Sample lab procedure and report

The Simple Pendulum

In this laboratory, you will investigate the effects of a few different physical variables on the period of a simple pendulum. The variables we consider are mass, length of the pendulum, and angle of initial dislocation.

Your pendulum will consist of a light string and a "bob" (the weight at the end of the string). For each situation, you will make three measurements of the period, T. This will allow you to produce graphs with *error bars* which will aid you in determining the dependence of the period on the variable being tested, or even whether there is a dependence on this variable within your experimental error. Additional information regarding the pendulum may be found in section 12.4 of your text.

For parts 1 and 2, use a small angle, about 5 degrees, for each trial. You can minimize your data-taking tasks by using some of the data from one part in another.

Part 1. Mass Dependence
A. For a fixed length of string (make it as long as possible) use three different bob materials. Having roughly the same shape and size, these bobs will have considerably different masses.
B. For each mass, make three measurements of the period T.
C. The period is the time it takes for the bob to start on the left and return to the left (or on the right….). To ensure accuracy, time the pendulum for 10 periods and divide by 10.
D. Do this three times for each bob to obtain a min, max, and average for each bob.

Part 2. Length Dependence
A. Using the heaviest bob, vary the length of the pendulum. It is easiest to do this by keeping the string attached to the bob but changing the string's connection to the support above it.
B. Measure the period for five different lengths of string. Measure the length from the anchor point to the *center* of the bob.
C. Perform three trials for each length, ten periods for each trial, as described in part 1.

Part 3. Angle Dependence
Using a long string length and the heaviest bob, measure T (as in previous parts of procedure, three trials for each angle) for three different starting angles. As a minimum angle, use 5 degrees and as a maximum use 80 degrees.

Data Analysis and Questions:
1. Plot the data from part 1 on a graph of period vs. mass. Be sure to include the error bars *for the period only* for your data points. Can you discern a relationship between T and m? Does the relationship increase, decrease, is it linear, etc.?
2. Plot the data from part 2 as T vs. L. Also, plot the data from part 2 as T vs. $\sqrt{L}$. Include error bars (period only) for both graphs and attempt to draw a "best-fit" straight line for

both. Which appears to be a better straight line? Which appears to be more consistent with the data points? (I.e. most closely passes through all points.) On which graph can you expect a straight line? What should the slope of that line be?

3. Plot the data from part 3 as T vs. sine(θ). Use error bars for T. Can you discern a relationship between T and θ? Should T depend upon θ?

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Purpose

The purpose of this experiment was to determine whether length, mass and angle of displacement affect the period of a pendulum.

Procedure

No significant deviations from the assigned procedure occurred. Our string broke during the second trial with the third length in part 2, so we got a new string and re-started data taking for the second length. Since the new string was identical to the old one, we kept all of our previous data.

Measured Data and Calculations

All of the periods were measured by timing 10 full oscillations and dividing the number from the stopwatch by 10. Only the results of that calculation are shown here. Four significant figures were kept, which is more than enough as the stopwatch only yielded hundredths of a second.

   The various repetitive calculations were carried out using Excel, as were the graphs. The "high error" and "low error" are the highest and lowest deviations of individual trial from the average. I report this rather than the min and max because that is the way Excel likes its data for errorbars. What follows are excerpts from that spreadsheet.

	Part 1		
T in s	L=1.5 m	5 degrees for all trials	
	Cork	Al	Steel
mass (kg)	0.008	0.032	0.093
Trial 1	2.512	2.437	2.532
Trial 2	2.466	2.502	2.504
Trial 3	2.455	2.474	2.447
Average	2.478	2.471	2.494
high error	0.034	0.031	0.038
low error	0.023	0.034	0.047

The graph, graph 1, is included on a separate sheet.

	Part2				
T in s	steel bob	5 degrees for all trials			
L in m	0.200	0.500	0.750	1.000	1.500
sqrt(L)	0.447	0.707	0.866	1.000	1.225
Trial 1	0.975	1.427	1.786	1.909	2.532
Trail 2	0.878	1.445	1.699	2.200	2.504
Trial 3	0.958	1.484	1.763	2.154	2.447
Average	0.937	1.452	1.749	2.088	2.494
high error	0.038	0.032	0.037	0.112	0.038
low error	0.059	0.025	0.050	0.179	0.047

The graphs for this section, graphs 2 and 3, are included on a separate sheet.

