ENERGY CONSERVATION AND UNCERTAINTY

Objectives: • Review energy of a simple mass on a spring.
• Investigate conservation of energy in the mass on a spring system.
• Introduction to error propagation.

To Do Before Lab: • Read this lab
• Read Taylor Ch. 1 & 2
• Think about Part 0 (1)
• What is the energy of a spring/mass system?

Apparatus: Secure stand, sonic ranger, k= “3.5” Nm^{-1} spring, mass hanger, mass set, labels, LoggerPro, Excel

Introduction:
When investigating physical systems it is very useful to have a quantity that stays the same, an *invariant.* For example, in dynamical systems with no frictional forces, total mechanical energy is conserved; it stays invariant during the time evolution of the system. Such invariants are very useful when solving problems. On a more fundamental level they are also very useful because the existence of an invariant usually means that there is a symmetry behind it. This is a great aid in formulating a physical theory.

However, it is a matter of experiment to determine whether a quantity is in fact an invariant. Is the initial quantity equal to the quantity some time later? The answer always comes down to the question of uncertainties. This lab will take a close look at how you can determine whether energy is conserved.

Part 0: Spring Constant
(1) Devise a procedure to find the spring constant of your spring. Record your procedure and write out the formula to find *k*. Box this equation. It will be very useful. Note that the Sonic Ranger can be used for static distance measurements.

(2) Using your method, find *k*.

(3) Find an uncertainty in *k*. (The method you use will depend on your procedure to find *k*.) Record your result as your best estimate plus/minus the uncertainty. Assume the masses and *g* are exact.

Part I: Data and Energy
You will use the sonic ranger to record the position vs. time of your mass on a spring. If the vertical position of the mass hanger can be described by the following simple equation

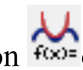
$$y(t) = y_0 + A\sin(\omega_o t + \varphi)$$

where y_0 is an offset of the equilibrium position from zero, A is the amplitude of the oscillation, ω_o is the angular frequency in rad/sec, and φ is a phase.

This data can then be copied into Excel where you can compute the energy.

(1) Set up the sonic ranger and mass hanger so that you can accurately record the full motion. Use the sonic ranger to find the equilibrium height and its uncertainty. Change the scale on the axes in LoggerPro to better see the uncertainty due to noise.

(2) Use the ranger to record the motion of the mass for 10 seconds. Make sure your graphs *x(t)*, *v(t)* and *a(t)* are as clean as possible.

(3) Select the position graph and click on the curve fit button 

on the tool bar. Select the sine function from the long list under "General Equation" and then click "try fit". Once you obtain something reasonable (if you are not sure- ask!), record the values with uncertainty. Associate each of these numbers with a physical quantity and with either initial conditions or to how the oscillator is built. Check to be sure that the angular frequency is agrees with what we expect from the equation of motion.

(4) Before making a quantitative measurement of the energy of the oscillator you need to adjust LoggerPro to reduce a systematic error. In the interest of producing nice smooth curves, LoggerPro averages a number of distance measurements to determine the velocity. You can increase the accuracy by changing the averaging to 3 points. This will improve the accuracy of the velocity values calculated by LoggerPro at the cost of increasing the "noise" in your graphs. You can change this setting in the ``Settings" option in the file menu.

(5) Starting with the mass pulled down and at rest, release the mass and record ~15 seconds worth of data. Start up Excel and copy the data table directly from LoggerPro into the Excel worksheet.

(6) Find the total energy: Using your book, memory, or other means find the expression for total mechanical energy. Recall that this has two parts, kinetic and potential. How do the variables you used in the energy compare with what the sonic ranger measures (and what you have in your spreadsheet)? Perform the necessary conversion and enter this into a new column in your worksheet.

> Note: Excel uses two different kinds of addresses: **relative** and **absolute**:
> A **relative** reference is like giving someone directions that explain where to go, based on where the person starts--"Go up 2 blocks and over 1." A relative reference tells Excel how to find another cell, starting from the cell that contains a formula. "A4" is a relative reference. If you type a formula in C4, which refers to A4, you are telling the computer to use the number 2 columns to the left in the calculation.
> An **absolute** reference tells Excel how to find a cell based on its exact location in the spreadsheet. To make a reference absolute, dollar signs are added before the column and row labels: "A4".

(7) Enter the energy formula into Excel. Use absolute referencing for your constants including the equilibrium position and your spring constant from Part 0.

(8) Graph the total energy as a function of time. What do you think? Examine and describe the effect of varying the equilibrium position and the spring constant on the appearance of your graph.

(9) **Is mechanical energy conserved?** Answer this carefully. We know that the mass will not bounce forever. Is mechanical energy conserved on short times scales of a few cycles? What about on longer scales (such as 15 seconds)? Refer to the data and uncertainties when you answer these questions.