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Seismic Slinky©

Modeling P and S waves in the Classroom

www.iris.edu/hq/inclass/video/202

Version 2.0 (Nov 2017)

Incorporated Research Institutions for Seismology

OVERVIEW

Students will produce P and S waves using a Slinky© to understand how seismic waves transfer energy as they travel through solids. All types of waves transmit energy, including beach waves, sound, light, and more. When an earthquake occurs it generates four different types of seismic waves (Appendix A). We will focus on two of these: Compressional-P (longitudinal) and shearing-S (transverse) "body waves." These travel through the Earth with distinct particle motion and predictable speed.

P waves travel at over 360 km/hr (225 mi/hr) through solid rock, compressing and dilating the Earth in the direction they are propagating, much like sound waves do. They also travel 60% faster than the shearing S waves. This velocity difference helps seismologists locate an earthquake's epicenter.

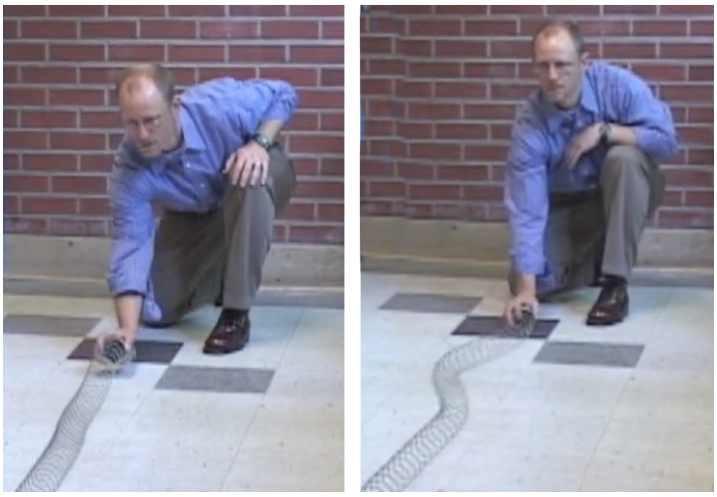
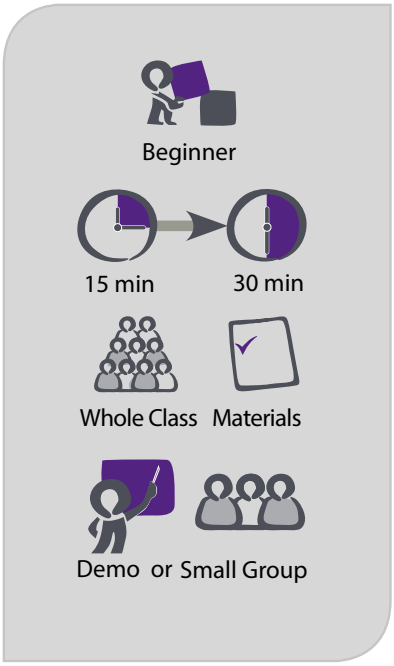


Figure 1: *Demonstration of the Slinky P wave (left) and S wave (right), from video of classroom demo (see link in* ***Teacher Background****).*



OBJECTIVES

By the end of the exercise, students should be able to:

- produce both P and S waves using a Slinky
- use the model as a tool to observe and understand waves properties
- describe the difference between P and S seimic waves based on the direction of particle motion relative to the direction of propagation

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MATERIALS

- 2-6 Slinkies; metal is best, but plastic OK. How many you need depends on if it will be a demo or if it will be done in small groups.
- OPTIONAL: A large metal Slinky works best as a whole-class demo and for illustrating more-complex wave actions in Methods 2, 3, and 4.
- String or tape to connect Slinkies together
- Student Worksheet, Page SW-1
- Stop watch (if you wish to time the waves)

TEACHER BACKGROUND

- Watch "Seismic Slinky: Modeling P & S Waves in the Classroom": www.iris.edu/hq/inclass/video/202
- **Prerequisite?** Consider preceding this demo with the "*Human Wave*" activity: www.iris.edu/hq/inclass/lesson/32
- Watch the animation on recording seismic-wave motion: www.iris.edu/hq/inclass/animation/115
- Download animations of seismic-wave motion: www.iris.edu/hq/inclass/animation/seismic_wave_motions4_waves_animated

TEACHER PREP

If you don't have a large Slinky, this lesson is most effective if you tape two slinkies together. This allows students to watch the compressions and dilations travel a longer path which can be timed with a stopwatch. Students can compare the speed of the P wave versus the S wave.

OPTION: A variation is to tape one metal Slinky to one plastic Slinky. This set up demonstrates what happens when seismic waves cross a density boundary: most of the energy crosses the boundary but some energy is reflected back toward the "earthquake" source.

