

## EXCEL GRAPHING PRIMER<sup>1</sup>

We are often asked to experimentally establish the mathematical relationship that links two variables by making a series of systematic measurements which will enable us to establish how one variable changes as the other is changed. In mathematical parlance, this is called variation. For example, we might want to determine how an object's mass varies as its volume is changed or how the pressure of a contained gas varies as its volume is changed.

Graphing is the method of choice for this endeavor since it is an effective way to visualize data as well as way to establish the variation between variables.

There are several common types of mathematical variation: direct, inverse, direct as the square of, etc. Our interest is variables that vary directly with respect to each other. When data of this type are graphed, it will exhibit a linear relationship having the general form:

$$(1) \quad y = mx + b$$

where  $y$  is the dependent variable,  $x$  is the independent variable,  $m$  is the slope of the line, and  $b$  is the  $y$ -intercept (the value of  $y$  when  $x = 0$ ). Slope is defined as:  $\frac{\text{change in } y}{\text{change in } x} = \frac{(y_2 - y_1)}{(x_2 - x_1)}$  where

$(x_2, y_2)$  and  $(x_1, y_1)$  are any two points that lie on the line. An inclining line has a positive slope and a declining line has a negative slope.

Equation (1) defines an exact algebraic relationship between  $x$  and  $y$ . It is unlikely that collected experimental data (*i.e.* measured values of  $x$  and  $y$ ) will exactly match this theoretical relationship. That's ok. Remember, measurements have both an associated uncertainty and error. However, if we make careful measurements, we should be able to say with confidence whether a linear relationship does or does not exist.

In all likelihood, you have constructed graphs before either manually with graph paper or with a graphing calculator or in Excel. The purpose of this exercise is to show you how to utilize Excel to build a graph and customize it to create a fully annotated, usable, and visually appealing graph that demands to be printed.

If you are already familiar with these features in Excel there is no need for you to complete this exercise. However, if you are new to Excel or have not used these features in Excel, you are strongly encouraged to complete this exercise.

The following data was obtained by measuring the potential difference (voltage) between two fixed points of a nichrome wire as the current was varied. You will graph this data to show the linear relationship of the data and to illustrate the customization process.

Current, A	Potential, V
0.36	1.55
0.62	2.59
0.99	4.39
1.34	5.80
2.44	10.72

---

<sup>1</sup> Instructions in this primer refer to Excel in Microsoft Office 2013. These instructions are applicable with some modest modifications to Excel in Office 2016 and 365.

You will begin by constructing a basic XY scatter plot that matches Figure 1 and customize it to match Figure 2, p D4. As you go through the exercise you should take note that any Excel graph can be customized. Additionally, there are alternate paths than those described in this exercise that accomplish the same result, and there are more customization options available than those utilized in this exercise. By all means, explore them.

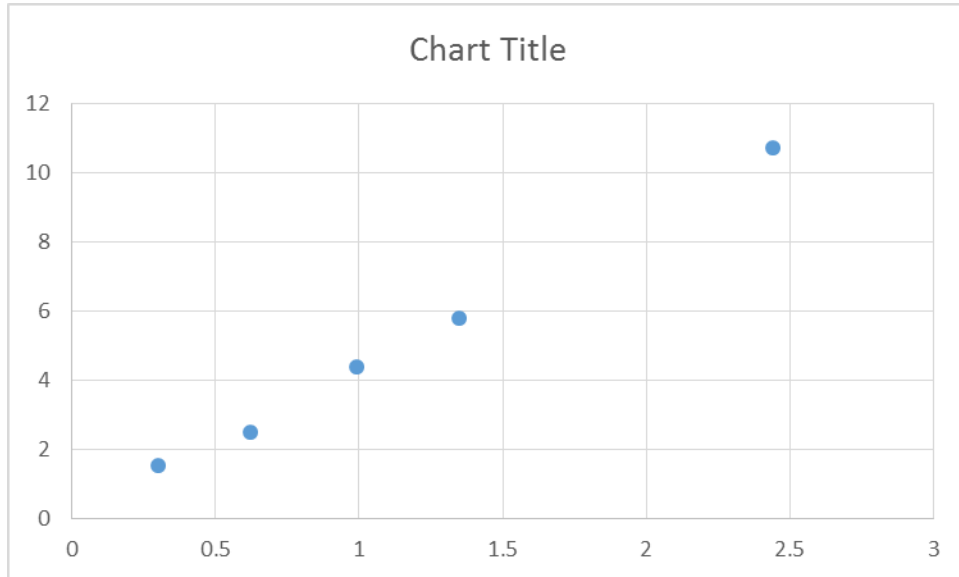


Figure 1

The customization steps that we will apply include:

- Adding a title and labeling the axes;
- Removing gridlines;
- Modifying the axes scale;
- Adding a trendline (regression line), extrapolating it to the y-axis, and displaying the corresponding regression equation on the graph;
- Removing the graph box border;
- Moving the graph to a separate worksheet (chart) and printing it.

