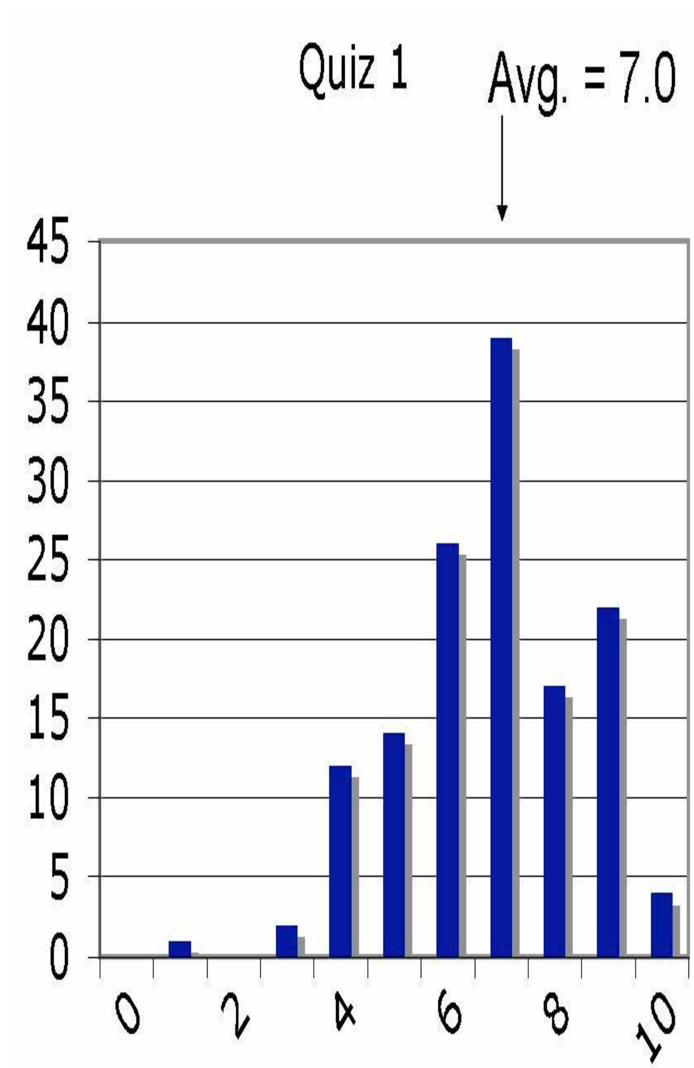
- **<u>Theme Music:</u> Superchunk**
  The Question is How Fast
- **<u>Cartoon:</u> Bill Amend**
  Foxtrot

Outline

- Go over Quiz #1
- Waves: Pulses on a spring
- Propagation of a pulse: What controls the speed of a pulse?
- Propagation of a pulse: What controls the width of a pulse in time?
- Superposition: How do waves combine?
- Waves: Foothold principles

Quiz 1

1.1	Y	N			1.2	1.3	1.4
a	20%	**80%**		a	**91%**	**76%**	**39%**
b	**28%**	**72%**		b	6%	3%	8%
c	**51%**	**49%**		c	1%	20%	**43%**
d	**86%**	14%		d	3%	1%	10%
e	24%	**76%**					
f	**18%**	**82%**					

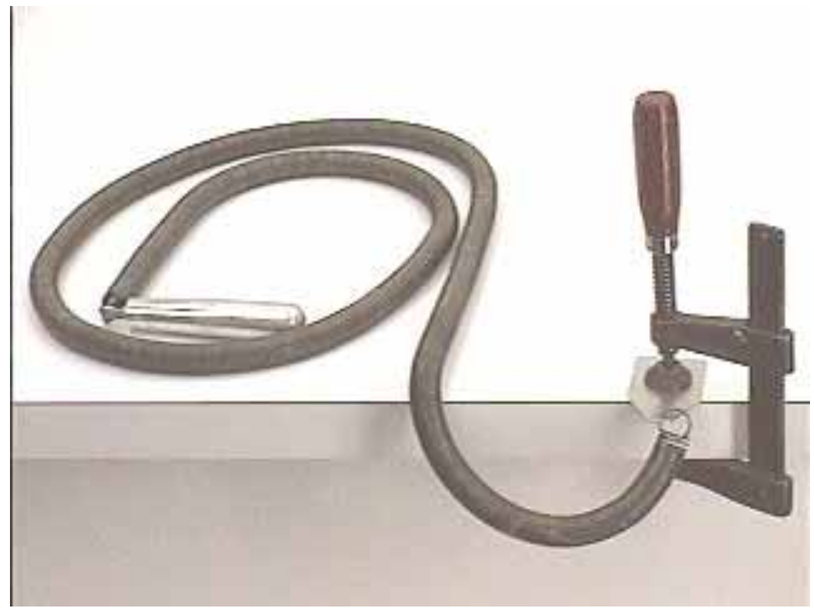


Waves

- Up to now, we have considered the motion of bits of matter. Now, we want to consider the motion of patterns of motion of bits of matter.
- The ideas we develop here will “cut loose” from the underlying matter and later develop an independent fundamental character of its own.