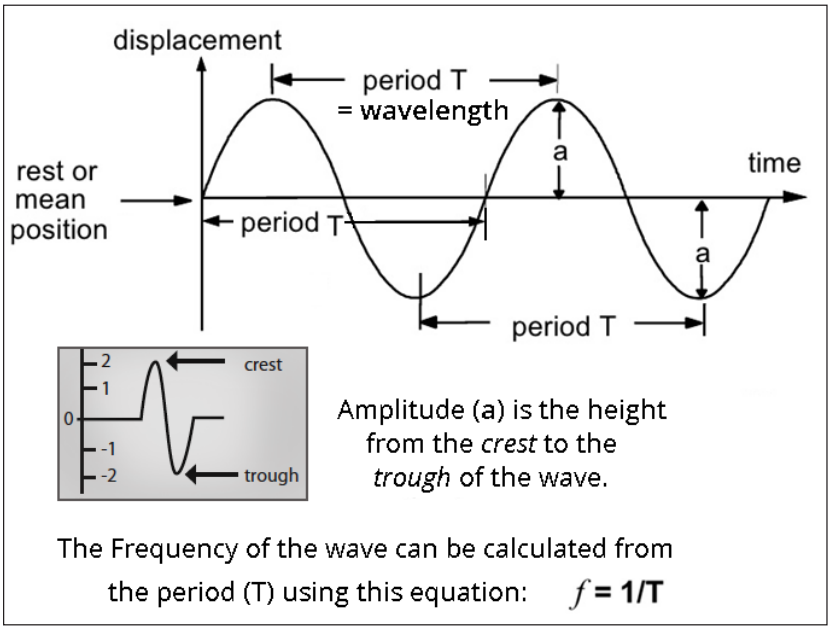


Figure 2: *The characteristics of a waveform include wavelength, amplitude, velocity, and frequency. All periodic waveforms have these common characteristics. Frequency describes the number of complete cycles which are completed during a given period of time.*

VOCABULARY

Elastic Properties: the measure of an objects ability to change shape when a force (stress) is applied to it, and return to its original shape when the force on it is released.

Seismic Wave: an elastic wave generated by an impulse such as an earthquake or an explosion. Seismic waves may travel either through the earth's interior (P and S waves; the fastest waves) or along or near the earth's surface (Rayleigh and Love waves). Seismic waves travel at speeds of several kilometers per second.

P Wave: compressional (longitudinal) waves. These body waves compress and expand (oscillate) the ground back and forth in the direction of travel, like sound waves that move back and forth as the waves travel from source to receiver. P wave is the fastest wave.

S Waves: shear (transverse) waves. These are secondary body waves that oscillate the ground perpendicular to the direction of wave travel producing vertical and horizontal motion of the ground.. They travel about 1.7 times slower than P waves. S waves can not travel through liquids like water, molten rock, or the Earth's outer core because liquids will not sustain shear stress.

LESSON DEVELOPMENT

Four methods of Seismic Slinky are offered, but the fixed-end method teaches basic P- and S-wave behavior. (Optional Method 4 introduces advanced concepts of wave interference.)

Before starting, students should understand:

- Seismic waves transfer energy from one place to another by repeated small vibrations of particles in the Earth (Appendix B).
- Seismic waves pass energy *through* earth materials. All matter returns to the same place after the wave has passed. (The exception? Materials and structures on Earth's surface will experience ground motion (acceleration) as a result of seismic waves, but may not recover their original position if not securely anchored.)

Before handing out the Slinkies, make it clear that the coiled springs get easily tangled, kinked, or overstretched. You want to avoid irreversible strain. A kink in the wire can affect wave motion.

Have two people hold the ends of the Slinky as far apart as is effective for the stretched length of the Slinky without overstressing it. There is a direct relationship between tension and speed: As the tension increases, the speed of the pulses will increase. If tension is decreased, the speed will decrease. Experiment with most effective length.

One partner holds the far end steady with no motion. His/her parner will generate the "earthquake" with one quick motion.

METHOD 1—BASIC FIXED END:

The P or compressional wave: One person should cup his or her hand over the end (the last 3-4 coils) of the Slinky and, when the Slinky is at rest, hit that hand with the fist of the other hand, making sure that the motion is toward the opposite end, and hand returns to start position. An alternate method to starting the energy wave is to rapidly push the hand holding the first few coils forward a prescribed distance, returning it to the starting position (as shown in video demo.) The compressional disturbance that is transmitted to the Slinky will propagate to the other person. The motion of each coil is either compressional or extensional with movement parallel to the direction of propagation (Figure 3). Notice that the wave does not stop when it reaches the end of the slinky; but reflects off the end and heads back to where it started. This will continue until the wave energy dies out.

?? *What happens to the P wave as it travels?*

ANSWER: The leading edge of the wave compresses the coils. Right behind it the coils dilate.

