GRAPHS

IDEAS TO REMEMBER!

•Visual presentation of data makes it easier to understand large amounts of data, trends, and relationships.

SUMMARY:

The purpose of this activity is to learn and develop some of the necessary techniques to graphically analyze data and extract relevant relationships between independent and dependent phenomena, and to communicate those relationships to others.

MATERIALS:

Access to spreadsheet program. Examples of spreadsheet programs:

- (Microsoft Excel is installed on laboratory desktops). This lab manual includes an Excel tutorial on how to use Excel to create professional-looking graphs, but you can also use other spreadsheet programs such as:
- Google Sheets
- LibreOffice
- iWork Numbers - Apple Office Suite

GRAPHING TECHNIQUES:

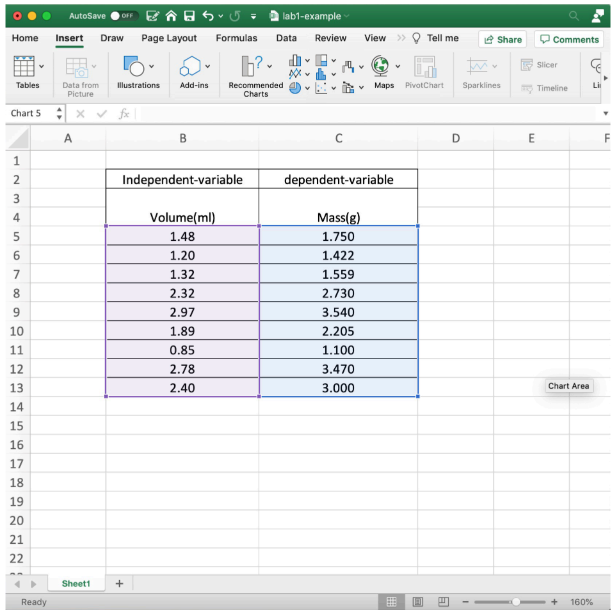
A graph frequently provides a clear illustration of the relationships between the physical quantities and how one physical quantity depends on the others. When making your graph, follow the instructions/steps listed below. The following issue will serve as an example of the steps.

Problem Statement: A student decided to determine the density of an unknown liquid by a series (9 data sets) of mass-volume measurements as shown in Table (1) . Graph her data by Excel using the graphing criteria listed below. The x-axis of your graph should represent the volume and the y-axis should represent the mass. Next, use the graphical information to find the average density of the unknown liquid.

- **Enter Data into Excel** –The data set must be tabulated and clearly labeled. You must first identify the dependent and independent variables. The independent variables are always placed on the x-axis, while the dependent variables are always placed on the Y axis. The volume is the independent variable in the preceding example, and the mass is the dependent variable. Figure (2) described how the

Volume (ml)	Mass(g)
1.48±0.2	1.750±0.3
1.20±0.2	1.422±0.3
1.32±0.2	1.559±0.3
2.32±0.2	2.730±0.3
2.97±0.2	3.540±0.3
1.89±0.2	2.205±0.3
0.85±0.2	1.100±0.3
2.78±0.2	3.470±0.3
2.40±0.2	3.000±0.3

Table 1: Mass(g) - Volume(ml) measurements



Independent-variable	dependent-variable
Volume(ml)	Mass(g)
1.48	1.750
1.20	1.422
1.32	1.559
2.32	2.730
2.97	3.540
1.89	2.205
0.85	1.100
2.78	3.470
2.40	3.000

Table 2

data from Table (1) must be represented accurately in Excel.

