Announcements 6 May 09

- **Homework #13 (last one!)**
  - **Written homework due on Monday in class**
  - **Online homework due Tuesday by 8 am**

- **Exam 3**
  - **TONIGHT from 7 to 9 pm**

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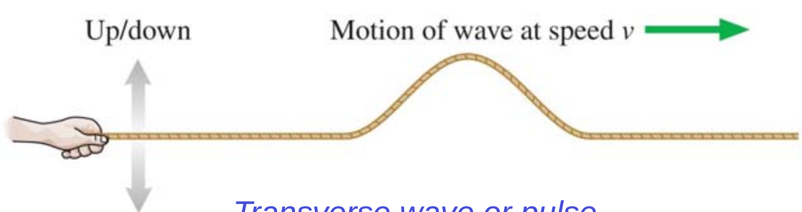
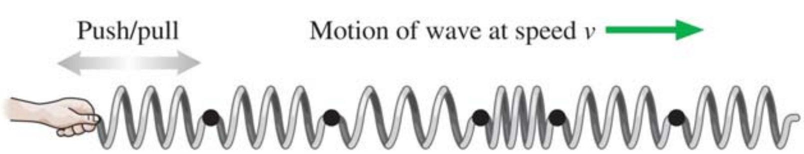
Types of Waves

DEMOS: Waves on a string, slinky, shive, stands



Transverse wave or pulse



Longitudinal wave or pulse

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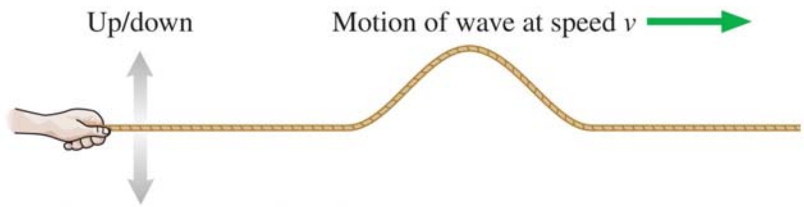
Speed of a wave vs. amplitude

PRS



How does the speed with which the wave propagates along the string change when it is shaken more vigorously?

A. The speed decreases.
B. The speed increases.
C. The speed stays the same.

DEMO: Wave on a string

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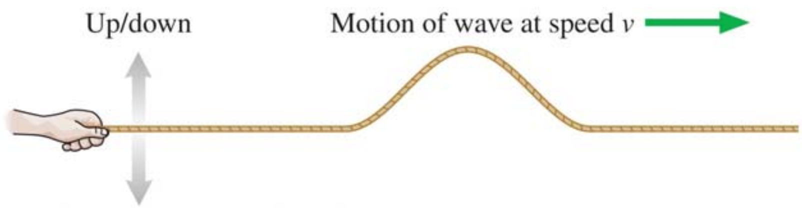
Speed of a wave vs. tension

PRS



How does the speed with which the wave propagates along the string change when the string tension increases?

A. The speed decreases.
B. The speed increases.
C. The speed stays the same.

DEMO: Wave on a string

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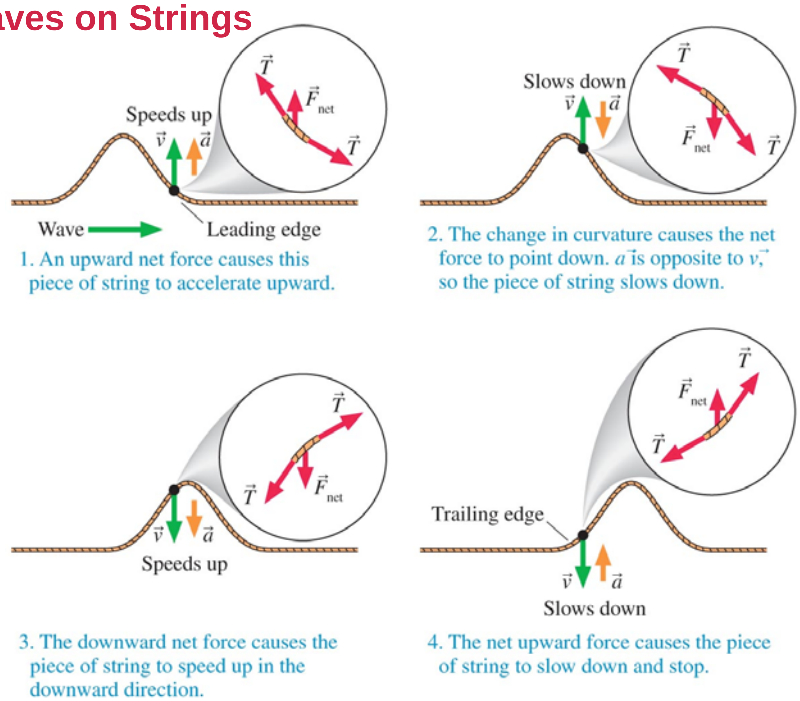
Waves on Strings