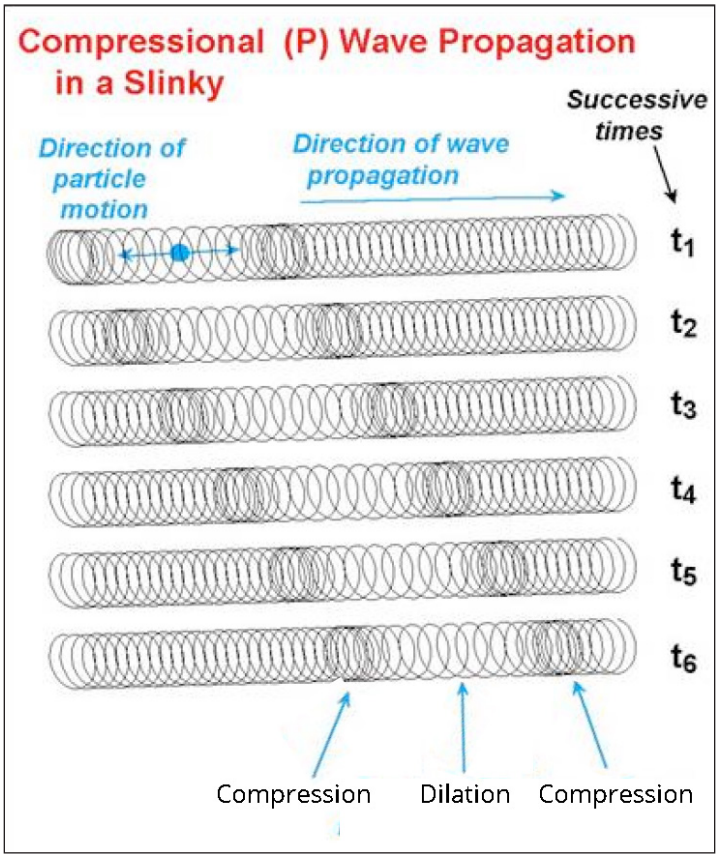


Figure 3: *P-wave behavior.* www.iris.edu/hq/inclass/animation/282

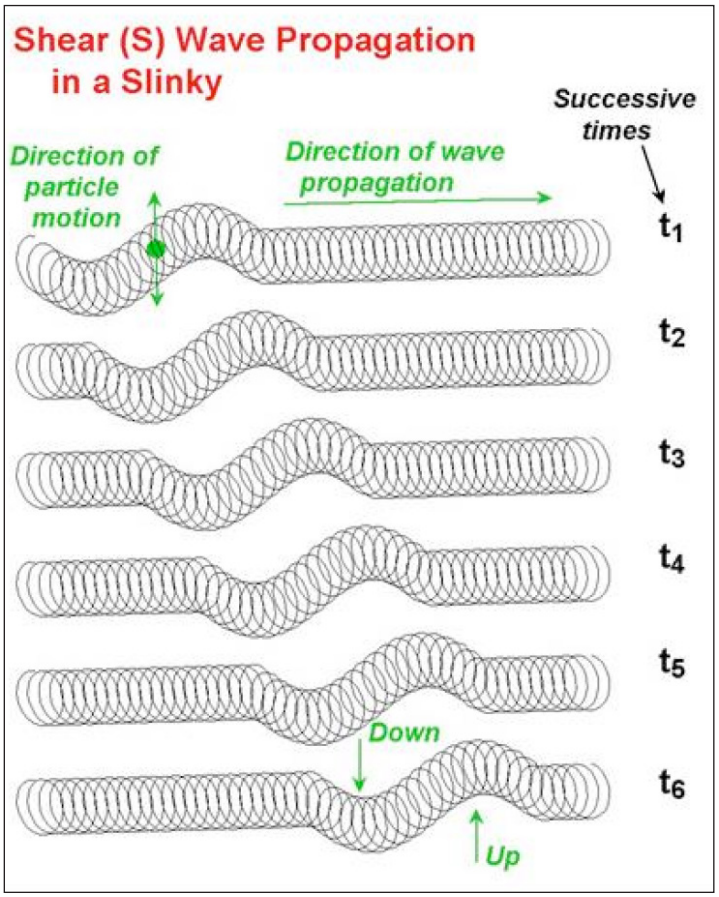


Figure 4: *S-wave behavior.* www.iris.edu/hq/inclass/animation/283

The S or shear wave: This is done by moving the hand abruptly up and then down (vertical), not toward the other end. This motion generates a motion of the coils *perpendicular* (transverse) to the direction of propagation, or the direction it is traveling. Note that the particle motion is not only *perpendicular* to the direction of motion but also in the *vertical* plane.
You can also produce shear waves in which the motion is in the horizontal plane by having the person move his/her hand abruptly left and then right. The propagation of the S wave by the Slinky is illustrated in Figure 4. As this process continues, the shear disturbance travels along the entire Slinky (elastic medium).

?? *What happens to the amplitude of the S wave as it travels*?
ANSWER: The amplitude decreases with distance.

?? Notice that, although the motion of the disturbance was purely perpendicular to the direction of propagation (no motion in the disturbing source was directed along the length of the Slinky), the disturbance still propagates away from the source, along the Slinky. *Why is that?*
ANSWER: This is because the material is elastic and the individual coils are connected (like the individual particles of a solid) and thus transmit their motion to the adjacent coils. [In the "Human Wave" activity referred to in Teacher Background, students learned about transverse particle motion.]

OPTIONAL

Put a small piece of masking tape on a coil in the middle of your slinky on top. Directly below put a piece of masking tape on the floor with the edge perpendicular to the slinky length. This will give reference point as the wave passes.

OPTIONAL METHOD 2—STORED ENERGY & ELASTIC-REBOUND

P and S waves can also be generated in the Slinky by an additional method that reinforces the concept of elasticity and the elastic rebound theory (see box at right).

