March 27, 2013 Physics 132 Prof. W. Losert

Outline

Waves

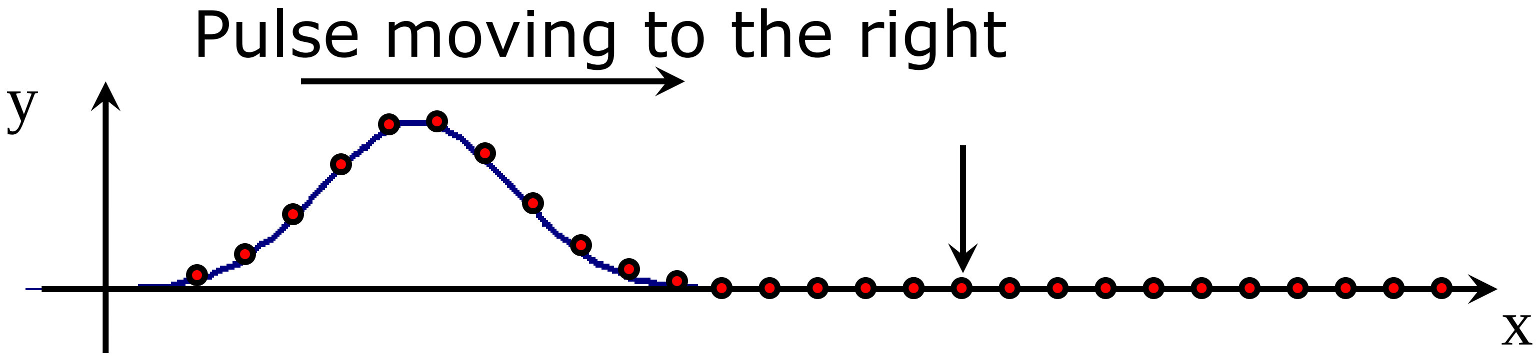
Midterm 2 next FRIDAY

Office hours Thursday 5-6.30

Displacements on an elastic string / spring

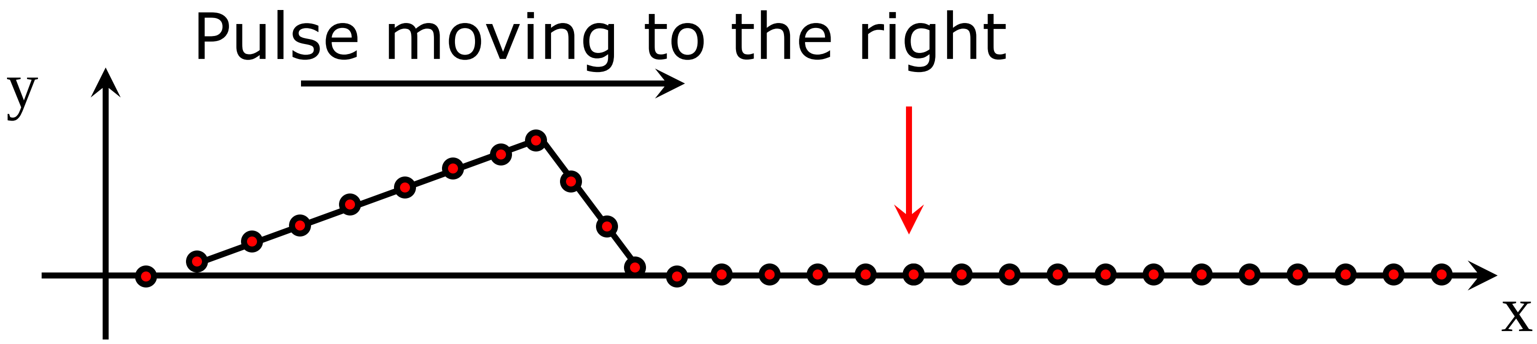
- Each bit of the string can move up or down (perpendicular to its length) – transverse waves
- Each bit of string can also move toward/away along the string length if the string is elastic (most notable on very deformable strings such as slinky, rubber band). – longitundinal waves

How do the beads move?



