LESSON 1 - AN INTRODUCTION TO WAVE PHENOMENA

Overview:

Through a combination of class discussion, animations, demonstrations, lab work and an individual activity, students will be introduced to waves and wave interference.

Suggested Timeline: 4 hours

Materials:

- Waves and Optics in Everyday Life – Unit Organizer
- Activity #1: Catching the Concept of Waves (Teacher Support Material)
- Activity #1 Review: Did You Catch the Concept of Waves (Teacher Support Material)
- Activity #1: Catching the Concept of Waves (Student Handout - Individual)
- Activity #1: Catching the Concept of Waves (Student Handout – Group)
- Activity #1 Review: Did You Catch the Concept of Waves (Student Handout)
- student access to computers with Internet
- computer and projector for display of wave animations and video clips
- bell jar and two cell phones
- starting pistol
- aquarium or large bowl
- floatable bath toy (e.g., rubber duckie)
- tin can ‘telephone’ (two tin cans connected by string)
- Activity #2: Using a Slinky to Investigate Waves (Student Handout)
- Activity #2: Using a Slinky to Investigate Waves (Teacher Support Material)
- the following materials for activity #2 (enough for 1 per 2-3 students):
  - Slinky© springs
  - 3 m pieces of heavy string, such as butcher cord
  - 15 cm pieces of ribbon
  - smaller diameter long springs
- Activity #3: Getting Into Interference (Teacher Support Material) – on overhead transparencies
- Activity #3: Getting Into Interference (Student Handout – Individual)
- Activity #3: Getting Into Interference (Student Handout – Group)

Method:

INDIVIDUAL FORMAT:

1. Have students preview the unit via an examination of their unit overview sheet.
2. Have students complete their ‘Activity #1: Catching the Concept of Waves’ (Student Handout – Individual) by using their student handout notes, a computer to access online animations and/or other textbooks or resources available.
3. Have students complete ‘Activity #1 Review – Did you Catch the Concept of Waves?’ (Student Handout) question sheet.

4. Prior to the lab, have students complete the vocabulary list for ‘Activity #2 – Using a Slinky to Investigate Waves’ (Student Handout).
5. In a large, open area, have students complete the lab, filling in their answers to questions along the way. Their lab handout may be submitted for grading.
6. After reviewing the sample question with them, students should work through ‘Activity #3 – Getting into Interference’ (Student Handout – Individual). Review the solutions on the overhead.

GROUP FORMAT:

1. Preview the unit by having students fill in the unit organizer as you go through it with them.
2. Have students complete their ‘Activity #1: Catching the Concept of Waves - Vocabulary’ (Student Handout) sheet by using their student handout notes and/or other textbooks or resources available.
3. Brainstorm everyday examples of waves with students. Use the ‘Activity #1: Catching the Concept of Waves’ (Teacher Support Material) and have students use the ‘Activity #1: Catching the Concepts of Waves’ (Student Handout - Group) as a note-taking guide.
4. Use the suggested demonstrations, animations and key questions to introduce types of waves and wave behavior.
5. Have students complete ‘Activity #1 Review – Did you Catch the Concept of Waves?’ (Student Handout) question sheet.
6. Have students complete the vocabulary at the start of the ‘Activity #2 – Using a Slinky© to Investigate Waves’ (Student Handout) by using the information in their handout and/or other textbooks or resources available.
7. In a large open area of the school or hallway, have students complete their Slinky© lab investigation and submit completed lab handout.
8. Go through example of how to graph the interference of pulses using ‘Activity #3 – Getting Interference’ (Teacher Handout). Students should use the ‘Activity #3 – Getting Into Interference’ (Student Handout – Group) and complete the rest of the questions individually.

Assessment and Evaluation:

- Assessment of students’ understanding of basic wave concepts through answers to questions.
- Student grade on lab.
- Assessment of students’ understanding of wave interference through questioning.

ACTIVITY OVERVIEW:

Suggested Sequencing:			
Activity	Suggested Timeline	Description	Assignment
1	1.5 hours	As a class or individually, preview unit using unit overview. Have students complete vocabulary list for the activity. Brainstorm everyday examples of waves. Using a series of demonstrations, animations and key questions, introduce the types of waves and basic wave behavior.	Review – Did you Catch the Concept of Waves? (SH)
2	1.5 hours	Have students complete the vocabulary list for the lab. Facilitate the completion of the 'Using a Slinky© to Investigate Waves' Lab.	Slinky Lab Handout (SH) Questions
3	1 hour	Work through the sample problem on the interference of pulses in the 'Getting Into Interference' handout. Facilitate the completion of worksheet problems on the interference of pulses. Review the solutions on the overhead.	Getting Into Interference (SH)

AN INTRODUCTION TO WAVE PHENOMENA

Activity #1 – Catching the Concept of Waves

Everyday examples of waves

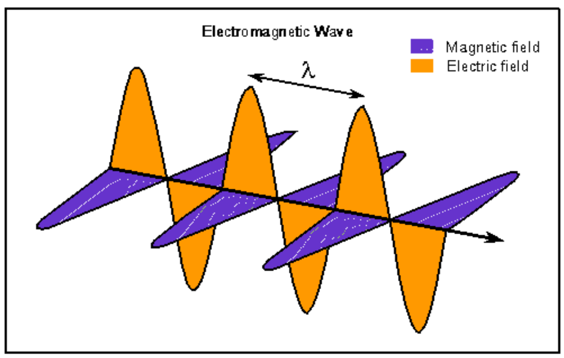
Water waves, waves in a rope or string, waves in a slinky, vibrations in a piece of steel (e.g., train tracks), earthquake waves, sound waves produced by a musical instrument, light waves (more challenging to grasp at this point), microwaves, X-rays, radio waves, the back and forth motion of a pendulum, waving one's hand back and forth

What is a wave?

A vibration or disturbance that moves through a substance (a medium) or through empty space.

There are two types of waves:

Electromagnetic waves: can travel through empty space e.g., light waves, X-rays, radio waves, microwaves



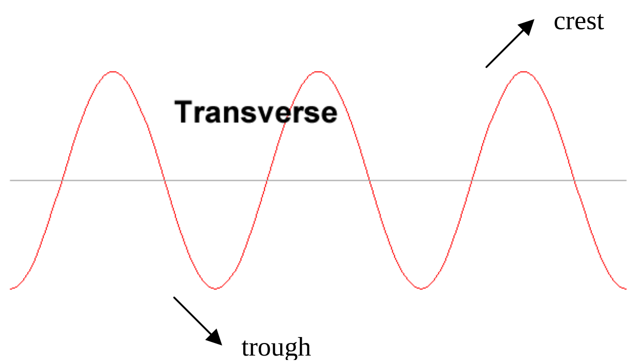
Animation: http://www.jb.man.ac.uk/distance/strobel/light/lighta.htm

Mechanical waves: need a substance or medium to pass through e.g., sound waves, waves through a rope, water waves.

Demonstration: Put a cell phone in a bell chamber. Dial the cell phone number and have it ring *before* evacuating the air. Everyone will be able to hear the ringing of the mechanical sound wave. Pump the air out of the chamber and dial the cell phone again. Leave a message on the phone. The ringing of the mechanical sound wave cannot be heard since there is no air in the chamber for it to travel through. Before removing the phone, ask students if they think that the message got to the phone – e.g., could the radio waves carrying the message reach the phone? Have a student listen to the message on the phone. Review the difference between mechanical and electromagnetic waves.

KEY Q: Why does sunlight reach us here on Earth while the sound of nuclear reactions happening on the sun does not?

a) Transverse waves are mechanical waves in which the particles of the substance carrying the wave vibrate up and down while the wave moves to the right or left (e.g., waves on a rope or spring). The high points of the wave are called crests while the low points are called troughs.



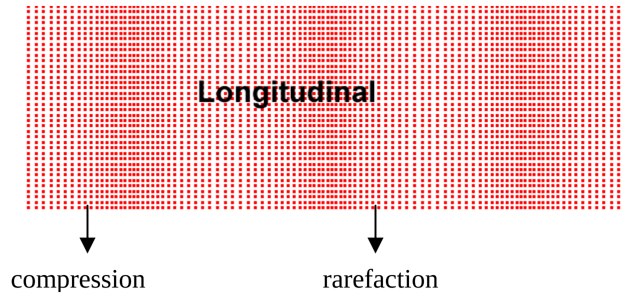
For each of the following demonstrations and animations, have students explain how each is an example of a transverse wave:

Demonstration: Have students do 'the wave'. Starting sitting down, have students stand up as you run past them in the classroom.

Demonstration: Have two students hold the ends of a slinky stretched out on the floor. Have one student move his/her hand from right to left.

Animation: transverse wave motion
http://www.kettering.edu/~drussell/Demos/waves/wavemotion.html

b) Longitudinal waves are mechanical waves in which the particles of the substance carrying the wave vibrate right to left and the wave moves right to left. Example, sound waves - the parts of the wave where the particles of the substance are close together are called compressions and the parts where the particles are far apart are called rarefactions.



For each of the following demonstrations and animations, have students explain how each is an example of a longitudinal wave:

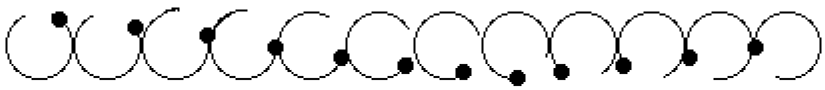
Demonstration: Have students do 'the *new age* wave'. Have all students stand up in a line, shoulder to shoulder, facing the front. As you run past them, have each student bump the student beside them in the shoulder.

Demonstration: Have two students hold the ends of a slinky stretched out on the floor. Have one student quickly push the slinky along its length and return to the starting position.

Animation: longitudinal waves
http://www.kettering.edu/~drussell/Demos/waves/wavemotion.html

c) Surface waves are mechanical waves in which the particles of the substance carrying the wave move in circles while the wave moves right to left (e.g., water waves).

Surface Wave



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

For each of the following demonstrations and animations, have students explain how each is an example of a surface wave:

Demonstration: Fill a large bowl or tank with water. Float a rubber duckie or other toy in the water and have a student make water waves by repeatedly tapping the surface of the water. Note that the wave travels through the water, from right to left, while the toy bobs up and down with some side to side motion.

Animations: surface waves
http://www.kettering.edu/~drussell/Demos/waves/wavemotion.html,
http://www.classzone.com/books/earth_science/terc/content/visualizations/es1604/es1604page01.cfm?chapter_no=visualization

Behaviour of Waves:

KEY Q: Think back to when you were part of 'the wave' (transverse wave) and 'the *new age* wave' (longitudinal wave). You were a particle of the substance through which the wave traveled. Did you change your location in the room from the start of generating the wave to your final position once the wave had passed? (No.)

Waves transfer energy from one location to another, but they *cannot* transfer matter.

KEY Q: Think about the last time you watched a live interview on TV when the interviewer was in a different location than the interviewee. There is often a delay between the interviewer asking the question and the interviewee responding. Can you think of why there might be a delay?

Different kinds of waves travel at different speeds. Examples, electromagnetic waves, such as visible light, travel at 300 000 km/s; mechanical waves, such as sound waves, travel at 0.343 km/s at room temperature through air.

Demonstration: Acquire a starting pistol used in track meets. Bring the students outdoors to an open area. Have the students stand about 100 m (or a significant distance) from you. Tell the students to watch the starting pistol and listen carefully to what they hear. Fire the pistol. The students should note that they see the smoke before they hear the starting pistol. Discuss this in terms of speed of light vs. speed of sound. Other examples: seeing lightning then hearing the thunder; seeing the bat strike the ball then hearing the crack.

Demonstration: Acquire a 'tin can telephone' (two cans connected by butcher cord or yarn about 20 ft long). Have one student hold each and move apart until the string between them is taut. First, without using the can apparatus, have one student whisper very quietly to the other. Then have the same student whisper at approximately the same volume to the other student but this time with the tin can up to his/her mouth. The second student should have the tin can up to his/her ear. The second student should hear a significant difference in volume. Discuss this difference.

The medium (material) that a mechanical wave, such as a sound wave, travels through affects its speed. Example, sound travels faster through rope than it does through air, since rope is more dense. Putting one's ear to the track to hear the train (not recommended ☺) rather than listening for the sound of the train in the air.

Activity #1 Review– Did You Catch the Concept of Waves?
Teacher Key

The correct answer is underlined for multiple choice questions.

1. A transverse wave is transporting energy from left to right. The particles of the medium will move
   a) only upward or downward
   b) <u>both upward and downward</u>
   c) only left or right
   d) both left and right

2. Which of the following is NOT a characteristic of mechanical waves?
   a) They consist of disturbances in a substance or medium.
   b) They transport energy.
   c) <u>They travel in a direction which is perpendicular or at right angles to the direction in which the particles of the medium travel (e.g., the wave might travel to the right, while the particles of the medium move up and down).</u>
   d) They are created by a vibrating source.

   Note to teacher: Although transverse waves do this, longitudinal (another type of mechanical wave) do not!

3. In a space movie, the inhabitants of one spaceship hear another spaceship zooming by. Think about the characteristics of sound waves (a type of mechanical wave). Why would this situation be impossible?

   ANSWER – Sound waves are mechanical waves and therefore need a medium to travel through. Space is essentially a vacuum; therefore sound could not travel through it.

4. Which of the following is NOT an example of an electromagnetic wave?
   a) X-ray b) <u>water wave</u> c) gamma ray d) visible light e) radio wave

5. Think again about the difference between mechanical and electromagnetic waves. Explain why we can see the sun, but we cannot hear the sound of nuclear reactions happening on it.

   ANSWER – We can see the sun because light is an electromagnetic wave and therefore can travel through the vacuum of space. We cannot hear the nuclear reactions because sound is a mechanical wave and cannot travel through the vacuum of space. Like all mechanical waves, it needs a medium to travel through.

6. Explain why one often hears the thunder after seeing the lightning (why is there a delay between the two events).

   ANSWER – Sound is a mechanical wave. Light is an electromagnetic wave. Sound travels MUCH slower than light (e.g., sound travels 343 m/s at room temperature, light travels at 3.00×10^8 m/s). You therefore see the lightning before hearing the thunder.

7. Water waves, a type of surface wave, are often described as being a combination of a transverse and a longitudinal wave. Why is this so?

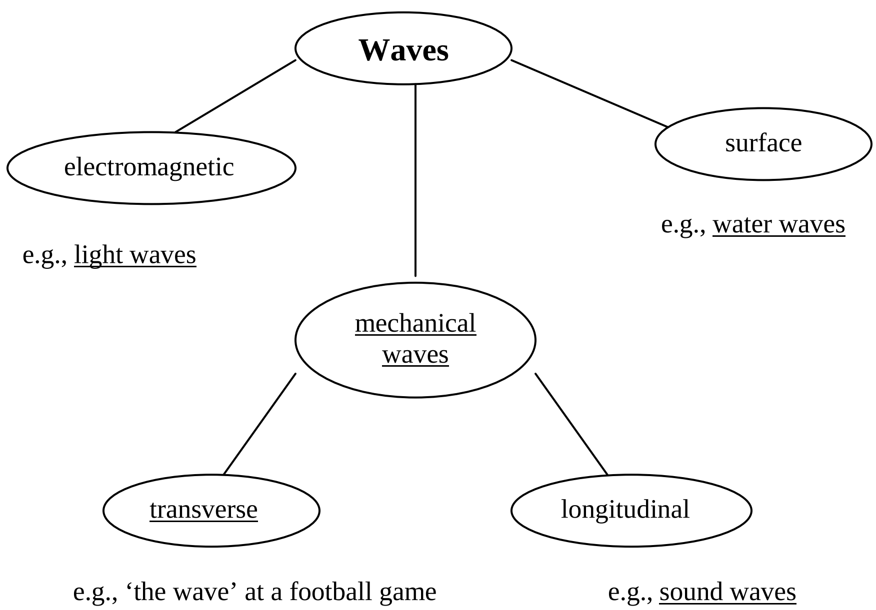
   ANSWER – The particles of the medium travel in circles. If one considers a wave traveling from left to right, the particles' movement is then an approximate combination of the up and down motion of the particles of a transverse wave and the side to side motion of the particles of a longitudinal wave).

