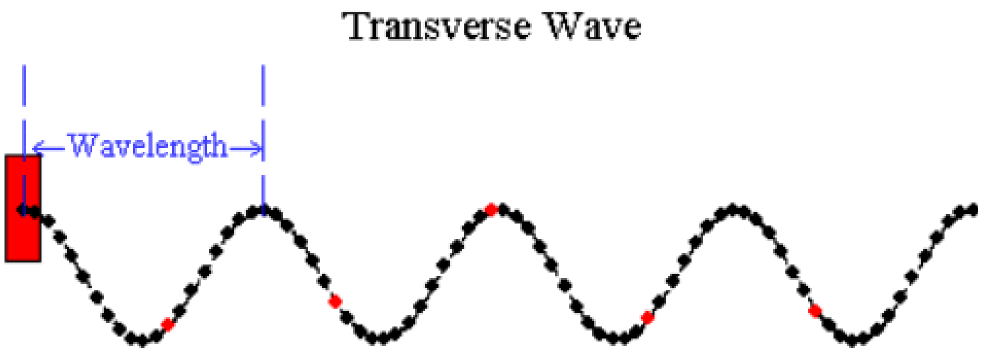
PHY131H1F - Hour 32



Today:

11.1 Transverse and Longitudinal Waves

11.2 Sinusoidal Waves

11.3 Wave Speed

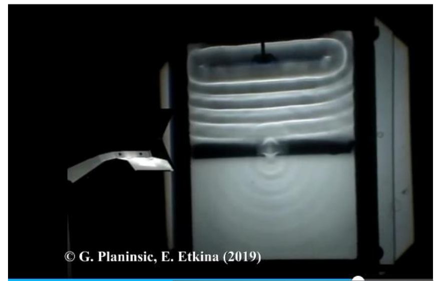
Mastering Physics

Soooooo… what's up on the MyLab and Mastering?

- Notice that Homework 11 – Optional has been posted on MasteringPhysics. It is not for marks, but you can do it if you wish, as it's meant to help you study Chapter 11 stuff.
- Also, I have posted an optional item called "Ch.11 Videos – Optional" which I recommend you check out.

Mastering Physics

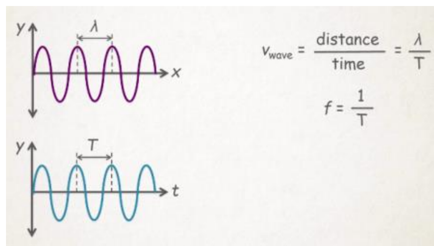
Chapter 11 Videos (Optional)



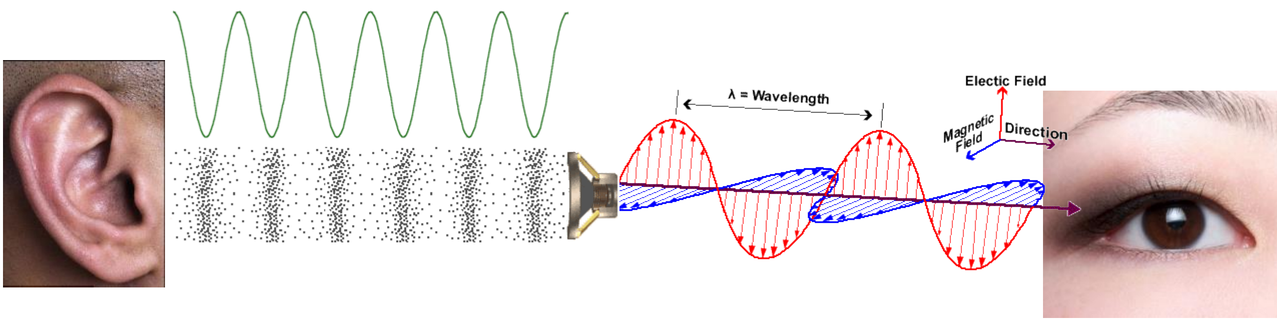
- Cool waves on an overhead projector video by the author of the book!

- *Buzzcut Guyyyyyy!!!* He’s back - and blasting his radio!

- And one last Khan-Academy-style video, all about Mechanical Waves



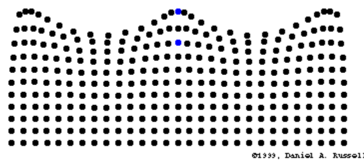
Last day I asked



- Two of the five senses depend on **waves** in order to work: which two?
- Answer: Sight and Sound!
- Sound is a pressure wave which travels through the air.
- Light is a wave in the electric and magnetic fields.