- Sketch the y position of the bead indicated by the arrow as a function of time

If this is the space-graph (photo at an instant of time) what does the time-graph look like for the bead marked with a red arrow?

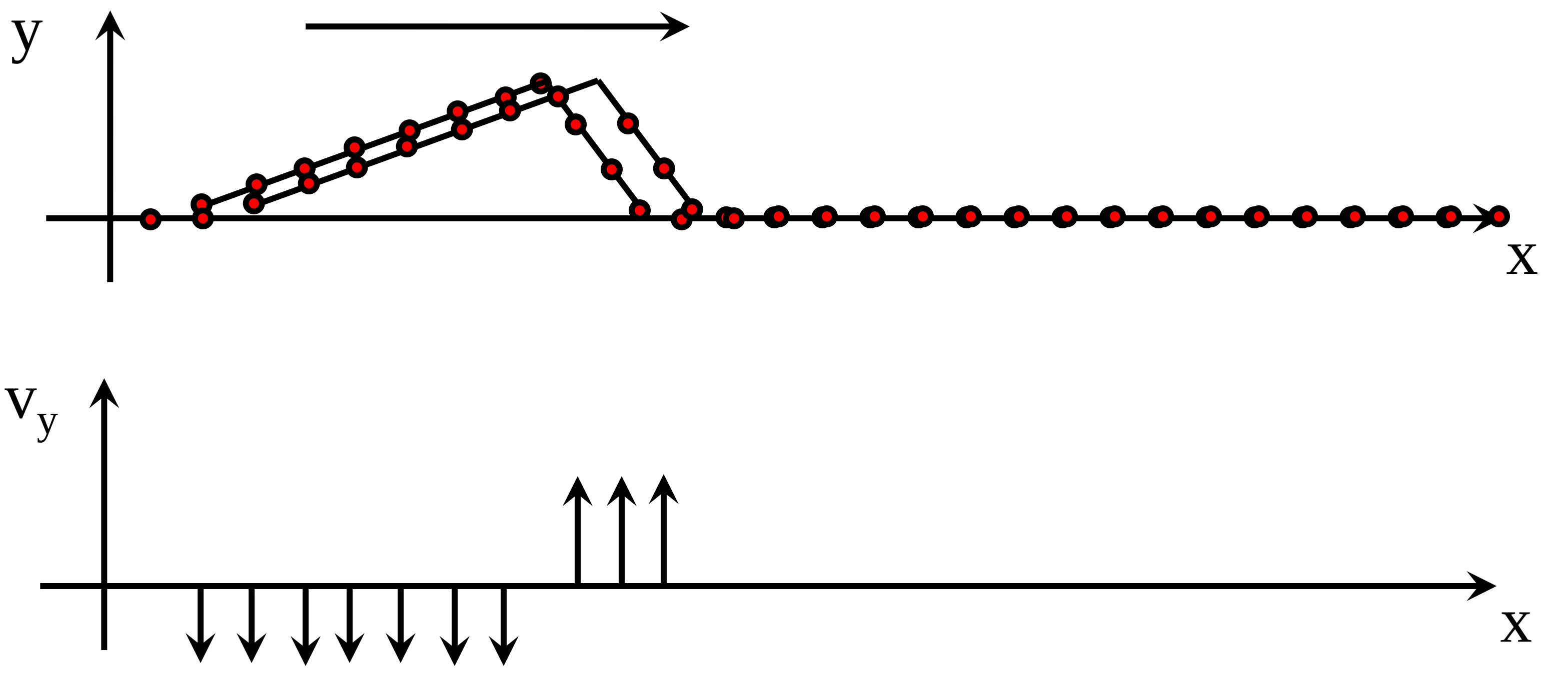


1. Choice One
2. Choice Two
3. Choice Three
4. Choice Four
5. Choice Five
6. Choice Six
7. Choice Seven
8. Choice Eight

Describing the motion of the beads

- Sketch the velocity of each bead in the top figure at the time shown

