Physics 2101
Section 3
Apr 14th

Announcements:

- Quiz Friday
- Midterm #4, April 28th 6 pm
- Final: May 11th-7:30am
- Make up Final: May 15th-7:30am

Class Website:

http://www.phys.lsu.edu/classes/spring2010/phys2101-3/

http://www.phys.lsu.edu/~jzhang/teaching.html

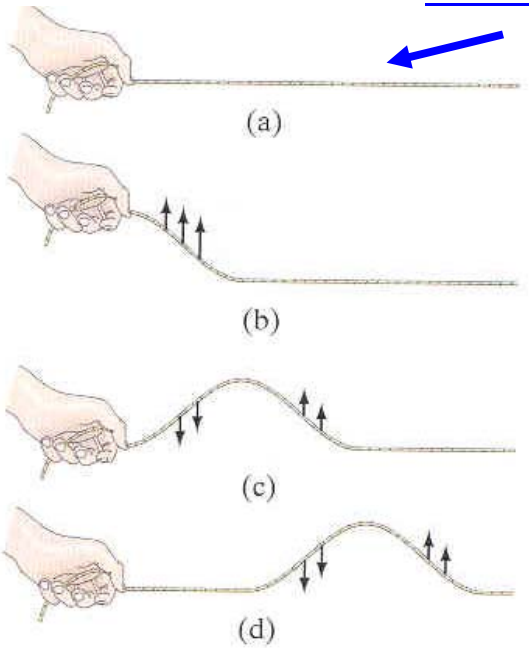
Chap. 16 Waves

Waves and particle

Vibration → waves

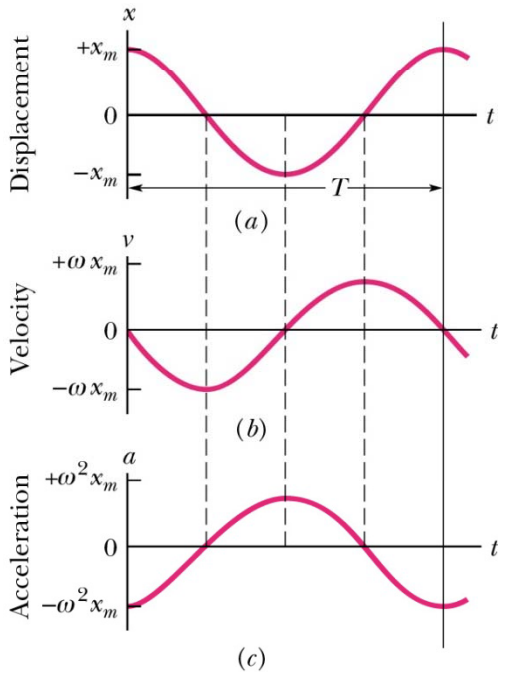
- Sound - medium vibrates
- Surface ocean waves - no net water is displaced
- Mechanical waves - Newton's equations with medium
- Electro-magnetic waves - NO MEDIUM light (photons)

WAVES



Pulse - single wave

Periodic wave - sinusoidal waves



Particle

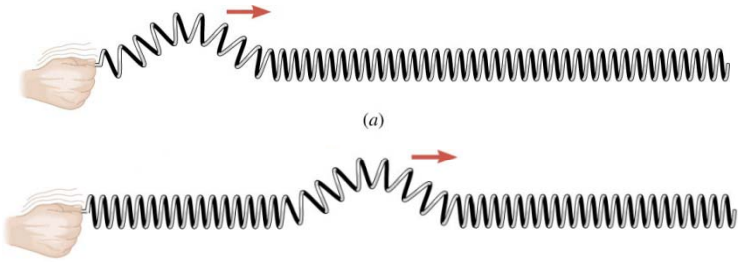
- Displacement
- Velocity
- Acceleration

