Physics 122 – Class #7 – Outline

- Announcements
- Traveling waves
  - Math of Sinewaves
  - Doppler Effect
- Superposition
  - Standing Waves
  - Math of Standing Waves

Announcements

Updated syllabus is posted

- Exam #1 is in two weeks

Read Chapter 21 (Superposition)

- Omit page 609-610.5
- Skim section 21.7.
- Need 21.8 for lab this week (standing waves and beats)

Clicker collector

Homework

HW WR-03 – Due Next Tuesday

21.3, 21.4, 21.9, 21.13, 21.52

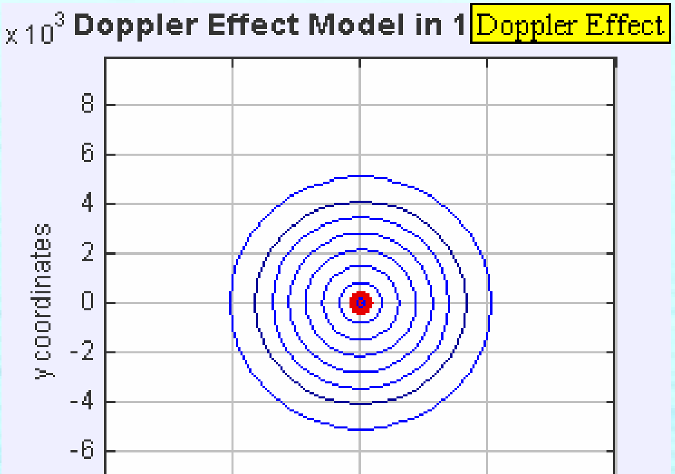
HW OL-04 posted … due Saturday

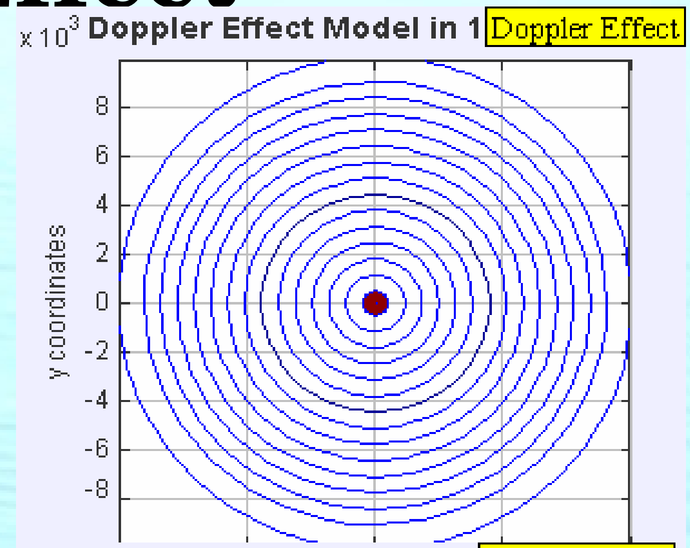
Doppler Effect

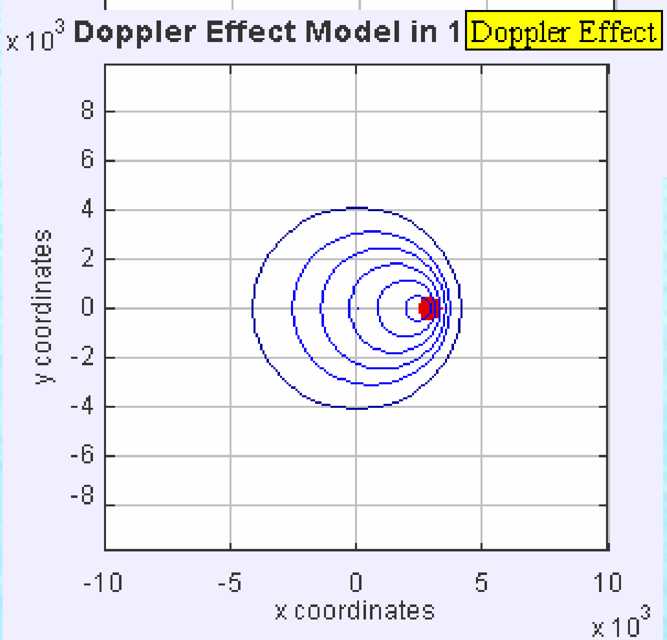
change of frequency due to motion of the wave source

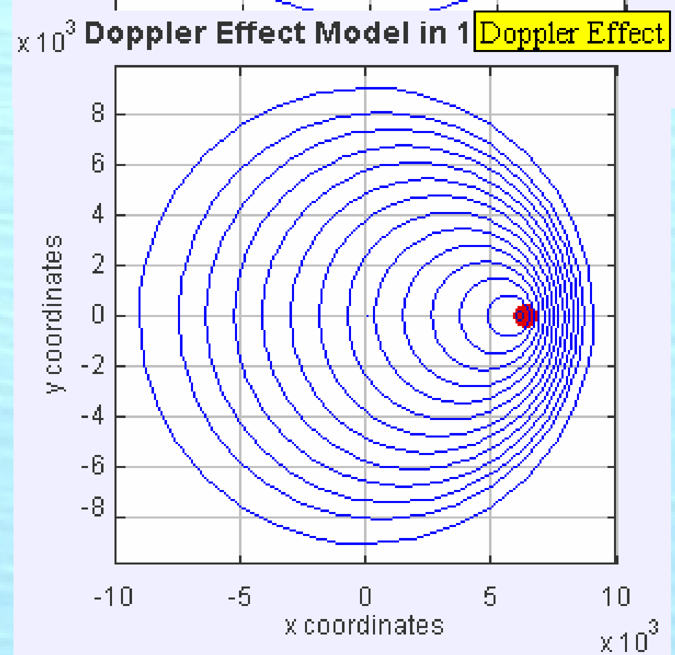
- frequency of waves increases as the siren approaches (hear higher pitch)
- frequency of waves decreases as siren moves away (hear lower pitch)
- Demo

Doppler Effect









$$f_{approaching} = (1 + v_0 / v) f_{stationary} \qquad f_{receding} = (1 - v_0 / v) f_{stationary}$$

CLICKER QUESTION

When a fire engine approaches you, the

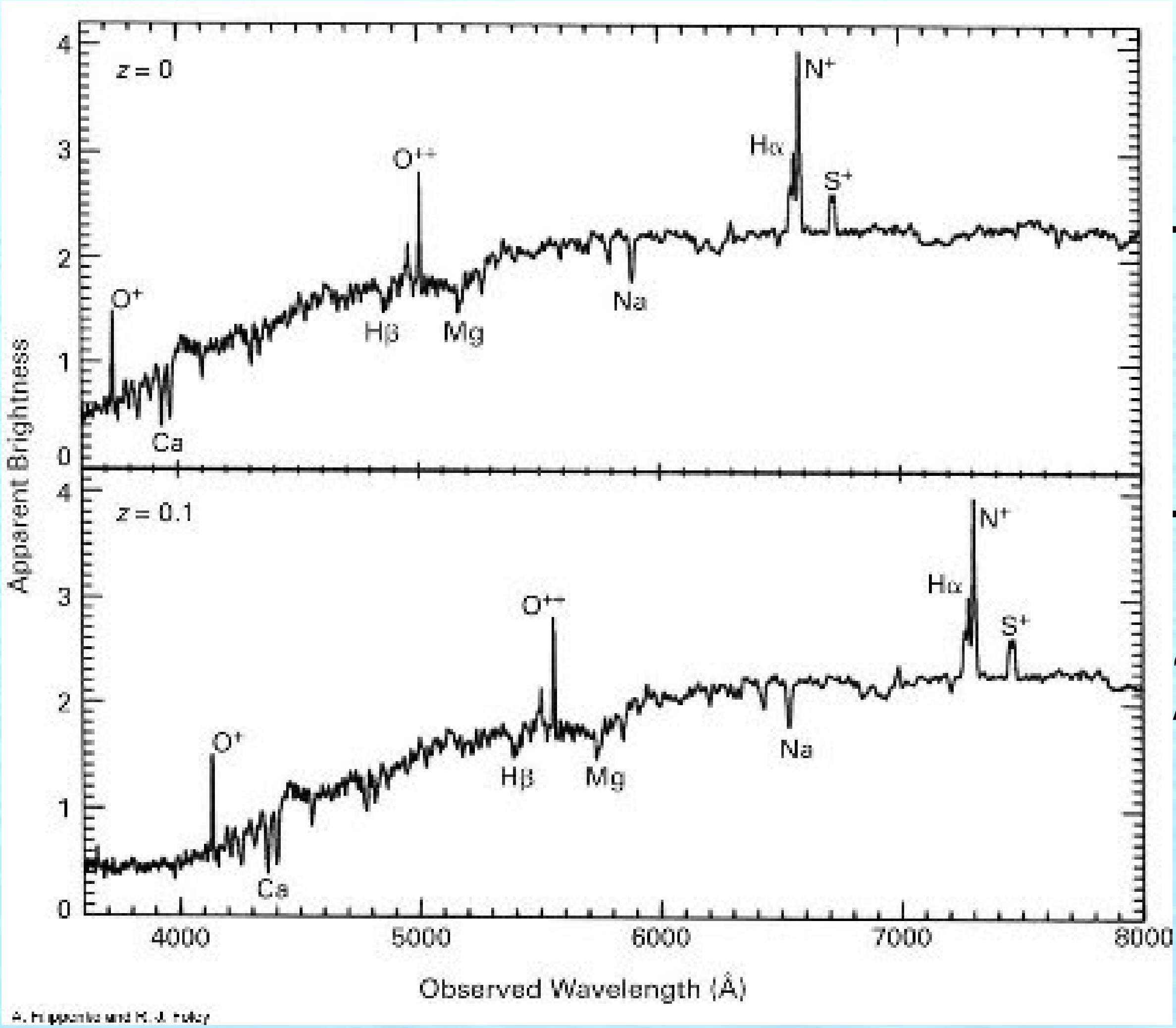
A. speed of its sound increases.
B. frequency of sound increases.
C. wavelength of its sound increases.
D. all of the above increase