Note that Excel does not show the significant ”0”in numbers such as 1.750, however, you will learn to format these cells to include these zeros by setting the number of decimal places for a selected range of cells. Excel always calculates values using their exact value and does not work with significant figures. You should show have Excel display the correct significant figure of each number or range of numbers. After entering all of the data, do the following, which is illustrated in the example below, but you will need to do the same for each graph in this lab:

- Select all ”Mass” cells holding values and perform the following range of commands: **(Menu bar) Format−−Cells −−Number −−Decimal Places”3”**
- Next, set the format for the ”Volume” values to 2 decimal places and mass values to 3 decimal places. Try doing these changes under the Home-Number tab and also try doing it by selecting the range of numbers and right-click and pick ”Format Cells”. See Figure (1)

- **Graph the data** – To graph the data using Excel:
  - First: click on **(Menu bar) insert** - **scatter plot as shown in Figure (2)** . Make sure always pick scatter-type graph and not the scatter with lines type graph.
  - Now right-click somewhere inside the graph and ”Select Data”. This screen allows you to add ”series” of data set on top of the same graph . Go ahead and delete (Remove) the ”series1” data set and ”Add” your data set as shown on Figure (3) then click on okay.

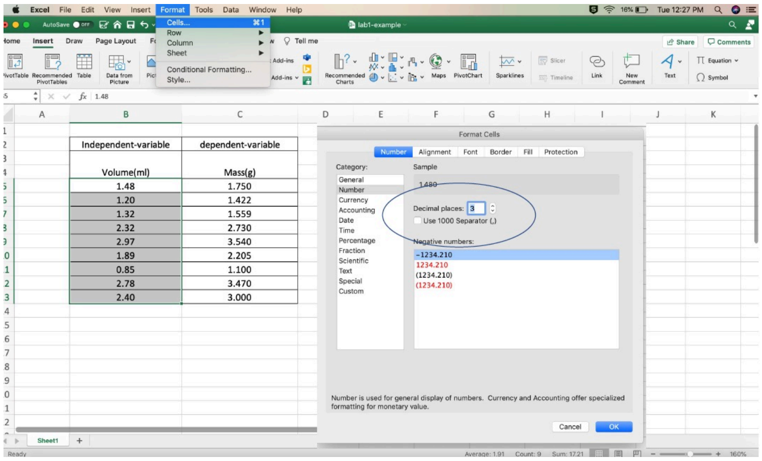


Figure 1

- Now you should be able to see the data points as shown on Figure (4).