Oscillation vs Wave

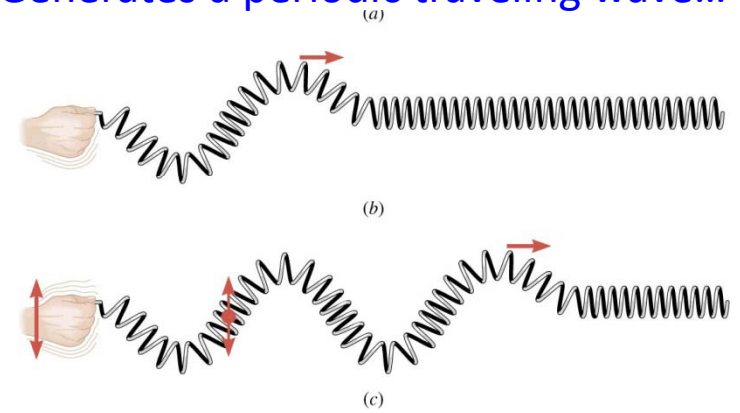
- How do you describe the motion?
- How many variables do you need?

Traveling Waves

A Pulse: A pulse can be sent along a spring… it travels to the right over time



Repeating the Pulse: Generates a periodic traveling wave…

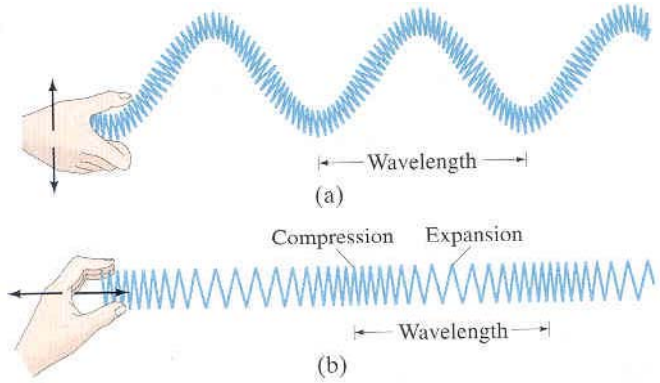


If it reflects off of the other (fixed) end correctly it becomes a Standing Wave – it looks like the wave is standing still

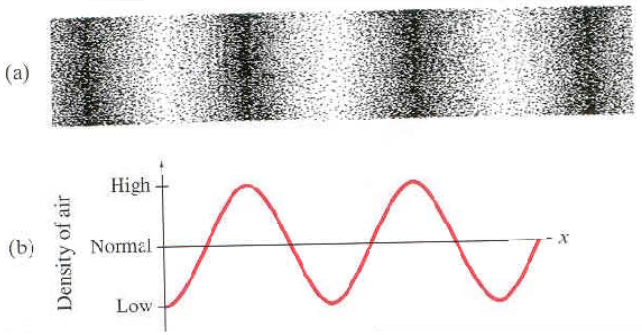
Transverse vs Longitudinal Waves

Transverse: Displacement of particle is perpendicular to the direction of wave propagation

Longitudinal: Displacement (vibration) of particles is along same direction as motion of wave



