Learning Enhancement Team

Other essential skills

Plotting a Graph by Hand

This guide explains the skill of plotting a graph by hand. It gives strategies to help you do this and draws the distinction between plotting a graph directly from a mathematical function and one from scientific data.

Introduction

One of the most useful skills for a scientist or mathematician to have is the ability to plot a graph by hand. There are many instances when you may be required to plot a graph, for example as a way to visually represent data collected from an experiment. Although many computer programs are available which plot graphs it is still a highly useful skill for you to master; it may be the case that you do not have access to a computer or the time to analyse the data electronically. You may have learned how to plot a graph at school in studies of either mathematics or science or you may have never plotted a graph at all; in either case this guide is designed to help you develop good strategies to enable you to plot graphs which are clear, tidy and accurate.

Different parts of a graph

In both science and mathematics, graphs are used as a means of visual representation for data or functions. Both types of graphs have many common features:

1.   Axes

Graphs have a vertical line and horizontal line called **axes** (the plural of **axis**) which define the area in which the graph is plotted.

> The **horizontal axis** represents the **independent variable**.
> The **vertical axis** represents the **dependent variable**.

In mathematics the independent variable, usually denoted by x, takes the values of the **domain** of a function. The dependent variable, usually called y or $f(x)$, encompasses the **range** of a function (see study guide: *Functions*). In scientific investigation, the independent variable is viewed as something that the scientist controls and the dependent variable is the result of an experimental measurement.

2.   Points

The actual objects that are plotted on a graph are called **points**. In mathematics they comprise pairs of numbers called **coordinates** which represent the input to a function (x) and its corresponding output (y). Coordinates are written as (x, y) where the value of the independent variable comes before that of the dependent variable. In science points represent collected data. For example if an experiment was investigating concentrations in a solution at certain times then data points would reflect this as time being the independent variable and concentration as the dependent variable.
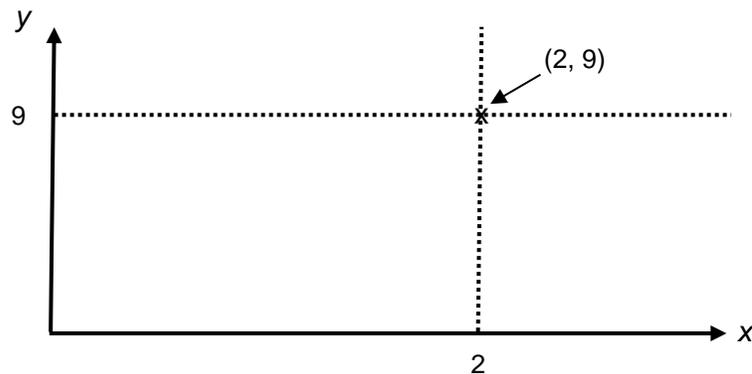
A Graph of a Point. The horizontal and vertical axes are labelled x and y respectively. The coordinate (2, 9) is labelled. Specifically $x = 2$ and $y = 9$ meaning that you have gone two steps horizontally and 9 steps vertically to reach that point.

3.   A Line

It is usually impossible to plot every single point of interest within the domain of a function or to take many thousands of data measurements. Many graphs in both mathematics and science have a line of some sort (either *straight or curved*) to represent what happens *in-between* the points. In mathematics, all the coordinates (points) fall exactly on the line – the line represents the function under investigation and all the points are given by the function. In science, data points are used to give an indication of an unknown line which represents any underlying law. Errors mean that it is highly

unlikely that all points will fall directly on a line deduced from an experiment. Consequently a line in science is called a **line of best fit** or a **trend line**. Importantly, once a line is drawn *through* a set of data points *it* becomes the representation of that data set – the points have essentially become redundant. (There are mathematical techniques called **regression** which enable the calculation of the exact line of best fit for a given data set.)

# Tips on graph plotting

1.   Paper

Choose a suitable graph paper to plot your graph, not normal, lined A4 paper. Many graph papers are available and you may want to look at a few different types. You may have to spend time staring intently at the paper so choose one that is easy on your eyes. There is no convention as to whether graphs should be plotted landscape or portrait, chose the one most suitable to the graph you are plotting.

