Waves and oscillators

Vibration = Oscillation = movement back and forth.

Equilibrium position or resting position = position when not oscillating.

Forced vibration = oscillating motion caused by force applied to a system in equilibrium

Applied force starts motion, restoring force moves object back towards equilibrium position.

In translational motion, object "permanently" displaced to new position.

In oscillation, object moves back and forth around the equilibrium position.

We have considered spring-mass and simple pendulum motion: SHM

A Tuning fork can be considered inverted pendulum

If there is no damping [dissipation of energy], the system will oscillate forever.

Hooke's law: $F = -kx$

For a mass-spring $\omega = \sqrt{[k/m]}$ $T = 2\pi\sqrt{[m/k]}$

For a pendulum: $\omega = \sqrt{[g/L]}$ $T = 2\pi\sqrt{[L/g]}$

Remember: frequency = 1/period $f = 1/T$

angular velocity $\omega = 2\pi f = 2\pi/T$

1. A pendulum is observed to complete 23 full cycles in 58 seconds. Determine the period and the frequency of the pendulum.

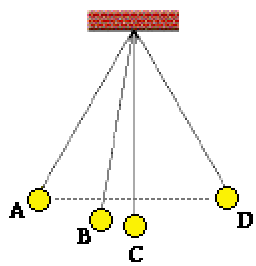
2. A mass is tied to a spring and begins vibrating periodically. The distance between its highest and its lowest position is 38 cm. What is the amplitude of the vibrations?

3. A pendulum bob is pulled back to position A and released from rest. The bob swings through its usual circular arc and is caught at position C. Determine the position (A, B, C or all the same) where the …

a. … force of gravity is the greatest?
b. … restoring force is the greatest?

c. … speed is the greatest?
d. … potential energy is the greatest?
e. … kinetic energy is the greatest
f. … total mechanical energy is the greatest?

4. Use energy conservation to fill in the blanks in the following diagram.



A: KE = 0 J
PE = 2.4 J

B: KE = 2.0 J
PE = ________ J

C: KE = ________ J
PE = 0 J

D: KE = ________ J
PE = ________ J

5. A pair of trapeze performers at the circus is swinging from ropes attached to a large elevated platform. Suppose that the performers can be treated as a simple pendulum with a length of 16 m. Determine the period for one complete back and forth cycle.

6. Which would have the highest *frequency* of vibration?

Pendulum A: A 200-g mass attached to a 1.0-m length string
Pendulum B: A 400-g mass attached to a 0.5-m length string

7. If you wish to make a simple pendulum that serves as a timing device such that its period is 1.00 second, what length must the pendulum have?

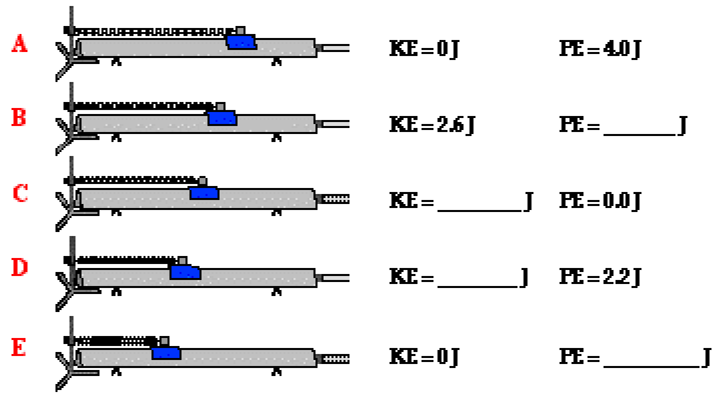
8. A force of 16 N is required to stretch a spring a distance of 40 cm from its rest position. What force (in Newtons) is required to stretch the same spring …

a. … twice the distance?
b. … three times the distance?
c. … one-half the distance?

9. Perpetually disturbed by the habit of the backyard squirrels to raid his bird feeders, Mr. H decides to use a little physics for better living. His current plot involves equipping his bird feeder with a spring system that stretches and oscillates when the mass of a squirrel lands on the feeder. He wishes to have the highest amplitude of vibration that is possible. Should he use a spring with a large spring constant or a small spring constant?

10. Referring to the previous question. If Mr. H wishes to have his bird feeder (and attached squirrel) vibrate with the highest possible frequency, should he use a spring with a large spring constant or a small spring constant?

11. Use energy conservation to fill in the blanks in the following diagram.



12. Which of the following mass-spring systems will have the highest *frequency* of vibration?

Case A: A spring with a k=300 N/m and a mass of 200 g suspended from it.
Case B: A spring with a k=400 N/m and a mass of 200 g suspended from it.

13. Which of the following mass-spring systems will have the highest *frequency* of vibration?

Case A: A spring with a k=300 N/m and a mass of 200 g suspended from it.
Case B: A spring with a k=300 N/m and a mass of 100 g suspended from it.

*   *   *   *   *   *   *   *   *   *

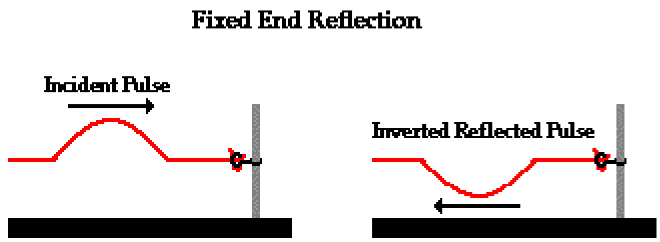
A wave is a disturbance that travels from one location to another. It MAY travel through a medium.

