2

Computer Activity: Graphing Techniques

Trial and Error

Purpose

Use graphing techniques to discover Kepler's third law of planetary motion.

Required Equipment and Supplies

Data Plotter graphing program
Apple II Series computer

Table 2.1

PLANET	PERIOD (YEARS)	AVERAGE RADIUS (AU)
MERCURY	0.241	0.39
VENUS	0.615	0.72
EARTH	1.00	1.00
MARS	1.88	1.52
JUPITER	11.8	5.20
SATURN	29.5	9.54
URANUS	84.0	19.18
NEPTUNE	165.	30.06
PLUTO	248.	39.44

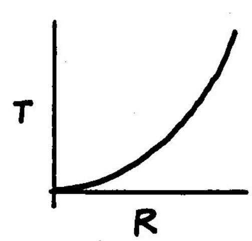


Figure 2.1

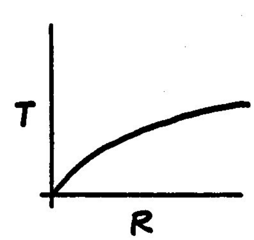


Figure 2.2

Discussion

Pretend you are a budding astronomer. In order to earn your Ph.D. degree, you are doing research on planetary motion. You are looking for a relationship between the time it takes a planet to orbit the sun (its *period*) and the average radial distance of the planet's orbit around the sun. It is customary to express radial distances in AUs, *A*stronomical *U*nits, where 1 AU is the average radius of the earth's orbit. Using a telescope, you have accumulated the planetary data shown in Table 2.1.

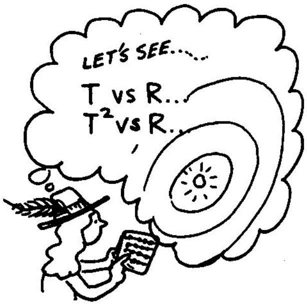
You have access to a computer program that allows you not only to plot data easily, but also to plot many different relationships between the variables that make up your x and y coordinates. For example, in addition to being able to plot period T vs. radius R, you can also plot T^2 vs. R, T vs. R^2, T vs. R^3, and so on. To discover how T and R are related, you must find the combination of powers that results in a graph that is a straight line. A linear graph means the quantity you are plotting on the vertical axis is *directly proportional* to the quantity you are plotting on the horizontal axis. Hence, the relationship between the variables is simply the ratio of the variables raised to the powers whose graph is a straight line. For example, if T vs. R^2 is a straight line, $T \sim R^2$, or $T/R^2 \sim$ constant.

Suppose you are plotting T vs. R. The name of the game is to get a straight line. That's because a straight line tells you that whatever you are plotting on the y-axis is *proportional* to whatever you are plotting on the x-axis. If, however, your graph curves upward as in Figure 2.1, it means T is increasing *faster* than R. That suggests you should try increasing the power of the x-values (R).

Suppose your graph of T vs. R looks like Figure 2.2. That means R is increasing *faster* than T. Straighten out the graph by re-plotting with a higher power of the y-values (T).

Procedure

Step 1. Follow the instructions on the *Data Plotter* program. Input the data from Table 2.1. Select the "Graph Set-Up" option to vary the powers of the x and y values. Sometimes the up or downward curve of a graph is very subtle, and a curved graph can be mistaken for a straight line. The "Least Squares Fit" option is helpful because it plots the best average straight line of your data. This enables you to see much more clearly if your graph is curving up or down.



Step 2. If the relationship between T and R cannot easily be discovered by modifying the power of only one variable at a time, try modifying the power of *both* variables at the same time.

If you find the relationship between T and R during this lab period, feel *good.* It took Johannes Kepler (1561-1630) ten *years* of painstaking effort to discover the relationship. Computers were not around in the sixteenth century!

Going Further

After modifying the powers of both variables, try re-plotting your data (restore your data to the first power) by graphing the logarithm (either base e or base 10 is OK) of the period vs. the logarithm of the average radius. Describe the resulting graph. What is the slope of the graph? How is this related to the functional relationship between the period and the average radius?

Analyzing your data in this manner is a powerful skill. Try performing the same procedure on other sets of data, such as those in Table 2.2 or others supplied by your instructor. What relationships, if any, do you discover?

Table 2.2
Intensity of point source of light as a function of distance.

DISTANCE (cm)	INTENSITY (%)
30	100
35	73
40	56
42.4	50
45	44.4
50	36
55	29
60	25
65	21
70	18
75	16
90	11.1
105	8.2
120	6.25