Teacher's Preparatory Guide

Part 1: Understanding Wave Motion – Slinky® vs. Snaky®: Which Spring is Dominant?

Purpose: This lab is designed to help students understand how light waves interact with matter. This activity is analogous to light traveling through optical media having different indices of refraction (densities). This lesson connects with the Big Ideas in Nanoscale Science (Stevens et al, 2009; NSTA Press) Big Idea – Forces and Interactions (All interactions can be described by multiple types of forces, but the relative impact of each type of force changes with scale. On the nanoscale, a range of electrical forces, with varying strengths, tend to dominate the interactions between objects.)

Level: Middle school or high school physical science or physics

Time required: One 50-minute class period

Materials for each group of 3 students:
- Slinky®
- Snaky®
- key ring, 1 inch diameter
- small, empty box (like a box of Jell-O®)

Slinky **Snaky**

Safety Information: Students should wear safety goggles in case the springs fly apart. Ask students to be mindful of jewelry (such as a bracelet or ring) and to tie back long hair so that it does not get caught in a moving spring.

Advance Preparation: Materials may be found here:

Hardware/ware-house store	SK Science Kit and Boreal Laboratories	Arbor Science
• key rings	• Snaky® (part no. 65940-00) (2 cm diameter × 1.8 m collapsed length) http://sciencekit.com/product.asp?pn=IG0023738 • Slinky® (part no. WW6637000) (7.3 cm diameter × 10 cm collapsed length) http://sciencekit.com/product.asp_Q_pn_E_IG0023739	• Snaky® (part no. 33-0140) (2 cm diameter × 180 cm collapsed length) http://www.arborsci.com/detail.aspx?ID=34 • Slinky® (part no 33-0130) (75 mm diameter × 150 mm collapsed length) http://www.arborsci.com/detail.aspx?ID=33

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1. BUY 10 SETS OF SNAKYS®, SLINKIES®, AND KEY RINGS

2. LOCATE A CLEAR AREA
   Locate a clear area (such as a hallway or an outside area of concrete or asphalt), with at least 8 feet of lateral clearance per student group. If convenient, you may wish to do this near stairs so that groups that finish early may have an opportunity to explore the spring behavior on the stairs.

Background Information: Light can bend when it travels from media having one optical density (or index of refraction) to another. Some students may already know that in astronomy, light also bends in space when it encounters a very strong gravitational pull, such as a very massive object or a black hole (which is a collapsed massive object). Gravitational effects will not be dealt with in this lab.

Teaching Strategies: This activity works best in groups of 3 students. Ask the questions in the *Guided Dialog* section below before beginning the lab and explain that this lab will be an analogy for light going through materials of differing optical densities. Review the materials and procedure with students *before* handing out the materials. Ask a student volunteer to assist you with the demonstration.

Demonstration: It is recommended that you demonstrate the procedure before having the students begin the activity.

1. Go to a clear area. Lab partners grab each end of the Snaky® and stretch it out along the ground.

2. Put the small box about 8 inches from the spring somewhere along the side of the spring (just outside of the normal path of the spring). Explain that students must wear goggles during this activity.

3. Sharply jerk the spring from the left to the right and back to the center (*transverse motion).* The box is there so that students can hit it with the spring (this seems to be effective in getting a good transverse wave, and is a lot of fun smacking the box.) Point out that the 3rd person should notice the wave and write down any questions.

4. Explain that they will do the same thing with the Slinky®. Ask

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students to rotate so that everyone has a chance to play with the spring.

5. Connect the springs together with the key ring. Point out that they will need to thread each spring through a few times.

6. Explain that they will do the same thing as the teacher showed in the demonstration. Point out that the 3rd person should *really* pay attention to what happens to the wave at the key ring and write down any questions that come up. Invite students to test their questions by playing with the springs. One person will continually record in each notebook. Each person should rotate so that everyone has a chance to write down what was tried with the spring.

Guided Dialog: Before beginning the lab, ask students questions to provoke thought and review what they already know. For example:

1. Can light bend or does it travel in straight lines? *Light can bend.*
2. Name some examples of *when* you have seen light bend. *Answers will vary, but examples include light bending through a prism or crystal and through water (as in a swimming pool).*

List any last minute details that the students must remember, including reiterating all safety precautions. Now, begin the lab.

Cleanup: Instruct students to wrap the Slinky® in newspaper like a mummy and put it in the plastic bag. Leave the key rings on the Snaky® and put it in the plastic bag.

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Name:______________________________Date:______________Class:_______________

Student Worksheet (with answers)

Slinky vs. Snaky: Which Spring is Dominant?

Safety
Wear goggles to protect your eyes from the springs, in case your partner releases the spring and it moves toward your face.

Materials
- Snaky®
- key rings
- Slinky®
- box

Rule: The spring(s) must always stay on the ground.

