**Experiment 4: Work and Energy**

**Electronic setup:**
1. The 750 interface should be powered on (green light comes on).
2. Connect the motion sensor (yellow plug into jack 1, black into 2) and the force sensor (channel A) to the SW750 interface.
3. Be sure to tare (zero) the force sensor before each measurement (button on the side).

**Mechanical setup:**
1. The motion sensor should be aimed slightly below the center of the cart or close to pointing directly at it.
2. The slide switch on top of the motion sensor should be set to the narrow beam position.
3. Raise the end of the track with the motion sensor by placing two short pieces of 2 × 4 under the motion sensor where it clips onto the track. The pieces should be set with their cut edges on the top and bottom. This should raise the end of the track about 12–13 cm above the table.
4. Measure from the table to the **bottom edge of the track** as shown in the diagram in the writeup.
5. You can calculate the sin(θ), which is all you will need in this experiment, using this height and the fact that the track is 122 cm long. Find $g \sin(\theta)$ using $g = 9.81 \text{ m/s}^2$.
6. Place a cart on the track with the end having the Velcro™ patches facing up the slope towards the motion sensor.
7. For practice, place the cart about halfway up the track from the force sensor and release it. It will roll down the track, bounce back up, and then repeat the motion.
8. **IMPORTANT** When you do the actual measurements, one member of the group needs to hold the force sensor firmly so the track doesn’t move when the cart bounces.

**To take data:**
1. The WorkEnergy program and the write-up can be found in the 8.01L sub-folder of the “Students’s Home” folder on the desktop.
2. If you get an error message, something is turned off or unplugged, so you need to check your setup.
3. Like our other LabVIEW programs, WorkEnergy is controlled by a pull-down menu near the top left side. There is also a pull-down menu to control data plotting.
4. The program has two tab displays, one for plots and one for fit results.
5. Be sure to tare (zero) the force sensor by pushing the button before each measurement.
6. When you are ready to measure, hold the cart in position, and choose Measure from the pull-down menu. The RUN button will change to bright green. Release the cart and click the RUN button. **IMPORTANT:** One member of the group needs to hold the force sensor firmly so the track doesn’t move when the cart bounces on the spring.
7. After 4 sec have elapsed, you should see a graph of raw data something like the picture in the writeup. The top curve is the position of the cart and the bottom curve is the output of the force sensor.
If your data looks different in any way from the example in the writeup, check the steps (especially Mechanical Setup steps 1 & 2) and try again. If that fails, ask for help right away.

To analyze data:
Now you will analyze these raw data in several different ways. The program computes the position, velocity, and acceleration using the raw position data by taking differences. You may plot these quantities or the force as a function of time by choosing from the Plot Control pull-down menu and then clicking the Replot button.

1 It’s best to do all of the measurements on the plots, record the numbers on your report, and then answer the questions later.
2 If you have forgotten how to manipulate the graph and the marker lines, see the section “Moving and measuring” below.
3 First, select the plot of velocity vs. time; it should look like a sawtooth plot, an expanded section of which is shown in the writeup. Note where the zero velocity point is and also note that positive velocity is up the incline.
4 The first step to answer the report questions is to fit the velocity versus time going up and down the incline (from B to C on picture in writeup) with a straight line to measure the average acceleration.
5 Position one of the marker lines a bit to the right of point B and other one a bit to the left of point C. When fitting these data, make sure your two line positions are in the linear region, not in the curved regions at the ends.
6 On the Table & Fits tab, make sure that the “Fit Function” type is Linear + BG.
7 On the Action menu select Fit Data. On your graph, you will see a green line through the fit section. The fit result (“Output Params” box) is under the Table & Fits tab. A1 is the slope, i.e. the acceleration. Record this value.
8 Lastly, move the lines to find the largest value of the velocity (the Y coordinate) near all three points, A, B, and C. The boxes above the plot give you the X and Y position of the lines. Be sure to read the value for the correct line color.
9 Now, go to the position vs. time plot. The first downward spike corresponds to the time when the mass first hits the spring. The curve following the spike corresponds to the mass going up and down the incline. Recall that up is positive. The second downward spike is when the cart hits the spring for the second time.
10 Move the marker lines to find the position (the Y coordinate) at the bottom of the first downward spike and at the top of the first curved section. You will use these numbers to calculate the distance the cart moved up the incline (d) as shown in the writeup.
11 Stop here and answer the questions on the report. Come back here if you have time left at the end of the hour.

12 Finally, go to the Force vs. time plot. Note that Force is also measured to be positive in the upward direction. The sharp spikes indicate where the cart hits the spring. Record the time (the X coordinate) where the Force first starts climbing steeply and also at the center of the top of the peak where the Force turns over. The maximum force occurs when the spring is most compressed, i.e. when the cart stops. If your
minimum force is not zero, you forgot to tare the force sensor. Don’t worry, just find the time when the force first deviates from the flat line.

13 Also, record the maximum force (or if you forgot to tare your sensor, the difference between the maximum and minimum force).

14 Notice what happens to the force after the cart leaves the spring, it goes down to zero but then bounces up and down with a small amplitude for a while.

Moving and measuring:

You will need to expand both the X and Y scales on the graph, read off marker line positions, and locate marker lines to do fits in order to carry out the analysis. You need to be familiar with using the zoom controls (center button on the graph control) and cursor (left button).

Each graph has two marker lines (red and blue), which you will use to read data values or to select which data points will be fit. When the cursor (left) button is selected on the graph control palette, you can position the marker lines by dragging them with the mouse. Initially they are on top of each other so you need to move one to see the second one. You can also move the lines by using the left and right arrow keys on the keyboard or by selecting blue or red using the button above the graph and clicking those left and right buttons. The two lines are always located on top of a data point with the values of the data points appearing in the boxes above the graph.

Whenever you do a fit, only the data points between the two lines are included in the fit. It doesn’t matter which line is on which side.

When the zoom control (center) button is selected, you first get icons which allow you to select vertical expansion (top right), horizontal expansion (top center), or return to full screen (bottom left). If you select an expansion option, the computer cursor turns into a magnifying glass. Position it where you want to start your expanded region, click and hold the left mouse button, move the cursor to the other side of the desired region and release the left button.

**NOTE#1:** This does not exit the expansion mode. You need to select the cursor button on the control palette to get back to cursor mode.

**NOTE#2:** If the blue and red lines are outside the expanded region, you cannot get them back. You need to move the lines into the region to be expanded first.

So, the sequence is:

1. Select cursor mode, move both marker lines into the region of interest.
2. Select expansion mode and expand the region of interest.
3. Select cursor mode again and move the lines where you need them.
4. If you need to go to another region, select the full screen expansion option.
5. Repeat.