AP Physics Unit 1: Physics Tool Kit

Lab 1-1: An Exploration of Graphical Methods and Analytical Tools

**Purpose:**

Graphs are very useful representations of the relationship between variables of interest. The data collection and analysis software Logger *Pro* is a powerful tool that assists you in your analysis of graphs of experimental data. This exploration affords you the opportunity to practice using Logger *Pro* to analyze relationships with which you are already familiar. It is commonly said that at age 3 a child will be half of his or her adult height. You may also have heard that teenagers grow “like weeds.” Logger *Pro* has a set of tools you can use in your analysis of experimental data. This activity give you practice using these tools in Logger *Pro* to answer these questions.

**Available Materials for Use:**

* Logger Pro
* Graph Paper
* Tape Measure
* Circular Objects

**Procedure:**

Part 1 Circumference *vs*. diameter

1. Start Logger *Pro*. Double-click on the header of the *x*-axis in the data table. This brings up a Manual Column Options box. Enter **diameter** as the name, **d** as the short name and **cm** as the units. Select Done.

2. Double-click on the header of the y-axis in the data table. Enter **circumference** as the name, **C** as the short name and **cm** as the units. Select Done.

3. Manually enter the data you have recorded. Press Return or Enter after typing the value to move the cursor to the next cell in the data table.

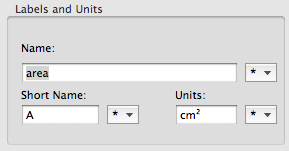
4. Choose Autoscale From 0 from the Analyze menu.

5. Choose Linear Fit from the Analyze menu to have Logger *Pro* draw a line of best fit through your data.

6. Write the equation for your best-fit line. After examining the value and units of the slope, write a general expression for the relationship between circumference and diameter. Compare your findings with those of other groups in class.

Part 2 Area *vs*. radius

1. Choose Add Page from the Page menu. Select New Data Set and Graph and give the page an appropriate name.

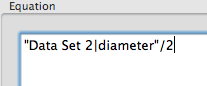


*Figure 1*

2. Note that the data table now shows Data Set 2. As you did in Part 1, re-name the column headers for the *x* and *y* axes. To choose appropriate units for area, you can use the pull down menu to the right of the Units field to choose ‘2’ as the superscript for cm (see Figure 1).

3. As you did in Part 1, manually enter your diameter and area data. Be careful after each entry for the area to make sure you return to the column for diameter for Data Set 2.

4. You can use Logger *Pro* to calculate and display the value of the radius of each of the circles in Part 2. Choose New Calculated Column from the Data menu. In the window that is displayed, name the column and choose in which Data Set it should appear. The window also provides a place where you can specify the equation used to calculate the values. Insert the cursor in the Equation field, then, rather than enter the variable name yourself, select Choose Specific Column from the Variables (Columns) menu. Specify Data Set 2|diameter and enter **/2** to divide the diameter by 2 (see Figure 2). Click Done.



*Figure 2*

5. At this point, you should have a graph of area *vs*. diameter. Click the horizontal axis label, then select **radius** as the variable for this axis. Autoscale the graph as you did in Part 1. You can also use the icon shown at left in the Toolbar to do this task.

6. What relationship appears to exist between area and the radius of your circles? While your first impulse might be to fit a curve to the data, you will first explore “linearizing” the graph[[1]](#footnote-1). As you did in Step 4, create a new calculated column. Enter **radius2** as the title and choose appropriate units. Then position the cursor in the Equation field, select radius from Variables (Columns) and enter **^2** to square the radius.

7. As you did in Step 5, click the horizontal label, select More, then, from the pull down menu, choose radius2 for the horizontal axis of your graph. Examine your graph. If the plot appears to be linear, choose a linear fit for your graph.

8. Write the equation for your best-fit line. After examining the value and units of the slope, write a general expression for the relationship between area and the square of the radius of your circles.

Now that you have analyzed the relationship between area and radius through linearization, you will now try a different approach using the curve-fitting tool in Logger *Pro*.

9. Choose Graph from the Insert menu. A small graph of circumference *vs.* diameter should appear on top of your first graph. Choose Auto Arrange from the Page menu; this re-sizes both graphs and arranges them nicely on the page.