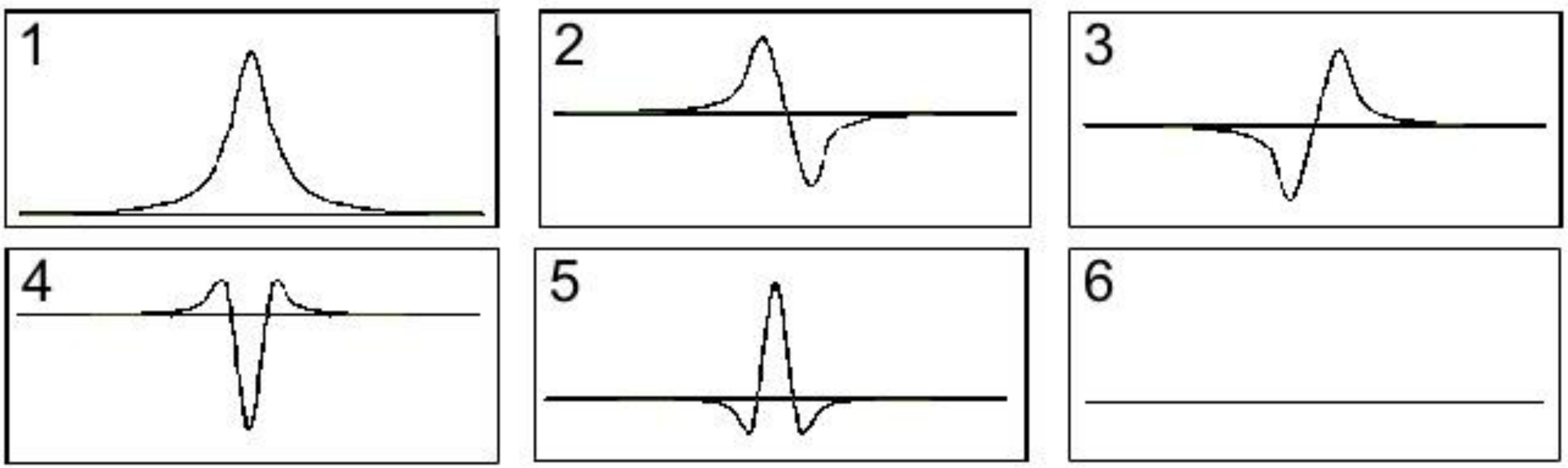
Pulse moving to the right



A pulse is started on the string moving to the right. At a time t_0 a photograph of the string would look like figure 1 below. A point on the string to the right of the pulse is marked by a spot of paint.

(x is horizontal and right, y is vertical and up)

Which graph would look most like a graph of the **y displacement** of the spot as a function of time?

