Physics 2101
Section 3
Apr 16th

Announcements:

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

Class Website:

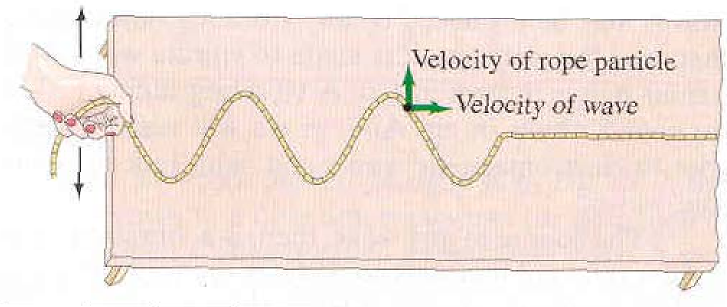
http://www.phys.lsu.edu/classes/spring2010/phys2101-3/

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

Wave speed on stretched string

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

Wavelength and period are NOT independent:
Wave speed depends on physical properties:
on properties of the medium in which it travels



If particles of medium move, then velocity must be a function of elasticity and mass (inertia)
{potential energy and kinetic energy}

Conceptually

1) the speed which the waves moves to right depends on how quickly one particle is accelerated upward in response to net pulling force by neighbors.

2) Newton's 2nd law - stronger force $\rightarrow$ greater upward acceleration (a = F/m)
-> leads to a faster moving wave

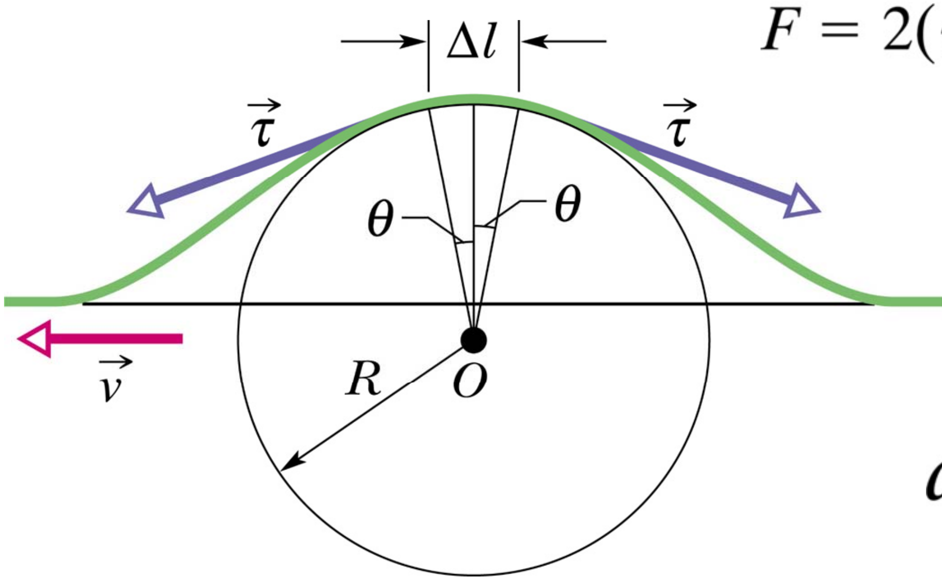
3) Ability to "pull on neighbors" depends on how tight the string is -> TENSION
greater tension $\rightarrow$ greater force $\rightarrow$ greater speed

4) Inertia $\rightarrow$ F = ma: travel faster with small mass (or linear mass density - mass/length)

$$v_{wave} = \sqrt{\frac{\tau}{\mu}} = \lambda f$$

For transverse wave in physical medium

Velocity is String



$$F = 2(\tau \sin\theta) \approx \tau(2\theta) = \tau \frac{\Delta l}{R} \qquad \text{(force)},$$

$$\Delta m = \mu\, \Delta l \qquad \text{(mass)},$$

$$a = \frac{v^2}{R} \qquad \text{(acceleration)}.$$

$$\frac{\tau \Delta l}{R} = (\mu \Delta l)\frac{v^2}{R}$$

$$v = \sqrt{\frac{\tau}{\mu}} \qquad \text{(speed)},$$

Wave speed on stretched string: example

$$v_{wave} = \sqrt{\frac{\tau}{\mu}} = \lambda f$$

Velocity has to do with tension and mass density
NOT frequency or amplitude

Guitar strings: What is wave velocity???