Chapter 11. Mechanical Waves

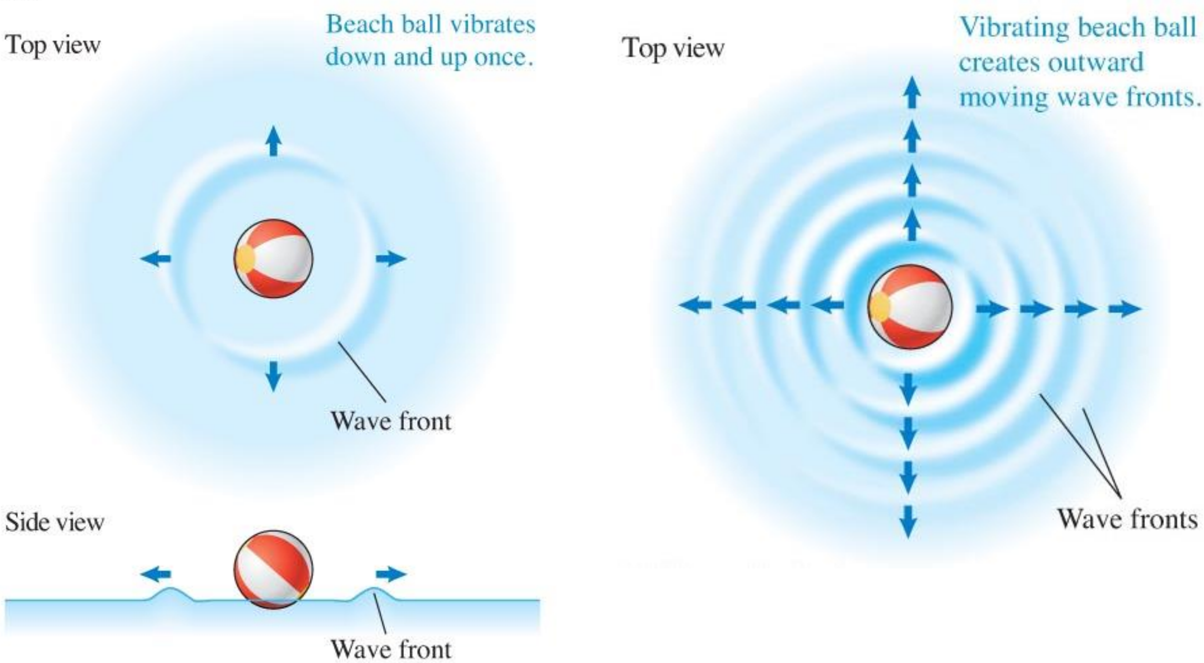
- A *vibration* is a periodic linear motion of a particle about an equilibrium position.
- When many particles vibrate and carry energy through space, this is a *wave.* A wave extends from one place to another.
- Examples are:
  - – water waves
  - – light, which is an electromagnetic wave
  - – sound



[image from https://webspace.utexas.edu/cokerwr/www/index.html/waves.html ©1999 by Daniel A. Russell]

Image from https://www.thehappycatsite.com/cat-drinking-a-lot-of-water/

(a)

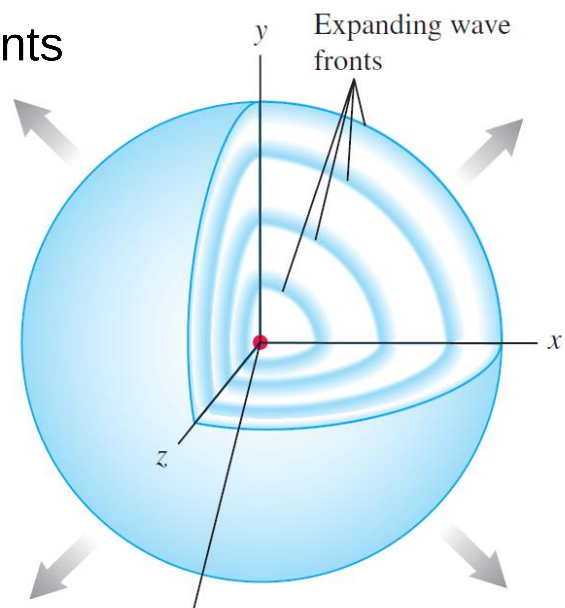


Waves and Wave Fronts

– A **wave front** is the locus of all crest points at which the *disturbance* of a wave is at a maximum.

