CH 222 Winter 2026:
"Graphing" ***Lab*** *Instructions*

Step One:

Get a printed copy of this lab! You will need a printed (hard copy) version of pages I-3-2 through I-3-9 to complete this lab. If you do not turn in a printed copy of the lab, there will be a 2-point deduction.

Step Two:

Watch the **video introduction** for this lab **here: http://mhchem.org/y/3.htm**
The video introduction will help prepare you for the lab and assist you in completing the work before turning it in to the instructor.
There are no PreLab questions for this lab.

Step Three:

Section L1 will complete this lab as a take home lab due to Martin Luther King Jr. day. Section H1 and Section H1 will bring the printed copy of the lab with you on **January, February 21 (section L2)** *or* **Friday, January 23 (section L3).** During lab in room AC 2507, you will use these sheets (with the valuable instructions!) to gather data, all of which will be recorded in the printed pages below.

Step Four:

Complete the lab work and calculations on your own, then **turn it in** (pages I-3-5 through I-3-9 *only* <u>with computer generated full page graphs</u> to avoid a point penalty) **at the beginning of recitation to the instructor on Monday, January 26 (section L1), Wednesday, January 28 (section L2)** *or* **Friday, January 30 (section L3).** The graded lab will be returned to you the following week during recitation.

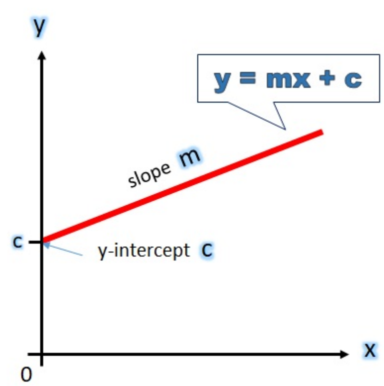
If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

Graphing

This lab will demonstrate the power and potential of a linear regression analysis while graphing linear data.

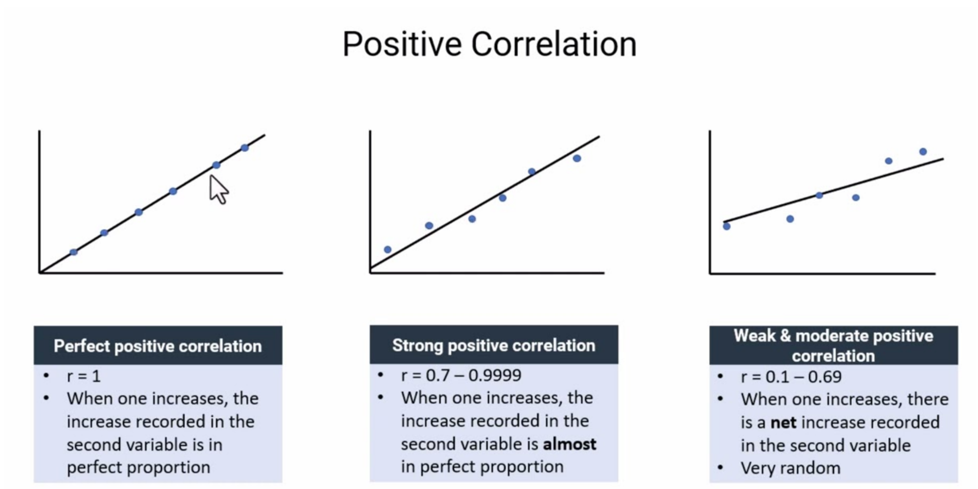
An **equation** is a mathematical model used to describe the relationship between variables. We will focus on **linear** equations in this lab which use a horizontal (X) axis (the **independent** variable, the variable we input when we make a measurement) and a vertical (Y) axis (the **dependent** variable, the number we measure after we set the X value.)

If the plotted data points form a straight line, this means we have a **linear equation.** Linear equations obey a simple mathematical relationship: $\mathbf{y = mx + c}$ where **y** is the vertical axis value, **x** is the horizontal axis value, **m** is the slope of the line, and **c** is the y-intercept (see image below.).



Computer programs and calculators can perform a **linear regression** analysis by plotting the "best fit" line through the linear data and then writing the slope-intercept equation.

The **correlation coefficient** (with the symbol "**r**") is a measure of how well the regression line fits with the observed data. A ***perfect*** fit produces a correlation coefficient of either +1.000 (positive slope) or -1.000 (negative slope), depending on if the line slopes up (a positive slope) or down (a negative slope.) The closer the correlation coefficient is to +/-1.000, the better the regression line expresses the data (the better fit for the data.)



Many graphing programs (Excel, etc.) provide R^2 and not r. To convert R^2 to r, take the square root of R^2 and add a negative sign if the slope is negative (which is observable through the sign of the slope (m) value or observable on a graph.)

$$\mathbf{r = \sqrt{R^2}} \textit{ (if slope positive), or } \mathbf{r = -\sqrt{R^2}} \textit{ (if slope negative)}$$

Procedural Notes for the Graphing Lab: *Complete the problems using the worksheets*

Each linear regression problem will require one or more **computer generated graphs** that will be **stapled** to the back of the worksheets. Recommended programs to graph your data include **Microsoft Excel** (**free** for MHCC students; see https://www.mhcc.edu/OfficeInstall/), **Apple Numbers** (free with a Mac computer, https://www.apple.com/numbers/), or **Google Sheets** (https://www.google.com/sheets). ***Note*** that Excel Online (the online version of Excel) and iPad/iPhone/Droid versions of these programs will generally not perform linear regressions, so try to use the "full" computer version instead. Calculators will perform linear regressions, but printing from a calculator might be difficult.