Demonstration: Waves on a long spring

- Pulses
  - Transverse
  - Longitudinal



Displacements on an elastic string / spring

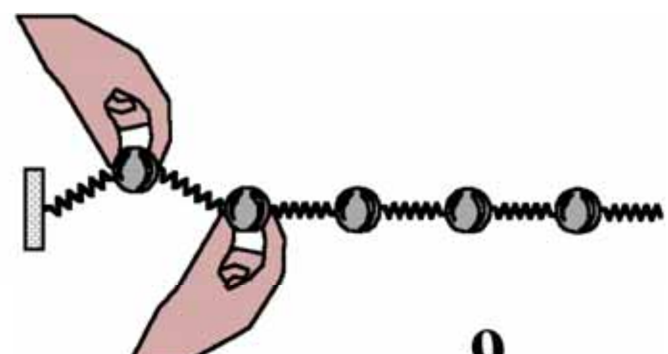
- Each bit of the string can move up or down (perpendicular to its length).
- To describe the motion of the string
  we need to describe the motion
  of <u>each bit of the string</u>
  at <u>every instant of</u> time.
- We therefore need to tell both which bit and when in order to specify a displacement.

$$y_i = f_i(t) \qquad\qquad y = f(x,t)$$

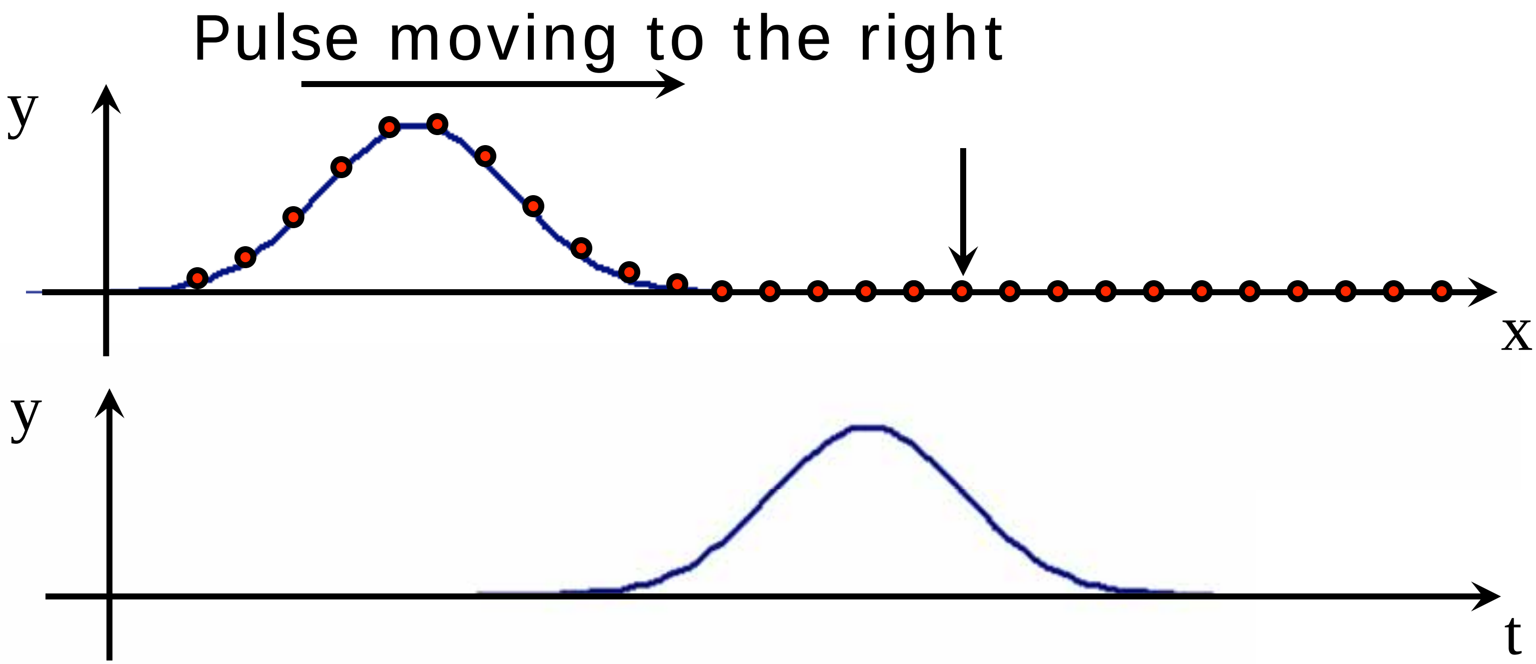
A Model

- The critical characteristics for what happens on the spring are:
  - The bits of the spring are elastic, so they pull displaced bits back towards equilibrium.
  - The bits of the spring have mass (implies intertia) so they overshoot.

- We will create a model that separates these characteristics so we can talk about them more easily:
  - massive beads
  - massless springs

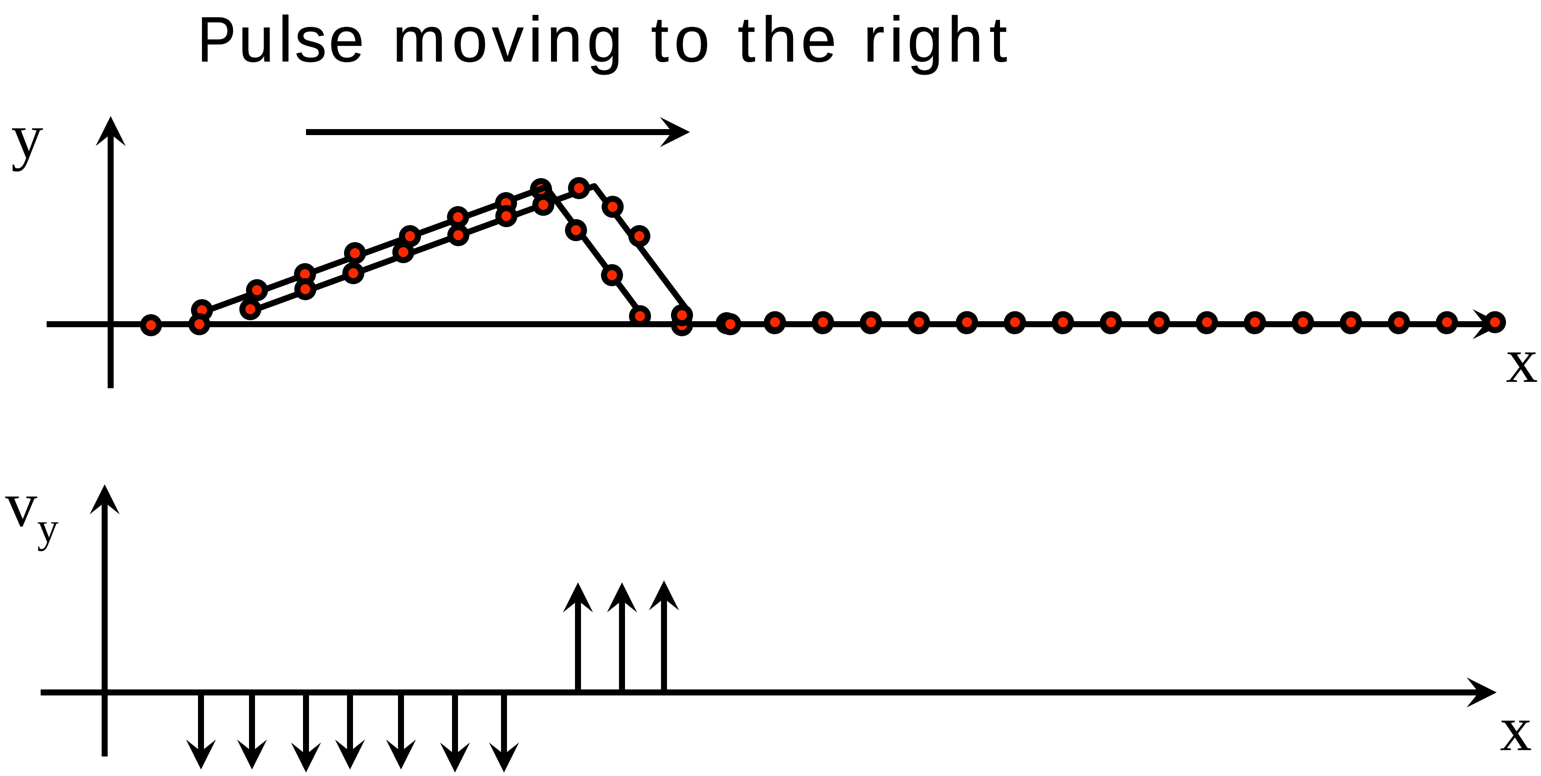


How do the beads move?