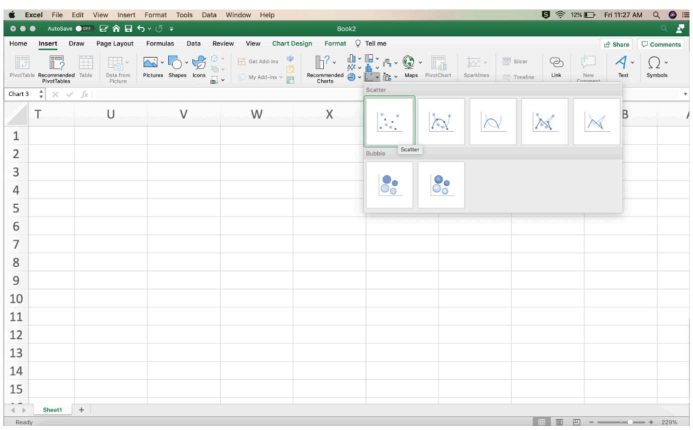


Figure 2

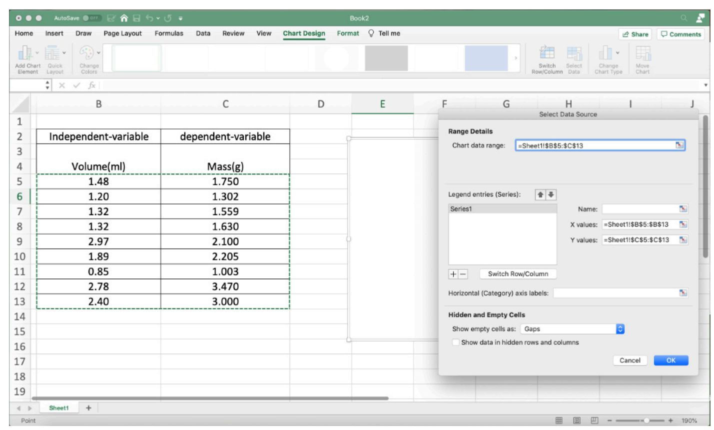


Figure 3

- **Labels** – Put a descriptive title at the top of the graph. Label the axes with the variable names or symbols. Put numbers at enough divisions to make the scale clear. Clearly indicate the units for each axis.
  Using Excel: Find the "Chart Tool" tab on the menu bar and click on the "Design" tab. You can a number of design features including axes titles as demonstrated in Figure (4). Figure (5) represent how the axes must be labeled for the variables and how the figure titled. **Please keep in mind that you must repeat these steps for all of the figures you will be asked to graph for this lab.**

- **Uncertainties** – If you know or can estimate the uncertainties in your data, use error bars to indicate a range of values rather than a precise point. Uncertainties are shown in Table (1) by using ±values.

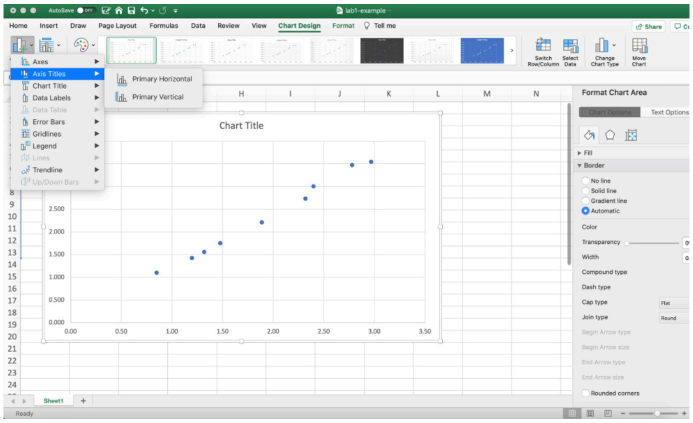


Figure 4

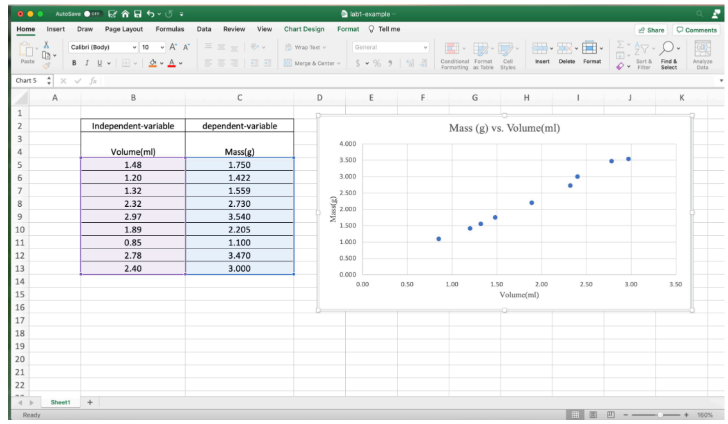


Figure 5

The uncertainties of the experimental values can be represent using the error bars which can be done as following:

- using ”Chart Tool” tab on the menu bar and click on the ”Design” tab. You can a number of design features including axes titles, error bars as demonstrated in Figure (4).
- In the Format Error Bars pane, on the Error Bar Options tab, under Error Amount, click fixed value.
- specify the amount of uncertainties for the horizontal error bars and the vertical error bars. See Figure (6)