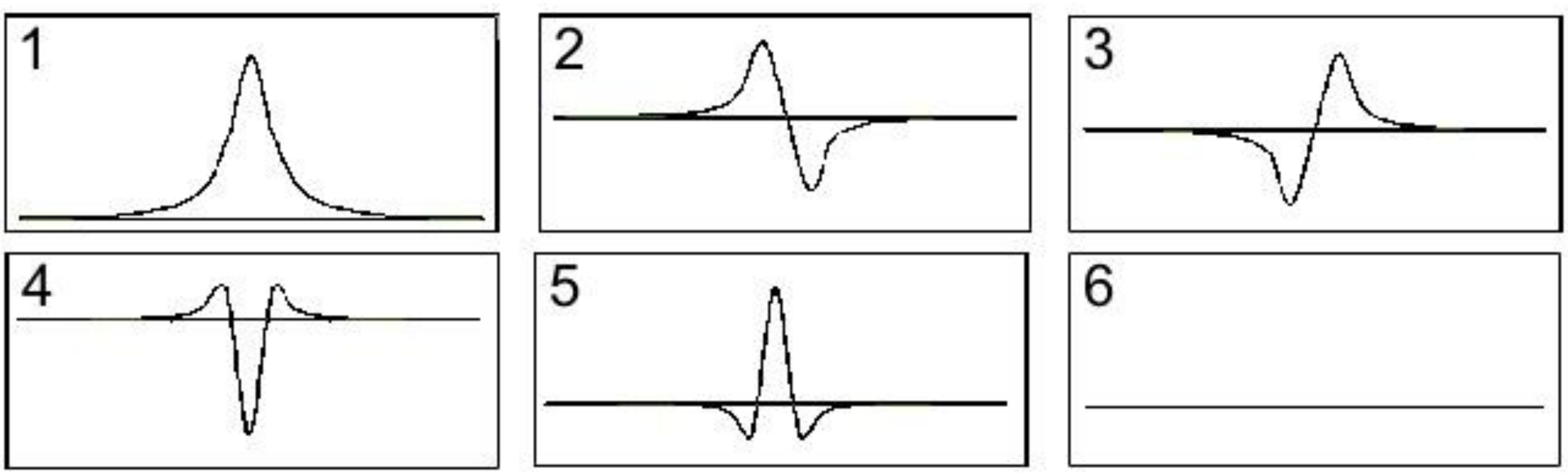


7 None of these

A pulse is started on the string moving to the right. At a time t_0 a photograph of the string would look like figure 1 below. A point on the string to the right of the pulse is marked by a spot of paint.

(x is horizontal and right, y is vertical and up)

Which graph would look most like a graph of the **x velocity** of the spot as a function of time?

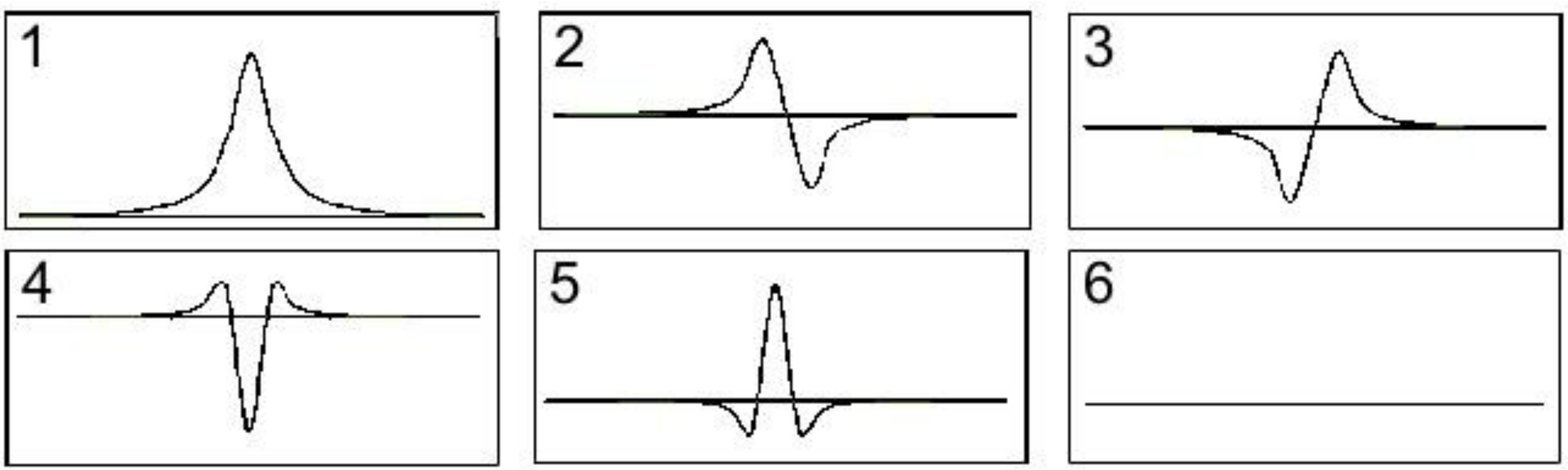


7 None of these

A pulse is started on the string moving to the right. At a time t_0 a photograph of the string would look like figure 1 below. A point on the string to the right of the pulse is marked by a spot of paint.

