Graphing and Curve Analysis Using Microsoft Excel©

Fall 2024

The following instructions guide you through the process of using Microsoft Excel to perform simple calculations, creating an x-y scatter plot (called a "chart" in Excel) from a set of data, and having Excel calculate and draw a line that best fits your data (called a "trendline" in Excel). The last page of this document details the analysis procedure you will use on your finished graph. Many of the experiments performed this semester use these graphing and analysis techniques, so it is important that you understand them.

IMPORTANT:

- The instructions to enter data into a spreadsheet and create a graph follow below.
- When working on the "Graphing and Curve Analysis…" exercise (*Lab 1b*), you will use a spreadsheet containing measured data of position and time for an object moving at a constant velocity.
    - Download the *Excel Graphing Exercise 2024* from the Canvas assignment *Lab 1b*. Save this spreadsheet to your OneDrive to make it easy to find. Open the spreadsheet in Excel.
    - After opening this sample data, **read step #1 below and then skip to step #2**. Note that you will start with step #1 when entering your own experimental data.
- Be sure to have a copy of these instructions available each week until you have mastered the procedure.

Entering Data and Performing Calculations

1. Excel is pretty picky about the arrangement of data to be plotted, so when you set up columns for your data in the spreadsheet, *make sure that the values you will plot along the horizontal (x) axis appear to the left of the values to be plotted along the vertical (y) axis*. **Include a title for each column, including the units; this will ensure that you are plotting your data correctly!** Boldface and center the column titles so that they stand out and be sure to save your spreadsheet since it will be submitted to your instructor.

2. If you are working on *Lab 1b*, you see data that measured the amount of time (t) that it takes a cart to travel to position 2 (x_2) on a track. The cart always starts at position $x_1 = 10.0$ *cm*, and the distance the cart travels, $L = x_2 - x_1$ (a sketch appears at the bottom of the spreadsheet). First, let's enter the correct value for position x_1 in the table.

    - *Pro tip*: Instead of typing '10' in column x_1 twenty-one times, simply type **10** in cell B2. Since there is already an existing column of numbers (the t values), you can double-click on the handle in the lower right corner of the cell, and that will copy this value down the correct number of times (**Figure 1**).

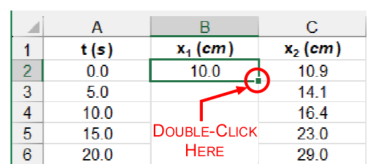

Figure 1 – Copy cell contents

3. Next, we need to calculate L, the distance the cart travels. Note that Excel uses letters (A, B, C, …) to designate columns, and numbers to designate rows. Since $L = x_2 - x_1$, we need to create an equation to subtract the values in column B from those in column C. Enter the following equation in cell D2; *note that an equation always starts with an equal sign*:

    = C2 – B2

    - *Pro tip*: When creating your equation, click each cell that will be used in the calculation instead of typing the cell address. So, for the equation above you would type '=', click cell **C2**, type '–', and then click cell **B2**.

4. Copy the equation down the rest of the column. You can use the tip shown in **Figure 1**, or simply grab the handle in the lower right corner of cell D2 and drag it down as far as needed.

Creating a Graph

5. Now that our data table is complete, we can select the data to be plotted. Since we are using Excel for our calculations, the data we will plot may not be in adjacent columns. We wish to create a distance vs. time graph from our data, so distance will be plotted along the vertical axis and time along the horizontal axis, so we need to select these two columns.

    - First, select the time column by clicking on the column label, **A**.
    - Next, we need to select the distance column while keeping the time column selected, but we don't want to select either x column. You need to hold down a modifier key while clicking, and that differs depending on whether you're using a Windows or Macintosh computer:
        - *Windows*: hold the *Control* (**Ctrl**) key down, and click on the column label, **D**.
        - *Macintosh*: hold the *Command* (⌘) key down, and click on the column label, **D**.

