

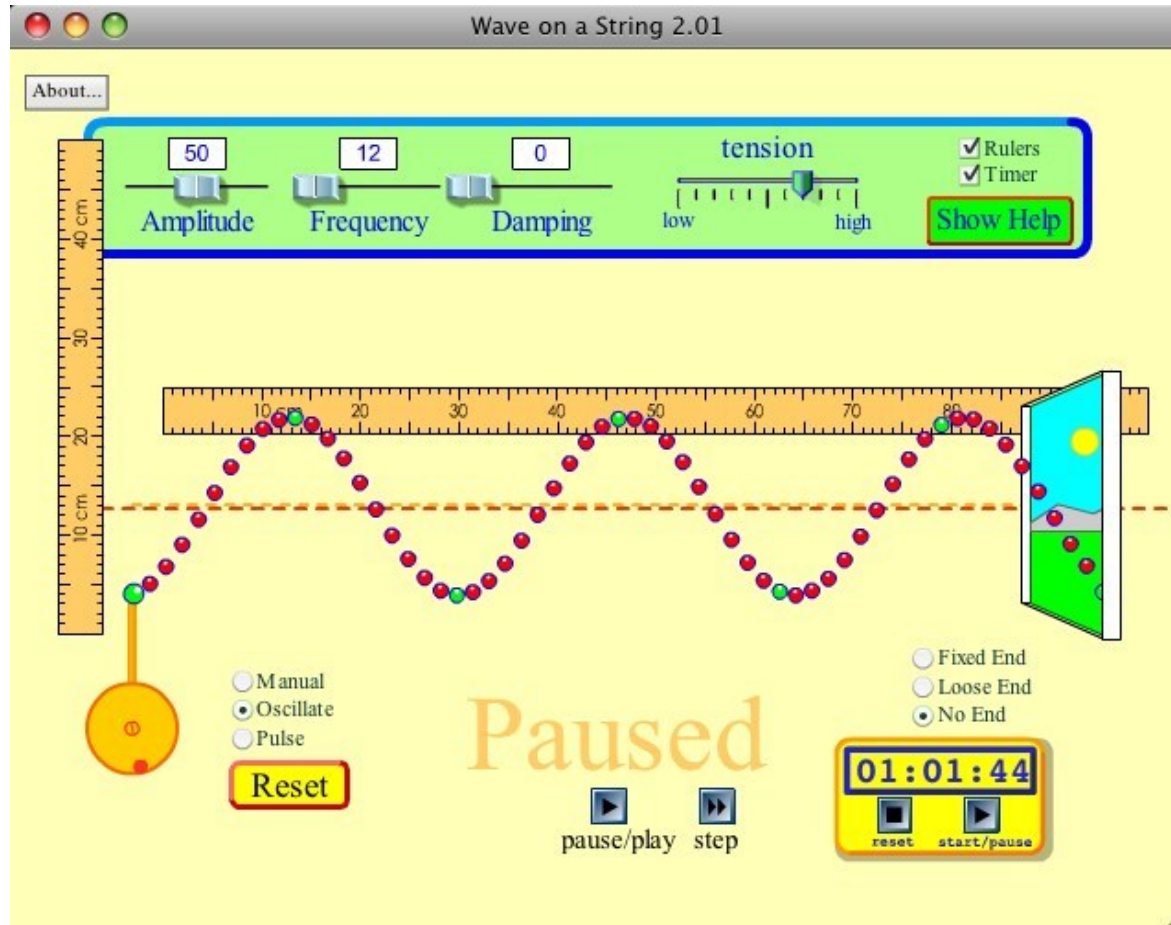
Outline

Standing Waves

Midterm II Makeup FRIDAY 3pm

Office hours in Course Center Thursday 11.30-1

Sinusoidal Waves: $y(x,t) = A \sin k(x - v_0 t)$

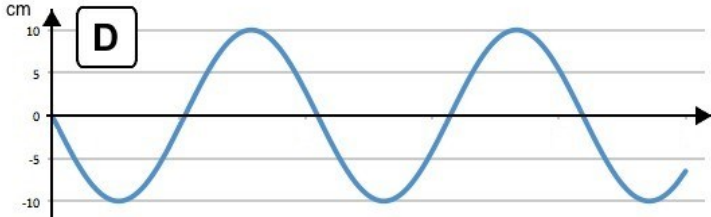
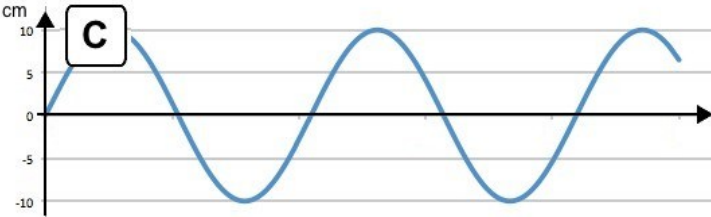
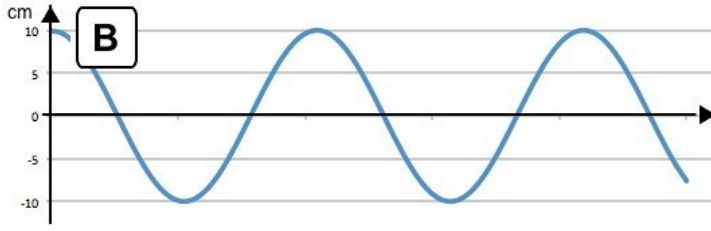
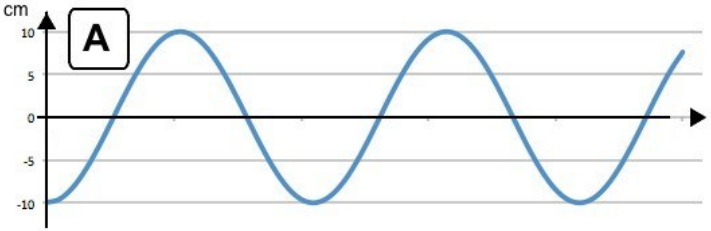
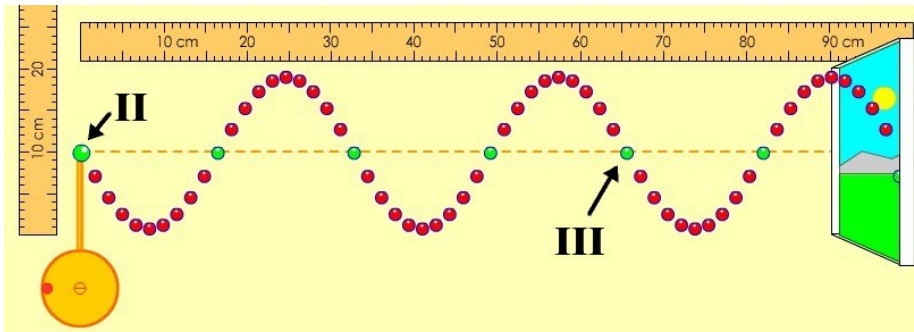


http://phet.colorado.edu/simulations/sims.php?sim=Wave_on_a_String

An elastic string (modeled as a series of beads) driven by a wheel driving one of the beads up and down sinusoidally. .

