Graphing: Basic

Graphing is a powerful tool to visualize distributions, trends and relationships. Analyzing graphs—finding the slopes, intercepts etc.—can give measurements of many physical quantities.

For example, by plotting the applied force on a spring versus its extension, one can discover that the extension depends linearly on the applied force for certain ranges. The slope of the graph shows how "stiff" the spring is, and is called a "spring constant".

We will focus on linear relationships because they are simple and common. Even for a generally speaking non-linear relationship, there could exist some regions where the relationship is linear, or we can adjust the quantities of both axes so it appears to be linear.

Graphing Tools

- Standard millimetre-ruled linear graph paper.
- Pencil: used to draw the data points and the lines.
- Pen: used for the title, axes names and units, and the slope calculations, etc.
- A long (30 cm), clear plastic ruler: used to draw the best lines.

Steps for drawing a graph

1. Decide what you are going to plot on each axis based on theory. For example, to test Hooke's Law, $F = k\Delta x$, you plot F vs. Δx. This is so chosen so that the slope equals the desired quantity k, rather than having the independent variable on the horizontal axis.

2. Tabulate the data that you want to plot. (Do not do this on the graph paper.)

3. Choose the orientation of the graph paper and the scale of each axis based on the data. You want the data to cover a large portion of the graph paper, and you want to use easily divisible numbers only (2, 5 and 10) when converting each block of the graph to real units. For example, 1 block is 0.2 Amp, 10 m/s, or 5 N, etc. The axes do not have to start from 0.

4. Label axes with the quantity name, quantity symbol and the unit. Mark the axes every 5 or 10 units.

5. Write the title of the graph. The title should be descriptive, giving people more information to help them understand the graph, rather than repeating the names of the axes.

6. Plot the data points. Use either a cross or a dot in a circle to indicate the data points.

7. Draw the best fit line with a long plastic ruler. The best fit line is a single straight line that is as close as possible to all the data points, trying to be in the middle of all the points, ideally with the points alternating above and below the line. Treat all points equally unless you have good physical reasons to neglect certain points. If you do neglect any points, write your reasons on the graph.

   You should not:
   - Force the line to pass through the origin, even if the theory says it should;
   - Join the first and last data points.

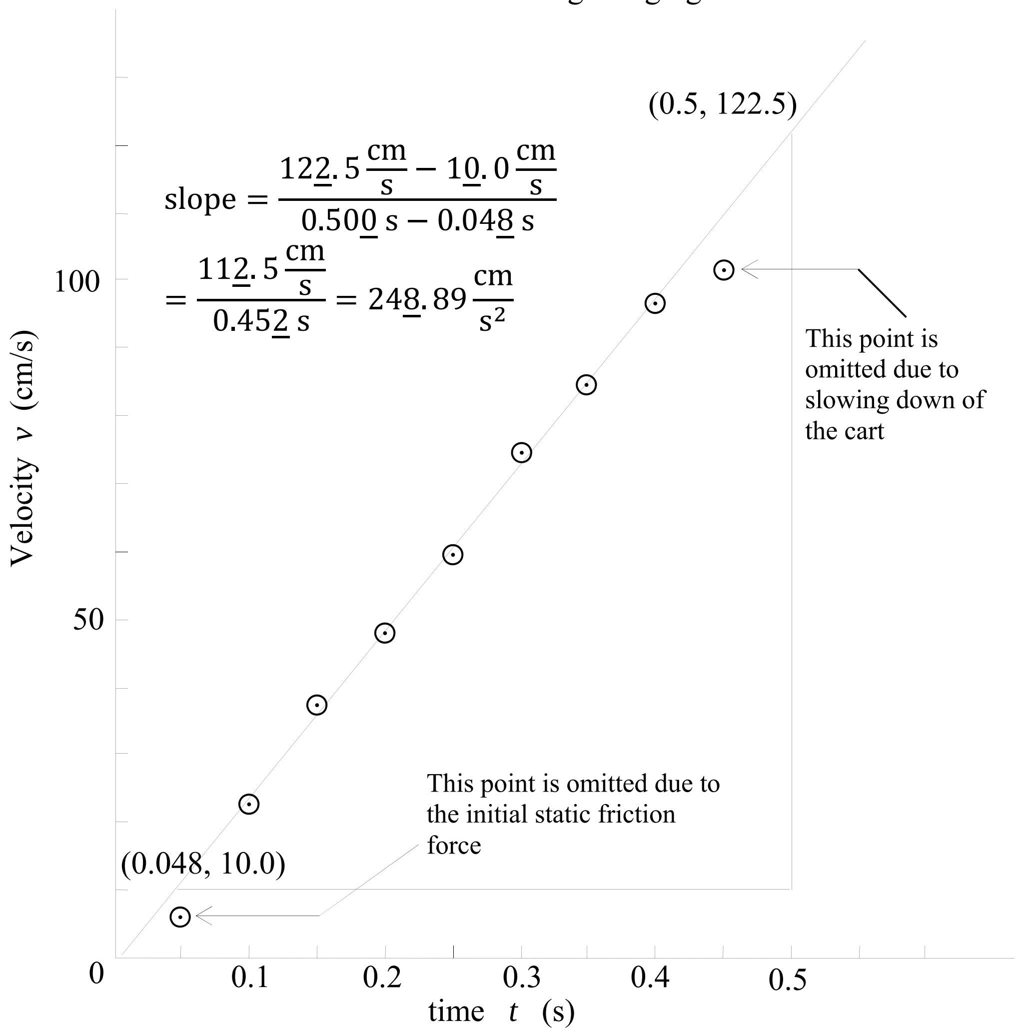
8. On an empty space of the graph, calculate the slope of the best fit line. Choose two points on the line that are far apart and are exactly at an intersection of the gridlines to ensure high accuracy. Original data points and values from your data table should not be used as the points are likely not exactly on the fit line. Mark the two points used clearly with symbols or a big triangle (see examples) and write down their coordinates (x_1, y_1) and (x_2, y_2). The slope is "rise" over "run":