### Building the graph

Open Excel. Enter the current and potential data that is listed above in adjacent columns with corresponding data pairs in the same row (e.g., A1 and B1 for the first pair, A2 and B2 for the second...). Place the cursor on the cell containing the first entered current. Press and hold the left mouse button, drag the cursor box so that all data entries in both columns are highlighted (selected), then release the mouse button.

Press the **Insert** tab, then press the 'Scatter' icon on the Charts group on the ribbon, and select the Scatter type (first icon) on the pull-down menu. A graph identical to Figure 1 will be displayed in the active worksheet.

### Customizing the graph

Most graph customization is accomplished by modifying chart elements. The 'Chart Elements' menu can be accessed directly by pressing the plus (top) icon that appears next to the graph when it is active (clicked). This menu contains the most commonly used customization tools

(e.g., axis, axis titles, chart title, trendline...). These can also be accessed via the **Design** tab in CHART TOOLS menu that is displayed on the ribbon (toolbar) when the chart is active (clicked). Excel automatically opens the **Design** tab when the chart type is selected. The 'Add Chart Element' icon is a pull-down menu in the Chart Layouts group on the ribbon.

Likewise, individual elements can be modified via the mouse by placing the cursor over a region of the graph to be customized. A message box (e.g., Plot Area, Chart Area...) will be displayed indicating the active region, and the corresponding menu is accessed directly by double clicking or indirectly by right clicking.

**ADD A TITLE:** Click the chart, place the mouse over the "Chart Title" text box and press. Replace "Chart Title" with "Potential vs Current (Nichrome Wire)".

**ADD AXES LABELS:** Click the chart and press the plus icon. Place the mouse over the Axis Titles entry in the pop-up menu the press the sub-menu icon, ►. Select Primary Horizontal Axis Title. A text box with the phrase "Axis Title" is inserted below the x-axis. Enter "Current, A" in the horizontal axis title box.

Repeat these steps to enter the y-axis title except select Primary Vertical Axis Title. Enter "Potential, V" in the y-axis title box.

**REMOVE GRIDLINES:** Click the chart and press the plus icon. Uncheck the Gridlines entry in the pop-up menu.

**ADD DATA LABELS (X, Y pairs):** Click the chart and press the plus icon. Place the mouse over the Data Labels entry and press the sub-menu icon. Select More Options (bottom entry) which will open the Format Data Labels menu. Check the X-value check-box in the Label Contains submenu and uncheck the Show Leader Lines check-box. Close the menu.

**ADD A TRENDLINE:** Click the chart and press the plus icon. Place the mouse over the Trendline entry and press the sub-menu icon. Select More Options which will open the Trendline Options sub-menu of the Format Trendline menu.

- The default Trend/Regression Type is linear – keep as is. In the Forecast box enter the smallest x-value (0.36) in the backward box. Check the Set Intercept box (= 0) (Note: the y-intercept should only be set to zero if there is ample justification for doing so. Otherwise, do not set it to zero.)
- Check the Display Equation on chart check-box.
- Open the Fill & Line sub-menu by pressing the right most icon at the top of the Format Trendline menu. On the Line submenu change Color to black, Width to 0.25 pt, and Dash type to solid. Close the Format Trendline menu.

**MODIFY THE AXES SCALE:** Click the chart and press the plus icon. Place the mouse over the Axis entry and press the sub-menu icon. Select More Options which will open the Axis Options sub-menu of the Format Axis menu. It defaults to the x-axis.

- On the Axis Options submenu enter 0, 3, 0.5 and 0.1 respectively in the Minimum, Maximum, Major Unit, and Minor Unit boxes.
- Open the Tick Marks sub-menu and choose Outside for the Minor type.
- Open Number submenu choose Number for Category entry.

To customize the y-axis, place the cursor over the y-axis. Click when the Vertical (Value) Axis message box appears. The axis options entries should now refer to the y-axis.

- Enter 0, 12, 1, 0.1 respectively in the Minimum, Maximum, Major Unit, and Minor Unit boxes.
- Open the Tick Marks sub-menu and choose Outside for the Minor type.
- Open the Number submenu and choose Number for the Category entry.

Place the cursor over the displayed regression equation. Click and hold the left mouse button and reposition the equation to the center of the graph.

**REMOVE THE BORDER:** Click the chart, place the mouse near the top border; right click when the message box Chart Area appears. Select Format Chart Area from the pop-up menu and select the No Line radio button in the Border sub-menu. Close the Format Chart Area menu.

**MOVE THE GRAPH TO A SEPARATE WORKSHEET:** Select the **Design** tab in the Chart Tools menu. Select Move Chart and select the New Sheet radio button.

