Physics 115 Lecture 5

Wave properties

February 1, 2018

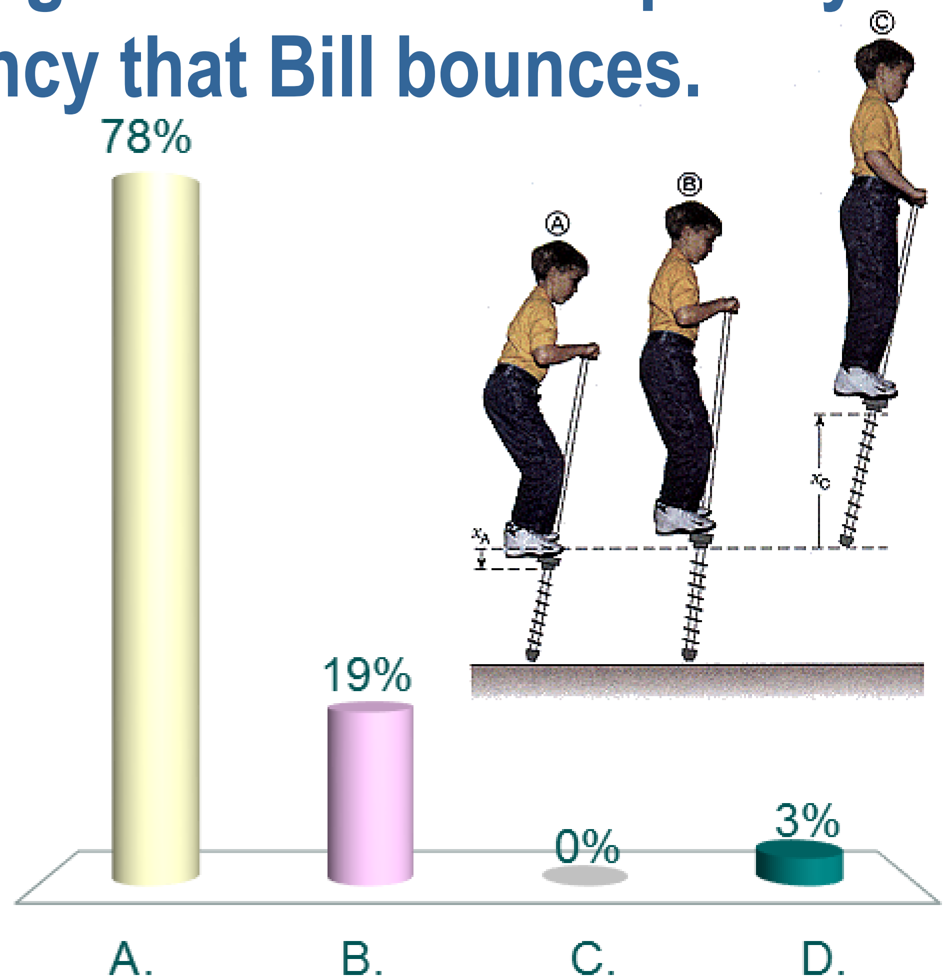
Class quiz #1: Bill bounces on a pogo stick like a mass on a spring. Ted, who has half the mass of Bill, will bounce on the pogo stick with a frequency that is _______ the frequency that Bill bounces.

A. twice

B. a factor of $\sqrt{2}$ times greater than

C. a factor of $\sqrt{2}$ times less than

D. half



0

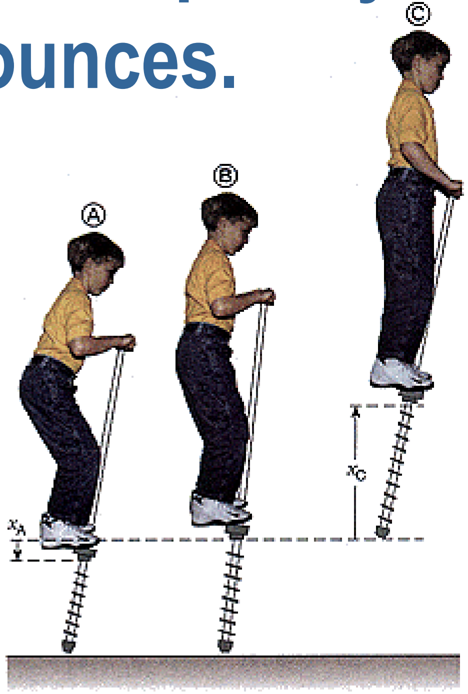
Class quiz #1: **Bill bounces on a pogo stick like a mass on a spring. Ted, who has half the mass of Bill, will bounce on the pogo stick with a frequency that is _______ the frequency that Bill bounces.**

A. twice

B. a factor of $\sqrt{2}$ times greater than

C. a factor of $\sqrt{2}$ times less than

D. half



Recall that $T = 2\pi\sqrt{m/k}$, or $f = \frac{1}{2\pi}\sqrt{k/m}$

f decreases with $\sqrt{m}$, so f will increase by a factor of $\sqrt{2}$ when m is cut in half. Or try a ratio:

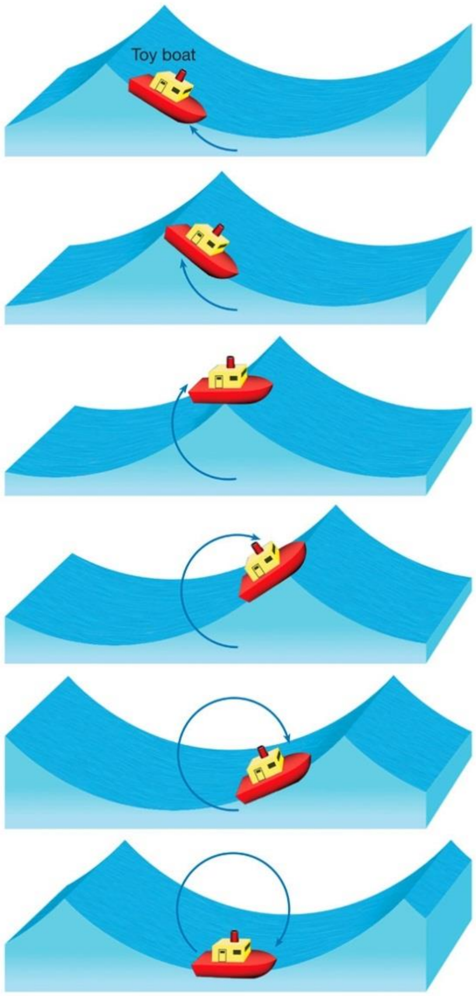
$$\frac{f_{\text{Ted}}}{f_{\text{Bill}}} = \frac{\frac{1}{2\pi}\sqrt{\dfrac{k}{m_{\text{Ted}}}}}{\frac{1}{2\pi}\sqrt{\dfrac{k}{m_{\text{Bill}}}}} = \sqrt{\frac{1/m_{\text{Ted}}}{1/m_{\text{Bill}}}} = \sqrt{\frac{m_{\text{Bill}}}{m_{\text{Ted}}}} = \sqrt{\frac{m_{\text{Bill}}}{\frac{1}{2}m_{\text{Bill}}}} = \boxed{\sqrt{2}}$$

