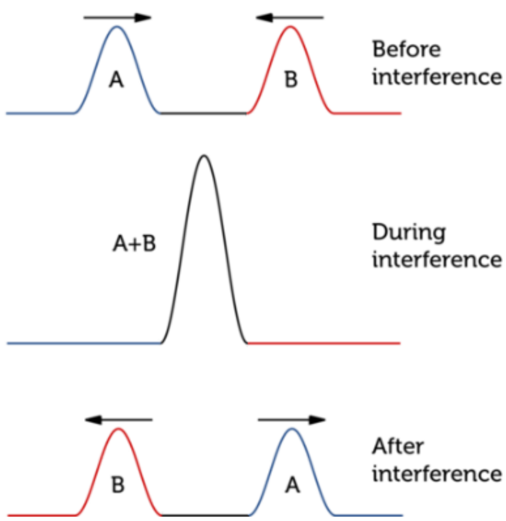
Pre-AP Physics **Week 2: Day 1 Notes**

Waves: Interference

Instructions: Read through the information below. Then answer the questions below.

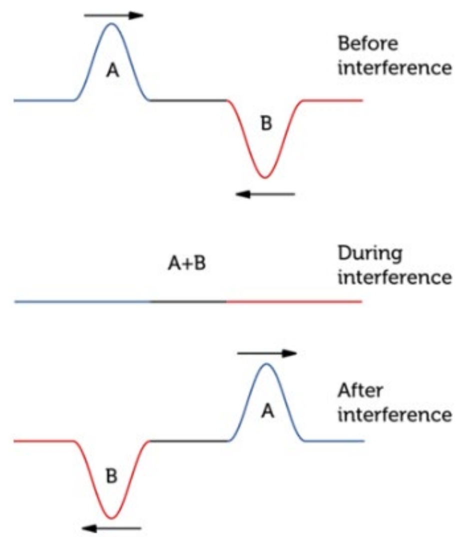
When two or more waves meet, they interact with each other. The interaction of waves with other waves is called **wave interference**. Wave interference may occur when two waves that are traveling in opposite directions meet. The two waves pass through each other, and this affects their amplitude. Amplitude is the maximum distance the particles of the medium move from their resting positions when a wave passes through. How amplitude is affected by wave interference depends on the type of interference. Interference can be **constructive** or **destructive**.

Constructive Interference



Constructive interference occurs when crests of one wave overlap the crests of the other wave. The figure above shows what happens. As the waves pass through each other, the crests combine to produce a wave with greater amplitude. The same can happen with two troughs interacting.

Destructive Interference



Destructive interference occurs when the crests of one wave overlap the troughs, or lowest points, of another wave. The figure above shows what happens. As the waves pass through each other, the crests and troughs cancel each other out to produce a wave with zero amplitude. (NOTE: They don't always have to fully cancel out. Destructive interference can be partial cancellation.)

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

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

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

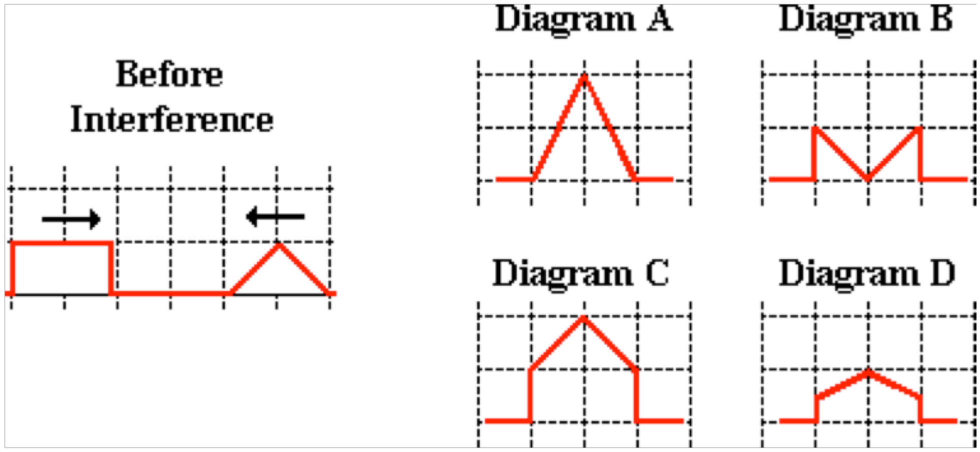
3. Destructive interference occurs when a pulse with an amplitude of +5 units interferes with a pulse with an amplitude of -5 units. _________________

