Lab I2: Introduction to Measurement Techniques and Data Analysis

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PH020-01
Lab performed: 29 August 2022
Lab submitted: 6 September 2022

Introduction and Theory:

In this experiment, we learned how to properly take and analyze data in the lab environment. There isn't a lot of introduction besides the fact that we did our lab online using the University of Colorado's PhET website, which allows us to do physics demonstrations without being in person.

Methods and Procedure:

Pendulum Lab

In this experiment, we used a website hosted by the University of Colorado; the purpose was to gather data in multiple ways so that we can find the average and standard deviation of each method. The first thing that we did was go to the pendulum simulation lab and go to the "intro" option. Afterward, we can check the "Stopwatch" option, as we'll be using that in a moment. The default length should be 0.70m and the default mass should be set to 1.0kg. We'll ensure that these settings are correct, and then check to make sure that the gravity was set to "Earth", the friction was set to "None", and the time was set to "Normal" with only a single pendulum showing. Next, we will try our three methods of measuring the amount of time it takes for the pendulum to make a full period. For every method, we'll be using the previous settings that we ensured were set, and set the pendulum angle to 10°. For the first method, we will start the pendulum, then once the ball reaches the max height on the left side of the swing, we will start the stopwatch. Once the ball makes a full period we'll hit stop on the stopwatch. We then repeat this action a total of five times, then move on to method 2. For method 2, we'll be using an external stopwatch instead of the stopwatch on the webpage, however, the rest of the method will be performed exactly the same. The third method was the same as the previous methods, but we'll perform the time measurements in "Slow" mode using the stopwatch on the web app. After writing down all of our data thus far, we will measure the amount of time that it takes to complete 10 full periods. We later ended up using this data to find the average amount of time that it takes for one full period to occur. Before measuring this one, however, we have to decide which method would be the best for the job. Method 3 would probably be the most accurate, however, it will also take a long time for ten periods to pass at less than half of the normal speed. We then decide to use method 2, as it seemed to have a higher amount of precision, most likely due to the fact that we didn't have to take our eyes off the play button in order to start and stop the stopwatch. Once we got the data for this step, we have one final step to finish our experiment. In the final step, we will measure a full period at different lengths.

Spring-Mass Simulation

In part two of the lab, we used a different online simulation. What we did was go to the Spring-Mass simulation and click the "Intro" option. We then used the left spring controls, the spring constant selector was put onto the third tick, Natural Length and Equilibrium Position are ticked, and Earth gravity was selected. We can then place each of the weights individually onto the spring and measure the displacement between the Natural Length and the Equilibrium Position.

Results / Data:

In this experiment, the results lead to

Table I2.1: Data taken in step 1e, testing the methods

Period (s)			
trial #	method 1	method 2	method 3
1	1.61	1.66	1.66
2	1.77	1.60	1.72
3	1.54	1.57	1.68
4	1.62	1.63	1.65
5	1.66	1.60	1.68

Table I2.2: Data taken in step 1f, averaging the ten periods

Trial #	10 Periods (s)
1	16.5
2	16.0
3	16.8
4	16.6
5	16.7

Table I2.3: Data taken in step 1g, measuring different lengths

	Periods				
length (m)	1	2	3	4	5
1	1.95	2.03	2.03	2.05	2.02
0.90	1.93	1.96	1.93	1.88	1.77
0.80	1.95	1.73	1.79	1.88	1.77
0.70	1.67	1.62	1.64	1.66	1.72
0.60	1.53	1.58	1.50	1.61	1.54
0.50	1.38	1.45	1.45	1.40	1.37
average (m)	1.74	1.73	1.72	1.75	1.70
period squared	3.01	2.99	2.97	3.05	2.88

Table I2.4: Data taken in step 2e, measuring difference in distance after adding weight

Mass (g)	Length (cm)
50	8
100	16
250	41
75	12
150	19
200	33

Analysis:

The first thing we did for the analysis was find the average of the values in each individual methods in Table I2.1. The average of each method was:

Table I2.5: Averages in seconds found in Table I2.1

Period (s)			
trial #	method 1	method 2	method 3
Average (s)	1.64	1.61	1.68

Then, we needed to check the standard deviation of the methods as well.

Table I2.6: Standard deviations found from Table I2.1

Period (s)			
trial #	method 1	method 2	method 3
standard dev	0.0846	0.0342	0.0268

Here we can see that the standard deviation for method 3 was the smallest, which means my assumption that method 2 was the most precise incorrect. However, it isn’t that far off method 3 and the averages are slightly different, which does pose some suspicion.

