Name: Key

Waves

Read from **Lesson 1** of the **Waves** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/waves/u10l1a.html
http://www.physicsclassroom.com/Class/waves/u10l1b.html
http://www.physicsclassroom.com/Class/waves/u10l1c.html

MOP Connection: Waves: sublevel 1

TRUE or FALSE: Identify the following statements as being either true (T) or false (F).

T or F?

T 1. Waves are created by a vibration.

F 2. As a wave moves through a medium, the individual particles of the medium move from the source of the wave to another location some distance away.

T 3. Waves are a means of transporting energy from one location to another without actually displacing matter from one location to another.

F 4. An ocean wave will transport ocean water from near the middle of the ocean to a location near the shore.

T 5. As mechanical waves move through a medium, particles of the medium undergo a periodic and repeated vibration about a fixed position.

6. Describe how a wave is different than a pulse.

Pulse - one jolt of energy

wave - repeated fluctuations

7. Mechanical waves propagate or move through a medium because ________.
   a. the particles of the medium are able to move along the curved wavelike pathway
   [✓ b.] one particle pushes or pulls on the adjacent particle which pushes or pulls on the next particle which ...
   c. the initial vibration of the medium causes the medium to assume the wavelike shape and this shape subsequently moves from one location to another.

8. Which of the following categories of waves require a medium in order to transport energy from one location to another?
   [✓ a.] mechanical
   b. electromagnetic

Wave Basics

9. What's Wrong With This?

Suppose you're watching a science fiction movie and one of the scenes involves a spaceship battle in outer space. Spaceship A launches a successful strike on spaceship B. The scene is presented from the perspective of spaceship A. The occupants of spaceship A view spaceship B blowing up as the result of the successful missile strike. They see the flames of the explosion and shortly thereafter hear the thunderous sound of the explosion.

While the scene is definitely exciting, there is a significant fault with it in terms of the physics. What law of physics was violated in the filming of the scene? Explain.

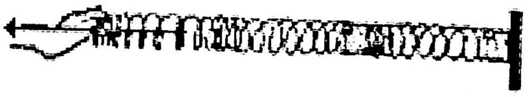
-no particles in space to carry the sound

10. The arrows on the diagrams below represent the direction of particle motion.

D:
a.

Diagram A

Diagram B



11. Compare the direction in which particles of the medium vibrate for a longitudinal wave compared to a transve

oscillate ↑ ↓

wave → ←

perpendicular to oscillations

oscillate ⇄

wave → ←

parallel to oscillations

Name: ____________________

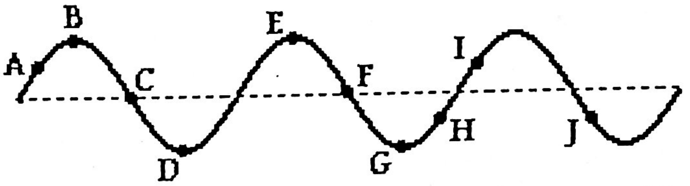
Describing Waves

Read from **Lesson 2** of the **Waves** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/waves/u10l2a.html
http://www.physicsclassroom.com/Class/waves/u10l2b.html
http://www.physicsclassroom.com/Class/waves/u10l2c.html
http://www.physicsclassroom.com/Class/waves/u10l2d.html

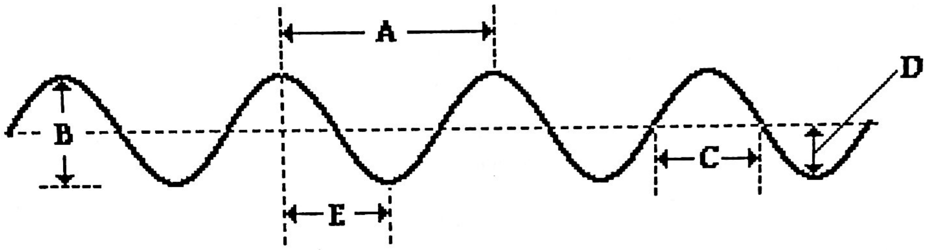
MOP Connection: Waves: sublevels 2 and 3

1. A wave is introduced into a medium and a snapshot of the medium at a particular instant in time is shown at the right. Several positions along the medium are labeled. Categorize the positions as either crests or troughs.

