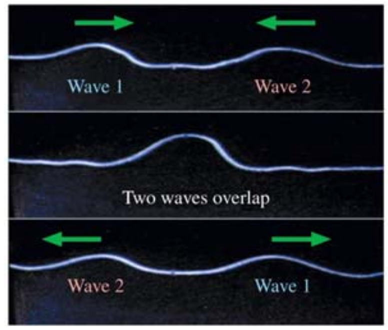
Principle of Superposition

- Waves can pass through one another, they can be present simultaneously at a single point in space
- The displacement of the medium at a given point is the sum of the displacements due to each individual wave



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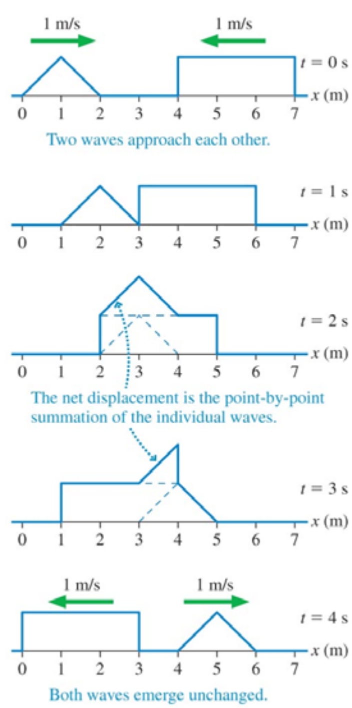
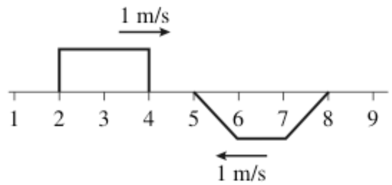


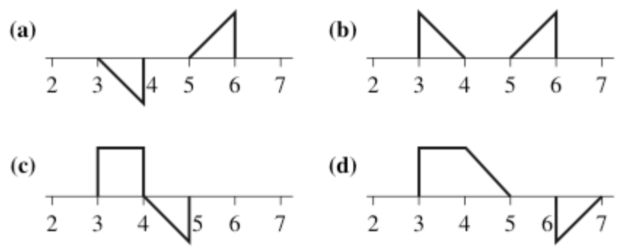
Wave superposition question

PRS

Two waves on a string are moving toward each other. A picture at t = 0 s appears as follows:



How does the string appear at t = 2 s?



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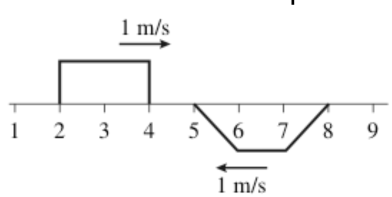

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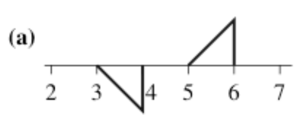
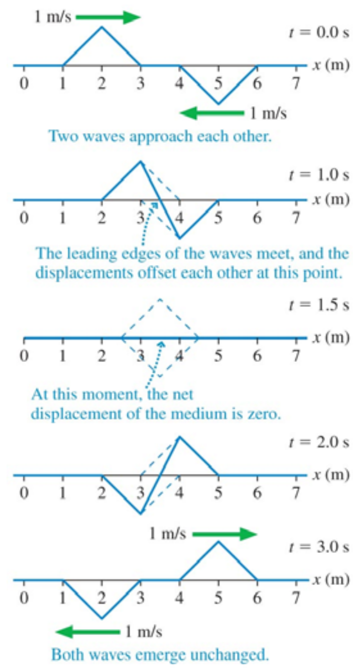


Principle of Superposition

- **Constructive interference:**
  if the displacement at a point is larger than that from either of the two waves taken separately

- **Destructive interference:**
  if the displacement at a point is smaller than that from either of the two waves taken separately



See animation
http://www.kettering.edu/~drussell/Demos/superposition/superposition.html

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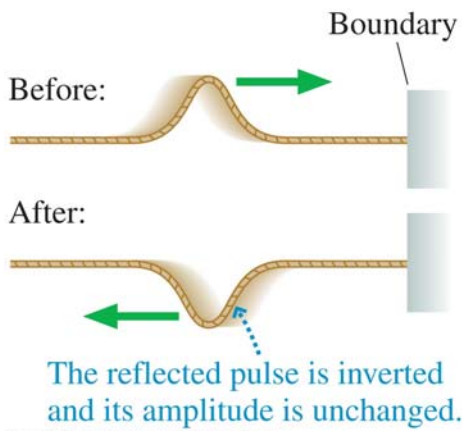
Standing waves: musical instruments

What happens when you pluck a guitar string?



