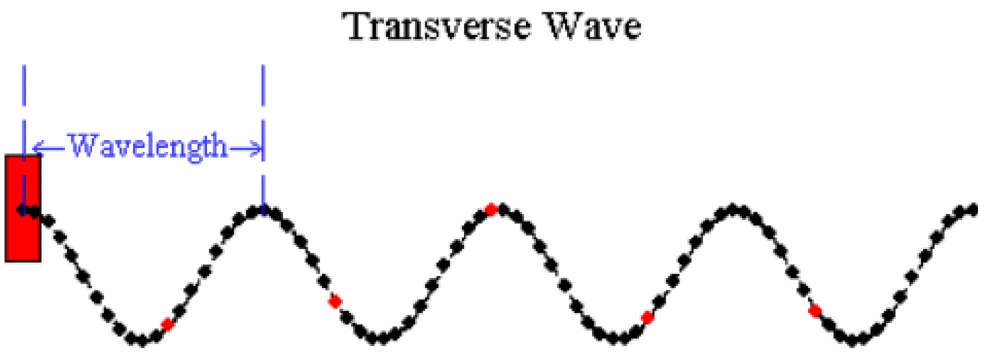
PHY131H1F - Hour 32



Today:

11.1 Transverse and Longitudinal Waves

11.2 Sinusoidal Waves

11.3 Wave Speed

Latest Comments from Learning Catalytics: "Please enter at least one specific question or concern you would like me to address in class."

- *"If you have some amount of potential energy and it's transferred to rotational kinetic and kinetic energy. Are the kinetic and rotational kinetic energy equal to each other?"*

Harlow answer: No. Objects can be rotating and translating, and have a variety of ratios of translational to rotational kinetic energy.

- *"Why is the relationship between linear and rotational energy 2.5 (homework 9 question 3)"*

Harlow answer: Ah. This was a "rolling without skidding" problem, in which you have the constraint that $v = \omega R$. In this case, you can solve for the ratio of K_{tran} to K_{rot}… shall we do this on the Doc Cam?

A round object is rolling without skidding.

What is the ratio of translation kinetic energy to rotational kinetic energy while it rolls?

Sketch and translate

Represent mathematically

Simplify and diagram

Solve and Evaluate

Bowling Ball?

Basketball?

Hockey Puck on its edge?

Latest Comments from Learning Catalytics: "Please enter at least one specific question or concern you would like me to address in class."

- *"Can you define the centre of mass of two different objects together if you consider them one system?"*

Harlow answer: Yes! Just use the x-positions of the centres of masses of the two objects, and then the centre of mass of the system is:

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

- *"is HW 10 the last hw set?"*

Harlow answer: For marks, yes. But there's one more that you can do for practice, if you wish.

Mastering Physics

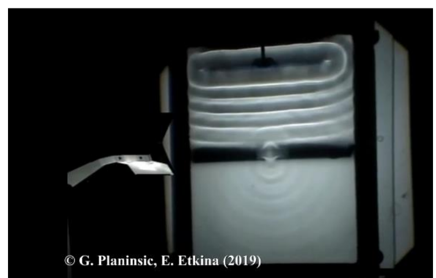
What’s up on the MyLab and Mastering?

- 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

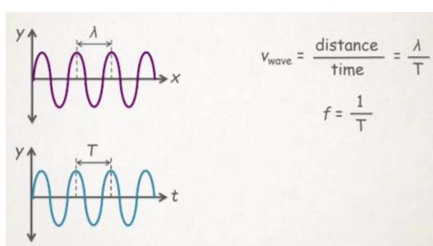
Chapter 11 Videos (Optional)

