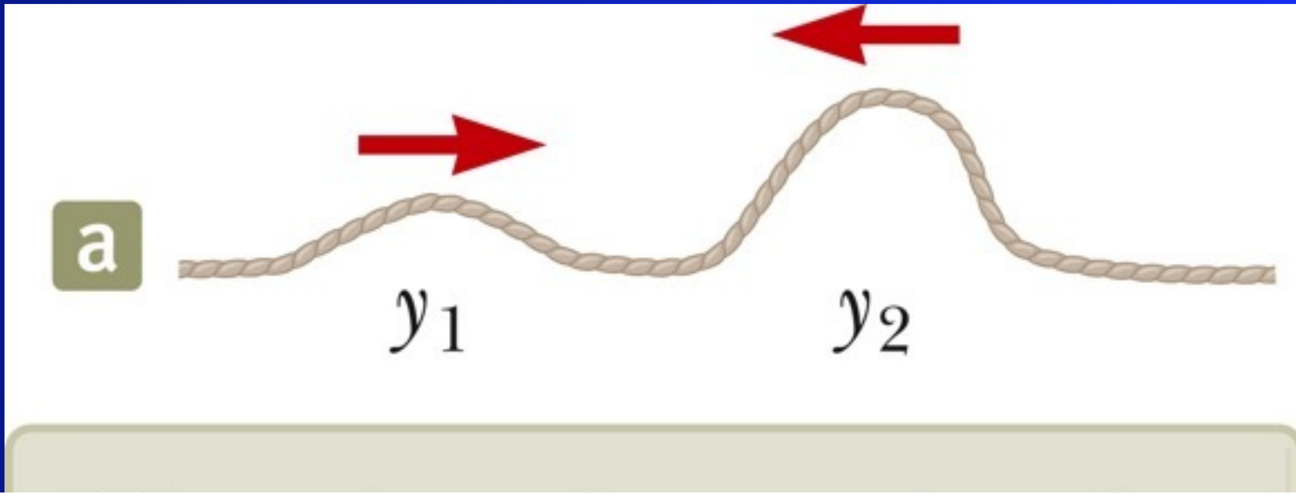
Physics 1C: Superposition and Standing Waves

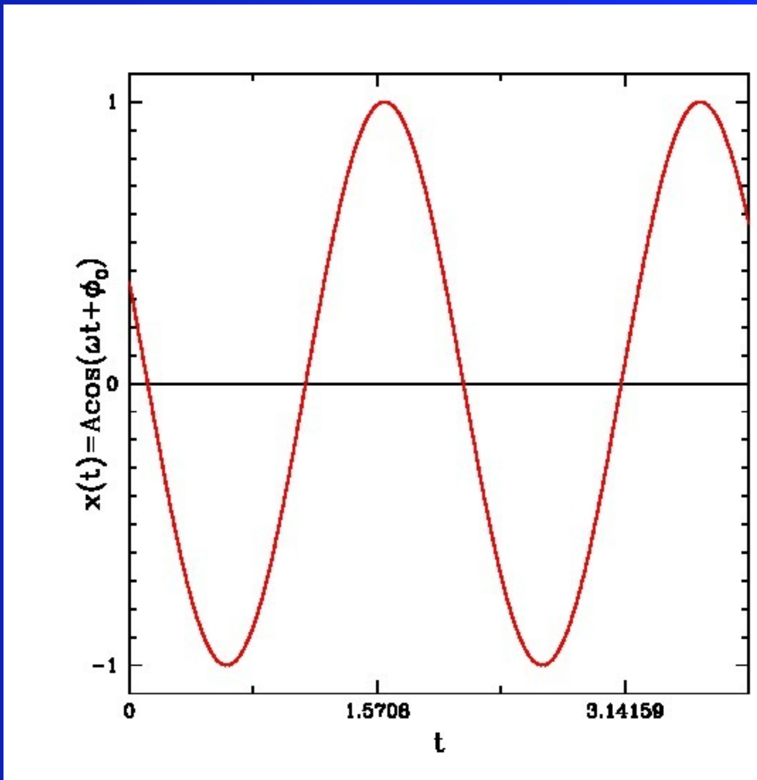
Wednesday, 15 April 2015



Reminders and Info

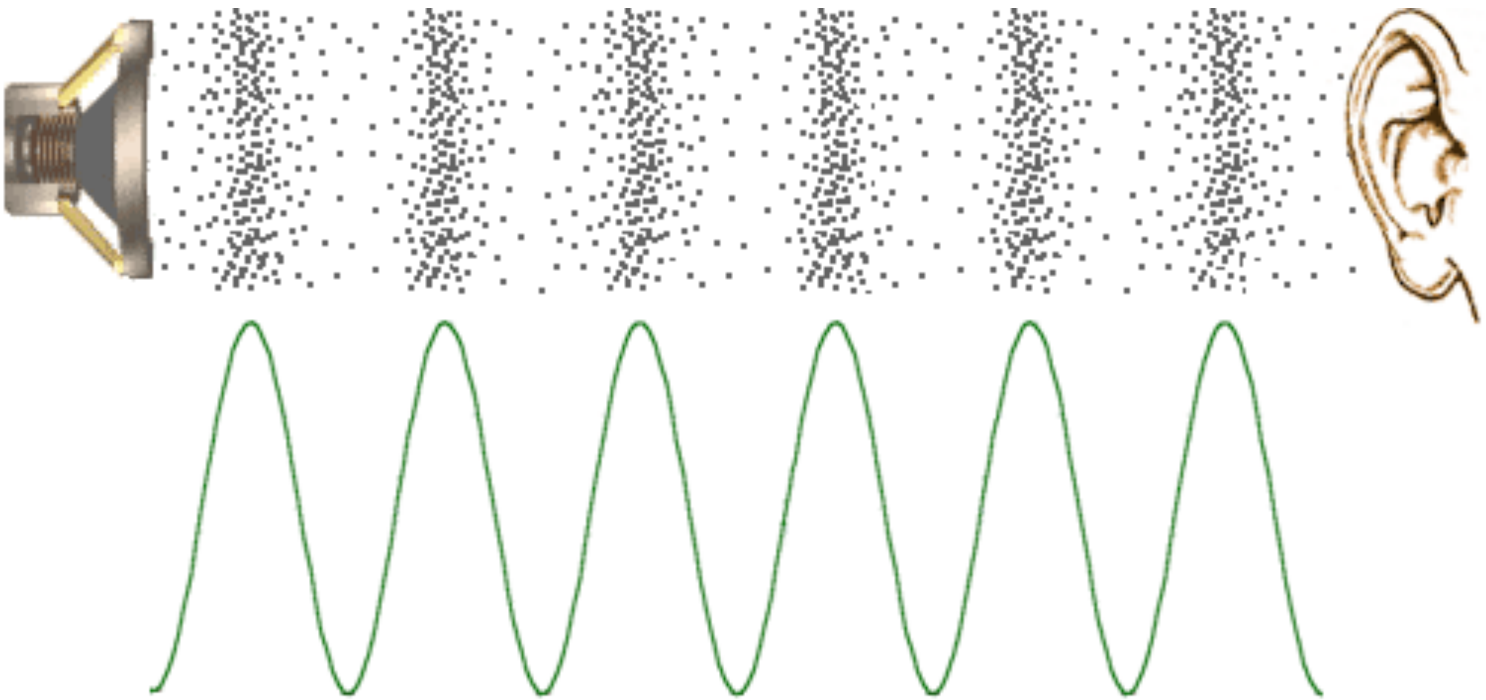
- your scores on quiz #1 will be posted on Ted course site (max: 9 points, average=6.3 points)
- a frequently missed question: $\cos(\omega t+\phi_0)$ graphs…
- figure out the questions and problems you got wrong, and if you received a low score, don't worry but see me if you'd like help
- homework and reading quiz due Friday