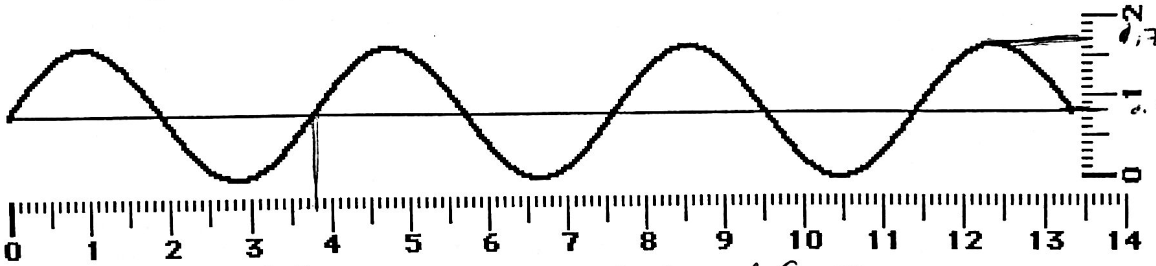


Crests: B, P, E, G   Troughs: D, G,   Neither: C, A, F, H, I, J

2. The wavelength of the wave in the diagram below is given by letter A and the amplitude of the wave in the diagram below is given by letter D.



3. A sine curve that represents a transverse wave is drawn below. Use the centimeter ruler to measure the wavelength and amplitude of the wave (show units).



a. Wavelength = 3.8cm   b. Amplitude = 0.9 cm

4. The number of cycles of a periodic wave per unit time is called the wave's frequency

5. Any repeated and periodic motion can be described by a frequency. For instance, the frequency of rotation of a second hand on a clock is a.
a. 1/60 Hz   b. 1/12 Hz   c. 1/2 Hz   d. 1 Hz e. 60 Hz

6. A pendulum makes 40 vibrations in 20 seconds. Calculate its period?

TIP

Throughout this unit, internalize the meaning of terms such as period, frequency, wavelength and speed. Utilize the meaning of these terms to answer conceptual questions; avoid *formula fixation.*

$\frac{40}{20} = \frac{2}{1}$ Hz

$T = \frac{1}{2}$ s

7. Olive Udadi 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 5.0 seconds. This statement provides info about the child's C.
a. speed   b. frequency   c. period

8. The frequency of Olive's periodic motion (in #7) is a.
a. 0.20 Hz   b. 0.40 Hz   c. 2.5 Hz   d. 5.0 Hz

9. A period of 5.0 seconds corresponds to a frequency of a Hz.
a. 0.2   b. 0.5   c. 0.02   d. 0.05   e. 0.002

10. The period of a 261-Hertz sound wave is 0.00385 s.

11. As the frequency of a wave increases, the period of the wave a.
[✓ a.] decreases   b. increases   c. remains the same

12. The speed of a wave refers to
a. how often it vibrates to and fro.
b. how high it vibrates.
c. how much time it takes to vibrate to and fro.
[✓ d.] how far a given point (e.g., a crest) on the wave travels per unit of time.

13. Write the two equations that can be used to determine the speed of a wave.

$d = vt$ $v = \lambda \cdot f$

14. 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. **PSYW**

$d = 50\,m$ (down + back)

$t = 25\,s$ $50 = v \cdot 25$

$v = 2\,\frac{m}{s}$

15. A fisherman uses a sonic ranger to determine the depth of a lake. The sound waves travel at 1210 m/s through the water and require 0.020 seconds to travel to the lake's bottom and back to the boat. How deep is the lake? **PSYW**

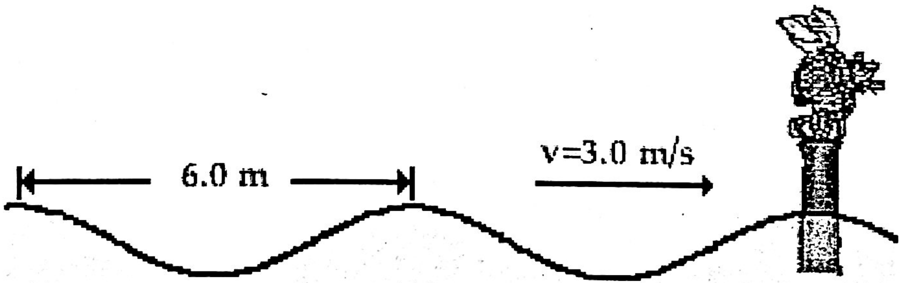
$v = 1210\,\frac{m}{s}$ $t = 0.02\,s$

24.2 m = down + back

$d = 1210\,\frac{m}{s} \cdot 0.02\,s = 24.2\,m$

depth = $\boxed{12.1\,m}$

16. The water waves below are traveling with a speed of 3.0 m/s and splashing periodically against the Wilbert's perch. Each adjacent crest is 6.0 meters apart and splashes Wilbert's feet upon reaching his perch. How much time passes between each successive drenching? ________ Answer and explain using complete sentences or a calculation.



$d = 6$

$v = 3\,\frac{m}{s}$

$d = vt$

$6 = 3 \cdot t$

$\boxed{t = 2\,s}$

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Wave Speed

Read from **Lesson 2** of the **Waves** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/waves/u10l2d.html
http://www.physicsclassroom.com/Class/waves/u10l2e.html

MOP Connection: Waves: sublevels 3 and 4

1. A physics teacher attaches a slinky to the wall and begins introducing pulses with different amplitude. Which of the two pulses below will take the least amount of time to reach the wall?

