The Falling Mass: Simple Pendulum

Purpose: Students' will investigate the relationship between force and velocity at the bottom of the swing of a simple pendulum.

Equipment and Materials: PASCO capstone software, laptop computer, SW 850 interface, force sensor, photogate, mass balance, simple pendulum and stand.

Introduction: A simple pendulum is a mass attached to a string that is attached to a fixed point. The mass swings back-and-forth in a predictable pattern. At the bottom of the swing, the mass experiences a centripetal force. From a free body diagram, one can derive this expression.

$$\Sigma F = T - mg = m\frac{v^2}{r}$$

From this equation, it is clear that the net force experienced by the mass is directly proportional to the square of the speed of the mass at the bottom of the swing. The speed of the mass is related to the height from which the mass is drop. This can be shown from 1D kinematics.

Experiment: The students' will determine an experimental relationship between the force exerted on the mass by the string and the speed of the mass.

Procedure: These instructions are not step-by-step procedures but rather a guide. Please note that the force sensor must be "tared" before each data run!

1) Setup the simple pendulum. Measure the mass and the radius of the arc the mass follows when freely swinging.
2) Start the software and attach the force sensor. The smart gate should be auto detected by the software. The force sensor you will have to add manually. Look for "economy force sensor".
3) The data displays on the screen should be a Force vs. time plot, a data table of the speeds, and a digit window with the speed. You will have to add this yourself.
4) Pull back on the pendulum and let go after you start the software. Perform a few trial runs until you have decided on the best way to release the mass. Stop the trial after the first swing.
5) Using a measuring stick, select a range of release heights that "make sense". You should have about 10 release heights over a reasonable range of the swing.
6) Take data for each release point. Repeat a few times to confirm your results.

Analysis: Perform the following analysis.

1) Generate a data table of force and speed of the mass for each data run. The force is found by "zooming in" on the lowest point of the first "dip" generated by the swinging pendulum. The speed is the first one in the speed table. If the mass only went through the gate once, it will also be the speed in the digits window.
2) Generate a plot of *"Force" versus speed* and attempt to fit this plot with a linear fit. What does *"Force"* mean in this case? Does it make sense to use a linear fit?
3) What two "variables" should you plot in order to get a linear fit? Recall that you have used two other methods this semester.
4) In either method, you can "extract" an experimental value for r. Compare this result with your direct measurement of the radius of motion.

Write up: Each student will produce a document that will take the place of lab work and the lab recap for this experiment. You will generate and turn in this one document. You must provide the usual basic data, your name, your lab partner's names, the time and day your lab meets. Then you must fill in as completely as you can the following five sections. You should assume a fellow PH 201 student will read this and they should be able to carry out the experiment and complete it with a thorough understanding of what occurred.

I. Objective of the lab/research question. You must produce a statement of what the point of the lab was and why you performed the lab. Please be as specific as possible. You may not use any statement related to the idea that you had to do the experiment as it is required as part of the lab.

II. **Brief but complete methodology of the lab work.** You must provide a methodology or procedure of how you performed the lab measurements and why. This is where you would include all relevant equations and ideas. Provide any supporting information.

III. Data. In this section, provide all data tables generated.

IV. Data/Error Analysis. In this section, you should provide all analysis work you performed this would include any plots you make to achieve your objective. Hint: a lack of plots probably results in a lack of credit for this lab. In addition to data analysis, you should make a reasonable assessment of what errors could make this lab difficult to reproduce by another group. Do not mention errors/issues that you have successfully dealt with or considered. Do not create a laundry list of possible sources of error. Consider carefully and provide supporting statements for the errors you consider.

V. Conclusions. Conclusions should contain the final results of your experiment and provide a context for how reasonable or unreasonable your results are.