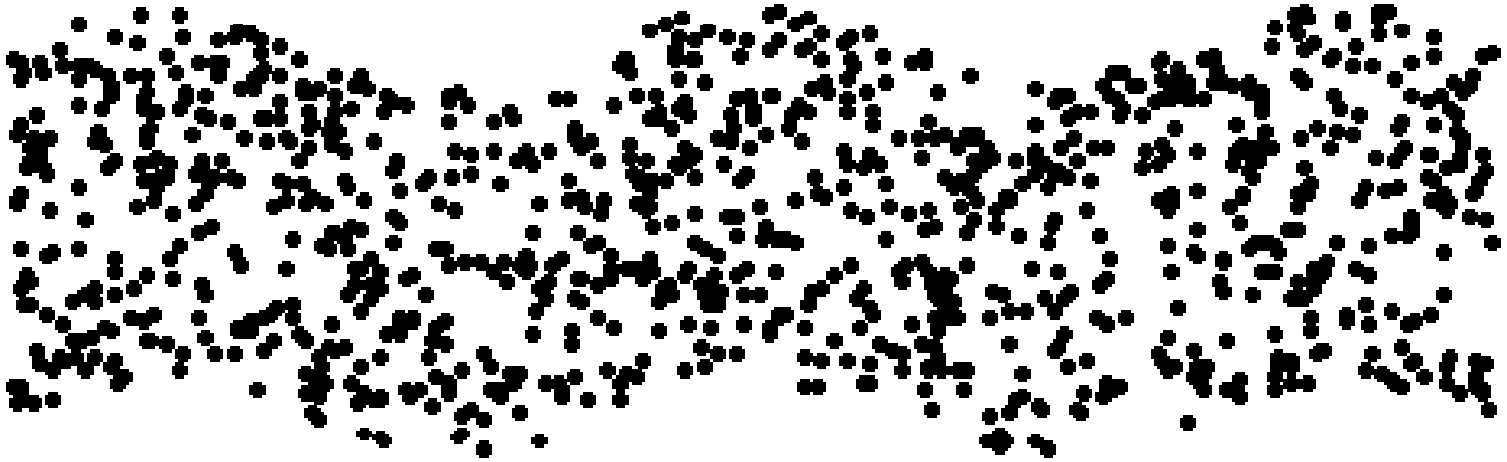
-Sound (fluids…)
-Ocean currents
- top vs bottom



Traveling Waves - they travel from one point to another - Nodes move
Standing Waves - they look like they're standing still - Nodes do not move

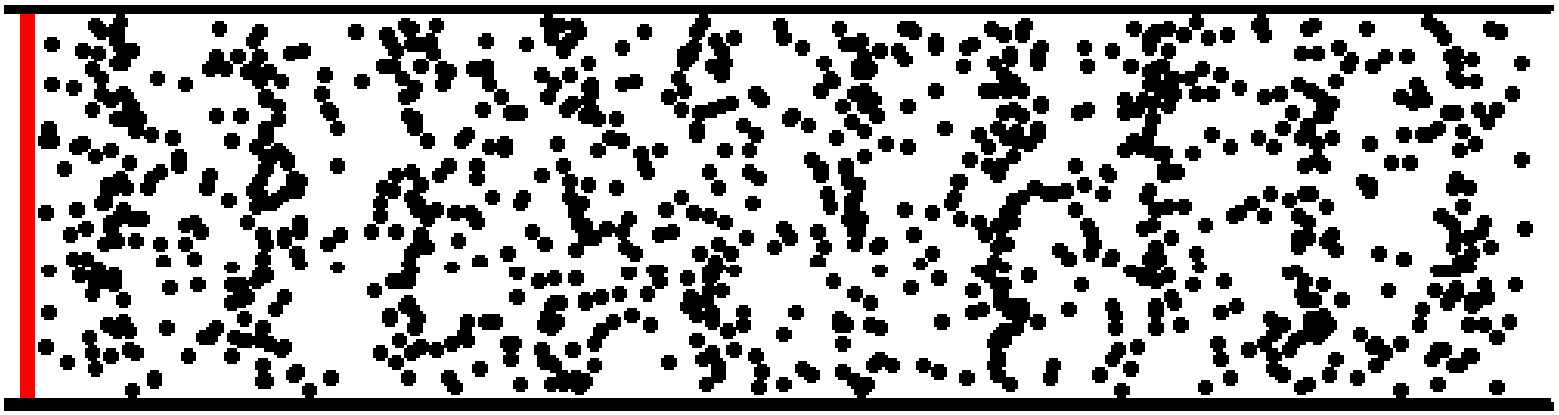
Transverse Waves

In a transverse wave the motion of the particles of the medium is perpendicular to the direction of the wave's travel