Length of string is fixed = 0.628 m

high E string (0.010") Mass = 0.20 g
low E string (0.046") Mass = 5.3 g

Tension is ~ 310 N (70 lbs) for both strings (Why?)

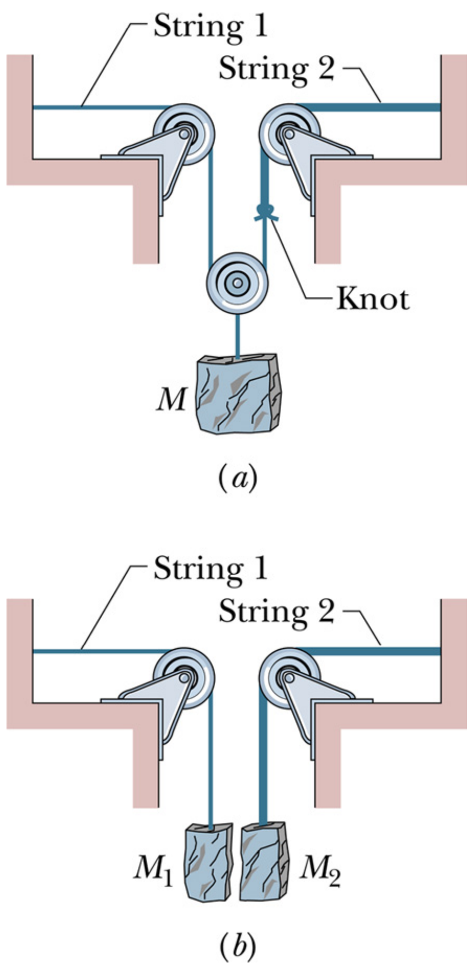
$$v_{E_{high}} = \sqrt{\frac{330 \cdot N}{\left(0.2 \times 10^{-3} \cdot kg\right) / \left(0.628 \cdot m\right)}} = 1020 \cdot m/s$$

$$v_{E_{low}} = \sqrt{\frac{330 \cdot N}{\left(5.3 \times 10^{-3} \cdot kg\right) / \left(0.628 \cdot m\right)}} = 200 \cdot m/s$$

16-24: String 1 has a linear density of μ_1 and string 2 of μ_2. They are under tension caused by a block M.

A) Calculate the wave speed in (a) 1 and (b) 2.

B) Calculate (c) M_1 and (d) M_2 such that the wave speeds are equal.



24. (a) The tension in each string is given by $\tau = Mg/2$. Thus, the wave speed in string 1 is

$$v_1 = \sqrt{\frac{\tau}{\mu_1}} = \sqrt{\frac{Mg}{2\mu_1}} = \sqrt{\frac{(500\,\text{g})(9.80\,\text{m/s}^2)}{2(3.00\,\text{g/m})}} = 28.6\,\text{m/s}.$$

(b) And the wave speed in string 2 is

$$v_2 = \sqrt{\frac{Mg}{2\mu_2}} = \sqrt{\frac{(500\,\text{g})(9.80\,\text{m/s}^2)}{2(5.00\,\text{g/m})}} = 22.1\,\text{m/s}.$$

(c) Let $v_1 = \sqrt{M_1 g/(2\mu_1)} = v_2 = \sqrt{M_2 g/(2\mu_2)}$ and $M_1 + M_2 = M$. We solve for M_1 and obtain

$$M_1 = \frac{M}{1 + \mu_2/\mu_1} = \frac{500\,\text{g}}{1 + 5.00/3.00} = 187.5\,\text{g} \approx 188\,\text{g}.$$

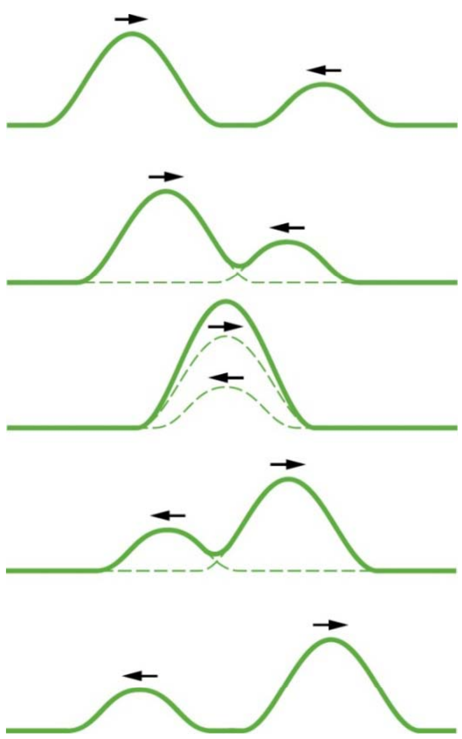
(d) And we solve for the second mass: $M_2 = M - M_1 = (500\ \text{g} - 187.5\ \text{g}) \approx 313\ \text{g}$.