announcement: Fleet Night of Science tomorrow night at Fleet Science Center (Balboa Park)

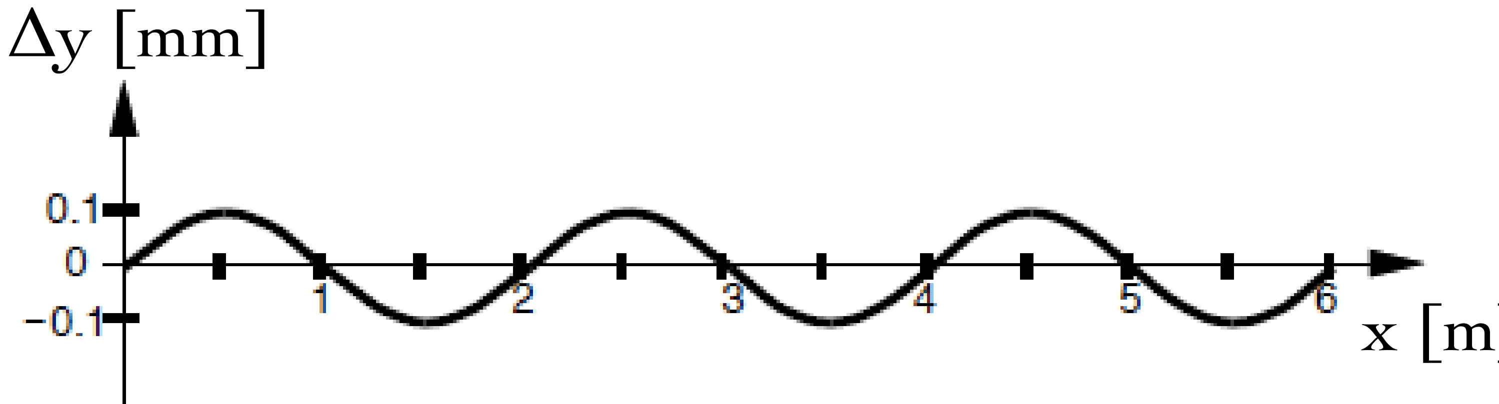


Sound Waves

- Longitudinal Wave traveling through the air
- speed of sound at room temperature ~ 340 m/s
- audio frequency range: 20-20,000 Hz



Sound Waves



The snapshot graph (at t = 0 s) above shows a wave traveling to the right with speed 4.0 m/s. What is the first time (t > 0) that a particle of the medium located at x = 3 m experiences zero velocity and negative acceleration?

A. 1/8 s
B. 2/8 s
C. 3/8 s
D. 4/8 s
E. none of these

use the fact that $v=dy/dt$ and $a=dv/dt$ and

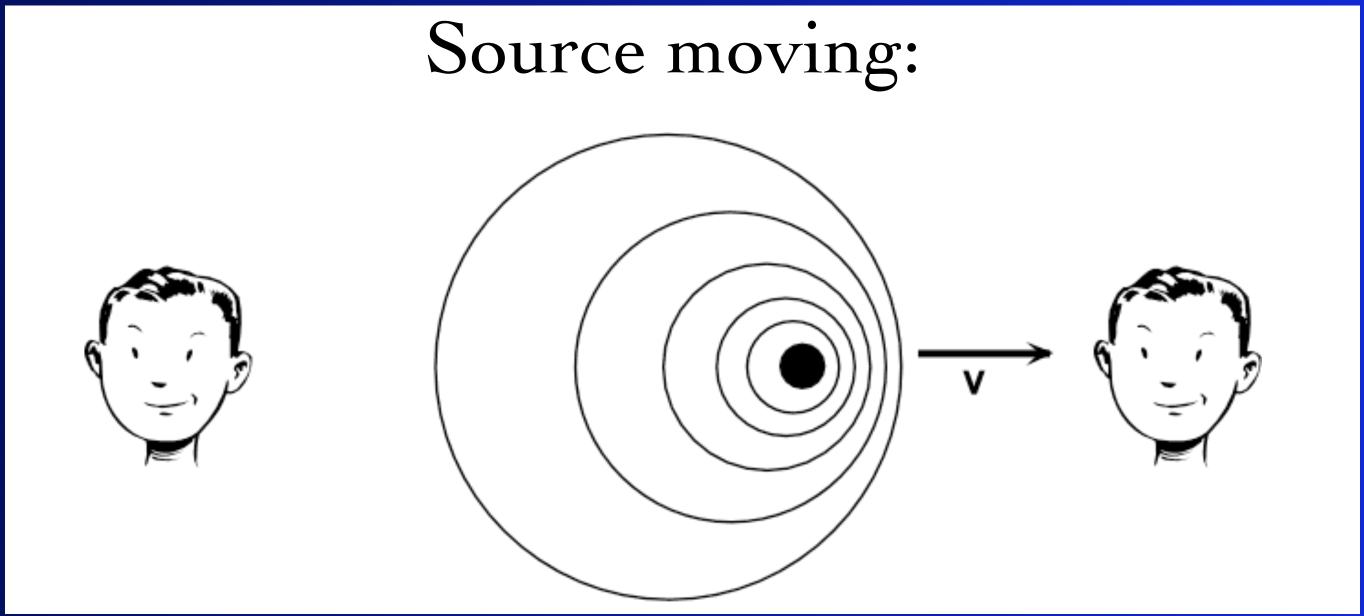
$y = A\sin(kx-\omega t) = A\sin((2\pi/\lambda)x-(2\pi v/\lambda)t)\ldots$

