# What Affects the Period of a Pendulum?

# LiveLab 4: Analysis of the data, Part 2

## In part 1 of this guide you should have analyzed the effects of the amplitude (angle). Any effects present were quite subtle, so the relevant question was: “is there an effect”? It should, however, be quite obvious from your data that length had an effect. So the relevant question for the length is not “is there an effect”, but rather, “what is the nature of the effect?”. More specifically, we would like to find a mathematical relationship between the length and the period. To this end, we will use the data transformation techniques we discussed in [Live Lab 2](https://smccd-my.sharepoint.com/:w:/g/personal/wongalex_smccd_edu/EfZh6VYSjeNGgIMc7E3rYK4BvUIXYdYD-8bS7DRcgLvKPA?e=CVbMuk). You can also reference the [Data Transformation Guide](https://smccd.instructure.com/files/5361739/download?download_frd=1).

## Calculating the Period for Each Setup

If you have not already done so, assemble your data for a series of trials where amplitude was held constant and length was varied. As we discussed in the experimental design, you want to have at least 4 (and ideally more) different lengths, and the lengths should range as much as possible. As we did in the previous lab, find the average period for each setup. The result should look something like this, (but with more rows):

|  |  |  |
| --- | --- | --- |
| Amplitude (deg) | Length (cm) | Period (s) |
| 30 | 5 | 0.50 |
| 30 | 15 | 0.75 |

1. Place the table with calculated periods in your GradeScope document.

## Initial Graph

Make a plot of the period vs. the length, using the [Plot and Monte Carlo Spreadsheet](https://smccd.instructure.com/files/5323928/download?download_frd=1). Be sure to include uncertainties in length and period, which you got in the Data Collection lab and Livelab 3, and should show up as error bars in the plot.

1. Title your plot and axes correctly, and place your plot here. If some of the error bars are too small to see on the plot, note that fact below the plot.

## Transforming the Data

You will likely observe that the data makes a curve rather than a line (if you do not see this, this means you need either more accurate data or data from a wider range of lengths). Your next step is to see whether either of the models that we proposed in live [Live Lab 2](https://smccd-my.sharepoint.com/:w:/g/personal/wongalex_smccd_edu/EfZh6VYSjeNGgIMc7E3rYK4BvUIXYdYD-8bS7DRcgLvKPA?e=CVbMuk), exponential () or power law () is a good fit to your data. (T is the symbol for period, L for length, and A, k, and p in the equations are constants).

1. Transform your data appropriately to test the exponential and power law hypotheses, and make the resulting plots with best-fit lines. (At this point you do not need error bars: if you want to use the Plot and Monte Carlo spreadsheet, you can just enter 0 for the uncertainties). Add appropriate axes labels and titles and place the resulting plots here. Also comment on which model better fits the data.

## Comparing Results Qualitatively with Theory

In the oscillations chapter we will learn that the period of a frictionless point pendulum with small oscillations is given by . Note that this is a power-law relationship: rewrite this equation in the form , and find theoretical values for C, ln (C), and p.

1. Use your best-fit line from the graph you made to test a power law relationship to determine experimental values for ln (C), and p. Calculate the percent error () for both ln(C) and p. Show your work and report your results in your GradeScope document.

## Propagating Uncertainty for Data Transformation

The percent errors give us a qualitative sense of how close the theory is to our data. But, unless there is no difference at all, the appropriate question to ask next is whether any differences observed are significant. To answer that question, we need uncertainties in the slopes and intercepts of our graph. We can do this using the Monte Carlo simulation, but there is one complication: in the appropriate plot, we took the natural log of both L and T. When we do that, what happens to the uncertainty?

Page i-8 of the [Error and Uncertainty packet](https://smccd.instructure.com/files/5075072/download?download_frd=1) describes the calculus method for propagating uncertainty. In brief, the idea is that if we have an uncertainty in a measured value A0, the uncertainty if some function is applied is given by

For example, say you measure an angle θ = 1.21 ± 0.05 rad, and you want to find the uncertainty in sin(θ). Then

You can use this approach with the ln function to determine the uncertainties in ln(x), where “x” is some data point you need to graph. Note that this procedure will lead to you having different uncertainties in each data point.

1. Use a spreadsheet and the method described above to calculate the uncertainties in the natural logs of your period and length measurements. (Note that now the uncertainties will be different for each data point). Place the resulting table in your GradeScope document.
2. Enter the uncertainties into the Plot and Monte Carlo spreadsheet and run the simulation. Title and label the axes on the resulting graph and place the graph in your GradeScope document.
3. Report your experimental values for the ln(C) and p with uncertainties. Compare these values to the theoretical values and make a definitive statement about whether each one agrees or does not agree with the theory. (Remember that in our class, for simplicity, when the difference is larger than the uncertainty, that difference will be considered a significant difference).