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

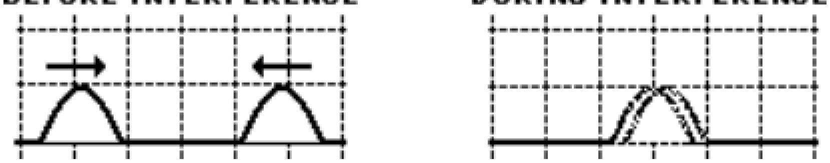
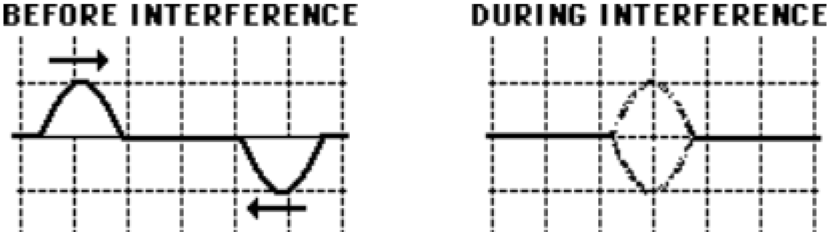
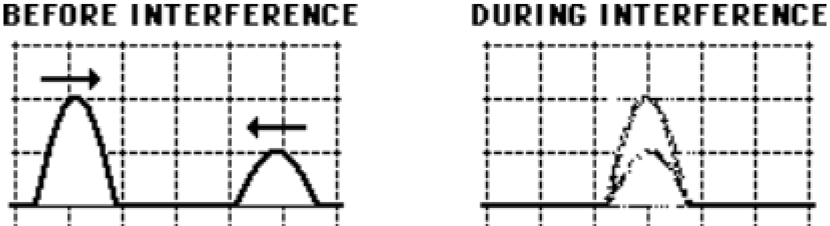
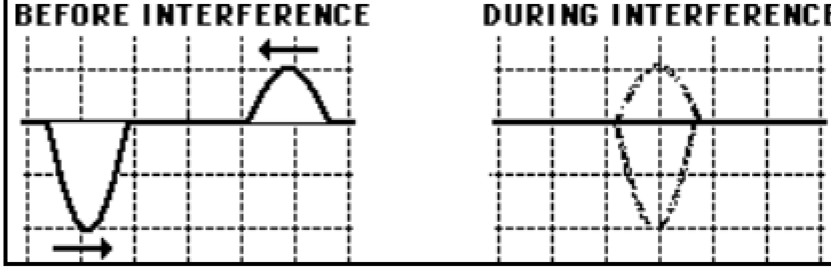
5. If a pulse with an amplitude of +5 units interferes with a pulse with an amplitude of -3 units, then neither constructive nor destructive interference occurs. _________________

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

1. The diagram below right shows two pulses - a square pulse and a triangle pulse - approaching each other along the same medium. Which diagram shows the shape of the medium when they are completely interfering?



2. 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 	
BEFORE INTERFERENCE DURING INTERFERENCE 	
BEFORE INTERFERENCE DURING INTERFERENCE 	
BEFORE INTERFERENCE DURING INTERFERENCE 	

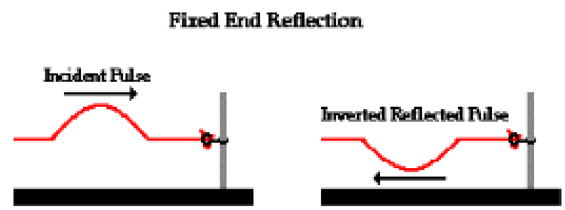
Waves: Boundary Behavior

Instructions: Read through the information below. Then complete the questions below.