Doppler Effect

Doppler effect also applies to light

- increase in light frequency (blue shift) when light source approaches you
- decrease in light frequency (red shift) when light source moves away from you
- The expansion and the age of the Universe (13.77 Billion years) is entirely measured by the Doppler Effect.
- v = H * D
  - v= speed of galaxy relative to Earth
  - H= Hubble constant
  - D=distance to galaxy

Doppler Effect and light



sound

$$f_{approaching} = (1 + v_0/v) f_{stationary}$$

light -- low speed

$$f_{approaching} = (1 + v_s/c) f_{stationary}$$

$$\lambda_{approaching} = (1 - v_s/c) \lambda_{stationary}$$

light -- high speed

$$\lambda_{approaching} = \sqrt{\frac{1 - v_s/c}{1 + v_s/c}} \lambda_{stationary}$$

$$\lambda_{receding} = \sqrt{\frac{1 + v_s/c}{1 - v_s/c}} \lambda_{stationary}$$

Doppler Effect and light

$$\lambda_{approaching} = \sqrt{\frac{1 - v_s/c}{1 + v_s/c}}\,\lambda_{stationary}$$

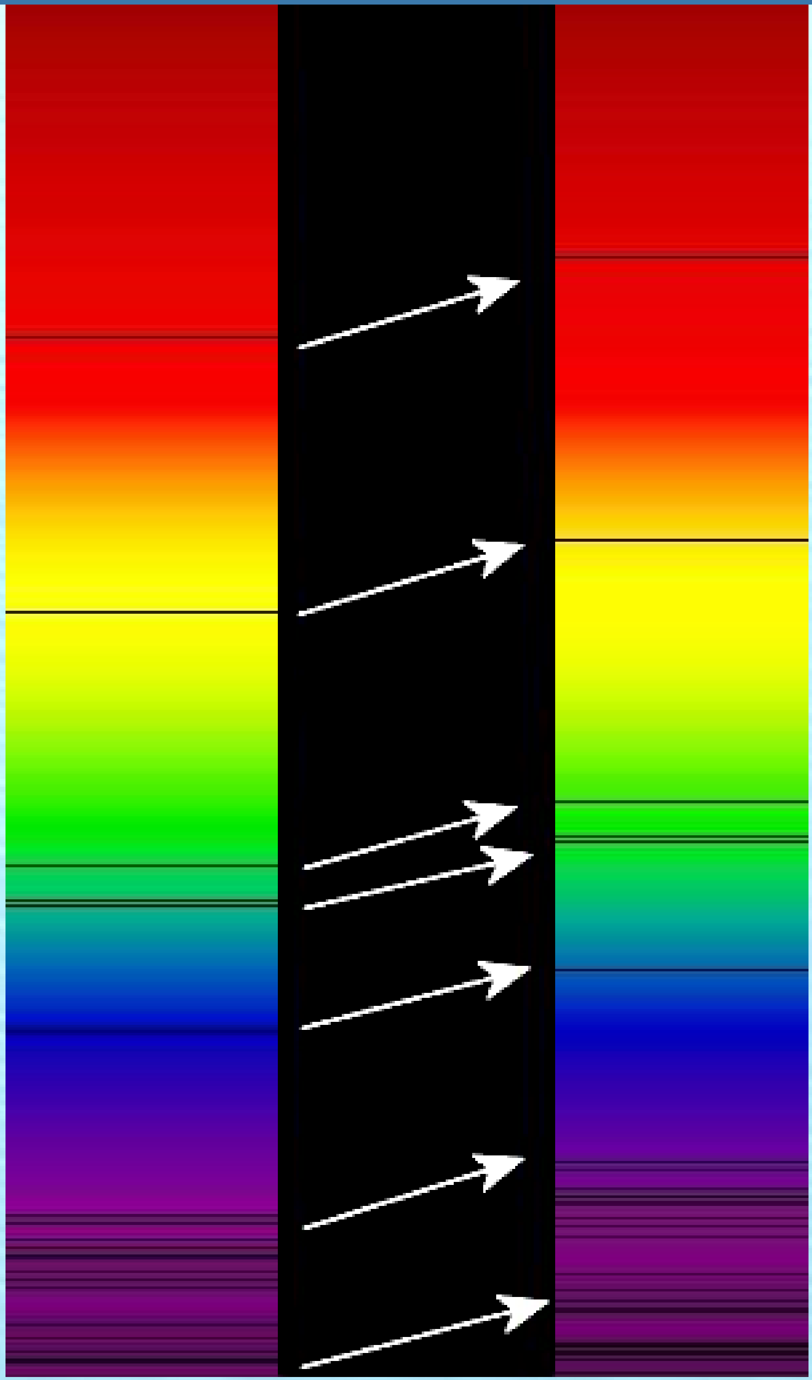
$$f_{approaching} = \left(1 + v_s/c\right) f_{stationary}$$