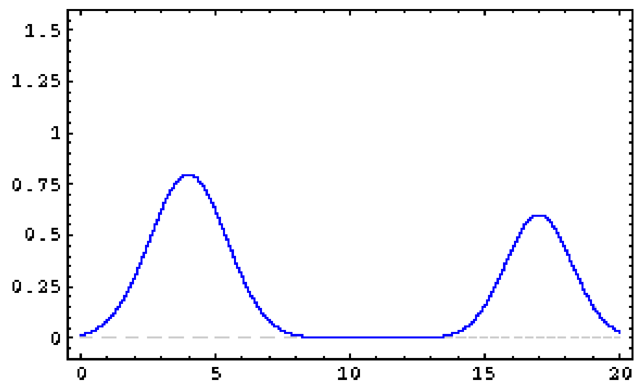
Superposition of Waves

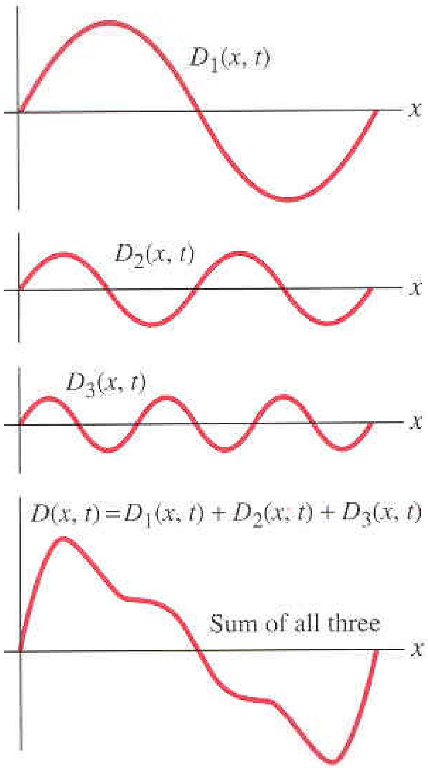
- **Overlapping waves algebraically add to produce a resultant wave**

- **Actual Displacement at any point x(t) is a algebraic sum of separate displacements**