The behavior of a 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.

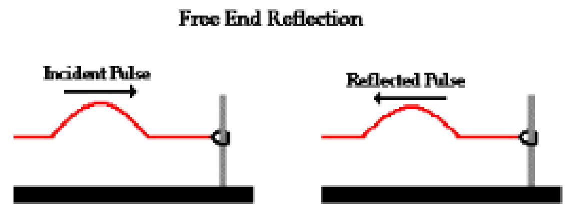
Fixed End Reflection

First consider an elastic rope stretched from end to end. One end will be securely attached to a pole on a lab bench while the other end will be held in the hand in order to introduce pulses into the medium. Because the right end of the rope is attached to a pole, the last particle of the rope will be unable to move when a disturbance reaches it. This end of the rope is referred to as a **fixed end**. When one observes the reflected pulse off the fixed end, there are several notable observations. First the reflected pulse is **inverted**.



Free End Reflection

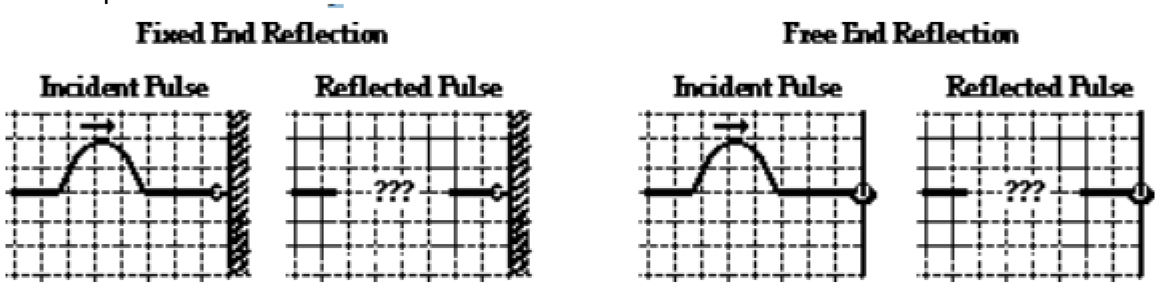
Now consider what would happen if the end of the rope were free to move. Instead of being securely attached to a lab pole, suppose it is attached to a ring that is loosely fit around the pole. Because the right end of the rope is no longer secured to the pole, the last *particle* of the rope will be able to move when a disturbance reaches it. This end of the rope is referred to as a **free end**. The result is that the reflected pulse is **not inverted**. When an upward displaced pulse is incident upon a free end, it returns as an upward displaced pulse after reflection. And when a downward displaced pulse is incident upon a free end, it returns as a downward displaced pulse after reflection.



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

2. State the rule that describes how a pulse will behave at a fixed-end.

3. 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.



Waves: Reflected vs. Transmitted Pulses

Instructions: Read through the information below. Then complete the questions below.

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 that 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 that is reflected is referred to as the **reflected pulse** and the portion that passes into the other medium is referred to as the **transmitted pulse**.

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.

The reflected pulse in medium 1 **will not** be inverted because **more dense to less dense acts like a free-end boundary**. The speed of the transmitted pulse will be **greater than** the speed of the incident pulse. The speed of the reflected pulse will be the **same as** the speed of the incident pulse. The wavelength of the transmitted pulse will be **greater than** 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.