A slinky can be used to illustrate waves.

Think of a slinky stretched from end to end and held at rest, coils evenly spaced.

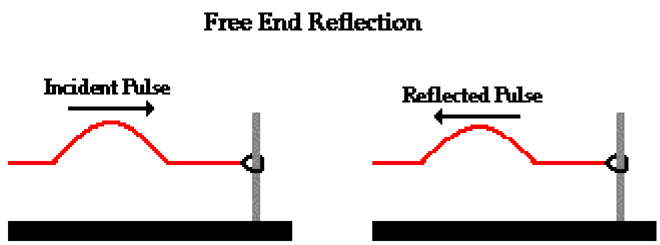
If the slinky is displaced close to one end, perpendicular to the length and released, the disturbance will travel as a pulse to the end.

A pulse is a single disturbance traveling through a medium.



When a pulse reaches a fixed end, it reverses direction and travels with same speed AND reverses amplitude as shown in sketch above.

When a pulse reaches a free end, it reverses direction and travels with same speed with SAME amplitude.



http://www.physicsclassroom.com/mmedia/waves/fix.cfm

a pulse reaching the end of a medium becomes inverted whenever it either

- reflects off a fixed end,
- or is moving in a less dense medium and reflects off a more dense medium.

Waves are an energy transport phenomenon.

As a disturbance moves through a medium from one particle to its adjacent particle, energy is being transported from one end of the medium to the other.

The particles of a medium oscillate only back and forth, as the wave moves the particles do not displace permanently.

stadium wave cheer

http://www.youtube.com/watch?v=3NxLh-3DdaE

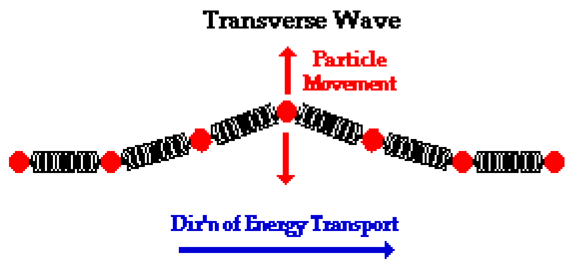
In a stadium wave, the fans do not get out of their seats and walk around the stadium.   Instead,   each fan rises up and returns to the original seat. The disturbance moves through the stadium, yet the fans are not transported. Waves involve the transport of energy without the transport of matter.

3 categories of waves

Longitudinal waves and transverse waves and surface waves

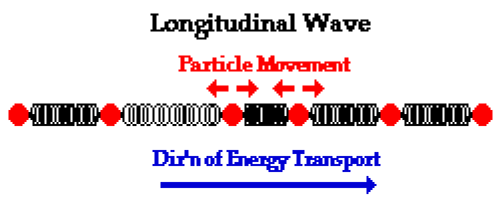
A **transverse wave** is a wave in which particles of the medium move in a direction <u>perpendicular</u> to the direction that the wave moves.

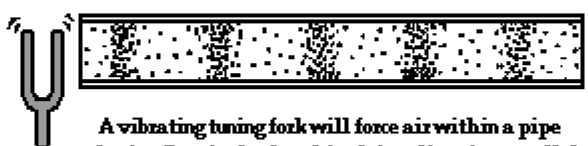
Light waves are transverse waves.



A **longitudinal wave** is a wave in which particles of the medium move in a direction <u>parallel</u> to the direction that the wave moves

Sound waves are **longitudinal waves**



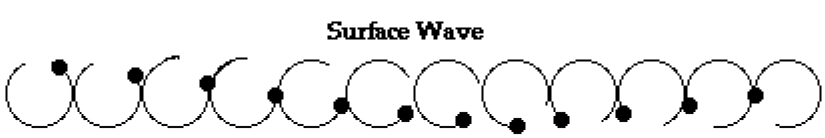


A vibrating tuning fork will force air within a pipe to begin vibrating back and forth in a direction parallel to the energy transport; sound is a longitudinal wave.

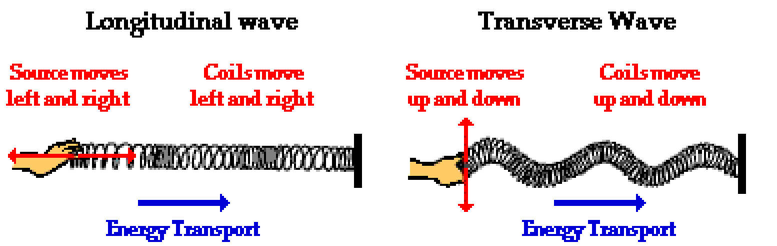
Waves traveling though a solid can be either longitudinal or transverse

Waves traveling through a liquid are only longitudinal.

A **surface wave** is a wave in which particles of the medium undergo a circular motion.



A surface wave is sometimes referred to as a circular wave since particles of the medium undergo a motion in a complete circle.