Written quiz #1

- Based on homework #1
- Posted answer key

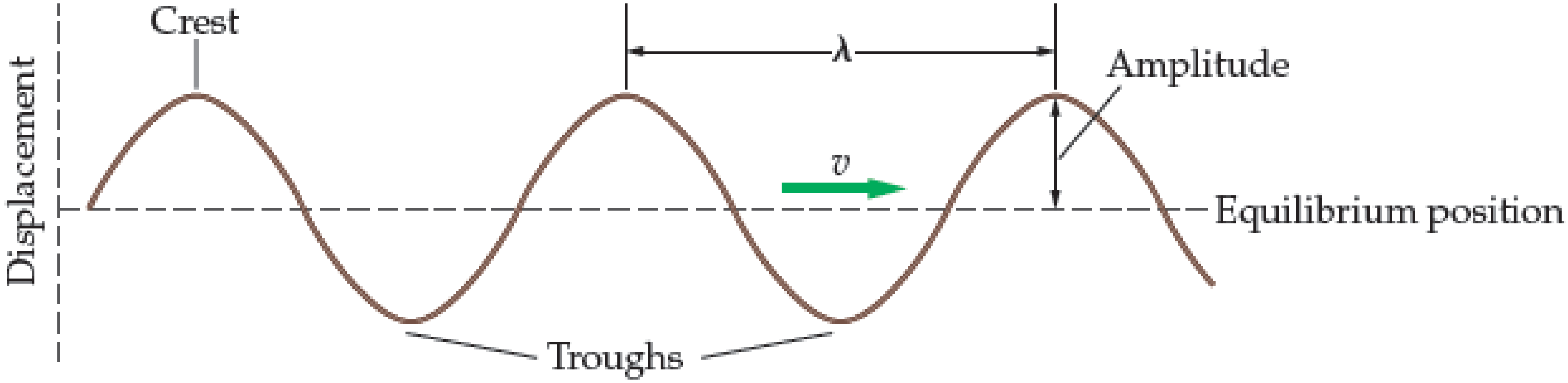
Waves and oscillations

- Waves make oscillations, and oscillations make waves
- Animated applet
- String waves example
- Radio waves example



Describing waves

- Wave features



Describing waves

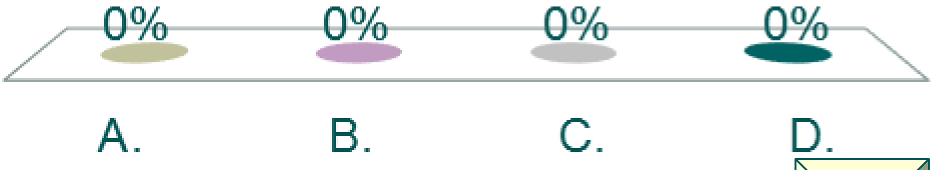
- Animated applet
- Frequency
- Wavelength applet
- Speed

$$v = \frac{\text{distance}}{\text{time}} = \frac{\lambda}{T} = \boxed{f\lambda = c}$$

- The speed of a wave is determined by the properties of the medium, NOT either frequency or wavelength

How far does a wave travel in one period?

A. It depends on the frequency
B. 0.50λ
C. 1.0λ
D. 2.0λ



0 of 46

120

How far does a wave travel in one period?

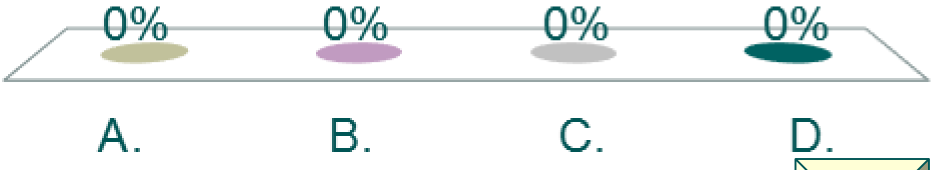
A. It depends on the frequency
B. 0.50λ
C. 1.0λ
D. 2.0λ

The speed of a wave depends *only* on the properties of the medium, not on the frequency or wavelength.

A wave *always* travels one wavelength during one oscillation period.

A wave oscillates 4.0 times a second and has a wavelength of 3.0 m. What is its speed?

A. 4.0 m/s
B. 0.75 m/s
C. 1.33 m/s
D. 12 m/s



0 of 46

180

A wave oscillates 4.0 times a second and has a wavelength of 3.0 m. What is its speed?