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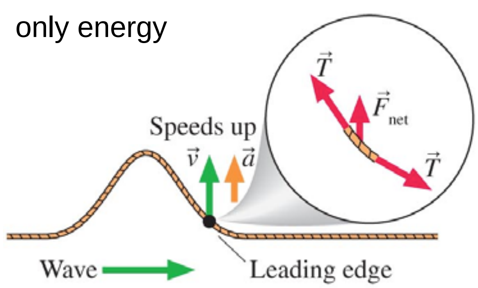
Waves on Strings and in Air

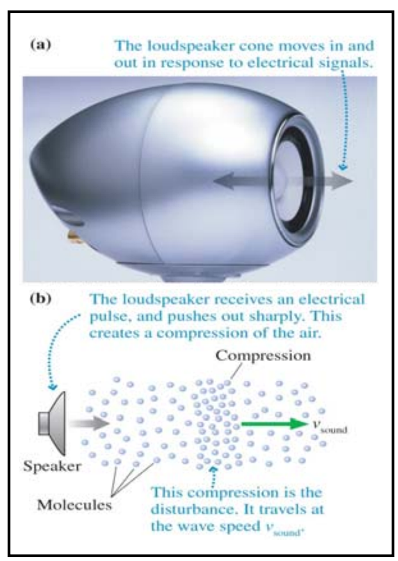
- Mechanical waves are disturbances that propagate through a medium
- Wave moves away from the source but *no material or substance is transferred*, only energy



Wave speed is determined by the properties of the medium

$$v_{\text{string}} = \sqrt{\frac{T_s}{\mu}}$$

Wave speed on a stretched string with tension T_s and linear density μ



String of mass m and length L
Linear density $\mu = m / L$

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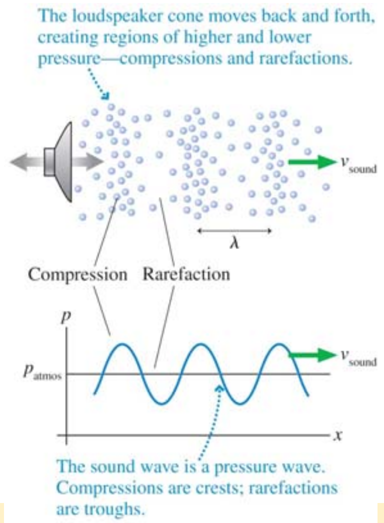
Sound Waves

Wave speed is determined by the properties of the medium

TABLE 15.1 The speed of sound

Medium	Speed (m/s)
Air (0°C)	331
Air (20°C)	343
Helium (0°C)	970
Ethyl alcohol	1170
Water	1480
Human tissue (ultrasound)	1540
Lead	1200
Aluminum	5100
Granite	6000
Diamond	12,000



$$v_{sound} = \sqrt{\frac{\gamma k_B T}{m}} = \sqrt{\frac{\gamma R T}{M}}$$

Sound speed in a gas at temperature T

See animation at
http://www.kettering.edu/~drussell/Demos/waves/wavemotion.html

γ = 1.67 for He or 1.40 for N and O
m = mass of atom, k_B = 1.38 x 10^{-23} J/K

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Traveling wave problem

A particular species of spider spins a web with silk threads of density 1300 kg/m^3 and diameter 3.0 μm. A typical tension in the radial threads of such a web is 7.0 mN. If a fly lands in this web, which will reach the spider first, the sound or the wave on the web silk?