You should find that t=5/8 s

Doppler Effect

- Observer moves toward Source:
  observes crests to occur *more* often ⇒ *higher* pitch
  (higher frequency *f*)

- Observer moves away from Source:
  observes crests to occur *less* often ⇒ *lower* pitch



Doppler Effect

- velocities are positive if observer/source are moving ***toward*** each other
- velocities are negative if observer/source are moving ***away*** from each other

$$f' = f\left(\frac{v + v_O}{v - v_S}\right)$$

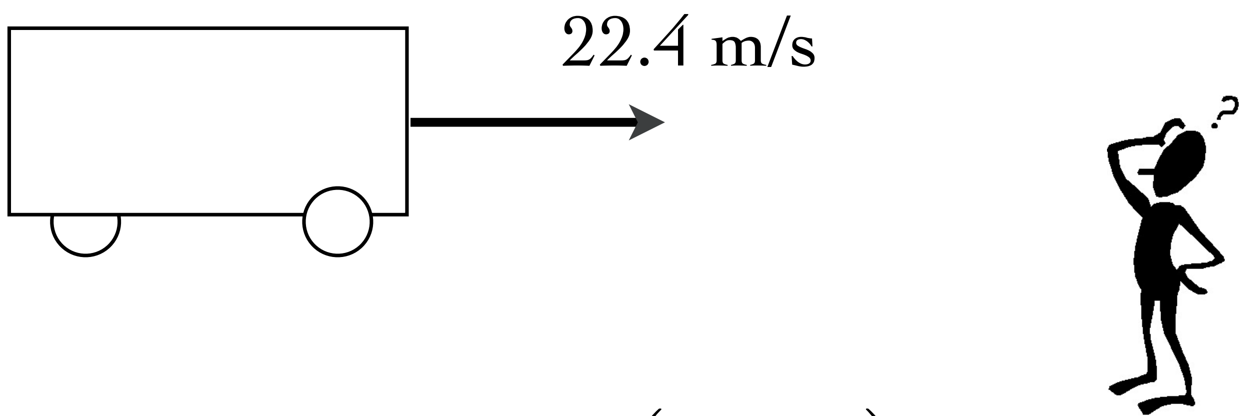
historical note: relativistic Doppler effect

- 50 years after Christian Doppler's death, Einstein calculated the relativistic version red/blue-shifted light sources in 1905:

$$f' = f\left(\frac{v + v_O}{v - v_S}\right) \quad \Rightarrow \quad f' = f\left(\frac{1 -/+ (v/c)}{1 +/- (v/c)}\right)$$

Doppler Effect: Example

An ambulance siren is blaring with 800 Hz sound. If you are stopped, pulled over on the side of the road, and the ambulance is headed toward you at 50 mph, what frequency of sound do you hear? Use the speed of sound of 340 m/s.



$$f' = f\left(\frac{v + v_O}{v - v_S}\right)$$

$$f' = (800\ \text{Hz})\left(\frac{340\ \text{m/s}}{340\ \text{m/s} - 22.4\ \text{m/s}}\right) = 856\ \text{Hz}$$

Doppler Effect: Example

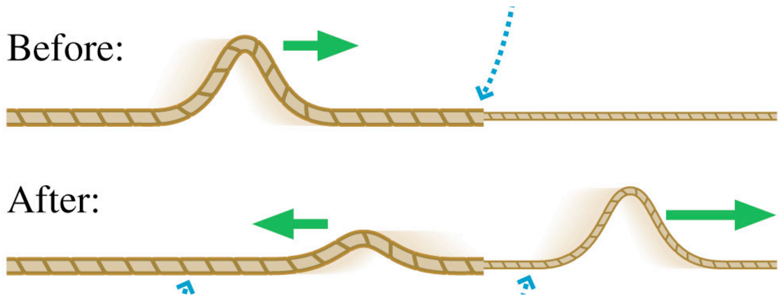
An ambulance siren is blaring with 800 Hz sound. You slow down to let the ambulance pass you. When the ambulance is traveling at 50 mph and you are now traveling at 35 mph (both in the same direction), the frequency you hear for the ambulance siren is

A. greater than 800 Hz
B. equal to 800 Hz
C. less than 800 Hz
D. totally lost

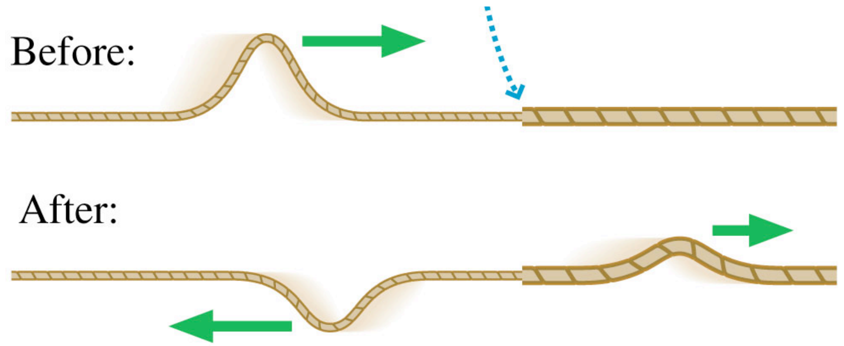
You should find that
f_{new} = 800Hz * 0.9815 = 785.2Hz

