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Appendix B: Graphing

An important step in the analysis of experimental data is recognizing patterns in the data and establishing mathematical relationships between measured physical quantities. Graphing the data is often an essential part of this process. In this appendix, we summarize the graphical analysis process.

B-1: Plotting data on a linear graph:

Height (m)	Force (N)
0.00	1.00
0.10	1.22
0.20	1.38
0.30	1.60
0.40	1.84
0.60	2.18
0.80	2.56
1.00	3.06
1.50	3.98

Linear graphs are the simplest types of plots to prepare for a set of data. Suppose we have made several sets of measurements for two physical quantities, obtaining the data shown in the table to the right. We wish to plot a linear graph of the data. First we must decide which variable is the independent variable and which is the dependent variable. Often, this is strictly a matter of choice as there is no reason to believe that one quantity "depends" on the other anymore than the other way around. If you are asked to make a linear plot, you can often tell which quantity is the dependent variable and which is the independent variable from the wording. If we are asked to plot *force as a function of* **height**, then *force* is the *dependent variable* and **height** is the **independent variable.** Similarly, the suggestion that you plot *force versus* **height** also implies that *force* is the *dependent variable* and **height** is the **independent variable.** The independent variable will always correspond to the horizontal axis of your graph while the dependent variable corresponds to the vertical axis.

Before you actually begin to plot your data, you should examine it carefully. What are the maximum and minimum values of each variable? You should be sure that you scale your graph so that you have room to plot all of your data. Since you should be using graph paper, you will need to take into account the dimensions of the grid in setting up your graph. It is sometimes useful to have the maximum and minimum points on your axes extend slightly beyond the maximum and minimum data values. A good range for the data above might be from 0 m to 1.60 m for the horizontal (height) axis and from 0 N to 5 N for the vertical (force) axis. Once you have decided upon the range and scale of your axis, you should label each axis and divide the axis into several equal increments. Choose round numbers for each increment and label the increments on the graph. Figure 1 (next page) shows a properly divided and labelled graph. Be sure to indicate the units for both variables on your graph.

Now it is time to actually plot the data. The location of each data point is simply the position on the graph which has co-ordinates corresponding to the data values. Note that you have already established the value for each grid line. Unless a data value corresponds to a previously assigned value for a grid line, it will not lie exactly on a grid line. Most points will lie between grid lines on your graph paper. Figure 1 shows the correctly plotted data from the table.

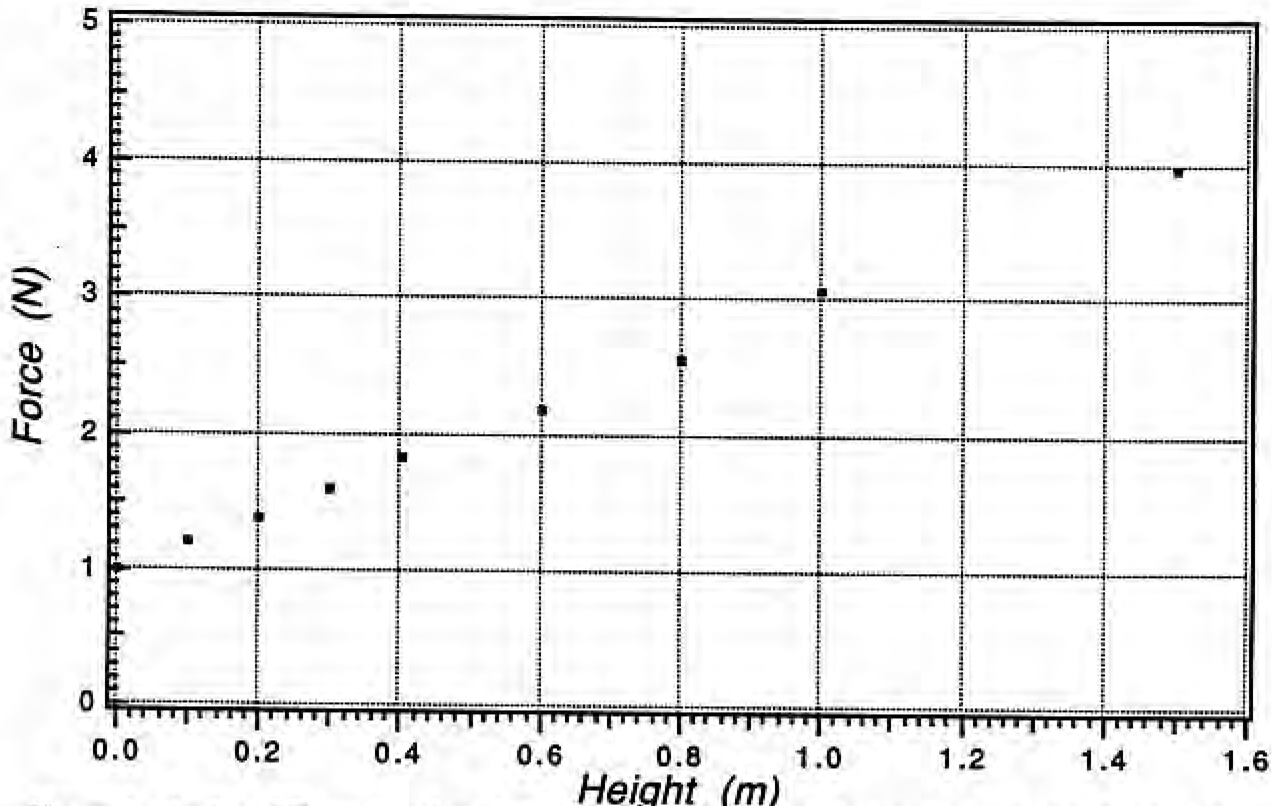

Figure 1: A plot of Force as a function of Height. The graph is scaled so that all of the data points can be plotted on the graph. The axes are labelled so that we know variables are being plotted and their units. Grid lines on the graph have also been labelled with their coordinates.