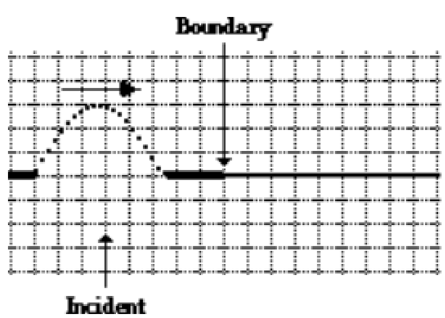
The reflected pulse in medium 2 **will be inverted** because **less dense to more dense acts like a fixed-end boundary**. The speed of the transmitted pulse will be **less than** the speed of the incident pulse. The speed of the reflected pulse will be the **same as** the speed of the incident pulse. The wavelength of the transmitted pulse will be **less than** the wavelength of the incident pulse.

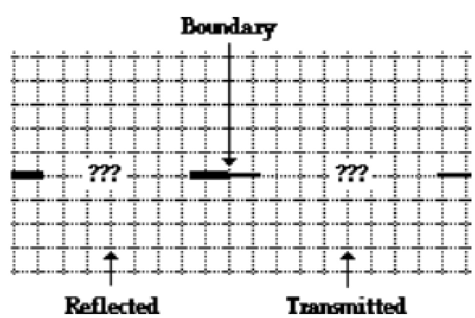
1. Summarize your understanding of boundary behavior by completing the following statements.

   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.

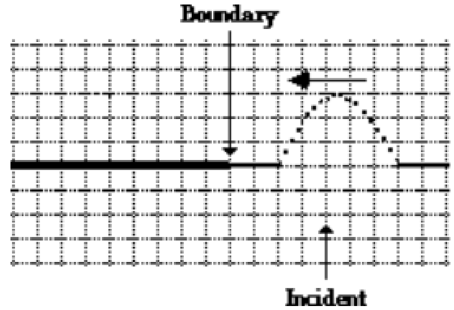
2. Express your understanding of the rules of boundary behavior by drawing the reflected and transmitted pulses in the following two situations. Show the orientation (inverted or non-inverted, wavelength and speed) of each pulse.

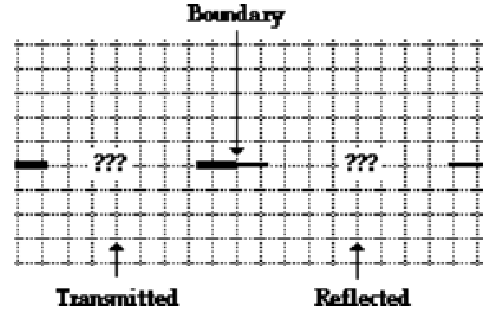
   Incident pulse is in the more dense medium and traveling toward the less dense medium.





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



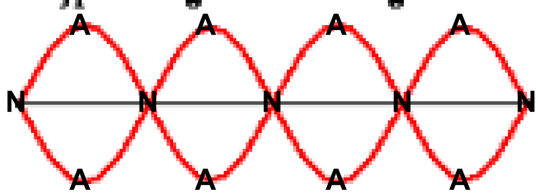


Waves: Standing Waves

Instructions: Read through the information below. Then complete the statements at the bottom of the page using the BOLD words from the page.

A **standing wave pattern** is a vibrational pattern created within a medium when the vibrational frequency of the source causes reflected waves from one end of the medium to interfere with incident waves from the source. This interference occurs in such a manner that specific points along the medium appear to be standing still. Because the observed wave pattern is characterized by points that appear to be standing still, the pattern is often called a *standing wave pattern*. Such patterns are only created within the medium at specific frequencies of vibration. These frequencies are known as harmonic frequencies, or merely **harmonics**. At any frequency other than a harmonic frequency, the interference of reflected and incident waves leads to a resulting disturbance of the medium that is irregular and non-repeating.

