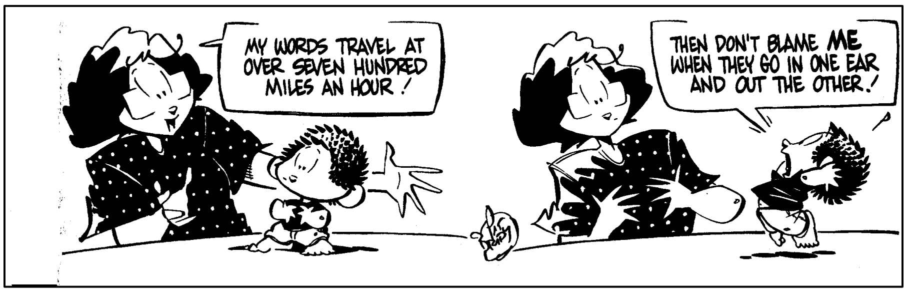
April 8, 2013 Physics 132 Prof. E. F. Redish

- **Theme Music:** **Antonio Carlos Jobim**
  Wave
- **Cartoon:** **Pat Brady**
  Rose is Rose



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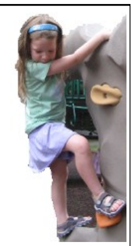
Foothold principles: Mechanical waves



- *Key concept*: We have to distinguish the motion of the bits of matter and the motion of the pattern.
- *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 size and shape of the pulse and on the pattern speed.
- *Mechanism*: the pulse propagates by each bit of string pulling on the next.

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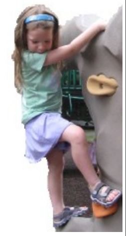
Foothold principles: Mechanical waves 2



- *Superposition*: when one or more disturbances overlap, the result is that each point displaces by the sum of the displacements it would have from the individual pulses. (signs matter)

Reading question

- In the case where two pulses move towards each other along the same line, the net force would be up, correct? But in the case where one pulse is the negative of the other, the forces cancel so there is no movement when they collide? Does this mean that the pulse "dies" ?

The math

- We express the position of a bit of string at a particular time by labeling which bit of string by its x position, so
  position of the bit at x at time $t = y(x,t)$.
- Since subtracting a d from the argument of a function ($f(x) \to f(x-d)$) shifts the graph of the function to the right by an amount d, if we want to set the graph of a shape $f(x)$ into motion at a constant speed, we just need to set $d = v_0 t$ and take

$$f(x) \to f(x - v_0 t)$$

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Sinusoidal waves

- Suppose we make a continuous wiggle. When we start our clock (t = 0) we might have created shape something like

$$y(x,0) = A \sin kx$$

Why do we need a "*k*"

- If this moves in the $+x$ direction, at later times it would look like

$$y(x,t) = A \sin k(x - v_0 t)$$

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What good are sinusoidal wiggles?

- Many systems naturally produce long strings of (nearly) sinusoidal wiggles.
  - Musical instruments (sound)
  - Electric power generators (AC current)
  - Animals
    - » dolphins
    - » birds
    - » people
  - Excited atoms (light)
    - » flames
    - » fluorescent lights
    - » stars
- Furthermore, (almost) any shape of signal can be made up by adding together sinusoidal wiggles.

Interpretation

$y = A\sin(kx - \omega t) \qquad \omega \equiv kv_0$

Fixed time: Wave goes a full cycle when

$kx : 0 \rightarrow 2\pi$

$x : 0 \rightarrow \frac{2\pi}{k} \equiv \lambda$ (wavelength)

Fixed position: Wave goes a full cycle when

$\omega t : 0 \rightarrow 2\pi$

$t : 0 \rightarrow \frac{2\pi}{\omega} \equiv T$ (period)

Find the dog

$\omega = kv_0$?

Interpret

$$\omega = 2\pi f = \frac{2\pi}{T} \qquad k = \frac{2\pi}{\lambda}$$

$$\omega = kv_0 \quad \Rightarrow \quad 2\pi f = \frac{2\pi}{\lambda} v_0 \quad \text{or}$$

$f\lambda = v_0$ (famous wave formula)

Interpret

$$\frac{1}{T}\lambda = v_0 \quad \Rightarrow \quad \lambda = v_0 T$$

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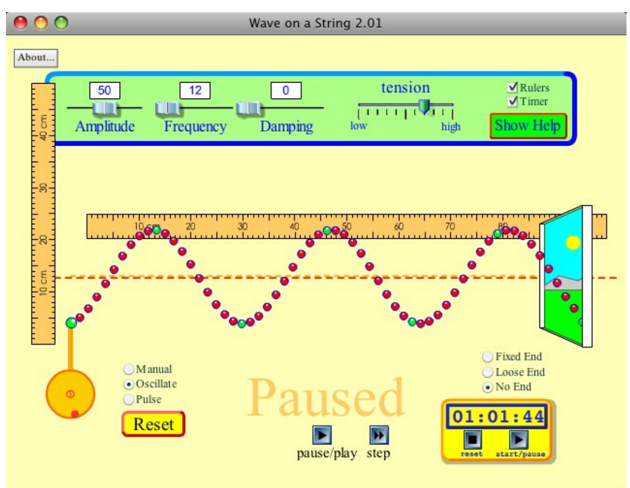
Explore with a simulation



http://phet.colorado.edu/simulations/sims.php?sim=Wave_on_a_String

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