Longitudinal Waves

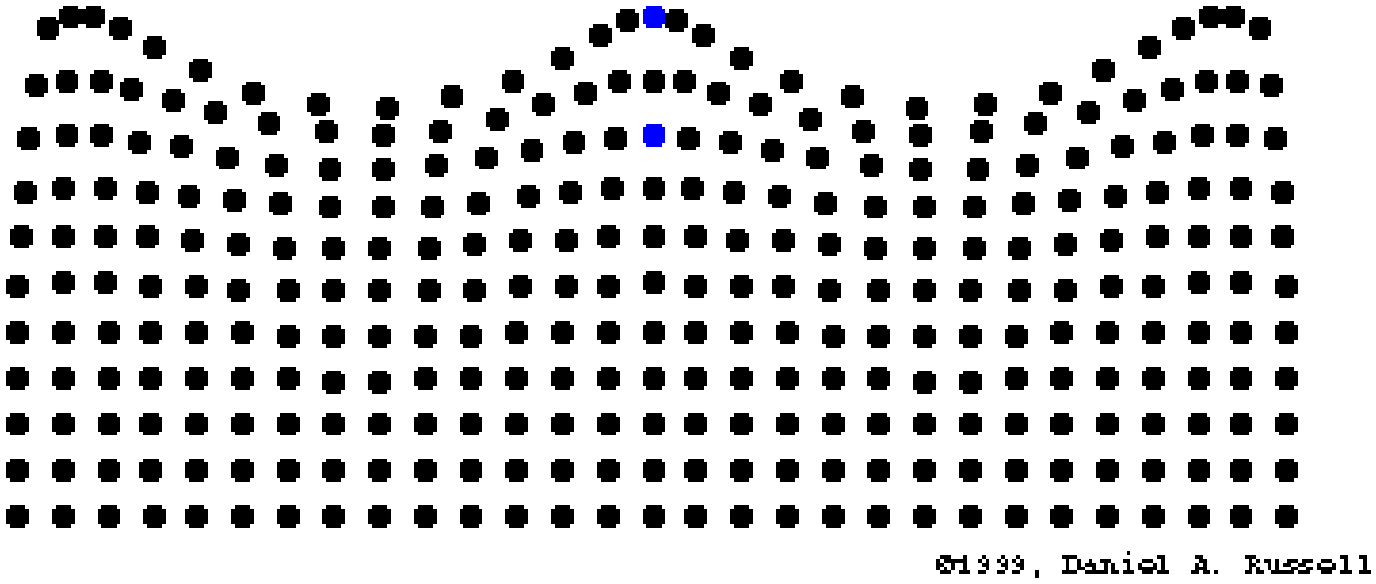
A longitudinal pulse travels along the medium but does not involve the transport of matter … just energy



Here are periodic longitudinal waves – pick a single particle and follow its motion as the wave goes by

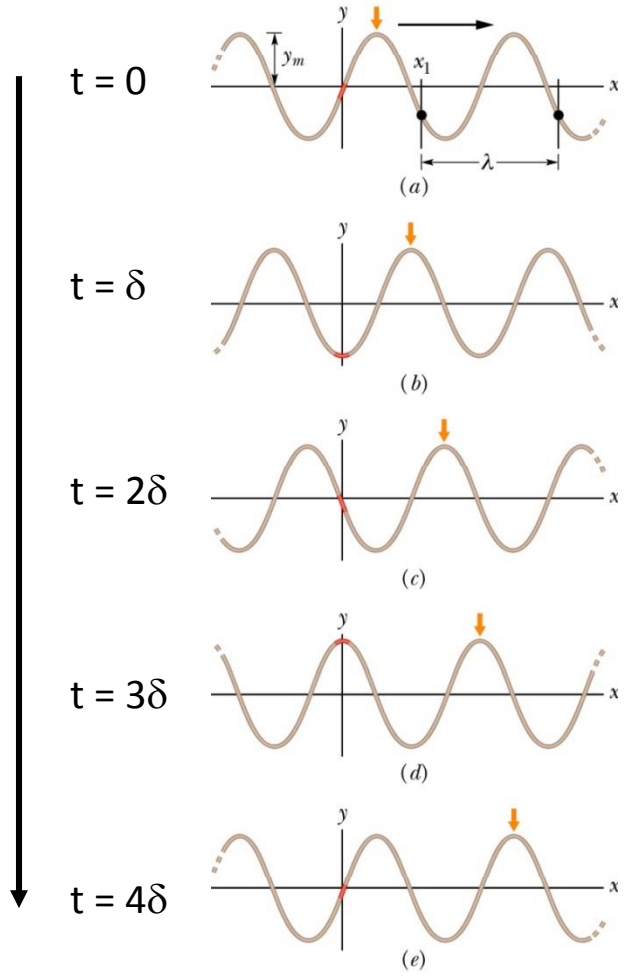
A Wave on the Water

A water wave is a combination of a **longitudinal** and a **transverse** wave … notice how the blue dots make a circular motion:



Description of *transverse* traveling wave

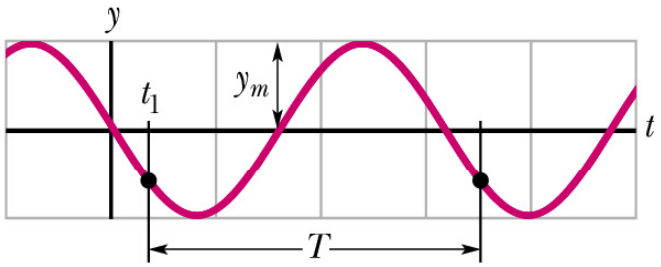
Displacement (y) versus position (x)



$$y(x,0) = y_{\max} \sin(kx) \qquad k = \frac{2\pi}{\lambda}$$

Spatially Periodic (repeats) : $k\lambda = 2\pi$

Temporally Periodic (repeats) : $\omega T = 2\pi$



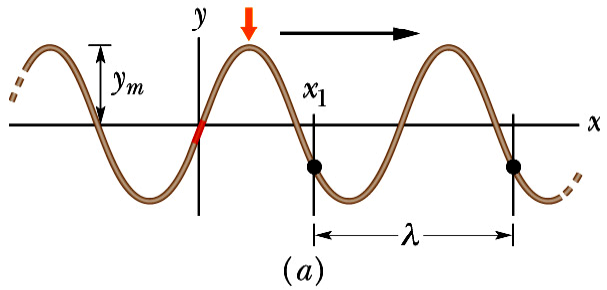
$$y(0,t) = y_{\max} \sin(-\omega t) \qquad \omega = \frac{2\pi}{T}$$

Displacement versus time does not show "shape"

Description of transverse wave

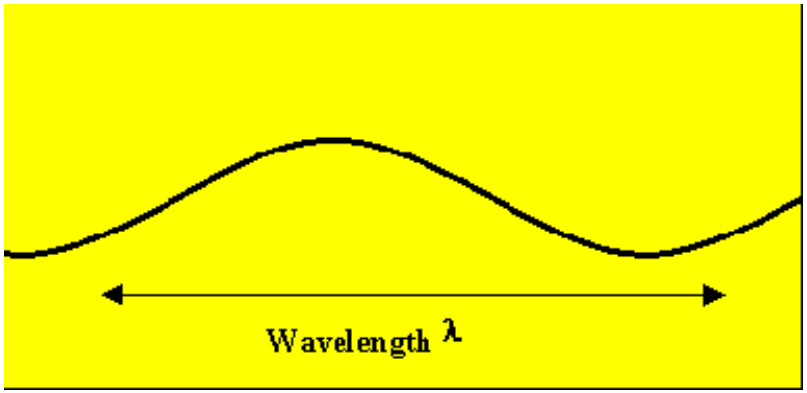
- To describe a wave (particle) on a “string” , the transverse displacement (y) depends on both the position (x) along the string and the time (t)

Displacement **Y** versus position **X**



Spatially Periodic (it repeats)