Waves are created, moving in opposite directions

DEMO: Wave on a string, horizontal shive (reflection)

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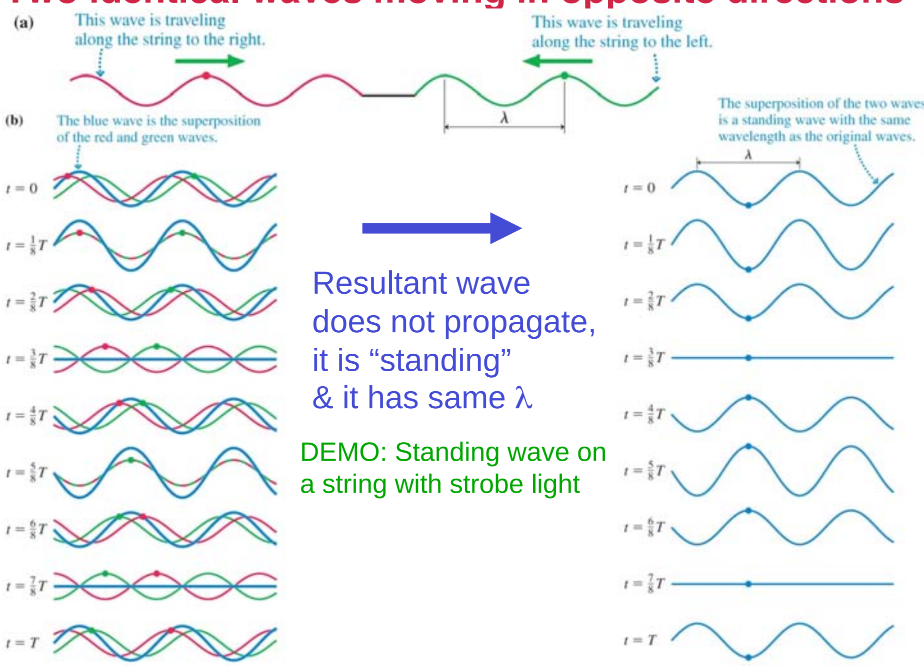
Two identical waves moving in opposite directions



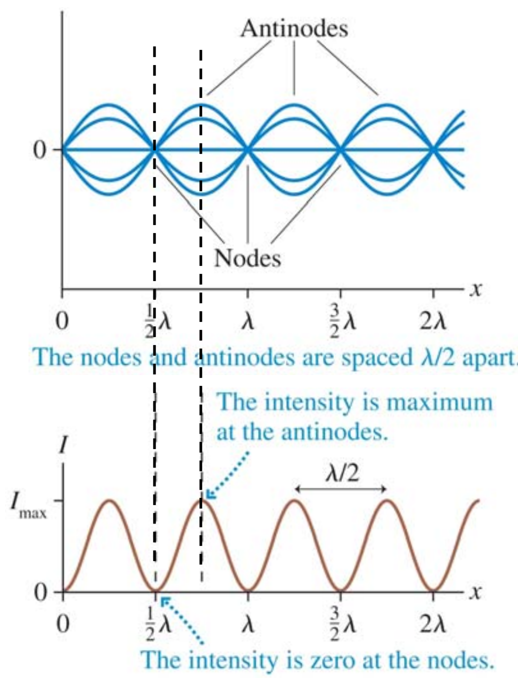
Resultant wave does not propagate, it is "standing" & it has same λ

DEMO: Standing wave on a string with strobe light

Nodes and Antinodes

- **Nodes:**
  points where interference is fully destructive
  ➔medium does not move!

- **Antinodes:**
  points where interference is fully constructive
  ➔medium moves with maximum displacement & intensity is maximum



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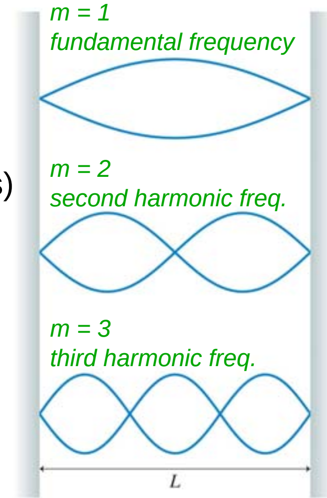
Standing Wave Modes

Standing wave on a string of length L needs to satisfy the following criteria:

- Displacements at x = 0 and x = L must be zero at all times (since string is attached at both ends)
- Nodes are equi-distant with a separation of $\lambda/2$



Standing wave has different modes of oscillation with specific wavelengths and frequencies:

$$\lambda_m = \frac{2L}{m} \qquad m = 1, 2, 3, 4, \ldots \qquad (16.1)$$

Wavelengths of standing wave modes of a string of length L

$$f_m = \frac{v}{\lambda_m} = \frac{v}{2L/m} = m\left(\frac{v}{2L}\right) \qquad m = 1, 2, 3, 4, \ldots \qquad (16.2)$$

Frequencies of standing wave modes of a string of length L

DEMOS: Standing wave on a string + Tacoma Narrows bridge (1940)

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Fundamental frequency question 1

PRS

Which of the following changes will increase the frequency of the lowest-frequency standing sound wave on a stretched string?

