

## **LAB 11: SIMPLE HARMONIC MOTION(TPL1)**

### **Goals:**

- **Explore the characteristics of periodic motion**
- **Explore the relationship among distance, velocity, acceleration and force**
- **Explore the relationship between force and acceleration**

### **Introduction**

Periodic motion is motion that repeats itself. You can see the repetition in the position, velocity, or acceleration- time graphs. The length of time to go through one cycle and begin to repeat the motion is called the **period**. The number of cycles in each second is called the **frequency**. The “center” of the motion (or the “resting place” of the mass on a vertical spring) is called the **equilibrium point**. The maximum displacement from the equilibrium position is called the **amplitude**. The unit of frequency, cycles-per-second is given a special name—Hertz (Hz). Simple Harmonic Motion (SHM) is a form of periodic motion where the force is proportional to the elongation of the spring:

$$F = -k(\Delta x)$$

In this investigation you will observe carefully the distance, velocity and acceleration graphs for simple harmonic motion. You will also observe the force graph for simple harmonic motion.

### **Part A - Supplement – Using DataStudio**

1. Load Supplement file. If you have never used DataStudio, or need a refresher, then take a look at this help document: [Using DataStudio](#).

### **Preliminary activities**

1. Prepare equipment. Connect the motion and force sensors through USB Links to your computer. Start the DataStudio software.

2. Load the experiment file. Download the DataStudio experiment file **Lab11\_MassOnSpring.ds** from the lab schedule webpage, and open it in DataStudio.

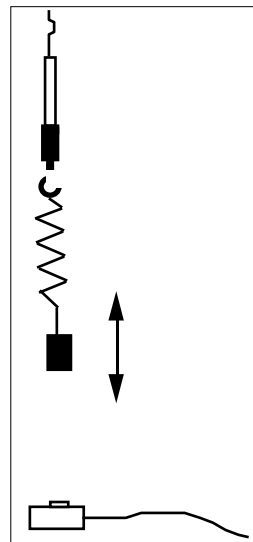
3. Preparing the force probe. Press the ZERO button on the side of the probe (this is a “mechanical” tare for the probe). We can’t “zero” the probe in DataStudio, so occasionally we might need to keep track of a zero “offset” and account for it.

## Part 1 Periodic Motion of a Spring and Mass

In this activity you will examine the graphical display of the motion of a mass hanging from a spring.

1. Check graph settings. DataStudio should be displaying Distance, Velocity, and Force graphs.

2. Setting up a mass on a spring. Hang the spring vertically from a support and attach 1500 grams (1kg + 500 gram) to the spring. Tape a small card to the bottom of the mass. Use a little bit of tape to hold the mass in place on the spring, and use a bit of tape to connect the spring to the force probe. Place the motion detector facing up directly below the spring. Use the protective cage for the motion detector. Push the mass straight up about 5-10 cm, and release. Adjust the height of the support so that the mass comes no closer than 0.5 m to the detector.



3. Recording the motion (practice). We will start graphing once we know we have a smooth motion (the periodic motion is what we want to look for, not the rough start of the motion). Click START to begin graphing. Be sure the motion detector "sees" the mass over its full motion and that there are no flat portions of your graph where the mass came too close to the detector.

4. Make some very clean distance and velocity graphs. Start the mass oscillating as you did in Part 1.2. When the motion is smooth, click START. When the collection process is finished, you should find some nice clean sinusoidal curves. Adjust the vertical axes of the graphs so that they are easier to read. See the [graph layout help page](#) for information on how to make these changes in DataStudio. Sketch the graphs on the Data/Question sheet. Save this experiment under a new name (for future reference).

**Comment** Note that when an object returns to the same position, it does not necessarily mean that a cycle is ending. It must return to the same position, and the velocity and acceleration must also return to the same values in both magnitude and direction for this to be the start of a new cycle.

5. Labeling graphs. Label the graphs (*after you print them*) with the following: (one example of each)

"B" at the BEGINNING of a cycle and.