For the P or compressional wave: In this method, for the P wave, one person should slowly gather a few of the end coils of the Slinky into his or her hand. This process stores elastic energy in the coils of the Slinky that are compressed (as compared to the other coils in the stretched Slinky) similar to the storage of elastic energy in rocks adjacent to a fault that are deformed by plate motions prior to slip along a fault plane in the elastic rebound process. When a few coils have been compressed, release them suddenly (holding on to the end coil of the Slinky) and a compressional wave disturbance will propagate along the Slinky.

This method helps illustrate the concept of the elastic properties of the Slinky and the storage of energy in the elastic rebound process. However, the compressional wave that it generates is not as simple or visible as the wave produced by using a blow of one's fist, so it is suggested that this method be demonstrated after the previously-described method using the fist.

For the S or shear wave: Similarly, using this "elastic rebound" method for the S waves, one person holding the end of the stretched Slinky should use their other hand to grab one of the coils about 10-12 coils away from the end of the Slinky. Slowly pull on this coil in a direction perpendicular to the direction defined by the stretched Slinky. This process applies a shearing

ELASTIC REBOUND

Elastic rebound is what happens to the crustal material on either side of a fault during an earthquake. The idea is that a fault is stuck until the strain accumulated in the rock on either side of the fault has overcome the friction making it stick. The rock becomes distorted, or bent, but holds its position until the earthquake occurs, and the rock snaps back into an unstrained position, releasing energy that produces seismic waves. (Learn more about the elastic rebound theory: U.S. Geological Survey)

VIDEOS on Elastic Rebound:

www.iris.edu/hq/inclass/video/67

www.iris.edu/hq/inclass/video/64

displacement to this end of the Slinky and stores elastic energy (strain) in the Slinky similar to the storage of strain energy in rocks adjacent to a fault or plate boundary by plate tectonic movements. After the coil has been displaced about 10 cm or so, release it suddenly (similar to the sudden slip along a fault plane in the elastic rebound process) and an S wave disturbance will propagate along the Slinky away from the source.

OPTIONAL METHOD 3—"EPICENTER"

P waves can also be generated in the Slinky by pinching a group about 1-inch thick, which will give tension (stored energy) on both sides of the extended slinky (Figure 5). This works best with a single metal slinky. You might have to experiment with the number of pinched coils, and/or how much to stretch the slinky for best results.
Quickly release the pinched group and compressional waves will move away from the center and return to the center. This is more like an actual earthquake that sends seismic waves in all directions.

OPTIONAL METHOD 4 (ADVANCED)—WAVE INTERFERENCE , P-P, S-S, and P-S

In this method, both partners will generate a wave simultaneously. Waves are energy and two waves can occupy the same physical space at the same time, unlike the mass of an object. This is called interference. It can be constructive (waves get bigger when they merge) or destructive (they get smaller). Although the waves interfere with each other when they meet, they continue traveling as if they had never encountered each other. When the waves move away from the point where they came together, in other words, their form and motion is the same as it was before they came together

Longitudinal (P wave) Pulse: At exactly the same time, have both partners generate waves of approximately equal amplitude by abruptly pushing their ends of the Slinky towards each other then returning to their starting position.
Observe what happens when the waves collide.

?? *What happens when the two pulses reach the center of the spring?*

Describe the size, shape, speed, and direction of each pulse during and after the interaction.
ANSWER: The principle of linear superposition says that when two or more waves come together in phase with each other, the result is the sum of the individual waves. Although

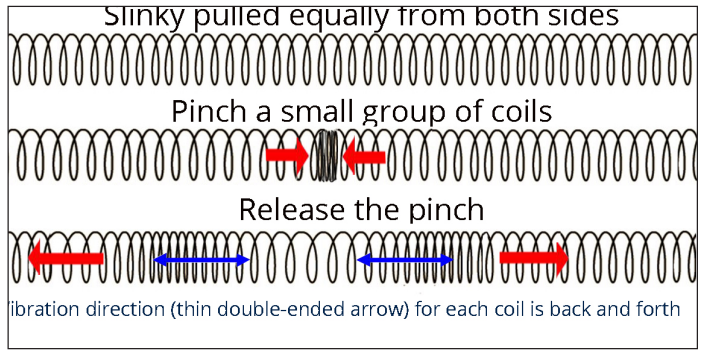


Figure 5: *By pinching a bunch of coils the center of the slinky and releasing, wave energy moves away from the "earthquake" in both directions.*

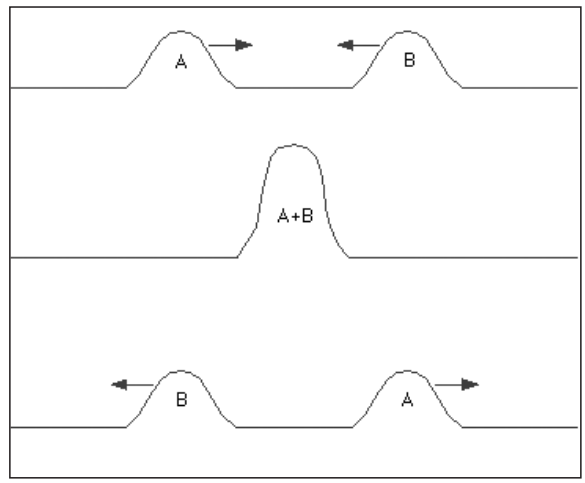


Figure 6: *Constructive interference*

the waves Interfere with each other when they meet, they continue traveling as if they had never encountered each other (Figure 6).

