

You should be aware of three ways by which a force can be exerted on a distant object without touching the object in any way. Throwing rocks at the object does not qualify because the rocks must touch the object to exert forces on it. Blowing air at the object doesn't count either, for the same reason. The three ways are _____al force, _____ic force, and _____ic force. In this chapter and the next you will study those three forms of magic. You will learn a little bit about how they behave and how they can be manipulated, but don't expect to learn why they work.

A. Gravitation:

1. We have known for centuries that the planets have periodic motions. Describing those motions in the earth's frame of reference is complicated. In 1543 Copernicus pointed out that describing the planetary motion from the *sun's* frame of reference is much simpler. He showed that the planets followed nearly circular orbits around the _____. That notion got him into a lot of trouble, but he was officially forgiven by the Pope in 1667. Galileo was forgiven in 1992 for the same idea.
- * 2. Between 1602 and 1619 Johannes Kepler used the data below to discover a relation between the periods of the planets and their orbit radii. We now call it Kepler's third law. It took him seventeen years, but you can discover the law in a few minutes by using the powerful methods you developed in chapter II. State your conclusion *clearly*. Describe the linear graph that you use to verify your equation, and *show* how its slope is calculated in SI units. Use powers of 10, round off properly and *keep a copy*.

Planet Name	Orbit Radius (in meters $\times 10^{10}$)	Period (in seconds $\times 10^7$)
Mercury	5.8	0.76
Venus	10.8	1.935
Earth	14.9	3.15
Mars	22.8	5.92

3. Between 1665 and 1684 Robert Hooke showed Isaac Newton how to calculate the centripetal acceleration of any planet from its orbit *RADIUS* and orbit *PERIOD*.
 - a. That equation is already recorded in #3a on RS VII. Copy it here: $a = \underline{\hspace{2cm}}$
 - b. Define the symbols in that equation clearly enough so that it cannot be misinterpreted.
 - c. (optional) Show how Hooke's centripetal acceleration (in 3a) equation can be made much simpler by expressing the acceleration in terms of orbit radius and "*angular velocity*", in radians per second.
4. Newton saw that a planet's centripetal acceleration can only be caused by a gravitational _____ exerted on the planet by the _____. (See #4 & 20 on RS III, and 5 & 11 on RS II.)
 - a. What letter have we used since chapter III to represent *gravitational field strength*? _____
 - * b. Review the two methods for measuring gravitational field strength that you described on pages 6, 33, 39, and 42. *Also see #2c & 4 on RS V*. Describe them clearly on the back of this paper.
 - * c. Prove that those two methods give results with identical units.
5. A *graph* could describe how the sun's gravitational field strength depends on distance from the sun.
 - a. Give the title of that graph and sketch its expected shape, as you did on page 60b and on RS III & IV.
 - b. Use Kepler's data (#2, above) with 3c on RS VII to calculate the strength of the sun's gravitational field at several distances from the sun. Avoid excessive roundoffs, and don't forget the units.
 - * c. Use the tricks that you learned in chapters I & II (or use a graphing calculator, as on 112c) to create an equation describing the relationship, as in 3b on page 18. Describe the linear graph that you use to verify your equation, and show how its slope is calculated from the given data, using SI units. You will earn *NO* credit if the units in your conclusion can not balance, and you will *LOSE* all of the credit that you earn here if you do not have copies of this discovery *and* the one in #2 when you need them on page 115. Where are you saving them? _____
- * 6. Copy the moon's orbit radius and period from a textbook. *Give credit to your source*.
 - a. Show how those figures are used with equation 3 to calculate the moon's acceleration in SI units.
 - b. What causes that acceleration? *Be specific*. -These results are recorded on RS _____.