8. You send a vibration through three different materials – a piece of foam, a steel rod and a piece of wood. In which material do you think that the wave vibration will travel the fastest? Explain your answer. (HINT: How do you hear a train coming the quickest…..by listening through the air or by putting your ear on the track?)

   ANSWER – A steel rod. It is the most dense so the energy transfer is the quickest.

9. 'The wave' often done in football stadiums is an example of a(n) __________ wave.
   a) electromagnetic   b) transverse   c) longitudinal

10. Complete the following concept map by putting the correct terms from the list below into the empty circles or blanks.



Words To Use: water waves, sound waves, mechanical waves, transverse waves, light waves

Activity #3: Getting Into Interference

KEY Q: Ask students if they have ever been to a concert or musical event in a hall where there was 'bad acoustics'. What did this sound like? What do waves do that could have been causing this to happen?

KEY Q: Who has seen the large headphones that airport workers out on the tarmac or those operating large machinery wear? Do they just cover one's ears, or is there more to them?

> (Contain small microphones that collect incoming sound waves. Circuitry inside the headphones process this noise and reproduce the noise in a form exactly out of phase with the original. This out-of-phase version is played back to the person wearing the headphones. Due to destructive interference, a quieter background is the result.)

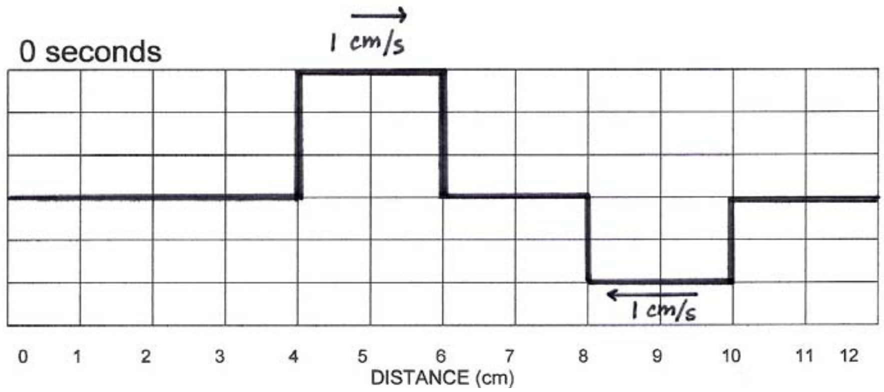
Demonstration: Access the following website to set up a demonstration of constructive and destructive interference of sound waves. Have students walk by the speakers to observe loud and quiet spots. You will need two speakers. http://www.falstad.com/interference/

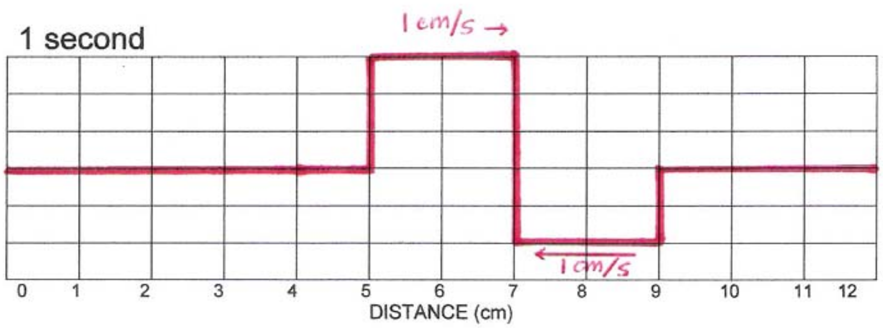
- To better understand interference, we can examine what happens to two pulses when they meet and how constructive or destructive interference occurs.
- The drawing below shows a string on which two rectangular pulses are traveling in opposite directions at a constant speed of 1 cm/s.

Teacher Key With Solutions:

Note: When parts of the original pulses 'disappear' due to interference, their original locations are sometimes indicated by dotted lines. It is not necessary for students to include these.

SAMPLE QUESTION: (to be done with students)





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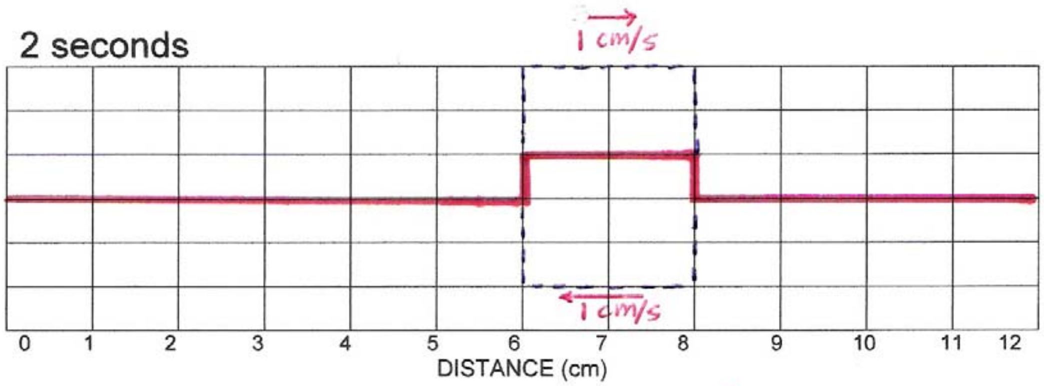

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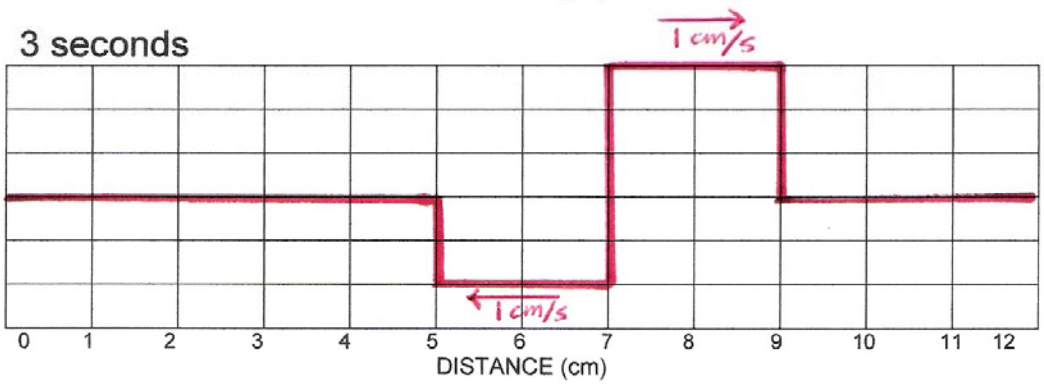

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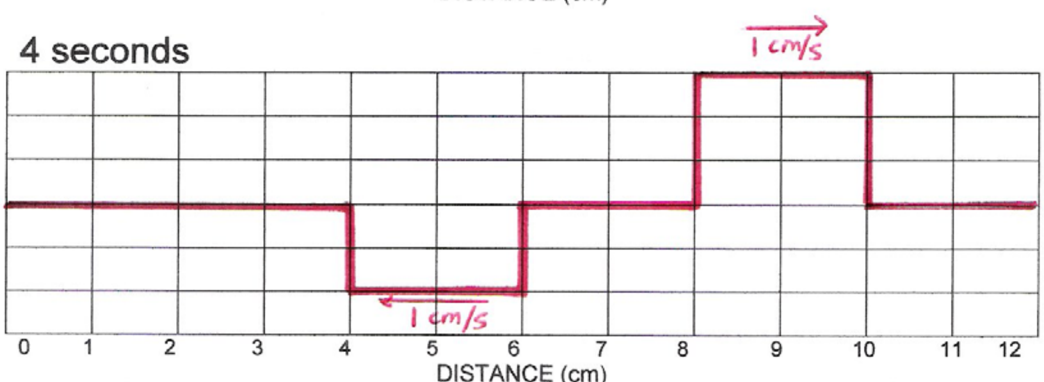

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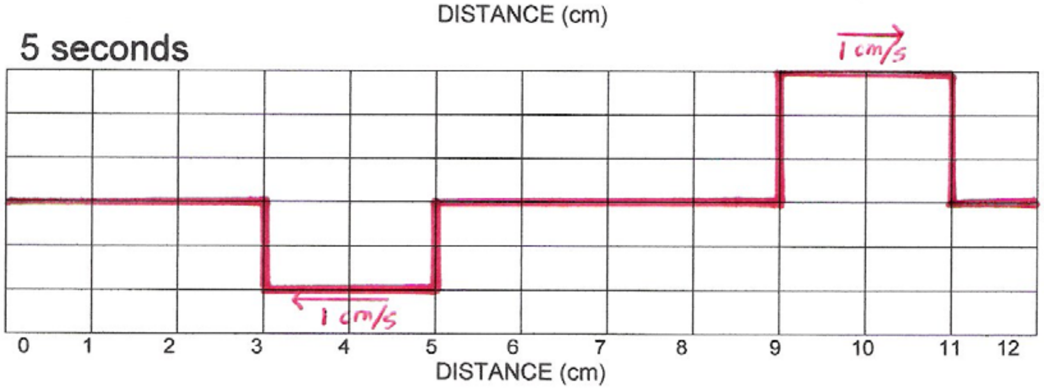
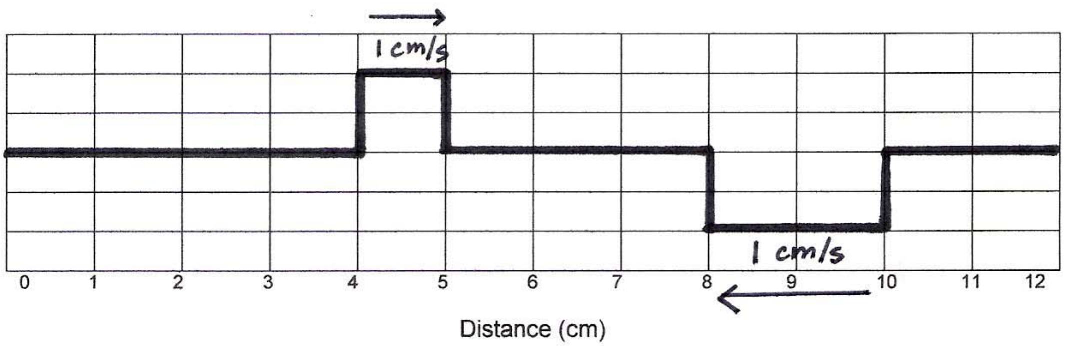


STUDENT PRACTICE:

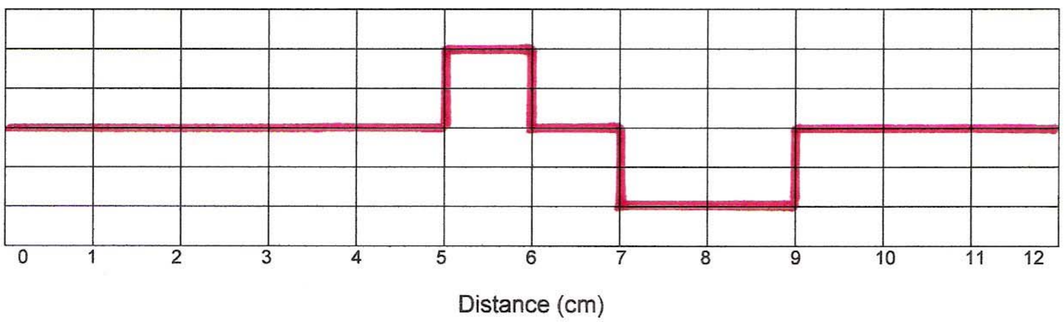
The following drawing shows a string on which two pulses are traveling at a constant speed of 1 cm/s at a t = 0.

t = 0 s

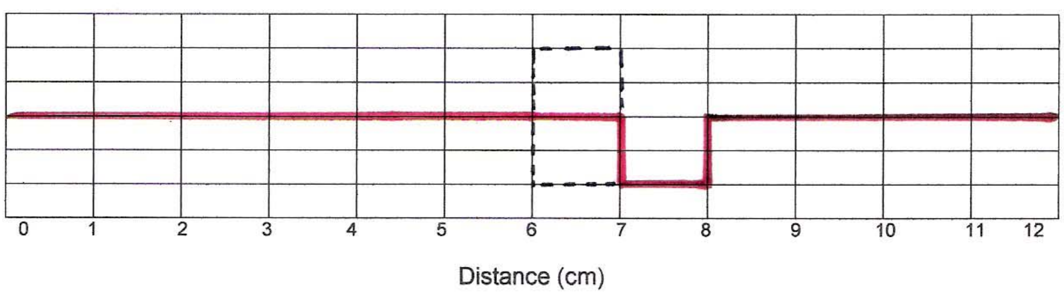


(a) Draw the shape of the string at t = 1 s, 2 s, 3 s, 4 s, and 5 s.