The driving wheel has generated a traveling wave of amplitude 10 cm moving to the right. (The string continues on for a long way to the right as indicated by its going “out the window.”) The figure shows $t = 0$, when the green bead marked “II” is passing through its equilibrium point.

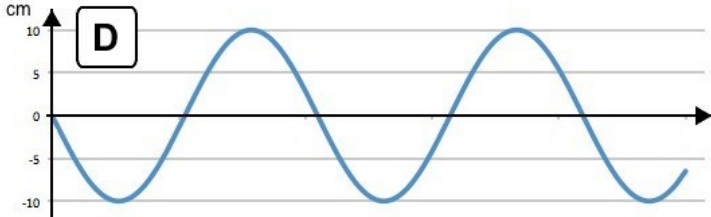
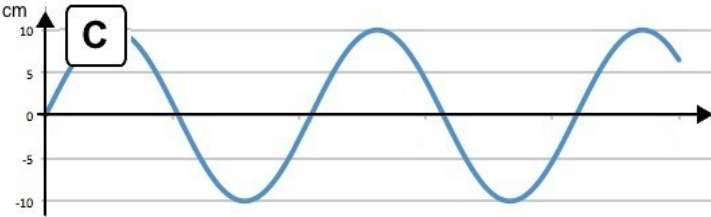
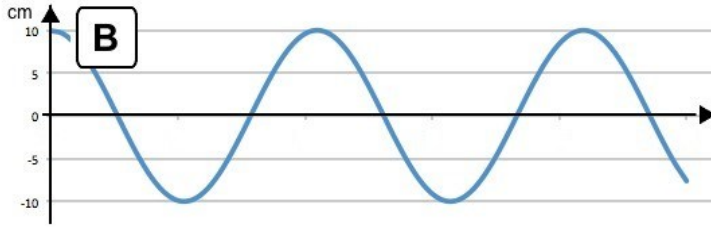
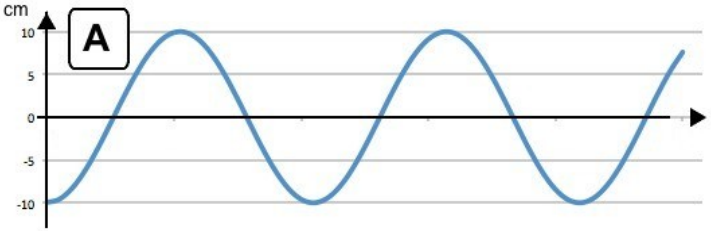
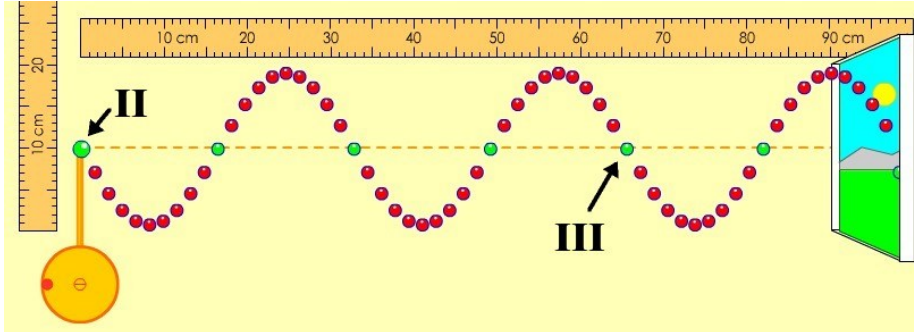
Which of the graphs could serve as the graph of **the vertical displacement of bead II** as a function of **time**?