Justify your answer:

Same medium, same velocity, same time.

2. The physics teacher then begins introducing pulses with a different wavelength. Which of the two pulses below will take the least amount of time to reach the wall?

Justify your answer:

same medium, same velocity, longer λ so shorter time.

3. Stan and Anna are conducting a slinky experiment. They are studying the possible effect of several variables upon the speed of a wave in a slinky. Their data table is shown below. Fill in the blanks in the table, analyze the data, and answer the following questions.

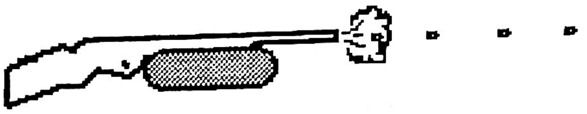
Medium	Wavelength	Frequency	Speed
Zinc, 1-in. dia. coils	1.75 m	2.0 Hz	3.5 m/s
Zinc, 1-in. dia. coils	0.90 m	3.9 Hz	3.51 m/s
Copper, 1-in. dia. coils	1.19 m	2.1 Hz	2.5 m/s
Copper, 1-in. dia. coils	0.60 m	4.2 Hz	2.52 m/s
Zinc, 3-in. dia. coils	1.82 m	2.2 Hz	4 m/s
Zinc, 3-in. dia. coils	0.95 m	4.2 Hz	3.99 m/s

4. As the wavelength of a wave in a uniform medium increases, its speed will _____.
   a. decrease b. increase [✓ c. remain the same] same medium

5. As the wavelength of a wave in a uniform medium increases, its frequency will _____.
   [✓ a. decrease] b. increase c. remain the same

6. The speed of a wave depends upon (i.e., is causally effected by) ...
   [✓ a. the properties of the medium through which the wave travels]
   b. the wavelength of the wave. c. the frequency of the wave.
   d. both the wavelength and the frequency of the wave.

7. A water gun fires 5 *squirts* per second. The speed of the *squirts* is 15 m/s.



   a. By how much distance is each consecutive *squirt* separated?

   $f = 5 Hz$ $V = 15 m/s$ $\lambda = ?$ $15 \frac{m}{s} = 5 Hz \cdot \lambda$ $\boxed{\lambda = 3 m}$

   b. What happens to the distance between the *squirts* if the rate of fire is increased?

   decreases

   c. Explain how this example is analogous to the relationship between wave frequency and wavelength.

   as frequency increases, & wavelength decreases

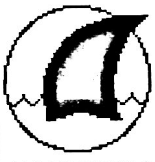
8. What is the speed of a wave that has a frequency of 200 Hz and a wavelength of 0.50 m? **PSYW**

   $V = 200 Hz \cdot 0.5 m = \boxed{100 m/s}$

9. Waves are observed to splash upon the rocks at the shore every 6.0 seconds. The distance measured from crest to adjacent crest is 8.0 m. The distance measured from the lowest to the highest point on the medium is 10.0 m. Determine the frequency, wavelength and speed of these waves. **PSYW**

   $T = 6 s$
   $\lambda = 8 m$
   $A = 10 m$

   $f = \frac{1}{T} = \boxed{\frac{1}{6} Hz}$ $\boxed{V = \frac{8 m}{6 s}}$ $\boxed{\lambda = 8 m}$



CAUTION!

Do you have *formula fixation?* A useful test: were you successful with questions #8-11?

10. The period of a wave is 0.0300 seconds. It travels at a velocity of 10.0 m/s. Determine the frequency and the wavelength of the wave. **PSYW**

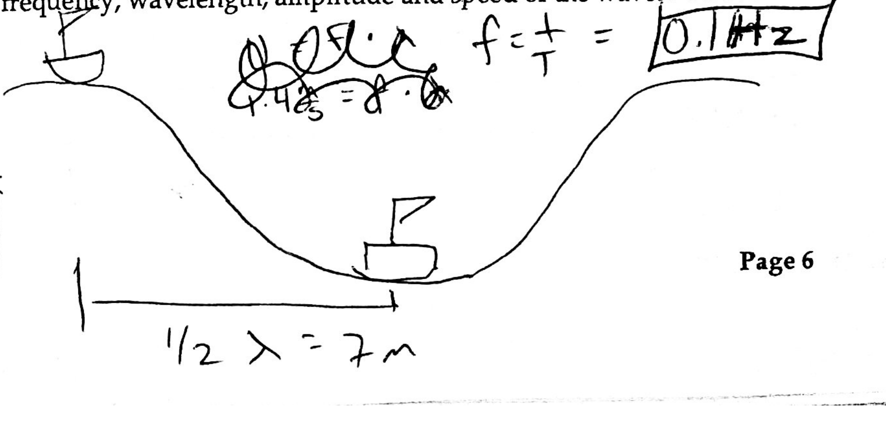
   $T = 0.0300 s$ $f = 33.\bar{3} Hz$
   $V = 10 \frac{m}{s} = 33.3 Hz \cdot \lambda$ $\boxed{\lambda = 0.3 m}$