Reflection & Transmission of Waves

low speed to high speed
reflected pulse not inverted



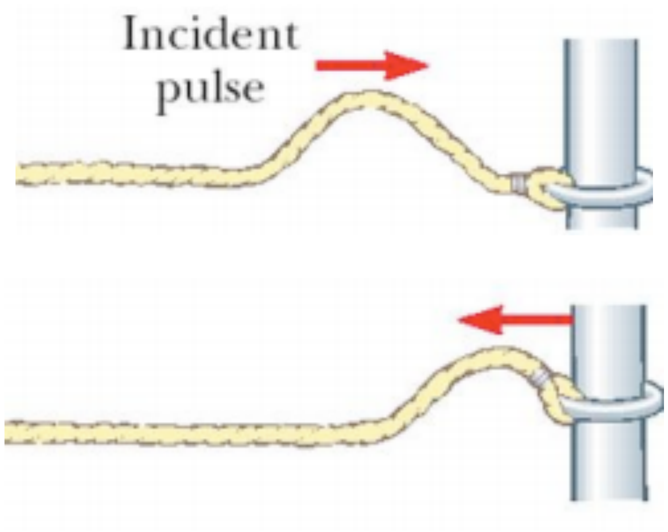
high speed to low speed
reflected pulse inverted



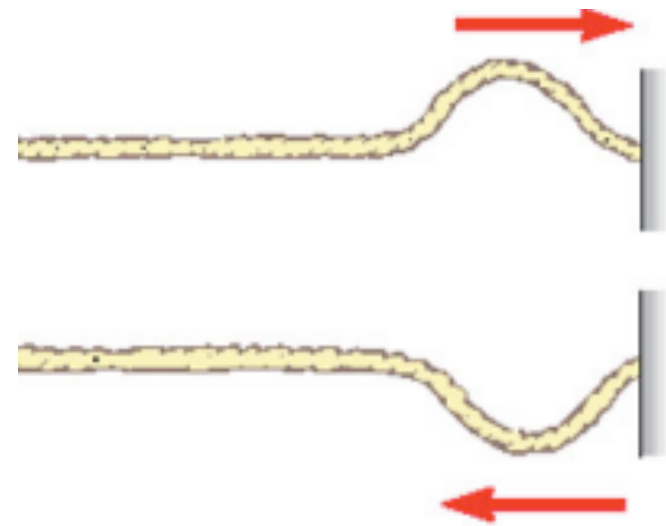
transmitted pulse not inverted

Reflection & Transmission of Waves

free end
reflected pulse not inverted



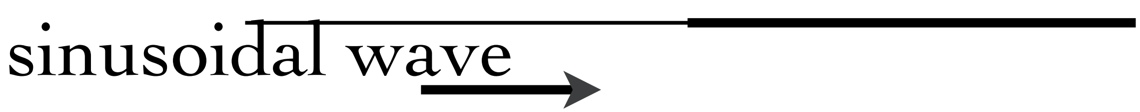
fixed end
reflected pulse inverted



Transmission of Waves: Example

A sinusoidal wave is transmitted from a thin string segment (high speed) to a thick string segment (low speed). The wavelength of the wave in the thick string segment is ______ the wavelength of the wave in the thin string segment. (Hint: property of the wave doesn't depend on the medium?)

A. longer than
B. equal to
C. shorter than
D. it depends...



Chapter 14: Superposition of Waves

Waves are very different from particles:

- An "ideal" particle is of zero size
- An "ideal" wave is of infinite length
- Two or more waves may combine at a single point in the same medium
- We can combine particles to form extended objects, but the particles must be at different locations

Superposition of Waves

Superposition Principle:

- If two or more traveling waves are moving through a medium, the resultant value of the wave function at any point is the algebraic sum of the values of the wave functions of the individual waves

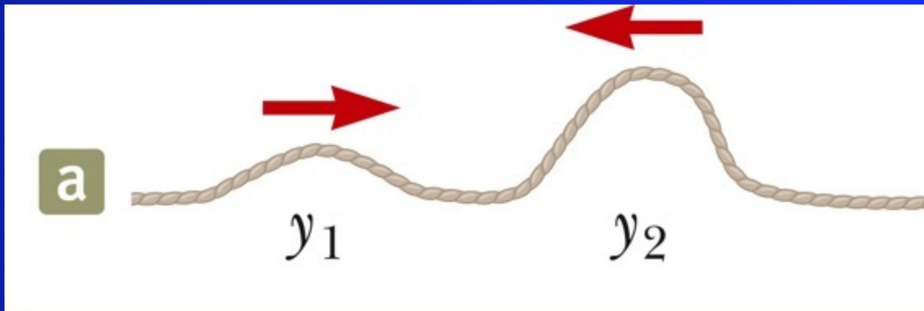
Waves that obey the superposition principle are **linear waves**

- Linear waves generally have amplitudes A much smaller than their wavelengths λ

Superposition of Waves

- when there are two moving waves at the same location, add their displacements

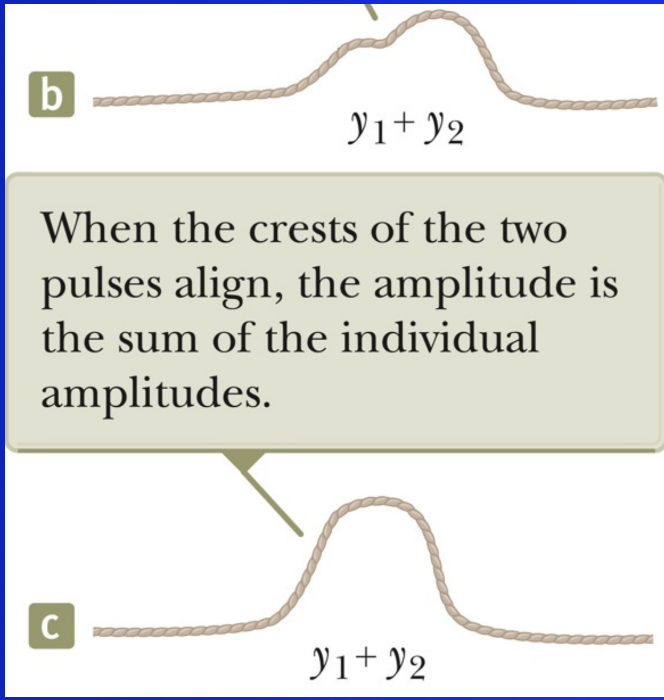
- in this example, the wave pulses have the same speed but different shapes
  - the displacement of the elements is *positive* for both



When the pulses overlap, the wave function is the sum of the individual wave functions.