?? *Would you call this constructive or destructive interference?*

ANSWER: Constructive.

?? *How does the pulse amplitude during interference compare with the individual amplitudes before and after this interaction?*
ANSWER: The result is that the waves are superimposed: they add together, with the amplitude at any point being the addition of the amplitudes of the individual waves at that point.

Now have one partner generate a larger pulse. It will be easier to see what happens in the interaction if one pulse is larger than the other.

?? *Would you call this constructive or destructive interference?*
ANSWER: This would still be constructive interference. If both people push the ends of their toward the center, they are both generating

compressional waves with the adjacent links on the slinky compressed closer than in the un-deformed condition. When these two compressive waves meet, the amounts of compression (= wave amplitudes) will add together. That's constructive interference

Transverse (S wave) Pulse: At exactly the same time, both partners generate back-and-forth waves of approximately equal amplitude by shifting the Slinky ends side to side, starting the motion going to the same side.

?? *What happens when the two pulses reach the center of the spring?*
ANSWER: When they meet in the center, they will add together to make a pulse that is as large as the sum of the two pulses (Figure 6).

Now have both partners generate back-and-forth waves of approximately equal amplitude by shifting the Slinky ends side to side, starting the motion going in opposite directions.

?? *What happens when the two pulses reach the center of the spring?*
ANSWER: If the waves are of equal amplitude, they will be destructive (Figure 7). Remember that the wave amplitudes add together when they meet. Because the wave coming from one side of the Slinky is a displacement in the opposite direction to the wave coming from the other side, the sum of waves is zero when they meet. They cancel eachother out so this is destructive interference .

When P meets S: We haven't addressed surface waves, as they are more complicated (Figure 8). Surface waves result from a complex interaction of P and S waves as they reach Earth's surface. It is not a simple merging of waves. P and S waves bounce (reflect) off the surface as well as generate rolling surface waves. At the surface they begin their journey around the Earth. Surface waves are the slowest waves.

Send two wave pulses toward one another again, but this time have one person send a transverse pulse and the other send a longitudinal pulse. Carefully watch the two wave pulses after they meet.

?? *Are they passing through each other or bouncing off each other?*
ANSWER: Passing through.

Describe the size, shape, speed, and direction of each pulse during and after the interaction.
ANSWER: The size, shape, speed, and direction of the two waves are unchanged by their passage through each other. However, during the interaction, the Slinky has both longitudinal motions (coils getting closer together and farther apart) and transverse motions (coils oscillating perpendicular to the length of the Slinky. This combination of longitudinal and transverse motions is particularly evident in the motion of the Rayleigh wave illustrated in Figure 8.