Doppler Effect

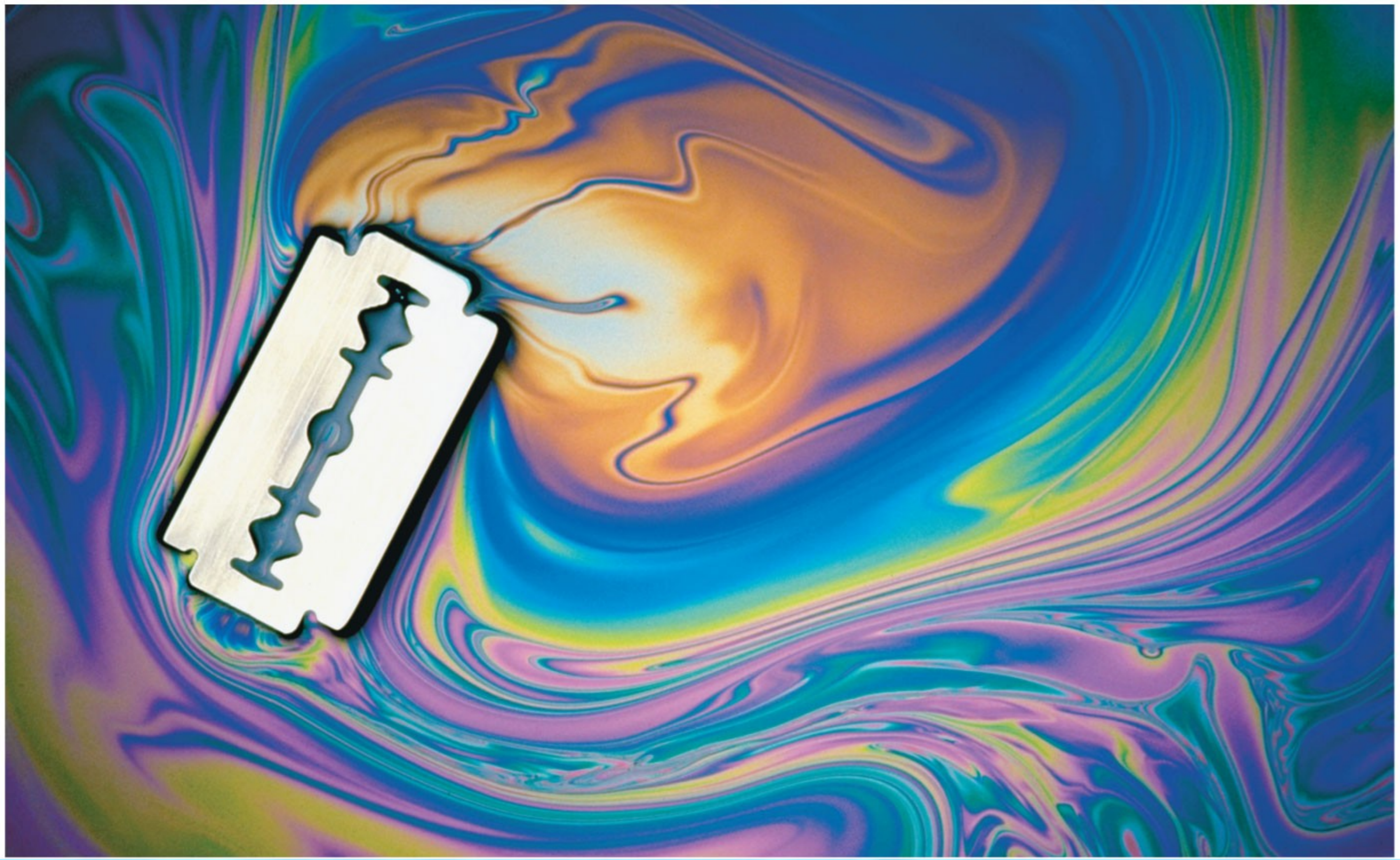
The panel on the left are spectral lines from the sun.

The panel at right are spectral lines of a distant Star.

The star is
[A] A different composition of gasses as our sun
[B] Moving away from Earth
[C] Moving toward Earth
[D] Not enough information.



Chapter 21: Superposition



Chapter Goal: To understand and use the idea of superposition.

Reading Question #1

When a wave pulse on a string reflects from a hard boundary, how is the reflected pulse related to the incident pulse?

A. Shape unchanged, amplitude unchanged.
B. Shape inverted, amplitude unchanged.
C. Shape unchanged, amplitude reduced.
D. Shape inverted, amplitude reduced.
E. Amplitude unchanged, speed reduced.

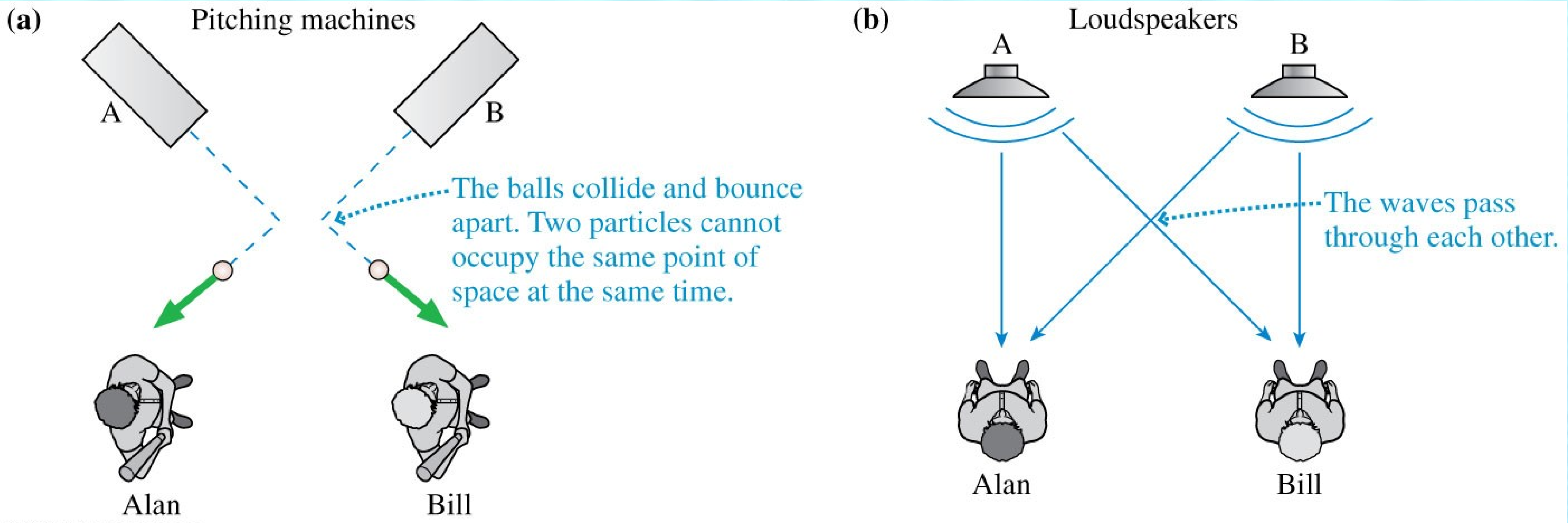
Reading Question #2

There are some points on a standing wave that never move. What are these points called?

A. Harmonics.
B. Normal Modes.
C. Nodes.
D. Anti-nodes.
E. Interference.

Particles vs. Waves

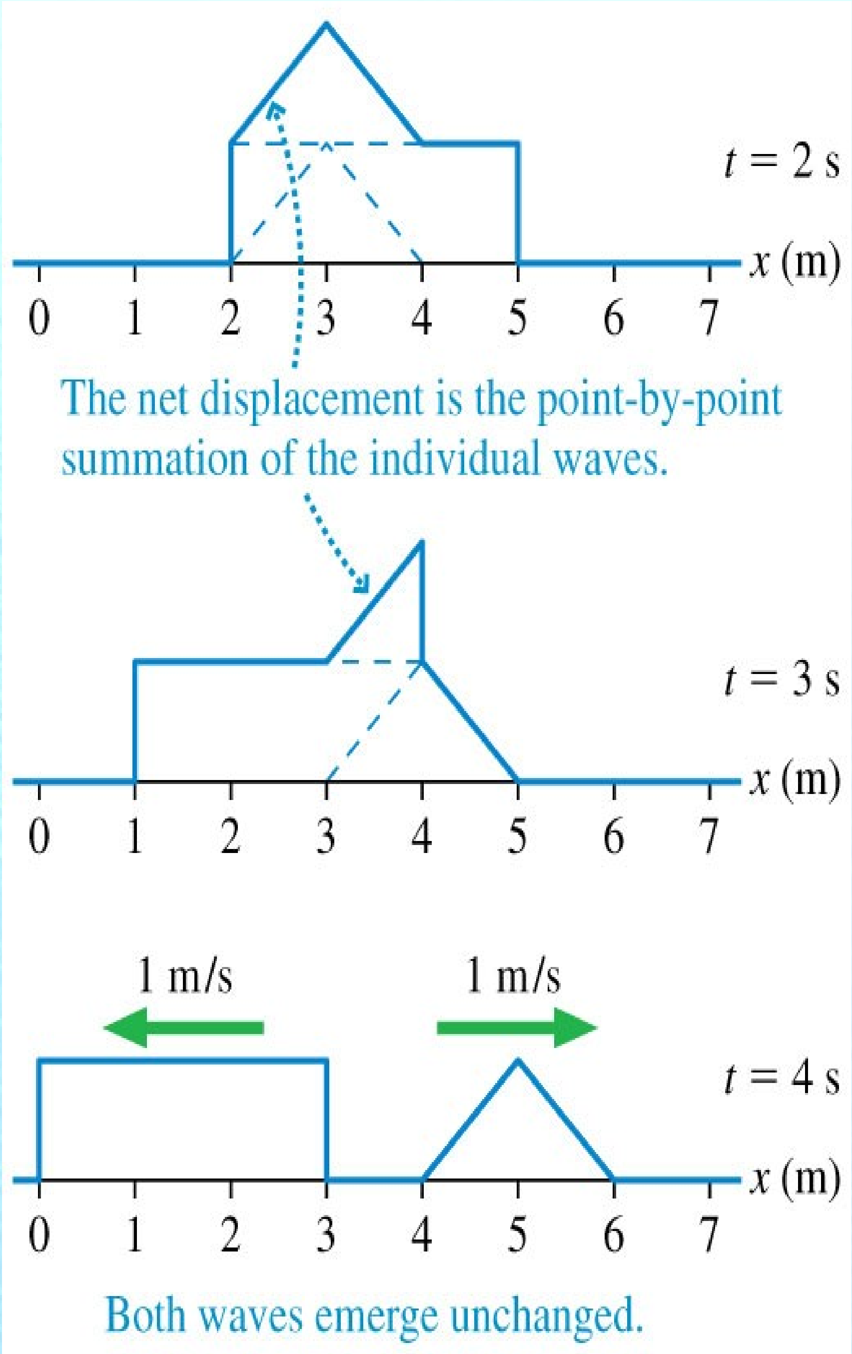
- Two particles flying through the same point at the same time will collide and bounce apart, as in Figure (a).
- But waves, unlike particles, can pass directly through each other, as in Figure (b).