A. 4.0 m/s

B. 0.75 m/s

C. 1.33 m/s

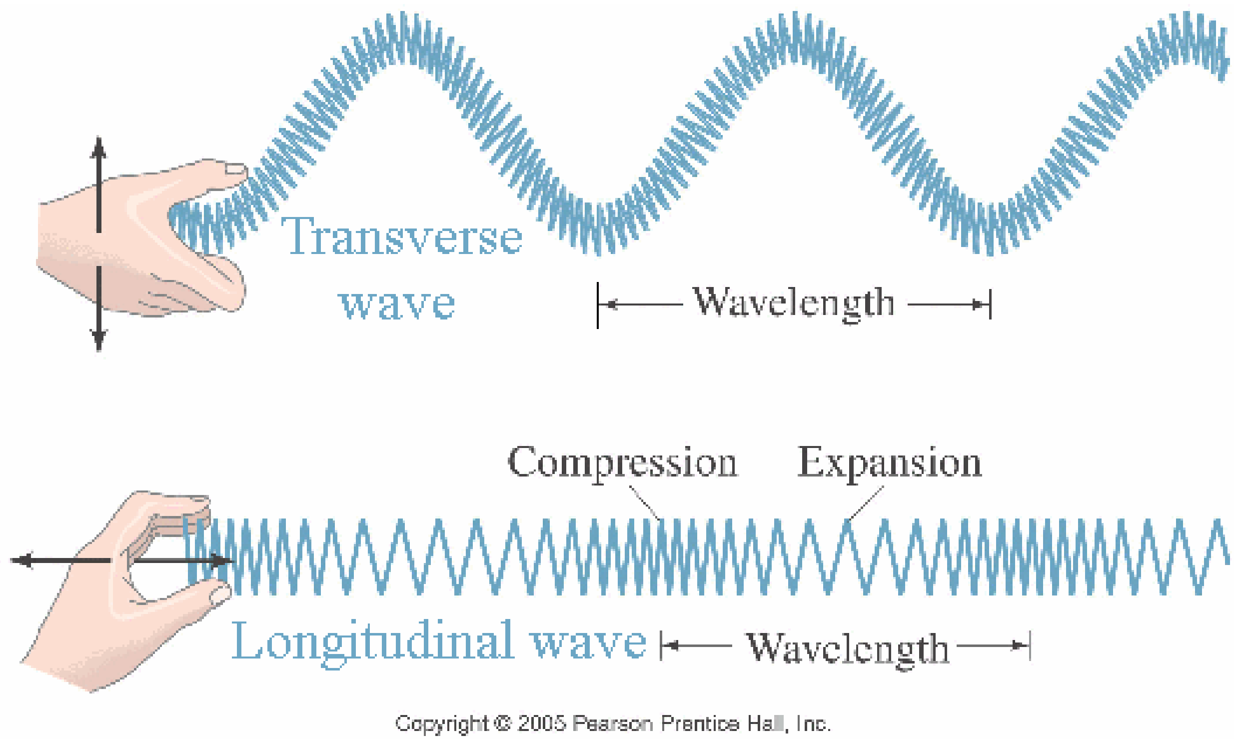
D. 12 m/s

$$c = f\lambda = \left(4.0\ \text{Hz}\right)\left(3.0\ \text{m}\right)$$

$$= \boxed{12\ \text{m/s}}$$

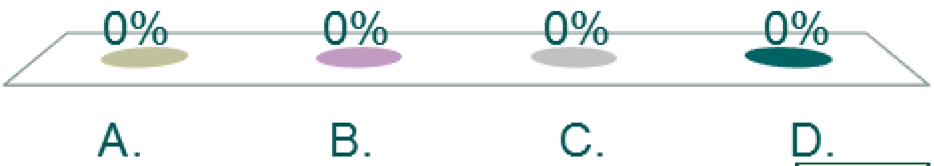
Transverse vs. Longitudinal Waves

- Transverse waves: Particle displacements are perpendicular to the direction of wave propagation.
- Longitudinal waves: Particle displacements are parallel to the direction of wave propagation.



The waves that travel across the surface of water are _____ waves.

A. particle
B. transverse
C. longitudinal
D. tangential



Response Counter

90

The waves that travel across the surface of water are _____ waves.

A. particle

B. transverse

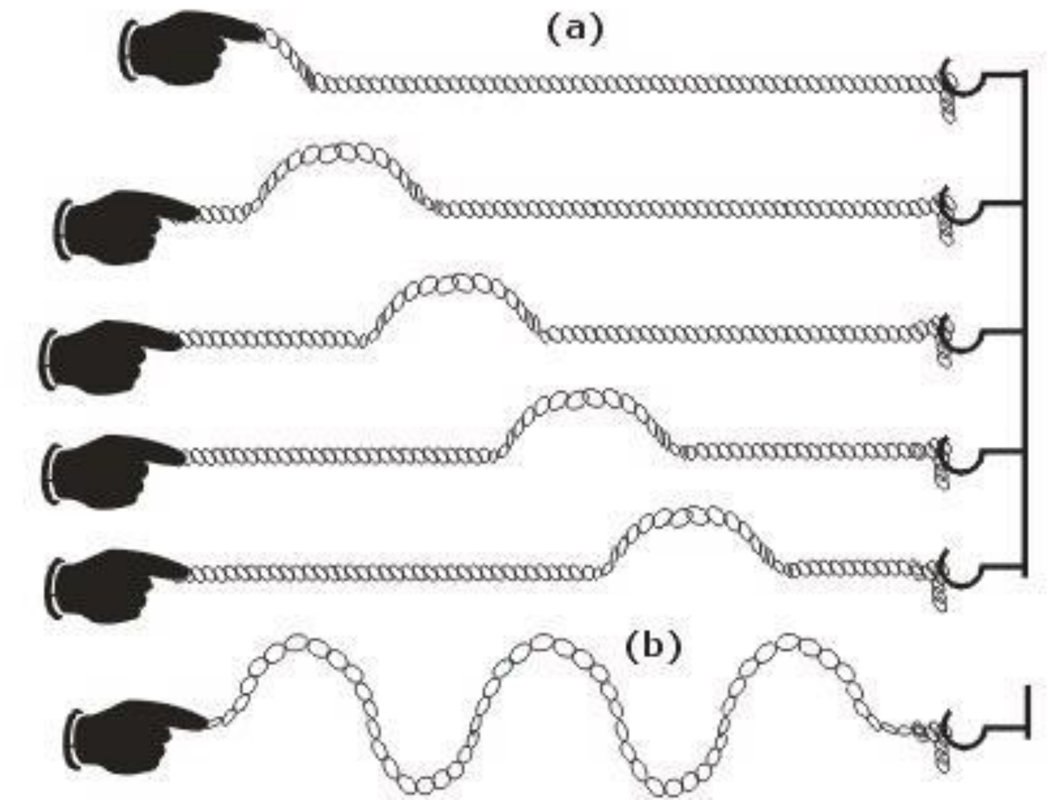
C. longitudinal

D. tangential

Transverse is the best answer because the oscillation is (mostly) perpendicular to the direction of propagation. However, surface water waves are actually a combination of transverse and longitudinal (see p.91). Sonar waves that travel through the *bulk* of fluids, beneath the surface, are longitudinal.