Part 3

T in s   steel bob   L=1.5 for all trials

angle	5.000	45.000	80.000
sine(angle)	0.087	0.707	0.985
Trial 1	2.532	2.594	2.744
Trail 2	2.504	2.567	2.784
Trial 3	2.447	2.597	2.800
Average	2.494	2.586	2.776
high error	0.038	0.011	0.024
low error	0.047	0.019	0.032

The graph for this section, graph 4, is included on the same sheet as graph 1.

Discussion

Part 1

When I graphed the data for this section, I decided to "zoom in" on that region of the y axis where all the data lie. When graphed with y=0 at the bottom of the graph, they all looked like the same values for the period.

When zoomed-in, though, one can see that there are slight differences among the periods of the different bobs. But the differences are small. In fact, the differences among the periods are smaller than the error bars. That is, if there are real differences for the different masses, our experiment was not accurate enough to determine them.

A more accurate timing method, one that doesn't depend on human reaction and judgment, would be needed to further investigate a possible mass dependence.

Part 2

The period vs. length and the period vs. square root of length graphs do show a definite trend that is much large than the error bars. That is, the period *definitely* depends upon the length, increasing as the length increases.

I tried to fit straight lines to both graphs. When making these graphs, I decided to include the point (0,0) because at zero length a pendulum would have nowhere to go, and thus no period. But zero length is impossible for our pendulum because the balls used as bobs have a real diameter; they aren't point masses. So including the origin is really an approximation. Clearly, graph 3 is more closely a straight line.