Anyway, the following thing that was done for the analysis was in Table I2.2, in which an additional column was created to find the time elapsed during one oscillation (it will divide the periods by 10).

Table I2.7: Average period time (periods divided by 10) in Table I2.2

Trial #	Period Avg (s)
1	1.65
2	1.60
3	1.68
4	1.66
5	1.67

We'll then also calculate the average and the standard deviation of the ten periods.

Table I2.8: Average and Standard deviation of the periods of Table I2.2

Trial #	10 Periods (s)
Average	16.5
standard dev	0.311

The next thing we performed was to calculate the average of the five trials in Table I2.3

Table I2.9: Average calculation of each 5 trials in Table I2.3

Periods	1	2	3	4	5
average (m)	1.74	1.73	1.72	1.75	1.70

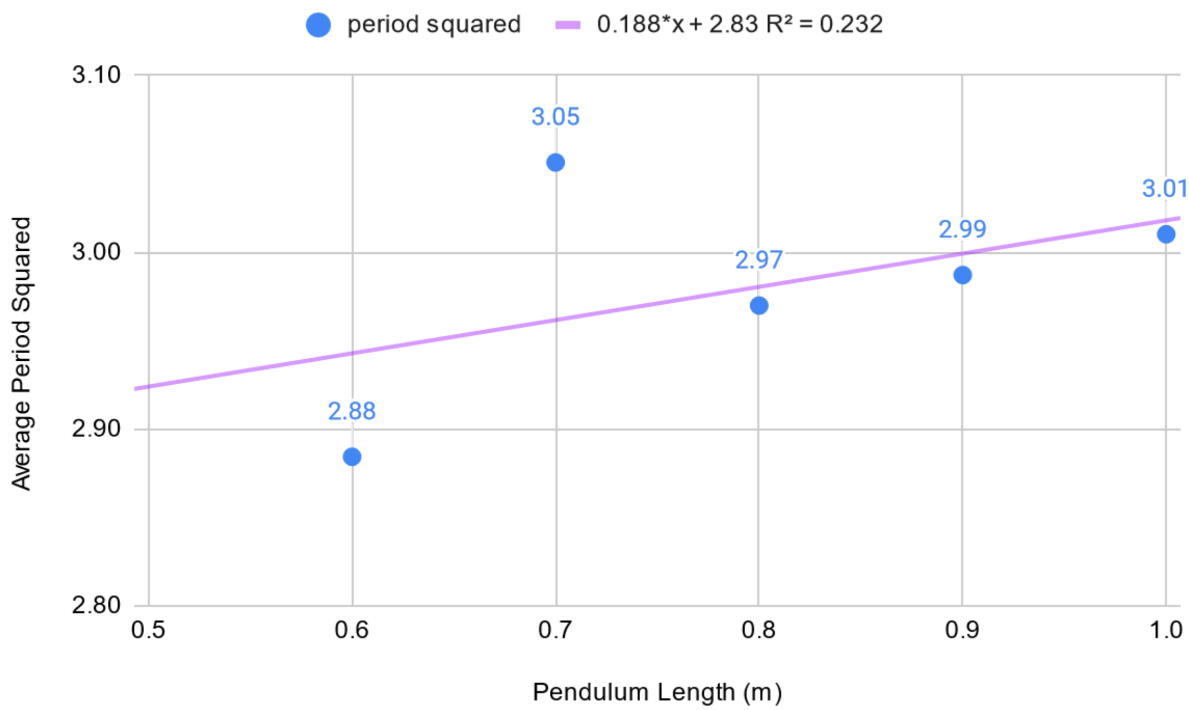
And then we will find the period squared

Table I2.10: Period Squared of the 5 trials of Table I2.3

Periods	1	2	3	4	5
period squared	3.01	2.99	2.97	3.05	2.88

Next, we created a graph to analyze the pendulum length and the average period squared

Graph I2.1: This graph shows the relationship between Average Period Squared and the Pendulum Length (m)



From here we can see that the slope = 0.188*x+2.83, and R^2 =0.232. Using the equation

$$s = \frac{4\pi^2}{g} \qquad \textit{Equation I2.1}$$

we can rearrange the equation to calculate g. Rearranging this gives us

$$g = \frac{4\pi^2}{s} \qquad \textit{Equation I2.2}$$

which gives us the value 210 for g. We can then calculate the uncertainty in g using slope by using

$$\sigma_g = g\frac{\sigma_s}{s} \qquad \textit{Equation I2.3}$$

giving us σ_g = 5.59.