$$y(x,t) = y_1(x,t) + y_2(x,t)$$







Breakdown:
- distortion
- dispersion

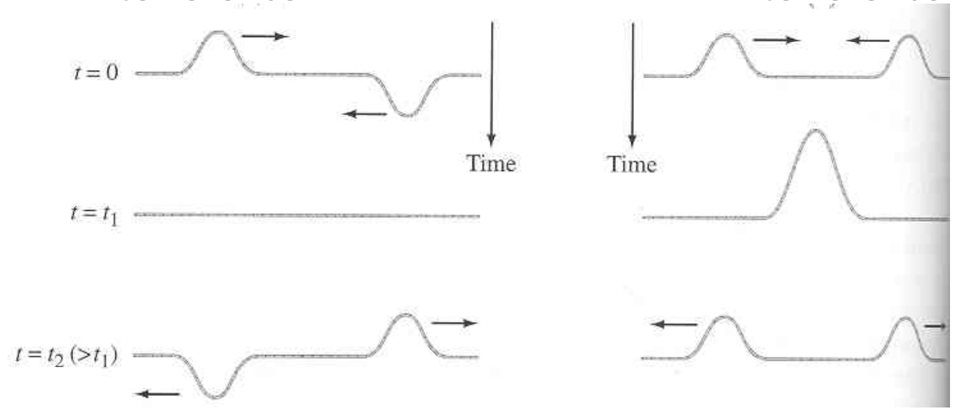
Interference of waves

- Happens when two waves enter the same region of space at the same time

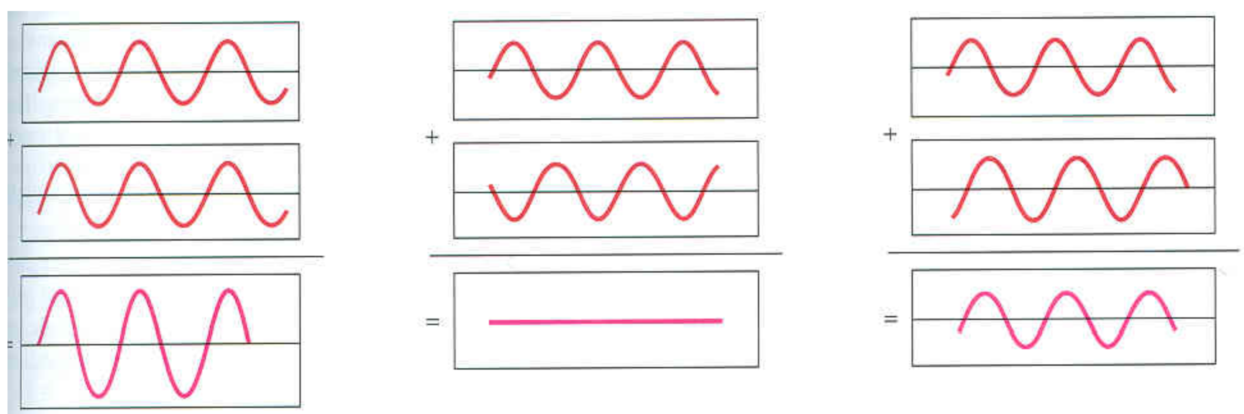
Destructive Interference

Constructive Interference

Two Pulses



Depends on relative phase between two waves



constructive

destructive

partially destructive

TABLE 16-1

Phase Difference and Resulting Interference Types[a]

Phase Difference, in			Amplitude of Resultant Wave	Type of Interference
Degrees	Radians	Wavelengths		
0	0	0	$2y_m$	Fully constructive
120	$\frac{2}{3}\pi$	0.33	y_m	Intermediate
180	π	0.50	0	Fully destructive
240	$\frac{4}{3}\pi$	0.67	y_m	Intermediate
360	2π	1.00	$2y_m$	Fully constructive
865	15.1	2.40	$0.60y_m$	Intermediate

[a]The phase difference is between two otherwise identical waves, with amplitude y_m, moving in the same direction.

Standing Waves

Here, two sinusoidal waves with same wavelength travel in <u>opposite</u> directions

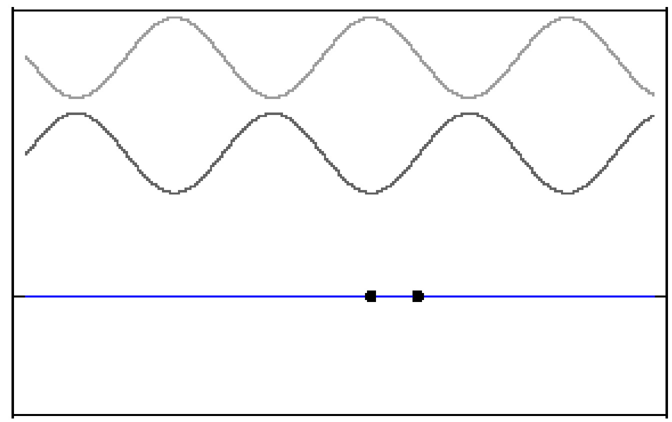
$$y_1(x,t) = y_m \sin(kx - \omega t)$$
$$+y_2(x,t) = y_m \sin(kx + \omega t)$$

$$\sin\alpha + \sin\beta = 2\sin\left(\frac{1}{2}(\alpha+\beta)\right)\cos\left(\frac{1}{2}(\alpha-\beta)\right)$$
$$\alpha = (kx - \omega t) \qquad \& \qquad \beta = (kx + \omega t)$$

$$y_{tot}(x,t) = y_m \sin(kx - \omega t) + y_m \sin(kx + \omega t)$$
$$= 2y_m \sin(kx)\cos(\omega t)$$

amplitude at position x — $\sin(kx)$

Oscillating term in time — $\cos(\omega t)$



Points of destructive and constructive interference are constant in time

<u>Amplitude is zero</u> when:

kx=π·n n = 0,1,2,3,…

$$x = n\frac{\lambda}{2}$$ Nodes

<u>Amplitude is max</u> when:

kx=π·(n+1/2) n = 0,1,2,3,…

$$x = \left(n + \frac{1}{2}\right)\frac{\lambda}{2}$$ Antinodes