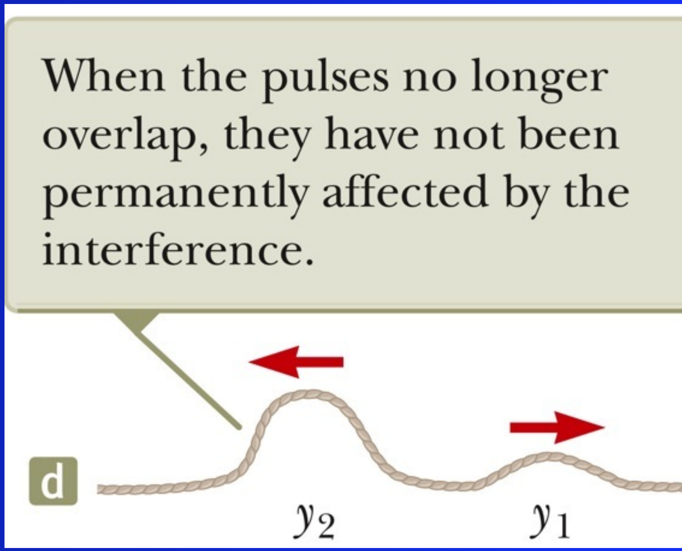
Superposition of Waves

- When the waves start to overlap, the resultant wave function is $y_1 + y_2$



- When crest meets crest, the resultant wave has a *larger amplitude* than the original waves

- The two pulses separate and continue moving in their original directions, while the pulses' shapes remain unchanged

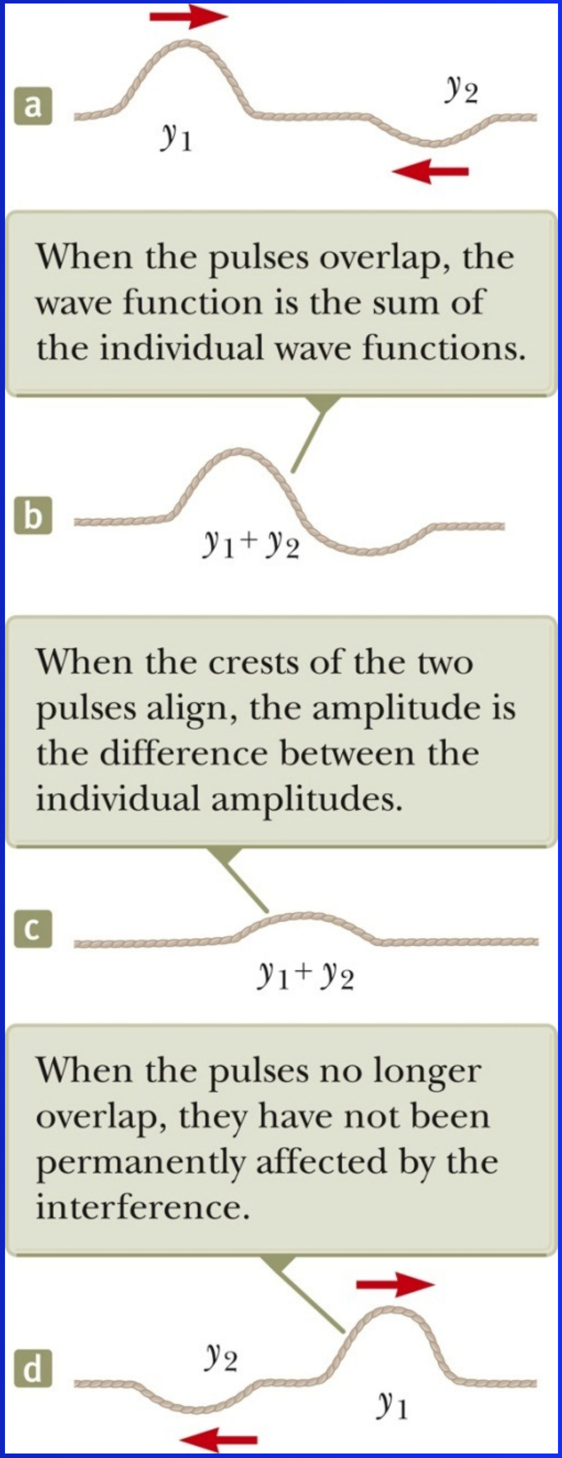


- The combination of separate waves in the same region to produce a resultant wave is called ***interference***

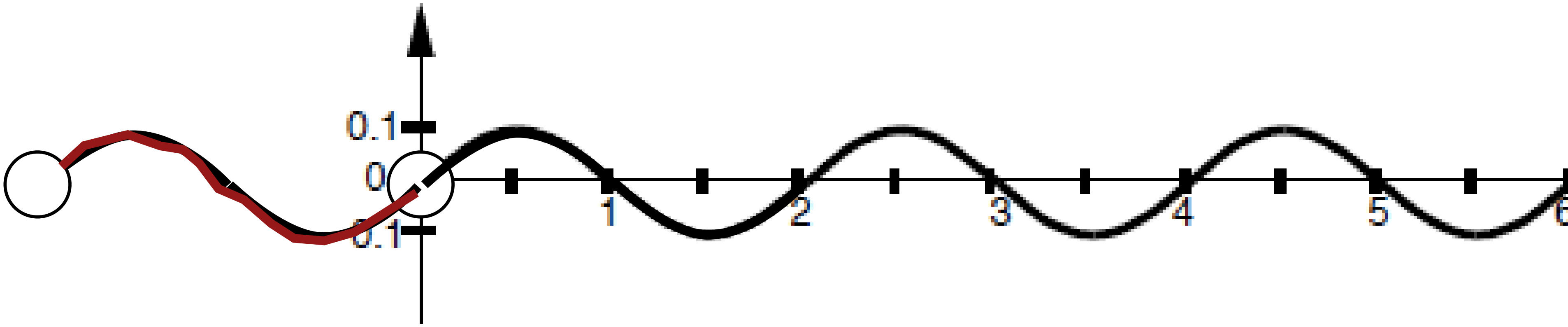
Superposition of Waves

- *Constructive interference* occurs when the displacements caused by the two pulses are in the *same* direction
  - amplitude of resultant pulse is greater than either individual pulse