The subsequent direction of motion of individual particles of a medium is the same as the direction of vibration of the source of the disturbance.

http://www.physicsclassroom.com/mmedia/waves/lw.cfm

Electromagnetic waves transmit energy without a medium.
Example: light waves
A mechanical wave must have a medium to transmit energy.
Examples: slinky waves, ropes, sound

* * * * * * * * * *

14) A transverse wave is transporting energy from east to west. The particles of the medium will move_____.

a. east to west only   b. both eastward and westward

c. north to south only   d. both northward and southward

15)A wave is transporting energy from left to right. The particles of the medium are moving back and forth in a leftward and rightward direction. This type of wave is known as a ____.

a. mechanical   b. electromagnetic
c. transverse   d. longitudinal

16) Describe how the fans in a stadium must move in order to produce a longitudinal stadium wave.

17) A sound wave is a **mechanical wave**, not an electromagnetic wave. This means that

a. particles of the medium move perpendicular to the direction of energy transport.

b. a sound wave transports its energy through a vacuum.

c. particles of the medium regularly and repeatedly oscillate about their rest position.

d. a medium is required in order for sound waves to transport energy.

18) A science fiction film depicts inhabitants of one spaceship (in outer space) hearing the sound of a nearby spaceship as it zooms past at high speeds. Critique the physics of this film.

19) If you strike a horizontal rod vertically from above, what can be said about the waves created in the rod?

a. The particles vibrate horizontally along the direction of the rod.

b. The particles vibrate vertically, perpendicular to the direction of the rod.

c. The particles vibrate in circles, perpendicular to the direction of the rod.

d. The particles travel along the rod from the point of impact to its end.

20) Which of the following is not a characteristic of mechanical waves?

a. They consist of disturbances or oscillations of a medium.

b. They transport energy.

c. They travel in a direction that is at right angles to the direction of the particles of the medium.

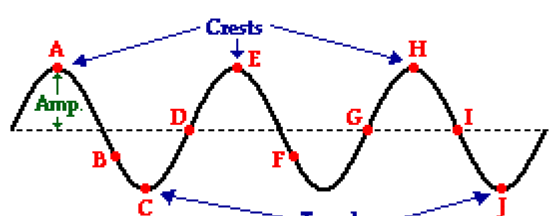
d. They are created by a vibrating source.

21) The sonar device on a fishing boat uses underwater sound to locate fish. Would you expect sonar to be a longitudinal or a transverse wave?

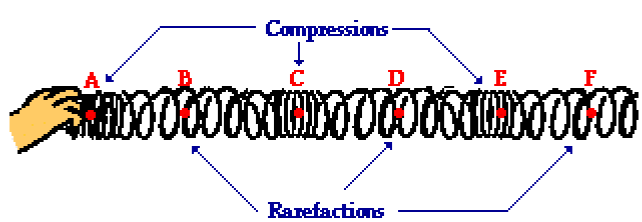
Waves

Transverse wave: dashed line is equilibrium position

Wavelength λ = length of one complete cycle; distance between successive same point, such as crests

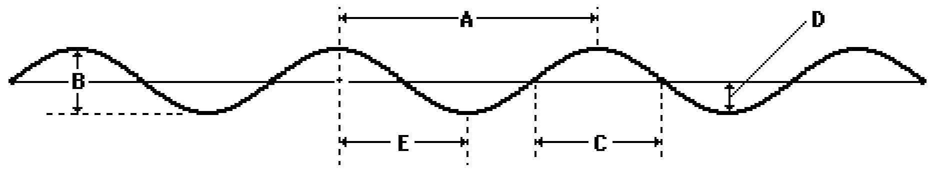


= distance A to E ,, or E t o H, pr D tp G etc



Longitudinal wave :

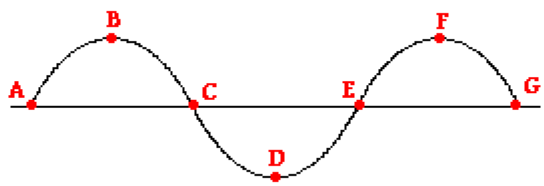
Consider the diagram below in order to answer questions #22-23



22. The wavelength of the wave in the diagram above is given by letter ______.

23. The amplitude of the wave in the diagram above is given by letter _____.

24. Indicate the interval that represents one full wavelength.



a. A to C b. B to D c. A to G d. C to G

wave frequency f = number of cycles/sec

period T = time for 1 complete cycle 1 Hz = 1 cycle/sec

T = 1/f f = 1/T

25. A wave is introduced into a thin wire held tight at each end. It has an amplitude of 3.8 cm, a frequency of 51.2 Hz and a distance from a crest to the neighboring trough of 12.8 cm. Determine the period of such a wave.

26. Frieda the fly flaps its wings back and forth 121 times each second. The period of the wing flapping is ____ sec.

27. A tennis coach paces back and forth along the sideline 10 times in 2 minutes. The frequency of her pacing is ________ Hz.

a. 5.0 b. 0.20 c. 0.12 d. 0.083

28. Non-digital clocks (which are becoming more rare) have a second hand that rotates around in a regular and repeating fashion. The frequency of rotation of a second hand on a clock is _______ Hz.

a. 1/60 b. 1/12 c. 1/2
d. 1 e. 60

29. Olive accompanies her father to the park for an afternoon of fun. While there, she hops on the swing and begins a motion characterized by a complete back-and-forth cycle every 2 seconds. The frequency of swing is _________.

a. 0.5 Hz b. 1 Hz c. 2 Hz

6. In problem #5, the period of swing is __________.

a. 0.5 sec b. 1 sec c. 2 sec

30. A period of 5.0 seconds corresponds to a frequency of ________ Hertz.

a. 0.2 b. 0.5 c. 0.02 d. 0.05 e. 0.002

31. A physics lab involves the study of the oscillations of a pendulum. If a pendulum makes 33 complete back-and-forth cycles of vibration in 11 seconds, then its period is ______.