11. A wave having a wavelength of 4.0 meters and an amplitude of 2.5 meters travels a distance of 24 meters in 8.0 seconds. Determine the frequency and the period of the wave. **PSYW**

   $\lambda = 4 m$
   $A = 2.5 m$
   $d = 24 m$
   $t = 8.0 s$
   $d = vt$
   $2.5 m = V \cdot 8 s$
   $U = 0.3125 \frac{m}{s} = \lambda \cdot f$
   $0.3125 \frac{m}{s} = 4 m \cdot f$
   $f = 0.078 Hz$
   $T = \frac{1}{f} = \boxed{12.8 s}$

12. Two boats are anchored 7.0 meters apart. They bob up and down, returning to the same up position every 10.0 seconds. The boats rise a vertical distance of 7.0 meters between their lowest and their highest point. When one is up the other is down. There are never any wave crests between the boats. Determine the period, frequency, wavelength, amplitude and speed of the waves. **PSYW**

   $\boxed{T = 10 s}$ $\boxed{A = 7/2}$
   $\lambda = ~~7m~~ 14 m$
   $V = \frac{\lambda}{T} = \frac{14 m}{10 s} = \boxed{1.4 \frac{m}{s}}$
   ~~[illegible]~~
   $f = \frac{1}{T} = \boxed{0.1 Hz}$



Name: ____________________

Standing Wave Mathematics

Read from **Lesson 4** of the **Waves** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/waves/u10l4a.html
http://www.physicsclassroom.com/Class/waves/u10l4b.html
http://www.physicsclassroom.com/Class/waves/u10l4c.html
http://www.physicsclassroom.com/Class/waves/u10l4d.html
http://www.physicsclassroom.com/Class/waves/u10l4e.html

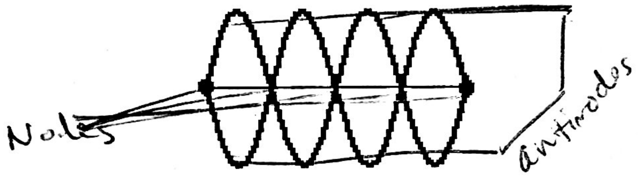
MOP Connection: Waves: sublevels 7 and 8

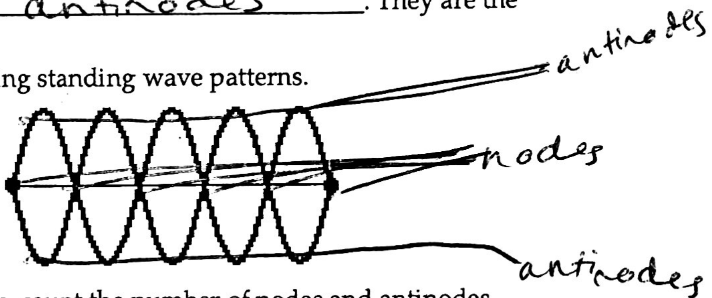
A standing wave pattern results in a string, rope or snakey as a result of the interaction between the waves introduced on one end with the reflection of the waves returning from the opposite end. At certain frequencies, a pattern will be established within the medium in which there are positions that always appear to be stationary. Midway between each of these stationary positions are positions which are undergoing rapid motion between a maximum positive and maximum negative displacement from their resting position.

1. The positions along the medium that appear to be stationary are known as nodes. They are points of **no dis**placement.

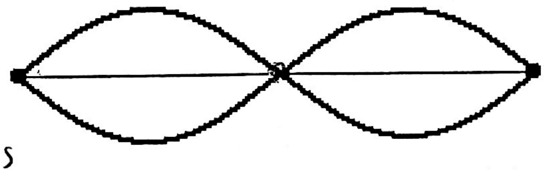
2. The positions along the medium that are undergoing rapid motion between a maximum positive and maximum negative displacement are known as antinodes. They are the **opposite of** the points of **no dis**placement.

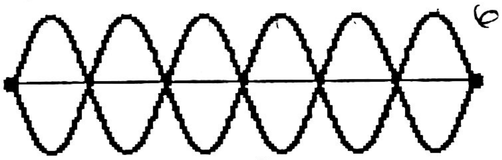
3. Label the nodes (N) and antinodes (AN) in the following standing wave patterns.





4. In each of the two diagrams of standing wave patterns, count the number of nodes and antinodes.





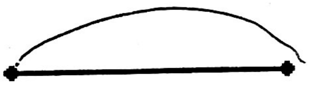
6 antinods
7nodes

3 nodes,
2 antinodes

5. Each node is separated by the adjacent node by a distance that is equal to $\frac{1}{2}$ wavelength.

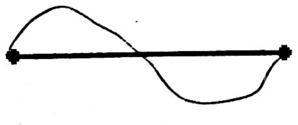
6. Draw the standing wave pattern that would result on the string below if the string vibrated with the first, second, and third harmonic wave patterns. State the relationship between length and wavelength for each of the three patterns.