"E" at the END of the same complete cycle

"A" on a spot where the mass is moving AWAY from the detector fastest

"T" on a spot where the mass is moving TOWARD the detector fastest

"S" on a spot where the mass is standing STILL

"F" where the mass is FARTHEST from the motion detector

"C" where the mass is CLOSEST to the motion detector

## Part 2 Investigating the motion of a Mass Undergoing SHM

1. Select three cycles. Scale the time axis so that you can see about 3 full cycles of the motion.

Questions Answer the series of questions on the Data/Question sheet.

### Part 3 Properties of Periodic Motion--Period, Frequency

1. Examining a cycle on the distance graph above. Click on the SMART TOOL icon (it will place a square cross-hairs into the graph which you can move around to identify data points). Find the beginning and end of one complete cycle (indicate them with an arrow on your distance graph above). (You may start with any part of the cycle but be consistent once you pick a starting point.) Remember: the time to complete one cycle is called the period.

2. Calculating period and frequency. What are the period and the frequency of the motion? Display around 10 cycles of the motion. For the best accuracy, use the SmartTool to measure the total time over as many complete cycles as possible. To calculate the period, we will then divide that total time by the number of cycles. Calculate the period and the frequency of the motion:

$$f = \frac{\# \text{ of cycles}}{\text{time}} \quad T = \frac{1}{f}$$

Number of cycles counted: \_\_\_\_\_

Time for these cycles: \_\_\_\_\_ sec

**Frequency  $f$ :** \_\_\_\_\_ Hz (cycles/sec)

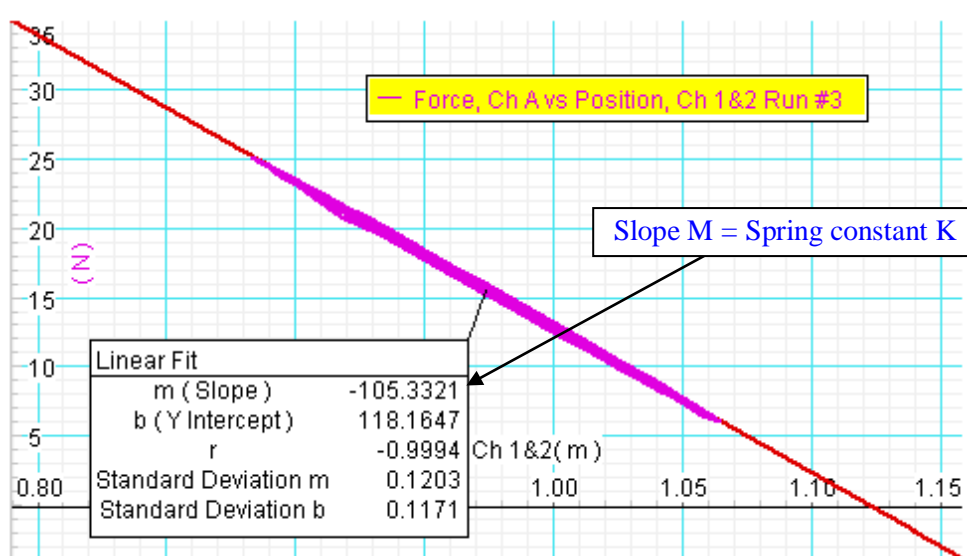
**Period  $T$ :** \_\_\_\_\_ sec

### Part 4 Spring Restoring Force and SHM

We can plot the force versus the distance and obtain the spring constant. Now, we have several cycles of the motion, so the graph will actually loop back and forth over a straight-line area (an example is shown below in the graph). If the data is good, it will resemble that graph – if not, it would be easy to retake the data.

1. Measure the force constant of your spring. Set one of the graphs to plot Force against the Distance. (Either double-click on the graph in the DISPLAYS panel, or choose from the WINDOW menu item.) You should get a straight line (when you scale the axes properly).

