Kepler's Third Law Spreadsheet

In this activity, you will use a Microsoft Excel spreadsheet to find a mathematical formula determining the rotational periods (years) of the planets in the Solar system.

Go to the class web site at http://www.barransclass.com/astr1070. Click on the "units" link, then on the "solar system" unit link. Right-click on "Kepler's Third Law Spreadsheet" and save it to your student account.

Enter the Data

Find the downloaded spreadsheet in your account and double-click to open it. The cells in the spreadsheet requiring your input are colored yellow. Look up the solar and planetary data called for in the spreadsheet and enter them in your spreadsheet.

To express a number that is written in exponential notation, use a lowercase "e" to indicate the exponent of 10. For example, 3.202×10^{23}, should be entered as "3.202e23". You may want to convert very large numbers to exponential notation. To do this, simply count digits from the right until the number is as short as you want it. You can then write the number with a decimal point placed where you stopped counting, and use the number of digits for the exponent. There can be more than one way to render the same number. For example, to convert "57,900,000" to exponential notation, you can write "5.79e7", "57.9e6", "579e5", "57900e3", or several other combinations. They all mean the same thing to Excel. (I find it easiest to count digits by groups of three, so I would enter the number as "57.9e6".)

The spreadsheet calls for orbital periods in days, but some of them are reported in the book in terms of Earth years, not days! You can easily get around this by making a formula in the cell: multiply the period in years by the number of days in a year, and that will give you the period in years! To make a formula in a cell:

- Begin by typing "=" to denote a formula. Then type the formula. For example, to convert 11.86 years to days, type "=11.86*365.26". Here, the "*" symbol means multiplication, and 365.24 is the number of days in an Earth year.
- You can also make a formula that means the same thing by referencing the cell in the spreadsheet that contains the orbital period of the Earth in days. Type "=11.86*" and then select with your cursor the cell containing the Earth's period. The formula will then read "=11.86*E5", where the Earth period cell is in column E, row 5. This formula means "multiply 11.86 by whatever is in cell E5". When you hit the "enter" key after entering the formula, the cell will display the calculated value. If you change the value in cell E5, the formula using it will automatically update.

Find the Relationship

Try to find a relationship that predicts the periods of the planets. Do this by graphing (see below) the orbital periods of the planets on the *y*-axis (vertical) of a graph and the quantity you think might be linked to the orbital periods on the *x*-axis (horizontal). Try a few things, and see what kinds of relationships you get.

Scientists trying to describe the world think that they are "on to" something if observations can be explained in a simple way. Once Kepler figured out from Tycho Brahe's data exactly what trajectories the planets followed, he struggled to find a simple formula to describe them. He found a very simple formula describing the orbital period of a planet in terms of only one other property of the planet. But what is the property? What is the formula? Kepler took years to find the answer. We don't have so long, but we can get some sense of what Kepler did.

Make graphs

One very powerful way to investigate the relationship between quantities is to make graphs. We will use graphs to see how the orbital periods of the planets vary with the other planetary quantities, and to see if any one of them looks to be the deciding factor.

If there is a simple relation determining the orbital period, we should be able to find a formula that makes a straight-line plot. In other words, if we plot orbital periods on the vertical axis and some function of the other properties on the horizontal axis, we should be able to get a straight line. Provided, that is, that we have the correct relationship.

Excel can make graphs for you! It calls them "charts". The easiest way to make a chart is to:

- Select the cells in the spreadsheet containing the data you want to graph.
- Click on the "insert" tab and select "XY (scatter)". Chose one of the sub-types that displays the points.
- To make it plot what you want, select the "series" tab. First delete all the series already there, then click the "Add" button to make a new series. To select the *x*-values for the graph, click on the pyramid icon button to the right of the "X values" field. This allows you to see the spreadsheet so that you can select the cells containing the *x* values. (*Don't select column headings!*) Once they are selected, click on the icon again to see the chart wizard. Select the *y* value data the same way. Click the "Next >" button.
- In the next screen you can choose to adjust the appearance of the graph. At least select "Titles" to give a title to the *x* and *y* axes. You can adjust other features as well, or you can just "Next >" to the next screen.
- Choose to place the chart "As object in:" the current worksheet. This puts the graph on the same sheet as the data. Click "Finish".
- You can move and re-size your plot with your mouse. If you select the plot and hit "delete", it will be deleted. You can also bring up change windows for many features of the graph by double-clicking the features.

Is your graph a perfectly straight line? If not, try to find other relationships between quantities. You may want to calculate other values from the data! (It took Kepler many years to finally find the proper relation, which is fairly simple but not obvious.)

Once you get a straight line, see if you can fit the data (Add trendline).

What happens if you also plot other orbital data, such as for the moons of a planet? Just copy your tables and formulas to another place on the sheet, and substitute the planet's data for the sun's and its moons' data for the planets'.