Nonrecurring vs. Periodic Waves

- Nonrecurring waves: Isolated pulses, like a thunderclap sound wave, or a tsunami.
- Periodic waves: Continuously repeating wave, like a tuning fork sound wave, or waves at a beach.



Sound and Media

- **Sound waves require a *medium*, such as gas, liquid, or solid.**
  - Sound waves that propagate through gas are longitudinal.
  - Sound waves that propagate through liquids and solids can have both transverse and longitudinal components. *
    http://www.acs.psu.edu/drussell/Demos/waves/wavemotion.html

    * Animation courtesy of Dr. Dan Russell, Penn State University

- Sound waves cannot propagate through a vacuum.

  (http://www.youtube.com/watch?v=q2pj9k1IrsM&feature=related)

  (Star Trek exception? http://www.youtube.com/watch?v=hdjL8WXjlGI)

Some Sounds You Hear, Some Sounds You Don't

- Audible Sound: 20 Hz to 20,000 Hz
- Infrasound ($f < 20$ Hz)
- Ultrasound ($f > 20{,}000$ Hz)
- Sounds abound! You are *never* free from sound.

How Do We Know that Sound is a Wave?

- Sound exhibits classical wave behavior, similar to the behavior of water waves and light waves. Such behavior includes ...

- Superposition: waves can pass through one another. When they do, their amplitudes add.
- Animated applet

another animation:
http://www.acs.psu.edu/drussell/Demos/superposition/superposition.html

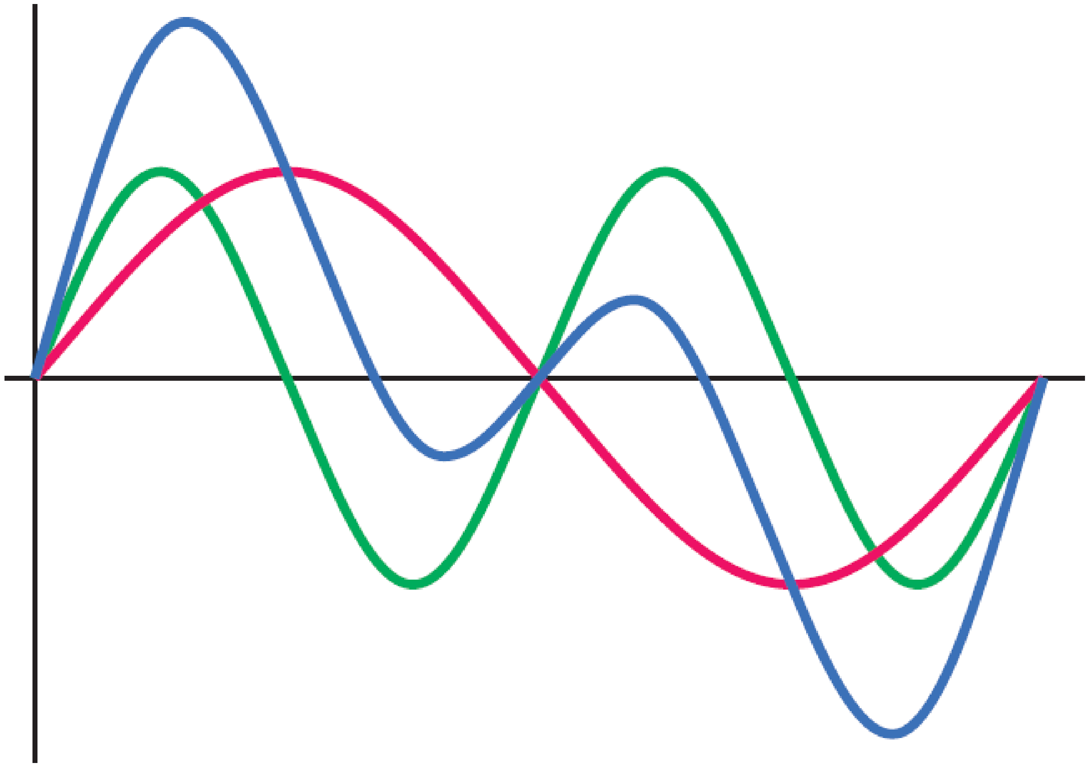
Which wave is the superposition of the other two?