Know :
$\rho = 1300\ kg/m^3$
$d = 3.0\ \mu m = 3.0\times 10^{-6}\ m$
$T_s = 7.0\ mN = 7.0\times 10^{-3}\ N$
Find : v_{thread}

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Traveling wave problem

$$v_{thread} = \sqrt{\frac{T_s}{\mu}} = ?$$

$$\rho = \text{density} = \frac{\text{mass}}{\text{volume}} = 1300 \text{ kg/m}^3$$

$$\mu = \text{linear density} = \frac{\text{mass}}{\text{length}} = ?$$

Know :

$\rho = 1300 \; kg/m^3$

$d = 3.0 \; \mu m = 3.0 \times 10^{-6} \; m$

$T_s = 7.0 \; mN = 7.0 \times 10^{-3} \; N$

Find : v_{thread}

volume of cylindrical thread = (area of circular cross section) x (length)

$$\Rightarrow \rho = \frac{\text{mass}}{\text{area circle x length}}$$

$$\Rightarrow \mu = \rho \times \left(\pi r^2\right) = \left(1300 \text{ kg/m}^3\right) \times \pi \times \left(\frac{3.0 \times 10^{-6} m}{2}\right)^2 = 9.18 \times 10^{-9} kg/m$$

$$v_{thread} = \sqrt{\frac{7.0 \times 10^{-3} N}{9.18 \times 10^{-9} kg/m}} = 873 \; m/s \; > \; v_{sound} = 343 \; m/s$$

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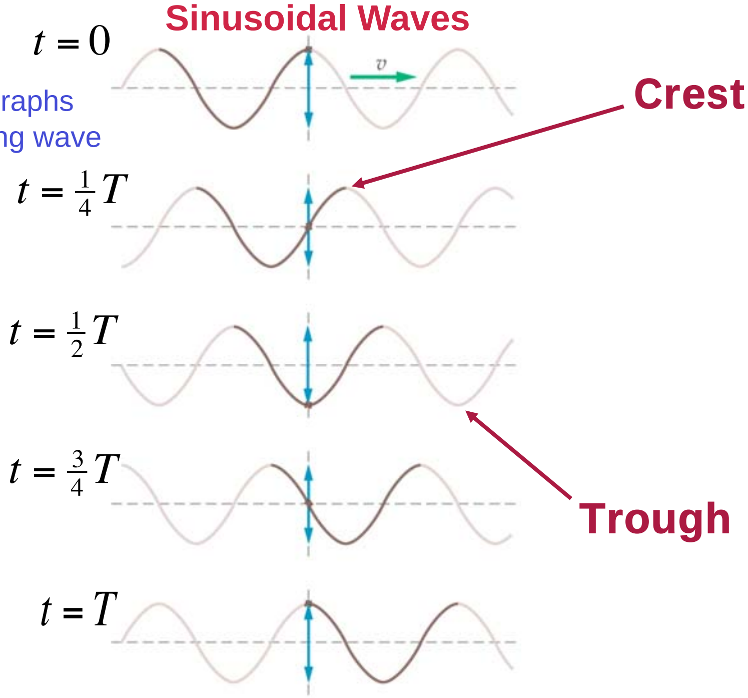
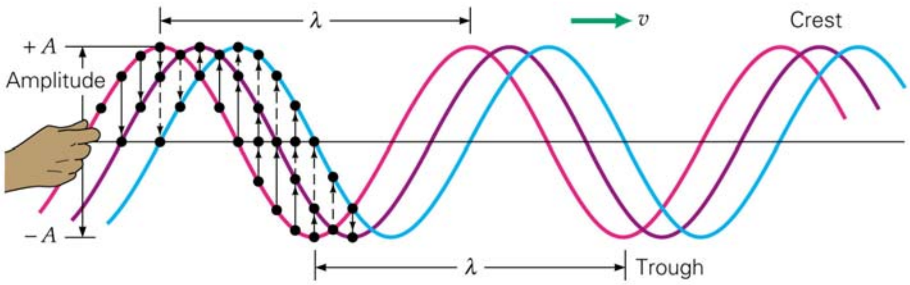
Sinusoidal Waves