6. With the two columns selected, click the **Insert** tab. In the **Charts** group, click the **Scatter (X, Y)** button, then choose "Scatter" (**Figure 2**, highlighted). A graph will appear in your worksheet.

7. The graph is inserted as a new object on the worksheet, which allows you to see the data and the graph at the same time. This is useful when creating the graph as you collect your data; you can check that the data points fall along the shape of the expected function. Later you will move the graph so that it is easier to read and analyze.

    Please, ***do not*** *remove the grid lines from your graph!*

8. You will next add axis labels as follows: Select the graph, which should switch you to the **Chart Design** tab. Click the **Add Chart Element** button, then **Axis Titles** and then **Primary Horizontal**. Repeat these steps, this time choosing **Primary Vertical**. Double-click each "Axis Title" and include an appropriate label; *you* ***must*** *include units on the axis labels!*

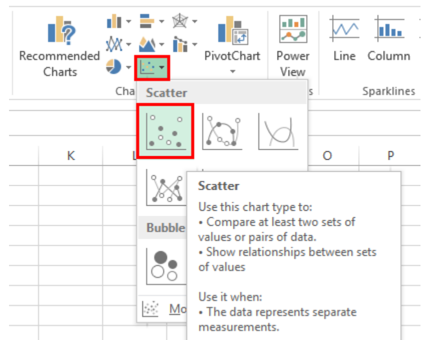

Figure 2 – Creating a scatter plot

9. Double-click the title region and enter a title for your graph. "L vs. t for a moving cart" is sufficient. <u>You do not need to include units in the title</u>.

Adding More Data to the Graph

10. When performing an experiment, you may decide that you need to add some extra data points after examining your graph. Let's add one more data point to your data table: enter **105** to the *t* column, and **102.3** to the x_2 column. Complete the entries for the x_1 and *D* columns.

11. Click the graph, and you will see the plotted data highlighted in the table. Click and drag downward on one of the handles that appear at the bottom of either selected column until the new data is selected (**Figure 3**). Let go of the handle and the new data point will appear on the graph.

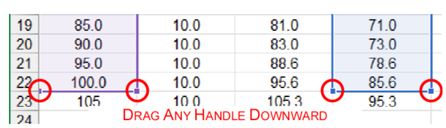

Figure 3 – Adding data to a graph

12. Corrections or additions to the data can now be made if needed. Simply change a number or delete a bad data point and the graph will update automatically.

Adding the Curve-Fit Function

13. Now that you have created your graph, you need to add a curve-fit line, called a *trendline* in Excel. Select any data point with a **right-click** (Windows) or **control-click** (Macintosh) and choose "Add Trendline..."; a linear fit is applied to your data (*even though this may not be the correct function for your data!*) The

"Format Trendline" panel appears to the right of your graph containing six curve-fit functions, also known as *regressions*.

Excel will determine which of the six can be used for your data *(but it doesn't pick the correct function for you!)* We might use four of these regressions in lab: "Exponential" ($y = ae^{bx}$); "Linear" ($y = mx + b$); "Polynomial" (of 2^{nd} order: $y = ax^2 + bx + c$); or "Power" ($y = ax^b$).

14. Select the function that best fits your data. Note that when performing an actual experiment, you will generally know the function that you expect to fit your data. *You will be guessing at the best fit when doing the "Graphing and Curve Analysis…" exercise*. If you pick the wrong regression and have closed the "Format Trendline" window, right-click or control-click on the *trendline* (not a data point) and choose **Format Trendline** again.

  - *Important note*: If you pick a function which cannot be applied to the selected data set, Excel will remove the trendline, and the dialog box will switch from "Format Trendline" to "Format Chart Area". Close this window and add the trendline again.

15. Next, you will **ALWAYS** put a check in the box next to **Display Equation on Chart**. This will display the appropriate equation for the line chosen. Excel calculates the values of the appropriate coefficients *a, b, c,* and *m*. You should note that more significant figures might be presented than are dictated by the accuracy of your measurements. It is from these coefficient values that you will be performing your analysis.