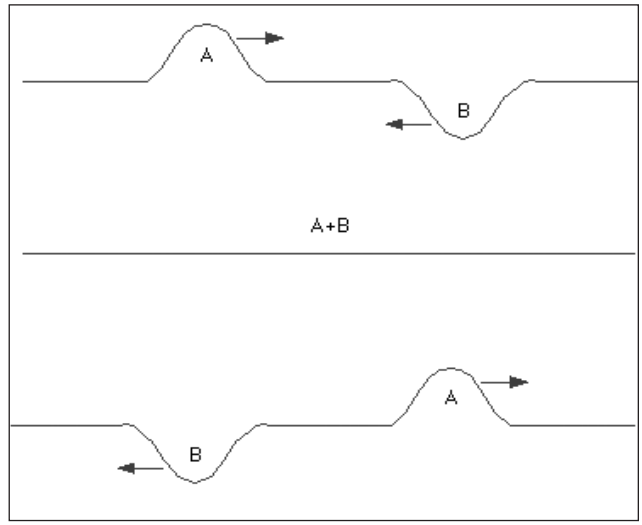


Figure 7: *Destructive interference*

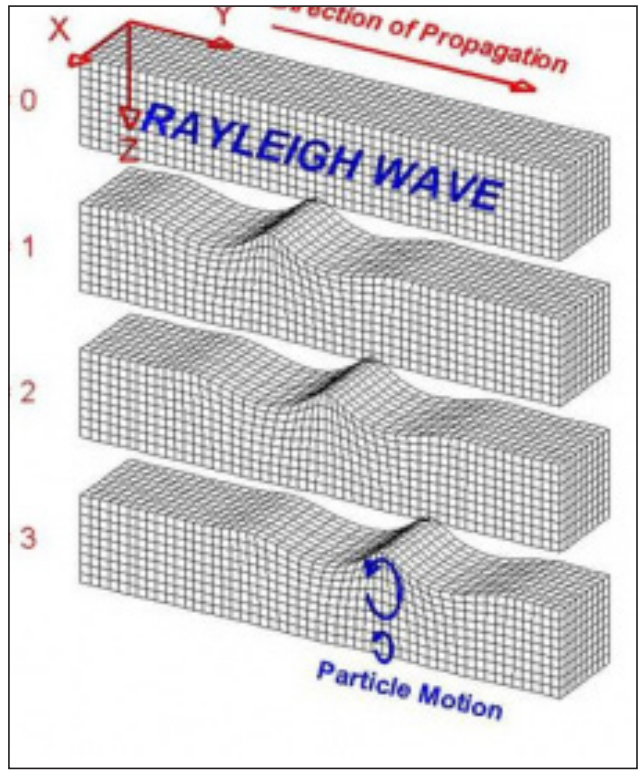
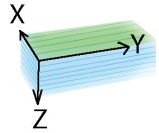


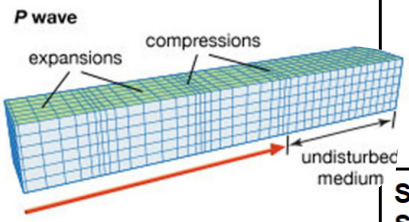
Figure 8: *The **Rayleigh** wave is a surface wave that travels along the upper surface of the Earth. Note that the deformation doesn't reach the bottom of the block, but moves in an undulating down-forward-up-back circular motion as the wave itself travels away from the epicenter. This is similar to how ocean waves develop in the deep ocean, moving along the surface towards shore.*
www.iris.edu/hq/inclass/animation/284

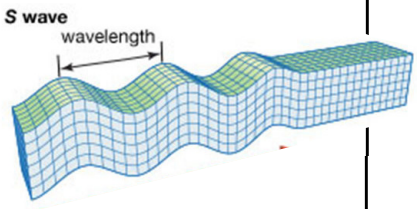
APPENDIX A

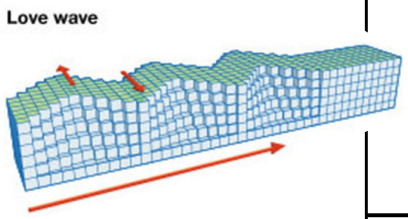
Types of seismic waves

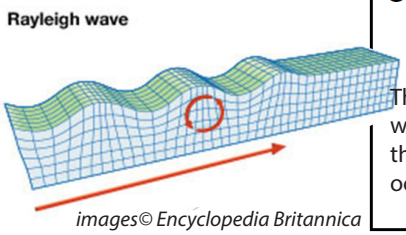
Perspective views of seismic-wave propagation through a grid representing a volume of material. X and Y are parallel to the Earth's surface; Z direction is depth.











images© Encyclopedia Britannica

Table 1: Seismic Waves

Wave Type (and names)	Particle Motion	Typical Velocity	Other Characteristics
P, **Compressional**, Primary, Longitudinal	Alternating compressions ("pushes") and dilations ("pulls") which are directed in the same direction as the wave is propagating (along the ray path); and therefore, perpendicular to the wavefront.	**V_P ~ 5 – 7 km/s in typical Earth's crust; >~ 8 km/s in Earth's mantle and core; ~1.5 km/s in water; ~0.3 km/s in air.**	P motion travels fastest in materials, so the P-wave is the first-arriving energy on a seismogram. Generally smaller and higher frequency than the S and Surface-waves. P waves in a liquid or gas are pressure waves, including sound waves.
S, **Shear**, Secondary, Transverse	Alternating transverse motions (perpendicular to the direction of propagation, and the ray path); commonly approximately polarized such that particle motion is in vertical or horizontal planes.	**V_S ~ 3 – 4 km/s in typical Earth's crust;** >~ 4.5 km/s in Earth's mantle; ~ 2.5-3.0 km/s in (solid) inner core.	S-waves do not travel through fluids, so do not exist in Earth's outer core (inferred to be primarily liquid iron) or in air or water or molten rock (magma). S waves travel slower than P waves in a solid and, therefore, arrive after the P wave.
L, **Love**, Surface waves, Long waves	Transverse horizontal motion, perpendicular to the direction of propagation and generally parallel to the Earth's surface.	V_L ~ 2.0 - 4.4 km/s in the Earth depending on frequency of the propagating wave, and therefore the depth of penetration of the waves. In general, the Love waves travel slightly faster than the Rayleigh waves.	Love waves exist because of the Earth's surface. They are largest at the surface and decrease in amplitude with depth. Love waves are dispersive, that is, the wave velocity is dependent on frequency, generally with low frequencies propagating at higher velocity. Depth of penetration of the Love waves is also dependent on frequency, with lower frequencies penetrating to greater depth.
R, **Rayleigh**, Surface waves, Long waves, Ground roll This is how ocean waves develop on the surface of the ocean.	Motion is both in the direction of propagation and perpendicular (in a vertical plane), and "phased" so that the motion is generally elliptical – either prograde or retrograde.	V_R ~ 2.0 - 4.2 km/s in the Earth depending on frequency of the propagating wave, and therefore the depth of penetration of the waves.	Rayleigh waves are also dispersive and the amplitudes generally decrease with depth in the Earth. Appearance and particle motion are similar to water waves. Depth of penetration of the Rayleigh waves is also dependent on frequency, with lower frequencies penetrating to greater depth.