snapshot graphs of a traveling wave



Sinusoidal waves



Wavelength λ = Distance from crest to crest or from trough to trough

Each point also oscillates with period T
We also know that in time T the pattern repeats and the wave has traveled a distance of λ

See animation at http://rt210.sl.psu.edu/phys_anim/waves/wave1.gif

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The propagation velocity is given by

$$v = \frac{\lambda}{T} = \lambda f$$

Example

The range of sound frequencies audible to the human ear extends from about 20 Hz to 20 kHz. If the speed of sound in air is 343 m/s, what are the limits of this audible range expressed in wavelengths?

Demos: Ripple tank with frequency-varying source

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Know :

$f_1 = 20\ Hz$

$f_2 = 20\ kHz$

$v = 343\ m/s$

Find :

$\lambda = ??$

Example

using : $v = \lambda f$

$$\lambda_1 = \frac{v}{f} = \frac{343 m/s}{20 Hz} = 17.15 m \quad \text{(lowest pitch)}$$

$$\lambda_2 = \frac{v}{f} = \frac{343 m/s}{20 \times 10^3 Hz} = 0.01715 m \quad \text{(highest pitch)}$$

Therefore we can hear sound waves that have wavelengths of about 17m to 1.7cm

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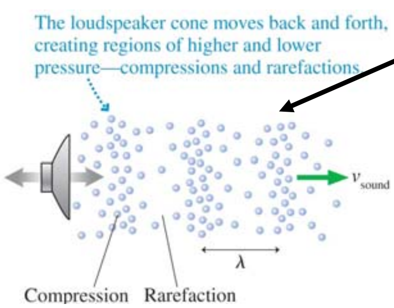
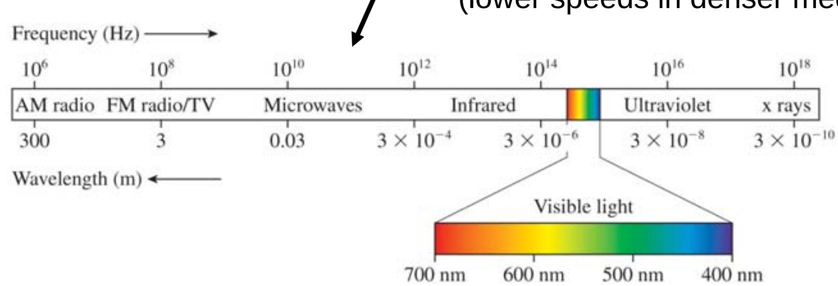
Sound and Light Waves



- The speed of sound varies with the medium
- Light and other electromagnetic waves *do not need a medium* to propagate
  They move at the same speed in vacuum and in air at $v = c = 3.0 \times 10^8$ m/s
  (lower speeds in denser media)



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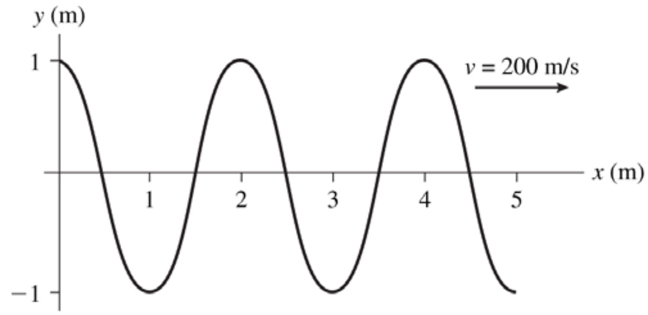
Wave frequency question

PRS

For this sinusoidal wave, what is the frequency?

A. 50 Hz
B. 100 Hz
C. 200 Hz
D. 400 Hz



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