2. Making a linear fit. Click on the FIT tool button (next to the “calculator” button). Check the LINEAR option. In the graph, you should find a textbox that shows the numbers for the Fit. See the example on the next page:



***Linear fit of Force vs. Displacement, and spring constant calculation***

**3. Finding the spring constant.** In the Linear Fit box, we will find the value for the spring constant. The intercept value can be ignored, and the “r” (correlation) should be very close in magnitude to 1.0 if we have a good set of data. The m value is the slope, of the graph, and is the spring constant  $k$  (absolute value of the slope, that is). Fill in the data on the Data/Question sheet.

**4. Compare with data.** We can calculate the spring constant by examining one data point of the motion. Unfortunately, since we can’t zero the motion detector or the force probe, we will have to do some preliminary calculations (we want the distance and the force measured from equilibrium – this is what is calculated in the spring constant value). Select the X and F graph (with time axes). Click once on the Position graph to make it active, and select the Smart Tool. Then do the same for the Force graph. Notice that the smart tools are “connected” so that they stay together. Using the Position smart tool, locate a point where the distance is at a local maximum (farthest from the detector) – write that value in the appropriate box on the data/question sheet. Using the smart tool on the Force graph, locate the force value FOR THAT X VALUE YOU JUST FOUND – and write that on the data/question sheet (this should be a minimum in the force graph). Now, find a minimum for the X graph, and the corresponding maximum for the Force graph – write those on the data question sheets. We can now calculate the average values (the equilibrium values) and from that get the  $\Delta x$  and  $\Delta F$  values that we will use to calculate the spring constant for that individual point. We can then find the percent difference between the two spring constant values. These calculations are made on the Data/Question sheets.

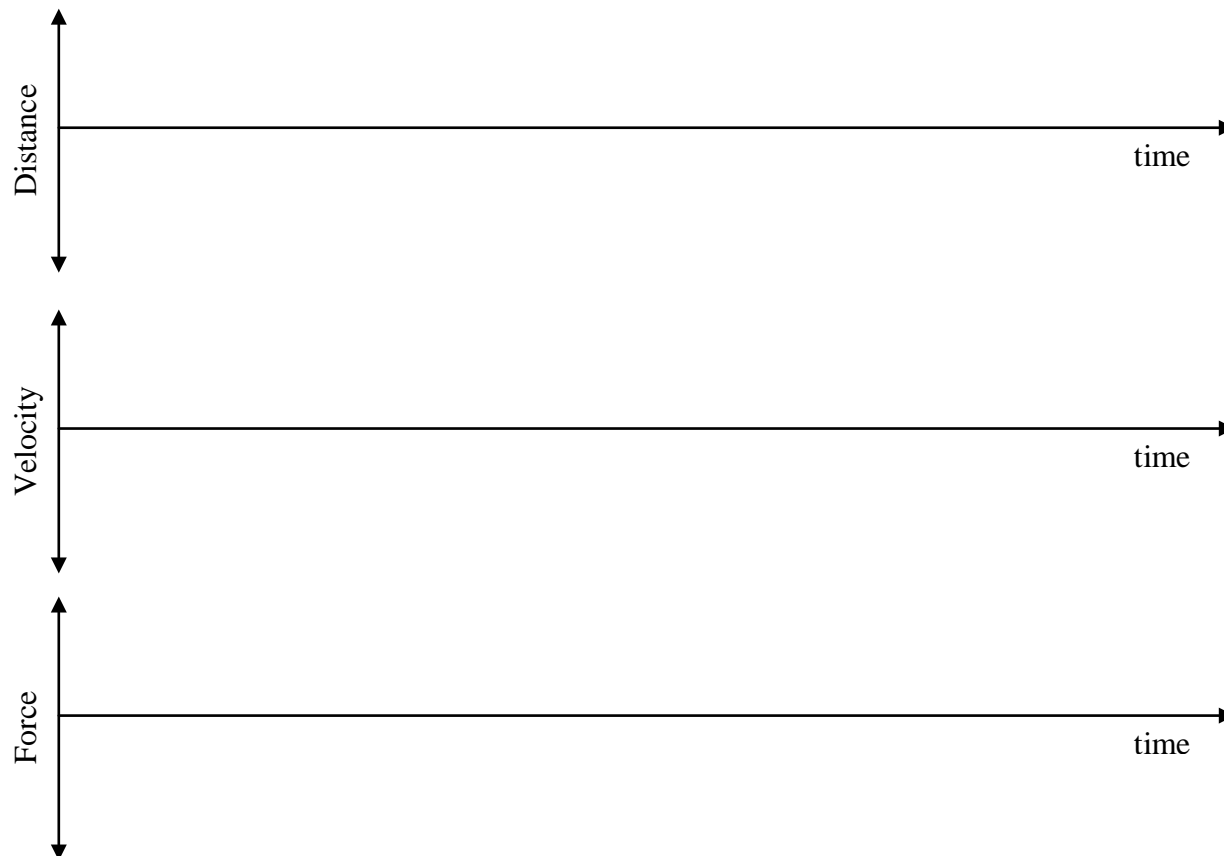
**Question** Answer on the Data/Question sheet.