– Spherical wave fronts of sound spread out uniformly in all directions from a point source.

– Electromagnetic waves in vacuum also spread out as shown here.

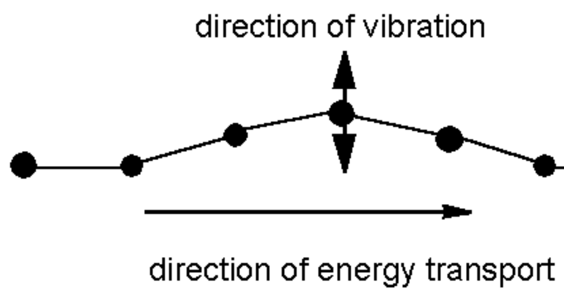


Point sound source producing spherical sound waves (alternating compressions and rarefactions of air)

Transverse waves

- Medium vibrates perpendicularly to direction of energy transfer
- Side-to-side movement

  Example:
  - Vibrations in stretched strings of musical instruments

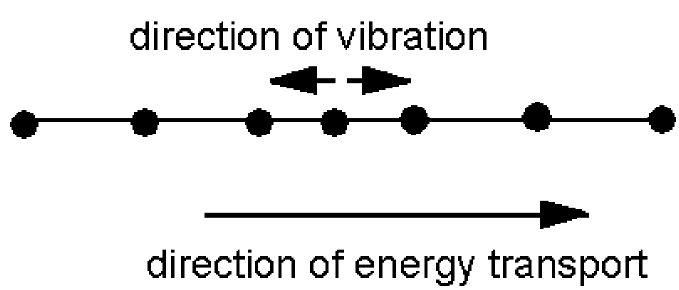


[image from http://www.maths.gla.ac.uk/~fhg/waves/waves1.html]

Longitudinal waves

- Medium vibrates parallel to direction of energy transfer
- Backward and forward movement consists of
  - compressions (wave compressed)
  - rarefactions (stretched region between compressions)

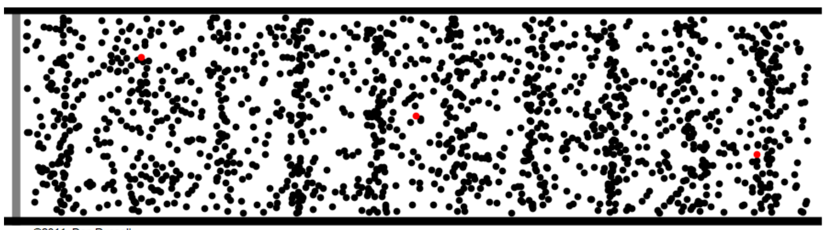
  Example: sound waves in solid, liquid, gas



[image from http://www.maths.gla.ac.uk/~fhg/waves/waves1.html]

Longitudinal Waves

- Sound is a longitudinal wave.
- Compression regions travel at the speed of sound.
- In a compression region, the density and pressure of the air is higher than the average density and pressure.



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Learning Catalytics Question

What is a "Transverse Wave"?

A. A wave in which the energy is transmitted in the opposite direction to the wave motion.

B. A wave in which the energy is transmitted in the same direction as the wave motion.

C. A wave in which the medium oscillates in a direction that is parallel to the direction the wave energy travels. Longitudinal.

D. A wave in which the medium oscillates in a direction that is perpendicular to the direction the wave energy travels. Transverse

Reflection from a Lighter end

- A pulse traveling to the right on a heavy string attached to a lighter string
- The reflected pulse is “upright”.
- Also a larger pulse is transmitted into the second medium.