(x is horizontal and right, y is vertical and up)

Which graph would look most like a graph of the **y velocity** of the spot as a function of time?

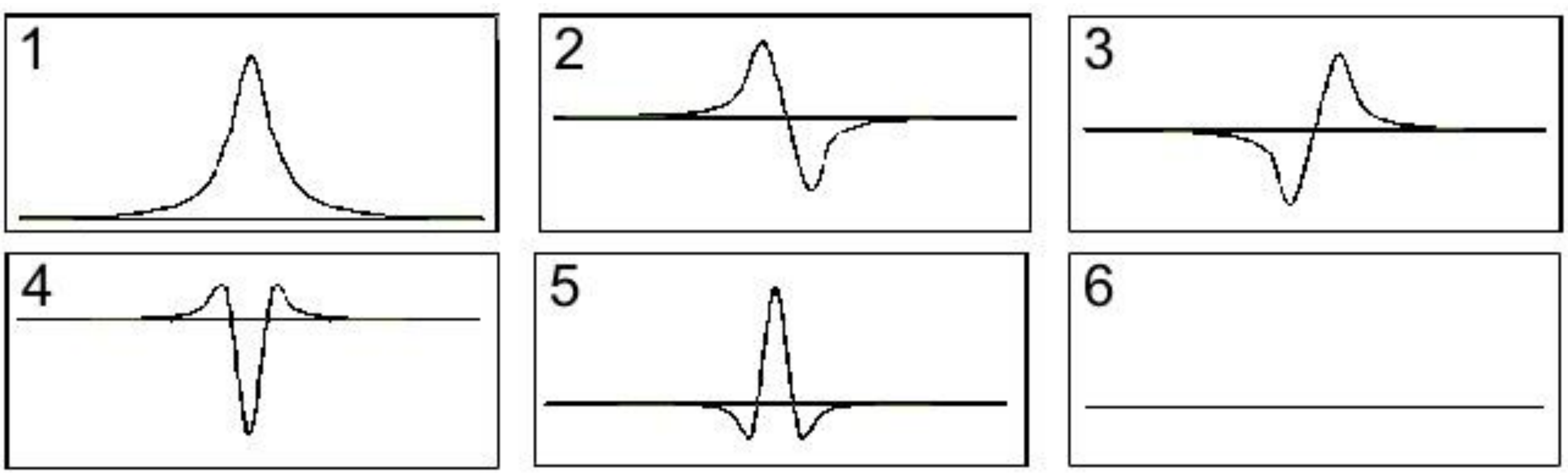


7 None of these

A pulse is started on the string moving to the right. At a time t_0 a photograph of the string would look like figure 1 below. A point on the string to the right of the pulse is marked by a spot of paint.