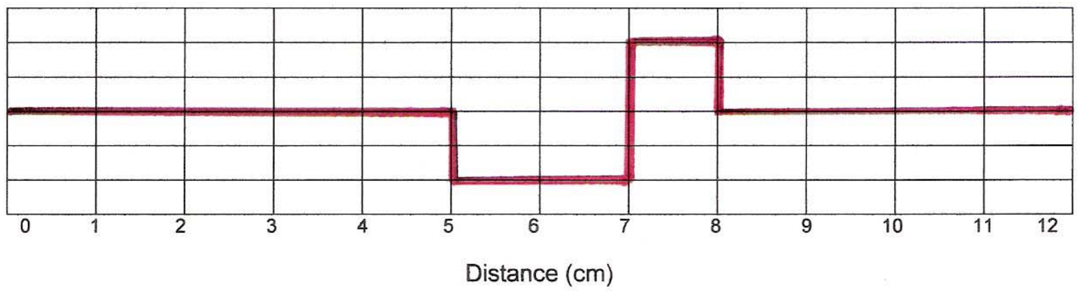
t = 1 s



t = 2 s



t= 3 s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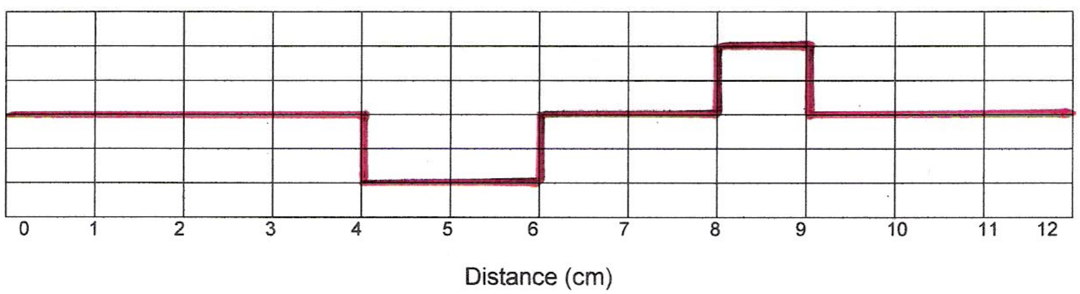
Distance (cm)

t = 4 s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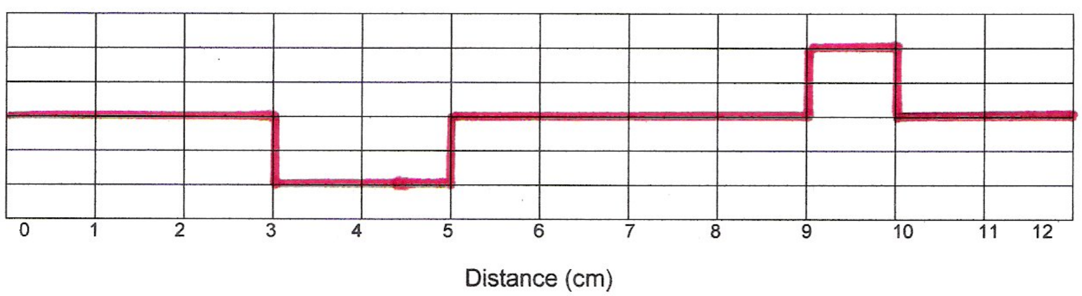
Distance (cm)

t = 5 s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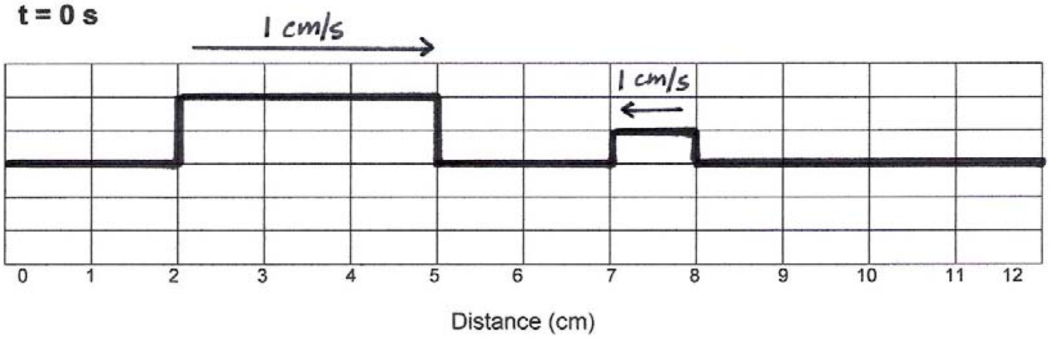
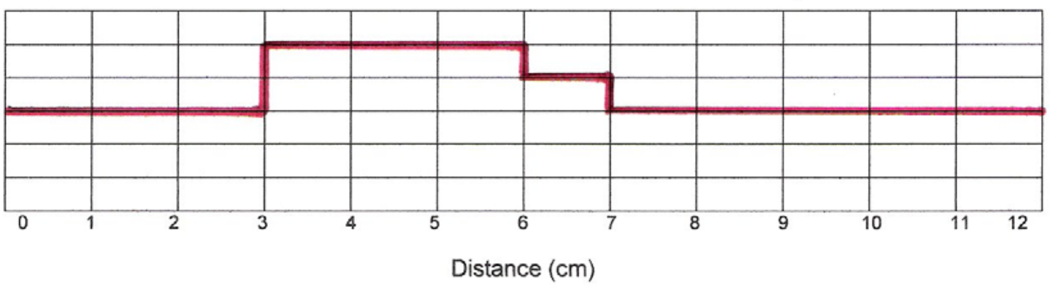
Distance (cm)

(b) Repeat problem (a), using the following diagram for the shape of the pulses at time = 0.

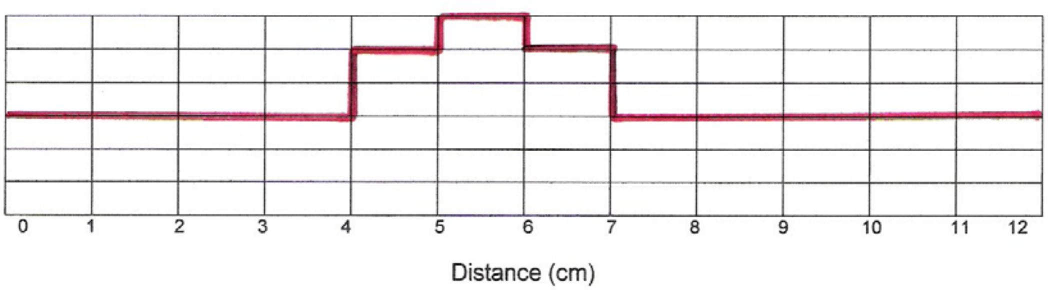
t = 0 s



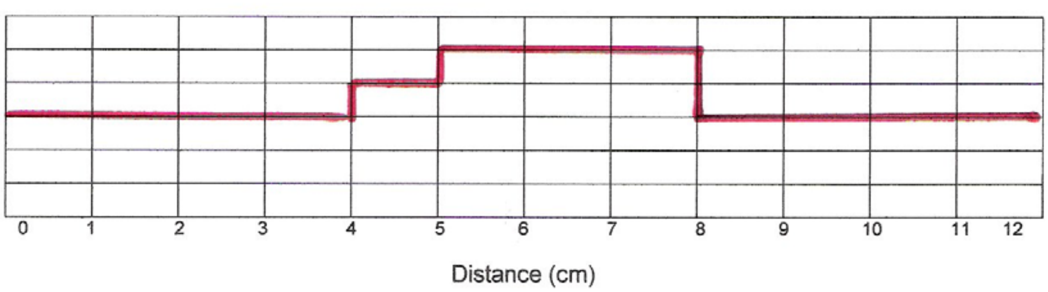
t = 1 s



t = 2 s

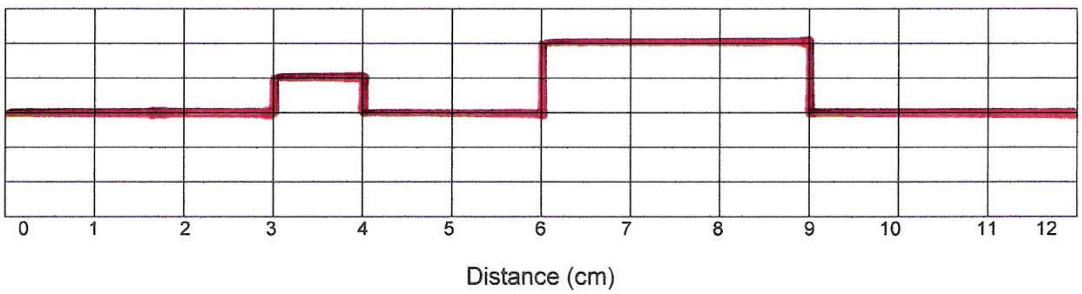


t = 3 s

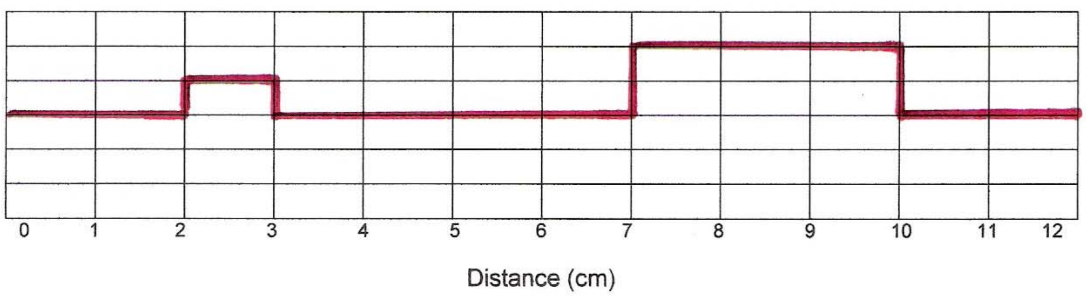


Teacher Support Material 13

t = 4 s



t = 5 s



TSM Teacher Support Material 14

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Activity #2: Using a Slinky© to Investigate Waves

Teacher Key

Note to teacher – This is intended to be a discovery type lab. Observing some of the described wave phenomena can be a challenge. Provide students with enough time to do many trials and make careful observations. For some observation type questions, you may choose to *not* deduct marks for a theoretically incorrect answer. In any case, be sure to discuss the theoretical answers thoroughly when the labs are graded and returned.

VOCABULARY (13 terms x 0.5 mark/each = **6.5 marks**)

equilibrium – the resting or undisturbed position of a wave

medium – a material through which a wave travels

transverse wave – a mechanical wave in which the particles of the medium move perpendicular to the direction of travel of the wave

longitudinal wave – a mechanical wave in which the particles of the medium move parallel to the direction of travel of the wave

amplitude – the distance that the wave travels from its resting position; the greater the amplitude, the greater the energy that the wave carries

pulse – a single disturbance through a medium

wavelength – a distance from one point on a wave to the next point after which the wave starts to repeat itself (e.g., distance from crest to crest or trough to trough)

frequency – how many wavelengths pass a given point per second (think….how 'frequent' the wave is)

open-end reflection – when a wave hits a 'softer' (less dense) medium and comes back

closed-end reflection – when a wave hits a 'harder' (more dense) medium and comes back

principle of superposition – the principle in physics that describes how waves add together or subtract from one another when they meet up or interfere

constructive interference – when two waves meet and the resulting wave is larger (greater amplitude) than either of the individual waves

destructive interference – when two waves meet and the resulting wave is smaller (smaller amplitude) than either of the individual waves

Introduction:

One of the most useful toys in physics is the Slinky©. The Slinky© can be used to demonstrate both kinds of mechanical waves: longitudinal and transverse. The Slinky© can also be used to investigate pulses, reflection and interference. In this lab, you will gather descriptive data of wave phenomenon.

Evaluation questions are found throughout the lab. Write your answer in the space provided. The marks given to each question are indicated in a box to the right of each question.

Materials:

- Slinky© with a 3 m piece of string attached to one end
- Smaller diameter and long physics spring
- approximately 15 cm length of ribbon

Method:

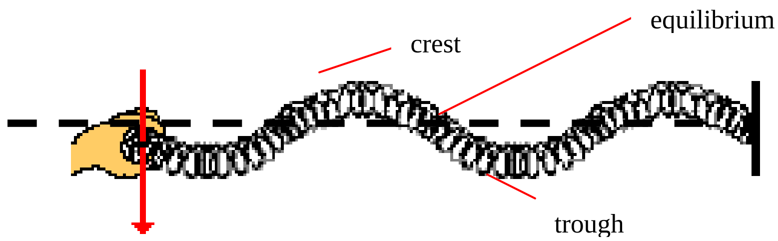
1. Find a large, open area to work. Have one partner hold the smaller diameter physics spring at one end and the other partner hold the spring at the other end. Crouch down and allow the slinky to rest on the floor. Slowly stretch out the spring – *do not stretch it too far or you will damage it. Do not release the spring when it is stretched out as you will tangle it.*

2. Note the position of the spring when you and your partner are facing one another directly and are not moving the spring. The spring is now at rest or in equilibrium.

When a slinky is stretched, the individual coils assume an equilibrium or rest position.

3. Have one partner make a transverse wave by RAPIDLY moving the end of the spring ON THE FLOOR to the right, to the left and back to the middle resting position (equilibrium). Watch the crests and troughs of the wave move along as the wave travels.

   Label the following on the picture below: crest, trough, line of equilibrium



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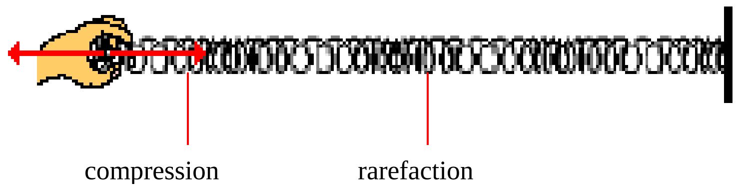
4. Have one partner make a longitudinal wave by rapidly pushing the end of the spring ON THE FLOOR toward his/her partner, toward him/herself and back to the starting position. Note the compressions and rarefactions in the wave as it travels along the spring.

Label the following on the picture below: compression, rarefaction



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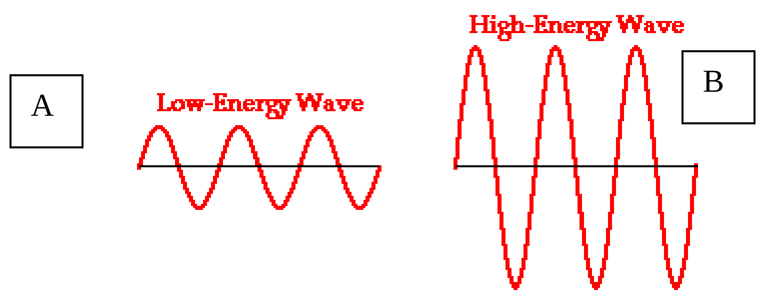
5. The amplitude of a wave is the maximum distance that a wave moves from equilibrium (its resting position). The higher the amplitude of a wave, the more energy it carries. (HINT: Think about which is more powerful…..a small wave crashing onto the shore at a lake in Saskatchewan or a large wave crashing onto the shore in the ocean that is rode by a surfer.) To better understand this, examine the two diagrams below:



The amplitude of a wave is related to the energy which it transports.

Note that wave B has a much higher amplitude than does wave A (it travels farther from the equilibrium, or resting position, that is shown as the flat line in the middle of each diagram).

The amplitude of a wave can be most easily seen in transverse waves. If the floor on which you are working has tiles, have one partner create a transverse wave with an amplitude of one floor tile. This can be done by rapidly moving your wrist ON THE FLOOR to the right a distance of one floor tile, to the left a distance of one floor tile and back to the starting position.

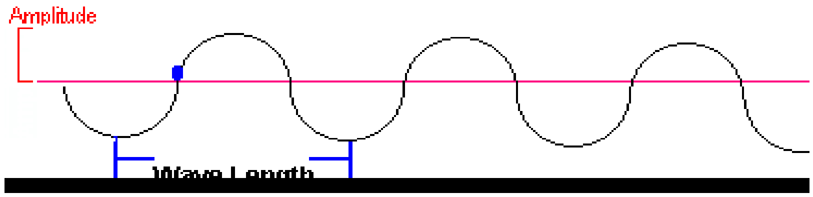
Now, triple the amplitude of the transverse wave that you create. How many floor tiles out from the equilibrium would you move?

