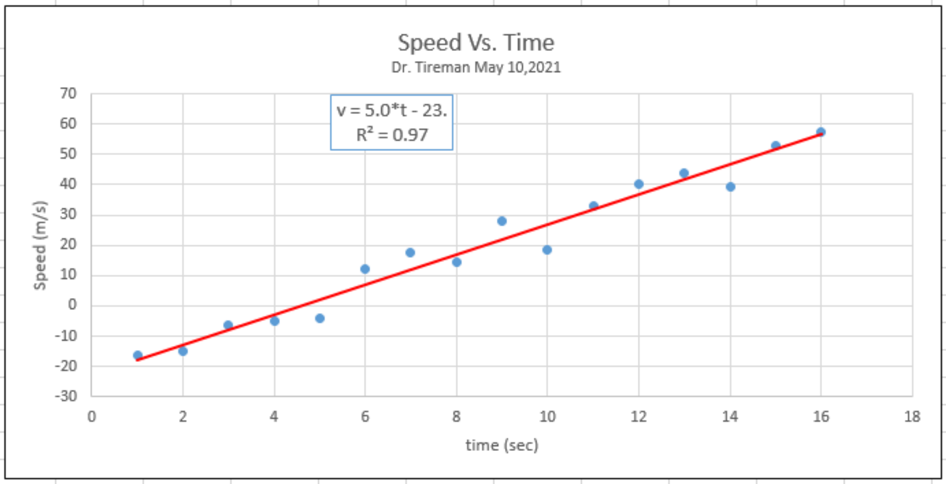
Laboratory 1: Graphing

Goals: To create well-presented tables and graphs with software like Excel, and to extract physical quantities with correct units from the slopes and intercepts of straight-line graphs.

Your instructor will first work through some examples. Work along on your computer to be sure you can find the same features. Make sure you understand the analysis and how to handle units. Then, you will get to do your own tables, graphs, and analysis using different data.

Example: Speed versus time.

Time (sec)	Speed (m/s)
1.0	-16.5
2.0	-14.9
3.0	-6.4
4.0	-4.9
5.0	-4.3
6.0	12.2
7.0	17.7
8.0	14.3
9.0	27.8
10.0	18.3
11.0	32.9
12.0	40.4
13.0	43.9
14.0	39.5
15.0	53.0
16.0	57.5



Your instructor will work through this example and discuss the Excel guidelines sheet. This will demonstrate how to format your table and graph so that they are readable and present the information effectively. It should look something like the above. For this graph, note that the axis numbers do not have decimal points, and they appear at the edges of the graph paper. Make sure you can adjust these and other things when necessary. For the table, know how to create the boxed grid, how to wrap and center the headings, and how to control the number of decimals in the columns. Get familiar with the many options in the software and figure out how to find them. Avoid automated features.

Terminology: Your instructor will explain the meaning of the terms '<u>linear</u>' and '<u>directly proportional</u>.' In the above, is the speed directly proportional to the time? Is the data <u>exactly</u> straight? Do you expect data from measurements to follow an exact mathematical relationship?

Analysis:
Make sure you understand how to use the trendline equation to find the <u>slope</u> and <u>intercept</u> of the best-fit line here. Both these quantities have units. Do you understand the process for finding those units?

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Power-law Example:

Not all data follows the trend of a straight line. The graph of a parabola is a common case. Consider the data here and hypothesize that it follows the equation $y = kx^n$ where k is a linear scaling constant and n is the power for the x- axis data. If you plot y vs. x, you will find the data to be strongly curved. Your instructor will demonstrate this.