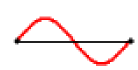
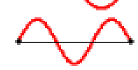
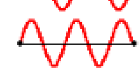
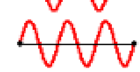
Typical Diagram of a Standing Wave



N = *Node*
A = *Antinode*

One characteristic of every standing wave pattern is that there are points along the medium that appear to be standing still. These points, sometimes described as points of no displacement, are referred to as **nodes**. There are other points along the medium that undergo vibrations between a large positive and large negative displacement. These are the points that undergo the maximum displacement during each vibrational cycle of the standing wave. In a sense, these points are the opposite of nodes, and so they are called **antinodes**. A standing wave pattern always consists of an alternating pattern of nodes and antinodes. The animation shown below depicts a rope vibrating with a standing wave pattern. The nodes and antinodes are labeled on the diagram. When a standing wave pattern is established in a medium, the nodes and the antinodes are always located at the same position along the medium; they are *standing still*. It is this characteristic that has earned the pattern the name *standing wave*. Each node is ½ **wavelength** away from each other in all standing waves.

Observe that each consecutive harmonic is characterized by having one additional node and antinode compared to the previous one. The table below summarizes the features of the standing wave patterns for the first several harmonics.

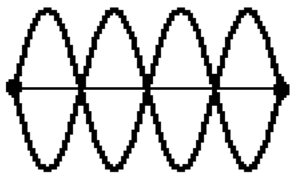
Harmonic	# of Nodes	# of Antinodes	Pattern
1st	2	1	
2nd	3	2	
3rd	4	3	
4th	5	4	
5th	6	5	
6th	7	6	
nth	n + 1	n	--

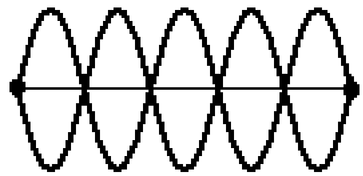
1. The positions along the medium that appear to be stationary are known as_________. They are points of **no displacement**.
2. The positions along the medium that are undergoing rapid motion between a maximum positive and maximum negative displacement are known as_________________. They are the **opposite** of the points of **no displacement**.
3. Each node is separated by the adjacent node by a distance that is equal to______ wavelength.

Video Reinforcer: https://www.youtube.com/watch?v=jz8IIk_bps0

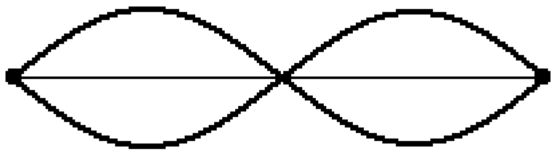
Pre-AP Physics — Week 2: Day 3 Practice

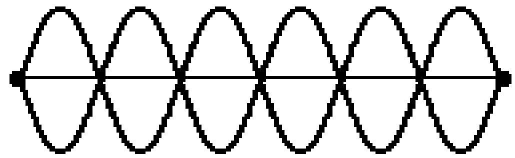
1. Label the nodes (**N**) and antinodes (**AN**) in the following standing wave patterns.
   (Don't forget to count the nodes on each end.)





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





4. 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 | **2nd Harmonic** | **3rd Harmonic**

L = _______ λ | L = _______ λ | L = _______ λ

5. 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 L =____________λ | ***2nd Harmonic*** L =____________λ | ***3rd Harmonic*** L =____________λ

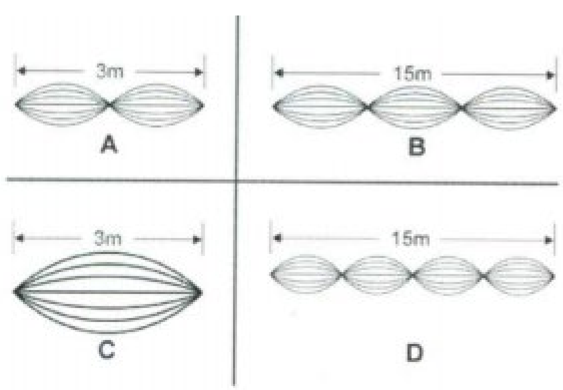
6. Use the graphic below to answer these questions.
   a. Which harmonic is shown in each of the waves below?