  - *Note #1*: The default font size for the equation box is 9-point, a very small size that your aging lab instructor will find difficult to read. Increase the font size by selecting the equation box, clicking the **Home** tab and changing the font size to **14**. Move the equation so that it does not obscure the line or any data points. *Thank you*.
  - *Note #2*: You do not need to check *Display R-squared value on chart*. The value of R^2 will always be very close to 1 in our experiments, so it does not provide us with any useful information.

Viewing and Printing the Graph

16. A full-sized graph is easier to analyze (bad measurements or interesting trends are more readily noticed), and the graph will look better if it needs to be printed. Move the graph to a new worksheet as follows: select the graph, which should switch the toolbar to **Chart Design**. Next click the **Move Chart** button, then click the button next to **New Sheet**, and then **OK**. The full-size graph now appears on a new worksheet (called *Chart1*) in front of the sheet that contained your data.
17. The worksheet containing the graph should appear *after* the sheet with your data, so click & drag the *Chart1* tab to the right, after the data sheet.
18. Occasionally, you may be asked to print your graph, so you will want your name and those of your partners to print on the graph to distinguish it from the others in the printer since everyone in the lab will collect similar data for a particular experiment. An elegant way of adding your names, the date and the experiment title to your graph is to put them in the *header* of the page. Again, the way you get to these options is slightly different on Windows and Macintosh:

  - *Windows*: Click the **File** tab, and then **Print**. Click **Page Setup...** (below the "Settings", center-left on the window), and then the **Header/Footer** tab.
  - *Macintosh*: Click the **File** menu, and then **Page Setup**, and then the **Header/Footer** tab.

19. Next click the **Custom Header...** button and type your names in the "Left Section" box. Put the experiment title in the "Center Section" box.
20. Insert the current date in the "Right Section" box by clicking the "Date" button (**Figure 4**). This will add ***&[Date]*** to the right section of the header and will print the current date on the graph.

Figure 4 – Date Button

21. Click **OK** twice to return to the print window. If the graph is to your liking, check that you are printing to the correct printer, set the number of copies and click the **Print** button.

Analyzing the Graph

Now you will analyze your graph to determine the results of your experiment. These results will come from the values calculated in your curve-fit function. How will you determine which results give you the quantities that you are seeking?

The first step of our analysis with graphed data will always be to look at the curve-fit function and see how it compares to the expected theory for the experiment. Today you should have chosen the Linear fit for this data (if you have previously read these instructions, you should know that already!) The form of a linear function is $y = (slope)\, x + y\text{-}intercept = m\,x + b$.

Next, you should look at your graph to determine what x and y represent. Today you plotted time, t on the horizontal (x) axis and distance, L on the vertical (y) axis. Now we can substitute t for x, and L for y so that our equation becomes:

$$y = m\,x + b$$
$$L = m\,t + b$$

We see that we have two unknown constants: the slope, m and the y-intercept, b. Next, we need to look at the relationship between distance and time. The definition of velocity gives us $v = L/t$; we can algebraically rearrange the velocity definition so that it follows the pattern of a linear function, as shown below:

$$L = v\,t$$
$$y = m\,x + b$$

This shows us that the slope of the line equals the velocity. What do you think is the y-intercept (the value of y when $x = 0$) and its units in this case?

22. What velocity do you get from your linear graph of distance vs. time? Write the value (*and the appropriate units!*) on your printed graph.

<u>This is how we will analyze graphed data in all future experiments</u>, whether the data is linear or non-linear (as you will see next week.) Note that in today's example, the expected intercept, b, is zero, but the graph shows that it has a small value. In future experiments, this may be an indication of an error, or the result of some initial conditions of your measurements, or perhaps something interesting that occurred while performing your experiment.