Theme Music: Superchunk
The Question is How Fast
Cartoon: Bill Amend
Foxtrot

First, I looked in the back of the book, but it wasn't an odd-numbered problem.
Then I asked my little brother, but he wanted me to pay him $5.
Finally, I found it on the Internet with Google.
My physics teacher wants us to show how we get our answers.
Ah.

April 5, 2013  Physics 132  Prof. E. F. Redish
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)

\[ \nu_0 = \sqrt{\frac{T}{\mu}} \]

- \( \nu_0 \) = speed of pulse
- \( T \) = tension of spring
- \( \mu \) = 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.
Dimensional analysis

- Square brackets are used to indicate a quantities dimensions
  - mass (\(M\)), length (\(L\)), or time (\(T\))
    - \([m] = M\)
    - \([L] = L\)
    - \([t] = T\)
    - \([F] = ML/T^2\)

- Build a velocity using mass (\(m\)), length (\(L\)), and tension (\(T\)) of the string:
  - \([v] = L/T\)
  - \([T] = ML/T^2\)
  - \([T/m] = L/T^2\)
  - \([TL/m] = L^2/T^2\)

\[ v_0^2 = \frac{TL}{m} \]

or, using \(\mu = \frac{m}{L}\) \(v_0 = \sqrt{\frac{T}{\mu}}\)
What controls the widths of the pulses in time and space?

\[ \Delta t \]

\[ \Delta L \]
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, $\Delta t$.
- The speed of the signal propagation on the string controls the width of the x-pulse, $\Delta L$.
  - 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 beads?
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.

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

\( dx = \) how far pulse moves in time \( dt \)

\( dy = \) how far bead moves in time \( dt \)
Doing the math: 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 each bit of the string at every instant of time.
- We therefore need to tell both which bit and when in order to specify a displacement.

\[ y_i = f_i(t) \quad \quad y = f(x, t) \]