      A _________ **B** _________ **C** _________ **D** _________

   b. Label the nodes (***N***) and antinodes (***A***) on each standing waves below.
   c. How many wavelengths does each standing wave contain?

      A _________ **B** _________ **C** _________ **D** _________

   d. Determine the wavelength of each standing wave below.



Waves: Standing Wave Mathematics

Instructions: Read through the information below. Then complete the questions below.

The wavelengths and frequencies of standing waves are:

$$\boxed{\lambda_n = \frac{2L}{n}, \qquad n = harmonic\ number\ \ldots.\ n = 1, 2, 3}$$

The wavelength of the nth harmonic is equal to two times Length divided by the harmonic number.

$$\boxed{v = f_n \cdot \lambda_n}$$

The velocity of a wave is equal to frequency at the nth harmonic times the wavelength of the nth harmonic

Rearrange equation to solve for frequency…

$$\boxed{f_n = \frac{v}{\lambda_n}}$$

The frequency at the nth harmonic equals the velocity divided by wavelength at the nth harmonic.

Substitute $\lambda_n = \frac{2L}{n}$ into $f_n = \frac{v}{\lambda_n}$

$$\boxed{f_n = n\ \frac{v}{2L}}$$

The frequency at the nth harmonic equals the harmonic number times the velocity divided by two times Length.

Last one…

$$\boxed{f_n = n\, f_1}$$

The frequency at the nth harmonic equals the harmonic number times the fundamental frequency

Use the equations above to answer the questions below. Be sure to show your work!

1. A guitar string vibrates with a fundamental frequency of 330 Hz. What are the frequencies of first four harmonics?

2. A stretched wire resonates in three loops at a frequency of 180 Hz. What are the first four harmonics?

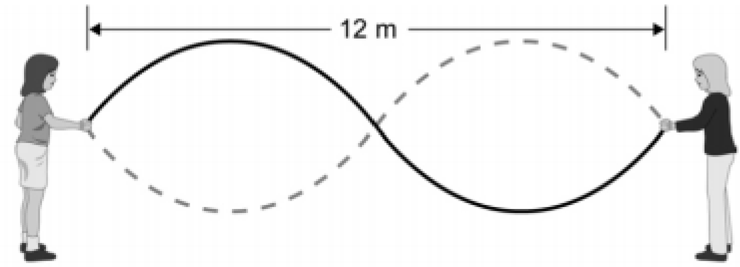
3. A stretched wire with a length of 2.0 m resonates in two loops. The wave speed is 120 m/s. What is the wavelength? What are the first three harmonics?

4. A violin string vibrates with a fundamental frequency of 450 Hz. What are the frequencies of first four harmonics?

5. A violin string with a length of 0.50 m resonates in five loops. The wave speed is 200 m/s. What is the wavelength? What are the first three harmonics?

Pre-AP Physics — Week 2: Day 4 Practice

Two students want to use a 12-m long rope to create standing waves. They first measure the speed at which a single wave pulse moves from one end of the rope to another and find that it is 36 m/s. This information can be used to determine the frequency at which they must vibrate the rope to create each harmonic. Follow the steps below to calculate these frequencies.



1. Draw the standing wave patterns for the first five harmonics.

2. Determine the wavelength and frequency for each harmonic on the 12-meter rope and input into the table below.

Harmonic	Wave Speed (m/s)	Wavelength (m)	Frequency (Hz)
1	36		
2	36		
3	36		
4	36		
5	36		

3. What happens to the frequency as the wavelength increases?

4. Suppose the students cut the rope in half. The speed of the wave on the rope only depends on the material from which the rope is made and its tension, so it will not change. Determine the wavelength and frequency for each harmonic on the 6 meter rope.

Harmonic	Wave Speed (m/s)	Wavelength (m)	Frequency (Hz)
1	36		
2	36		
3	36		
4	36		
5	36		

5. What effect did using a shorter rope have on the wavelength and frequency?