[Animation courtesy of Dan Russell, Penn State]

Reflection from a Heavier end

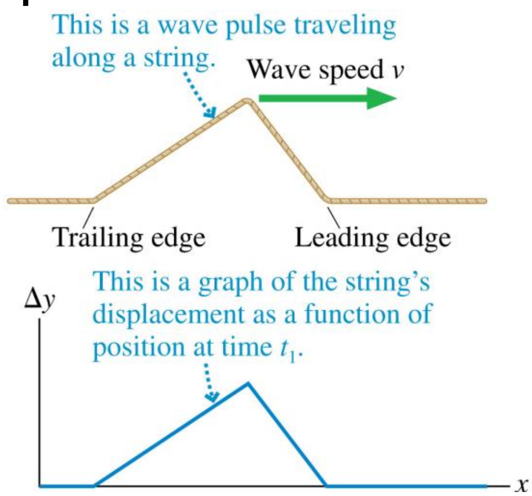
- A pulse traveling to the right on a light string attached to a heavier string
- The reflected pulse is “inverted”.
- Also a small pulse is transmitted into the second medium.

[Animation courtesy of Dan Russell, Penn State]

[Demonstration]

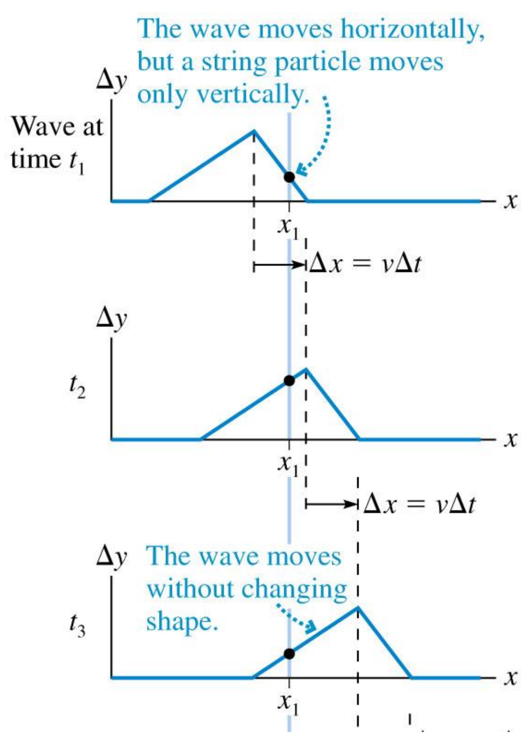
Snapshot Graph

- A graph that shows the wave's displacement as a function of position at a single instant of time is called a **snapshot graph**.
- For a wave on a string, a snapshot graph is literally a picture of the wave at this instant.



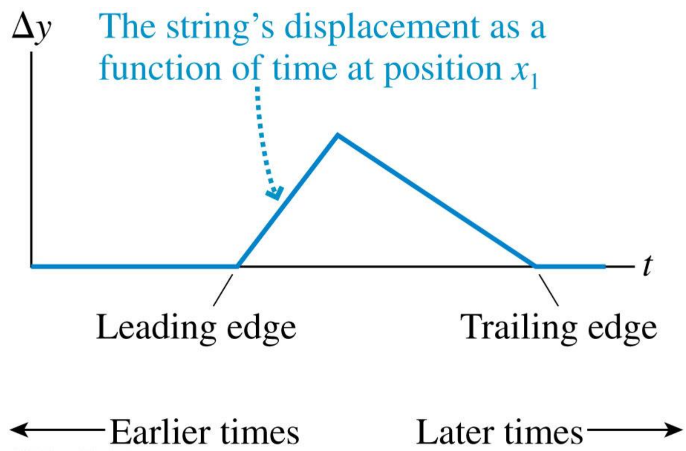
One-Dimensional Waves

- The figure shows a sequence of snapshot graphs as a wave pulse moves.
- These are like successive frames from a movie.
- Notice that the wave pulse moves forward distance $\Delta x = v\Delta t$ during the time interval Δt.
- That is, the wave moves with *constant speed.*



