15815 Super Spring - Teacher

Accessories Needed, Not Included:

- *Required Accessories:*
  - string (2 to 4 meters needed)
  - C-clamp (or any other fixed clamp on a bench)
  - Stopwatch
  - masking tape or labels
  - One or more of the following: heavier cord or rope, different spring, rubber tubing, bungee cord, etc.
  - Meter stick or tape measure
- *Optional Accessories:*
  - Snakey (15820)
  - Other springs

PURPOSE

The Super Spring Wave Demonstrator is used to demonstrate properties and behaviors of several types of waves in a way that provides more viewing time with better storage between experiments. The student will observe several types of waves, investigate how these waves are produced and interact, describe the observations and speculate on other related wave behaviors

OBJECTIVES

- To study the motion of waves through a medium
- To study how waves interact with each other
- To study how energy is transferred through a spring
- To study the Law of Superposition

SAFETY

While a Super Spring is not inherently dangerous, care should be taken not to release a stretched Super Spring as it will return to equilibrium rapidly. It may snap back fast, and can cause injury if care is not taken. Also, this rapid return to equilibrium may cause damage to the Super Spring. The Super Spring should not be extended more than 12 meters (39 feet). Eye protection should be worn.

ASSEMBLY

The Super Spring requires no assembly.

SUGGESTIONS

- For all procedures, the Super Spring allows more viewing time than the Spring does due to the fact that it is longer. If space is an issue a Spring (# 15810) would work fine.
- Keep objects off the floor and away from Super Spring movement to prevent tangling.

- **<u>DO NOT OVERSTRETCH THE SUPER SPRING!!!!</u>** The Super Spring works fine stretched to a limit of 12 meters (39 feet). Beyond that, the Super Spring may become permanently distorted.
- To make the movements of the spring more obvious, attach a piece of colored string or tape to a point at approximately the center of the spring. This gives a place to focus on, rather than trying to observe the entire spring.
- If consistency in amplitude is desired, tile floors can be used as grids to maintain amplitude from one demonstration to the next. If these demonstrations are being used as a lab, and data taking is required, tile floors can make a grid for more precise measurements.
- There are several ways to create consistent transverse wave pulses: quick shaking of an end, hit the side with your hand, or hit the spring with a meter stick or broom handle. Whatever method works best for you and your students is the one you should use. There are several ways to create consistent longitudinal wave pulses: gather up a set number of coils and release with your hand, stretch out a section of set coils near your hand and release them, or use a small stick (Popsicle stick or small ruler) to gather up a set number of coils and release them. If you use a stick of some sort to create the wave pulses, take care not to get the stick tangled in the spring, as this will damage it.

BRIEF DESCRIPTION OF PROCEDURES

Following are a few examples of demonstrations that can be done to show types of waves and energy in waves. Other examples of demonstrations can be found in the laboratory guides of the Project Physics and the Physical Science Study Committee (PSSC) courses, as well as many other places. Some suggestions for demonstrations are given below. The questions in the different sections are ideal for discussion questions, rather than homework questions, as they allow students to develop the concept themselves, and also allows for class interaction during the experiment. Some assessment questions have been provided at the end of the student materials, and these are designed to be more homework-like questions and answers, allowing for some expansion of knowledge and reaffirming of ideas gained in the experiments. The questions cover many different levels of thinking and explaining, and some may be more suitable for upper level classes than younger students. Which, if any, questions you use will be left to your discretion. It is recommended that all of the demonstrations are completed in order, as each successive one builds knowledge based on the previous one.

Procedure A: Procedure A is designed to introduce students to the different types of waves, or to refresh their memory on the waves if they have already done transverse and longitudinal waves. Procedure A also introduces the idea of energy in a wave, and how waves show the presence of kinetic and potential energy in a spring.

Procedure B: Procedure B is designed to introduce students to reflection and refraction of waves, through fixed end reflection, free end reflection, and refraction when entering a new medium.

Procedure C: Procedure C is designed to examine wave speed, and how wave speed depends on the different properties of the spring, including tension. Also, it examines how wave speed is related to a change in medium (tension, density, etc), and also how speed and amplitude are related.

Procedure D: Procedure D is designed to examine superposition of waves through the use of standing waves and transverse waves. Transverse wave superposition is achieved through introducing two waves to the spring, while standing wave superposition is achieved through continuous transverse waves. Standing waves are examined both qualitatively and quantitatively, while transverse superposition is examined mainly through qualitative investigation. The transverse superposition could be examined quantitatively if desired, and a good way to measure the amplitude change is to use a tile floor as a grid, and measure the amplitude in tiles, then that can be converted into numbers for calculations.