Animations: www.iris.edu/hq/inclass/animation/seismic_wave_motions4_waves_animated

APPENDIX B

Teaching about Wave basics*

The challenge: How to demonstrate that rather than the entire physical object moving across distance through space, a disturbance (wave) is propagating within a given medium.

One way to bridge the gap between an understanding of the motion of particles and the motion of waves is to consider a Slinky© or other spring-like tool. Unless you plan to throw the slinky across the room, in which case it will behave like a particle, the slinky can be used to demonstrate wave motion in a medium that is visible to students, with equally visible consequences. A general problem I have encountered when trying to convey abstract concepts is that without some means of visualizing it, the students are not able to manipulate the idea to meet new and different situations and the topic remains abstract and paper based. At the same time, a too-pervasive analogy likewise restricts students' abilities to expand past the suggested example. Therefore, the introduction of the nature of waves must be structured in such a way that students grasp the concept that a wave is a moving disturbance without being restricted to the examples of a slinky or telephone cord. Otherwise, students will not grasp the connection between a graph drawn on a board and light and sound waves. This can be done by taking a two-pronged approach: observing the position of an entire medium at a single point in time, and observing the motion of a single point throughout time.

Fundamental to the definition of waves, are the concepts of energy and the idea of a disturbance moving rather than the entire medium. Sound can't travel in space as there aren't any molecules in space to transmit the energy in the wave. In real life, you can't hear anything in space (unless you're inside a spaceship or space suit that has an atmosphere).

The majority of topics encountered in physical science and other early science curricula deal with concrete objects--balls, cars, and such--moving in observable ways, such that the idea of a wave presents a new and different phenomenon. As a result, dealing with student misconceptions about the structure and nature of the waves up front is critical. A wave differs from a classical particle, such as a ball, in that it is not a single "object" moving through space. Rather, it is a change, either transverse or longitudinal, in the arrangement or position of parts of a substance. The exact nature of this change depends on the type of wave and the medium.

Like all waves, the velocity of a sound wave only depends on the material it's traveling through. In general, the denser the material, the faster the sound wave will travel (the molecules of the material are closer together so they can collide faster and transfer the energy faster).

Once the nature of wave as a disturbance has been established, it is a fairly straightforward jump to explaining how waves transfer energy, particularly how this varies from a particle, and a graphical 2D representation of a wave. By this point in the year, students should be familiar with the ideas of energy and force, with a particularly heavy emphasis on potential and kinetic energy. While "light energy" is previously discussed briefly to the extent that it exists in light sources, there is no mention of how this light energy varies between types of light and why, and therefore up to this point is a simple matter of identification. Understanding that waves transfer energy and then identifying light as a wave would enable students to make better sense of the term "light energy". In order to do this, physical demonstrations and observations of propagating waves serve as a useful tool: students can observe that in a mass oscillating on a spring energy is being transferred from potential to kinetic and back again, and that each kind of energy is being transmitted through the medium, eventually reaching the other "end."

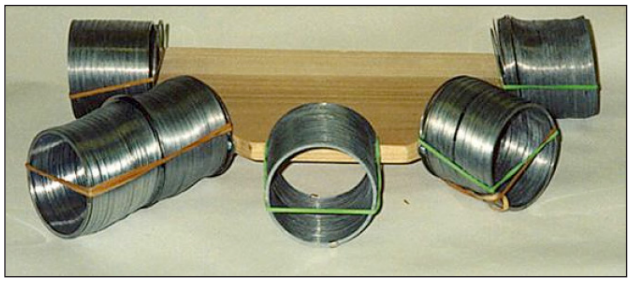
** Modified from: Physics of Music: Making Waves in a Science Classroom, Rosalind Echols and Yale National Initiative.*

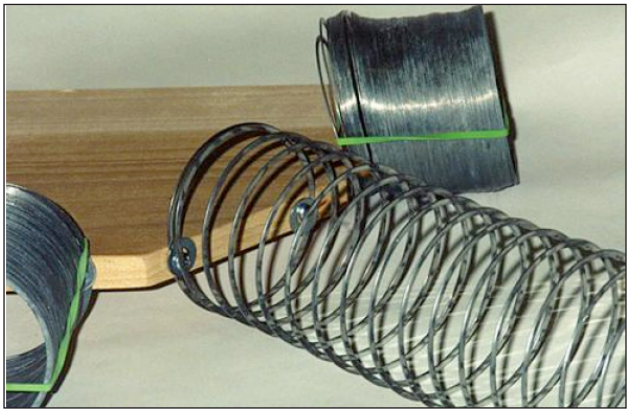
APPENDIX C

FOLLOW UP—SEISMIC WAVES TRAVEL IN ALL DIRECTIONS

For more background, and a multiple-Slinky method of showing seismic waves traveling in 5 directions, see Dr. Larry Braile's *Exploring Seismic Waves With Slinkies*:

www.iris.edu/hq/inclass/lesson/exploring_seismic_waves_with_slinkys





***ABOVE**: Photograph of five slinky model.*

***RIGHT:** Close-up view of five slinky model showing attachment of slinky using screws and washers.*

Seismologist John Lahr demonstrates how seismic waves go in all directions from an earthquake source. (image from http://www.exo.net/~pauld/