Attempting to fit with a linear model will result in a poor visual result. To obtain a linear fit, we can modify the data and generate a new plot. This is called “linearizing the data”. There are two approaches to linearization. We will discuss the approach that linearizes the data by predicting the power (n value) in advance. For the following data, the theoretical equation is $\mathrm{m} = \frac{1}{2}\mathrm{qt}^2$

time (sec)	mass (kg)
1.0	1.9
1.5	5.1
2.0	9.2
2.5	15.0
3.0	24.8
3.5	33.4
4.0	32.4
4.5	46.6
5.0	77.5
5.5	79.4
6.0	81.0
6.5	119
7.0	135
7.5	128
8.0	186
8.5	182
9.0	213

Your instructor will walk you through the data analysis and extraction process. Below are steps in the analysis and questions that guide the extraction of important parameters.

a. Recreate the table and add additional columns as needed below
b. *Graph mass versus time*. Is the graph linear? If it is curved, **do not** add a linear trendline.
c. *Graph mass versus time squared*. It should look somewhat linear. Include the linear trendline and find q.
d. *Graph the square root of the mass versus the time*. Use the linear fit to find the value of the constant q.

Log Analysis example:

For nonlinear data, a method for determining the power *n* in the power law is to perform a log-log analysis. Applying logarithm rules to $\mathrm{y} = \mathrm{kx}^\mathrm{n}$ yields

$$\mathrm{Ln[y]} = \mathrm{n} * \mathrm{Ln[x]} + \mathrm{Ln[k]}$$

To analyze the data using this method, take the natural log of the data and plot the results on an xy scatter plot. For data that follows a power law, the log-log plot will now be linear and can be fitted with a linear fit. The slope of the linear fit is the power n while the y-intercept will contain direct connection to constants. Using the data in the table above, your instructor will walk you through this analysis.

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Exercises

Perform the following exercises using the data provided. All tables and graphs should be generated using MS Excel or similar software.

Exercise 1

Theory: $\mathbf{GPE = mgh}$

1) Generate a plot of Gravitational Potential Energy vs. Height.
2) What do you do with outlier points? What defines an outlier?
3) Fit the data with a linear fit and extract the slope and y-intercept.

Height (m)	Gravitational Potential Energy (J)
0.20	0.49
0.40	1.04
0.60	1.33
0.80	1.96
1.00	2.49
1.20	3.21
1.40	3.43
1.60	3.93
1.80	4.54
2.00	1.73

Exercise 2:

Theory: $\mathbf{T = 2\pi\sqrt{\frac{L}{g}}}$

1) Generate a plot of *Square of Oscillation Period vs. length*.
2) Fit the plot with a linear fit and determine slope and intercept.
3) From the slope, extract a value for the acceleration of gravity, g.

Length (m)	Oscillation Period (s)
0.15	0.816
0.30	1.13
0.40	1.32
0.50	1.44
0.60	1.59
0.77	1.77

Exercise 3

1) Using the same data from Exercise 2, generate a plot of *natural log of oscillation period vs. natural log of length*.
2) Fit the plot with a linear fit and determine slope and intercept.
3) From the intercept, extract a value for the acceleration of gravity, *g*.

<u>What to turn in</u>

1) The following summary sheets filled out completely.
2) Any additional work that doesn't fit on the summary sheets should be included.
3) Data tables and graphs following rules and guidelines specified by your instructor.

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Graphing Summary Sheet **Name: ____**

Gravitational Potential Energy vs. Height

Slope from trendline equation (with unit) = ______________________

Using the methods shown previously and the theoretical equation for this data, discuss the significance of the slope reported above.

Square of Oscillation Period vs. Length

Slope from trendline equation (with unit) = ___________________________

Y-intercept from trendline equation (with unit) = ___________________________

Using the methods shown by your instructor, determine a value for the acceleration of gravity, gg. Show your work below.

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Natural log of oscillation Period vs. natural log of Length

Slope from trendline equation (with unit) = ___________________________

Y-intercept from trendline equation (with unit) = ___________________________

Using the methods shown by your instructor, determine a value for the acceleration of gravity, gg. Show your work below.

Comparisons

The accepted value for the acceleration due to gravity is $g = 9.81\ m/s^2$. Compare the results for g you obtained in the above analyses using the formula

$$\%\ difference = \frac{|g_{measured} - g_{accepted}|}{g_{accepted}} * 100\%$$

There are 2 extractions so 2 percent differences.