32. A child in a swing makes one complete back and forth motion in 3.2 seconds. This statement provides information about the child's

a. speed b. frequency c. period

33. The period of the sound wave produced by a 440 Hertz tuning fork is ___________.

34. As the frequency of a wave increases, the period of the wave ___________.

a. decreases b. increases c. remains the same

A wave is an energy transport phenomenon.

The energy is imparted to the medium as work is done for the initial displacement of a coil or string and the coil acquires KE.

Energy transmitted is proportional to the square of the amplitude of the wave.

$$E \propto A^2$$

35) Mac and Tosh stand 8 meters apart and demonstrate the motion of a transverse wave on a snakey. The wave e can be described as having a vertical distance of 32 cm from a trough to a crest, a frequency of 2.4 Hz, and a horizontal distance of 48 cm from a crest to the nearest trough. Determine the amplitude, period, and wavelength of such a wave.

36) An ocean wave has an amplitude of 2.5 m. Weather conditions suddenly change such that the wave has an amplitude of 5.0 m. The amount of energy transported by the wave is __________.

a. halved b. doubled c. quadrupled d. remains the same

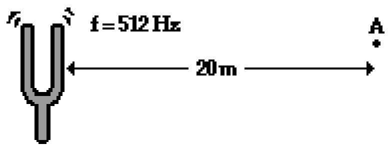
37) Two waves are traveling through a container of an inert gas. Wave A has an amplitude of .1 cm. Wave B has an amplitude of .2 cm. The energy transported by wave B must be __________ the energy transported by wave A.

a. one-fourth b. one-half c. two times larger than d. four times larger than

Speed of a wave: wave speed = distance/time

Tension in rope affects wave speed:

38) The time required for the sound waves (v = 340 m/s) to travel from the tuning fork to point A is _____



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a. 0.020 sec b. 0.059 sec c. 0.59 sec d. 2.9 sec
c. 0.59 second d. 2.9 second

39) Two waves are traveling through the same container of nitrogen gas. Wave A has a wavelength of 1.5 m. Wave B has a wavelength of 4.5 m. The speed of wave B must be ________ the speed of wave A.

a. one-ninth b. one-third
c. the same as d. three times larger than

40). An automatic focus camera is able to focus on objects by use of an ultrasonic sound wave. The camera sends out sound waves that reflect off distant objects and return to the camera. A sensor detects the time it takes for the waves to return and then determines the distance an object is from the camera. The camera lens then focuses at that distance. Now that's a smart camera! In a subsequent life, you might have to be a camera; so try this problem for practice:

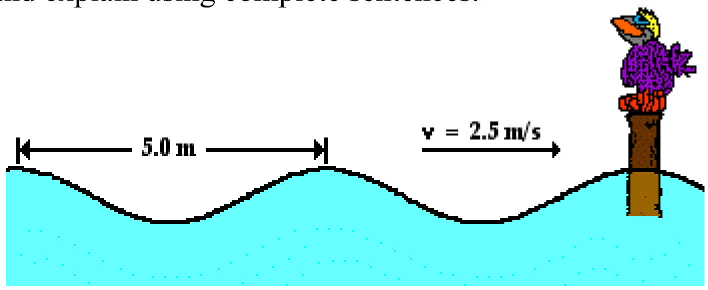
If a sound wave (speed = 340 m/s) returns to the camera 0.150 seconds after leaving the camera, then how far away is the object?

41) **TRUE** or **FALSE**:Doubling the frequency of a wave source doubles the speed of the waves.

42) While hiking through a canyon, Noah Formula lets out a scream. An echo (reflection of the scream off a nearby canyon wall) is heard 0.82 seconds after the scream. The speed of the sound wave in air is 342 m/s. Calculate the distance from Noah to the nearby canyon wall.

43) Mac and Tosh are resting on top of the water near the end of the pool when Mac creates a surface wave. The wave travels the length of the pool and back in 25 seconds. The pool is 25 meters long. Determine the speed of the wave.

44) The water waves below are traveling along the surface of the ocean at a speed of 2.5 m/s and splashing periodically against Wilbert's perch. Each adjacent crest is 5 meters apart. The crests splash Wilbert's feet upon reaching his perch. How much time passes between each successive drenching? Answer and explain using complete sentences.



Wave equation : wavespeed = wavelength/period = wavelenth●frequency

Vel = λ/T = λf [remember: $\nu = c/\lambda$]

45) Two waves on identical strings have frequencies in a ratio of 2 to 1. If their wave speeds are the same, then how do their wavelengths compare?

a. 2:1 b. 1:2 c. 4:1 d. 1:4

46) Mac and Tosh stand 8 meters apart and demonstrate the motion of a transverse wave on a snakey. The wave e can be described as having a vertical distance of 32 cm from a trough to a crest, a frequency of 2.4 Hz, and a horizontal distance of 48 cm from a crest to the nearest trough. Determine the amplitude, period, and wavelength and speed of such a wave.