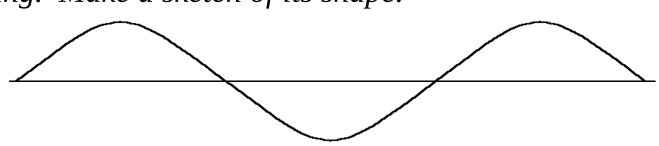
OTHER OPTIONAL DEMONSTRATIONS:

For more demonstrations on energy, a Super Spring can be used to send a can moving. To do this, place a can near the Super Spring, and send a transverse wave down the Super Spring such that the wave is on the same side as the can. When the wave hits the can, the spring will impart energy to it, and send the can flying. (This demonstration is easily accomplished with the Super Spring, but is better demonstrated with the Snakey spring (TSS#15820) as the Snakey allows transverse waves to be more defined.) A similar but less dramatic demonstration of this is with longitudinal waves. Insert a straw or Popsicle stick in the Super Spring, and place a can in front of the stick. Send a longitudinal wave down the Super Spring, and the stick will impart energy to the can, moving it. See the diagrams below for reference of these two optional demonstrations.

PROCEDURE A - QUESTIONS AND ANSWERS

Q1. Describe the wave pulse that travels down the Super Spring. Make a sketch of its shape.

Answers will vary, and might include the wave is U-shaped, looks like a water wave, etc.



Q2. Describe the motion of the point in the Super Spring marked by the piece of tape as a wave pulse passes through.

Tape moves up and down. Doesn't travel from side to side

Q3. Taken as a whole, what is the motion of the Super Spring as a transverse wave passes down its length?

Steady and straight until wave encounters area. Moves from equilibrium to a point of greatest energy (the highest point, distance from equilibrium equal to the amplitude of the wave). Returns to equilibrium after wave has passed.

Q4. What is actually moving from your end to the fixed end of the Super Spring?

Energy is moving from one end to the other end, not the Super Spring.

Q5. In what way does a wave pulse show the presence of potential energy?

The spring is stretched when the wave is created- a stretched spring is moved from equilibrium, and therefore has potential energy.

Q6. In what way does a wave pulse show the presence of kinetic energy?

When the spring moves due to the energy of the wave, kinetic energy is shown to be in the spring.

Q7. What is the source of this kinetic and potential energy in the Super Spring?

Kinetic- movement applied to the spring, energy imparted to the spring
Potential- movement from equilibrium

Also, if there is one type of energy in the system, there must be the other type of energy in the system (conservation of energy).

Q8. Describe the wave pulse that travels down the Super Spring. Try to make a sketch of its shape in the Super Spring.

Areas of compression as wave moves down spring.

Q9. Describe the motion of the point in the Super Spring marked by the piece of tape as a longitudinal wave pulse propagates?

Moves back and forth, not up and down.

Q10. Taken as a whole, what is the motion of the Super Spring as a longitudinal wave passes down its length?

As wave moves through the Super Spring, there are areas of compression and stretching (rarefaction) that appear to move through the Super Spring.

Q11. What is actually moving from your end to the fixed end of the Super Spring?

The energy is what is moving from end to end, not the Super Spring.

Q12. In what way does a longitudinal wave pulse show the presence of potential energy?

The spring is compressed and stretched, thus moved from equilibrium, and thus containing potential energy.

Q13. In what way does a longitudinal wave pulse show the presence of kinetic energy?

Movement of any sorts shows the presence of kinetic energy.

PROCEDURE B – REFLECTION AND REFRACTION

Q1. Is the reflected wave on the same side of the Super Spring or on the opposite side as compared to the original wave pulse?

Opposite side

Q2. Describe any other changes that you see in the shape or size of the reflected wave pulse.

No apparent change in shape or size

Q3. Is this situation a fixed end or a free end? How do you know?

Fixed end. Reflected wave is on opposite side from incident wave. (See introduction for details)

Q4. Describe any changes in the reflected wave pulse.

No apparent change in shape or size.

Q5. Is the reflected wave on the same side of the Super Spring or on the opposite side as compared to the original wave pulse?

Same side

Q6. Describe any other changes that you see in the shape or size of the reflected wave pulse.

No apparent change in shape or size

Q7. Is this situation a fixed end or a free end? How do you know?

Free end- reflected wave is on the same side as incident wave. (See introduction for details)

Q8. Is the transmitted wave on the same side of the Super Spring or on the opposite side as compared to the original wave pulse?

Same side

Q9. Describe any other changes that you see in the shape, size, or speed of the transmitted wave pulse.

Same shape, wider wave, smaller amplitude, moves faster.

Q10. To the extent that you are able, describe all of the wave behaviors that you observe in this system of two different materials carrying waves. (Hint: Have each person describe to the group what they saw in their portion, so that all possible detail gets included.)

High density to low density- in less dense material, transmitted wave will go faster and will be wider. Reflected wave will be on same side as incident wave with same speed and wavelength as incident wave. Both have smaller amplitudes than incident wave.