This view gives you an opportunity to admire your work and to decide whether to print the graph in a landscape or portrait orientation. To switch orientations, select the **Page Layout** tab then select Orientation pull-down menu on the ribbon and choose Portrait.

If you print the graph in the portrait orientation it should be essentially identical to the Figure 2. Congratulations, you now have the expertise to customize any Excel graph!

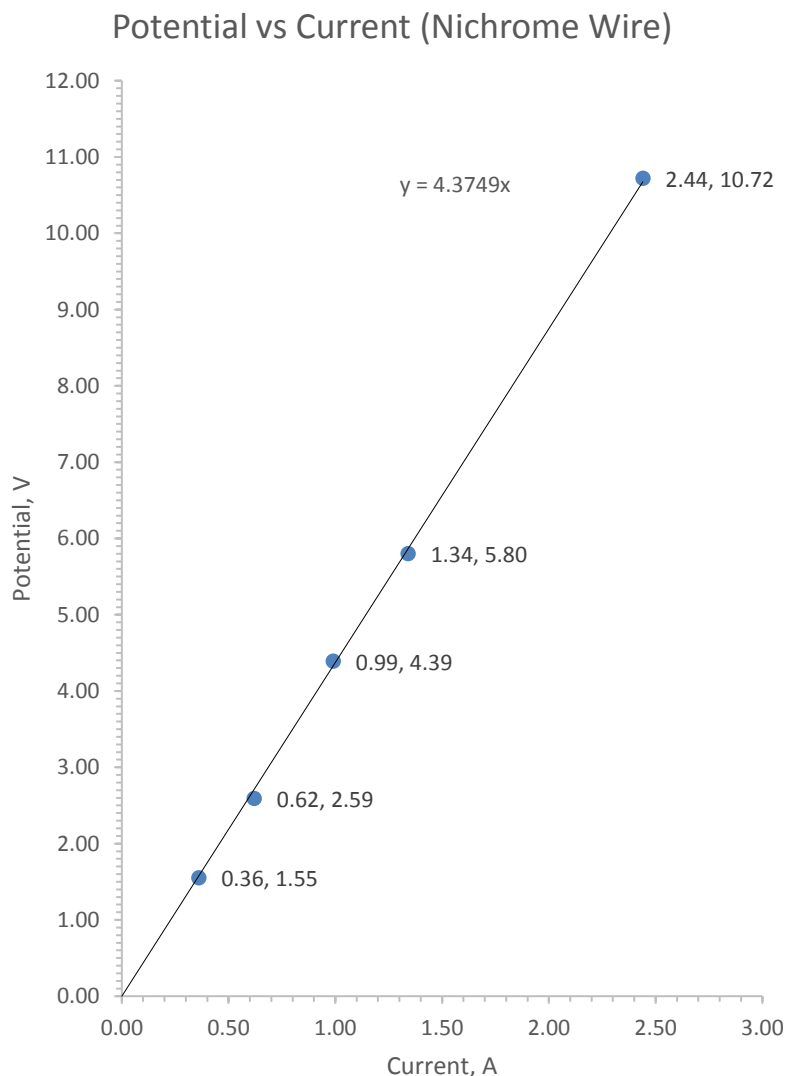


Figure 2

Now that you've completed this exercise, you should be able to create, customize, and print any Excel graph and do so in less time than it takes to construct a similar graph manually. Indeed, there are many advantages to graphing in Excel compared to manual graphing. These include the ability to:

- scale each axis to match the precision of the data being graphed;
- resize the graph when it is a worksheet object;
- calculate a regression line and equation using a linear least squares algorithm (which can be used to calculate a y-value from a specified x-value or vice versa);
- modify the graph essentially *ad infinitum* in just a matter of minutes;
- graph more than one data set on the same graph;
- replace data in the graph without having to rebuild the graph. Like standard spreadsheet functions, cells containing data used to construct the graph are linked to it. If the data in these cells is changed, the graph – including the axes, trendline, and regression equation – will automatically update. (Note: the axes will only change if autoscaling of the range – minimum and maximum values – is enabled.)

Just for fun, try to figure out how to do the following:

- Change the orientation of the numbers on the axis scale from horizontal to vertical;
- Change the slope in the regression equation from expanded notation to scientific (exponential) notation;
- Change the font and font size of the title and underline the title;
- Graph a second data series on this same graph use the following data (x,y): (1,2), (2,3), (3,4), (4,5).

Lastly, the data utilized in this exercise is an illustration of Ohm's law for a metal conductor which may be more familiar to you in its algebraic form:

$$(2) \quad \text{current} = \text{potential/resistance} \rightarrow i = V/R$$

or in the form of a line:

$$(3) \quad V = R \times i$$

From equation (3), it is apparent that resistance is equivalent to the slope of the best line.