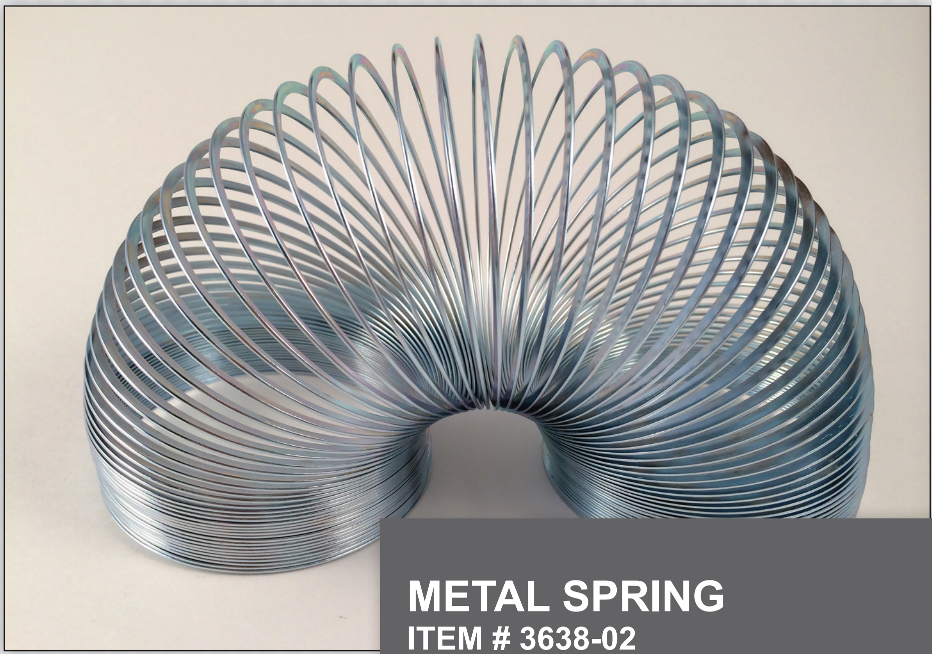
TEACHERS GUIDE



METAL SPRING
ITEM # 3638-02

ENERGY - MOTION

Waves are all around us. From sound waves, to electromagnetic waves, to seismic waves, we experience wave motion on a daily basis. For as common as waves are, their motion and properties can sometimes be challenging to visualize. What is the difference between longitudinal waves and transverse waves, and how do these differences affect the world around us?

Materials

- block of wood
- screws
- washers
- poster board
- clear tape
- scissors
- electrical tape
- additional metal and/or plastic springs

Goals & Objectives

See page 8 for Next Generation Science Standards (NGSS)

INTRODUCTION

Waves are all around us. From sound waves, to electromagnetic waves, to seismic waves, we experience wave motion on a daily basis. For as common as waves are, their motion and properties can sometimes be challenging to visualize. What is the difference between longitudinal waves and transverse waves, and how do these differences affect the world around us?

Metal springs are an excellent way to visually demonstrate and explore the mechanics and phenomena of wave motion. While the 60 x 75mm Metal Spring should provide ample opportunities to investigate waves, you may also find it valuable to have various lengths and types of springs (plastic, more tightly wound, longer, etc.). The metal spring is perfect for instructor-led demonstrations, but they are engaging enough for constructivist learning, as well. So be sure to let your students play, too!

How It Works

The metal spring is an excellent way to demonstrate wave motion, because it is easy to see how energy can be passed from one part of the spring to the next much like energy passes from one particle of air, liquid, or solid to the next in sound and seismic waves. The wave moves along the spring as the energy passes from one section to the next, yet at the end, the spring returns to its original formation, much like the vibrated air particles stay in relatively the same space and do not travel with the wave.

GLOSSARY

Vocabulary:

- amplitude
- antinodes
- compression
- compressional waves
- dilation
- echo
- energy transfer
- frequency
- hertz
- longitudinal wave
- Love waves
- nodes
- p waves
- Rayleigh waves
- reflected pulse
- s waves
- seismic waves
- shear waves
- sound waves
- standing waves
- surface waves
- transmitted pulse
- transverse wave
- wave reflection
- wave propagation
- wavelength

ACTIVITIES

For younger students, focus on science practice skills such as predicting, making observations, and explaining at an age appropriate level. More complex physics and geological concepts can be addressed using the same activities with middle school through college-level students. Any of the activities could be enhanced by video recording the wave action, and then slowing it down – even frame by frame – during the replay.

Use the metal spring to demonstrate and/or allow students to investigate different kinds of waves and discuss how the different waves are experienced or found in the world around us (sound waves, light waves, seismic waves, etc.). Most of the demonstrations are best done on the floor with a smooth, hard surface.

1 ***Longitudinal waves:***
Stretch the metal spring out between two students or between a person and a fixed point. Have one person pull back a few extra coils of the spring and then let go.

- What happens?
- What is the direction of the vibration?
- What is the direction of wave propagation?

Examples of longitudinal waves are sound waves, as well as compressional, or p, waves in the earth. Try continuing the motion over and over, rather than just one initial motion. Try different rates of propagation.