A. Replacing the string with a thicker string.
B. Increasing the tension in the string.
C. Plucking the string harder.
D. Doubling the length of the string.

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Standing wave problem

A particular species of spider spins a web with silk threads of density 1300 kg/m^3 and diameter 3.0 μm. A passing insect brushes a 12-cm-long strand of the web, which has a tension of 1.0 mN, and excites the lowest frequency standing wave. With what frequency will the strand vibrate?

MP PROBLEM-SOLVING STRATEGY 16.1 **Standing waves**

PREPARE

- For sound waves, determine what sort of pipe or tube you have: open-open, closed-closed, or open-closed.
- For string or light waves, the ends will be fixed points.
- Determine known values: length of the tube or string, frequency, wavelength, positions of nodes or antinodes.
- It may be useful to sketch a visual overview, including a picture of the relevant mode.

SOLVE For a string, the allowed frequencies and wavelengths are given by Equations 16.1 and 16.2. For sound waves in an open-open or closed-closed tube, the allowed frequencies and wavelengths are given by Equation 16.6; for an open-closed tube, by Equation 16.7.

ASSESS Does your final answer seem reasonable? Is there another way to check on your results? For example, the number of antinodes gives the mode. Does this agree?

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Standing wave problem

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Know

$\rho = 1300\ kg/m^3$

$d = 3.0\ \mu m = 3.0 \times 10^{-6} m$

$L = 12\ cm = 0.12\ m$

$T_s = 1.0\ mN = 1.0 \times 10^{-3} N$

$\mu = 9.18 \times 10^{-9}\ kg/m$

(see previous solution)

Find

$f_1 = ?$ (for $m = 1$)

Solve $\lambda_m = \dfrac{2L}{m}$

fundamental mode (m = 1) has longest λ and lowest frequency f

$$\lambda_1 = \frac{2L}{1} \text{ and } f_1 = \frac{v}{\lambda_1}$$

wave speed on string $v = \sqrt{\dfrac{T_s}{\mu}}$

$$v = \sqrt{\frac{1.0 \times 10^{-3} N}{9.18 \times 10^{-9}\ kg/m}} = 330\ m/s$$

$$\Rightarrow f_1 = \frac{v}{\lambda_1} = \frac{330 m/s}{0.24 m} = 1.38 \times 10^3 Hz$$

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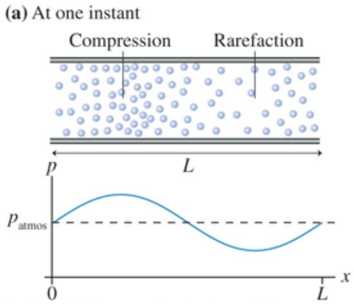
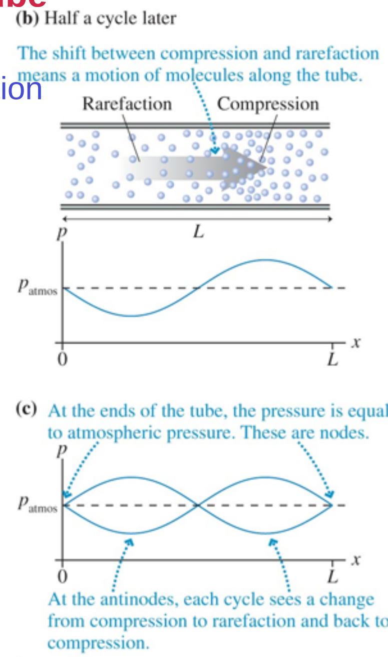
Standing Sound Waves in a Tube

Sound waves in a tube of length L
Propagation of compression/rarefaction of the medium



Standing wave forms due to the superposition of waves reflected from the tube ends
Open end: node
Closed end: antinode



Standing Sound Waves in Tubes

DEMOS:
Slide whistle
Resonance cavities
Hollow tubes
Dancing flames

$$\begin{cases} \lambda_m = \dfrac{2L}{m} \\ f_m = m\left(\dfrac{v}{2L}\right) = mf_1 \end{cases} \qquad m = 1, 2, 3, 4, \ldots$$

Wavelengths and frequencies of standing sound wave modes in an open-open or closed-closed tube

$$\begin{cases} \lambda_m = \dfrac{4L}{m} \\ f_m = m\dfrac{v}{4L} = mf_1 \end{cases} \qquad m = 1, 3, 5, 7, \ldots$$

Wavelengths and frequencies of standing sound wave modes in an open-closed tube