Low density to high density- in more dense material, transmitted wave will be slower and smaller (wavelength less). Reflected wave will be on opposite side of incident wave with same speed and wavelength. Both have smaller amplitudes than incident wave.

PROCEDURE C - Wave Speed

Q1. How does the speed of the wave appear to change when it enters a new medium?
If new medium more dense, will slow down. If less dense, will speed up.
Q2. How does the speed of the wave appear to change when it enters a new medium?
If new medium more dense, will slow down. If less dense, will speed up.
Q3. Does the wave move down the Super Spring faster or slower than when the Super Spring was at its original tension?
Faster
Q4. Does the wave move down the Super Spring faster or slower than before?
Faster
Q5. What is the relationship between the tension in the Super Spring and the wave speed in the Super Spring?
As tension increases, speed increases
Q6. As the amplitude increases, what happens to the speed of the wave?
Speed remains the same

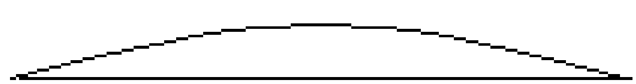
PROCEDURE D - Superposition of Waves.

1. Superposition of Transverse wave pulses

Q1. What happens when the waves meet? After they have passed the middle point?
When they meet, they form one big wave with an amplitude equal to the sum of the two individual waves (in this case, should be twice as large as one incident wave). After they have passed each other- will look like they did originally.
Q2. What happens when the waves meet? After they have passed the middle point?
When they meet, they form one big wave with an amplitude equal to the sum of the two individual waves. After they have passed each other- will look like they did originally.
Q3. How does this situation compare the previous situation?
Same idea behind both- Law of Superposition. Combined wave is sum of individual waves.
Q4. What happens when the waves meet? After they have passed the middle point?
When they meet, there should be no wave. Each wave cancels out the effect of the other. After they have passed, they look like they did originally.
Q5. How does this situation compare to the previous two situations? What is the same in both? What is different in both?
Where the waves meet, they add together to form the new wave. In situation 1, the two waves combined to make a large wave, and in situation 2, the two waves combined to make no wave.

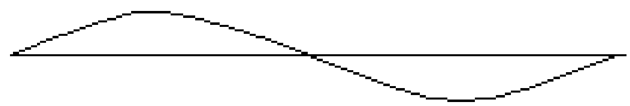
2. Standing waves- Part 1

Q6. What does the Super Spring look like at this frequency? Draw a picture.
This will depend on the amplitude and frequency they choose. An example might be:



Q7. What does the Super Spring look like at this frequency? Draw a picture.

This will depend on the amplitude and frequency they choose. An example might be:



Q8. What is different about the two standing waves you have created?

Number of nodes and antinodes ("peaks, valleys, zero-points"), wavelength, etc.

Q9. Compare each standing wave to the ones you have created before it. What is the same in each situation? What is different in each situation?

Keep increasing number of nodes and antinodes, wavelength gets shorter, etc.

Q10. Do these frequencies create standing wave patterns now?

Depending on the frequency and tension of the Super Spring, they may create standing waves. Whether or not the frequency will create a standing wave will be determined by the tension.

3. Standing Waves- part 2

Values in the data table will vary depending on the tension of the Super Spring

Q1. Using the measured length of the stretched Spring, what is the wavelength (in meters or feet) of each number of wavelengths used in the experiment?

Answers will vary depending on the length of the stretched Spring.

Q2. What is the frequency of each wavelength?

Answers will vary depending on the length of the stretched Spring.

Q3. What is the relationship between the number of wavelengths and the frequency of the spring? Describe this relationship, or develop a formula relating number of wavelengths and frequency.

Inversely proportional with a constant wave velocity.

A possible formula: Frequency = (Constant)/(Number of wavelengths)

THE CONSTANT DEPENDS UPON WAVE SPEED AND LENGTH OF THE SPRING.

SUMMARY & REVIEW QUESTIONS

1. Water waves are not exactly the same as the kinds of waves observed in the Super Spring. However, they are similar to one of the types of waves you have used. Are water waves more like transverse or longitudinal waves? Describes ways in which these waves are similar and ways in which they are different.

Water waves are more like transverse waves in that they move up and down, rather than side to side or front to back. (Assuming it is a calm day with gentle waves) Transverse waves transfer energy through the up and down motion of the spring, where as longitudinal waves transfer energy through the back and forth motion of the spring.

2. Sound waves are also not exactly the same as the kinds of waves observed in the Super Spring. However, they are similar to one of the types of waves you have used. Are sound waves more like transverse or longitudinal waves? Describes ways in which these waves are similar and ways in which they are different.

Sound waves are more like longitudinal waves in that they compress and stretch the medium to travel.

