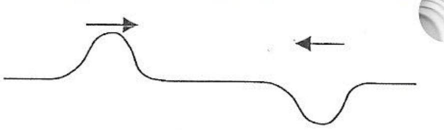
SPH3U: Interference

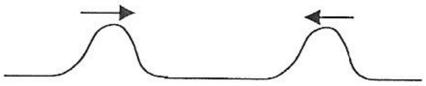
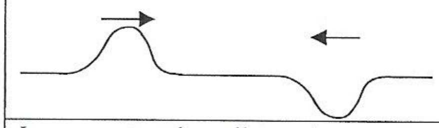
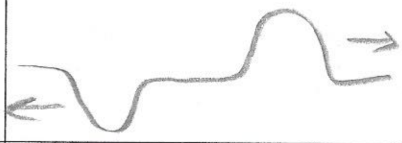
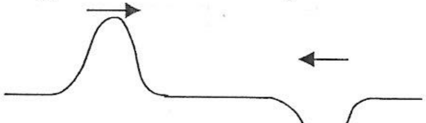
A: When Waves Meet

1. What happens when two waves travel through the same medium and meet? Suppose two waves are heading towards each other. What might happen? Give some options.



- could bounce off eachother
- could cancel eachother out
- could pass through ~~or~~ eachother

2. Watch the video and draw your observations of the spring when the pulses overlap and after they have overlapped.

Before	Overlapping	After
Two crests 	 cons.	
Two Troughs 	 cons.	
Equal crest and trough 	 dest.	
Large crest and small trough 	dest. 	

3. Describe what happens when the waves overlap.

The result is a combination of both waves combined.

4. Do the waves bounce off one another or do they travel through one another?

Trough

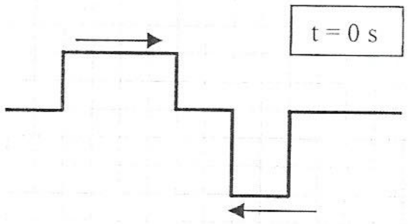
When two ideal waves overlap, one does not in any way alter the travel of the other. While overlapping, the displacement of each particle in the medium is the sum of the two displacements it would have had from each wave independently. This is the *principle of superposition* which describes the combination of overlapping waves or *wave interference*. When a crest overlaps with a crest, a *supercrest* is produced. When a trough and a trough overlap, a *supertrough* is produced. If the result of two waves interfering is a greater displacement in the medium *constructive interference* has occurred. If the result is a smaller displacement, *destructive interference* has occurred.

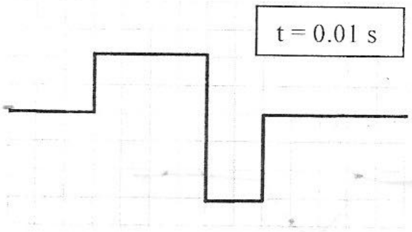
5. Label each example in the "Overlapping" column of your chart as either constructive or destructive interference.

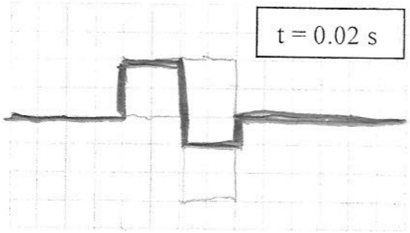
✓

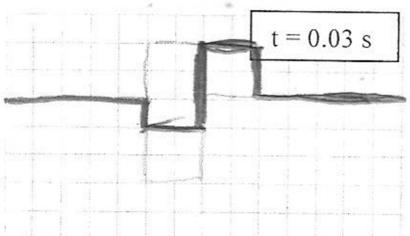
B: Interference Frozen in Time

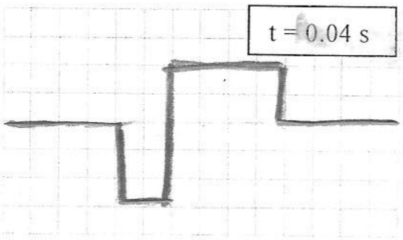
Let's apply the principle of superposition to some sample waves and learn how to predict the resulting wave shapes. Each pulse moves with a speed of 100 cm/s. Each block represents 1 cm.

