# What Affects the Period of a Pendulum?

## Lab 2: Data Range and Data Transformation

In the formal lab, we aim to assess how the amplitude and length of a pendulum affect its period. Before collecting the data, we need to understand how this type of data- data where one variable is related to another variable- can be assessed. In this lab you will investigate how to analyze such data.

### Microsoft Excel

We will be using Microsoft Excel to help us analyze our data. Being able to use Excel (or another spreadsheet program like Google Sheets) is a super-useful skill that every student (and professional) should have. If you do not have Excel on your computer, you can [get it for free](https://www.microsoft.com/en-us/education/products/office) from CSM- but if you choose this option you must install it on your machine: Excel Online will not work. Alternatively, you can use [VMWare](https://smccd.instructure.com/courses/35406/files/5209697/download) to remotely log in to one of CSM’s Learning Center computers to run Excel.

If you have not used Excel to do basic calculations and plotting before, use this [brief Excel crash course](https://smccd.instructure.com/files/5209719/download?download_frd=1) to learn the basics before starting the lab.

### Data Range

Imagine you are conducting an experiment where you are measuring the distance travelled by a freely falling object. Setting t=0 when the object is released from rest, you get the following data:

|  |  |
| --- | --- |
| Time (s) | Distance Travelled (m) |
| 1.0 | 4.900 |
| 1.1 | 5.929 |
| 1.2 | 7.056 |

1. Enter the above data into an Excel Spreadsheet and make a scatter plot of it, with the time on the x-axis and the distance on the y-axis. Show your plot in your GradeScope document.
2. Now we know that the distance travelled by a falling object is supposed to be given by , which should be parabolic, not be linear. Yet, if you just eyeball the graph, it looks pretty linear. Comment on why this might be in your GradeScope document.

One possible “fix” to the above might be to take more data. So let’s say you go back to your experiment, set it to collect more data, and get the following results:

|  |  |
| --- | --- |
| Time (s) | Distance Travelled (m) |
| 1.00 | 4.90000 |
| 1.05 | 5.40225 |
| 1.10 | 5.92900 |
| 1.15 | 6.48025 |
| 1.20 | 7.05600 |

1. Enter the above data into an Excel Spreadsheet and make a scatter plot of it, with the time on the x-axis and the distance on the y-axis. Show your plot in your GradeScope document. Below the plot, comment on whether it is easier to tell that the data lies on a curve here. How much easier?
2. If you were designing the above experiment, what would you do to ensure that your experiment clearly detected the parabolic (rather than linear) relationship between distance and time? How could you apply these lessons to your pendulum experiments? (“Collecting more data” is not enough of an answer here: specify how you will organize your data collection.)

### Transforming Data

After an experiment, you are often presented with data for two variables that appear to be correlated. By using a combination of physical theory, intuition, and statistical techniques, you can use your data to establish a relationship between the variables. For example, say you are doing an experiment on the relationship between the intensity of light and the strength of the electric field that is part of that light. You collect the following data:

|  |  |
| --- | --- |
| Field Strength (Arbitrary units) | Light intensity (Arbitrary units) |
| 2.0 | 6.15 |
| 3.0 | 13.35 |
| 4.0 | 24.00 |
| 5.0 | 37.80 |
| 6.0 | 53.70 |

1. Enter the data above into an MS Excel spreadsheet and plot it with the field on the x-axis and the intensity on the y-axis using a scatter plot. Make a best-fit line and look at the equation and R^2 value, and put the result in your GradeScope document. Also comment on whether the data looks linear.
2. Consider the potential physical significance of your best fit line. For example, if the best fit line represents a physical law, what will it predict about the intensity of the light when then field strength is zero? Is this a reasonable prediction?

Now let’s consider some alternative nonlinear relationships between theory and experiment. While anything is possible, common relationships between physical variables take the forms:

or

Where k, p, A, and are constants. We can do a visual test to see if one of these formulas is true via a process called **data transformation** or **linearization**. The idea here is to assume a relationship is true, then plot the data in such a way that, if the relationship is true, it will make a straight line. For example, if we assume , and we take the ln of both sides we get

Notice that we can “assign” different parts of the above equation to the y-variable, x-variable, slope, and intercept in a linear equation. So, if we plot on the y-axis and x on the x-axis, we should get a straight line IF the data fits this model. And if the data does fit the model, then the slope on the plot will be , and the y-intercept will be .

1. Using the ideas presented above, make the correct plot to transform the data to test if the data is consistent with a theory of the form

Copy the plot to your GradeScope document. If your data is consistent with the above equation, find values for A and .

1. Now use a similar technique to test if the data is consistent with a theory of the form

(You will need to figure out what variable to plot on the x-axis and what to plot on the y-axis)

Copy the plot to your GradeScope document. If your data is consistent with the above equation, find values for k and p.