3. What properties of a medium may affect the wave speed of waves traveling through that medium? Also try to suggest how those properties affect the wave speed, making waves faster or slower.

Tension of the medium (the greater the tension, the faster the wave goes), density of the medium (the higher the density, the faster the wave goes).

4. Considering your answers to the previous question, how might properties of different gases affect the speed of sound through those gases (as compared to the speed of sound in air)? Consider air at different pressure or different temperature. Also, consider different gases such as helium or carbon dioxide.

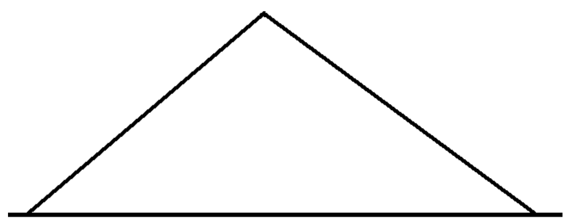
The density of the gas will determine how fast the wave travels through it. The greater the density, the faster the speed. As temperature increases, speed increases. As pressure increases, speed increases. (the Ideal Gas Law PV = nRT)

5. Similarly, how would the speed of sound be affected by the different properties of water or steel as opposed to sound traveling through air?

As density increases, speed increases.

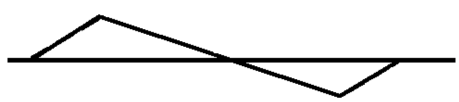
6. The sketch below shows two wave pulses approaching each other along a normally-straight medium. Make a sketch to show the shape of the medium when the two pulses have traveled to the point where the peak of each wave is at the same point.

Student drawing should be that the two waves combine to create one large wave of twice the amplitude of the individual waves.



7. Same problem as #6, but this time the wave pulses are originally on opposite sides of the medium. Draw what the wave would look like when the peaks overlap.

Student drawing should be that the two waves combine, and in parts they cancel out and in other parts they don't. The drawing should look something like:



8. The wave equation that applies to all types of waves is

v = fl

where 'v' is wave speed (m/s)
'f' is frequency (Hz)
and 'l' is wavelength (m).

If wave speed is constant, what is the mathematical relationship between wavelength and frequency? Is this verified by your results in Q1 in part D3? Explain how. (Hint: what is the wave speed for each wavelength you timed?)

Wavelength and frequency are inversely proportional to each other if speed is constant. Verification is best done through calculation of wave speeds. (The calculations may not yield exact matches in wave speed due to inaccuracies in measurements of time and frequency)

9. If a frequency of 3.0 Hz causes a standing wave pattern of exactly one wavelength in a Super Spring, what frequency would cause a standing wave pattern of 1.5 wavelengths? What other information do you need to determine the actual wave speed in the Super Spring?

If wave speed is the same in both situations (tension/density the same), then the frequency would be

$$f_1 l_1 = f_2 l_2$$

$$(3.0\ \text{Hz})*(1.0\ \text{wavelength}) = f_2*(1.5\ \text{wavelength})$$

$$f_2 = 3.0\ \text{Hz}*\text{wavelength} / 1.5\ \text{wavelength}$$

$$f_2 = 2.0\ \text{Hz}$$

To determine actual speed, need length of original wavelength (in meters), which would be the length of the Super Spring.

10. Determine the wave speed for the different wavelengths measured in D3.
Answers will vary depending on the length the Spring is stretched and how accurate the data is.

SUGGESTIONS FOR FURTHER STUDY

Please share these with your students.

This is the website for the Physics Classroom. The website gives information about waves (properties, behavior, etc), as well as gives graphical and animation representations of the wave motion. Seems good for students if they are doing this work at home or without the apparatus in front of them, as a refresher for the information they learned in the demonstrations. (Not a substitute for the experiments, but a good reinforcement.) http://www.physicsclassroom.com/mmedia/waves/wavesTOC.html

To satisfy earth science requirements, an introduction to waves in nature could be made, and students could research and report on different waves in nature, such as water waves (from regular waves driven by wind to tsunamis created by massive changes in the surrounding ground), sound waves, light waves, different waves in an earthquake, electromagnetic waves, radio waves, gamma rays, x-rays, etc. In this research, they could reference what they have seen in these demonstrations as a way to help explain the natural phenomena.

SAFETY AND DISPOSAL

- **DO NOT OVERSTRETCH THE SUPER SPRING!!!!**
- The Super Spring works fine stretched to a limit of 12 meters (39 feet). Beyond that, the Super Spring may become permanently distorted.
- Eye protection should be worn.
- Be careful with extended Super Spring and Snakey, as rapid release may cause them to snap back and hurt someone
- When storing the Super Spring, make sure to place it carefully on the stand provided, as this will prevent the Super Spring from becoming distorted or tangled.