47) Dawn and Aram have stretched a slinky between them and begin experimenting with waves. As the frequency of the waves is doubled,

a. the wavelength is halved and the speed remains constant

b. the wavelength remains constant and the speed is doubled

c. both the wavelength and the speed are halved.

d. both the wavelength and the speed remain constant.

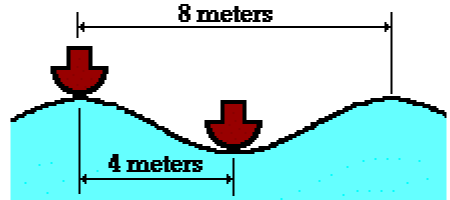
48) A ruby-throated hummingbird beats its wings at a rate of about 70 wing beats per second.

a. What is the frequency in Hertz of the sound wave?

b. Assuming the sound wave moves with a velocity of 350 m/s, what is the wavelength of the wave?

5. Ocean waves are observed to travel along the water surface during a developing storm. A Coast Guard weather station observes that there is a vertical distance from high point to low point of 4.6 meters and a horizontal distance of 8.6 meters between adjacent crests. The waves splash into the station once every 6.2 seconds. Determine the frequency and the speed of these waves.

6. Two boats are anchored 4 meters apart. They bob up and down, returning to the same up position every 3 seconds. When one is up the other is down. There are never any wave crests between the boats. Calculate the speed of the waves.

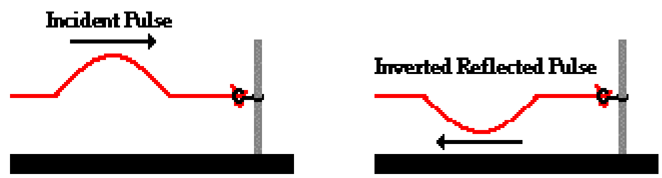


Boundary behavior= behavior of wave or pulse at a boundary.

A boundary is where a medium ends or a different medium begins

Remember Sound waves bounce back from a hard surface.

Waves in strings:



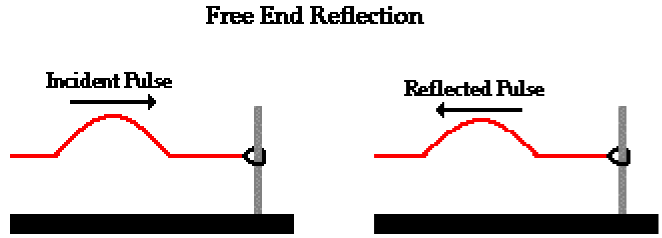
Fixed end behavior: reflected wave inverts

- the speed of the reflected pulse is the same as the speed of the incident pulse.

- The wavelength of the reflected pulse is the same as the wavelength of the incident pulse.
- The amplitude of the reflected pulse is less than the amplitude of the incident pulse.

http://www.physicsclassroom.com/mmedia/waves/fix.cfm

free end behavior: reflected wave only travels opposite direction



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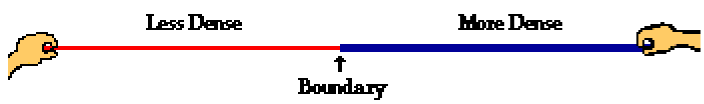
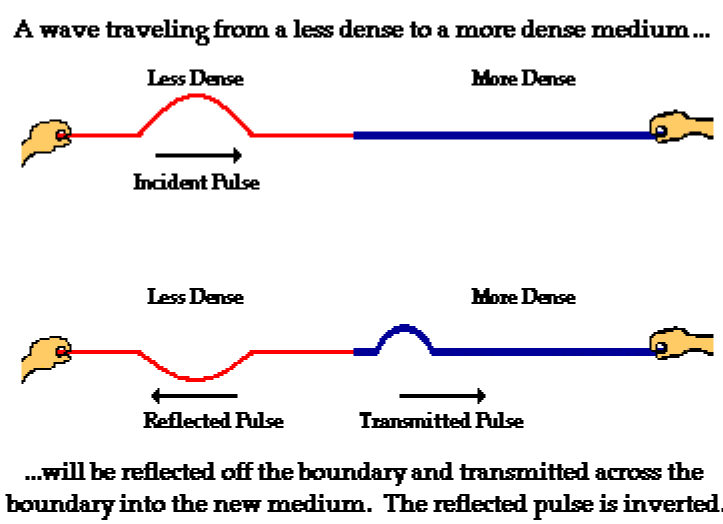
Transmission from less dense to more dense medium



Upon reaching the boundary, the usual two behaviors will occur.

- A portion of the energy carried by the incident pulse is reflected and returns towards the left end of the thin rope. The disturbance that returns to the left after bouncing off the boundary is known as the **reflected pulse**.
- A portion of the energy carried by the incident pulse is transmitted into the thick rope. The disturbance that continues moving to the right is known as the **transmitted pulse**.



Comparisons can also be made between the characteristics of the transmitted pulse and those of the reflected pulse. Once more there are several noteworthy characteristics.

- The transmitted pulse (in the more dense medium) is traveling slower than the reflected pulse (in the less dense medium).
- The transmitted pulse (in the more dense medium) has a smaller wavelength than the reflected pulse (in the less dense medium).
- The speed and the wavelength of the reflected pulse are the same as the speed and the wavelength of the incident pulse.