- *Destructive interference* occurs when the displacements caused by the two pulses are in *opposite* directions
  - amplitude of resultant pulse is less than either individual pulse



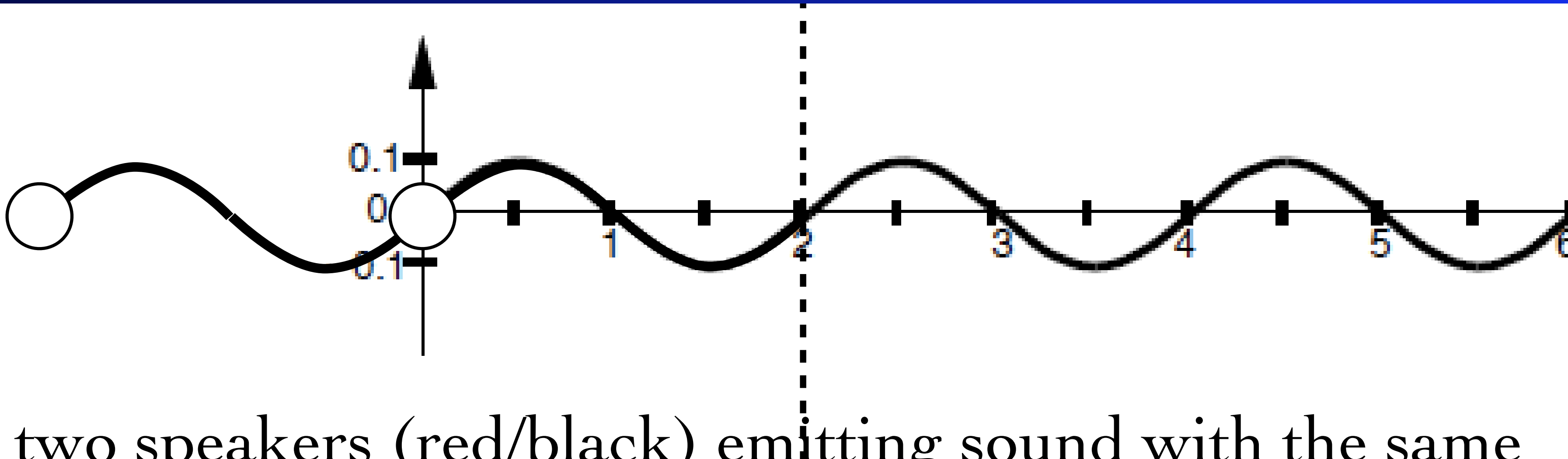
What happens if...



two speakers (red/black) emitting sound with the same frequency and in phase with each other

does the superposition of these waves make an overall stronger or weaker wave?

What happens if…

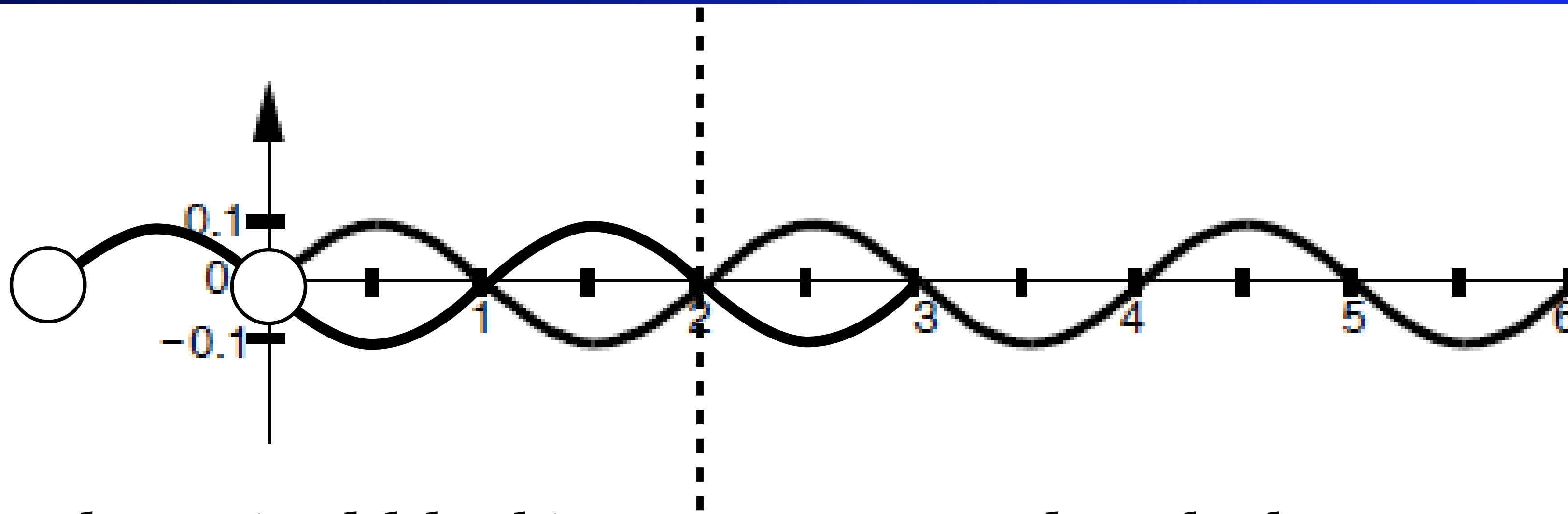


two speakers (red/black) emitting sound with the same frequency and in phase with each other

as the waves travel, the two always add to make a larger wave:
constructive interference

$$\Delta r = \lambda, 2\lambda, \ldots$$

What happens if…



two speakers (red/black) emitting sound with the same frequency and in phase with each other

as the waves travel, the two always subtract to make a smaller wave:

destructive interference

$$\Delta r = \frac{1}{2}\lambda, \frac{3}{2}\lambda, \ldots$$

Constructive/Destructive Interference

Constructive Interference

$$\Delta r = \lambda, 2\lambda, \ldots$$

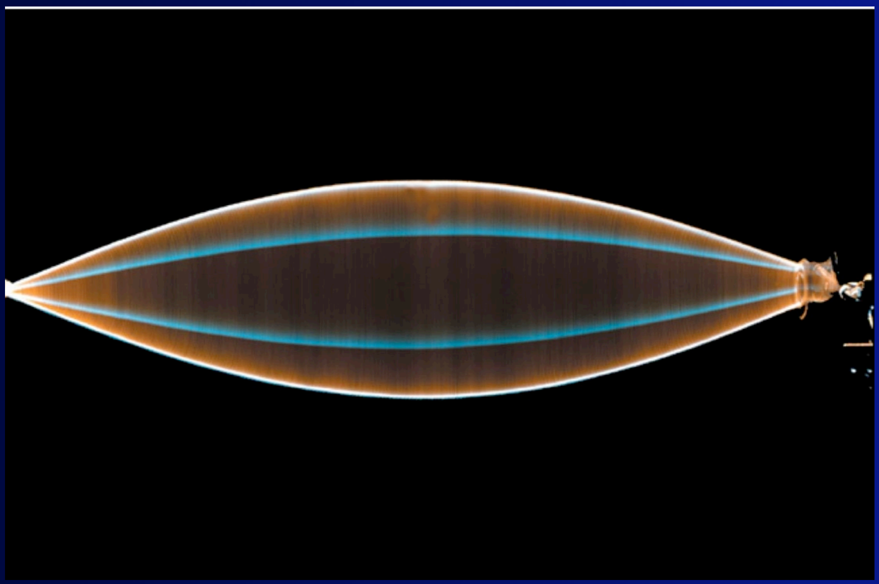
Destructive interference

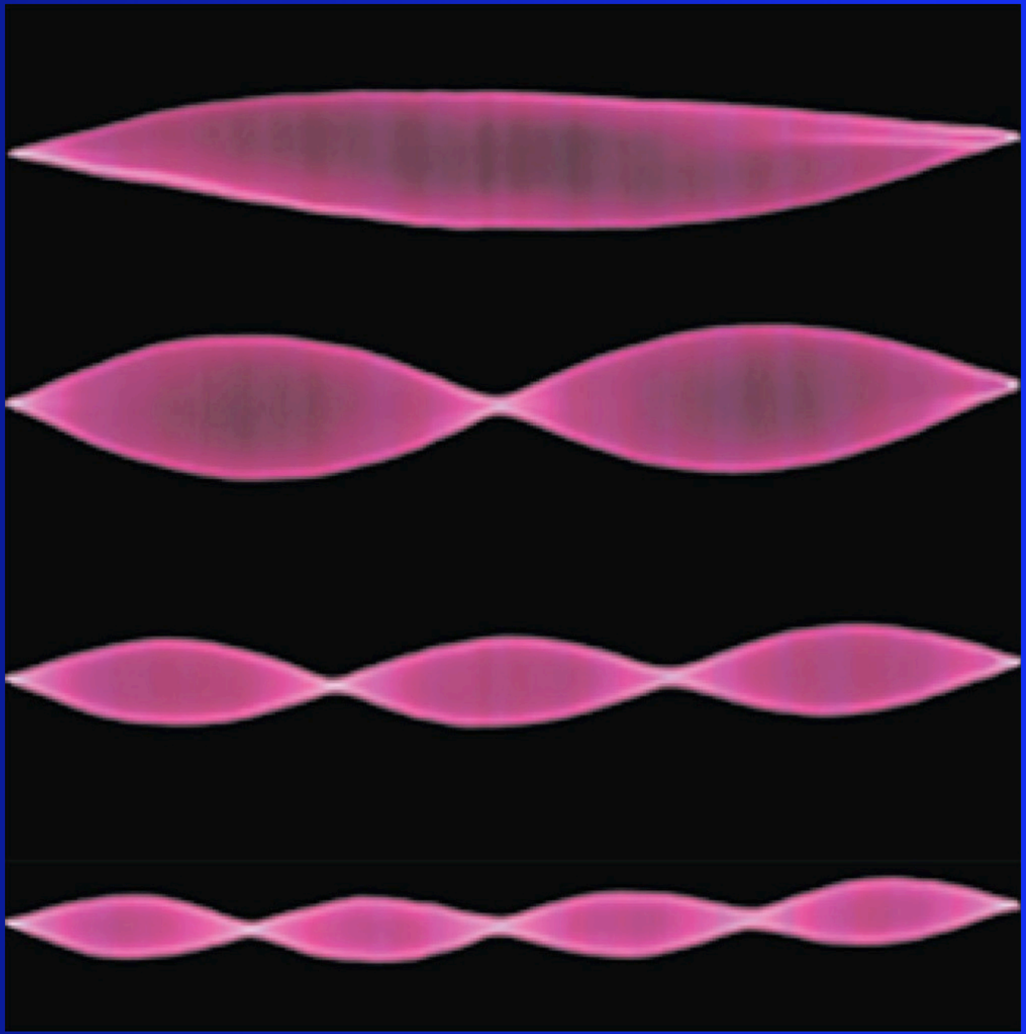
$$\Delta r = \frac{1}{2}\lambda, \frac{3}{2}\lambda, \ldots$$