Procedure

1. Find out all you can about sending waves through a spring.
2. Play with each spring separately, and then connect them together.
3. You will share what you notice with the class (write it down).

Students should notice that a transverse wave does not return when the springs are by themselves. Students may notice that the wave changes (comes back reversed) when two springs are attached. They may also notice that the wave bounces back when they start a wave with the Snaky and it doesn't with the Slinky. Students may contribute some information about compression waves. This is not the focus of this lab, but is good for them to notice.

Challenge #1
What do you need to do to hit a box with the spring(s)?
Students need to make a sharp movement and use more force.

Challenge #2
Move the box about a foot away. What do you need to do to hit a box with the spring(s)?
Students need to make a sharp movement and use even more force.

Challenge #3
Play with the distance between the box and the spring. Do you notice any relationships?
more force on the spring = larger wave (greater amplitude)
less force on the spring = smaller wave (smaller amplitude)

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Enhancing understanding Cover this section *after* the activity.

1. Have each group present at least one thing that they wondered about and tried with the springs. Students should describe what they noticed. Summarize their statements on the board.
2. If time allows, you may wish to introduce (or review) these terms. Invite students to guess their meaning by relating these terms with the activity.

   Source wave *The wave generated by the student, going in the forward direction.*
   Transmitted wave *The wave moving from one slinky to the next at the boundary or interface where the two Slinkies® are joined as a coupled spring.*
   Reflected wave *The wave that moves in the reverse direction after reaching the interface, or at the fixed end.*
   Interface *Where the two Slinkies® are connected as a coupled spring.*
   Fixed end *Where the slinky meets a wall or the student who is holding it tightly and not letting it move.*
   Wavelength *Length of one cycle of a wave, measured between two consecutive parts of the wave, such as the crests, and measured perpendicular to its direction of motion.*
   Amplitude *The height of a wave; in this experiment it was the distance from the springs resting point to the box (when the box was hit).*
3. To summarize, relate this activity back to the introduction (light being bent). Feel free to use any of these analogies, depending on your student's level of understanding:
   - Ask students to describe what happens when a bulldog barks at a chihuahua. *In this case, the bulldog (the dominant dog) will then walk away with its head and tail held high, whereas the chihuahua, (the submissive dog) will put it's head down, lay down, and put it's tail between its legs.* Point out that the less dominant dog changes itself, but the more dominant dog does not. Ask students to explain which spring is more dominant, the Slinky® or the Snaky®? *The Snaky®, because the wave came back and changed.*
   - The Slinky®, being less massive, shorter, and having a larger diameter, represents a transparent media material having a low index of refraction and allowing waves to pass through it quite easily without slowing it down or bending (refracting) the waves.
   - The Snaky®, being more massive, longer, and having a smaller diameter, represents a media material having a greater index of refraction and being harder to pass waves through.
   - The waves themselves represent a wave of light with varying wavelengths, including infrared light, which is often used in computer networks.
   - This lab gives an analogy about the different indices of refraction when light waves move through materials of different optical density or indices of refraction. For example, the index of refraction *(n)* of air is $n = 1$ and the index of refraction of water is n = 1.3. This lab illustrates Snell's Law of Refraction, where $n_1 \sin\theta_1 = n_2 \sin\theta_2$, where 1 refers to the incident wave and 2 refers to the refracted or reflected wave.

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Assessment

Students should be able to:

- verbally explain the items in red on the student worksheet.
- understand the relationship between force and amplitude (on the student worksheet).
- explain what happens to a transverse wave when it hits a fixed end. *A transverse wave moves forward (with a displacement to the right) and returns in the opposite direction, but this time it has a displacement to the left (also called "inverted").*
- explain what happens if the Snaky® is the source wave and the Slinky® is the transmitted wave. *The Snaky source wave moves to the interface and stops because it is more massive than the Slinky. After hitting the fixed end, the* Slinky *becomes inverted and comes back to meet the Snaky and the wave is transmitted into the Snaky, but the Slinky bounces back a bit and is inverted.*
- explain what happens if the Slinky® is the source wave and the Snaky® is the transmitted wave. *The Slinky source wave moves to the interface and then is reflected back and is inverted.*

Advanced students should be able to (bonus points or a higher grade may be awarded):

- explain why the wave inverts at the fixed end. *The transverse wave inverts because the fixed end is more massive than either of the springs.*
- explain why the wave will invert at the key ring interface. *The less massive spring will invert (or be less dominant) when it meets the more massive (or dominant spring); the Snaky is more dominant than the Slinky.*

National Science Education Standards (Grades 5–8)

Content Standard A: Scientific as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Motions and forces
- Transfer of energy

National Science Education Standards (Grades 9–12)

Content Standard A: Scientific as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Motions and forces
- Interactions of energy and matter

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