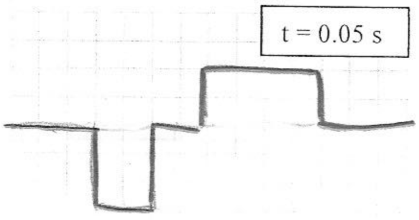


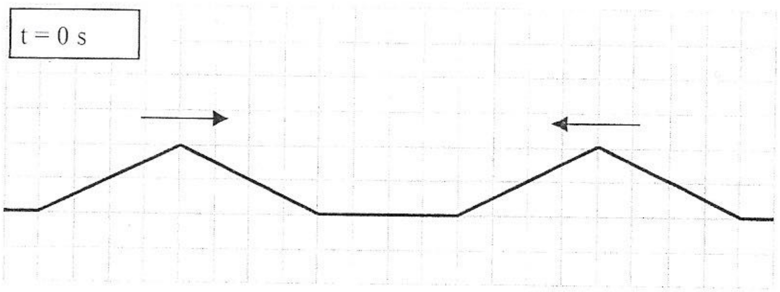


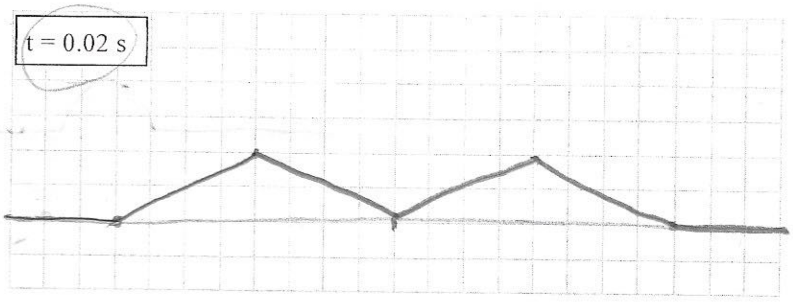


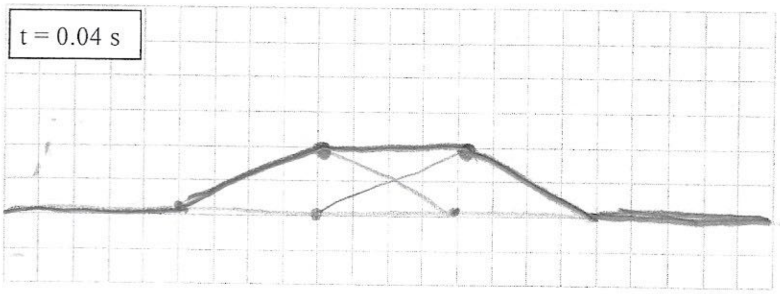


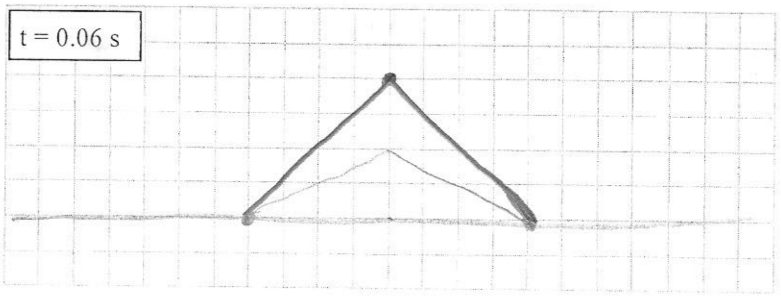


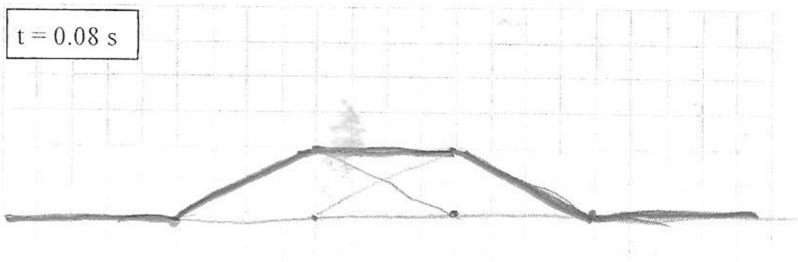










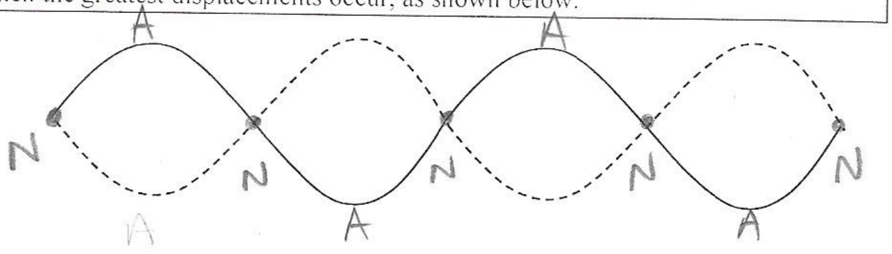


Adapted from *Activity-Based Tutorials*, by Wittmann, M., et al. John Wiley, 2004

4. **Represent.** Label the locations in the medium where nodes and antinodes are found in your sketches.

Since a standing wave pattern is a moving phenomena, we need a *standing wave diagram* to represent it. In this diagram, we show the wave at the two moments in time when the greatest displacements occur, as shown below.

5. **Represent.** Label locations in the medium where nodes and antinodes occur in the standing wave diagram.