The Principle of Superposition

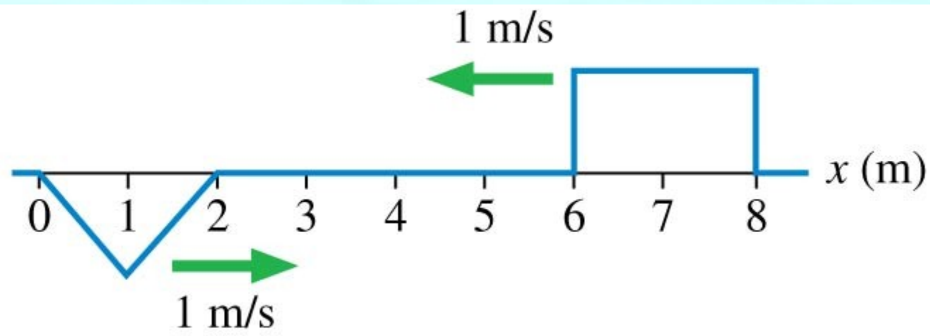
If wave 1 displaces a particle in the medium by D_1 and wave 2 simultaneously displaces it by D_2, the net displacement of the particle is $D_1 + D_2$.

http://video.mit.edu/watch/bell-labs-wave-machine-superposition-7047/



Clicker Question

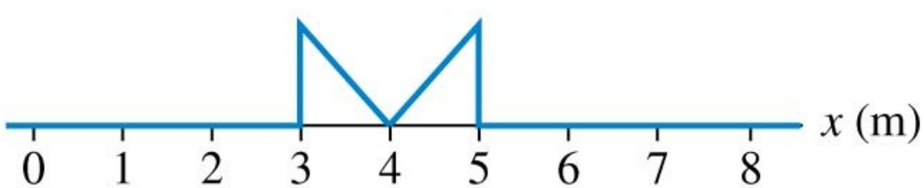
Two wave pulses on a string approach each other at speeds of 1 m/s. How does the string look at $t = 3$ s?



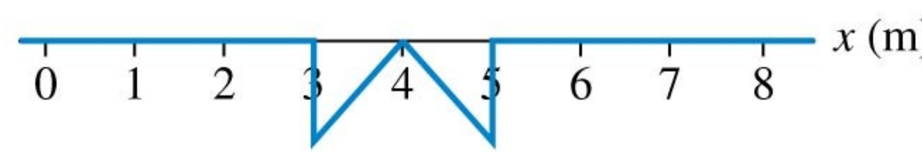
Approaching pulses at $t = 0$ s

A.

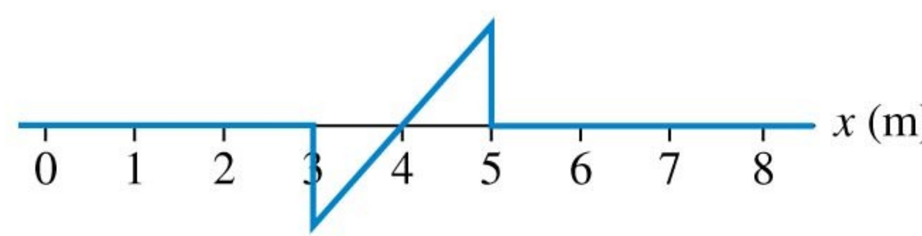
B.



C.

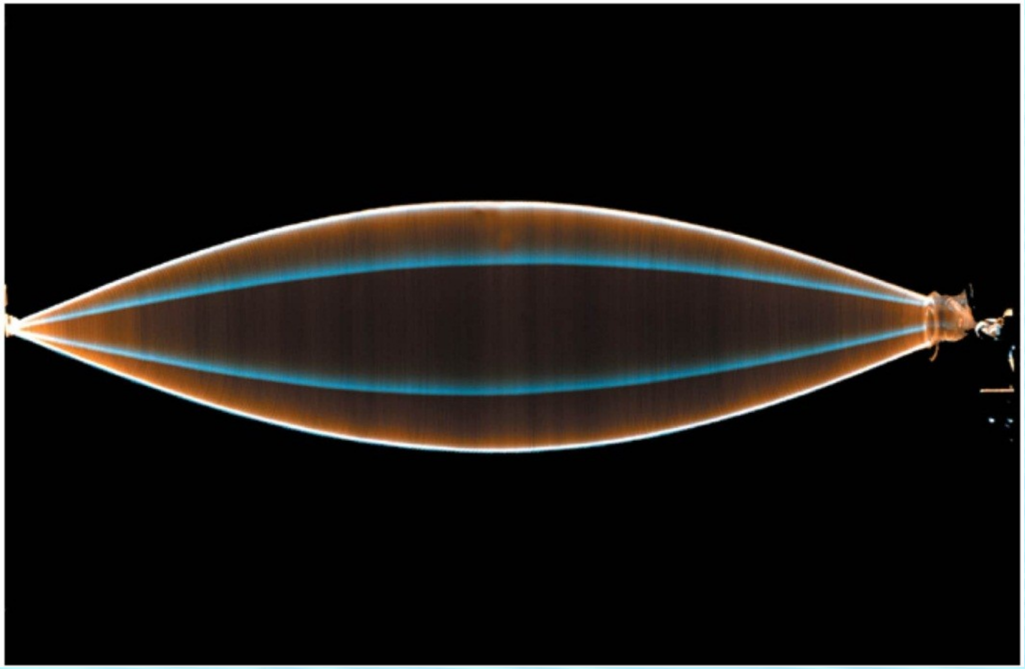


D.



Standing Waves

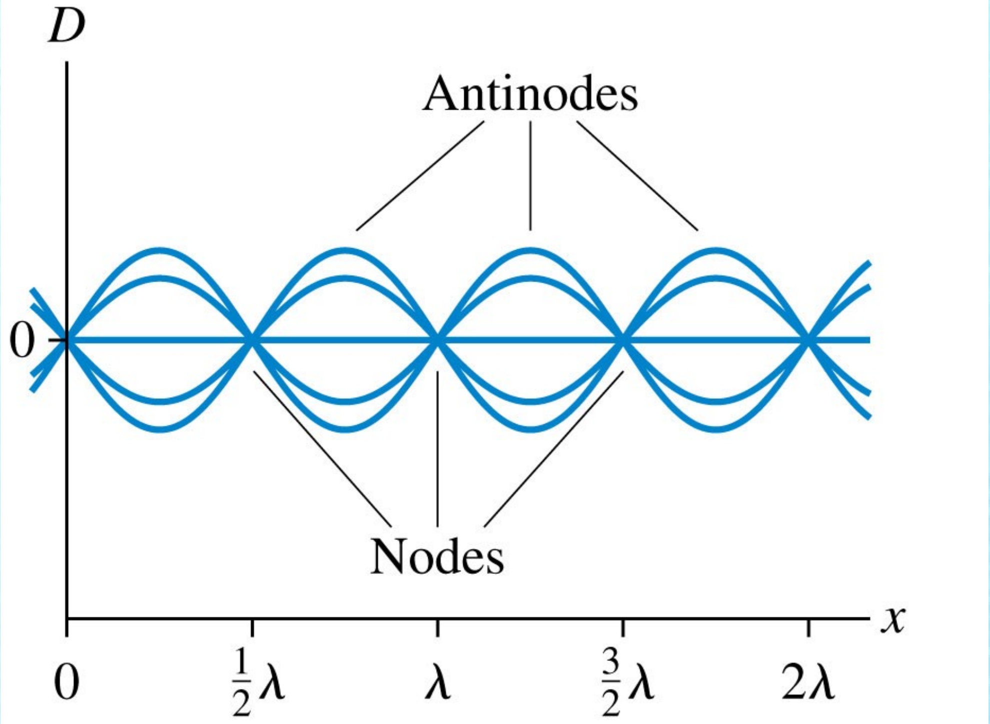
- Shown is a time-lapse photograph of a *standing wave* on a vibrating string.
- It's not obvious from the photograph, but this is actually a superposition of two waves.