$$\text{slope} = \frac{y_2 - y_1}{x_2 - x_1}$$

   In this course, the number of significant figures (sig figs) of x_1 is assigned to be the same as the number of sig figs in the x of the closest valid data point. A similar procedure is used for y_1, x_2 and y_2. Then, the number of sig figs, in the slope is determined using the calculation rules (see "Measurements: Basic"). The slope should have units and should be written to 5 non-zero digits, as you may do further calculations with the slope. Mark the last sig fig with an underline.

Graphing Example (with illustrations)

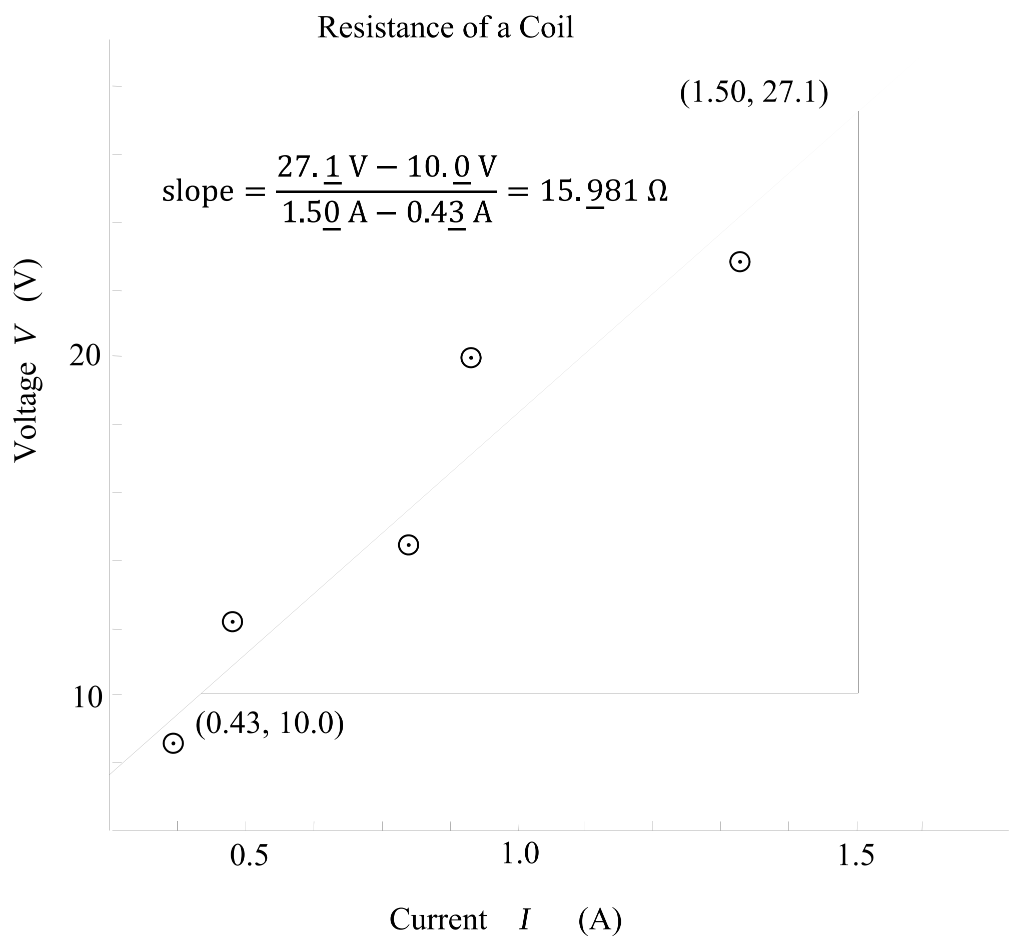
Acceleration of the Cart with a 300 g Hanging Mass



The sig figs of the two slope points are the same as the sig figs of the nearest velocity and time data. They determine the number of sig figs in the slope.

Note that if we choose two points that are too close, like $2\underline{2}.5$ cm/s - $1\underline{0}.0$ cm/s, our slope would have 2 sig figs instead of 3.

Graphing Example with Poor Fit



Here the fit to a straight line here is in doubt. If this happens, check the following:

- Are any points plotted at the wrong places?
- Are there any mistakes in the measurements?
- Should any points be neglected? You must explain the physical reason if you neglect any point!

When these factors are ruled out, try to draw the line the best as you can. Keep the line as close as possible to all the data points. Keep roughly the same number of points above and below the line.