6. **Reason.** What fraction of a cycle has elapsed between the two images of the wave?

$\frac{1}{2}$

C: Standing Wave Patterns

We will continue using the phet simulation phet.colorado.edu/en/simulation/wave-on-a-string. Add a VERY small amount of Damping and set Tension to Medium. Set Amplitude to 0.75 m.

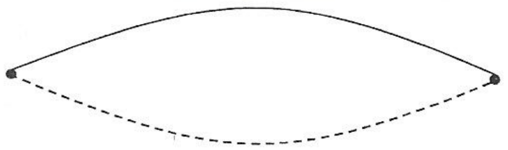
make notes?

1. **Observe.** Start with a very low frequency and gradually increase the driving frequency until it is as high as possible. Try to create some standing waves – you want certain balls to move a lot and others to move just a little.

2. **Observe.** Create a standing wave with the lowest frequency you can manage. You've got the correct pattern if there is only one anti-node. Measure and record the length of the spring and the period of the wave in the table below.

3. **Observe.** Gradually increase the frequency driving the spring until you find the next standing wave pattern or oscillation mode. Every time, a new node should appear. Measure the period. Repeat this and complete the chart below.

reconsider...

Mode	# of Anti-Nodes	# of Nodes	Length (λ)	λ (m)	T (s)	f(Hz)	Diagram
1	1	2	½				
2	2	3	1				
3	3	4	1.5				

4. **Predict.** What is the standing wave pattern and all its characteristics for the 5th mode. Sketch it below.

4th

Patterns like those above are examples of *resonance*, where a small, periodic driving force can cause an object to vibrate with a large amplitude. An object will *resonate* when the *driving frequency* matches the object's *resonant frequency*. The value of the resonance frequency depends on the composition and construction of the object. If the driving frequency is slightly higher or lower than the resonance frequency, the amplitude of waves in the object is much smaller and the vibrating pattern will not be regular.

$\lambda_n = \frac{2L}{n}$

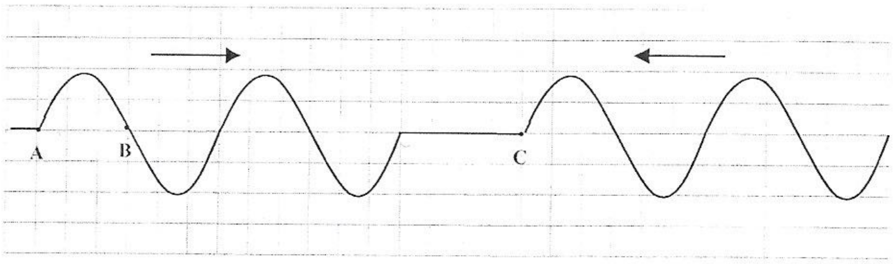
formula/equation summary.

SPH3U: Standing Waves

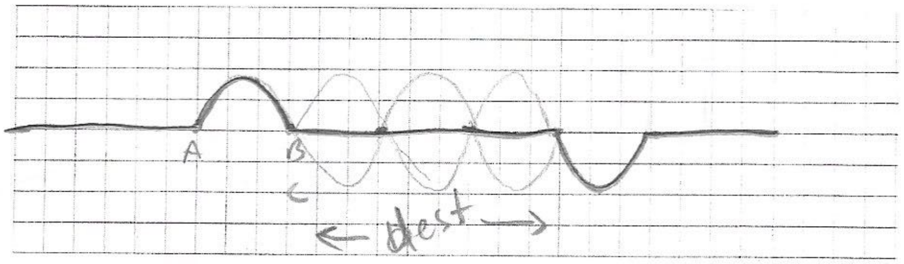
A: When Continuous Waves Interfere

The diagram to the right shows two waves travelling in opposite directions in a spring.

The points A, B, and C are points of constant phase and **travel with the wave**. We will use these to help keep track of the wave.



1. Use dotted lines to draw the shapes of the individual waves when points B and C coincide. Draw the displacement of the actual medium using a solid line. You should be able to do this without detailed math work. (**Borrow the transparencies of these waves to help visualize this.**) Label the regions where constructive or destructive interference occurs.



2. Use dotted lines to draw the shapes of the individual waves when points A and C coincide. Draw the displacement of the actual medium using a solid line.

B: Representing Standing Waves

When the interfering process we examined above repeats, a standing wave is created. We will continue to use phet.colorado.edu/en/simulation/wave-on-a-string , this time to make a standing wave.