Answer: three

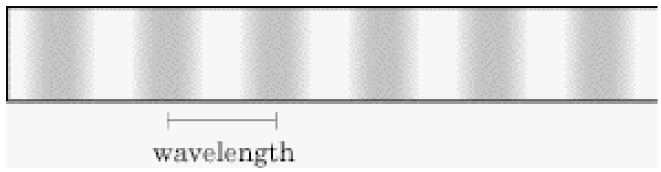
1

6. The wavelength of a wave is the shortest distance between points where the wave pattern repeats itself.

In a transverse wave the wavelength is the distance from crest to crest or trough to trough. Create a transverse wave (see step #3 above) and observe the wavelength.



In a longitudinal wave, the wavelength is the distance from compression to compression or rarefaction to rarefaction. Create a longitudinal wave (see step #4 above) and observe the wavelength.



7. The <u>frequency</u> of a wave is how many complete cycles it makes every second (the number of waves that pass per second is becoming more *frequent*).

   Have one partner continuously make transverse waves (see step #3). The partner should then move his/her hand more rapidly back and forth. He/she has just increased the frequency of the transverse wave.

   Have the other partner continuously make longitudinal waves (see step #4). The partner should then move his/her hand forwards and backwards more rapidly. He/she has just increased the frequency of the longitudinal wave.

   When the frequency was increased, what happened to the wavelength (e.g., the distance from crest to crest, trough to trough, compression to compression or rarefaction to rarefaction)?

   Answer: It decreased.

   ___ 1

8. A <u>pulse</u> is a single disturbance through a medium.

   Have one partner make a transverse pulse by rapidly moving the end of the spring ON THE FLOOR to the right and back to the starting point. This will be called a ‘right pulse.’

   Have one partner make a transverse pulse by rapidly moving the end of the spring ON THE FLOOR to the left and back to the starting point. This will be called a ‘left pulse.’

   Take turns making right and left pulses.

9. When a pulse or wave hits a harder medium and comes back, it is called <u>closed end reflection</u>.

   Create another ‘right pulse.’ Watch what happens to the ‘right pulse’ when it reaches the other end. Does it come back as a ‘right pulse’ or a ‘left pulse’? (HINT: You may have to create several ‘right pulses’ to come up with an answer.)

   ___ 1

Answer: It comes back as a left pulse (it inverts)

10. When a pulse or wave hits a softer medium and comes back, it is called open end reflection.

Use the Slinky© with a 3 m piece of string attached to one end for this step. ON THE FLOOR, have one person hold the Slinky© end and the other person hold the string end.

Have the person holding the Slinky© create a ‘right pulse’. This time, watch what happens at the point where the Slinky© meets the string. Note that some of the energy of the wave passes on into the string and some returns back into the Slinky©.

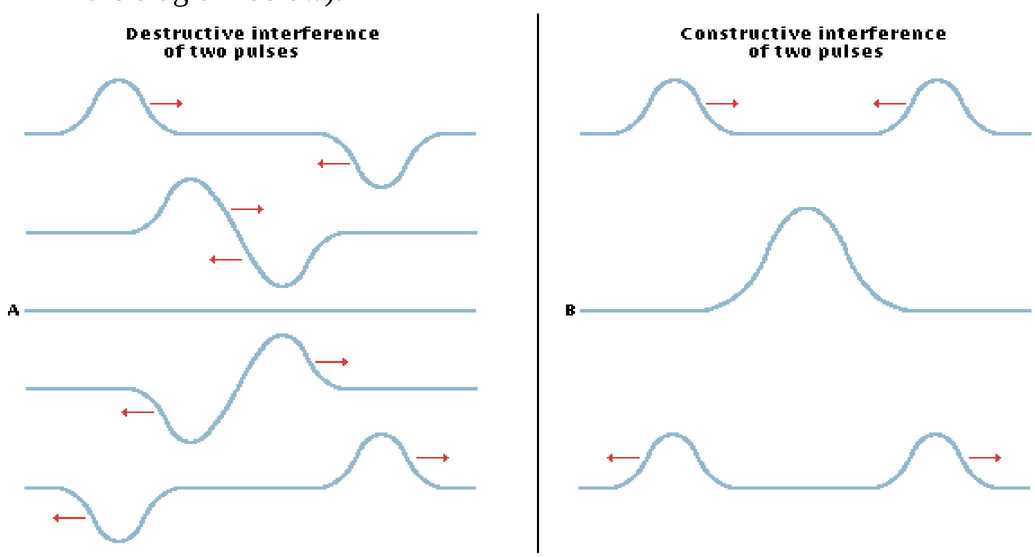
Watch the reflected portion of the wave that passes back into the Slinky©. Does it come back as a ‘right pulse’ or a ‘left pulse’? (HINT: You may have to create several ‘right pulses’ to come up with an answer)

___ / 1

Answer: It comes back as a right pulse (it does not invert)

11. When two waves meet with one another, they can either add together to make a bigger wave or cancel parts of each other out to result in a smaller wave. This way in which waves interfere is called the principle of superposition.

When two waves meet to make a wave that is smaller than either of the two waves, it is called destructive interference (see ‘A’ in the diagram below). When two waves meet to make a wave that is larger than either of the two waves, it is called constructive interference (see ‘B’ in the diagram below).



This phenomenon can most easily be seen by observing how transverse pulses interfere. Use the long, small diameter physics spring for this step. To do this, complete the following steps:

a) Tie a piece of ribbon to a coil of the spring in the middle of the spring.

b) Have the person at each end of the spring generate a right pulse of approximately the same amplitude (if you have tiles on the floor, make each pulse one tile high). Practice doing this several times by counting down from three to make the pulse at the EXACT SAME TIME. Because the two students are facing each other, they should be making pulses on opposite sides of the spring.

c) Observe what happens to the pulses when they meet at the middle of the spring (at the location of the ribbon). Does the 'hump' that you see appear larger or smaller than the individual pulses that have met there?

Answer: smaller

Is this an example of constructive or destructive interference?

$\overline{\quad 2 \quad}$

Answer: destructive

d) Now, have one person generate a right pulse and the other generate a left pulse of approximately the same amplitude. Again, practice doing this several times by counting down from three to make the pulse at the EXACT SAME TIME. Because the two students are facing each other, they should be making pulses on the same side of the spring.

e) Observe what happens to the pulses when they meet at the middle of the spring (at the location of the ribbon). Does the 'hump' that you see appear larger or smaller than the individual pulses that have met there?

Answer: larger

Is this an example of constructive or destructive interference?

$\overline{\quad 2 \quad}$

Answer: constructive

Student
Handout
INDIVIDUAL

Activity #1: CATCHING THE CONCEPT OF

WAVES

VOCABULARY

wave **–**

medium –

electromagnetic wave –

mechanical wave –

transverse wave –

longitudinal wave –

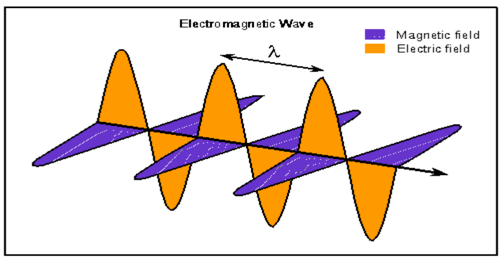
surface wave –

List some everyday examples of waves in the space below:

What is a wave?
A vibration or disturbance that moves through a substance or through empty space.

There are two types of waves:

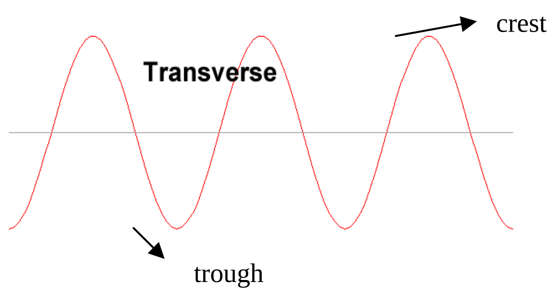
Electromagnetic waves: can travel through empty space e.g., light waves, X-rays, radio waves, microwaves



Go to the following link to see a cool animation of a moving electromagnetic wave: http://www.jb.man.ac.uk/distance/strobel/light/lighta.htm

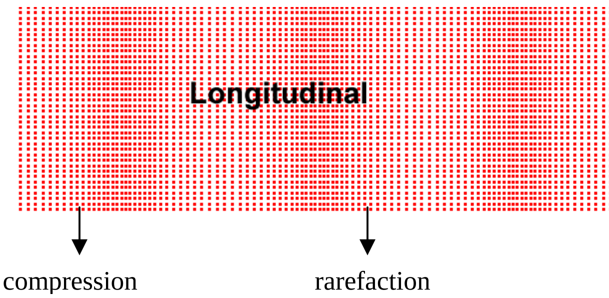
Mechanical waves: need a substance or medium to pass through e.g., sound waves, waves through a rope, water waves

a) **transverse waves**: are mechanical waves in which the particles of the substance carrying the wave vibrate up and down while the wave moves to the right or left. E.g., waves on a rope or spring. The high points of the wave are called crests while the low points are called troughs.



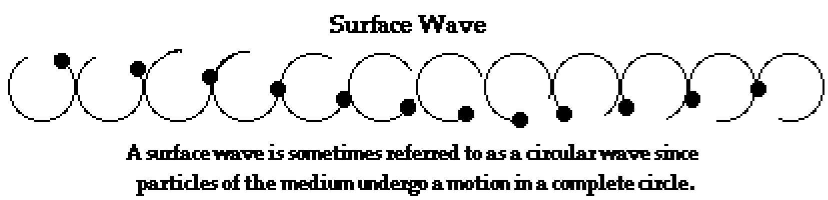
Go to the following link to see an animation of a transverse wave:
http://www.kettering.edu/~drussell/Demos/waves/wavemotion.html

b) **longitudinal waves**: are mechanical waves in which the particles of the substance carrying the wave vibrate right to left and the wave moves right to left e.g., sound waves. The parts of the wave where the particles of the substance are close together are called compressions and the parts where the particles are far apart are called rarefactions.



Go to the following link to see an animation of a longitudinal wave:
http://www.kettering.edu/~drussell/Demos/waves/wavemotion.html

c) **surface waves:** are mechanical waves in which the particles of the substance carrying the wave move in circles while the wave moves right to left e.g., water waves.



Go to the following links to see animations of surface waves:
http://www.kettering.edu/~drussell/Demos/waves/wavemotion.html
http://www.classzone.com/books/earth_science/terc/content/visualizations/es1604/es1604page01.cfm?chapter_no=visualization

Behavior of Waves

Waves transfer energy from one location to another, but they *cannot* transfer matter.

Different kinds of waves travel at different speeds. Examples include: electromagnetic waves, such as visible light, travel at 300 000 km/s; mechanical waves, such as sound waves, travel at 0.343 km/s at room temperature through air

The medium (material) that a mechanical wave, such as a sound wave, travels through affects its speed. Sound travels faster through rope than it does through air, since rope is more dense; putting one’s ear to the track to hear the train (not recommended) rather than listening for the sound of the train in the air

SH
Student
Handout
GROUP

Activity #1: CATCHING THE CONCEPT OF

WAVES

VOCABULARY

wave **–**

medium –

electromagnetic wave –

mechanical wave –

transverse wave –

longitudinal wave –

surface wave –

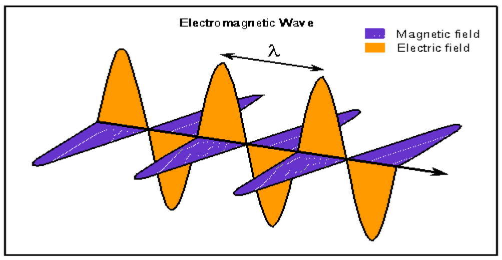
Student Handout GROUP

Everyday examples of waves:

What is a wave?
A vibration or disturbance that moves through a substance or through empty space.

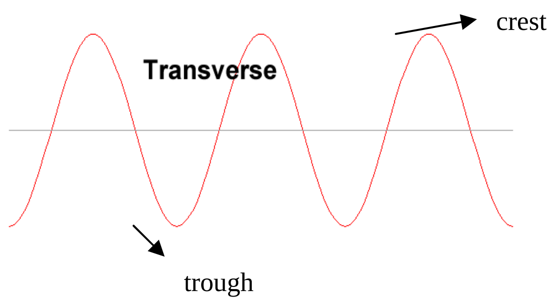
There are two types of waves:

1. Electromagnetic waves: can travel through empty space e.g., light waves, X-rays, radio waves, microwaves

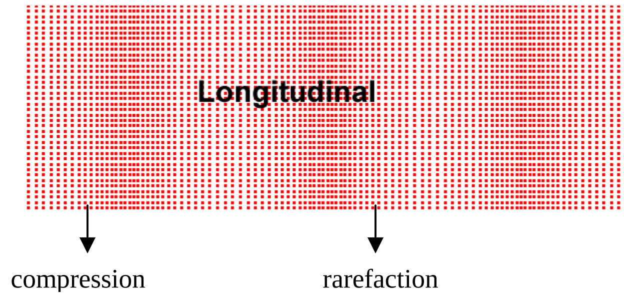


2. Mechanical waves: need a substance or medium to pass through e.g., sound waves, waves through a rope, water waves

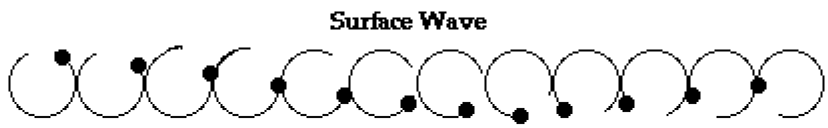
   a) **transverse waves**: are mechanical waves in which the particles of the substance carrying the wave vibrate up and down while the wave moves to the right or left. Example: waves on a rope or spring. The high points of the wave are called crests while the low points are called troughs.



   b) **longitudinal waves**: are mechanical waves in which the particles of the substance carrying the wave vibrate right to left and the wave moves right to left e.g., sound waves The parts of the wave where the particles of the substance are close together are called compressions and the parts where the particles are far apart are called rarefactions.



c) **surface waves:** are mechanical waves in which the particles of the substance carrying the wave move in circles while the wave moves right to left e.g., water waves



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

Behavior of Waves:
Waves transfer energy from one location to another, but they *cannot* transfer matter.

Different kinds of waves travel at different speeds. Example: electromagnetic waves, such as visible light, travel at 300 000 km/s and mechanical waves, such as sound waves, travel at 0.343 km/s at room temperature through air

The medium (material) that a mechanical wave, such as a sound wave, travels through affects its speed. Example: sound travels faster through rope than it does through air, since rope is more dense. Putting one's ear to the track to hear the train (not recommended) rather than listening for the sound of the train in the air

Activity #1 Review– Did you Catch the Concept of Waves? ☺

1. A transverse wave is transporting energy from left to right. The particles of the medium will move
   a) only upward or downward
   b) both upward and downward
   c) only left or right
   d) both left and right

2. Which of the following is NOT a characteristic of mechanical waves?
   a) They consist of disturbances in a substance or medium.
   b) They transport energy.
   c) They travel in a direction which is perpendicular or at right angles to the direction in which the particles of the medium travel (ie: The wave might travel to the right, while the particles of the medium move up and down).
   d) They are created by a vibrating source.

3. In a space movie, the inhabitants of one spaceship hear another spaceship zooming by. Think about the characteristics of sound waves (a type of mechanical wave). Why would this situation be impossible?