APPENDIX D

APPENDIX C—NGSS SCIENCE STANDARDS & 3 DIMENSIONAL LEARNING

Touch the url links to get more information

Energy

MS-PS3-2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=160

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.	**PS3.A: Definitions of Energy** A system of objects may also contain stored (potential) energy, depending on their relative positions.	**Systems and System Models** Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

MS-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=166

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).	**PS3.B: Conservation of Energy and Energy Transfer** When the motion energy of an object changes, there is inevitably some other change in energy at the same time.	**Energy and Matter** Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion)

Waves and Their Applications in Technologies for Information Transfer:

MS-PS4-1 Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=168

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 6–8 level builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.	**PS4.A: Wave Properties** A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.	**Patterns** Graphs and charts can be used to identify patterns in data..

(Cont. Waves and Their Applications in Technologies for Information Transfer)

- **HS-PS4-1** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.]
  http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=116

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 6–8 level builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.	**PS4.A: Wave Properties** A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.	**Patterns** Graphs and charts can be used to identify patterns in data..

NAME: _____

PERIOD: _____ DATE:_____

www.iris.edu/earthquake

SEISMIC SLINKY: P & S SEISMIC WAVES

Analysis: Answer the following questions using complete sentences.

1. Draw what you see the waves doing:

P (Compressional)	S (Transverse)

2. Which one is faster? Why?

3. Which wave has the greatest amplitude?

4. Does the Slinky model solids, liquids, or both?

5. What are seismic waves?

6. Draw a picture of a simple waveform in the box:

7. List four wave characteristics below and write a short description in your own words. Once you have done this, label the parts of the wave on your drawing of a transverse wave (not compressional!)

1. _____ — _____

2. _____ — _____

3. _____ — _____

4. _____ — _____

NAME: _____

PERIOD: _____ DATE: _____

www.iris.edu/earthquake

SEISMIC SLINKY: P & S SEISMIC WAVES

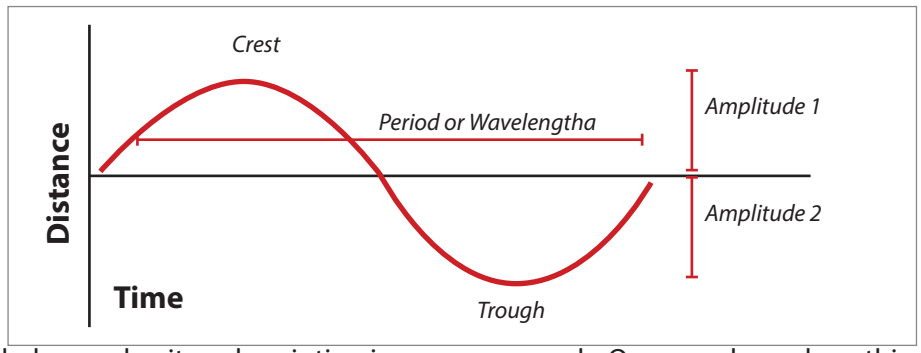
Analysis: Answer the following questions using complete sentences.

1. Draw what you see the waves doing:

P (Compressional):	S (Transverse):

2. Which one is faster? Why?
   - P-waves travel 60% faster than S-waves on average. Compression waves apply a force in the direction of travel which is faster than the perpendicular motion of the S-wave. The S wave may appear faster in the demo because there is less friction in the perpendicular motion of the Slinky coils. The P wave has more drag on the floor.
3. Which wave has the greatest amplitude?
   - Between P and S waves, the S-waves have the greatest amplitude (Surface waves have greater amplitude than S waves.) S waves are shear waves, which means that the motion of the medium is perpendicular to the direction of travel of the wave. The energy is thus less easily transmitted through the medium, and S-waves are slow and higher.
4. Does the Slinky model solids, liquids, or both?
   - The slinky models only seismic waves through solids. Why? Because the molecules are coupled together. To model seismic waves through liquids, the "Human Wave" is a good analogy.
5. What are seismic waves? possible answers:
   - An elastic wave in the earth produced by an earthquake or underground explosion.
   - A wave of energy that is generated by an earthquake or other earth vibration.
   - Any of several forms of vibrational waves that travel through the Earth as the result of an earthquake.

6. Draw a picture of a wave in the box



7. List the wave characteristics below and write a description in your own words. Once you have done this, label the parts of the wave on your drawing of a transverse wave (not compressional!)

   1. Period (or Wavelength) — distance from crest to crest, trough to trough, **OR** from a pt on one wave cycle to the corresponding pt on the adjacent wave cycle. **OR**... time it takes a particle to complete one full cycle

   2. Amplitude — The height between the mean (zero) and the crest (high) or the trough (low).

   3. Crest — The highest point on any wave

   4. Trough — The lowest point on any wave