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

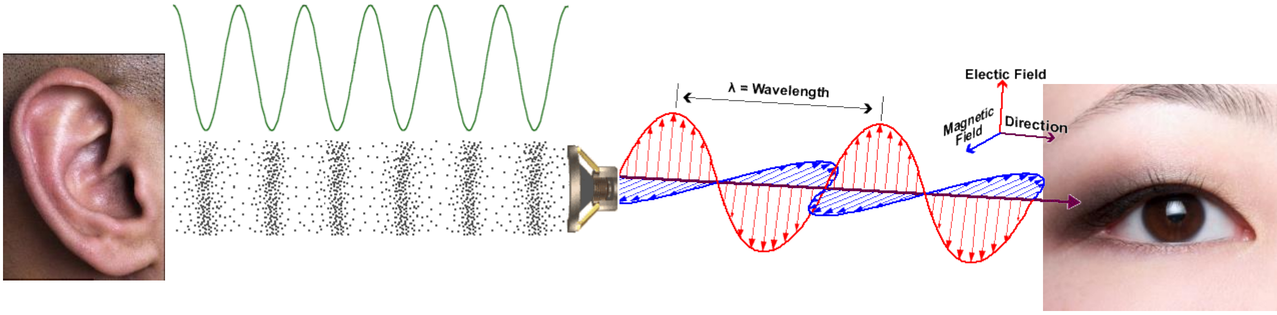


- *Buzzcut Guyyyyyy!!!* He’s back - and blasting his radio!

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



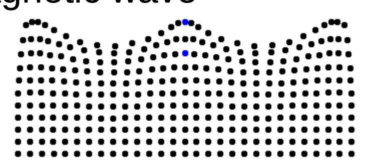
Last day I asked



- 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]