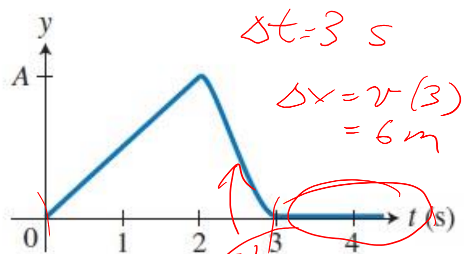
History Graph

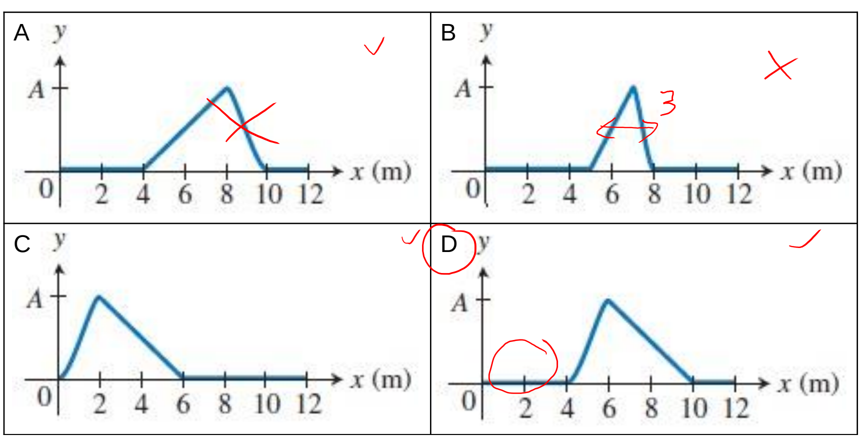
- A graph that shows the wave's displacement as a function of time at a single **position** in space is called a **history graph.**
- This graph tells the history of that particular point in the medium.
- Note that for a wave moving from left to right, the shape of the history graph is *reversed* compared to the snapshot graph.



Learning Catalytics Question

The figure shows the displacement-versus-time graph of the left end of a 12-m-long rope. The wave velocity on the rope is +2 m/s. Which graph below correctly shows a snapshot of the rope at a clock reading of $t = 5$ s?





$\Delta t = 3$ s

$\Delta x = v(3) = 6$ m

Steep edge is trailing.

at 5 s the pulse will be $2 \times 2 = 4$ m beyond $x = 0$.

“Cosine” is one shape a wave can have!

λ = "lambda" = wavelength.

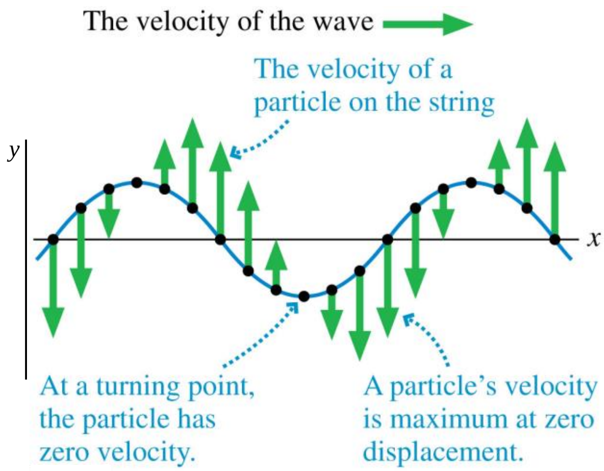
$y = A\cos\left[2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)\right]$ is a “sinusoidal” wave traveling in the $+x$ direction.

$y = A\cos\left[2\pi\left(\frac{t}{T} + \frac{x}{\lambda}\right)\right]$ is a “sinusoidal” wave traveling in the $-x$ direction.

- The **Period** T in seconds is the time for one complete vibration of a point in the medium anywhere along the wave’s path.
- The **Frequency** f in Hz (s^{-1}) $f = 1/T$, is the number of vibrations per second of a point in the medium as the wave passes.
- The **Amplitude** A is the maximum distance of a point of the medium from its equilibrium position as the wave passes.
- The **Wave Speed** v in m/s is the distance a disturbance travels in a time interval divided by that time interval.

Sinusoidal Wave on a String

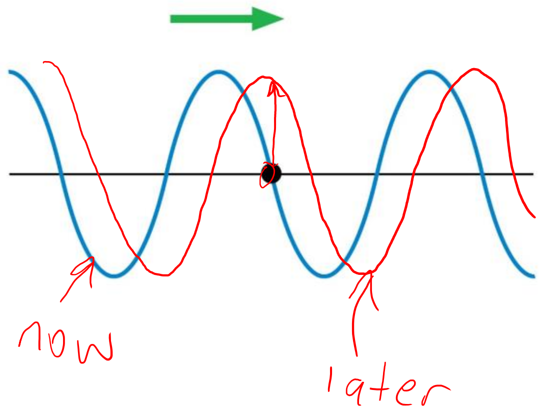
- Shown is a snapshot graph of a wave on a string with vectors showing the velocity of the string at various points.
- As the wave moves along x, the velocity of a particle on the string is in the y-direction.