1. First, let's clear out some space in the calculator's data table:
 - a. Turn the calculator **ON**. Hit the **STAT** key, then **ENTER**. A data table appears on the screen. There are six columns, labelled L1, L2, ... L6. (The letter "L" stands for "List".)
 - b. Notice that you can move the cursor around in the data table by using the four arrow keys.
 - c. To erase old data from a column, move the cursor to the column header, such as L1. Then hit **CLEAR**, and **ENTER**. Do that for each of the six columns.
2. Let's put some data into the table:
 - a. To avoid confusion later, it's a good idea to write the full column headings on paper first. For example, you might write something like this:

$$L1 = \text{Orbit Radius in meter} \times 10^{10} \quad \text{and} \quad L2 = \text{Orbit Period in sec} \times 10^7.$$
 (You *could* enter the powers of 10 into each box in the data table, but that would be foolish.)
 - b. Move the cursor to the space just below "L1".
 - c. Type the first orbit radius (5.8) and hit **ENTER**.
 - d. Enter the rest of the orbit radii in similar fashion.
 - e. Put the orbit periods into the second column in similar fashion, so that the data table looks like the one at the right:

	<u>L1</u>	<u>L2</u>
	5.8	0.76
	10.8	1.935
	14.9	3.15
	22.8	5.92
3. Let's see if there is any pattern in this set of data. The TI-82 can make graphs of three sets of data simultaneously, called PLOT 1, PLOT 2, and PLOT 3. For now we just want one graph on the screen, so we'll switch all three off and then switch on PLOT 1 by following these steps:
 - a. Hit the blue **2ND** button, and then the **Y=** button right above it to make the "STATPLOT" menu appear.
 - b. Enter the numeral 4 to switch all plots *off*. Then hit **ENTER**.
If you see a bunch of stuff on the screen then use the **CLEAR** button to make it go away.
 - c. Repeat the steps in 3a to bring back the "statplot" menu. Choice number 1 is already highlighted so you can just hit **ENTER** to get into the Plot 1 menu. Hit **ENTER** again to turn plot 1 on.
 - d. Use the down-arrow key to move the cursor to the next line, where you can choose the type of graph that you want. The first choice just gives you data points, the second gives you data points with a zig-zag line connecting them. Use the arrow key to put the cursor on one of the choices and hit **ENTER**.
 - e. Move the cursor down to the "X-list" line. Since we want a graph of period vs orbit radius, we want the "x-axis" of our graph to be "L1". (See 2a.) Move the cursor to that choice and hit **ENTER**.
 - f. Move the cursor down to the "Y-list" line and select "L2". Hit **ENTER** again.
4. The TI-82 is also sometimes used to display graphs of equations. To see if the calculator now contains any equations waiting to be graphed, hit the "Y=" key. If you see any equations on the screen you can erase them with the **DELETE** key OR you can simply "switch them off" so that they can be brought back later. To switch an equation off or on, use the arrow keys to move the cursor until it is on top of the equal sign and then hit **ENTER**. If the equal sign is highlighted when you move the cursor away then the equation is **ON**, which means it will be graphed on the screen the next time you hit **PLOT**. Right now we do not want to graph any equations, so do *not* leave any equal signs highlighted.
5. Now we are ready to see a graph of the data which we left in the data table.
If you hit the **GRAPH** key, you will probably see the graph with a poor choice of scale.
 - a. To choose scales so that the graph is not squashed and doesn't go beyond the edges of the screen, hit the **ZOOM** key in the top row, select choice **9** for automatic scaling, and then hit **ENTER**.
 - b. Unfortunately, that cuts off the origin. To remedy that, hit **WINDOW**.
Move down to X_{MIN} , hit 0, **ENTER**. Do the same for Y_{MIN} . Then hit **GRAPH**.
6. Can you guess an equation that might fit the data? If so, try entering it into the **Y=** screen. Then hit **GRAPH** to see how well it fits. You will need to adjust the proportionality constant in your equation to make the curve go close to the data points.
7. You can also use the calculator to create such an equation: Hit **PROGRAM**, select A12PLOT, hit **ENTER** four times, then select the type of equation that you want. You can try as many different kinds as you like. When you finish playing with it you must select **QUIT** to escape from the program.