1st Harmonic



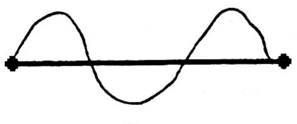
L = $\frac{1}{2}$ λ

2nd Harmonic



L = 1 λ

3rd Harmonic



L = $\frac{3}{2}$ λ

7. Suppose that the string in the above diagram is 1.2 meters long. Determine the wavelength of the waves shown in each of these three patterns.

1st Harmonic

$1.2 = \frac{1}{2}\lambda$

$\lambda = 2.4m$

2nd Harmonic

$1.2 = 1\lambda$

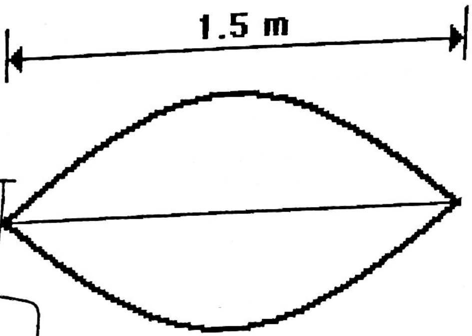
$\lambda = 1.2m$

3rd Harmonic

$1.2 = \frac{3}{2}\lambda$

$\lambda = 0.8m$

8. The string at the right is 1.5 meters long and is vibrating as the first harmonic. The string vibrates up and down with 33 cycles in 10 seconds. Determine the frequency, period, wavelength and speed for this wave. **PSAYW**



$1.5 = \frac{1}{2}\lambda$

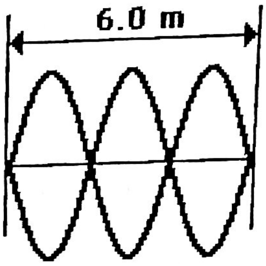
$\lambda = 3m$

$\frac{33 cycles}{10 sec} = \boxed{3.3 Hz = f}$

$\boxed{T = 0.3s}$

$V = 3m \cdot 3.3Hz = \boxed{9.9 \frac{m}{s}}$

9. The string at the right is 6.0 meters long and is vibrating as the third harmonic. The string vibrates up and down with 45 cycles in 10 seconds. Determine the frequency, period, wavelength and speed for this wave. **PSAYW**



$= 1.5\lambda$

$6 = 1.5\lambda \rightarrow \boxed{\lambda = 4m}$

$\frac{45 cycles}{10 sec} = \boxed{4.5 Hz = f}$

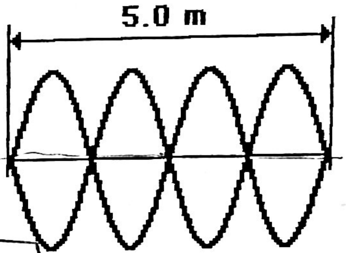
$v = \lambda \cdot f$

$V = 4 \cdot 4.5$

$\boxed{V = 18 m/s}$

$T = \frac{1}{4.5} = \boxed{0.\bar{2}s}$

10. The string at the right is 5.0 meters long and is vibrating as the fourth harmonic. The string vibrates up and down with 48 cycles in 20 seconds. Determine the frequency, period, wavelength and speed for this wave. **PSAYW**



2λ

$5m = 2\lambda$

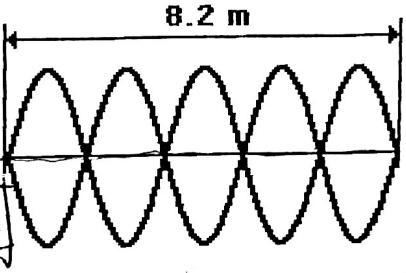
$\boxed{2.5m = \lambda}$

$\frac{48 cycles}{20 sec} = \boxed{2.4 Hz}$

$T = \frac{1}{2.4 Hz} = \boxed{0.417s}$

$V = 2.5 \cdot 2.4 = \boxed{6 \frac{m}{s}}$

11. The string at the right is 8.2 meters long and is vibrating as the fifth harmonic. The string vibrates up and down with 21 cycles in 5 seconds. Determine the frequency, period, wavelength and speed for this wave. **PSAYW**



3.5λ

$8.2m = 3.5\lambda$

$\boxed{\lambda = 2.34m}$

$\frac{21 cycles}{5 sec} = \boxed{4.2Hz}$

$\boxed{T = \frac{1}{4.2} = 0.238s}$

$v = \lambda \cdot f$

$V = 2.34m \cdot 4.2Hz$

$\boxed{V = 9.828 \frac{m}{s}}$

Name: ______________________

Interference of Waves

Read from **Lesson 3** of the **Waves** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/waves/u10l3c.html

MOP Connection: Waves: sublevel 6

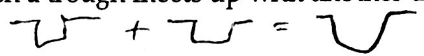
TRUE or FALSE: Identify the following statements as being either true (T) or false (F).