Why do I draw beads on the x-graph but not on the t?
Are the widths of the x- and t-graphs the same?

Describing the motion of the beads



What Controls the Speed of the Pulse?

- Doing the wave
  - Does it matter how high you stand up?
  - Does it matter how the next person gets their info on when you moved?

Speed of a wave on a string

- The masses (m) in a string of beads of length (L) are pulled by the tensions (T) of the springs.
- The speed of the pulse must depend on these – and only these parameters.
- Can we create a velocity from these using dimensional analysis?

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 $\mu = m/L$ $\qquad v_0 = \sqrt{\frac{T}{\mu}}$

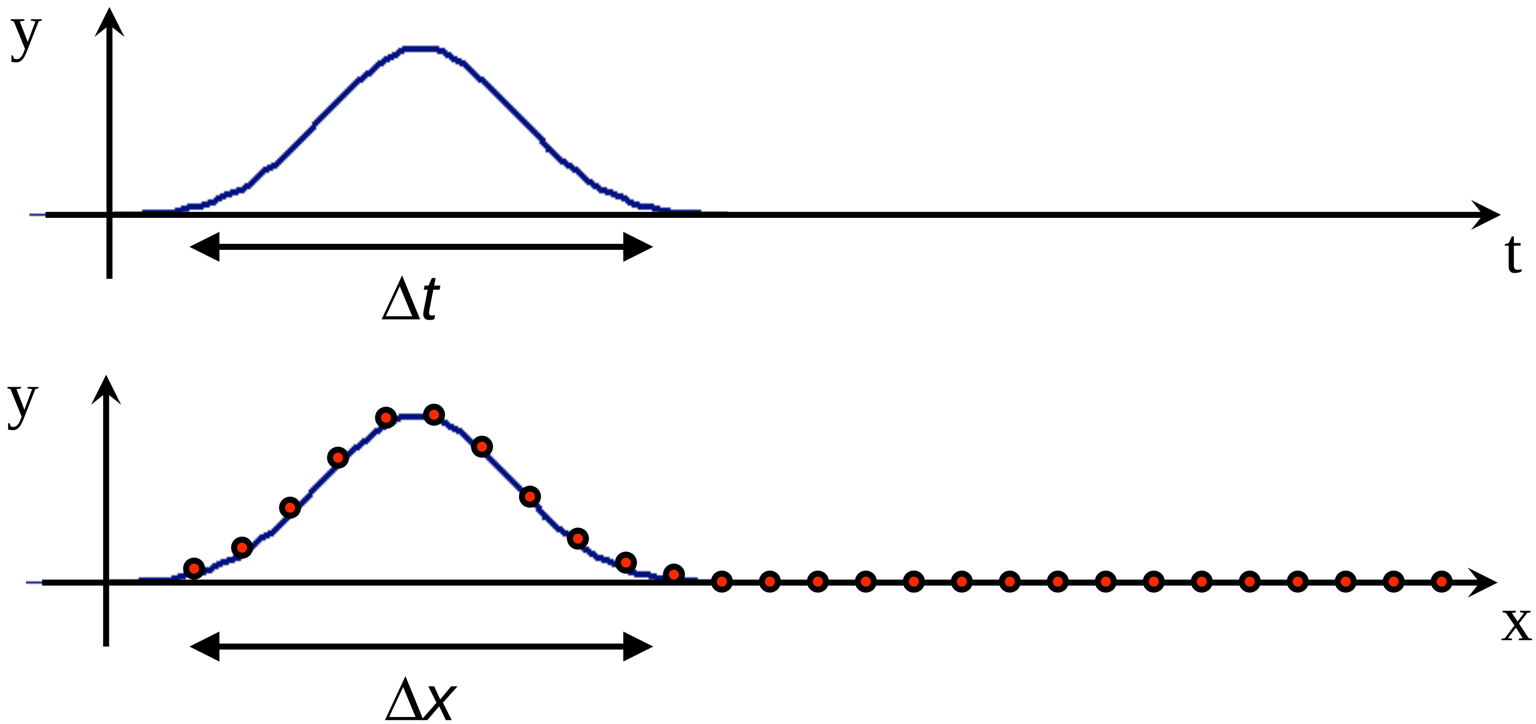
Motion of a wave pulse

- Whatever shape we make, it moves down the spring without changing its shape with a speed

$$v_0 = \sqrt{T/\mu}$$

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

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



Propagating 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.

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