How does the spring constant value from the linear fit compare to the single point value? If there were a noticeable difference, how would you explain that?

## DATA/QUESTION SHEET - LAB 11: SIMPLE HARMONIC MOTION

### Part 1 Periodic Motion of a Spring and Mass

4. Make some very clean distance and velocity graphs.



*Figure 1 – Periodic motion of a mass on a spring*

5. Labeling graphs. For each of the situations below, pick one graph above, and label one point on that graph to illustrate that particular situation:

- "B" at the BEGINNING of a cycle and.
- "E" at the END of the same complete cycle.
- "A" on a spot where the mass is moving AWAY from the detector fastest.
- "T" on a spot where the mass is moving TOWARD the detector fastest.
- "S" on a spot where the mass is standing STILL.
- "F" where the mass is FARTHEST from the motion detector.
- "C" where the mass is CLOSEST to the motion detector.

**[These graphs, and your annotations, will be useful on the next page when you answer the questions. When you print the graphs for the final report – repeat this procedure on the Logger Pro printout.]**

**Part 2 Investigating the motion of a Mass Undergoing SHM**

**For these questions – use your graph from the previous page in Part 1 – and you want to give answers as “descriptive comments” – not numerical values!**

Questions a) When the mass is at its **maximum distance** from the *equilibrium position*, how would you describe the velocity of the mass? How would you describe the velocity of the mass when it is **at the equilibrium position**?

\_\_\_\_\_

\_\_\_\_\_

b) When the mass has its maximum **positive** velocity, how would you describe its distance from the *equilibrium position*? What about when it reaches maximum **negative** velocity? Explain.

\_\_\_\_\_

\_\_\_\_\_

c) How does the **acceleration** curve compare to the **force** curve? What differences are there? From your graphs, what would you say is the relationship between force and acceleration?

\_\_\_\_\_

\_\_\_\_\_

d) How does the **force** curve compare to the **distance** curve? What differences are there? What would you say is the relationship between force and position?

\_\_\_\_\_

\_\_\_\_\_

e) Do the **distance** and **velocity** graphs have the same period? Do their peaks occur at the same times? If not, how are the peaks related in time?

\_\_\_\_\_

\_\_\_\_\_

f) According to your graphs, for what **distances** from the *equilibrium position* is the **acceleration** maximum? How would you describe the distances when the acceleration is zero? How would you describe the velocity of the mass in each of these cases?

\_\_\_\_\_

\_\_\_\_\_

**Part 4 Spring Restoring Force and SHM**

3. Finding the spring constant.

$$k_{\text{graph}} = \text{spring constant} = |\text{slope}| = \text{_____} \text{ N/m}$$

4. Compare with data.

$$k = \frac{|F|}{|\text{distance}|} = \text{_____} \text{ N/m} \quad \% \text{ difference} = \frac{|k_{\text{single}} - k_{\text{graph}}|}{\left(\frac{k_{\text{single}} + k_{\text{graph}}}{2}\right)} (100\%) = \text{_____}$$

Question How does the spring constant value from the linear fit compare to the single point value? If there were a noticeable difference, how would you explain that? \_\_\_\_\_

\_\_\_\_\_

Questions/Suggestions -> James Nolta - Nolta@LTU.EDU