Displacement **Y** versus time **t**



Temporally Periodic (it repeats)

$$vT = \lambda$$

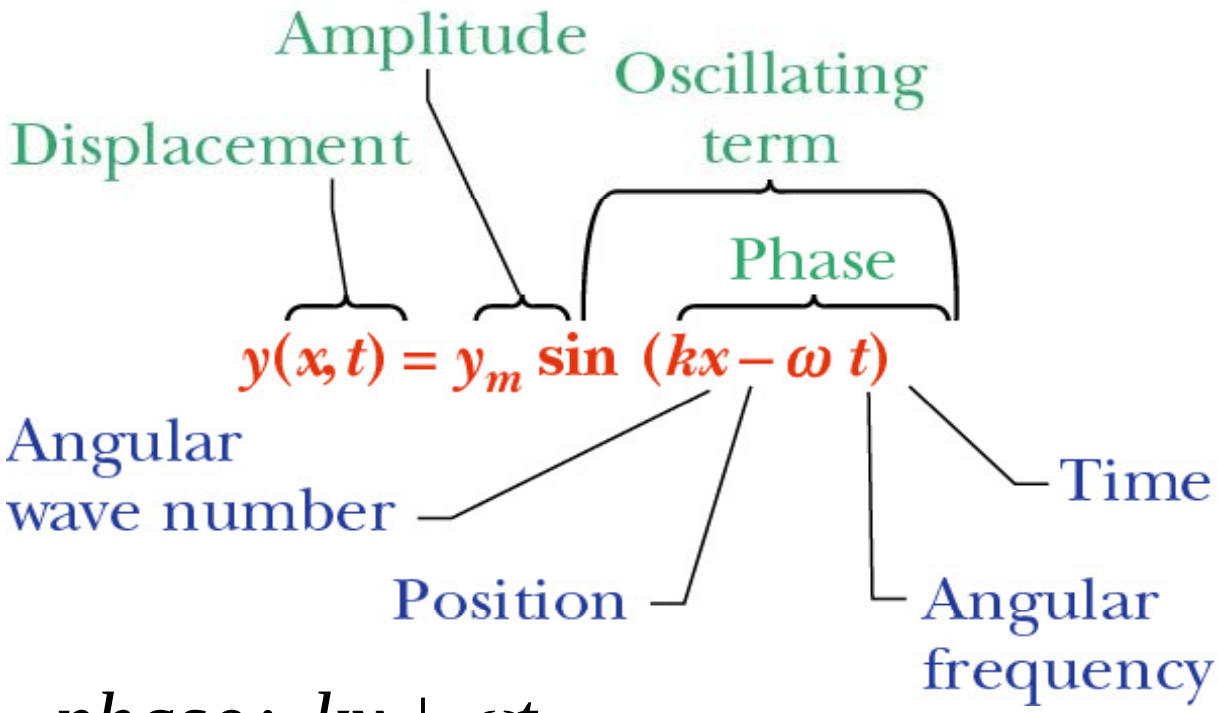
$$v = \frac{\lambda}{T} = f\lambda$$

$$f = \frac{1}{T}$$

velocity * period is wavelength

period & frequency

Description of traveling wave: mathematical



$$k = \frac{2\pi}{\lambda}$$

$$\omega = \frac{2\pi}{T}$$

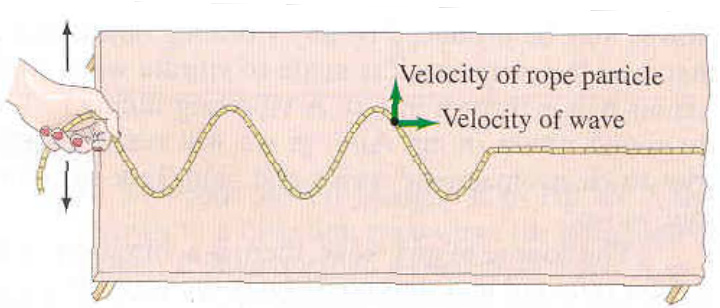
$$phase: \; kx \pm \omega t$$

$kx - \omega t \Rightarrow$ Wave traveling in + x direction

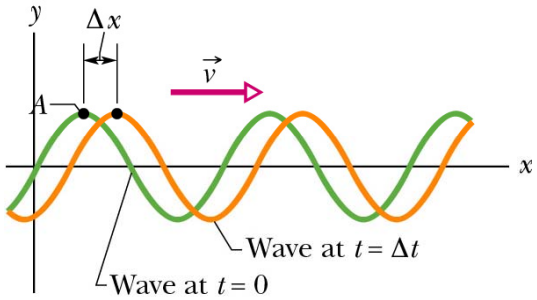
$kx + \omega t \Rightarrow$ Wave traveling in - x direction

What is the velocity at which the wave crests move?