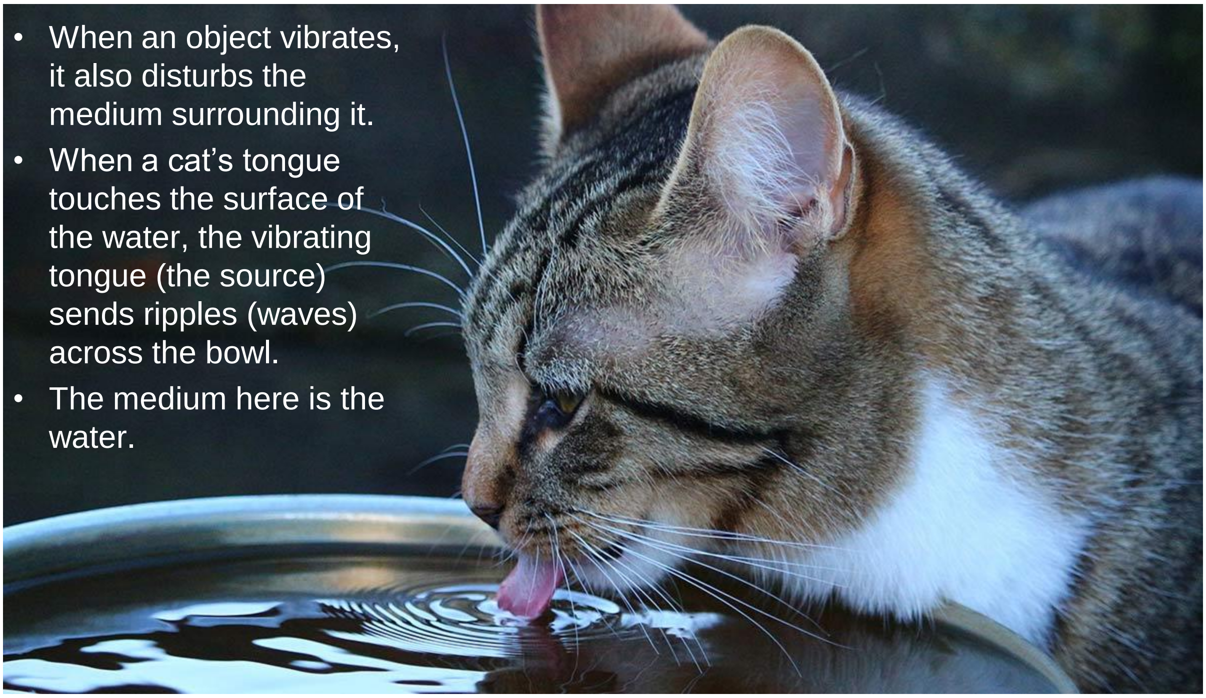
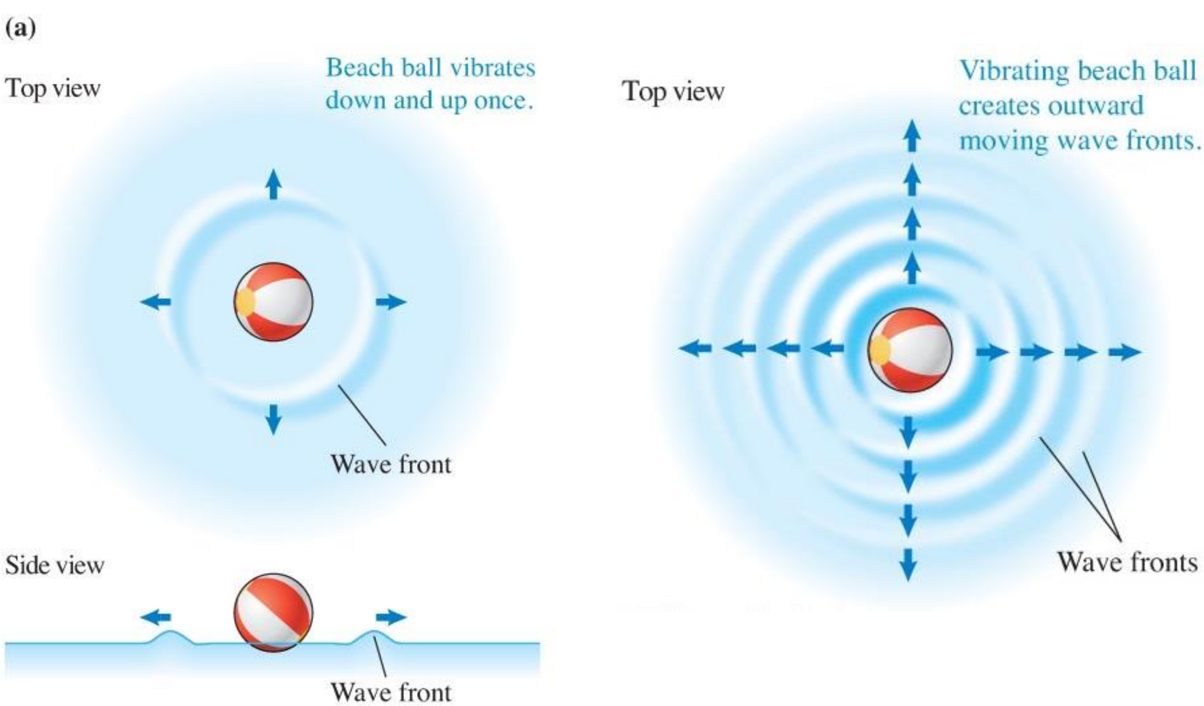
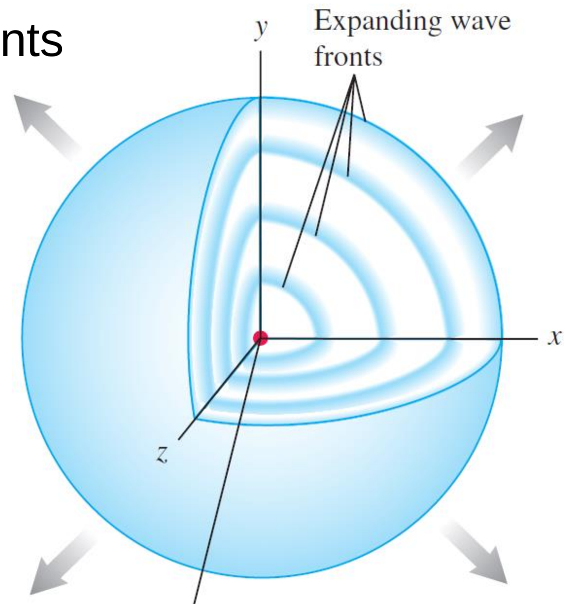


Image from https://www.thehappycatsite.com/cat-drinking-a-lot-of-water/



Waves and Wave Fronts

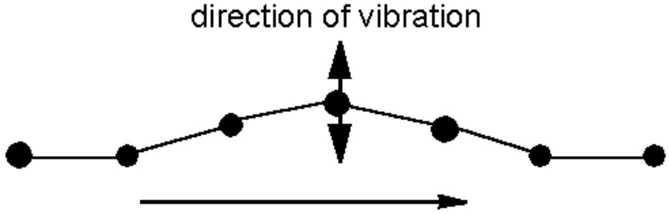
- A **wave front** is the locus of all crest points at which the *disturbance* of a wave is at a maximum.
- Spherical wave fronts of sound spread out uniformly in all directions from a point source.
- Electromagnetic waves in vacuum also spread out as shown here.