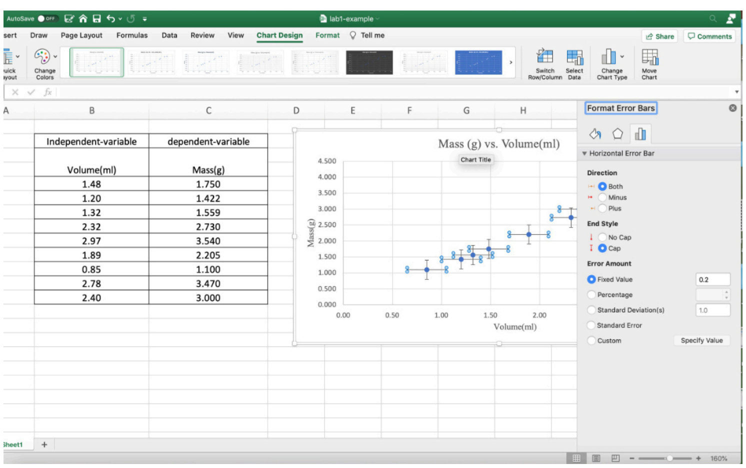


Figure 6

- **Trendline** – The next step is to find a smooth line or curve that fits the plotted data points. There are two main types of relationships that can be distinguished by the type of trendline:

- Some data points can be fitted with a straight line to express the **linear relationships**.
- **non-linear** relationships are data points that can be fitted using a curve.

By adding trendlines to the figure, Position the cursor over the data sets on the graph and right-click to select "Add Trendline," as shown in Figure (7). Choose "Linear" from the menu. (see Figure (8))

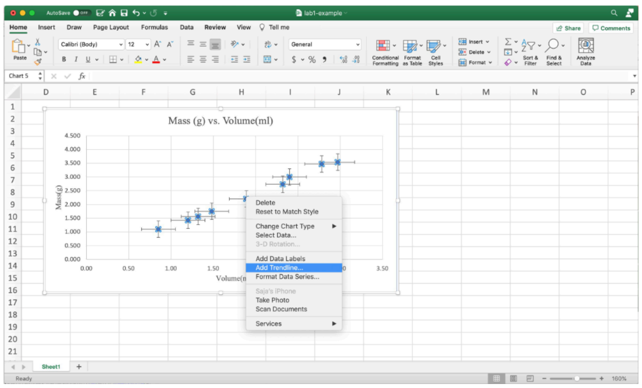


Figure 7

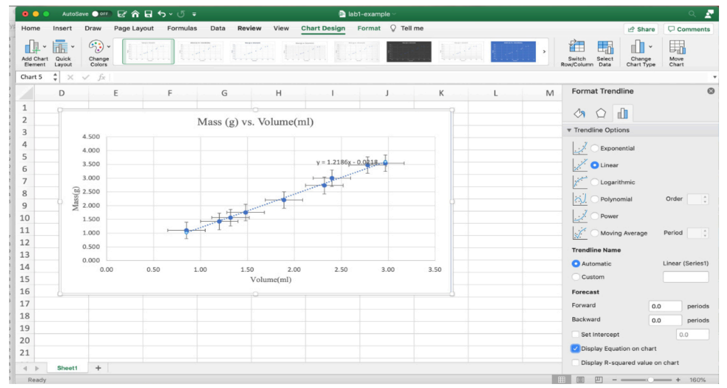


Figure 8

Will you be able to create your graph using the previous steps? If the answer is yes then congratulations on making your first professional looking chart! The next part is extract relevant relationships from the graphs.

- **Finding relationships** –Though some of the relationships in nature are extremely complicated, it happens frequently that one variable merely depends on the power of another. Once your graph has been created, you must be able to interpret a relationship from the experimental data by putting the dependent and independent variables' relationships into a mathematical expression. **For this lab, we are just using the following mathematical relationship:**

$$Y = m x^k + b \tag{1}$$

  - If a graph is linear and the y-axis changes linearly with k = 1, a straight line can be used to fit the relationship, providing the following straight line equation:

$$Y = m x + b \tag{2}$$

    For both of these equation, m is the slope and b is the y-intercept.