This is as expected. On page 418 of the textbook the period of a simple pendulum is given by $T = 2\pi\sqrt{L/g}$. Therefore, I expected that T would depend upon $\sqrt{L}$, not L. The period should be proportional to $\sqrt{L}$ and the slope of the straight line should be the factor in front of $\sqrt{L}$ which is $T = 2\pi/\sqrt{g} = 2.007 \, s/m^{-1/2}$. The slope for my graph 3 is 2.0515 which is very close.
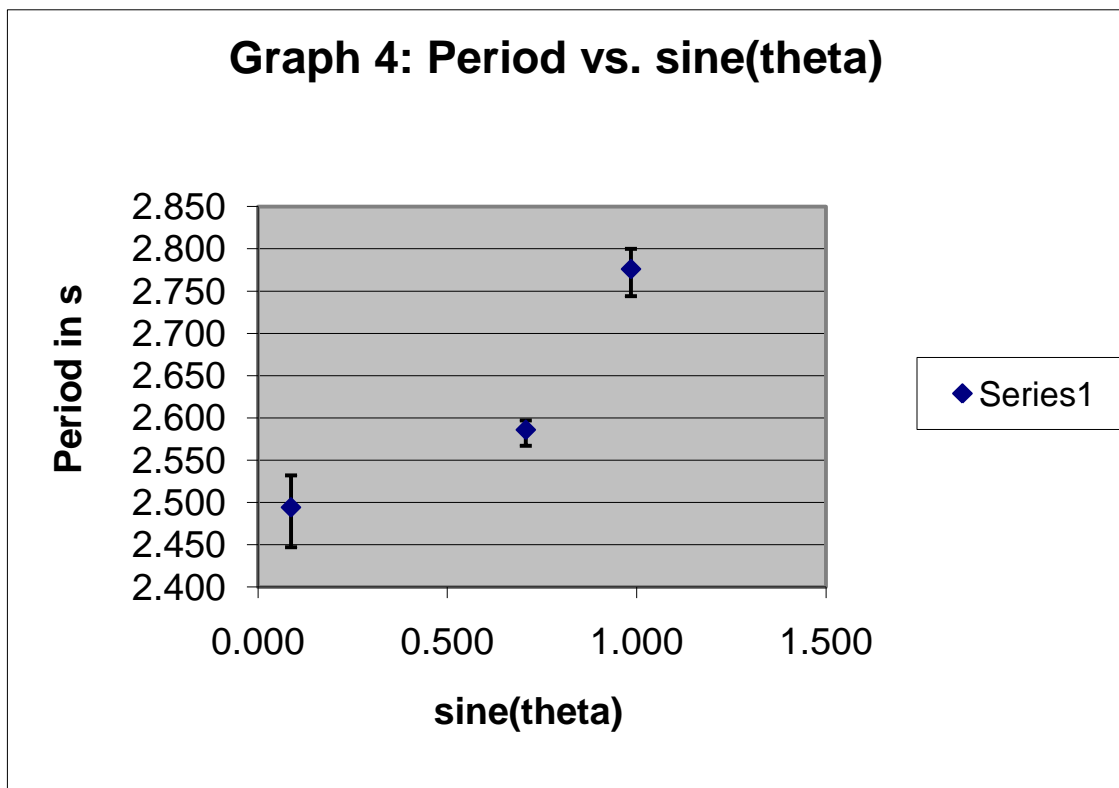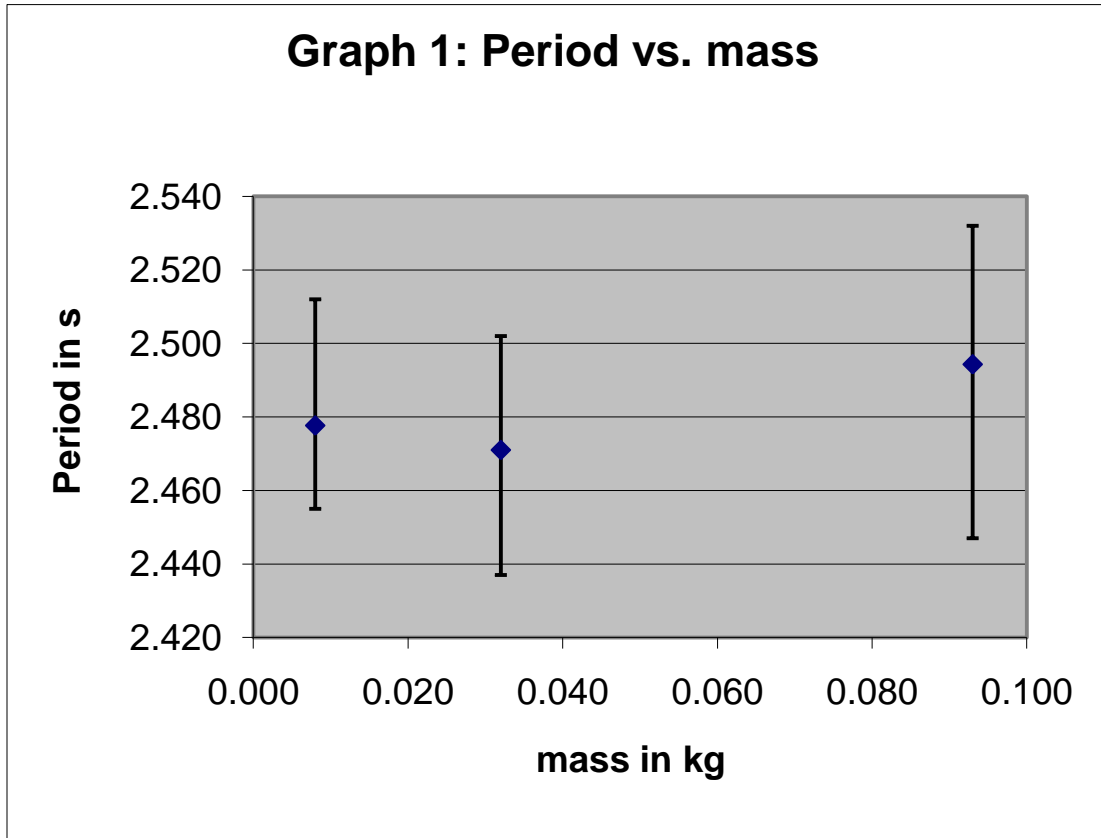
Part 3