Transverse waves

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

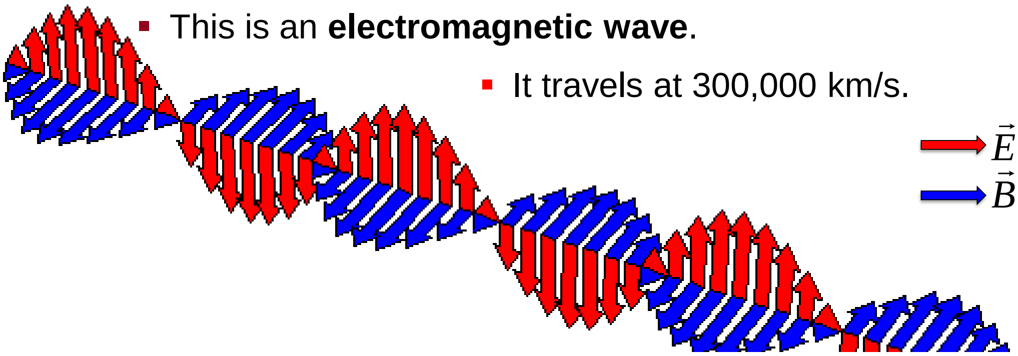
  Example:
  - Vibrations in stretched strings of musical instruments



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

Transverse Waves
Maxwell's Theory of Electromagnetic Waves

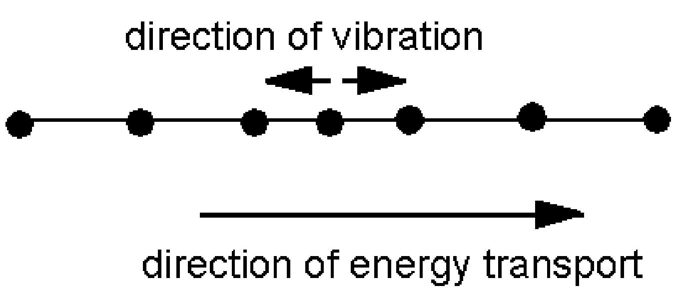
- A changing electric field creates a magnetic field, which then changes in just the right way to recreate the electric field, which then changes in just the right way to again recreate the magnetic field, and so on.
- This is an **electromagnetic wave**.
  - It travels at 300,000 km/s.



Longitudinal waves

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

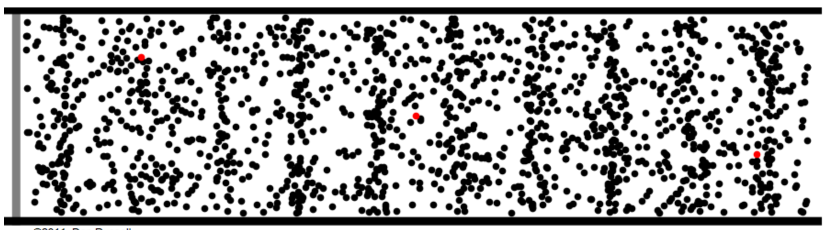
Example: sound waves in solid, liquid, gas



[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.



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]

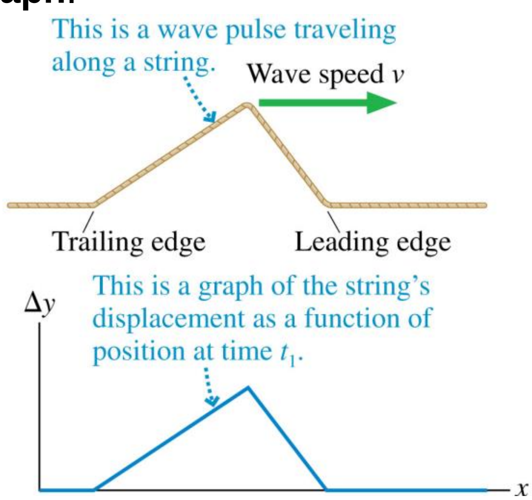
Reflection from a Lighter end

- 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]