T or F?

F 1. When two pulses meet up with each other while moving through the same medium, they have a tendency to bounce off each other and return back to their origin.

T 2. Constructive interference occurs when a crest meets up with another crest at a given location along the medium.

T 3. Destructive interference occurs when a pulse with an amplitude of +5 units interferes with a pulse with an amplitude of -5 units.

F 4. Destructive interference occurs when a trough meets up with another trough at a given location along the medium. 

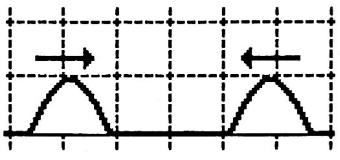
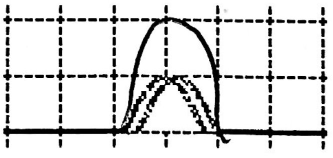
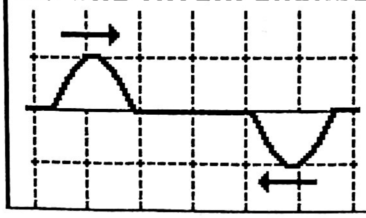
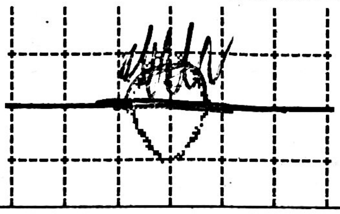
F 5. If a pulse with an amplitude of +5 units interferes with a pulse with an amplitude of +3 units, the resulting amplitude of the medium will be +4 units - the average of the two individual amplitudes.

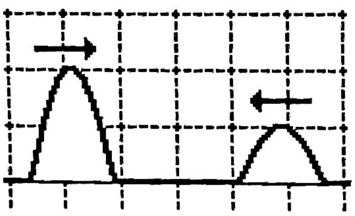
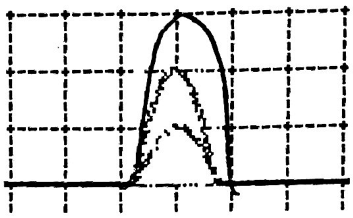
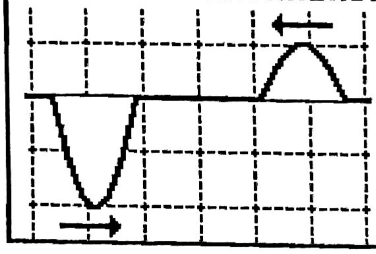
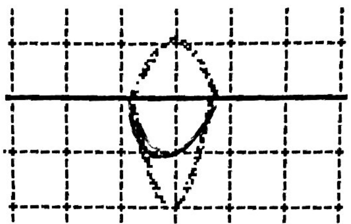
F 6. If a pulse with an amplitude of +5 units interferes with a pulse with an amplitude of -3 units, then neither constructive nor destructive interference occurs. destructive - smaller

F 7. Two sound waves could never interfere in such a manner as to cancel each other out and produce silence.

Principle of Superposition: The effect of two interfering waves upon a medium is to produce a resulting shape and size that is the combination of the shapes and sizes of the individual waves. The amount of displacement of the medium at any given location is simply the vector sum of the displacement of the two individual waves at that location.

8. The diagrams below depict two pulses traveling towards each other and at the moment when they are completely superimposed on each other. For each diagram, sketch the resultant of the two pulses during the interference. Finally, indicate if the example represents a case of constructive or destructive interference.

"Snapshot" of Two Pulses Before and During Interference		Constructive or Destructive?
BEFORE INTERFERENCE 	**DURING INTERFERENCE** 	Const.
BEFORE INTERFERENCE 	**DURING INTERFERENCE** 	dest.

--Continued from front side: **BEFORE INTERFERENCE** 	**DURING INTERFERENCE** 	Const.
BEFORE INTERFERENCE 	**DURING INTERFERENCE** 	dest.

