

# An Exploration of Graphical Methods

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. If you are new to *Logger Pro*, consider exploring the tutorials (especially 5 and 10) found in the Experiments folder in the *Logger Pro* folder before you attempt this exploration activity.

## OBJECTIVES

In this activity, you will

- Practice manual entry of data in *Logger Pro*.
- Perform linear fits to data and analyze the resulting equations.
- Linearize data to find the relationship between the variables.
- Perform a curve fit to data and analyze the resulting equation.

## MATERIALS

computer  
*Logger Pro*  
centimeter-ruled graph paper

variety of circular objects: cans,  
jars, glasses, bowls, plates  
flexible metric tape measure

## PROCEDURE

### Part 1 Circumference vs. diameter

You should have available to you a number of objects that have a circular cross section. Ideally, the largest of these should have a diameter at least ten times as great as the smallest. Using your metric tape, measure and record the diameter and circumference of at least 6 of these objects.

### Part 2 Area vs. radius

1. Place one of these objects as close to the center of the centimeter-ruled graph paper as you can. Trace the circular cross section of the object on the paper. Measure and record the diameter of this circle.
2. Count the number of squares enclosed by this circle. Since your circle cuts through some squares, count only those squares that are completely enclosed or have at least half of the square enclosed. If a portion of the circle consistently encloses less than half a square, estimate how many squares should be added to your total.
3. Repeat Steps 1 and 2 for five other circular objects.

## EVALUATION OF DATA

### 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.
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.

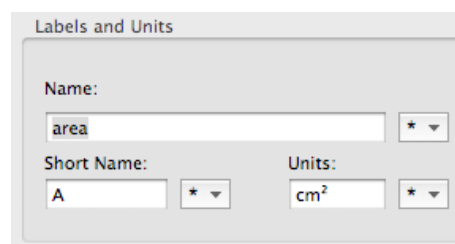


Figure 1

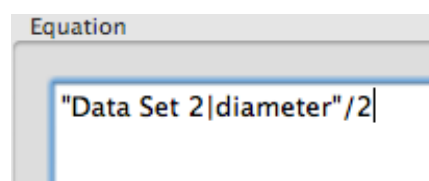


Figure 2



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<sup>1</sup>. As you did in Step 4, create a new calculated column. Enter **radius<sup>2</sup>** 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 radius<sup>2</sup> 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.

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<sup>1</sup> If you have never done this before, now might be a good time to explore Tutorial 10-2 Linearization. Save your current file and open the tutorial. After completing it, return to the file for your activity.