Lab 3A:
A Video Creation for the Wave Equation

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We are going to begin playing with a new phenomenon. As much as possible, we would like to dive in and allow the data most immediately and vividly pressing on our senses to guide our way (with as little as possible bias, prejudice or expectation).

In order to establish a little bit of context or motivation, however, please consider a few of the larger objectives that lurk behind the types of investigation we will begin today – and that are described informally below.

A1. First, there are some broader, longer-term goals – of the sort you might just tuck away in the back of your mind for rainy-day moments in which you question the extent to which the academic pieces of your life do or do not comprise a coherent whole. . .

1. To grow acquainted with the Vernier/LoggerPro approach to laboratory video analysis.
2. To observe, capture and analyze the way in which wave motion comprises simple harmonic functions of both time and space.

A2. Then, there are some more specific, immediate goals—of the procedural sort for which you will be held accountable, as you tinker with a new phenomenon and gather data in pursuit of answers to the research questions that burn and drive you, such as the ones mentioned and emphasized directly below the specific and immediate goals mentioned directly above:

To produce two graphs for transverse waves propagating back and forth along a long, tight spring.

1. $y = A_1 \cos(\omega t)$,
2. $y = A_2 \cos(kx)$.

A3. <u>**The strongly suggested RESEARCH QUESTIONS for Lab 3A:**</u>

Treat the following as a Group of connected questions; NOT a set of choices:

If waves travel along an x-Axis defined by some 1-D medium (such as a stretched spring or string), then

A) What mathematical function describes how the y-Position of any given particle depends on Time?

   i. In what units are the constants measured;
   ii. to what physical parameters do these constants refer?

B) What mathematical function describes how the y-Position of any given particle depends on the particle's x-Position?

   i. In what units are the constants measured;
   ii. to what physical parameters do these constants refer?

C) What second-order Differential Equation fully describes wave motion?

   i. Are the individual (single-variable) functions discovered above related/connected to this Differential Equation?

      (a) If so, how?
      (b) If not, how not?

   ii. In what way is Wave Motion similar to Simple Harmonic Motion? ii.

   iii. In what way is Wave Motion different from Simple Harmonic Motion?

D) **Very particularly, what is the speed ('*phase velocity*') at which a ripple ('*pulse*' or '*disturbance*') travels ('*propagates*') from one end of our (very particular) spring to the other end?**

E) **Very generally, how can the speed ('*phase velocity*') of a typical 1-D ripple ('*pulse*') be found or predicted? On what measurable properties or determinants does the speed seem to generally depend?**

B. **Necessary Equipment**

1. Long, tight, metal spring
2. Personal device, such as cell phone, capable of capturing video
   -- OR video camera on lab laptop
   -- OR appropriate video downloaded and cited from internet
3. Laptop computer with LoggerPro software
4. Meter Stick

C. **Procedures**

1) Have one lab group member hold one end of the spring. Have another group member hold the other end of the spring. Have the two people walk far away from each other—while still holding their ends of the spring. They should walk far enough to make the spring horizontal and tightly stretched. The string should definitely not have slack. It should not feel relaxed.

2) Using the meter stick, measure and record the length of the stretched, horizontal spring.

3) With one person holding his/her end fixed, have the other person shake his/her end up and down.

4) The goal is to create steady, regular, continuous wave ***pulses*** that travel back and forth along the spring. This is best accomplished if one person creates the pulses while the other person maintains a fixed boundary (holds still) at his/her end.

5) For a while, the goal should remain just creating nice, smooth, observable waves. This should involve some trial and error, some practice and some experimental time—just getting used to the feel of different amplitudes and frequencies.

6) Whoever makes the waves should make certain that s/he can feel the difference between altering amplitude and altering frequency.

7) Is it possible to alter the speed at which the wave pulses travel along the spring? Why or why not?
8) Before taking any data, partners should take turns at creating the ***disturbance*** and the ***boundary.*** All lab group members should get a chance to try both roles before any data is recorded.

9) Once wave pulses are steadily and reliably ***propagating*** back and forth along the spring, it is distinctly possible that forward-traveling and back-traveling pulses will ***interfere*** with one another in such a patterned nice way that horizontal motion will cease to be observable! It can and will be the case that we will only observe peaks and troughs flipping up and down; we will even, if this steady state is achieved, notice discrete points that remain almost permanently stationary! This pattern of pattern of patterns is called ***standing waves*** and the stationary points are called ***nodes***.

10) Once you can achieve standing waves, take turns so that everybody in the group has a chance to create them. The goal for each person is to create a steady series of standing waves involving the greatest number of nodes possible.

11) Write down the greatest number of nodes your group created. Think, calculate and justify: What was the wavelength for the standing waves that involved this maximum number of nodes. HINT: Your response to direction (2), above, will help.

12) Using an iPhone or similar device, take a careful, clear video of the standing waves. Somehow, make absolutely certain that a full readable meter stick is visible in the video frame. This meter stick will serve as a scale for actual length once the video is displayed and used on a computer screen.

13) Using trial and error, help from instructors and any directions in Vernier on-line literature, figure out how to import and ***save*** your video into LoggerPro. This itself might be challenging, but it is part of the process.

14) From here on in, your two ultimate goals are the ones described at the top of this lab. We will try to provide hints and guidance, but, when all is said and done, you need to take whatever steps you think make the most sense in order to generate two graphs from your video:

    Produce:

    One graph of vertical position as a function of time (horizontal position fixed)

    and

    One graph of vertical position as a function of horizontal position (time fixed).