Wave speed



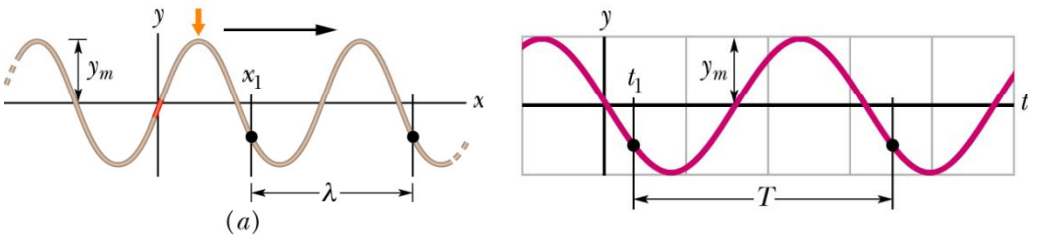
Velocity at which crests move = wave velocity or phase velocity



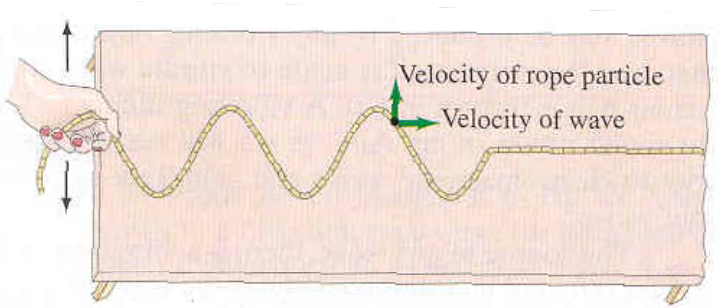
$$phase:\ kx-\omega t=const. \qquad \Rightarrow k\frac{dx}{dt}-\omega=0$$

$$v_{wave}=\frac{dx}{dt}=\frac{\omega}{k}=\frac{\lambda}{T}=\lambda f$$

A wave crest travels a distance of one wavelength, λ, in one period, T



Wave speed



Velocity at which crests move = wave velocity or phase velocity

$$v_{wave} = \frac{dx}{dt} = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f$$

A wave crest travels a distance of one wavelength, λ, in one period, T

Velocity of particle

$$y(x,t) = y_m \sin(kx - \omega t)$$

$$v_t(x,t) = -\omega y_m \cos(kx - \omega t)$$

$$\left|v_t(x,t)\right|_{\max} = \omega y_m$$

Wavelengths of Radio Stations

Waves like radio, light, x-rays etc. are part of the electromagnetic spectrum. They travel with a velocity:

$$v = c = \text{speed of light} = 3\times10^{8}\, m/s$$

What is the wavelength of talk radio WJBO am 1150?

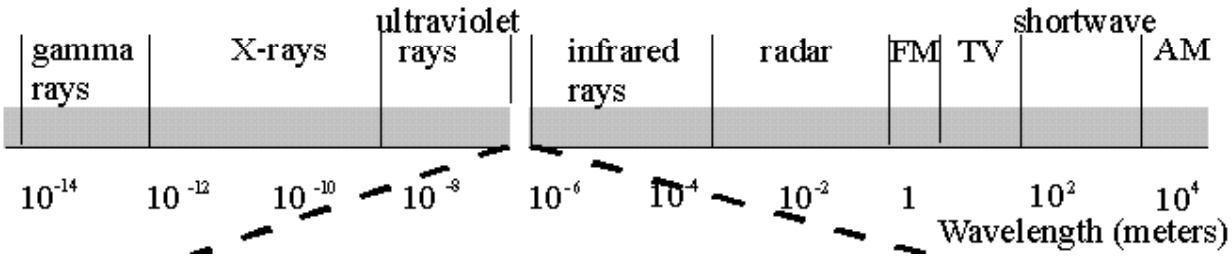
$$f = 1150\ kHz = 1150\times10^{3}\ Hz = 1.15\times10^{6}\ Hz$$

$$\lambda = \frac{c}{f} = \frac{3\times10^{8}\ m/s}{1.15\times10^{6}\ /s} = 261\ m$$