- To understand this, consider two sinusoidal waves with the **same frequency, wavelength, and amplitude** traveling in opposite directions.

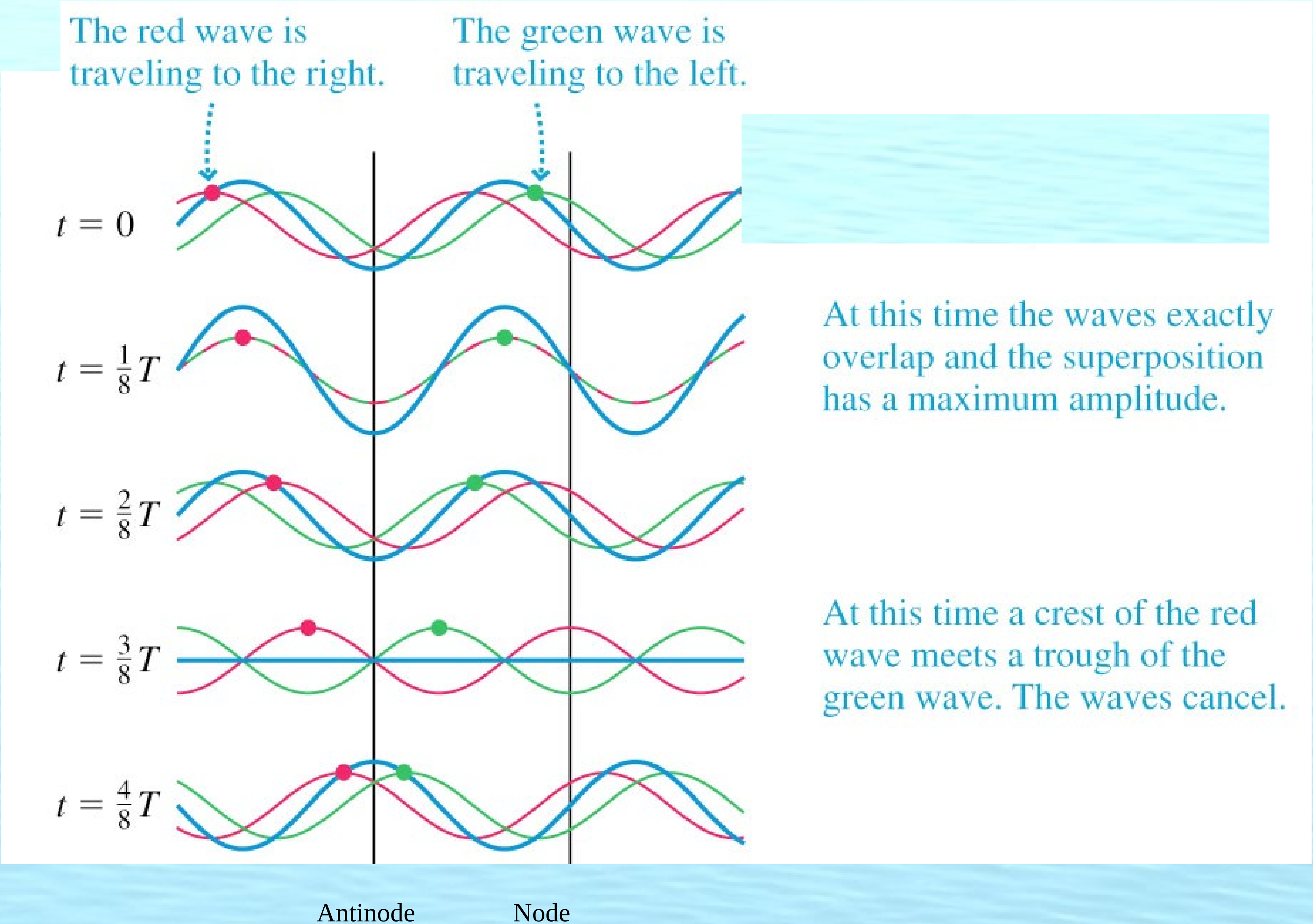
Standing Waves

- Animation shows a wave traveling to the right, then one to the left, then the sum.
- Note the nodes and the antinodes spaced lambda/2 apart.



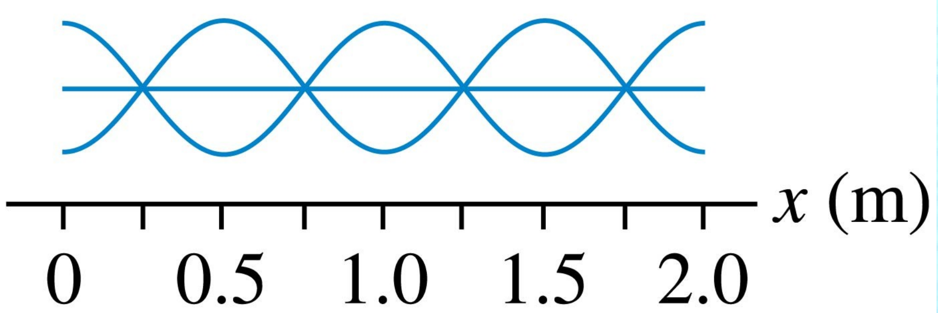
The nodes and antinodes are spaced $\lambda/2$ apart.

Standing Waves



Clicker Question

What is the wavelength of this standing wave?



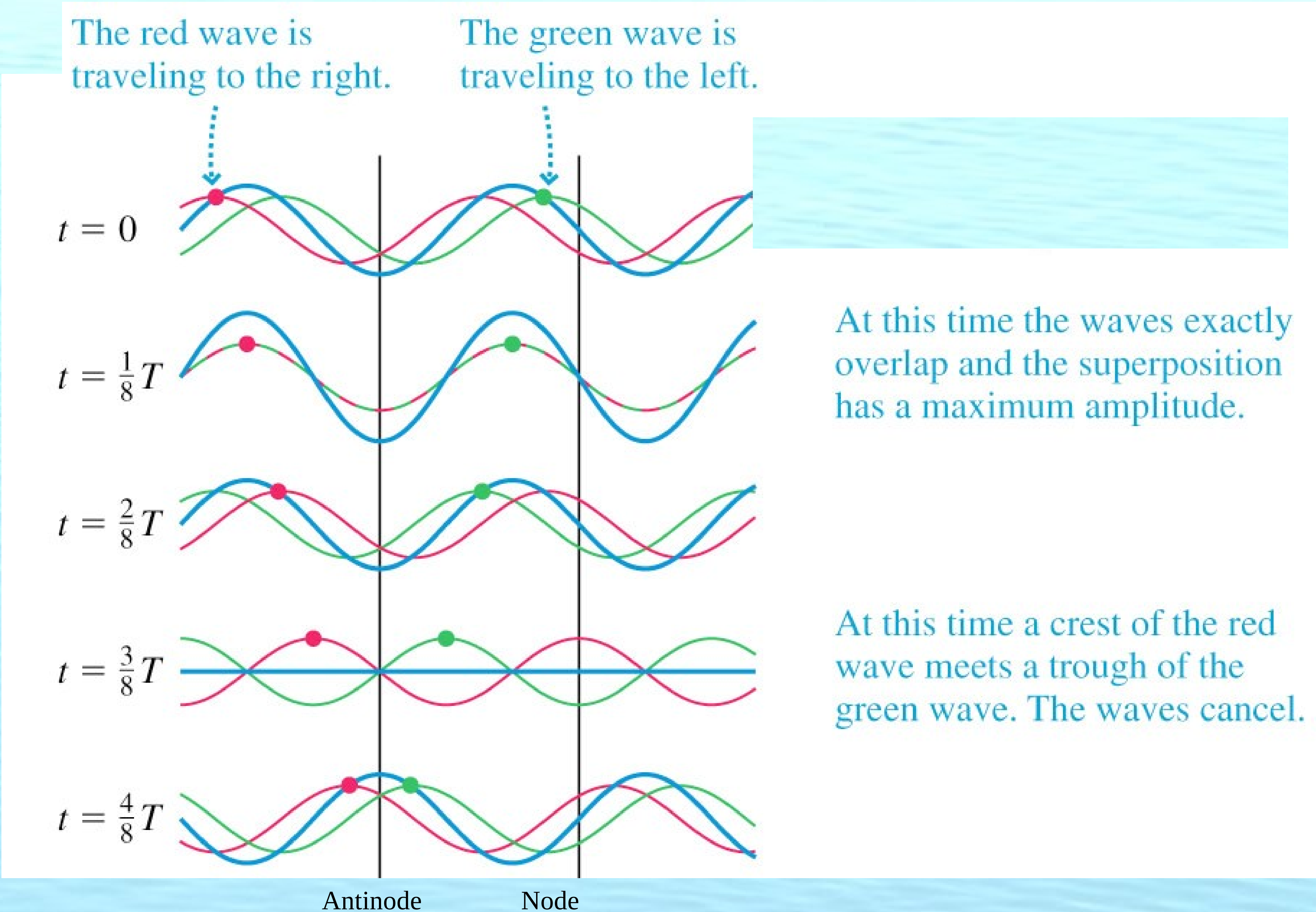
A. 0.25 m.
B. 0.5 m.
C. 1.0 m.
D. 2.0 m.
E. Standing waves don't have a wavelength.