4. Which of the following is NOT an example of an electromagnetic wave?
   a) X-ray b) water wave c) gamma ray d) visible light e) radio wave

5. Think again about the difference between mechanical and electromagnetic waves. Explain why we can see the sun, but we cannot hear the sound of nuclear reactions happening on it.

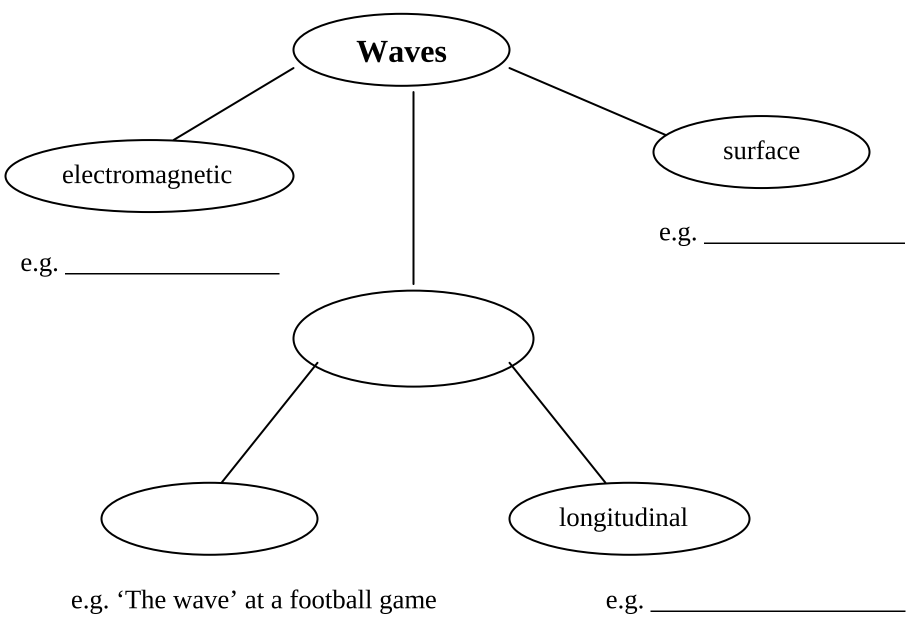
6. Explain why one often hears the thunder after seeing the lightning (ie: why is there a delay between the two events).

7. Water waves, a type of surface wave, are often described as being a combination of a transverse and a longitudinal wave. Why is this so?

8. You send a vibration through three different materials – a piece of foam, a steel rod and a piece of wood. In which material do you think that the wave vibration will travel the fastest? Explain your answer. (HINT: How do you hear a train coming the quickest…..by listening through the air or by putting your ear on the track?)

9. ‘The wave’ often done in football stadiums is an example of a(n) __________ wave.
a) electromagnetic b) transverse c) longitudinal

10. Complete the following concept map by putting the correct terms from the list below into the empty circles or blanks.



WORDS TO USE: water waves, sound waves, mechanical waves, transverse waves, light waves

Student Handout

Name: ____________________ Date: _____________ Period: _____

_____
19.5

Activity #2: Using a Slinky© to Investigate Waves

VOCABULARY (13 terms x 0.5 mark/each = **6.5 marks**)

equilibrium -

medium -

transverse wave -

longitudinal wave -

amplitude -

pulse -

wavelength -

frequency -

open-end reflection -

closed-end reflection -

principle of superposition -

constructive interference -

destructive interference -

Student Handout

Introduction:
One of the most useful toys in physics is the Slinky©. The Slinky© can be used to demonstrate both kinds of mechanical waves: longitudinal and transverse. The Slinky© can also be used to investigate pulses, reflection and interference. In this lab, you will gather descriptive data of wave phenomenon.

Evaluation questions are found throughout the lab. Write your answer in the space provided. The marks given to each question are indicated in a box to the right of each question.

Materials:
- Slinky© with a 3 m piece of string attached to one end
- Smaller diameter and long physics spring
- approximately 15 cm length of ribbon

Method:
1. Find a large, open area to work. Have one partner hold the smaller diameter physics spring at one end and the other partner hold the spring at the other end. Crouch down and allow the slinky to rest on the floor. Slowly stretch out the spring – *do not stretch it too far or you will damage it. Do not release the spring when it is stretched out as you will tangle it.*

2. Note the position of the spring when you and your partner are facing one another directly and are not moving the spring. The spring is now at rest or in equilibrium.

When a slinky is stretched, the individual coils assume an equilibrium or rest position.

3. Have one partner make a transverse wave by RAPIDLY moving the end of the spring ON THE FLOOR to the right, to the left and back to the middle resting position (equilibrium). Watch the crests and troughs of the wave move along as the wave travels.

   Label the following on the picture below: crest, trough, line of equilibrium

___ / 3

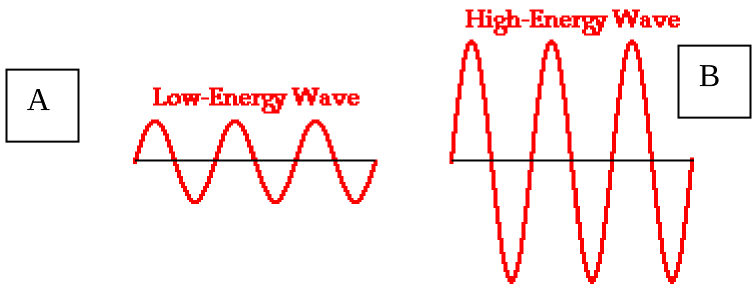
4. Have one partner make a longitudinal wave by rapidly pushing the end of the spring ON THE FLOOR toward his/her partner, toward him/herself and back to the starting position. Note the compressions and rarefactions in the wave as it travels along the spring.

   Label the following on the picture below: compression, rarefaction.

Student Handout

2

5. The amplitude of a wave is the maximum distance that a wave moves from equilibrium (its resting position). The higher the amplitude of a wave, the more energy it carries. (HINT: Think about which is more powerful…..a small wave crashing onto the shore at a lake in Saskatchewan or a large wave crashing onto the shore in the ocean that is rode by a surfer.) To better understand this, examine the two diagrams below:



The amplitude of a wave is related to the energy which it transports.

Note that wave B has a much higher amplitude than does wave A (it travels farther from the equilibrium, or resting position, that is shown as the flat line in the middle of each diagram).

The amplitude of a wave can be most easily seen in transverse waves. If the floor on which you are working has tiles, have one partner create a transverse wave with an amplitude of one floor tile. This can be done by rapidly moving your wrist ON THE FLOOR to the right a distance of one floor tile, to the left a distance of one floor tile and back to the starting position.

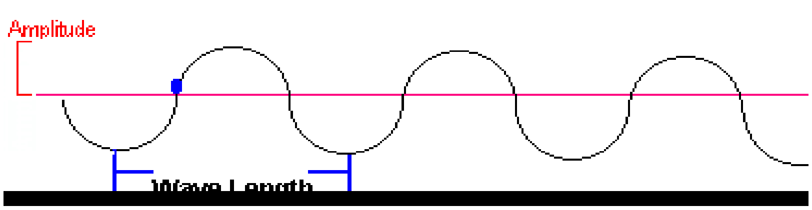
Now, triple the amplitude of the transverse wave that you create. How many floor tiles out from the equilibrium would you move?

____

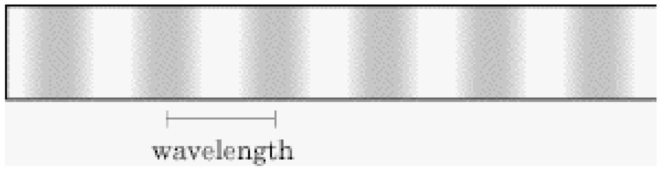
1

6. The wavelength of a wave is the shortest distance between points where the wave pattern repeats itself.

In a transverse wave the wavelength is the distance from crest to crest or trough to trough. Create a transverse wave (see step #3 above) and observe the wavelength.



In a longitudinal wave, the wavelength is the distance from compression to compression or rarefaction to rarefaction. Create a longitudinal wave (see step #4 above) and observe the wavelength.



7. The frequency of a wave is how many complete cycles it makes every second (the number of waves that pass per second is becoming more *frequent*).

   Have one partner continuously make transverse waves (see step #3). The partner should then move his/her hand more rapidly back and forth. He/she has just increased the frequency of the transverse wave.

   Have the other partner continuously make longitudinal waves (see step #4). The partner should then move his/her hand forwards and backwards more rapidly. He/she has just increased the frequency of the longitudinal wave.

   When the frequency was increased, what happened to the wavelength (e.g., the distance from crest to crest, trough to trough, compression to compression or rarefaction to rarefaction)?

   ________________________________ ___ / 1

8. A pulse is a single disturbance through a medium.

   Have one partner make a transverse pulse by rapidly moving the end of the spring ON THE FLOOR to the right and back to the starting point. This will be called a 'right pulse.'

   Have one partner make a transverse pulse by rapidly moving the end of the spring ON THE FLOOR to the left and back to the starting point. This will be called a 'left pulse.'

   Take turns making right and left pulses.

9. When a pulse or wave hits a harder medium and comes back, it is called closed end reflection.

   Create another 'right pulse.' Watch what happens to the 'right pulse' when it reaches the other end. Does it come back as a 'right pulse' or a 'left pulse'? (HINT: You may have to create several 'right pulses' to come up with an answer)

   ________________________________ ___ / 1

10. When a pulse or wave hits a softer medium and comes back, it is called open end reflection.

Use the Slinky© with a 3 m piece of string attached to one end for this step. ON THE FLOOR, have one person hold the Slinky© end and the other person hold the string end.

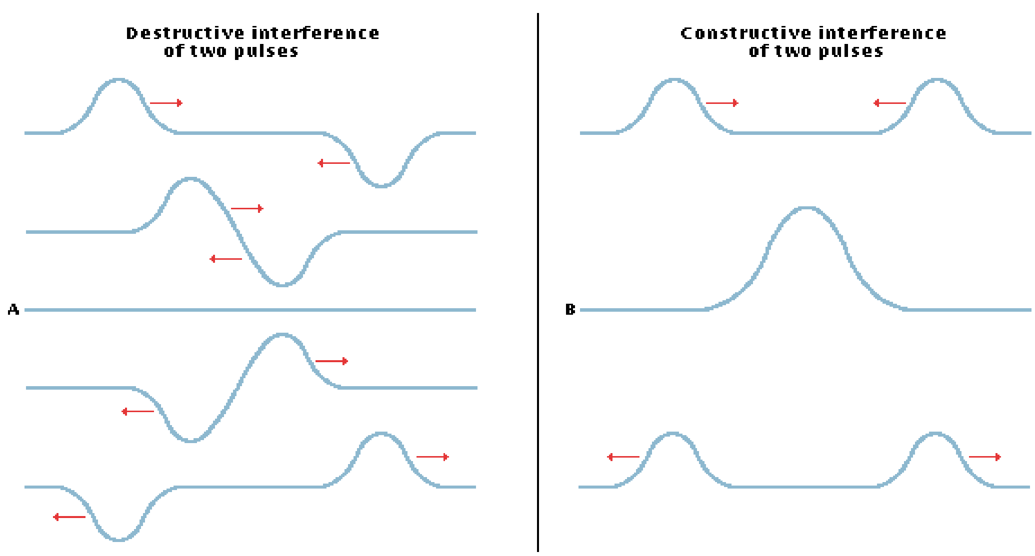
Have the person holding the Slinky© create a 'right pulse'. This time, watch what happens at the point where the Slinky© meets the string. Note that some of the energy of the wave passes on into the string and some returns back into the Slinky©.

Watch the reflected portion of the wave that passes back into the Slinky©. Does it come back as a 'right pulse' or a 'left pulse'? (HINT: You may have to create several 'right pulses' to come up with an answer)

______________________________ __ / 1

11. When two waves meet with one another, they can either add together to make a bigger wave or cancel parts of each other out to result in a smaller wave. This way in which waves interfere is called the principle of superposition.

When two waves meet to make a wave that is smaller than either of the two waves, it is called destructive interference (see 'A' in the diagram below). When two waves meet to make a wave that is larger than either of the two waves, it is called constructive interference (see 'B' in the diagram below).



This phenomenon can most easily be seen by observing how transverse pulses interfere. Use the long, small diameter physics spring for this step. To do this, complete the following steps:

a. Tie a piece of ribbon to a coil of the spring in the middle of the spring.

b. Have the person at each end of the spring generate a right pulse of approximately the same amplitude (if you have tiles on the floor, make each pulse one tile high). Practice doing this several times by counting down from three to make the pulse at the EXACT SAME TIME. Because the two students are facing each other, they should be making pulses on opposite sides of the spring.

c. Observe what happens to the pulses when they meet at the middle of the spring (at the location of the ribbon). Does the 'hump' that you see appear larger or smaller than the individual pulses that have met there?

____

Is this an example of constructive or destructive interference?

___ / 2

____

d. Now, have one person generate a right pulse and the other generate a left pulse of approximately the same amplitude. Again, practice doing this several times by counting down from three to make the pulse at the EXACT SAME TIME. Because the two students are facing each other, they should be making pulses on the same side of the spring.

e. Observe what happens to the pulses when they meet at the middle of the spring (at the location of the ribbon). Does the 'hump' that you see appear larger or smaller than the individual pulses that have met there?

____

Is this an example of constructive or destructive interference?

____

___ / 2

Student Handout INDIVIDUAL

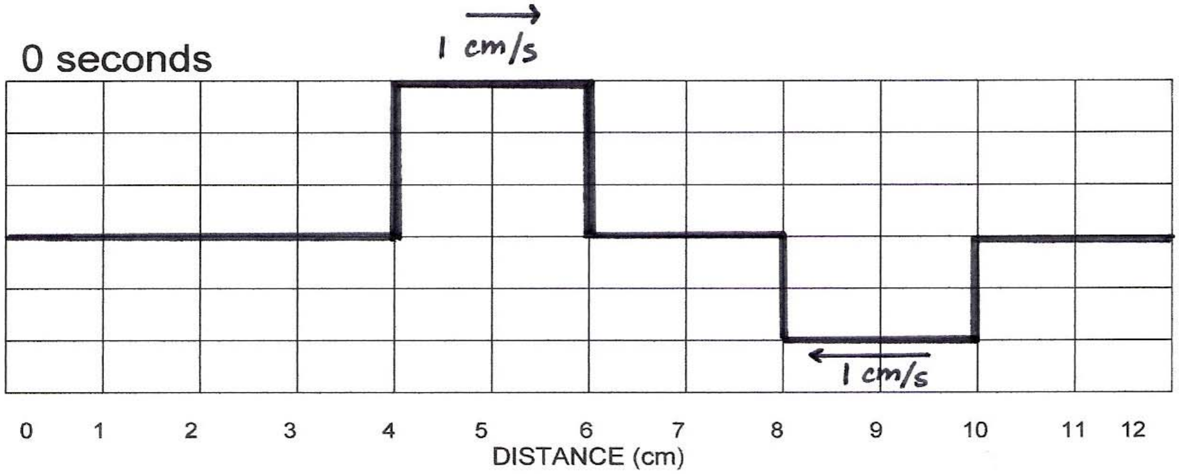
Activity #3: Getting Into Interference

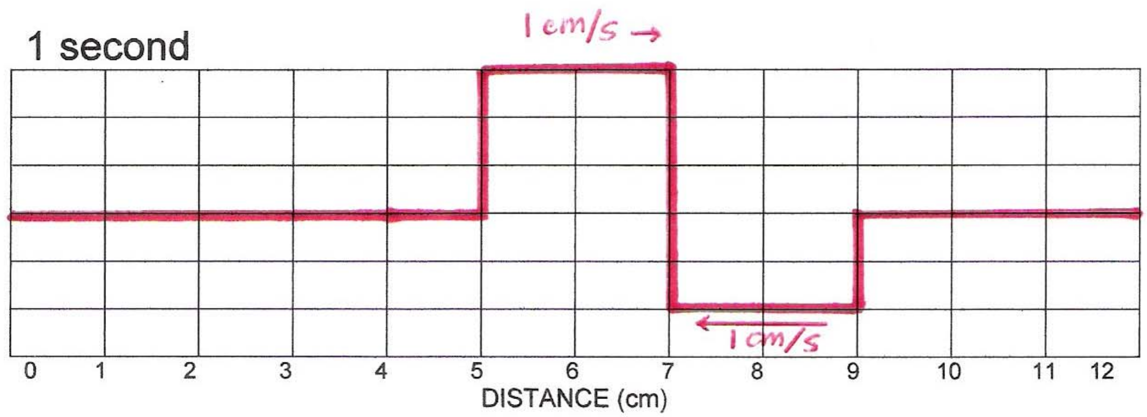
To better understand interference, we can examine what happens to two pulses when they meet and how constructive or destructive interference occurs.