Recall the speed of a wave is dependent upon the properties of the medium.

Waves always travel fastest in the least dense medium, so the reflected pulse will be traveling faster than the transmitted pulse.

Particles in the more dense medium will be vibrating with the same frequency as particles in the less dense medium. So the reflected and transmitted pulses have the different speeds but the same frequency.

the boundary behavior of waves in ropes can be summarized by the following principles:

- The wave speed is always greatest in the least dense rope.
- The wavelength is always greatest in the least dense rope.
- The frequency of a wave is not altered by crossing a boundary.
- The reflected pulse becomes inverted when a wave in a less dense rope is heading towards a boundary with a more dense rope.
- The amplitude of the incident pulse is always greater than the amplitude of the reflected pulse.

http://www.physicsclassroom.com/mmedia/waves/ltm.cfm

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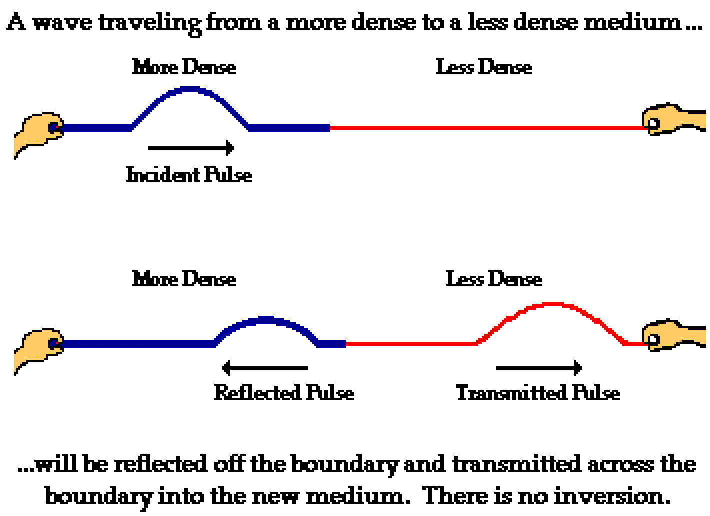


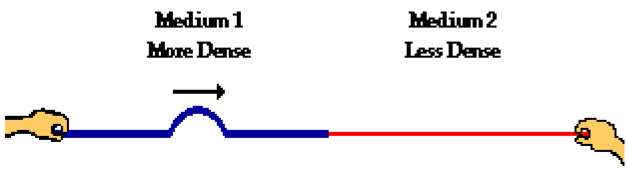
Comparisons between the characteristics of the transmitted pulse and the reflected pulse lead to the following observations.

- The transmitted pulse (in the less dense medium) is traveling faster than the reflected pulse (in the more dense medium).
- The transmitted pulse (in the less dense medium) has a larger wavelength than the reflected pulse (in the more dense medium).
- The speed and the wavelength of the reflected pulse are the same as the speed and the wavelength of the incident pulse.

The boundary behavior of waves in ropes can be summarized by the following principles:

- The wave speed is always greatest in the least dense rope.
- The wavelength is always greatest in the least dense rope.
- The frequency of a wave is not altered by crossing a boundary.
- The reflected pulse becomes inverted when a wave in a less dense rope is heading towards a boundary with a more dense rope.
- The amplitude of the incident pulse is always greater than the amplitude of the reflected pulse

Case 1: A pulse in a more dense medium is traveling towards the boundary with a less dense medium.



1. The reflected pulse in medium 1 ________ (will, will not) be inverted because _______.

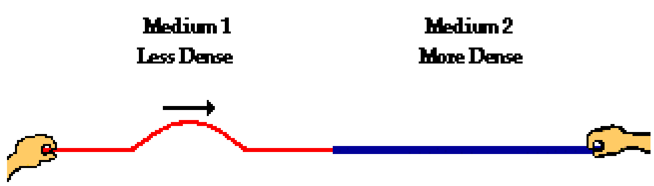
2. The speed of the transmitted pulse will be ___________ (greater than, less than, the same as) the speed of the incident pulse.

3. The speed of the reflected pulse will be ______________ (greater than, less than, the same as) the speed of the incident pulse.

4. The wavelength of the transmitted pulse will be ___________ (greater than, less than, the same as) the wavelength of the incident pulse.

5. The frequency of the transmitted pulse will be ___________ (greater than, less than, the same as) the frequency of the incident pulse.

Case 2: A pulse in a less dense medium is traveling towards the boundary with a more dense medium.



6. The reflected pulse in medium 1 ________ (will, will not) be inverted because _____________.

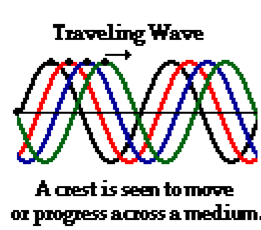
7. The speed of the transmitted pulse will be ___________ (greater than, less than, the same as) the speed of the incident pulse.

8. The speed of the reflected pulse will be ______________ (greater than, less than, the same as) the speed of the incident pulse.

9. The wavelength of the transmitted pulse will be ___________ (greater than, less than, the same as) the wavelength of the incident pulse.