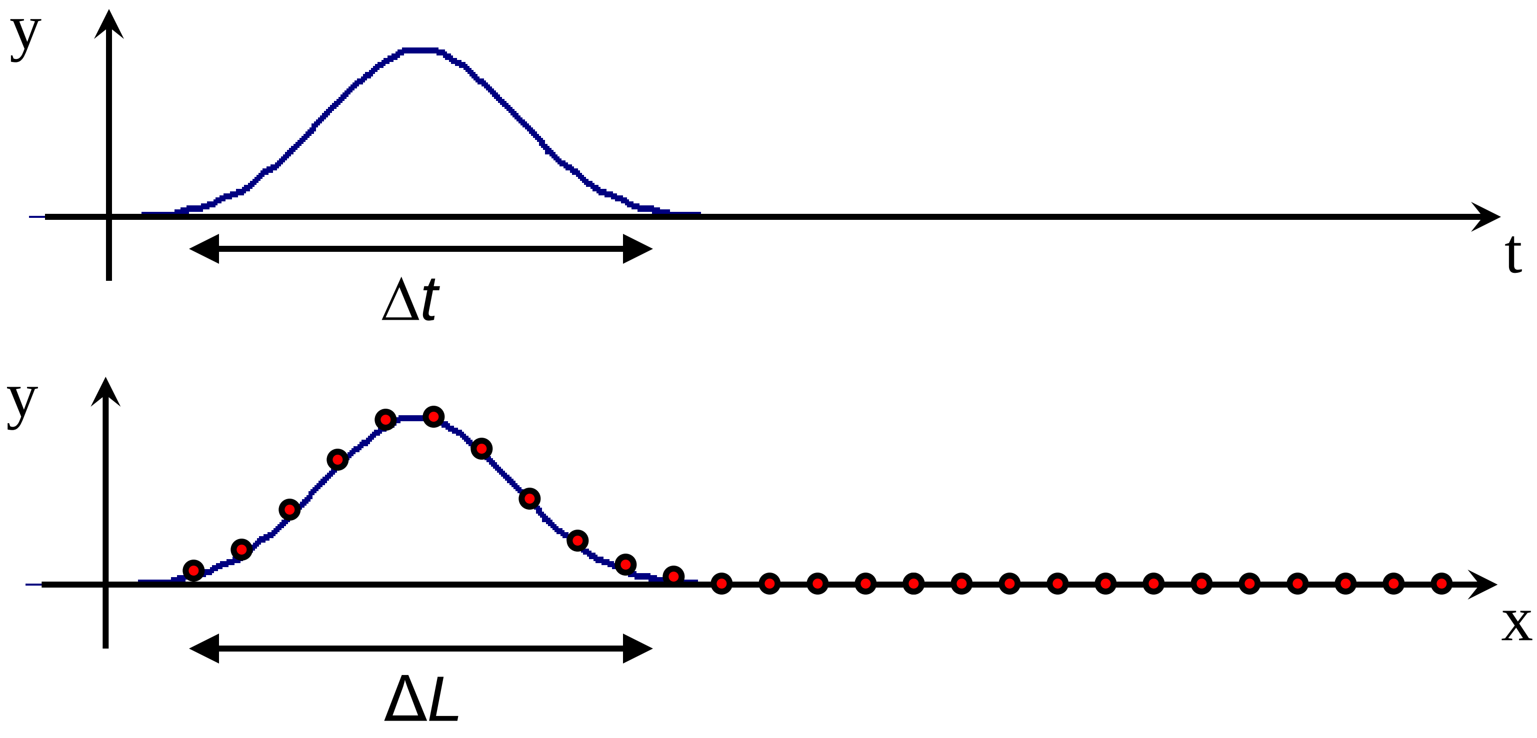
(x is horizontal and right, y is vertical and up)

Which graph would look most like a graph of the **y force** on the spot as a function of time?



7 None of these

What controls the widths of the pulses in time and space?

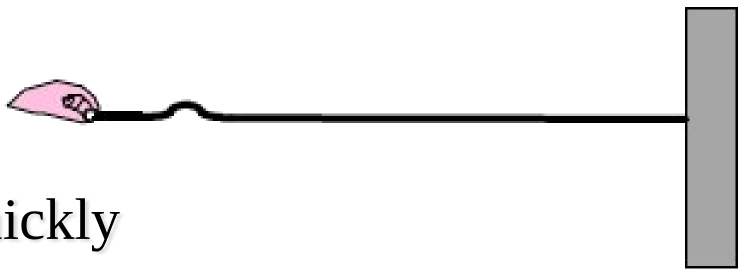


Width of a pulse

- The amount of time the demonstrator's hand was displaced up and down determines the time width of the t-pulse, Δt.
- The speed of the signal propagation on the string controls the width of the x-pulse, ΔL.
  – The leading edge takes off with some speed, v_0.
  – The pulse is over when the trailing edge is done.
  – The width is determined by "how far the leading edge got to" before the displacement was over.

$$\Delta L = v_0 \Delta t$$

What Controls the Speed of the Pulse on a Spring?