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Which of the graphs could serve as a graph of **the vertical displacement of bead III** as a function of **time**?



36 Amplitude 50 Frequency 3 Damping tension (low to high) Rulers Timer [Show Help](#)

10 cm 20 30 40 50 60 70 80 90

Manual Oscillate Pulse Fixed End Loose End No End

[Restart](#) **Paused** pause/play step



This is the state of the PhET wave-on-a-string simulation when the string is very long so reflection can be ignored. What is the speed of the wave (assuming that the frequency is given in cycles/min)?

What happens at a fixed end?

1. Pass through like before
2. Stop and die
3. Bounce back right side up
4. Bounce back upside down
5. 3 but delayed
6. 4 but delayed

What happens at a loose end?

1. Pass through like before
2. Stop and die
3. Bounce back right side up
4. Bounce back upside down
5. 3 but delayed
6. 4 but delayed

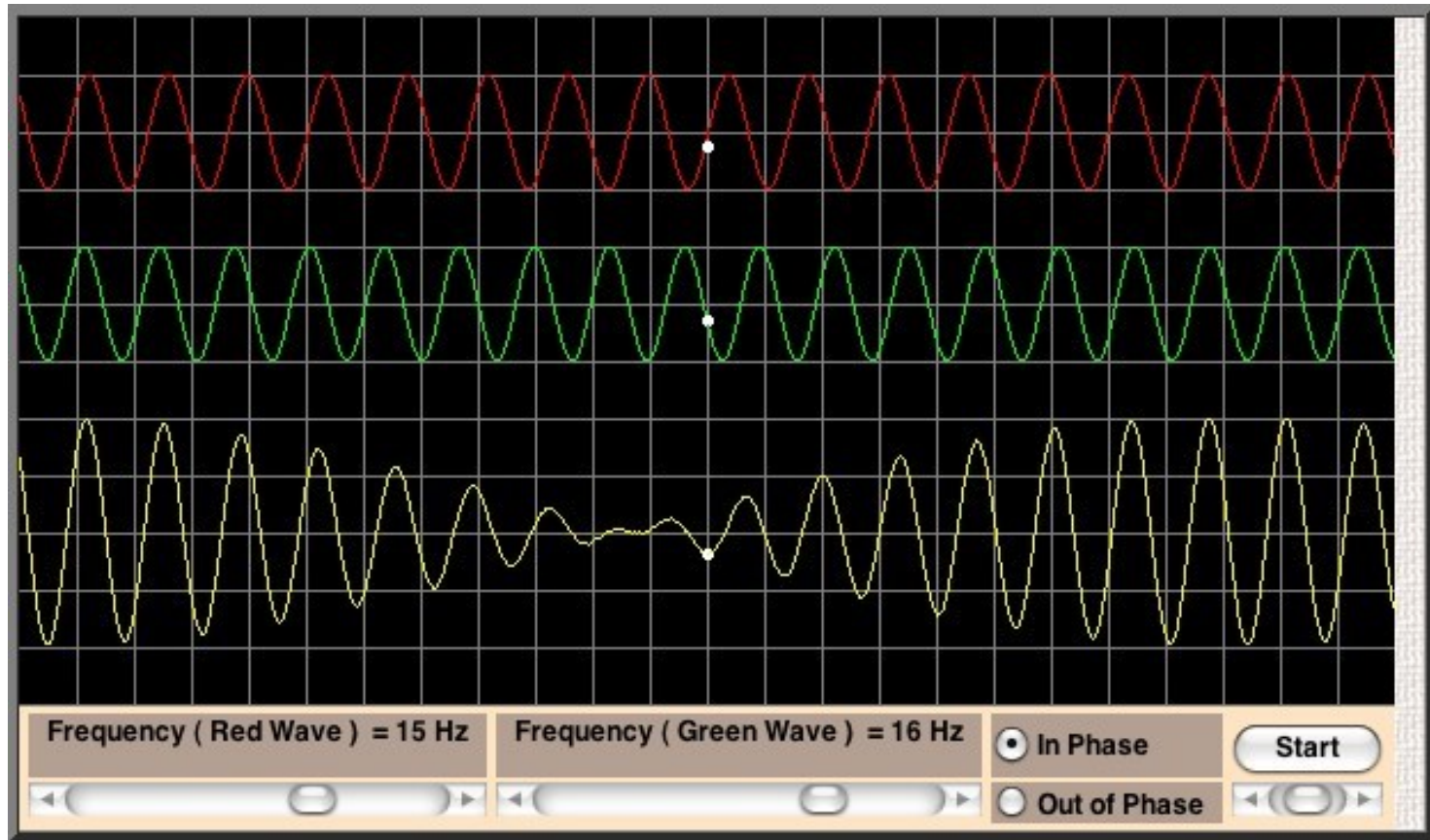
Foothold principles:

Superposition of Mechanical waves



- *Superposition*: when two or more waves (or pulses) overlap, the result is that each point displaces by the sum of the displacements it would have from the individual pulses. (signs matter)
 - *Beats*: When sinusoidal waves of different frequencies travel in the same direction, you get variations in amplitude (when you fix either space or time) that happen at a rate that depends on the difference of the frequencies.
 - *Standing waves*: When sinusoidal waves of the same frequency travel in opposite directions, you get a stationary oscillating pattern with fixed nodes.

Beats



<http://www.mta.ca/faculty/science/physics/suren/Beats/Beats.html>

Standing waves: Sinusoidal Waves, same frequency, going in opposite directions

$$y(x, t) = A \sin(kx - \omega t) + A \sin(kx + \omega t)$$

Using trig identities (sc+cs...) we can show

$$y(x, t) = 2A \sin(kx) \cos(\omega t)$$

For each point on the string labeled “x” it oscillates with an amplitude that depends on where it is — but all parts of the string go up and down together.

Adding Sinusoidal Waves – an example

$$y = A \sin(kx - \omega t) + A \sin(kx + \omega t)$$

$$y = 2A \sin(kx) \cos(\omega t)$$

Is there a position for which this function is zero at all times?

$$y(x = 0, t) = A \sin(-\omega t) + A \sin(\omega t)$$

$$y(kx = \pi, t) = A \sin(\pi - \omega t) + A \sin(\pi + \omega t)$$

The function is also zero
wherever kx is a multiple of π

Standing Waves

- Some points in this pattern (values of x for which $kx = n\pi$) are always 0. (NODES)
- To wiggle like this (all parts oscillating together in a “standing wave”) we need to have the end fixed

$$L = n \frac{\lambda}{2}$$

- We still have $v_0 = \omega/k$ that is $v_0 = \lambda f$

The interface features a control panel at the top with a green background. It includes three sliders for 'Amplitude' (set to 10), 'Frequency' (set to 50), and 'Damping' (set to 5). A 'tension' slider is also present, ranging from 'low' to 'high'. A 'Show Help' button is highlighted in red. On the right, there are checkboxes for 'Rulers' (checked) and 'Timer' (unchecked).

The main simulation area shows a string of red beads fixed to a red clamp on the right. A vertical ruler on the left indicates a 40 cm scale. A horizontal ruler below the string shows a 90 cm scale. The string is currently in a flat, horizontal state.

At the bottom left, there is a circular control knob with a red dot. Below it are three radio buttons: 'Manual' (unselected), 'Oscillate' (selected), and 'Pulse' (unselected). A 'Restart' button is highlighted in red.

In the center, the word 'Paused' is displayed in large orange text. Below it are two buttons: 'pause/play' (a play button icon) and 'step' (a double right arrow icon).

At the bottom right, there are three radio buttons for boundary conditions: 'Fixed End' (selected), 'Loose End' (unselected), and 'No End' (unselected).



For what frequencies will I generate a large (resonant) standing wave if I drive it with a small amplitude?