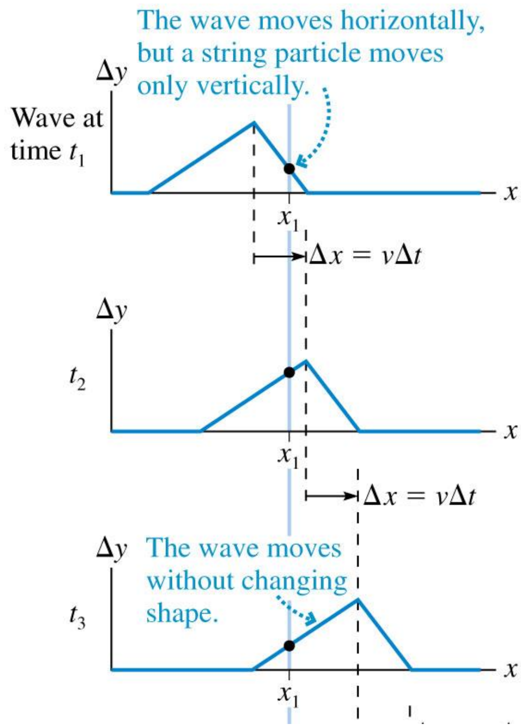
Snapshot Graph

- 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.



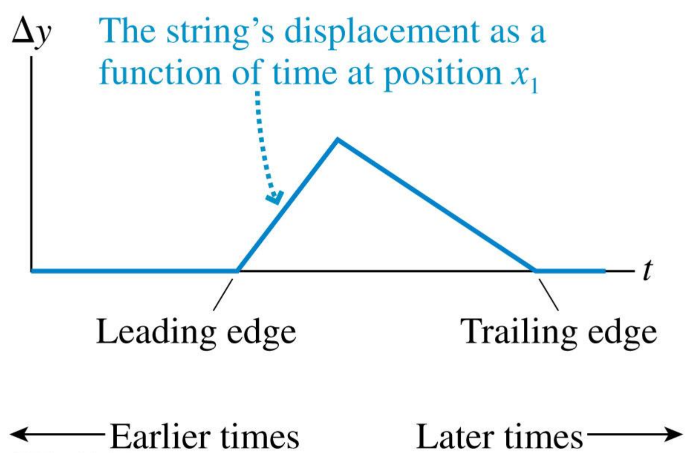
One-Dimensional Waves

- 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.*



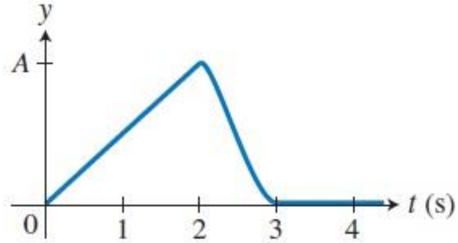
History Graph

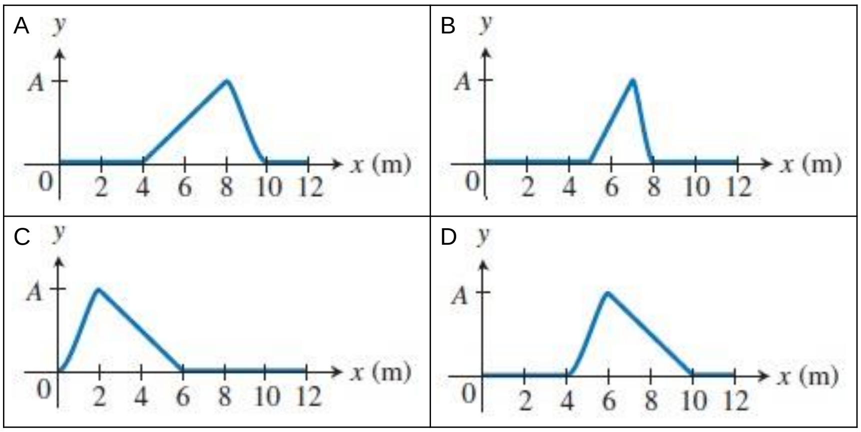
- A graph that shows the wave's displacement as a function of time at a single **position** in space is called a **history graph.**
- This graph tells the history of that particular point in the medium.
- Note that for a wave moving from left to right, the shape of the history graph is *reversed* compared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





“Cosine” is one shape a wave can have!