Math of Standing Sine Waves

Find $D_1 + D_2$

Given $D_1(x,t) = A\sin(kx - \omega t)$ $D_2(x,t) = A\sin(kx + \omega t)$

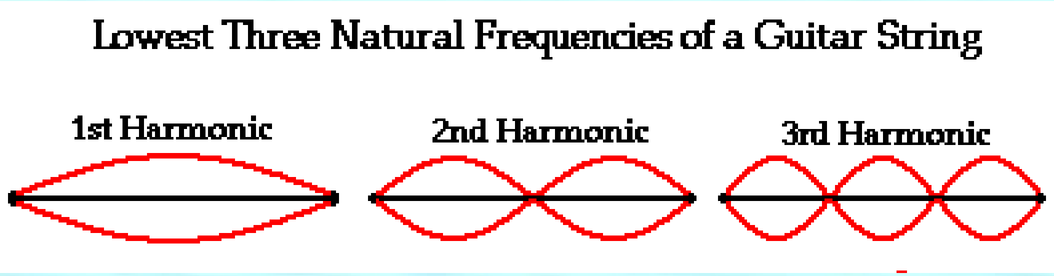
Standing Waves



Normal Modes Demo pHeT

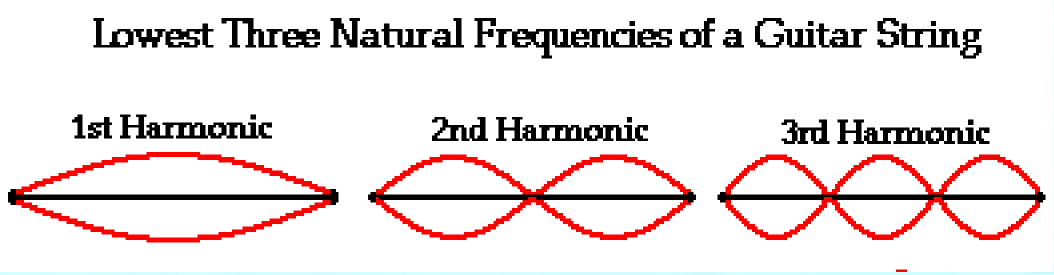
Standing Waves and Musical Instruments

- Standing waves can arise from traveling waves moving in opposite directions
- You more often notice them with fixed “boundary conditions” that force “nodes” on the end of a medium
- The nodes force the following relationship
- n is an integer “mode number” and L is length of string



$$n\lambda/2=L$$

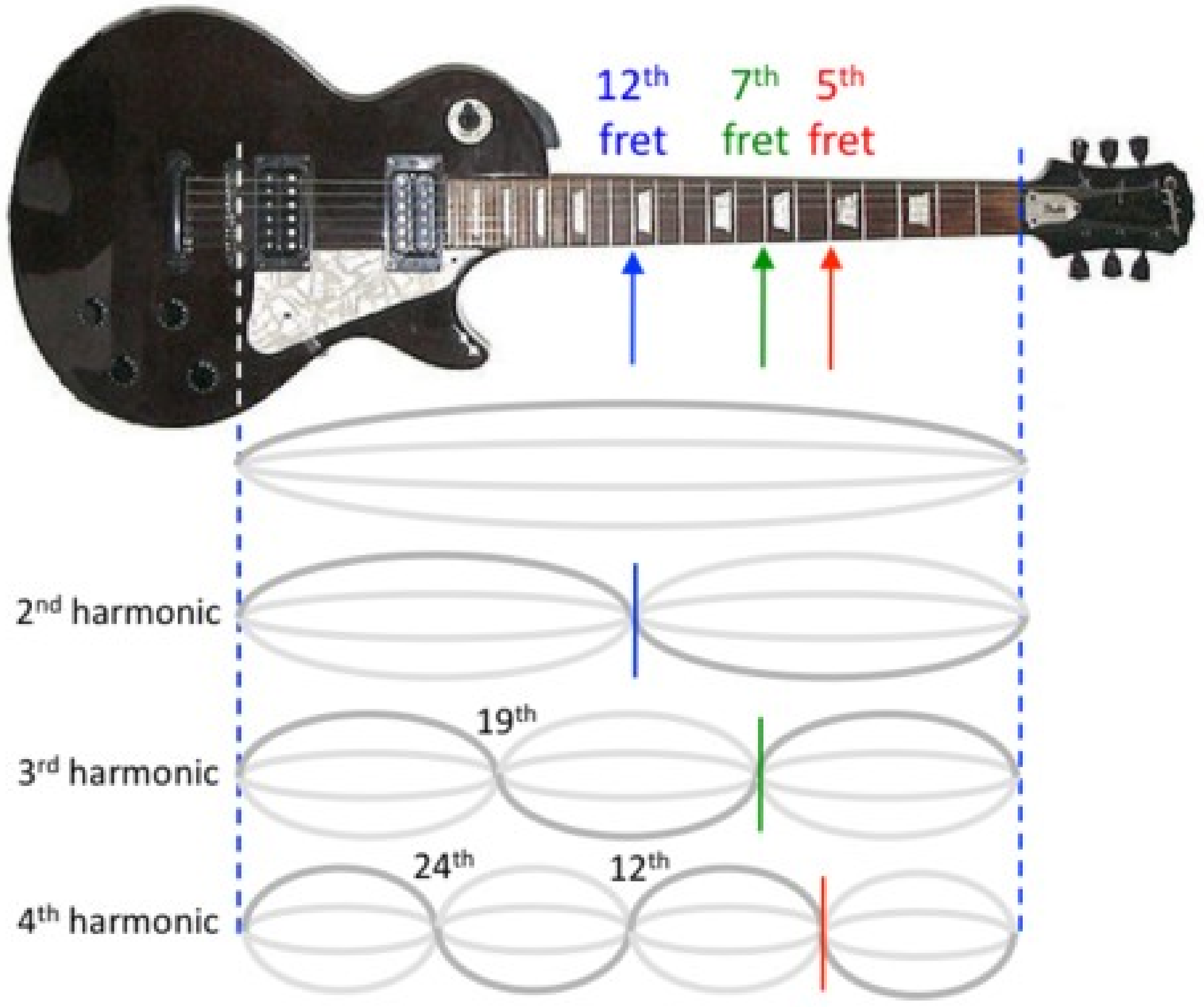
Clicker Question



If the string at right is 1 meter long, what are the wavelengths of the first three modes?