9. Two waves are traveling along the same medium. The diagrams below show the waves on the medium at an instant in time. Utilize the principle of superposition in order to construct the shape of the medium at the instant shown in each diagram. To do so, begin by determining the resulting displacement of the medium at each of the marked locations (†). Approximate the shape of the remainder of the medium by sketching *from dot to dot.*

Diagram A

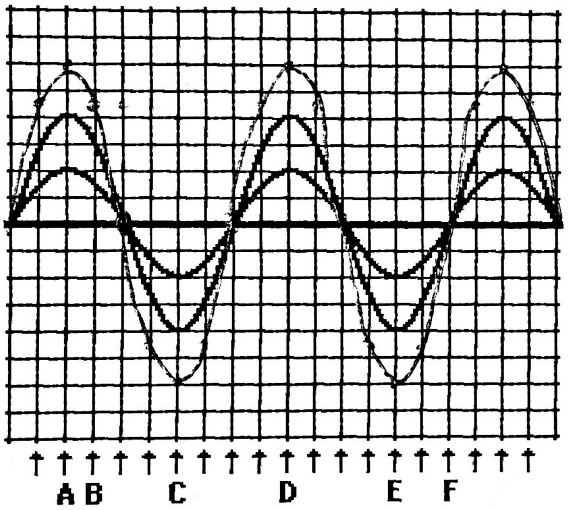
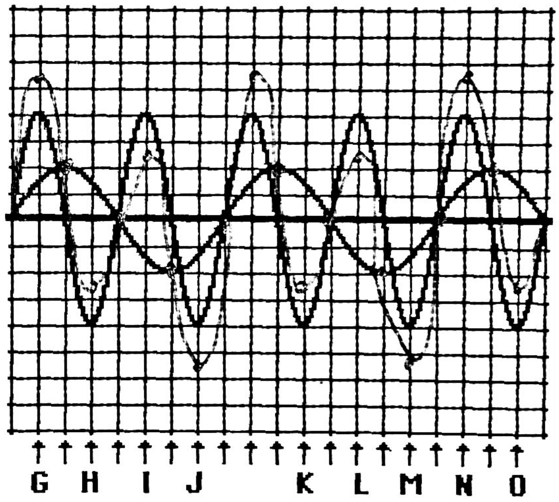


Diagram B



10. Several of the marked positions (†) above are labeled with a letter. Categorize each labeled position along the medium as being a position where either constructive or destructive interference occurs.

Constructive Interference	Destructive Interference
A, B, C, D, E, G, J, M, N	H, I, K, L, O

Neither: F

Name: ______________________________

Boundary Behavior

Read from **Lesson 3** of the **Waves** chapter at **The Physics Classroom:**

http://www.physicsclassroom.com/Class/waves/u10l3a.html

MOP Connection: Waves: sublevel 5

Background:

The behavior of a traveling wave (or pulse) upon reaching the end of a medium is referred to as **boundary behavior**. When one medium ends, another medium begins; the interface of the two media is referred to as the **boundary** and the behavior of a wave at that boundary is described as its boundary behavior. A pulse which is approaching a boundary is referred to as the **incident pulse**. Upon reaching the boundary, a portion of the incident pulse will be reflected and remain in the same medium; and a portion of the incident pulse will pass into (or be transmitted into) the other medium which lies beyond the boundary. The portion of the pulse which is reflected is referred to as the **reflected pulse** and the portion which passes into the other medium is referred to as the **transmitted pulse.** A proper understanding of the boundary behavior of waves involves an ability to answer the following questions.

Fixed and Free End Reflection:

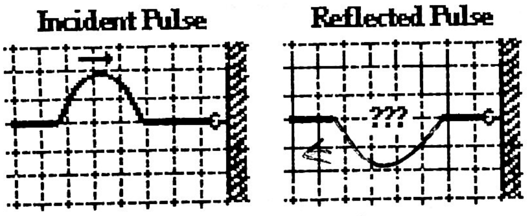
1. State the rule that describes how a pulse will behave at a free- and a fixed-end.

Free - does not invert

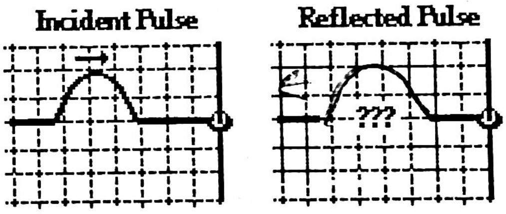
Fixed - inverts

2. Express your understanding of reflection of waves at the end of a medium by drawing the size and orientation of the reflected pulse for the two cases below - reflection off a free end and a fixed end.

Fixed End Reflection

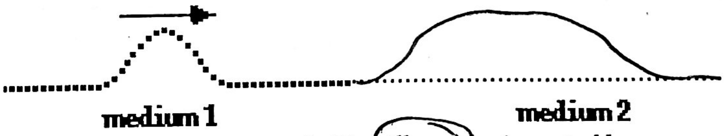


Free End Reflection



Reflection and Transmission of an Incident Pulse at a Boundary Between Two Media:

A pulse is moving from a more dense medium to a less dense medium as shown in the diagram below.



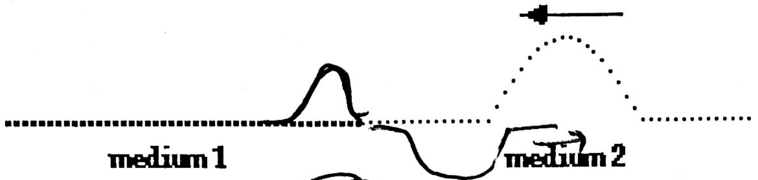
3. The reflected pulse in medium 1 _______ (will, [✓ will not]) be inverted because medium 2 is less dense.