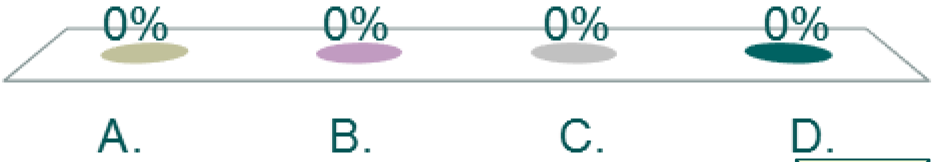
A. red

B. blue

C. green

D. None of them.





Response Counter

120

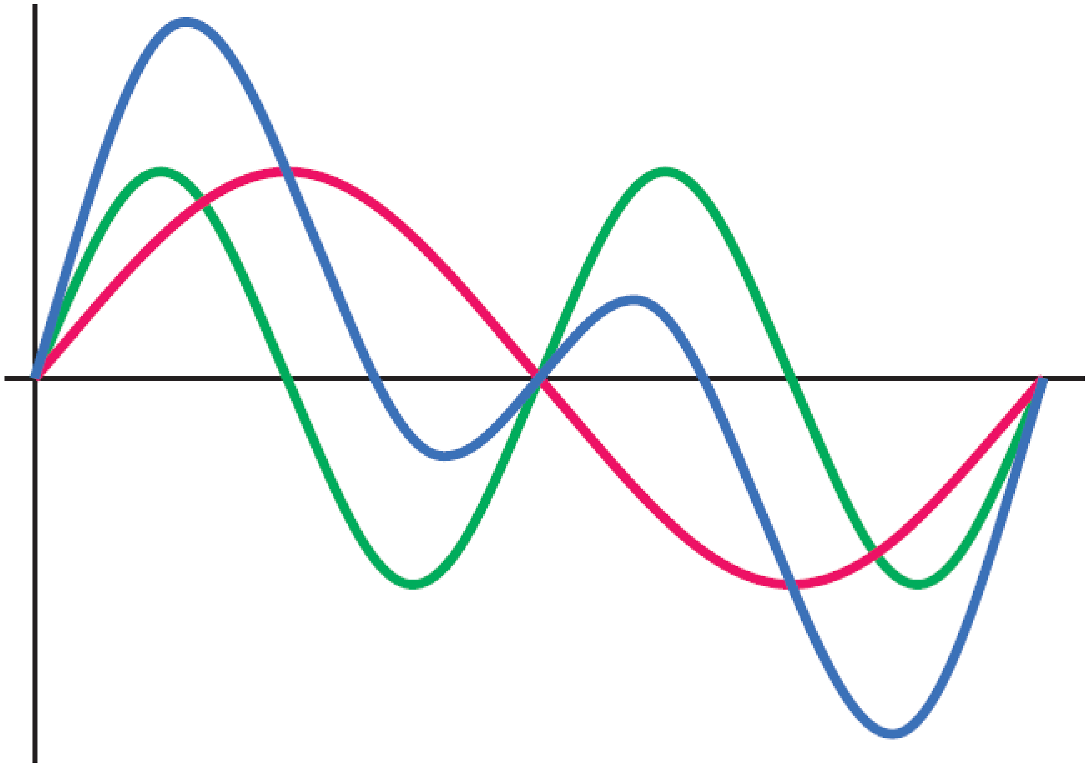
Which wave is the superposition of the other two?

A. red

B. blue

C. green

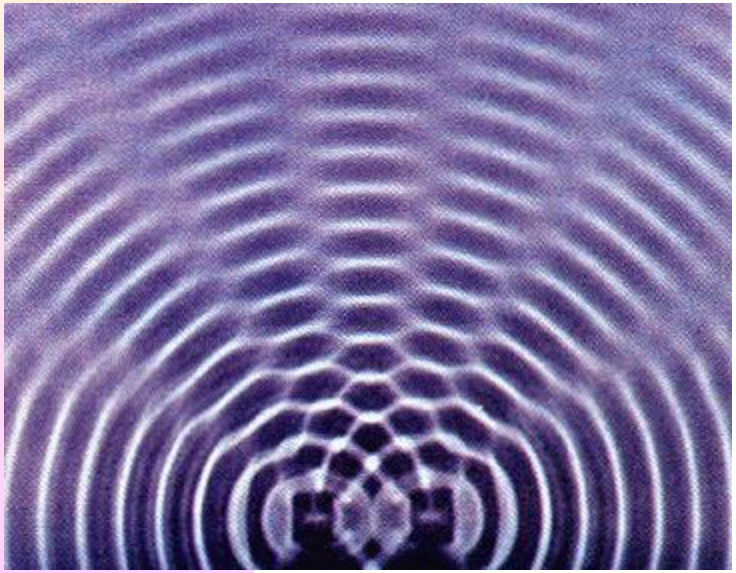
D. None of them.



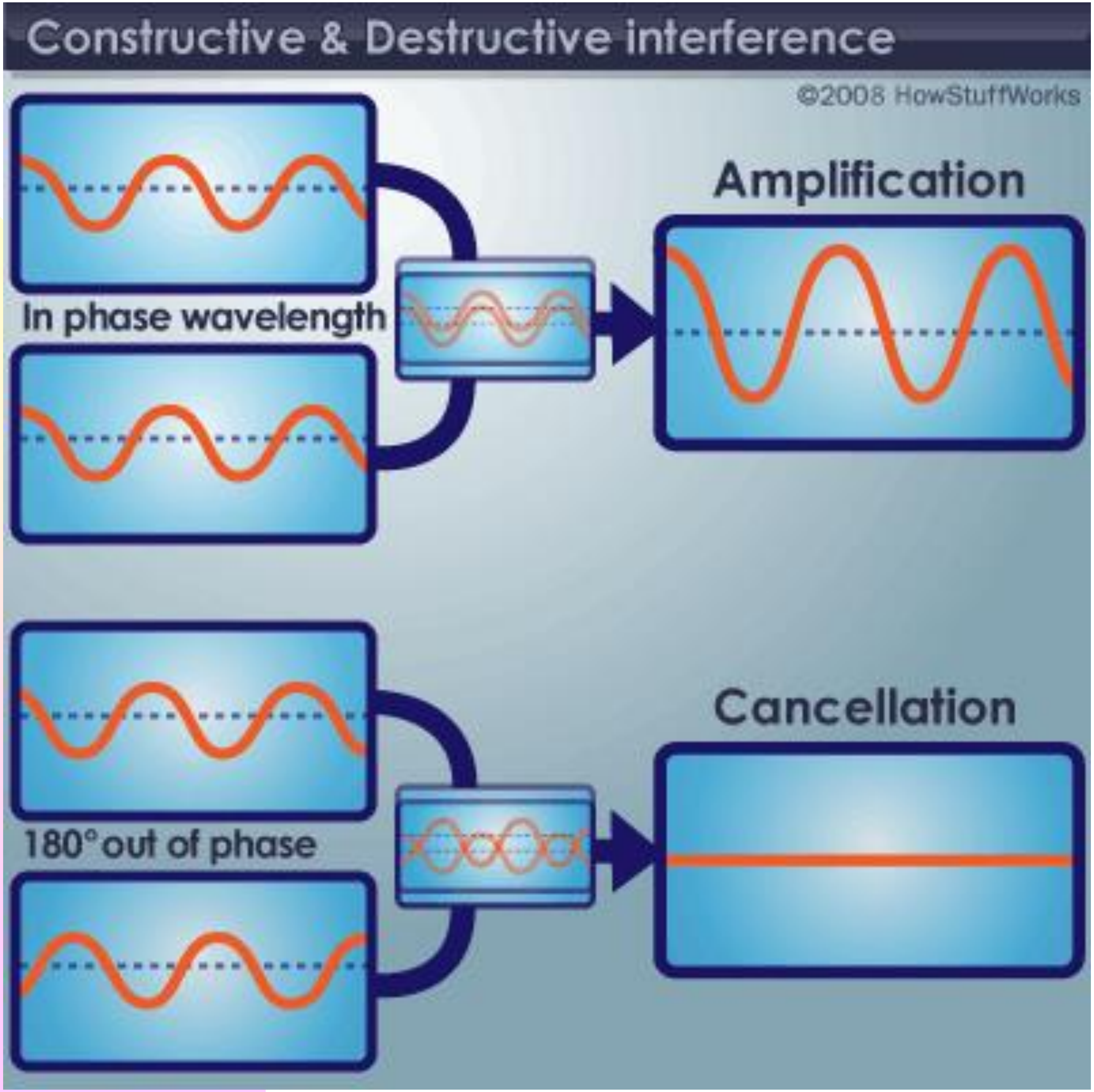
The blue wave has a larger amplitude than the other two waves because its amplitude is the superposition of the other two.