A. 1 m, 2 m, 3 m
B. 1 m, ½ m, 1/3 m
C. ½ m, ¼ m, 1/8 m
D. 2 m, 1 m, 2/3 m
E. No change in wavelength because all modes on the same string

Harmonics on a Guitar



Problem 21.10

Standing waves on a 1.0 m long string fixed at both ends are seen at successive frequencies of 36 Hz and 48 Hz.

- What are the fundamental frequency and wave speed?
- Draw the standing wave pattern at 48 Hz.

Guitar Oscillations Captured with iPhone 4

Standing Waves Generated by String Vibration

Problem 21.11

A heavy piece of hanging sculpture is suspended by a 90 cm long, 5.0 g steel wire. When the wind blows hard, the wire hums at 80 Hz. What is the mass of the sculpture?

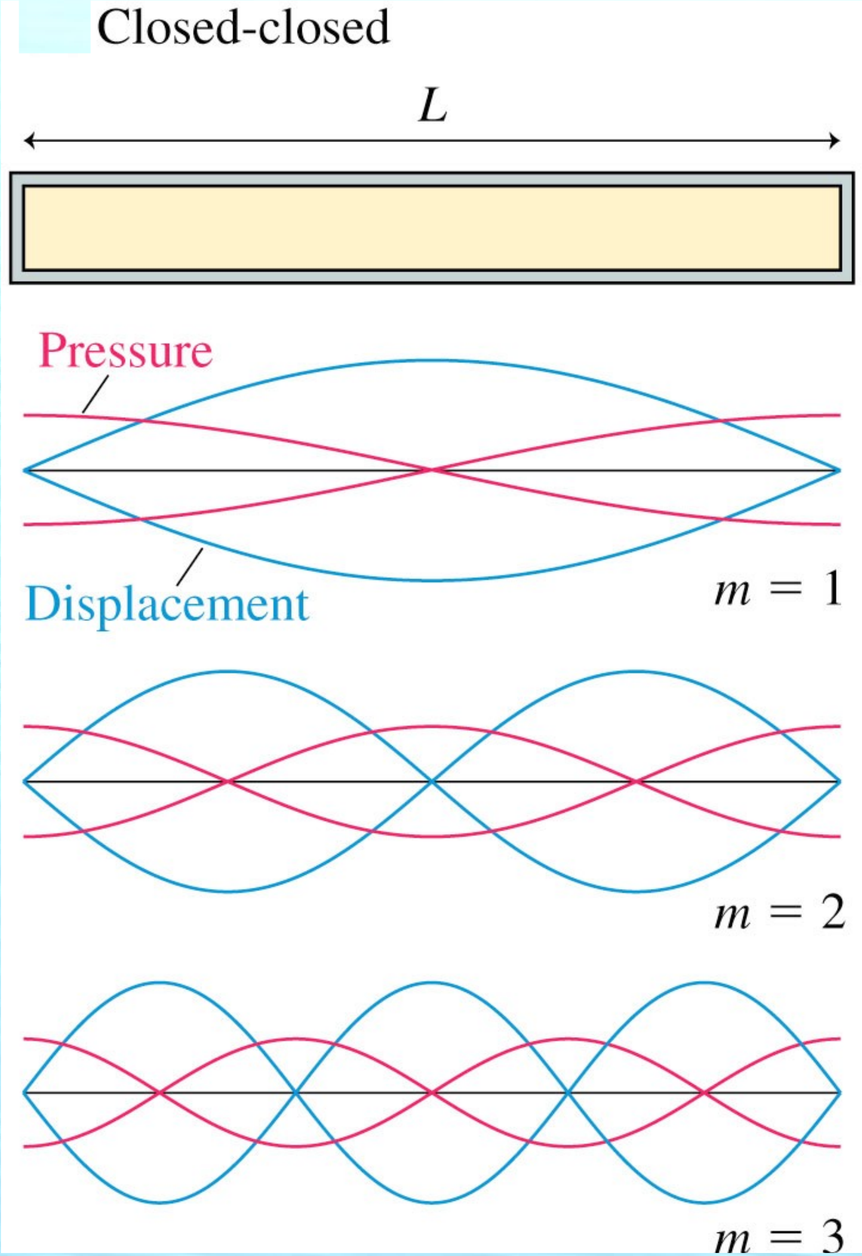
Standing Sound Waves

Shown are displacement and pressure graphs for the first three standing-wave modes of a tube closed at both ends:

$$\lambda_m = \frac{2L}{m}$$

$$f_m = m\frac{v}{2L}$$

$$m = 1, 2, 3, 4, \ldots$$



Standing Sound Waves

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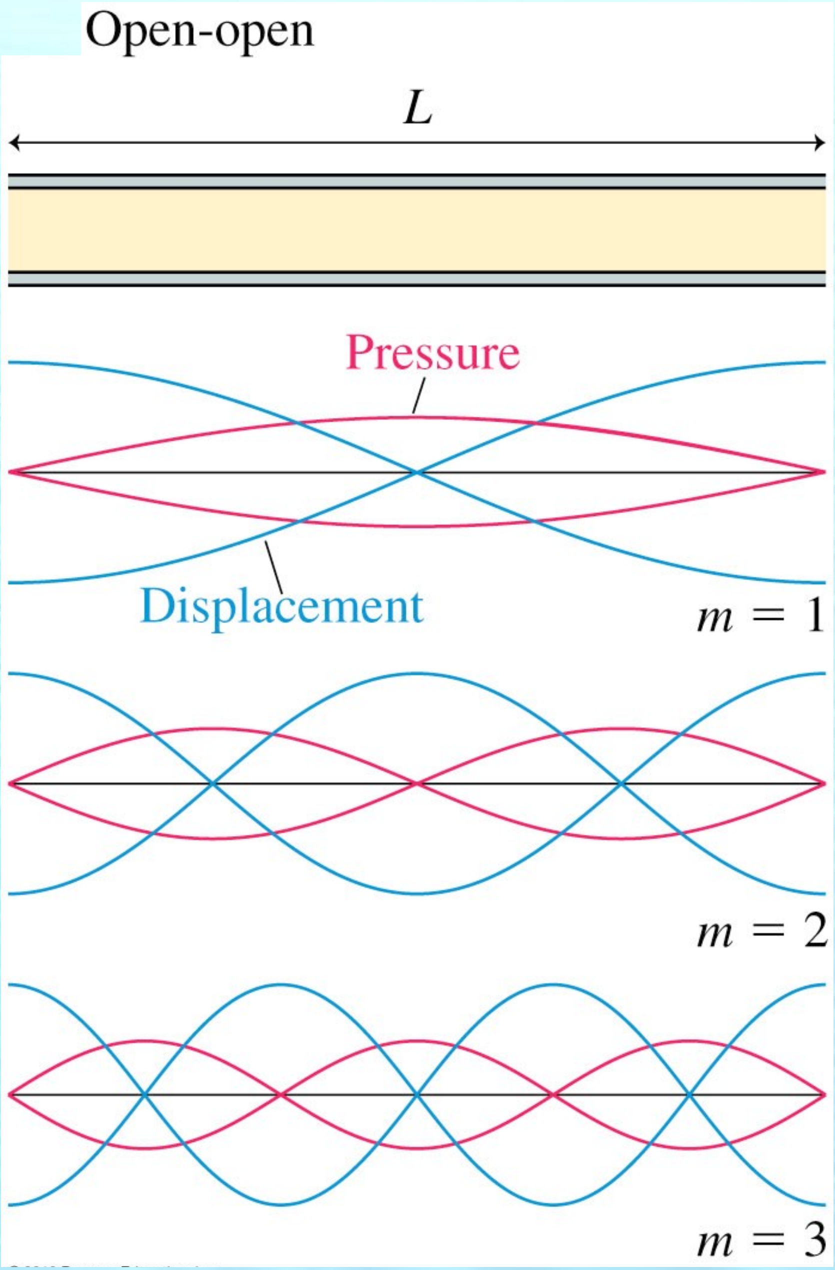