The drawing below shows a string on which two rectangular pulses are traveling in opposite directions at a constant speed of 1 cm/s.

The original location of the pulses is given for time = 0 seconds. Follow the solutions for time = 1 – 5 seconds to see the resultant pulse(s). When they interfere, the original location of the pulses is noted by dotted lines. It is not necessary for you to sketch in the dotted lines when you complete your own practice problems. These are included to aid in your understanding.

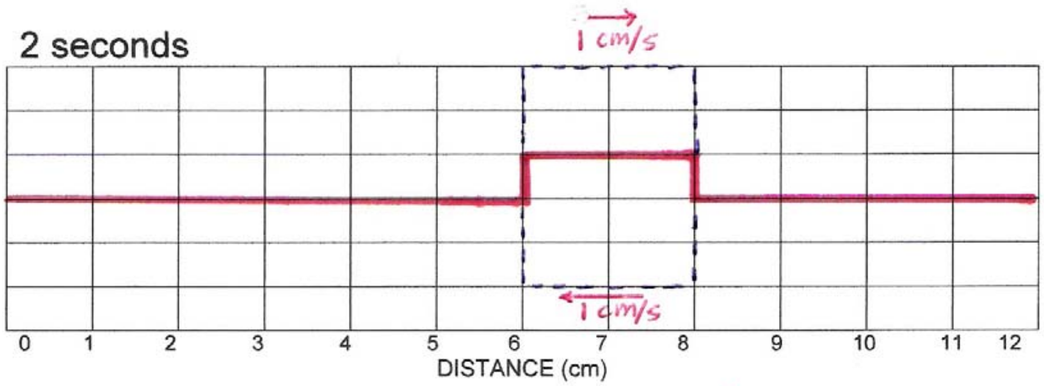
SAMPLE QUESTION:



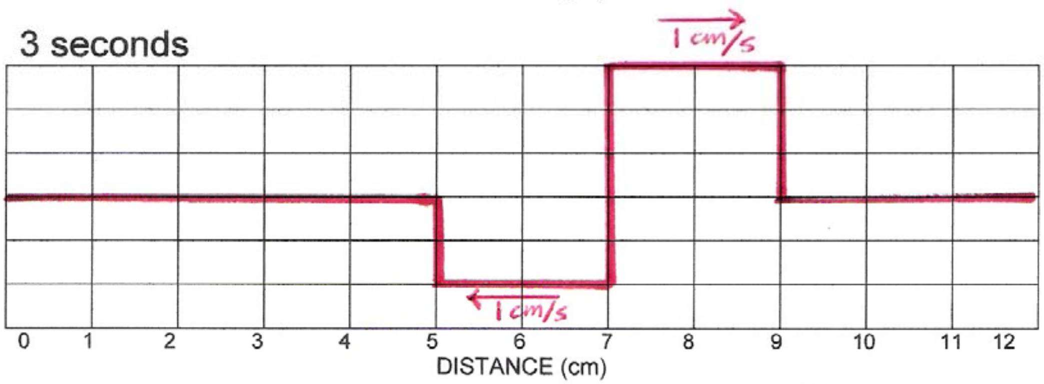


Student Handout
INDIVIDUAL

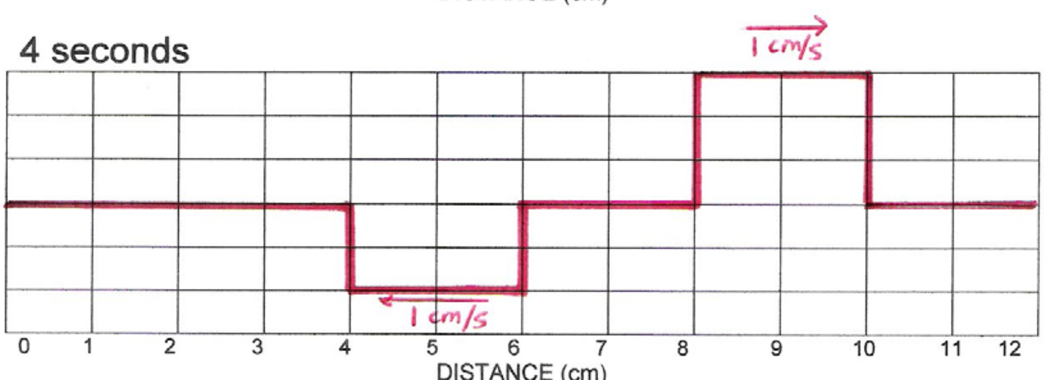
2 seconds



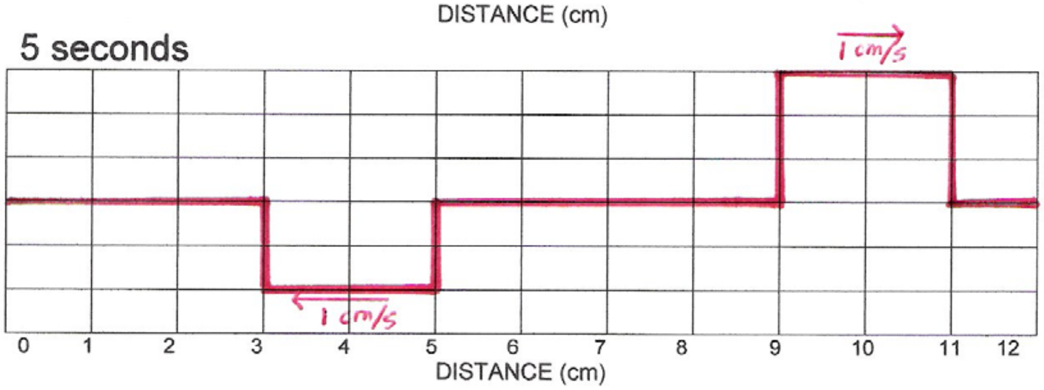
3 seconds



4 seconds



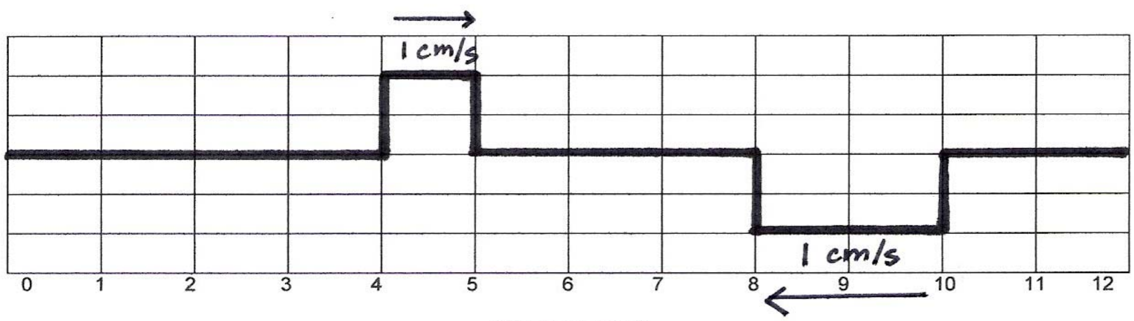
5 seconds



STUDENT PRACTICE:

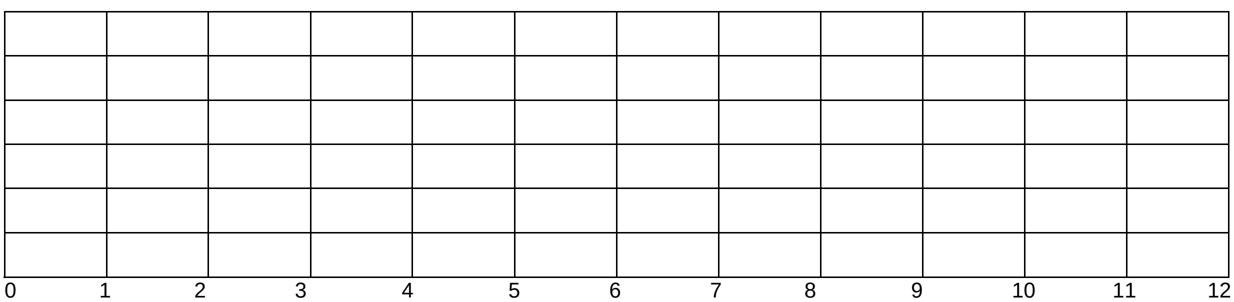
The following drawing shows a string on which two pulses are traveling at a constant speed of 1 cm/s at a t = 0.

t = 0 s



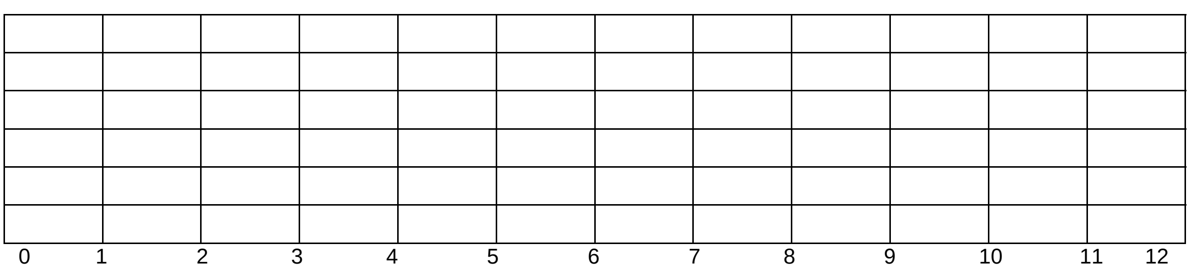
a) Draw the shape of the string at t = 1 s, 2 s, 3 s, 4 s, and 5 s.

t = 1 s



Distance (cm)

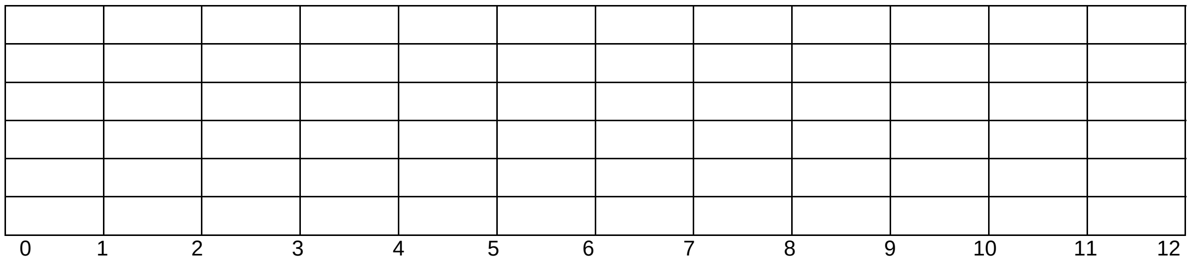
t = 2 s



Distance (cm)

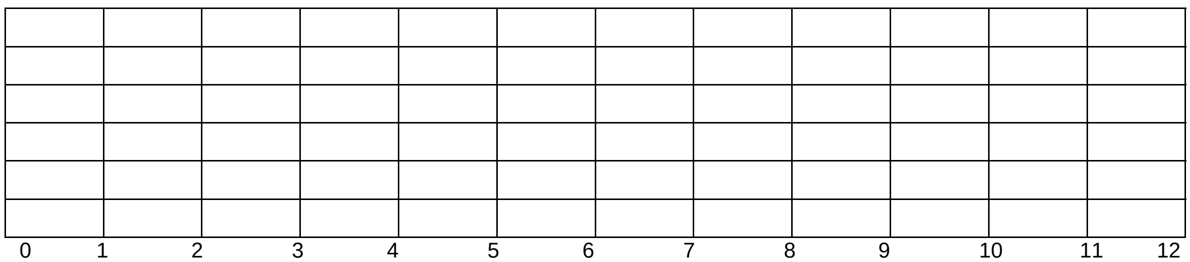
Student Handout
INDIVIDUAL

t= 3 s



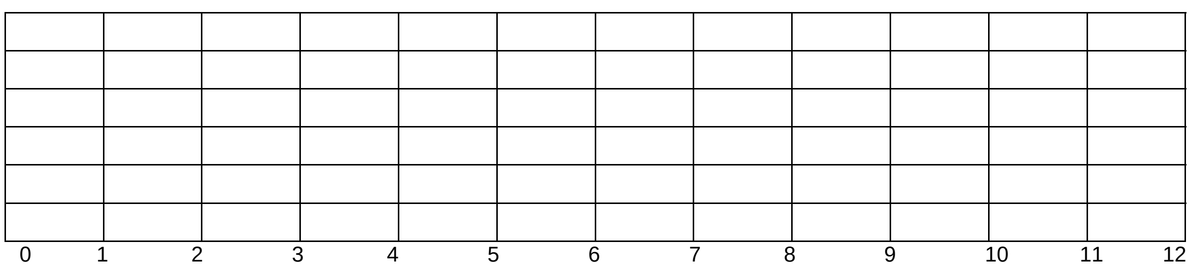
Distance (cm)

t = 4 s



Distance (cm)

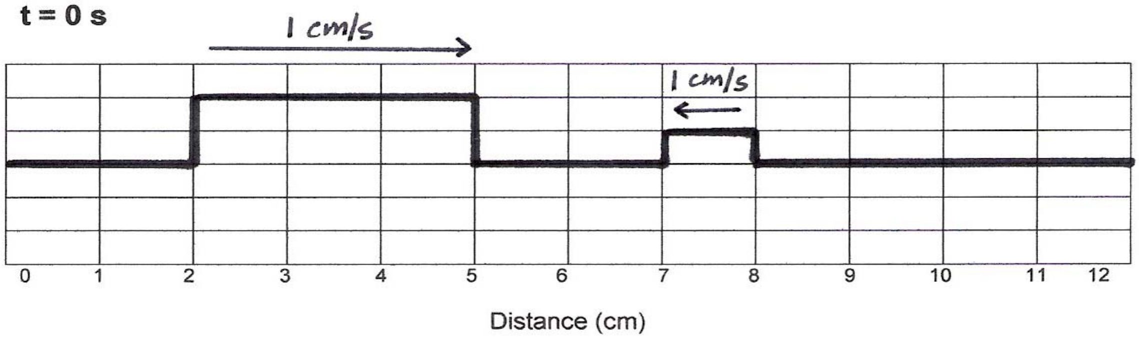
t = 5 s



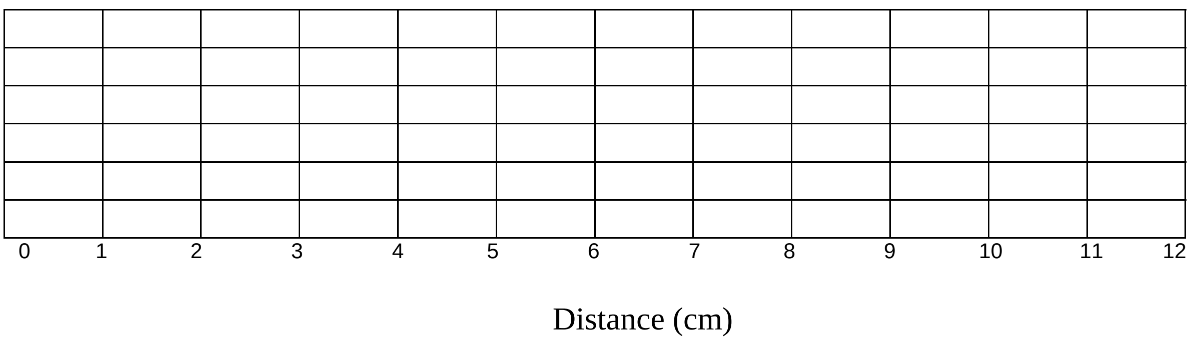
Distance (cm)

(b) Repeat problem (a), using the following diagram for the shape of the pulses at time = 0.