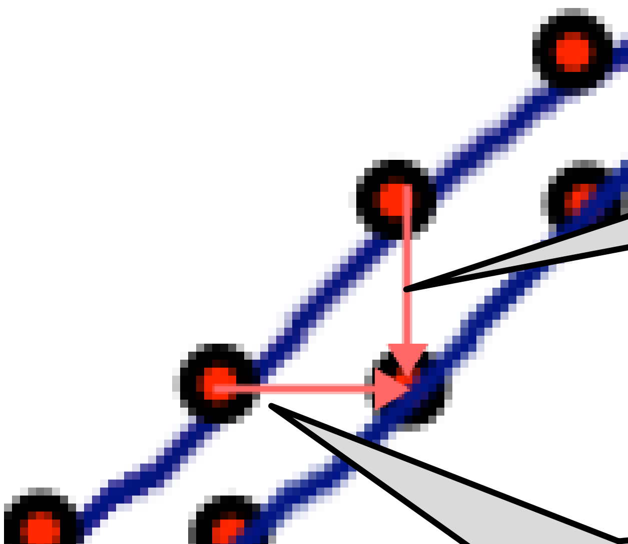


To make the pulse go to the wall faster

1. Move your hand up and down more quickly (but by the same amount).
2. Move your hand up and down more slowly (but by the same amount).
3. Move your hand up and down a larger distance in the same time.
4. Move your hand up and down a smaller distance in the same time.
5. Use a heavier string of the same length under the same tension.
6. Use a string of the same density but decrease the tension.
7. Use a string of the same density but increase the tension.
8. Put more force into the wave,
9. Put less force into the wave.

Speed of a bead

- The speed the bead moves depends on how fast the pulse is moving and how far it needs to travel to stay on the string.



$$v(x,t) = \frac{dy(x,t)}{dt} = \left(\frac{dy}{dx}\right)\left(\frac{dx}{dt}\right) = \left(\frac{dy}{dx}\right) v_0$$

slope of pulse

speed of bead

speed of pulse

Foothold principles: Mechanical waves

- *Key concept*: We have to distinguish the motion of the bits of matter and the motion of the pattern.
- *Mechanism*: the pulse propagates by each bit of string pulling on the next.
- *Pattern speed*: a disturbance moves into a medium with a speed that depends on the properties of the medium (but not on the shape of the disturbance)

- *Matter speed*: the speed of the bits of matter depend on both the **Amplitude** and **shape of the pulse** and **pattern speed**.

Dimensional analysis

- Square brackets are used to indicate a quantities dimensions – mass ($\mathcal{M}$), length ($\mathcal{L}$), or time ($\mathcal{T}$)
  - $[m] = \mathcal{M}$
  - $[L] = \mathcal{L}$
  - $[t] = \mathcal{T}$
  - $[F] = \mathcal{M}\mathcal{L}/\mathcal{T}^2$
- Build a velocity using mass (m), length (L), and tension (T) of the string:
  - $[v] = \mathcal{L}/\mathcal{T}$
  - $[T] = \mathcal{M}\mathcal{L}/\mathcal{T}^2$
  - $[T/m] = \mathcal{L}/\mathcal{T}^2$
  - $[TL/m] = \mathcal{L}^2/\mathcal{T}^2$

$$v_0^2 = \frac{TL}{m}$$

or, using $\mu = {}^{m}/_{L}$ $\quad v_0 = \sqrt{\frac{T}{\mu}}$

Foothold principles: Mechanical waves

- *Key concept*: We have to distinguish the motion of the bits of matter and the motion of the pattern.
- *Mechanism*: the pulse propagates by each bit of string pulling on the next.
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$$v_0 = \sqrt{T/m}$$

v_0 = speed of pulse
T = tension of spring
μ = mass density of spring (M/L)

- *Matter speed*: the speed of the bits of matter depend on both the size and shape of the pulse and pattern speed.