How Do We Know that Sound is a Wave?

- Interference: one wave can cancel or reinforce another. (animated applet)



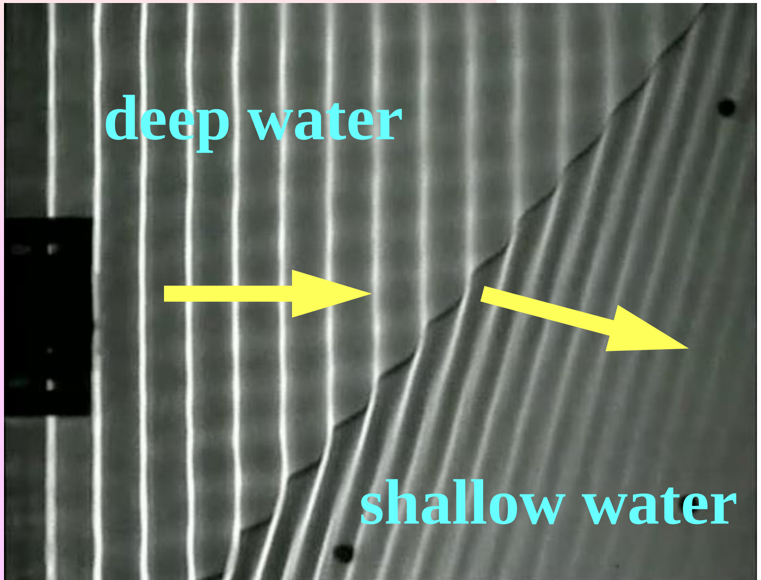
interference pattern formed by two sources of periodic waves in a water ripple tank

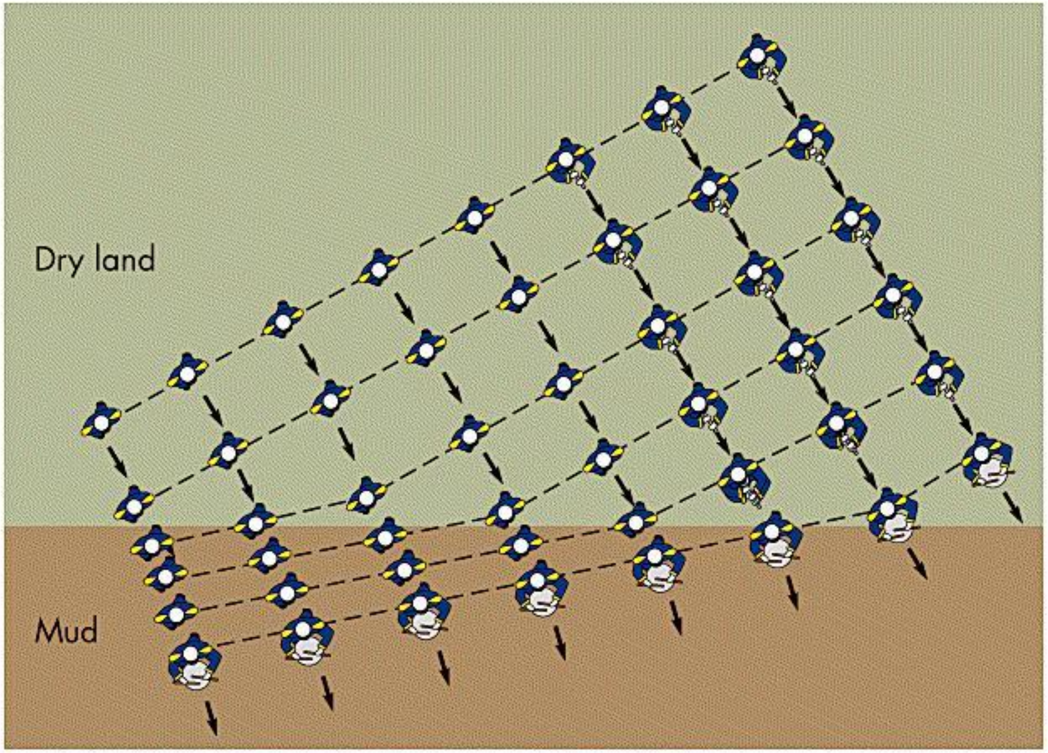

Constructive & Destructive interference
©2008 HowStuffWorks
Amplification
In phase wavelength
Cancellation
180° out of phase

How Do We Know that Sound is a Wave?

- Refraction: when the wave enters a new medium, its direction of propagation can change.