10. Click the vertical axis label and choose More. Uncheck Circumference and check Area from Data Set 2 for this axis. In a like manner, choose Radius for the horizontal axis, then autoscale the graph.

11. Choose Curve Fit from the Analyze menu. The Curve Fit dialog box will be displayed. Under the test plot of your data are a number of general equations from which you could choose to fit your data. Scroll down until you find Power (*Ar^B*), select that equation, then increase the value of the *B* coefficient by clicking the up arrow next to the field until the value 2 appears. Note how the test plot changes with the value of *B*.

12. Now, gradually increase the *A* coefficient until the curve on the test plot best matches your data, then click OK. You have now performed a manual curve fit to your plot of area *vs*. radius. In what ways is the information provided by the two methods the same; how does it differ?

extension

Account for the fact that the constant of proportionality you obtained in your two linear relationships may have differed somewhat from the expected value.

1. Open the Logger *Pro* file, A3 Height v age.cmbl, provided on the CD that accompanies this book. Note how Colin’s height increases as he grows older. To better describe how his growth depends on his age you can use Logger *Pro* to determine the rate of change of height with age.

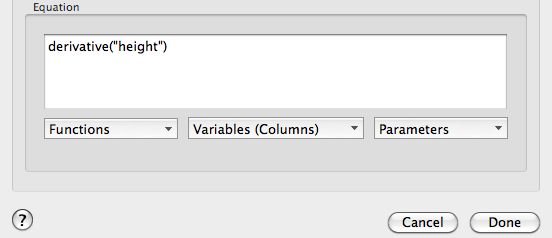
2. Choose New Calculated Column from the Data menu. This brings up a dialogue box in which you can name the column (e.g., growth rate) and units (m/yr) as well as specify the equation used to calculate the values. Insert the cursor in the Equation field, then, choose calculus►derivative from the Function list. Choose height as the Variable, then click Done (see Figure 1). The newly created column should now appear in your data table.

Figure 1

3. By adding a graph you can view how both Colin’s height and his growth rate vary with time. Choose Graph from the Insert menu; a small graph of growth rate *vs.* age appears superimposed on your data table and graph. Choose Auto Arrange from the Page menu; this re-sizes both graphs and arranges them nicely on the page.

4. Select the height *vs.* age graph and activate the Tangent tool. You can do this either by choosing Tangent from the Analyze menu or by clicking the button in the toolbar shown on the right. Move the cursor across the graph to see how the software displays a portion of the tangent line drawn at a given point and gives the value of its slope.

5. Now select the growth rate *vs.* age graph and activate the Examine tool. You can do this either by choosing Examine from the Analyze menu or by clicking the button in the toolbar shown on the right. Move the cursor across the graph to see how the software displays a vertical line on the graph. In the information box the values of both variables for the nearest point are displayed.

6. To link both graphs so that these tools work simultaneously, select both graphs then choose Group Graphs (X-Axes) from the Page menu. As you move your mouse, note that the tangent and examine lines move in tandem. How does the value of the slope of the tangent in the top graph compare to the value of the growth rate in the bottom graph?

7. Deactivate these tools on each graph either by selecting a graph and clicking the tool you chose (it behaves like a toggle switch), or by clicking the little ‘x’ in the upper left corner of the information box.

8. Now select an age interval (e.g., from age 5 to 10) on the top graph by drag-selecting your mouse across a portion of the graph. Note that this action highlights a portion of the graph and the relevant entries in the data table as well. Choose Statistics from the Analyze menu or click the button in the toolbar shown to the right. From the maximum and minimum values determine Colin’s change in height during this interval.

9. Now select this same age interval on the bottom graph. Choose Integral from the Analyze menu or click the button in the toolbar shown on the right. Note how Logger *Pro* shades in the area under the curve for this interval. Examine the units of the variables on the axes of this graph; what would you expect this area to represent? How does the value of the selected area compare to the value you obtained in Step 8?

10. Close the Logger *Pro* file, but do not save changes. Assuming Colin reached his maximum height at age 20, does the generalization made in the introduction apply? Was he growing most rapidly as a teenager? If not, at what age was he growing most rapidly?

1. [↑](#footnote-ref-1)