4. The speed of the transmitted pulse will be __________ ([✓ greater than], less than, the same as) the speed of the incident pulse.

5. The speed of the reflected pulse will be ____________ (greater than, less than, [✓ the same as]) the speed of the incident pulse.
↑ same medium

6. The wavelength of the transmitted pulse will be __________ ([✓ greater than], less than, the same as) the wavelength of the incident pulse.

A pulse is moving from a less dense medium to a more dense medium as shown in the diagram below.



7. The reflected pulse in medium 2 ________ ([✓ will], will not) be inverted because Medium 1 B more dense

8. The speed of the transmitted pulse will be __________ (greater than, [✓ less than], the same as) the speed of the incident pulse.

9. The speed of the reflected pulse will be _____________ (greater than, less than, [✓ the same as]) the speed of the incident pulse.

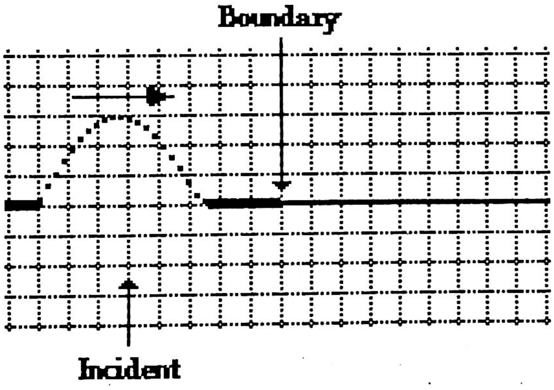
10. The wavelength of the transmitted pulse will be Smaller (greater than, [✓ less than] the same as) the wavelength of the incident pulse.

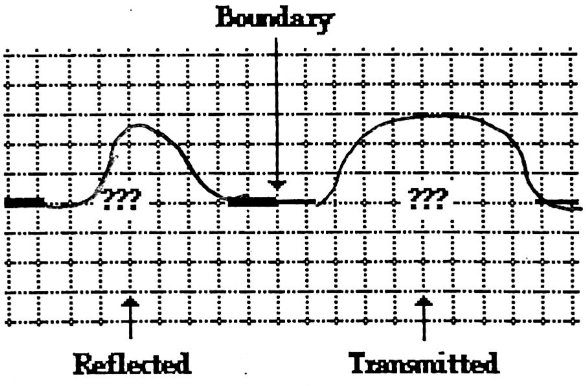
11. Summarize your understanding of boundary behavior by completing the following statements.

When a wave passes across the boundary from one medium to another medium, the ...
... speed is _______________ ([✓ greatest], smallest) in the least dense media.
... wavelength is _______________ ([✓ greatest], smallest) in the least dense media.
... the reflected pulse becomes inverted only when the incident wave is in the __________ (more, [✓ less]) dense medium and heading toward the __________ ([✓ more], less) dense medium.

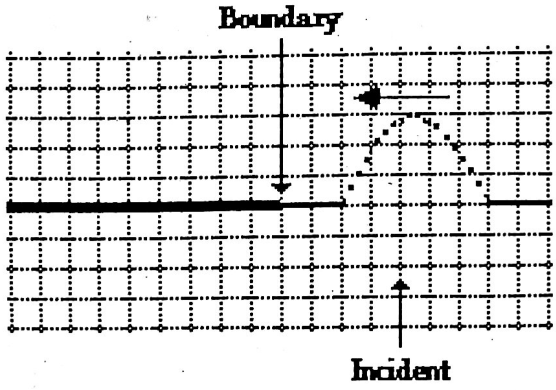
Express your understanding of the rules of boundary behavior by drawing the reflected and transmitted pulses in the following two situations. Show the orientation (inverted or non-inverted, wavelength and speed) of each pulse.

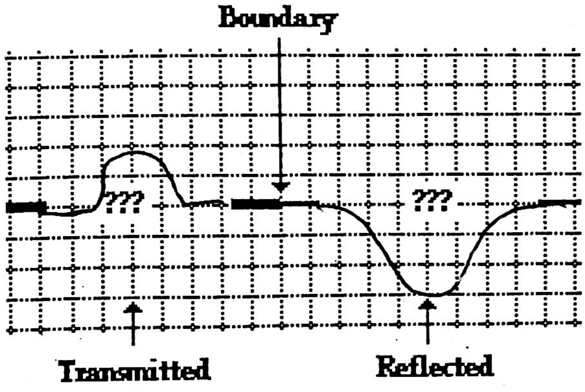
12. Incident pulse is in the more dense medium and traveling toward the less dense medium.





13. Incident pulse is in the less dense medium and traveling toward the more dense medium.





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