2.   Axes

The scale for each axis should be chosen so that the whole graph fills as much of the piece of graph paper/space available as possible. Count the number of squares you have available and deduce a sensible scale for each square. Graph paper usually has a variety of sizes of square so ensure that you choose a scale which allows you to easily plot your data points. In science it is useful if the axes extend so that the largest positive (and if necessary, negative) point fits easily on the paper, leaving room for **extrapolation** (the extension of a line). Each axis must have a linear scale, i.e. the value for each square is consistent along the axis. The axes themselves (i.e. the lines) should be drawn in pencil, using a ruler but must be labelled in ink. Labels consist of **ticks** (which give values along the axis for example 1, 2, 3 …) and an indication of what the axis represents. In mathematics this is usually *x* and *y*. In science the exact nature of the measurement *and the associated units* are required. The format is usually the symbol used for the variable and its associated unit (in standard form) in brackets afterwards, for example *t* (s) would represent time in seconds.

3.   The Points

Points should be plotted as an 'x' using a sharp pencil with the centre of the 'x' coinciding with the required data point or coordinate. **Outliers** (sometime called **rogue** or **anomalous points**) should never be deleted but can be indicated by circling the point (see the graph on the next page).
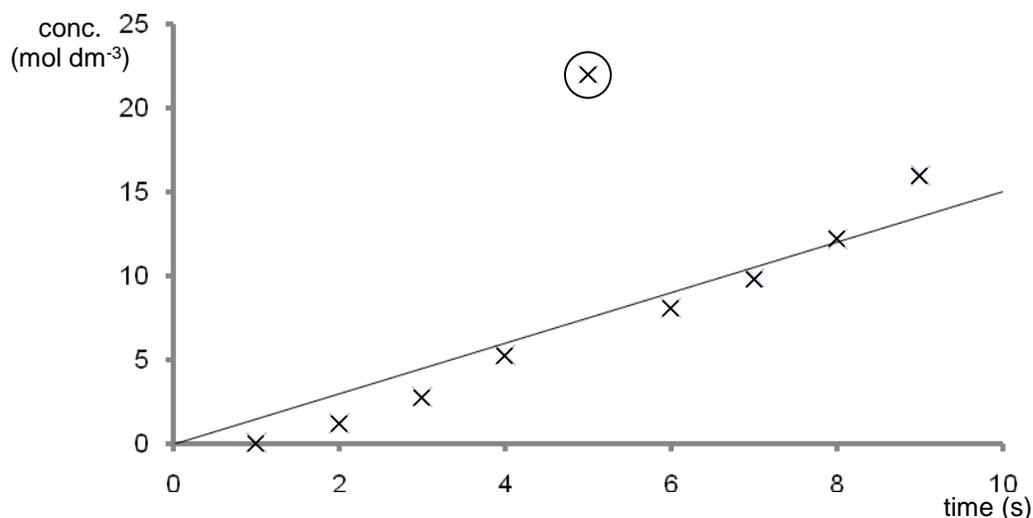
A Graph of Scientific Data. Both axes are labelled with variable and unit. The outlier is circled and plays no part in the calculation of the line of best fit. Note how few (if any) data points fall precisely on the line. Any subsequent readings which you may require are taken from the line NOT the direct data.

4. The Line

If points require a line to be drawn through them, the line will either be straight or a curve. Straight lines should be drawn using a ruler; the exact line can be calculated using a mathematical procedure called **linear regression** (or **least squares**). Curves should be smooth and not made up of several, individual, little 'brush strokes'. When drawing a curve, position your paper so the curve can be drawn comfortably. Fix your elbow and practice the curve a couple of times without touching the paper. When you are happy you have the 'feel' of the curve, draw it smoothly, quickly and confidently. Drawing a curve in this way requires practice. Also remember that graphs are not dot-to-dot puzzles and the points should not be connected in this way unless specifically requested.

5. Titles and Labelling

For graphs of mathematical functions, the line *and* any interesting points must be labelled with the function and the coordinate(s) respectively. Graphs of scientific data should have a title which describes the contents of the graph. The title should be at the top of the graph and written in ink. If you are finding it difficult to give your graph a title you can restate the labels you have used on the axes, for example "A Graph to show how concentration changes with time".

6.   Taking Readings Off a Graph

A graph is a working diagram and you may be required to take readings or calculate a gradient from it. You should always use your completed graph for these purposes. Do not be worried if your workings spoil the aesthetics of your graph. In science, readings should always be taken from your line of best-fit and *not* from the points you have plotted. The same is true for gradient calculations.

Want to know more?

If you have any further questions about this topic you can make an appointment to see a **Learning Enhancement Tutor** in the **Student Support Service**, as well as speaking to your lecturer or adviser.

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