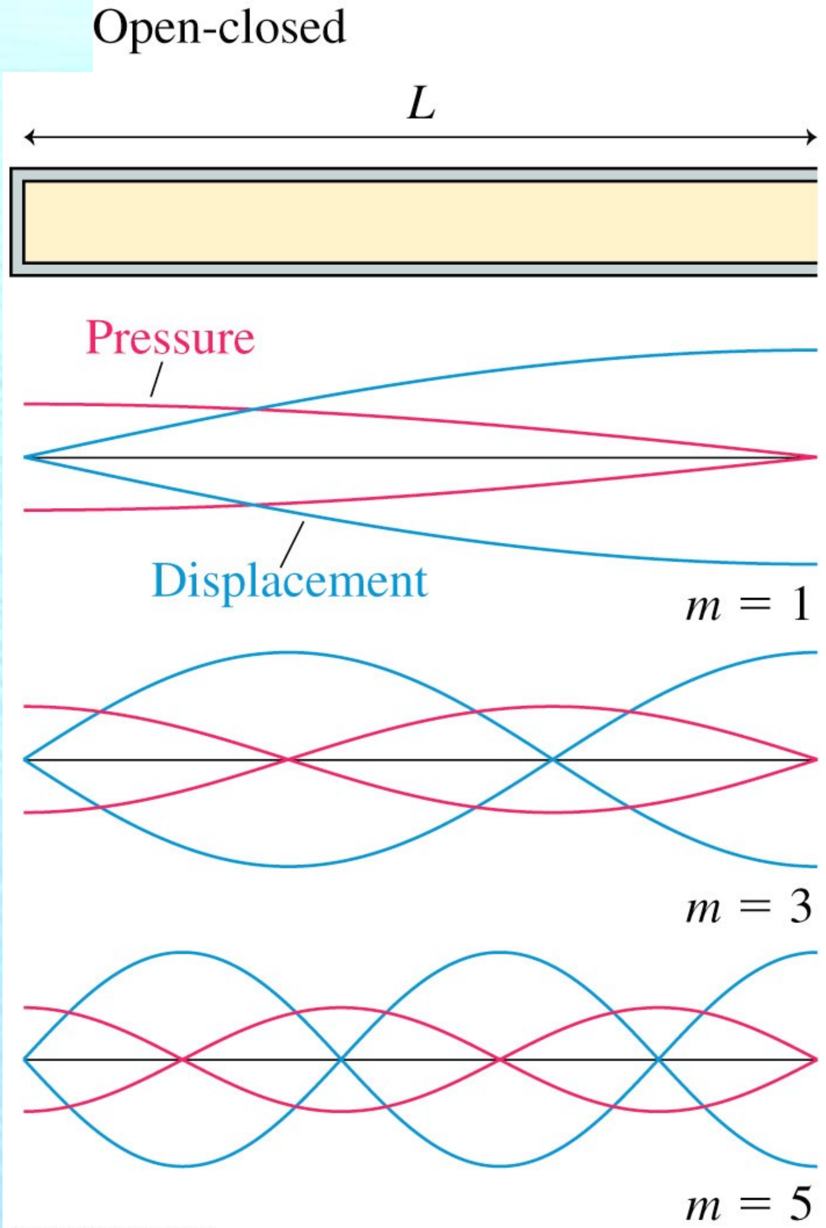
Standing Sound Waves

Shown are displacement and pressure graphs for the first three standing-wave modes of a tube open at one end but closed at the other:

$$\lambda_m = \frac{4L}{m}$$

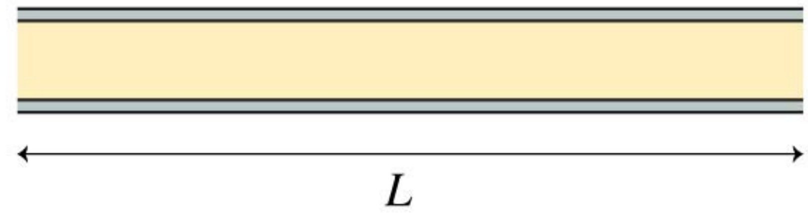
$$f_m = m\frac{v}{4L}$$

$$m = 1, 3, 5, 7, \ldots$$

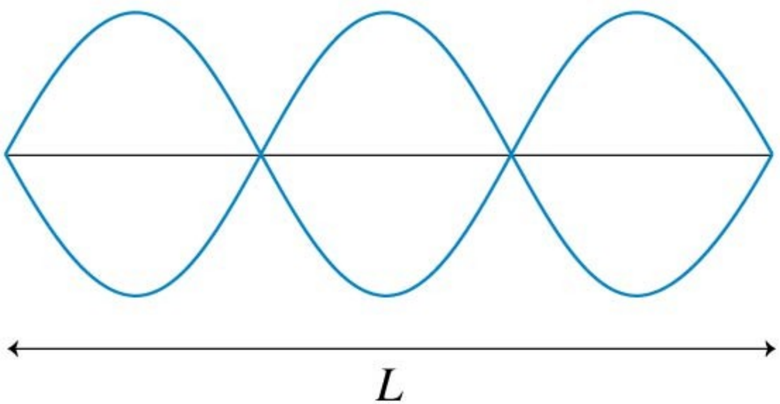


Clicker Questions

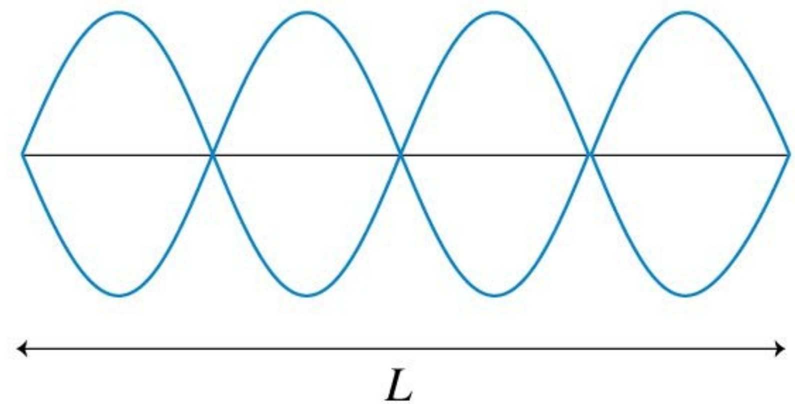
An open-open tube of air has length L. Which is the displacement graph of the $m = 3$ standing wave in this tube?



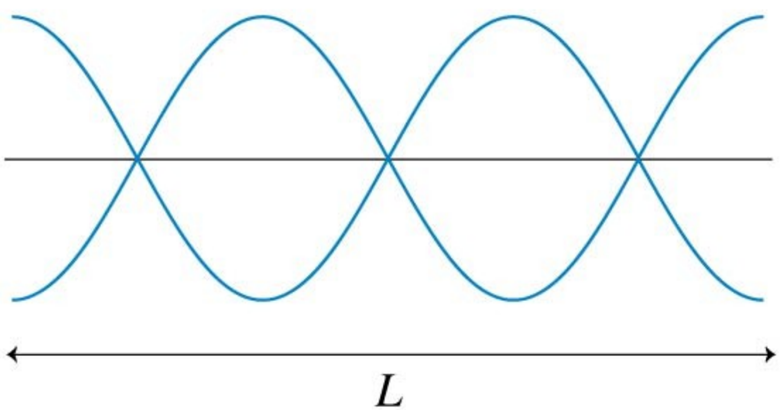
A.



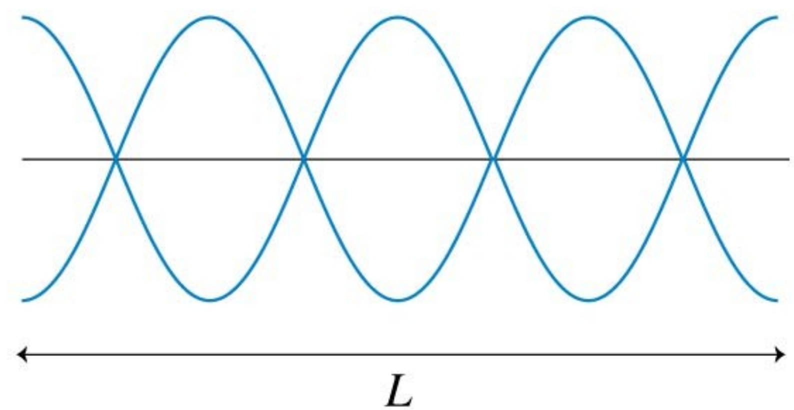
C.



B.



D.



Next Time

Beats

2-D and 3-D interference