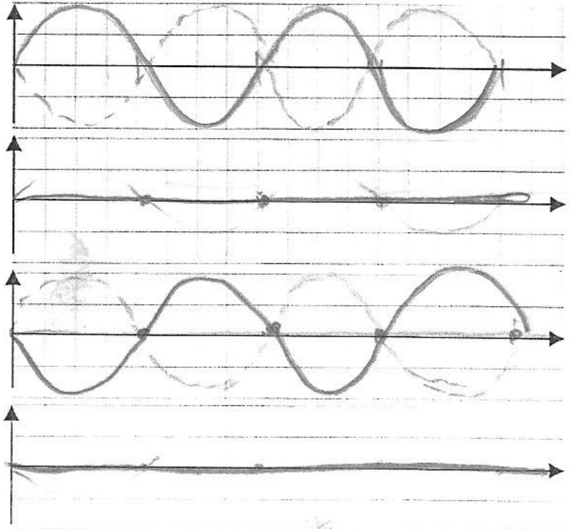
make a video in phet

1. **Reason.** Why do you think the term "standing wave" is used?

2. **Observe.** Do all particles in the medium oscillate equal amounts? Describe the pattern of oscillations.

Some move a lot, some only move a little.

3. **Observe.** Your teacher will freeze the video to help us study the standing wave pattern at different moments in time, separated by ¼ period. Sketch the displacement of the medium at each moment.



A *standing wave* is a wave pattern created by the interference of two continuous waves travelling in opposite directions in the same medium. It is called a standing wave because there are locations in the medium where the waves always interfere destructively and the particles do not move (or hardly move). These locations are called *nodes* or *minima*. There are other locations where the waves always interfere constructively. These locations are called *antinodes* or *maxima*.

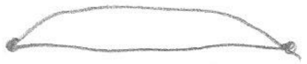
$\lambda_n = \frac{2(L)}{n}$

SPH3U: Standing Wave / Resonance Homework

A: Pure as the Driven Spring

A spring is stretched out and held fixed on the ground at two points 2.9 m apart. Its wave speed at that length is 4.5 m/s.

1. **Calculate and Explain.** What is the wavelength when vibrating in the first and second harmonics? Explain your result.



2.9x2 = 5.8 m

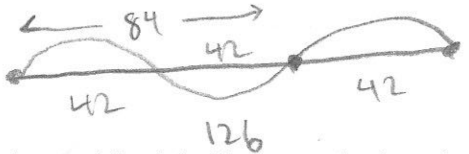
2.9m

2. **Calculate.** What frequency should the student use to create a standing wave in the first and second harmonics?

$v = f\lambda$ $4.5\ m/s = f(5.8)$ $4.5\ m/s = f(2.9)$

$f = 0.78$ cycles/sec. $f = 1.55\ Hz$

3. **Explain.** You create a wave that has a wavelength of 84 cm in a spring stretched out to a distance of 126 cm. Will resonance occur? (Will a standing wave be created?) Use a standing wave diagram to help explain.



Yes it will

4. **Calculate and Explain.** The two ends of a spring are held fixed on the ground 5.3 m apart. Waves travel in the spring at 4.7 m/s. A student drives the spring using a frequency of 2.9 Hz. Will resonance occur? Explain how you decide.

$v = f\lambda$ $\lambda_n = \frac{2L}{n}$

$v = f\lambda$

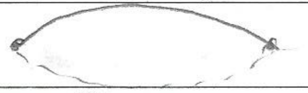
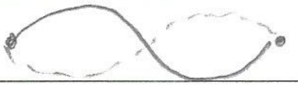
$4.7 = 2.9\lambda$

$\lambda = 1.62\ m$ wavelength

$5.3 \div 1.62 = 3.27$

No resonance... this would need to be 2, 2.5, 3, 3.5, etc.

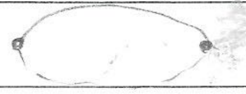
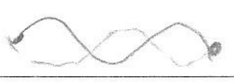
5. You have a spring stretched along the floor to a length of 3.9 m.
   (a) **Calculate and Represent.** Draw a standing wave diagram for the first three harmonics. Determine the wavelength of each harmonic.
   (b) **Calculate and Describe.** Waves travel with a speed of 6.1 m/s in your spring. Determine the first three resonant frequencies for your spring. What do you notice about the pattern of frequencies?

	Standing Wave Diagram	λ	*f*
1		7.8	0.78
2		3.9	1.56
3		2.6	2.35

$v = f\lambda$ $f = \frac{v}{\lambda}$

↳ increasing by constant amount

6. **Reason and Calculate.** You hold one end of a new meter stick against the desk. The length of the vibrating part of the stick is 0.75 m and it vibrates in its first harmonic with a frequency of 5.3 Hz. What are the frequencies of the next two harmonics? (Hint: use the fact that all the lengths are the same)

	Standing Wave Diagram	L= λ	*f*
1		1.5m	5.3
2		0.75m	10.6 Hz
3		0.5m	15.9

$v = f\lambda$

$v = (5.3)(1.5)$

$= 7.95\ m/s$

$f = \frac{v}{\lambda}$