  - In the case of the non-linear (curve) graph, the graph of y versus x will be curved, while the graph of y vs x^kwill be straight. and Equation (1) must be used to express the relationship.[1]

Physicists often generically refer to the vertical axis as the "y" axis and the horizontal as the "x" axis, but these axes are usually given specific names, as with the graphs in the figures here. In some cases, one of the axes will be called ?x" but will not be the horizontal axis, as in some of the examples the problems below. In physics we use symbols to mean more than one thing; for example "x" can refer to either the generic horizontal axis or to the vertical axis of a graph of position versus time (a common graph in physics). Do not naturally assume that "x" values go on the horizontal axis

- **Slope** – usually the slope of a graph is the quantity of interest, The question now how we can fined the slope from the graph:
  - If you are dealing with linear graph so you need to do the following:
    1. Pick two points along the just drawn straight line. We'll refer to these two points as (x1, y1) and (x2, y2). When selecting the two points, keep the following things in mind: To reduce error, first choose these two spots so that they are as far apart as is logically conceivable. Second: as close to gridlines as possible to make it easy to determine their values (for convenience).
    2. Then, create a right triangle by drawing horizontal and vertical lines. See Figure (9).

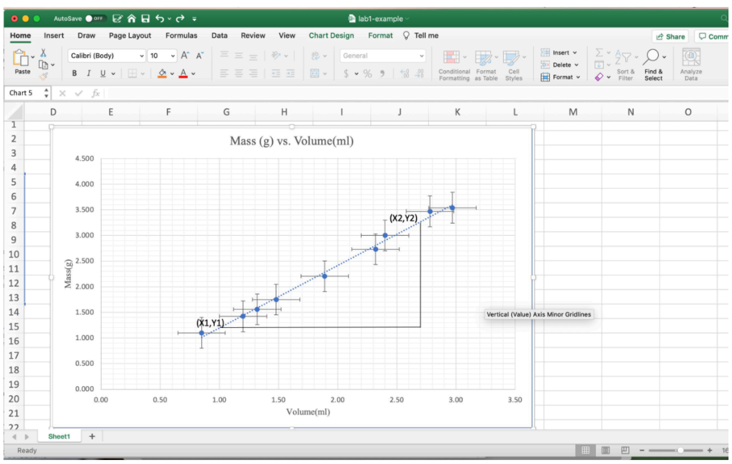


Figure 9

    3. the equation is used to get the slope.

$$m = (y2 - y1)/(x2 - x1) = \quad y/ \quad x \tag{3}$$

    4. You can use excel as an alternative way to find the slope. This can be done if by double -click on the linear trendline. see Figure (8). Check-mark "Display the Equation on Chart" (displays it in the form: Y = mX + b) then you will be able to find the slope.
    5. Sometimes it is more convenient to know the value of the slope without plotting the data and/or for situations when one has to use this value in a subsequent calculation. in this case you can type the following equation using excel[=slope(y-range, x-range)] which Calculates and reports the slope of a linear Trendline for a data set without actually plotting it.
  - When trying to determine a relationship from experimental data, if y vs x does not give a straight line (to within experimental uncertainty) then **the slope will change and will not be constant**, it happens that you need to find the slope at one point. To do so, you should draw a straight line tangent to the graph at the point of interest. then you find the slope of the tangent using the same steps of finding the slope of a straight line.

- To write the mathematical expression for the non linear- relations and using equation(1), the slope must be constant. Then before you found the slope, you need to plot the y vs x^kgraph which gives linear relationship. With experience and some thought you ?!!know which has the best chance of giving a straight line. There are three main non-linear relationships that can be seen in this lab:
  1. if y change with x^klinearly with K =2. then it's called quadratic relationship. where y vs x graph will look like Figure (10)
  2. if y change with x^klinearly. with K=1/2 or 0.5, then it's called square-root relationship. where y vs x graph will look like Figure (11)
  3. If y decreases as x increases, you may need to consider y vs x -1 (= 1/x), then it's called inverse relationship. where y vs x graph will look like Figure (12)

Figure 10

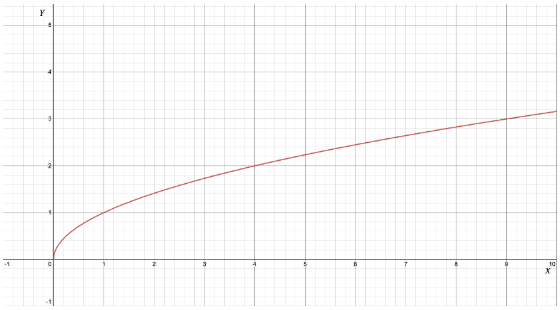


Figure 11

Figure 12

After you plot the linear relationships, the slope, y-intercept can be found and the final equation can be written.