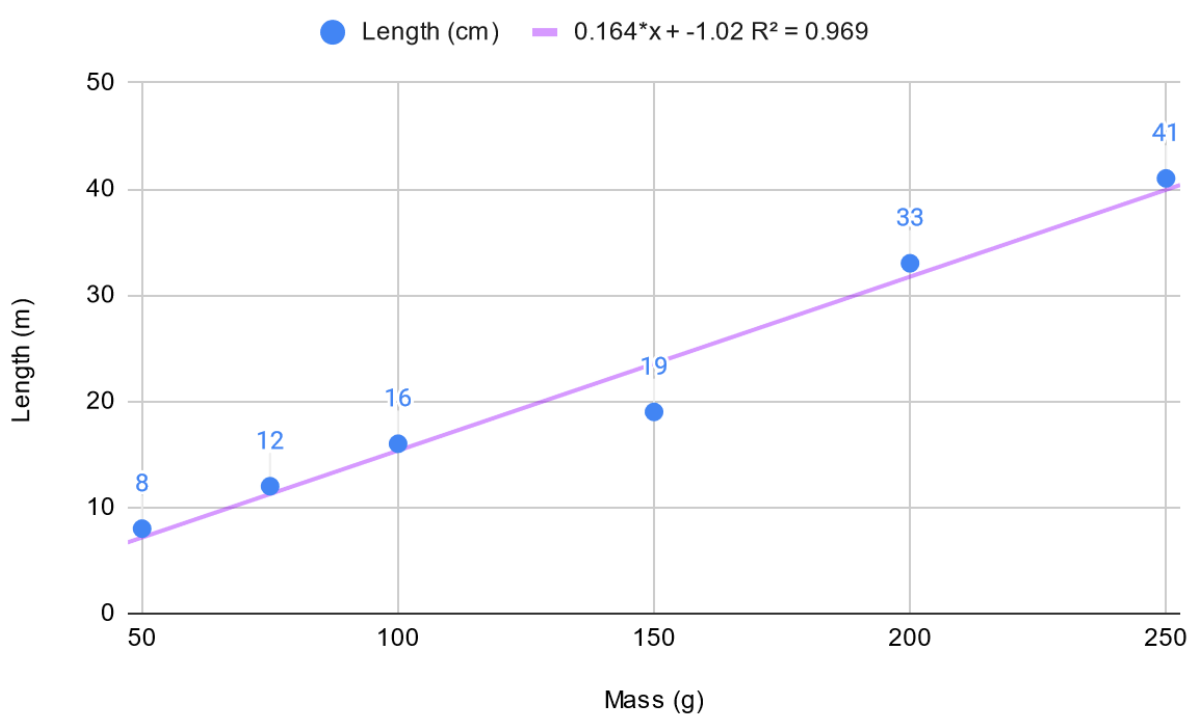
The next thing to analyze is the data of Table I2.4, in which we added an addition column where we had calculated the mass in kg from g and the extension in m from cm

Table I2.11: This is an analysis of Table I2.4 where we convert the units

Mass (kg)	Length (m)
0.05	0.08
0.1	0.16
0.25	0.41
0.075	0.12
0.15	0.19
0.2	0.33

and the final analysis we had to do was plot a graph where the mass is along the x-axis and the length is on the y-axis.

Graph I2.2: A graph of the relationship between the Length(m) and Mass7(g) in Table I2.4



Here we can identify that the slope is 0.164. From there we can rearrange

$$\Delta x = \frac{g}{k}m \quad \textit{Equation I2.4}$$

We can then see that the slope of the trendline is equal to g/k, which means that

$$s = \frac{g}{k} \quad \textit{Equation I2.5}$$

And to rearrange this to get our constant, k, we can input our slope into s and 9.8 into our g which gives us