- Can you see the wave reflect back from the stationary end?
- Can you create a standing wave?

Transverse waves:
2 Stretch the metal spring out between two students or between a person and a fixed point. Have one person quickly move their end up and then down (or left and then right).

- What happens?
- What is the direction of the vibration?
- What is the direction of the wave propagation?

Examples of transverse waves include waves along the electromagnetic spectrum (including light) and shear, or s, waves in the earth. Try continuing the motion over and over, rather than just one initial motion. Try different rates of propagation (faster, slower). Try bigger and smaller movements to create

***Note**
It is always wise to DO an experiment ahead of time to be able to best present it to the class.

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ACTIVITIES

Activities continued

different amplitudes.

- Can you see the wave reflect back from the stationary end?
- Can you create a standing wave?

3 ***Other seismic demonstrations:***

Love waves:

- Stretch out the metal spring on the floor to show that the motion is at the surface. Move one end of the spring quickly from side to side. Explain that under the ground, the wave motion is the same, but the amplitude decreases with depth.

Rayleigh waves:

- Stretch out the slinky between two people. One person can generate the wave by quickly moving one end in a circular or elliptical motion – first up and back and then down and forward to complete the circle or ellipse. Explain that this wave is also limited to the surface of the earth.

Earthquake demos and design challenge:

- Attach one end of the metal spring to a block of wood using screws and washers. Propagate different kinds of seismic waves my moving the opposite end of the spring. Observe the motion of the block. Create a building out of poster board and tape to set on the wooden block. Observe the movement of the building during different kinds of waves. Expand upon this activity by challenging students to engineer a building that best stands up to the energy transferred by the wave motions.

4 ***Compare waves at different distances and through different mediums:***

Have different pairs of students use different lengths of metal springs. For shorter lengths, students can hold a portion of the spring together in their hands. Have the people who will propagate the waves stand in the center of the room with their backs together, while their partners stretch out the springs like spokes on a wheel.
Have all teams propagate the waves at the same time, and have the receiving partners call out when the wave reaches them. Make visual observations, as well.

- How does this activity relate to how different places feel earth movement based on their relative distance from the epicenter?

Compare each of the waves through different mediums by

ACTIVITIES

Activities continued

4 using different kinds of springs. Try using a plastic spring and/or a less tightly wound metal spring.

- What do you notice about the wave patterns?

Observe what happens when a wave crosses a boundary from one medium to another. Using electrical tape, connect the end of one kind of spring to the end of another.

Try using a plastic spring and/ or more tightly wound “snaky” spring. Try propagating the wave from one end first.

- What happens?
- Can you see some of the energy (and wave motion) reflect back on the first spring?
- How does the wave motion transfer to the second spring?

Try propagating the wave from the second spring.

- What do you notice?

5 ***The metal spring can also be used to demonstrate other physics concepts:***

Stair walking: inertia and momentum.

As with the traditional toy, demonstrate to students how the spring can seemingly “walk” down a set of stairs. Use the demonstration to discuss momentum and inertia. Compare the heavier, metal spring to a plastic spring.

- Which works best for this demonstration? Why?

The surprising dropping spring:

This demo is best observed in slow-motion, so consider video recording it and then playing it back at reduced speed.

Hold the spring up from one end, while allowing the other end to be pulled down by gravity. Ask your students to predict what will happen when you drop your end of the spring. They should be more detailed than to simply say that it will fall. Ask them to describe how the spring will fall.

Once everyone has made their prediction, drop the spring.

- What happens? How can the phenomenon be explained?

This demo could be made even more dramatic by connecting a few springs together with electrical tape and making a very long spring that could be released over a railing or out of a window. What do the results of this demonstration tell us about the sum of the forces on the bottom of the metal spring? For advanced students, investigate some of the websites and scientific papers in the resources for a full explanation of what is happening.

DISCUSSION

Additional Discussion and Real Life Applications

1. How is the metal spring able to move down a set of stairs on its own? Why does it not stop once it has gone down just one step?

2. How do waves transfer energy?

   How can energy be added into a wave system?

3. Sound travels quickest through solids and slowest through gasses. Using the metal spring as a model, explain this phenomenon.

4. In a longitudinal wave, the motion of the disturbance is up and down or side to side. Why, then, does the wave propagate in a direction perpendicular to the initial motion?

5. Considering that light waves are transverse waves, how could you use metal springs to explain or demonstrate why the light from the sun appears brighter than the light from distant stars?

RESOURCES

Unruh, W.G. “The Falling Slinky.” Message to Cornell University Library. 19 Oct. 2011. Email.
http://arxiv.org/abs/1110.4368

Veritasium. “Slinky Drop Answer.” 21 Sept. 2011. Video.
https://www.youtube.com/watch?v=eCMmmEEyOO0

Veritasium. “Slinky drop Extended.” 21 Sept. 2011. Video.
https://www.youtube.com/watch?v=oKb2tCtpvNU

Next Generation Science Standards

Students who demonstrate understanding can:

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.

4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.

5-ESS1-1. Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science
LS = Life Science
ES = Earth Science
ETS = Engineering, Technology and the Application of Science

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MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.