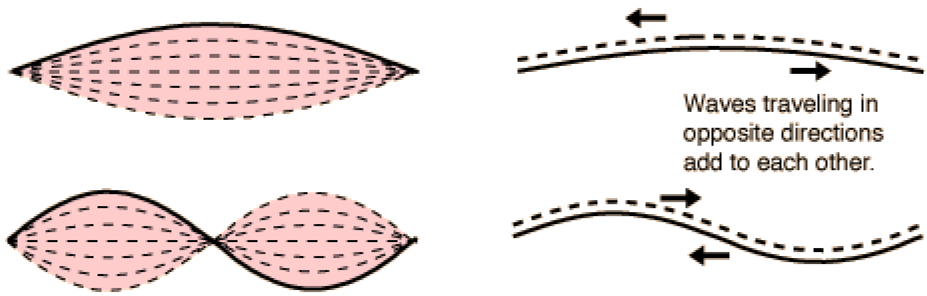
10. The frequency of the transmitted pulse will be ___________ (greater than, less than, the same as) the frequency of the incident pulse.

Traveling wave: wave traveling through a medium



Standing Waves

The term standing wave is often applied to a resonant mode of an extended vibrating object. The resonance is created by constructive interference of two waves which travel in opposite directions in the medium, but the visual effect is that of an entire system moving in simple harmonic motion. The sketches illustrate the fundamental and second harmonic standing waves for a stretched string.

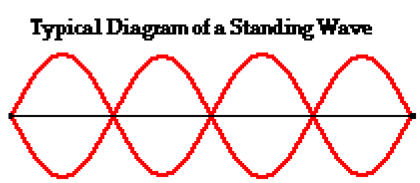


Standing wave: a wave confined at both ends

For certain wavelengths on a string of length L

The forward and reflected waves are superpositioned

The waves appear to be standing still, with fixed nodes and antinodes



http://www.physicsclassroom.com/Class/waves/U10l4c.cfm

Suppose that there was a *ride* at an amusement park that was titled *The Standing Wave*. Which location - node or antinode - on the ride would give the greatest thrill?

2. A standing wave is formed when ____.

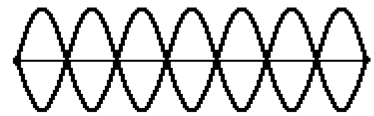
a. a wave refracts due to changes in the properties of the medium.

b. a wave reflects off a canyon wall and is heard shortly after it is formed.

c. red, orange, and yellow wavelengths bend around suspended atmospheric particles.

d. two identical waves moving different directions along the same medium interfere.

3. The number of nodes in the standing wave shown in the diagram at the right is ____.



a. 6 b. 7 c. 8 d. 14

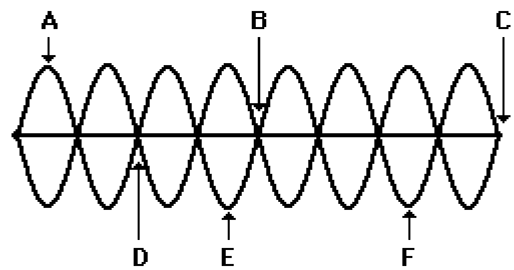
4. The number of antinodes in the standing wave shown in the diagram above right is ____.

a. 6 b. 7 c. 8 d. 14

Consider the standing wave pattern at the right in answering these next two questions.

5. The number of nodes in the entire pattern is ___.

a. 7 b. 8 c.9 d. 16



6. Of all the labeled points, destructive interference occurs at point(s) ____.

a. B, C, and D b. A, E, and F c. A only
d. C only e. all points

Standing waves are an interference phenomenon.
http://www.physicsclassroom.com/mmedia/waves/harm4.cfm

Harmonics and overtones

Resonant frequency is the natural frequency of a vibrating object.

1. It is easy to get an object to vibrate at its resonant frequencies, hard to get it to vibrate at other frequencies.
2. A vibrating object will pick out its resonant frequencies from a complex excitation and vibrate at those frequencies, essentially "filtering out" other frequencies present in the excitation.
3. Most vibrating objects have multiple resonant frequencies.

For a fixed string of length L

Harmonics

An ideal vibrating string will vibrate with its fundamental frequency and all harmonics of that frequency. The position of nodes and antinodes is just the opposite of those for an open air column.

The fundamental frequency can be calculated from

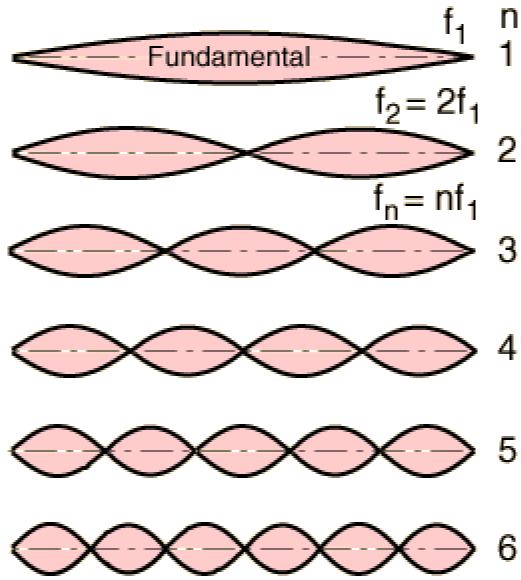
$$f_1 = \frac{v_{wave\ on\ string}}{2L}$$

where

$$v_{wave\ in\ string} = \sqrt{\frac{T}{m/L}}$$

and the harmonics are integer multiples.