GRAPHS WORKSHEET

You will have one graph in Part 1 and two graphs each from Parts 2 - 4.

1. **Part1: linear graph** The data in Table 1 were chosen to correspond closely to a straight line. Represent uncertainties in the y values by error bars. For example, at x = 3, y is between 8 and 10. Plot y vs. x then using this plot answer the following questions:

Table 3: Table for use with part1

x (m)	y
-1	-6.5±2.0
2	+5±2.0
3	+9±2.0
4	+16±2.0
7	+26±2.0
8	+29±2.0

   (a) Draw the best straight line on your graph
   (b) What is the graphical relationship between y and x ?
   (c) compute its slope and intercept from the graph using the mathematical equation (3). (show your calculations below)
   (d) Write your equation for y as a function of x (based on your graph).

Part 2: non-linear graphs:

2. The data in Table(4) gives position in meters versus time in seconds for a moving particle. The uncertainties are negligible. Plot x vs t, then using this plot answer the following questions:

Table 4: Table for use with part2.2

t(sec)	x(meters)	
0.3	0.2	
1.5	4.5	
2.1	8.8	
3.5	24.5	
4.2	35.3	
5.4	58.3	

   (a) Is the slope changing?
   (b) If the answer is yes, then compute the slope at t = 1 sec. What are the units for this slope?
   (c) What is the graphical relationship between x and t ?

(d) determine an appropriate value for the exponent k based on the graphical relationship between x and t, then use the blank column in the data table to compute t^k.

(e) plot x vs. t^k. Is it a linear relationship?

(f) using the previous plot compute it's slope and intercept from the graph using the mathematical equation (3). (show your calculations below)

(g) Write your equation for x as a function of t (based on your graph).

3. The data in Table(5) contains realistic data for the average speed of air molecules as a function of absolute temperature – i.e. the number of degrees above absolute zero. Room temperature is about 300 kelvins. Plot V vs. T then answer the following questions:

Table 5: Table for use with part2.3

T(kelvins)	v(m/s)	
40	180	
90	290	
150	360	
210	420	
290	510	
340	530	

(a) From your V vs. T graph, what do you think is the speed of the average air molecule in this room?

(b) determine the functional dependence of molecular speed on temperature in other word What is the graphical relationship ?

(c) determine an appropriate value for the exponent k based on the graphical relationship between V and T. Then Use the blank column in the data table to compute T^k.

(d) plot V vs. T^k. Is it a linear relationship?

(e) using the previous plot compute its slope and intercept from the graph using the mathematical equation (3). (show your calculations below)

(f) Write your equation for V as a function of T (based on your graph).

4. The data in Table(6) contains data that indicates what happens when ultraviolet or visible light "knocks" electrons from the surface of a material. $KE_{max}$is the maximum energy with which the electrons "fly" off, and $\lambda$is the wavelength of the incident radiation. Do not be concerned that the units of energy, electron volts (eV), may be unfamiliar. The units of wavelength are nanometers (nm); 1 nm = 1 x 10^{-9}meters. Plot KE_{max}vs. λthen answer the following questions:

(a) What is the graphical relationship between KE_{max} vs λ?

Table 6: Table for use with part2.4

λ(nm)	KE_{max}(eV)	
200	3.9	
280	2.1	
340	1.4	
390	0.9	
440	0.50	
480	0.30	
520	0.10	

(b) determine an appropriate value for the exponent k based on the graphical relationship between KE_{max} and λ, then use the blank column in the data table to compute λ^k.

(c) plot KE_{max} vs. λ Is it a linear relationship?

(d) using the previous plot compute its slope and intercept from the graph using the mathematical equation (3). (show your calculations below)

(e) write your equation for KE_{max} as a function of λ (based on your graph).