A marching band analogy of a wave changing direction when it enters a slower medium





Refraction

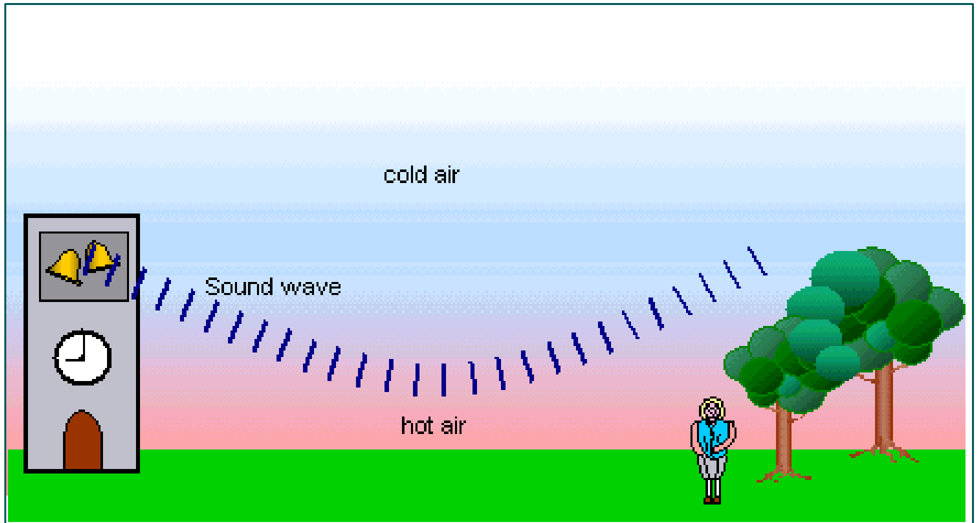


Figure 1

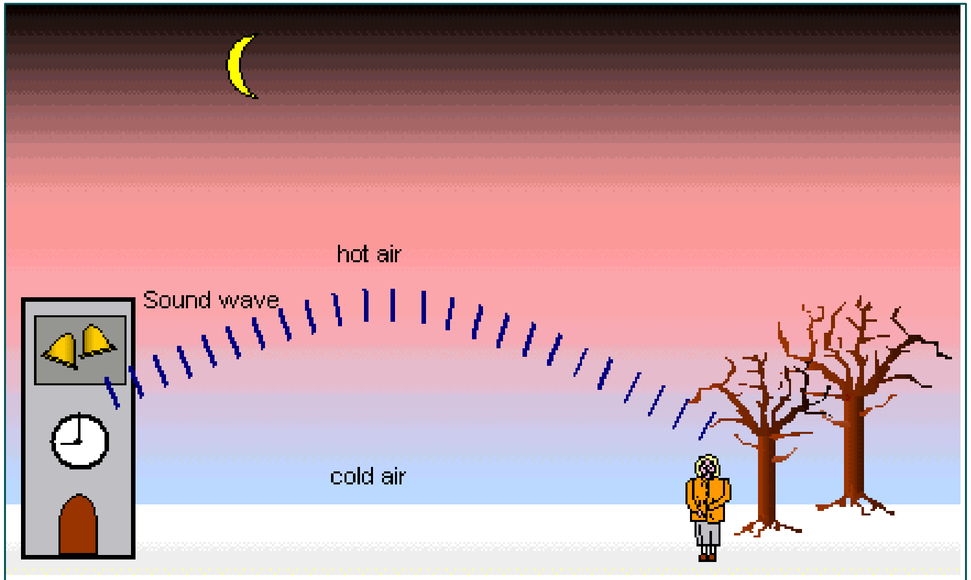
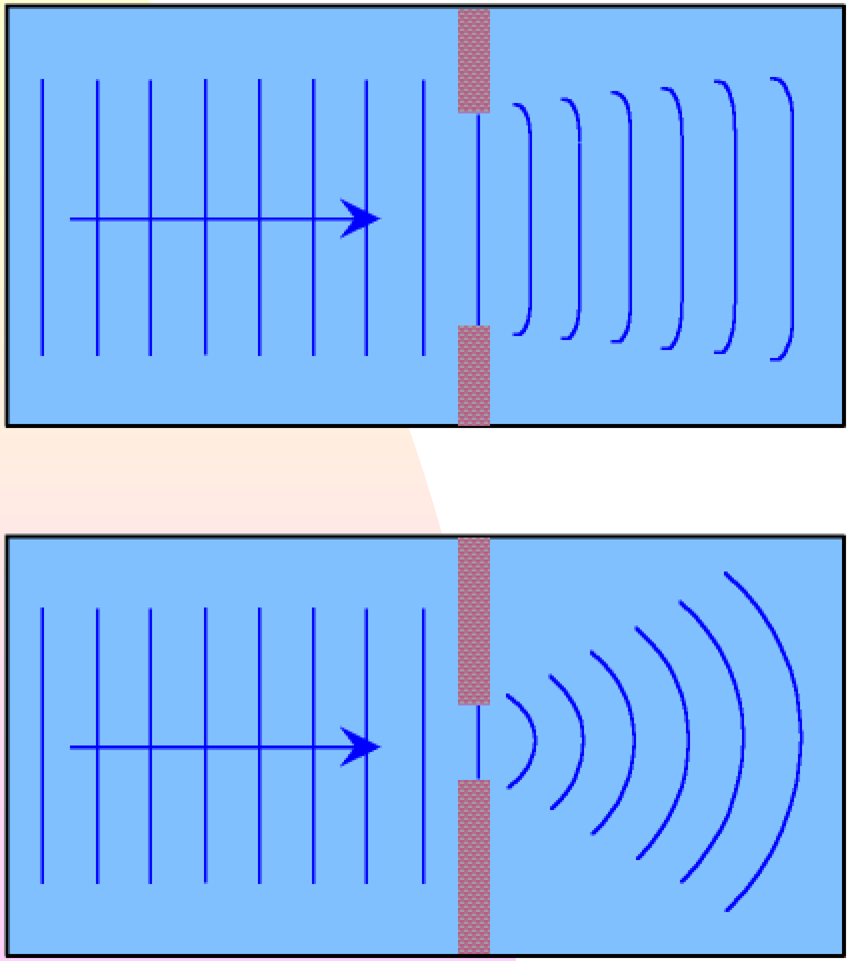