Δr: the difference in the distance from location to each source of waves

Standing Waves

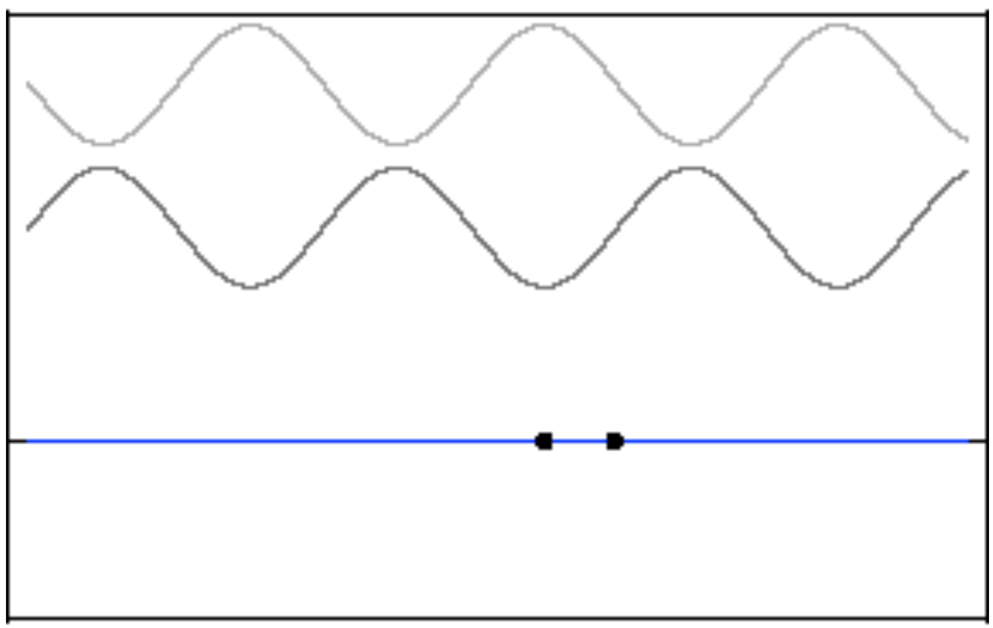
- a wave with fixed points that do not vibrate (nodes)





Standing Waves

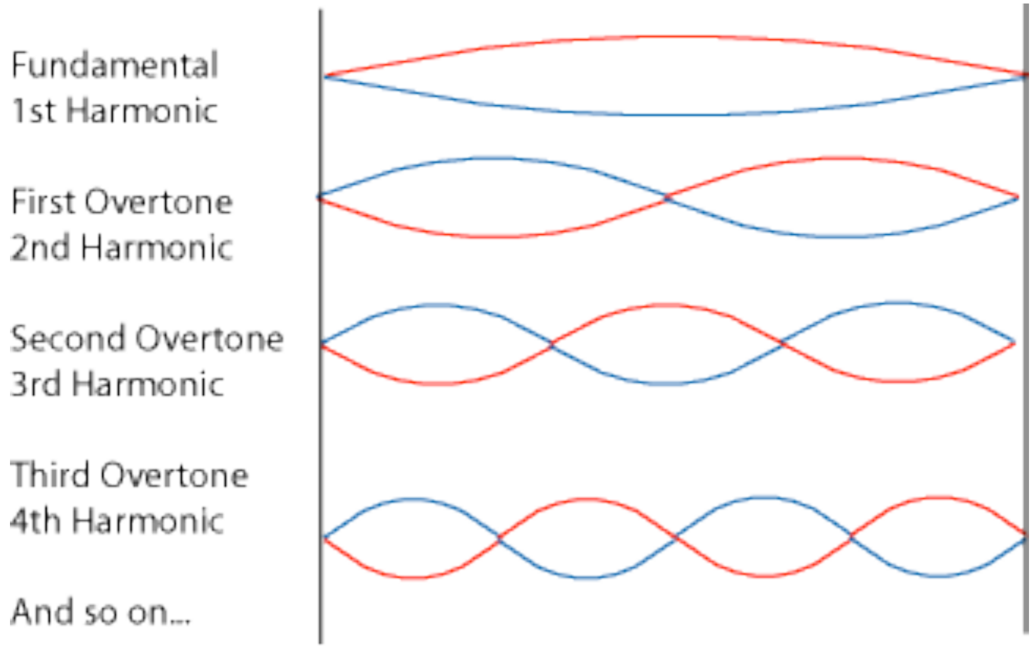
- standing waves are the superposition of two opposite directed waves



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

$$v = \sqrt{\frac{T}{\mu}}$$

Standing Waves: Harmonics



$$\lambda_1 = 2L$$

$$\lambda_2 = L$$

$$\lambda_3 = \frac{2L}{3}$$

$$\lambda_4 = \frac{L}{2}$$

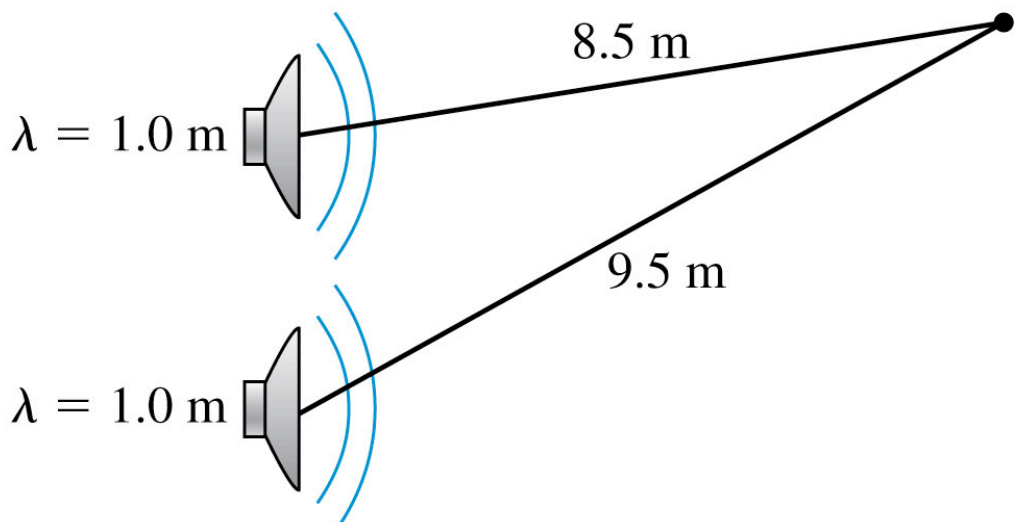
$$\vdots$$

$$\lambda_n = \frac{2L}{n}$$

Wave Interference: Example

Two speakers emit sound waves in phase with each other with wavelength 1.0 m. The distance from a given location to each speaker is shown. A listener at the location shown will experience:

A. constructive interference
B. destructive interference
C. something in between the two
D. huh?



For Friday:

1. make sure you turn in your homework and reading quiz on www.webassign.net
2. make sure that you understand the Doppler effect for sound waves
3. read up to sections 14.3 (waves under boundary conditions) and 14.4 (standing waves in air columns) to prepare for class