Let’s do “The Wave”

Learning Catalytics Question

- A wave on a string is traveling to the right.
- The green arrow shows the direction of the motion of the wave energy.
- At this instant, the piece of string marked with a dot is moving.
- In what *direction* is the piece of string marked with a dot moving at this instant?
- [sketch an arrow with your device - the length of the arrow does not matter.]

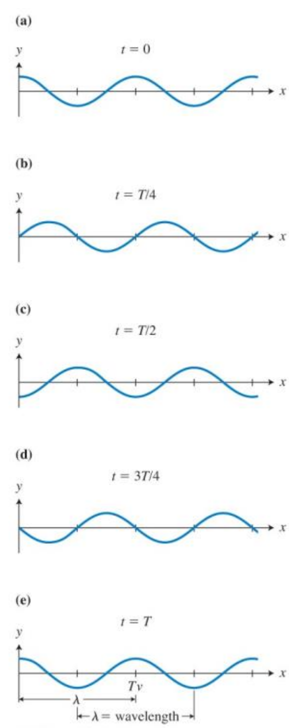


"Wave Speed" means speed of the **Pattern**

- Figure 11.8 on page 319 shows five "snapshots" as a wave pattern moves along the $+x$ direction.
- 11.8(e) shows that the pattern repeats at a distance Tv (period multiplied by the wave speed). This distance is called the wavelength:

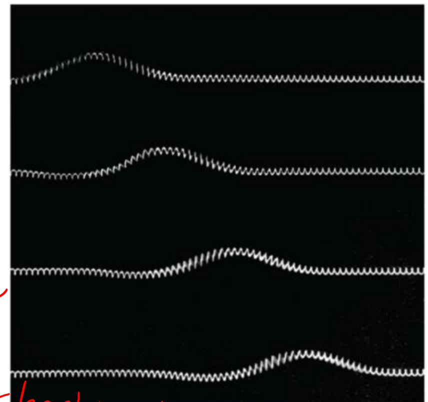
$$\lambda = Tv$$

- Whenever you have two out of three of the following, you can use the equation above to solve for the third:
  1. Wave speed v
  2. Period T
  3. Wavelength λ



Transverse waves

The speed of transverse waves on a string stretched with tension F is:



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

F is used for tension, since T means period in chapter 11.

Where μ is the string's mass-to-length ratio, also called the **linear density**:

"mu" →

$$\mu = \frac{m}{L}$$

Units: [kg/m]

[Doc Cam Example]

An 80 kg climber hangs from a rope, 20 m below a rocky overhang. The rope has a linear density of 37 g/m. Approximately how long would it take a transverse pulse to travel the length of the rope from the climber to the overhang?

Sketch and translate

$\mu = 37\ \frac{g}{m} = 0.037\ \frac{kg}{m}$

Pulse speed: $v = \sqrt{\frac{F}{\mu}}$.

Climber is supported by tension, F.

Simplify and diagram

Force diagram for climber:

↑F

↓mg

Equilibrium: $F = mg$

Wave speed: $v = \sqrt{\frac{mg}{\mu}}$

Assume constant wave speed: $d = vt$

Represent mathematically

$t = \frac{d}{v} = d\sqrt{\frac{\mu}{mg}} = 20\ m\sqrt{\frac{0.037\ kg/m}{(80\ kg)\,9.8}}$

$t = 0.14\ s$

Solve and Evaluate

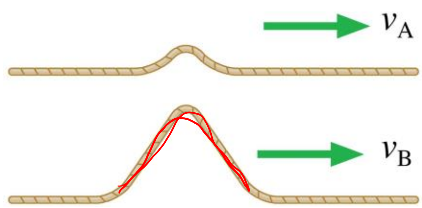
We neglected the mass of the rope. The actual tension at the top supports the climber + rope:

$m_{tot} = 80\ kg + (20)(0.037) \approx 81\ kg$.

→ waves are slightly faster at top.

Learning Catalytics Question

These two wave pulses travel along the same stretched string, one after the other. Which is true?



A. $v_A > v_B$

B. $v_B > v_A$

C. $v_A = v_B$

D. Not enough information to tell.

wave speed does not depend on amplitude

Learning Catalytics Question

For a wave pulse on a string to travel twice as fast, the string tension must be

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

F = tension.

A. Increased by a factor of 4.

B. Increased by a factor of 2.

C. Decreased to one half its initial value.

D. Decreased to one fourth its initial value.

E. Not possible. The pulse speed is always the same.