$$k = g/s \quad \textit{Equation I2.6}$$

Showing us that our constant is 59.8. The error propagation equation is

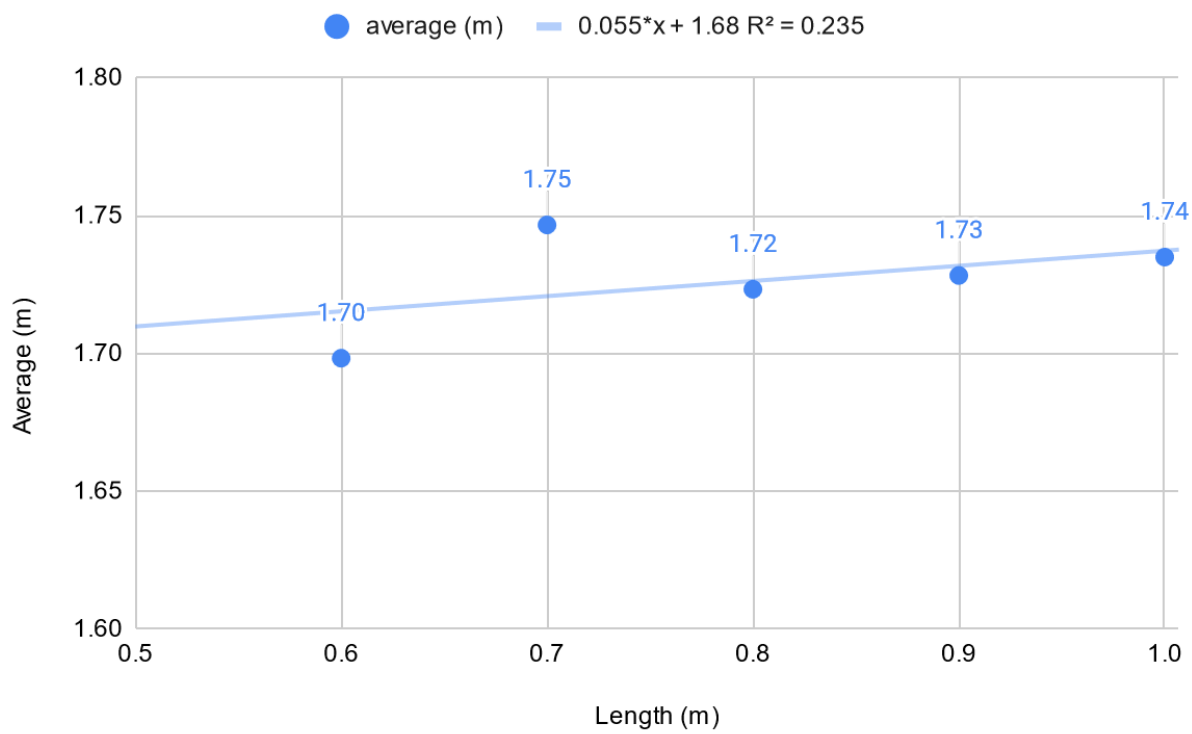
$$\sigma_k = k\frac{\sigma_s}{s} \quad \textit{Equation I2.7}$$

Which would give our value of σ_k a value of 18.2.

Discussion:

The first question that needs to be answered is what is the accuracy of the data when we find the average and the standard deviation in Table I2.1. We can see that method 3 had the lowest standard deviation, meaning that it was the most precise measurement. This makes sense considering time was slowed in that test, giving us a smaller margin of error when starting and ending the stopwatch. The next question asks us how the average and standard deviation compare from the experiment where we took the average of ten periods. Our choice in the method isn't that far off, considering the average is 1.65 and the average for method 1 was 1.64. The standard deviation for the first method was the highest, so maybe it should have been our choice. The third question asks if our findings in the form g+-σ_g agreed with the accepted value, in which yes it does since σ_g = 5.59 which absolutely falls within the range. The next question that is asked if why did we plot the period squared instead of the period, which I'm not even exactly sure why. Plotting the period as opposed to the period squared would be just as easy

Graph I2.3: Showing the relationship between the Average and Length instead of Period Squared



And if we square any of the labeled numbers, we get our Average Squared. The following question pertains to the fact that earlier we had graphed the extension versus mass and identified the slope that way. How would the analysis had changed if we knew the constant but not the acceleration due to gravity? I don't think that the analysis would have changed much, we would have simply plugged in the spring constant into the equation instead of the acceleration of gravity. The results would be very similar if not the exact same. The final question that is asked is if the actual value of k is 6.0N/m then does the result agree with the actual value? This value of k does not agree with our result, however, it also doesn't agree with the graph presented previously, as it does not follow the slope at all.

Conclusion:

In this lab, we learned how to take and analyze data, as well as practice using excel functions and determining when and how to use each one. Throughout this lab, our main goal seemed to be taking measurements, thus we did that when taking time measurements a lot in the first part of the lab, and then distance displacement measurements in the second half of the lab.

References:

Murphy, Joseph, R. and Kessler, J. M. “Lab I2: Introduction to Measurement Techniques and Data Analysis” Introductory Physics Laboratory Manual. 29 August 2022, Southeast Missouri State University Department of Chemistry and Physics.

Murphy, Joseph, R. and Kessler, J. M. “Lab 0: Plotting Data and Graphical Analysis” Introductory Physics Laboratory Manual. 29 August 2022, Southeast Missouri State University Department of Chemistry and Physics.