Looking at graph 4, one can see that there is definitely an upward trend. That is, as θ increases so does T. I could not find a function that matched the trend very well, though. (I tried several in Excel.)
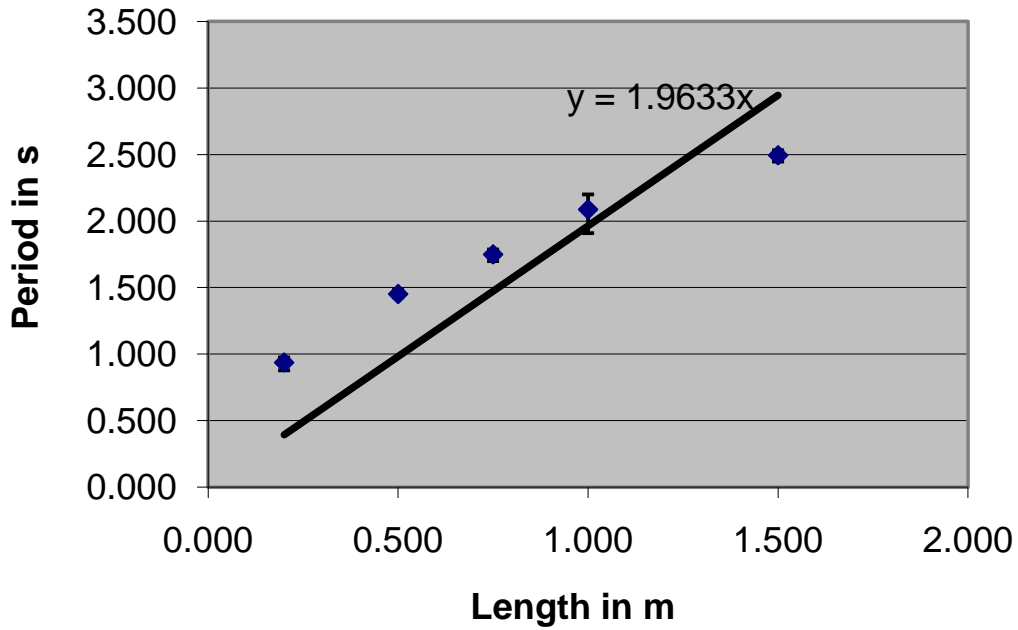
The text says that the period is independent of angle, but they also say that that is just an approximation for small angles. I quote here "Pitfall Prevention 12.5" from page 417: "…The pendulum does not exhibit simple harmonic motion for any angle. If the angle is less than $10°$ the motion may be modeled as simple harmonic." Since two of our angles, $45°$ and $80°$, were much greater, I wouldn't expect the pendulum to behave the same as at $5°$. The book doesn't say whether it gets slower or faster as θ gets larger, but our results indicate that it gets slower. For example, for the $80°$ angle, we got an average period of 2.776 s but the equation $T = 2\pi\sqrt{L/g}$ predicts 2.458 s.

Conclusion

From our experiment, I conclude that the period of a pendulum depends on length primarily and agrees with the theory that says for a simple pendulum, $T = 2\pi\sqrt{L/g}$. But this only works for small angles, about $5°$ or so. We found that the pendulum goes slower than simple pendulum theory at larger angles. The period does not depend upon the mass, at least for an angle of $5°$, which the only angle at which we tested the mass dependence.

Graph 1: Period vs. mass

Period in s

2.540
2.520
2.500
2.480
2.460
2.440
2.420

0.000   0.020   0.040   0.060   0.080   0.100

mass in kg

Graph 4: Period vs. sine(theta)

Period in s

2.850
2.800
2.750
2.700
2.650
2.600
2.550
2.500
2.450
2.400

0.000   0.500   1.000   1.500

sine(theta)

◆ Series1

Graph 2: Period vs. length

y = 1.9633x

Period in s

Length in m

Graph 3: Period vs. sqare root of length

y = 2.0515x

Period in s

Sqaure root of Length in m^1/2