Figure 2

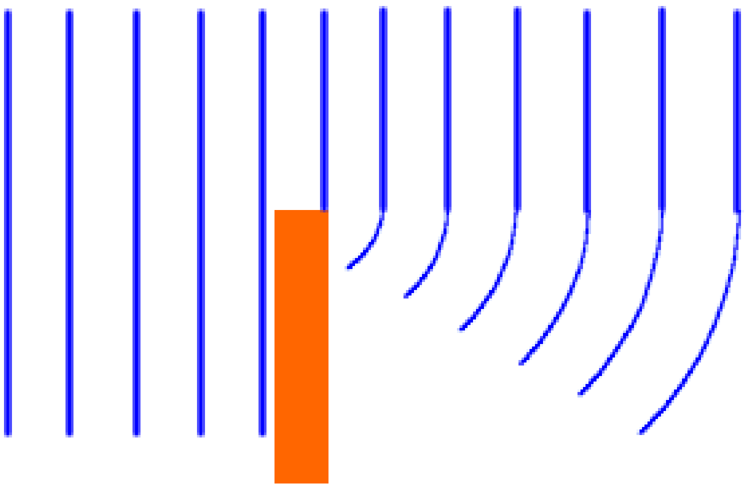
How Do We Know that Sound is a Wave?

- Diffraction: Waves spread out after passing through an aperture or upon encountering an obstacle.

Diffraction



APERTURE



OBSTACLE

How Do We Know that Sound is a Wave?

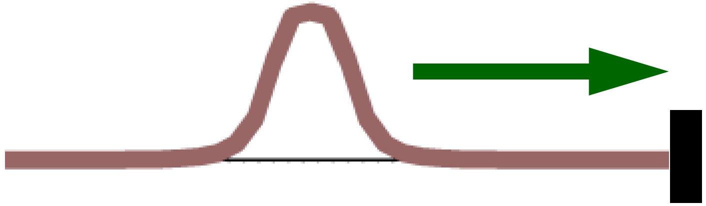
- Doppler effect: The wave frequency measured by an observer is affected by the motion of the wave source and/or by the motion of the observer.
- (More about the Doppler effect later in the course!)

How Do We Know that Sound is a Wave?

- Sound exhibits classical wave behavior, similar to the behavior of water waves and light waves. Such behavior includes ...
  - Superposition: waves can pass through one another. When they do, their amplitudes add.
  - Interference: one wave can cancel or reinforce another.
  - Refraction: when the wave enters a new medium, its direction of propagation can change.
  - Diffraction: Waves spread out after passing through an aperture or upon encountering an obstacle.
  - Doppler effect: The wave frequency measured by an observer is affected by the motion of the wave source and/or by motion of the observer.

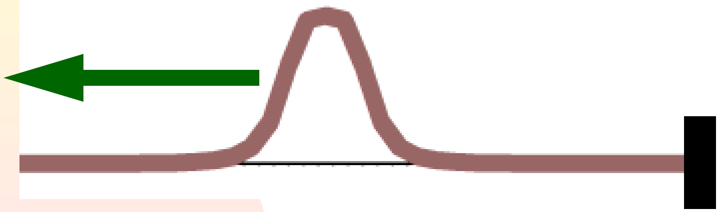
Reflection

- Waves also behave differently than particles when they reflect
- When a wave encounters a *slower* medium, a reflected crest becomes a trough
- When a wave encounters a *faster* medium, a reflected crest remains a crest
- Animated applet
- Interactive PhET applet



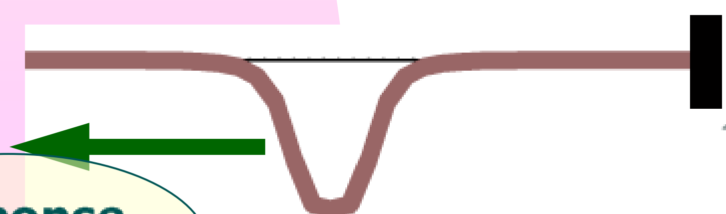
You observe a wave shape traveling along a rope. What will happen after the wave reflects from an end that's securely fixed to a post?

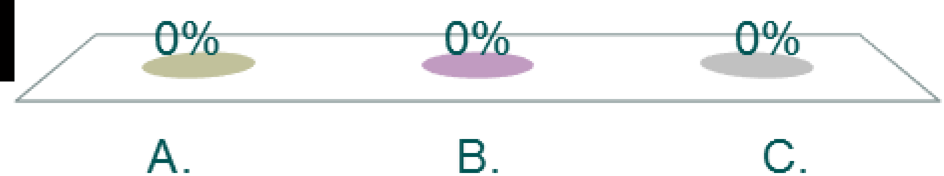
A.



B.

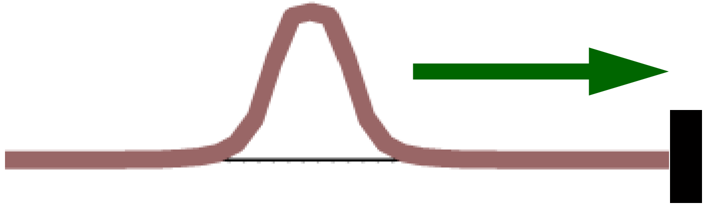
C.





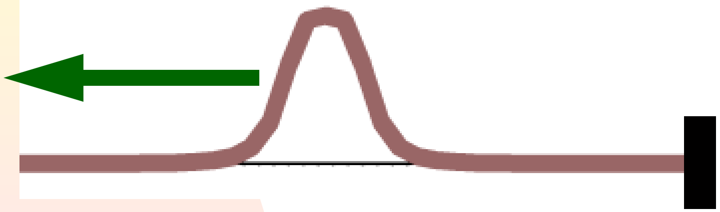
Response Counter

90



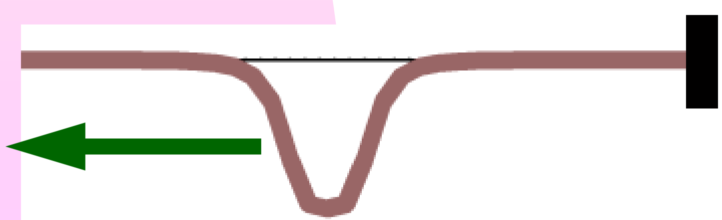
You observe a wave shape traveling along a rope. What will happen after the wave reflects from an end that's securely fixed to a post?

A.



B.

C.



The wave will invert after meeting the fixed end, where the wave speed is zero