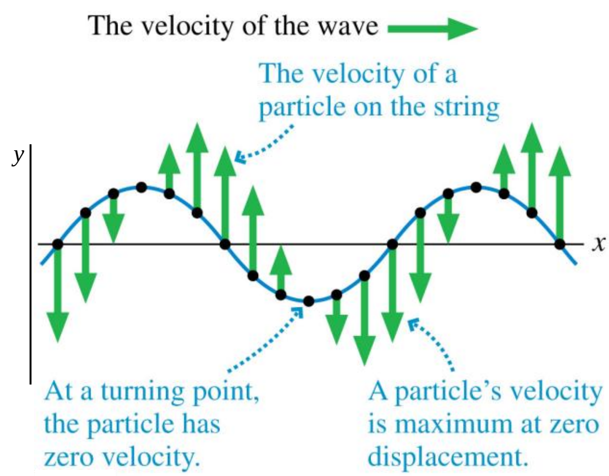
$y = A\cos\left[2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)\right]$ is a “sinusoidal” wave traveling in the $+x$ direction.

$y = A\cos\left[2\pi\left(\frac{t}{T} + \frac{x}{\lambda}\right)\right]$ 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

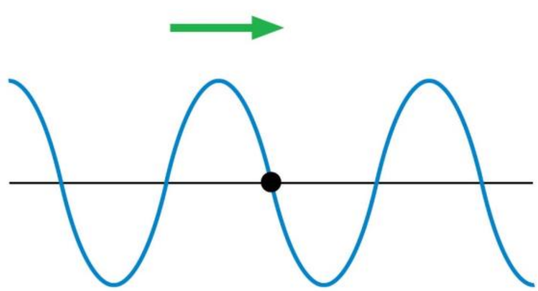
- Shown is a snapshot graph of a wave on a string with vectors showing the velocity of the string at various points.
- As the wave moves along x, the velocity of a particle on the string is in the y-direction.



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.]

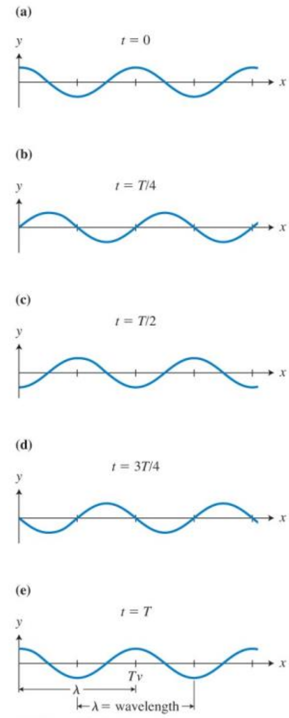


“Wave Speed” means speed of the **Pattern**

- 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:

$$\lambda = Tv$$

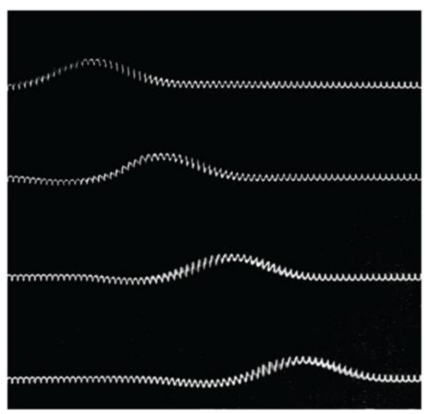
- Whenever you have two out of three of the following, you can use the equation above to solve for the third:
  1. Wave speed v
  2. Period T
  3. Wavelength λ



Transverse waves

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

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



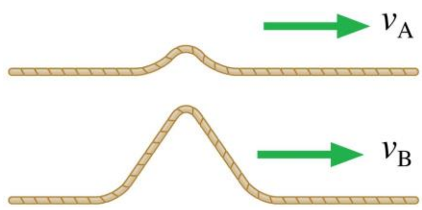
Where μ is the string’s mass-to-length ratio, also called the **linear density**:

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

Units: [kg/m]

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.

Learning Catalytics Question

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

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.

[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?