B-2: Determination of linear relationships between measured quantities:

When we plot experimental data, we find that the data often lie on or near a straight line. If we draw a single straight line which passes through (or near) as many of our data points as possible, we can use this "best fit" straight line to determine the mathematical relationship between the two quantities which we have plotted. Figure 2 (next page) shows such a "best fit" straight line for the data plotted in Figure 1. Note that the line does not pass through all of the points. This is normal for experimental data.

Straight lines on a graph are described by a simple mathematical relationship. If the straight line is a plot of y (dependent variable) as a function of x (independent variable), then the equation which describes the line is

$$y = mx + b \qquad \text{(B-1)}$$

Of course, we will not always be plotting y as a function of x. In Figures 1 and 2, we have plotted force as a function of height. If we let F = force and h = height, then the straight line in Figure 2 is described by an equation similar to Equation B-1.

$$F = mh + b \qquad \text{(B-2)}$$

In writing down Equation B-2, we have used our independent variable, h, in place of x and our dependent variable, F, instead of y. In both Equation B-1 and B-2, the quantities m and b are

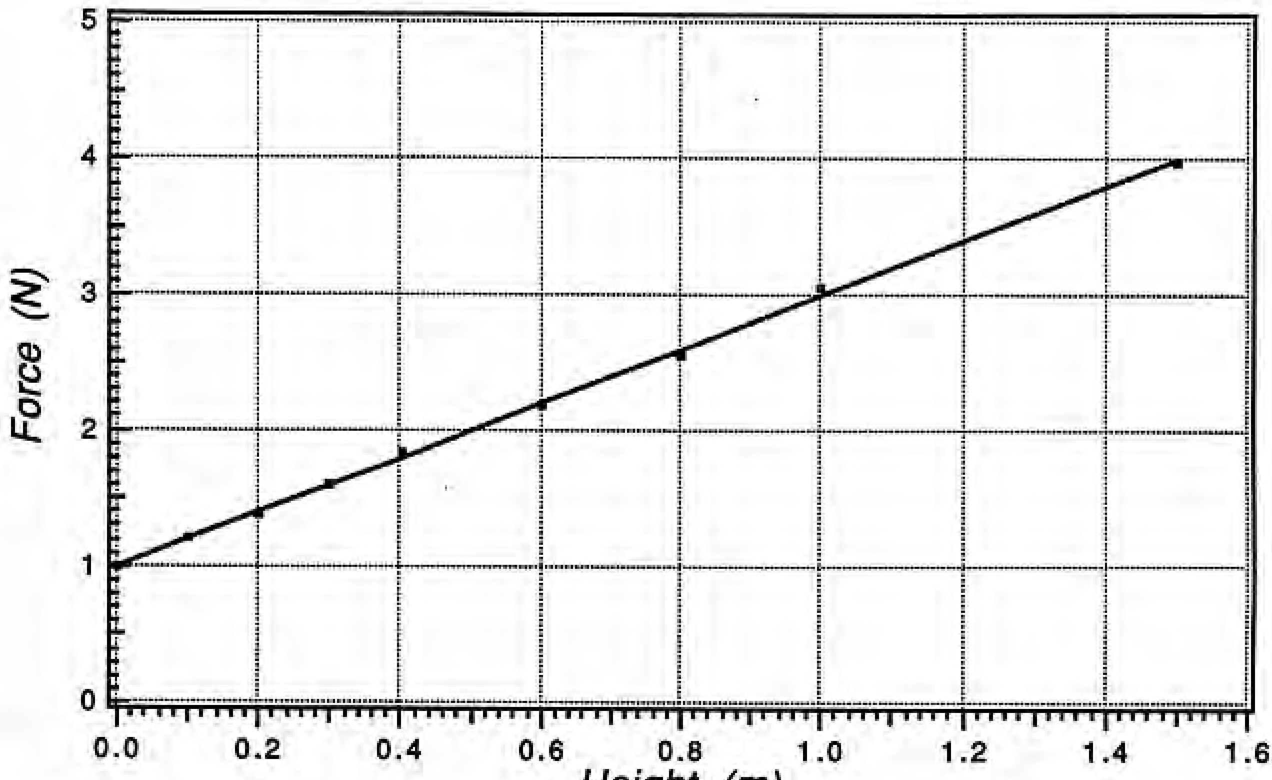

Figure 2: Graph of data showing "best fit" straight line. This line has a slope of 2.0 N/m and a vertical intercept of 1.0 N.

constants which can be determined from coordinates of points which lie along the straight line. We call m the slope of the line and b the vertical intercept. We see from the equations that b is simply the value of the dependent variable when the independent variable is zero. In Figure 2, the vertical intercept is b = 1.0 N. We must use two points along the line to determine the value of the slope, m.

$$m = \frac{\text{difference in dependent coordinate of points}}{\text{difference in independent coordinate of points}} \qquad \text{(B-3)}$$

Choosing two points which lie on the line in Figure 2(not simply two data points since they aren't all on the line), we find

$$m = \frac{\Delta F}{\Delta h} = \frac{3.0\ \text{N} - 1.0\ \text{N}}{1.0\ \text{m} - 0\ \text{m}} = 2.0\ \text{N/m}.$$

Note that both the slope and the vertical intercept must have units which make Equation B-2 dimensionally correct. Once we have found the slope, m, and the vertical intercept, b, we can write the complete mathematical equation which describes our data:

$$F = (2.0\ \text{N/m})h + 1.0\ \text{N}$$

We can use this same method to determine the mathematical relationship for any set of data points which lie on or near a straight line.