What is the wavelength of KLSU fm 91.1?

$$f = 91.1\ MHz = 91.1\times10^{6}\ Hz = 9.11\times10^{7}\ Hz$$

$$\lambda = \frac{c}{f} = \frac{3\times10^{8}\ m/s}{9.11\times10^{7}\ /s} = 3.29\ m$$



Problems

Sample problem 16

A wave traveling along a string is described by: $y(x,t) = 0.00327 \sin(72.1x - 2.72t)$

in which the numerical constants are in SI units (0.00327 m, 72.1 rad/m, and 2.72 rad/s).

a) Which direction are the waves traveling? Positive x-direction

b) What is the amplitude of the waves? y_{max} = 0.00327 m = 3.27 mm

c) What is the wavelength? k = 72.1 rad/m → λ = 0.0871 m = 87.1 mm

d) What is the period? ω= 2.72 rad/s → T = 2.31 s

e) What is the frequency? T = 2.31 s → f = 0.433 Hz

f) What is the velocity of the wave (v_w)? $v_w = \omega / k = \lambda f$ =38 mm/s

g) What is the displacement y at x = 22.5 cm and t=18.9 s? y = 1.92 mm

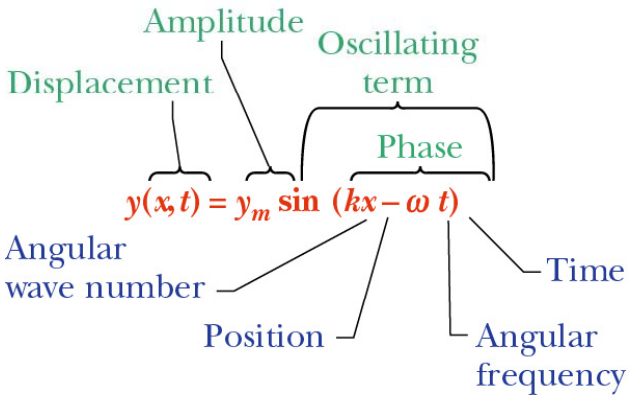
make sure your calculator is in radians

h) What is u, (or v_t) the transverse velocity, at x = 22.5 cm and t=18.9 s? $u=-\omega y_m \cos(kx-\omega t)$

i) What is a_t, the transverse acceleration, at x = 22.5 cm and t=18.9 s? $a_t = -\omega^2 y(x,t)$

Problems

(a) write an equation describing a sinusoidal transverse wave traveling on a cord in the +x direction with a wavelength of 10 cm, a frequency of 400 Hz, and an amplitude of 2.0 cm.



$$k = \frac{2\pi}{\lambda} = \frac{2\pi \cdot rad}{(0.10 \cdot m)} = 62.8 \cdot rad/m \qquad \omega = \frac{2\pi}{T} = 2\pi f = 2\pi \cdot rad(400 \cdot 1/s) = 2513 \cdot rad/s$$

$$y(x,t) = (0.02 \cdot m)\sin\left[(62.8 \cdot rad/m)x - (2513 \cdot rad/s)t\right]$$

(b) What is the maximum speed of a point on the cord

$$|u|_{\max} = \omega y_{\max} = (2513 \cdot s^{-1})(0.02 \cdot m) = 50.3 \cdot m/s$$

(c) What is the speed of the wave?

$$v_{wave} = \frac{\lambda}{T} = \frac{\omega}{k} = \frac{2513 \cdot s^{-1}}{62.8 \cdot m^{-1}} = 40 \cdot m/s$$