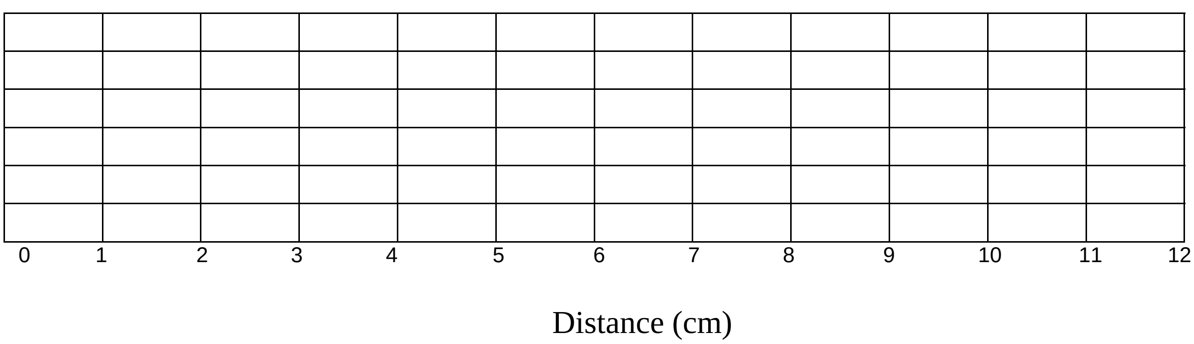
t = 0 s



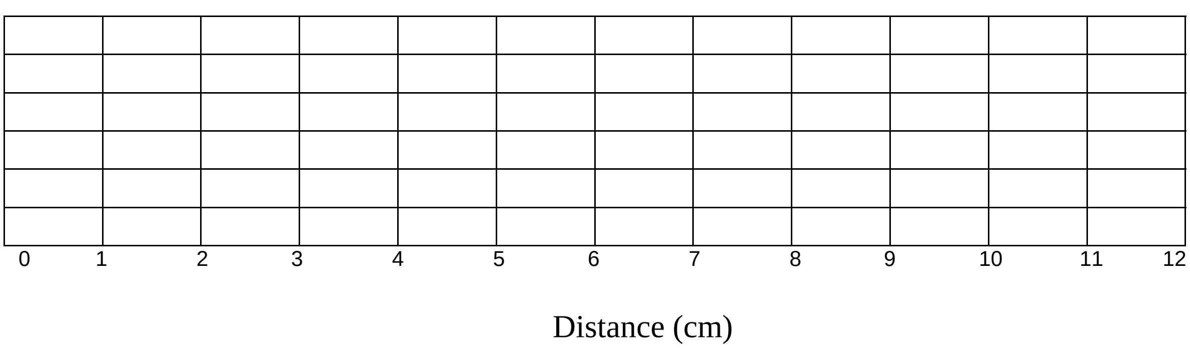
t = 1 s



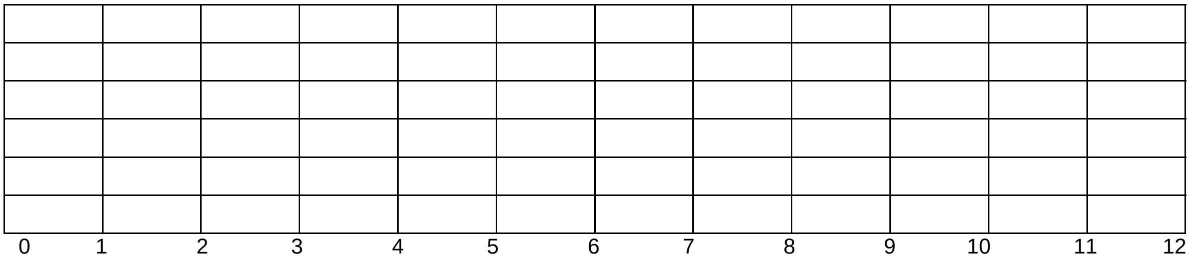
t = 2 s



t = 3 s

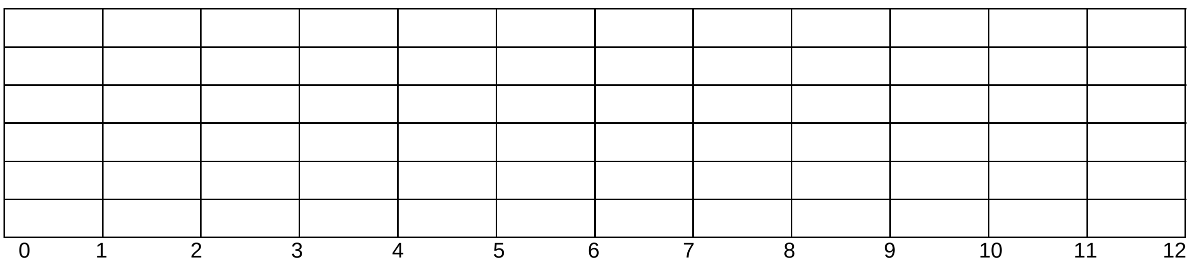


t = 4 s



Distance (cm)

t = 5 s



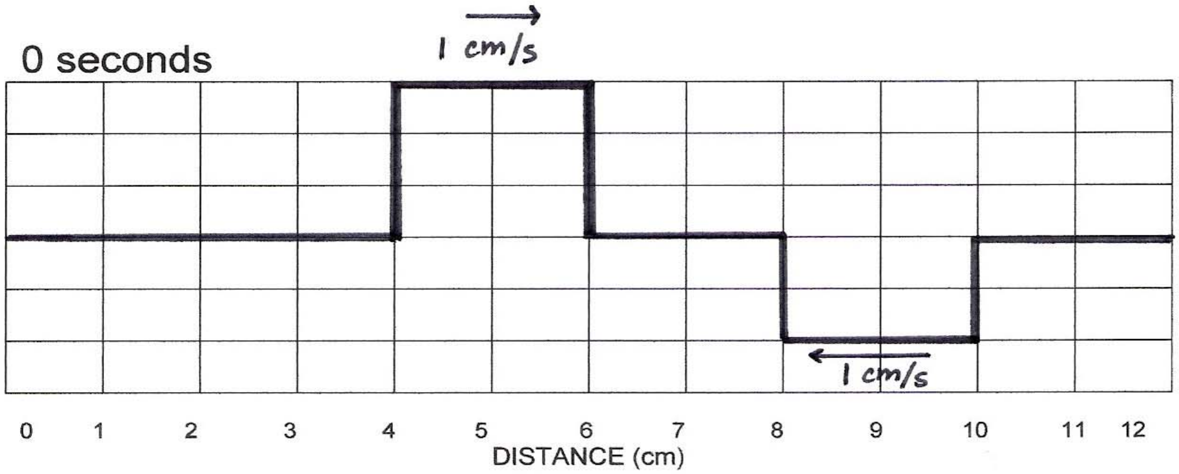
Distance (cm)

Activity #3: Getting Into Interference

To better understand interference, we can examine what happens to two pulses when they meet and how constructive or destructive interference occurs.

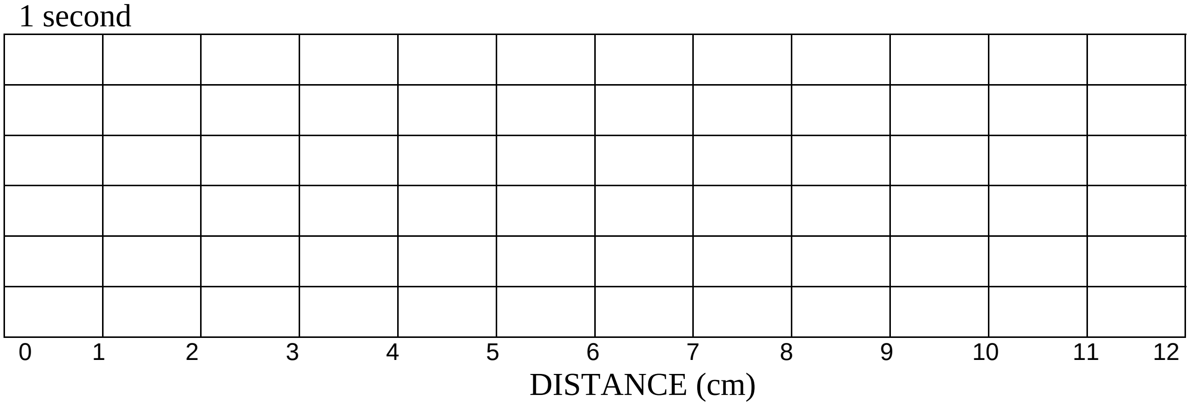
The drawing below shows a string on which two rectangular pulses are traveling in opposite directions at a constant speed of 1 cm/s.

SAMPLE QUESTION:

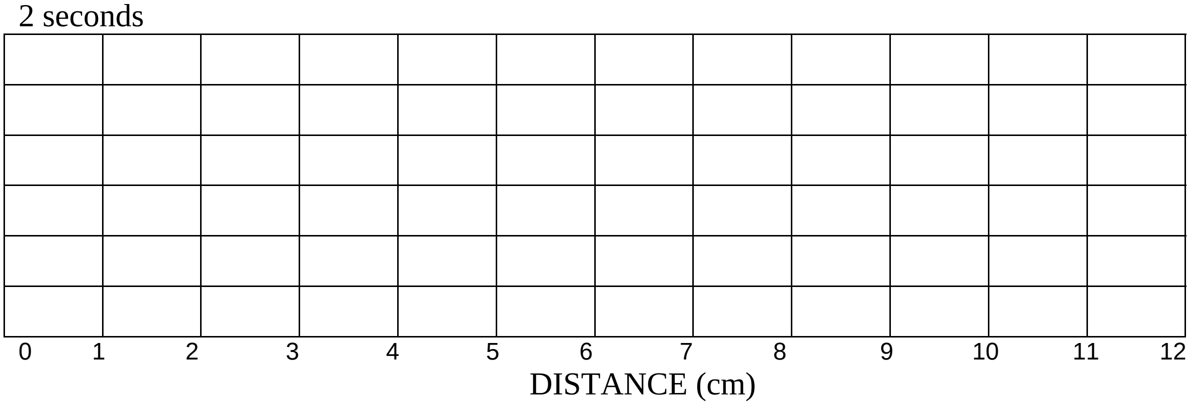


Draw the resultant pulse(s) at the following times:

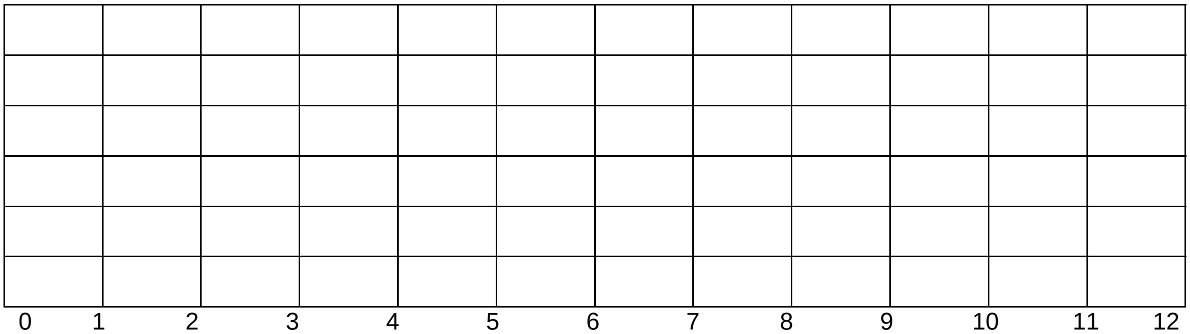
1 second



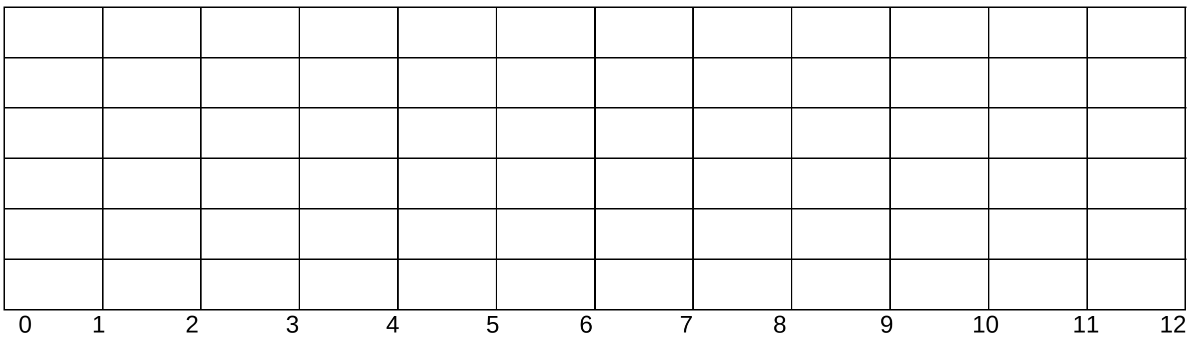
2 seconds



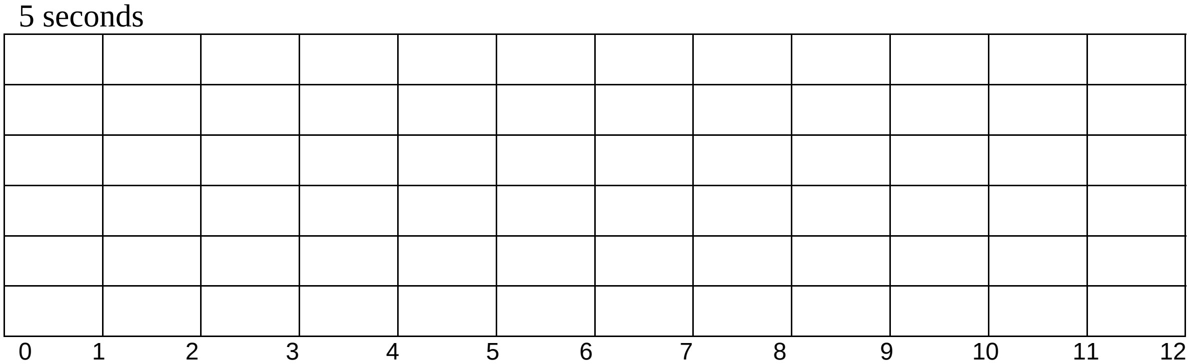
3 seconds



4 seconds



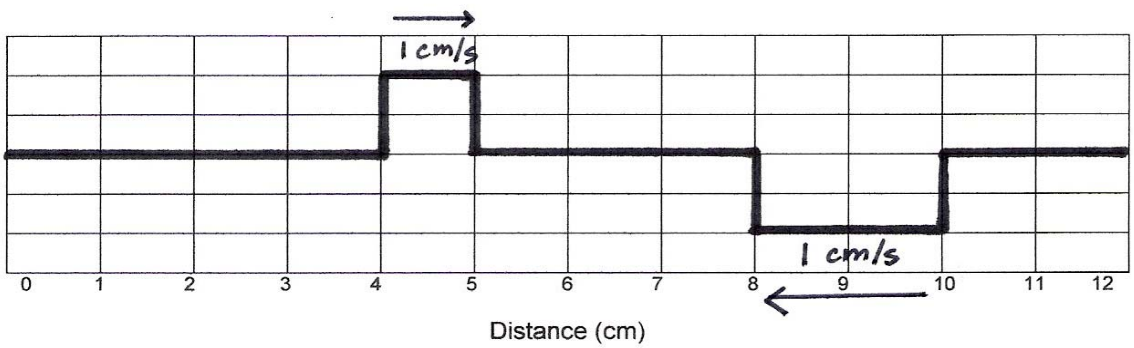
5 seconds



Student Handout GROUP

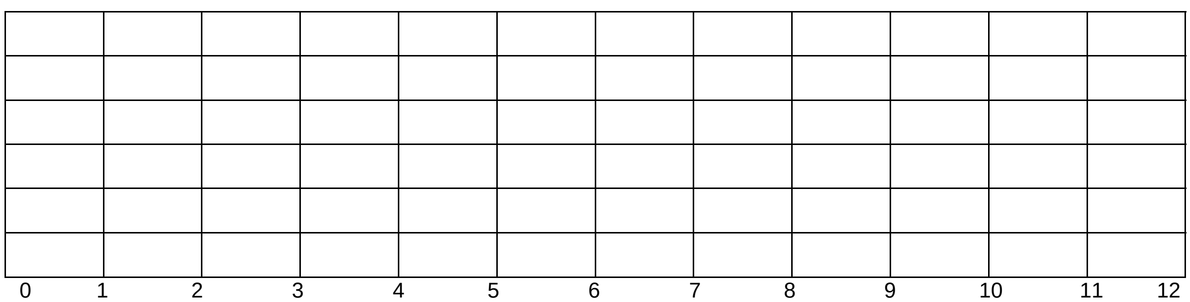
STUDENT PRACTICE:
The following drawing shows a string on which two pulses are traveling at a constant speed of 1 cm/s at a t = 0.

t = 0 s



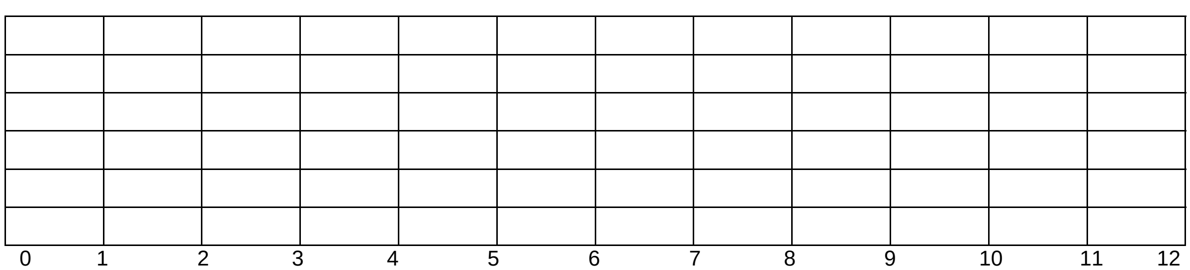
a) Draw the shape of the string at t = 1 s, 2 s, 3 s, 4 s, and 5 s.

t = 1 s



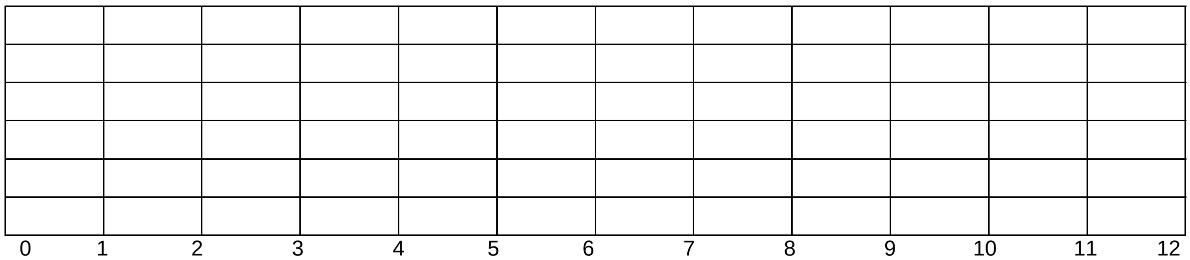
Distance (cm)

t = 2 s



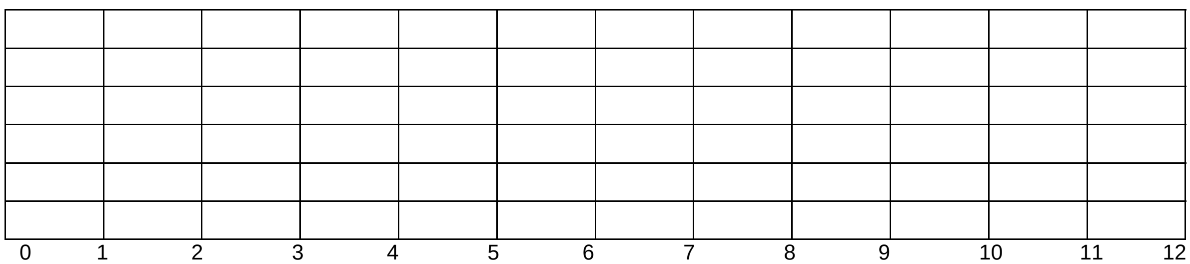
Distance (cm)

t= 3 s



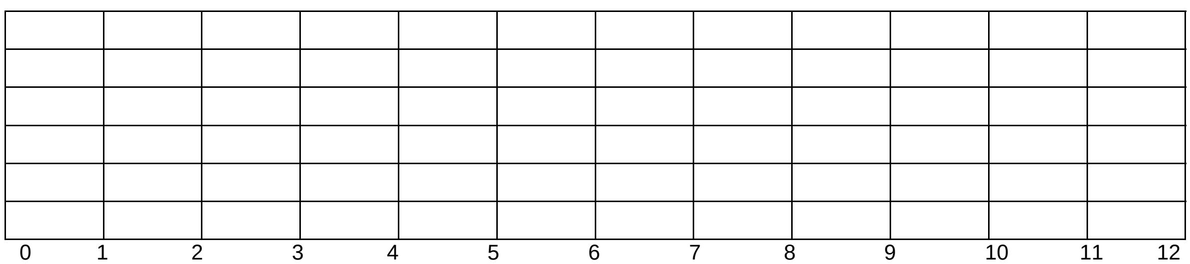
Distance (cm)

t = 4 s



Distance (cm)

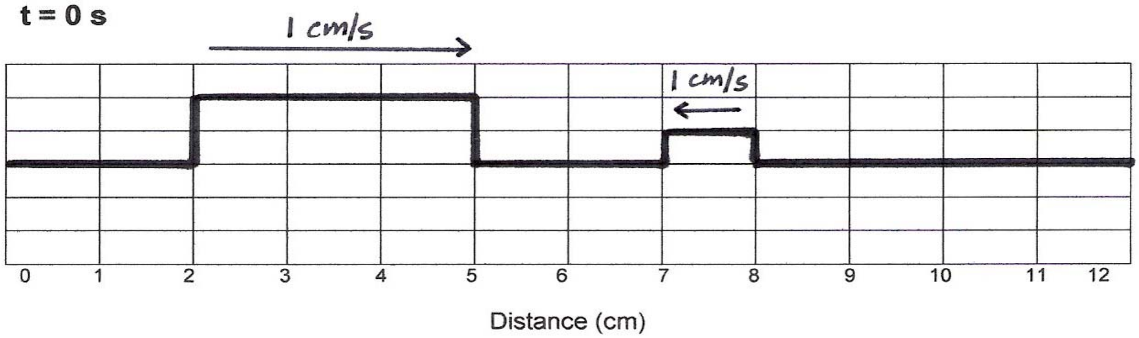
t = 5 s



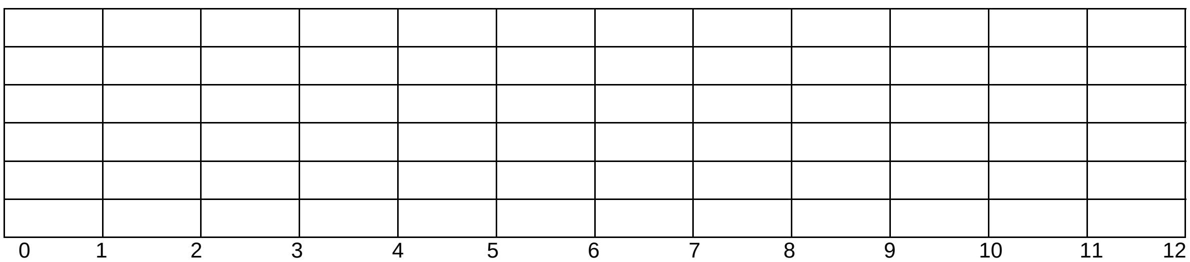
Distance (cm)

(b) Repeat problem (a), using the following diagram for the shape of the pulses at time = 0.

t = 0 s

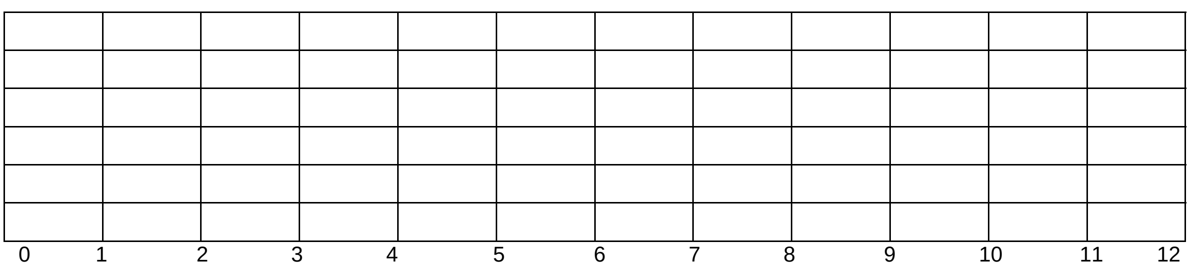


t = 1 s



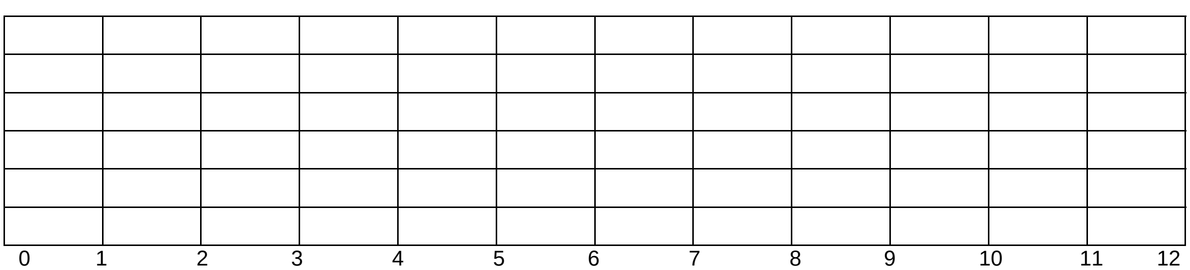
Distance (cm)

t = 2 s



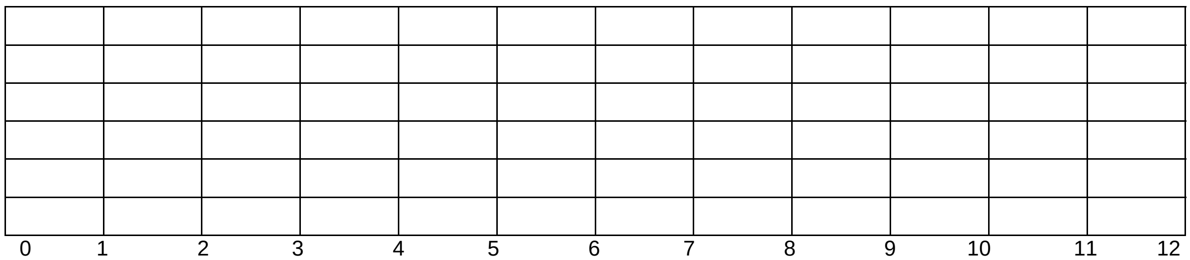
Distance (cm)

t = 3 s



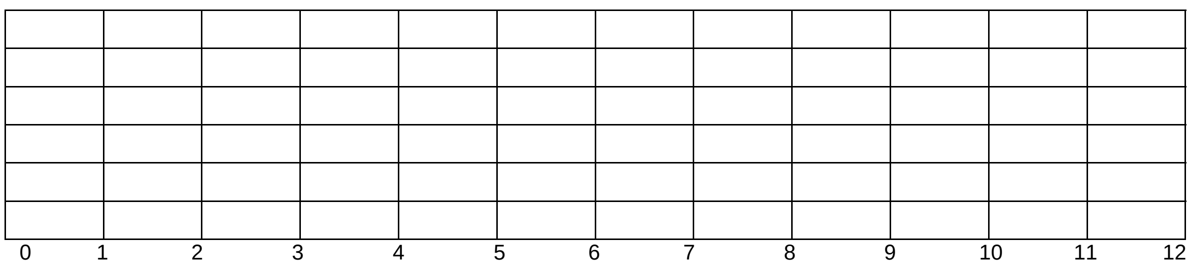
Distance (cm)

t = 4 s



Distance (cm)

t = 5 s



Distance (cm)