T = string tension
m = string mass
L = string length



first harmonic : node at each end and antinode in center. wavelength λ = 2L

Section 6 Forced Vibrations; Resonance

Tacoma bridge: http://www.youtube.com/watch?v=j-zczJXSxnw

A forced vibration is produced by applying a force that has its own particular frequency. The frequency of the external force is the frequency of the vibration.

22) TRUE or FALSE It is possible for a small force to create a large amplitude for harmonic motion.

The natural frequency is the frequency an object tends to vibrate when struck or disturbed. All objects have a natural frequency at which they vibrate.

If the frequency is within the range of human hearing, we hear the vibration :

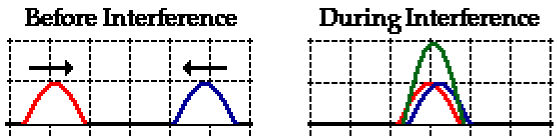
Human hearing range: 20 Hz to 20,000 Hz.

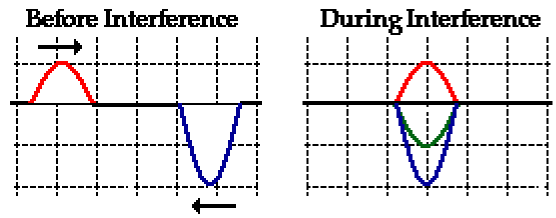
Less than 20 Hz is *infrasound* *or infrasonic wave*

Greater than 20,000 Hz is *ultrasound* *or ultrasonic wave*

Dogs: 50 to 45,000 Hz Cats: 45 to 85,000 Hz Bats as high as 120,000 hz

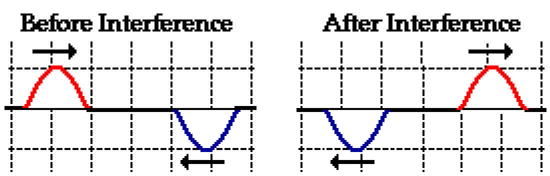
Most humans can detect differences in waves that are more than 7 Hz apart which results in interference and superposition of waves.





Superposition is the addition of waves.   The pulses in the left sketches   constructively interfere[larger amplitude]. The pulses in the right sketches destructively interfere [cancel] because opposite amplitudes cancel out.

Two identical opposite waves, completely in phase,   completely cancel. This is used in factories to cancel noises made by machinery



Resonance exists if the frequency of the driving force is equal to the natural frequency of the system. *Name some situations in which resonance is desired and some in which it is destructive.*

<u>Section 7 Wave Motion</u>

A pulse is a single, localized disturbance that travels in a medium. *A periodic wave is a repeated propagation of a disturbance through a medium (except for light) without any net displacement of the medium.

20) TRUE or FALSE Each particle of a water wave merely oscillates about an equilibrium point.

21) define wave amplitude, wavelength, frequency

22)The fundamental equation of wave propagation is $v = \lambda f$. It is true for all waves. For waves of small amplitude on a string v =

<u>Section 8 Types of Waves: Transverse and Longitudinal</u>

For a longitudinal wave the medium oscillates in SHM parallel to the wave velocity direction. For a transverse wave the medium oscillates in SHM perpendicular to the wave velocity direction.

23)List two transverse waves: List two longitudinal waves:

24) TRUE or FALSE A water wave is a transverse wave.

Sections 9 & 10 Energy Transported by Waves

The energy transmitted by a wave is proportional to the square of the frequency and the square of the amplitude of the wave. The intensity of a wave is a measure of the amount of power transmitted through a unit of area. I = P/A e.g. watts/m^2 The intensity of sunlight at the top of the earth's atmosphere is 1,370 watts/m^2 .

25) What minimum area of a solar collector is needed if the solar collector is to be the sole power source for a 100 watt light bulb?

26) What is the intensity of sunlight at the top of the Mar's atmosphere? Mars is 2.28 x 10^6 km from the sun.

Section 11 Reflection and Interference of Waves

When a pulse on a string hits a wall it reflects with a 180^o phase shift.

27) Write down the definitions for wave front, ray, plane wave

*The **principle of superposition**: If two waves occupy the same space at the same time then the net displacement of the medium is the sum of the individual wave displacements. (This assumes that the medium does not exceed its elastic limit.)

If both waves have the same sign of displacement then the net displacement will be larger than each individual displacement. *This situation is called **constructive interference**. The two waves are said to be **in phase**. If the displacements have opposite signs then the net displacement will be smaller than the magnitude of the largest displacement. *This situation is called **destructive interference**. The two waves are said to be **out of phase**.

Section 12 Standing Waves; Resonance

If two interfering waves have the same wavelengths and amplitudes and opposite directions of travel a standing wave is produced. There will be locations (nodes) at which the displacement of the medium is always zero. The distance between adjacent nodes is ½ wavelength. Between the nodes are antinodes. The medium has its maximum vibration at the antinodes. There is ¼ wavelength between a node and antinode.

*The lowest frequency of a standing wave is called the **fundamental frequency**. For a string anchored at both ends the fundamental frequency is

$f_1 = V / (2L)$

The harmonic frequencies are integer multiples of the fundamental frequency. $f_n = n * f_1$

28) The speed of a transverse wave on a string is given by V =