Information on making an acceptable graph in this class can be found here: https://mhchem.org/lab

When creating your graph, select **X-Y scatter plot** when graphing all of these data sets. **The computer program will analyze the data and perform the linear regression analysis** for you. Each program is different, but generally the user selects the actual data points on the X-Y Scatter plot and either right-clicks or control-clicks on the data to see a new menu…. you wish to "Add a Trendline" and "Display the R^2 value". If an equation appears with an R^2 value, you have performed your linear regression.

Each graph should take up an entire page of paper (8.5 x 11 inches) for full credit (do not include smaller graphs.)

Help on performing the graphing and linear regression lab can be acquired in the Learning Success Center / AVID Center at MHCC. You can also search YouTube for videos (i.e. search "linear regression Excel 2019" and almost inevitably a helpful video appears.)

Converting R^2 to r is not difficult. Take the square root of R^2 to get r. If the value of the slope is a negative number, then the value of r will also be negative…. watch for this in this lab! Calculators will often give both R^2 and r values when linear regression techniques are applied.

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Graphing Lab

Staple *clearly labeled computer generated graphs to the* ***back*** *of this lab report.*

YOUR NAME: ______________________
first and last name

<u>Problem 1</u>: The Relationship Between Celsius and Fahrenheit

In 1724, the German scientist Gabriel Fahrenheit developed a temperature scale based on phenomenon he thought could be easily repeated in laboratories around the world. For his zero degree point, Fahrenheit chose the coldest mixture of ice, water, and salt that he could produce in his laboratory. For ninety-six degrees, he chose what he believed to be normal body temperature. Fahrenheit wanted a temperature scale that could be divided into twelfths. On this scale, pure water freezes at 32 degrees, and pure water boils at sea level at 212 degrees.

A few years later, in 1742, the Swedish scientist Anders Celsius developed a different temperature scale. This scale used pure water as its standard. Zero degrees was the temperature where pure water froze, and one hundred degrees was the temperature where pure water boiled at sea level. Because Celsius had one hundred degrees between the two reference points on his temperature scale, it was called the *centigrade* scale. Recently this was renamed the Celsius scale in honor of Anders Celsius.

A student measures the following data points in the laboratory using two thermometers:

Temperature (°C)	20.0	40.0	60.0	80.0	100.0	*independent*
Temperature (°F)	67.6	104.8	141.1	175.0	211.1	*dependent*

1. Construct and print a graph of degrees Fahrenheit (y) as a function of temperature in degrees Celsius (x).
2. Perform a linear regression to determine the mathematical equation of °F as a function of °C as well as the correlation coefficient, r. Record r to at least four significant figures.
3. Using the actual equation: °F = 1.8°C + 32 *and* your experimental equation, convert 29.0 °C to °F. Calculate **percent error** = (difference / actual value) x 100% *Show your work below.*

Linear Regression equation: **y =** ______________________________________

r = ____________ *Percent Error:* ________________________

Why is the percent error not zero? Explain briefly.

<u>Problem 2</u>: Solubility of Lead(II) Nitrate in Water

The solubility of lead(II) nitrate in water was measured as a function of temperature. The solubility is given in units of grams of lead(II) nitrate per 100 grams of water.

Temperature (°C)	20.0	40.0	60.0	80.0	100.0	*independent*
Solubility (g / 100 g water)	56.9	74.5	93.4	114.1	131.1	*dependent*

1. Graph and print the data; temperature will be the independent (x) variable.
2. Determine the equation of the best-fit line. Record the equation and correlation coefficient, r.
3. What is the solubility of lead(II) nitrate at 47.0 °C? *Show your work below.*

Linear Regression equation: **y =** ____

r = ______________ *Solubility of lead(II) nitrate at 47.0 °C:* ________________
Show calculation below.

Problem 3: Colorimetry

The colors in the visible spectrum of light are shown by a rainbow. Colored substances absorb segments of the visible spectrum of light. Pink solutions, for example, are pink because they absorb green light and transmit all other colors of the visible spectrum. If light of the particular color absorbed is passed through a sample, the amount of light absorbed will be related to the number of absorbing molecules in the light beam. Dilute solutions absorb little light, concentrated solutions absorb more. Typically the amount of light transmitted through the solution is measured; *transmittance* is inversely proportional to *absorbance*. The following data was obtained for the transmittance of 525 nm light by solutions containing different concentrations of permanganate ion.

Concentration (mg/100 mL)	1.00	2.00	3.00	4.00	*independent*
Transmittance *(unitless)*	0.418	0.149	0.058	0.0260	*dependent*

1. **Convert the Transmittance values to Absorbance** using the following equation: **A = log (1/T)**, where A = Absorbance and T = Transmittance. **Use 3 sig figs for your absorbance values**.
2. Graph and print the Absorbance (y) versus Concentration (x) data. Perform a linear regression analysis. Record the equation and the correlation coefficient.
3. Predict the absorbance of 2.50 mg permanganate ion / 100 mL solution (and show your work.)

Convert the four transmittance values into absorbance below. *Show your work on the right side.*

Transmittance	Absorbance *(3 sig figs)*
0.418	________
0.149	________
0.058	________
0.0260	________

Linear Regression equation: **y =** ______________________________ **r =** __________

Absorbance of 2.50 mg permanganate in 100 mL solution: ______________________

Problem 4: **Kinetics**

The branch of chemistry that studies the rate or speed of reactions is called *kinetics*. One must often plot concentration versus time data in a variety of mathematical formats to find a linear relationship; this assists in finding the *order of reaction*. We shall explore this topic more in CH 222. The following data was collected at 25.6 °C while measuring the disappearance of NH_3:

Concentration [NH_3] (mol/L)	$8.00 * 10^{-7}$	$6.75 * 10^{-7}$	$5.84 * 10^{-7}$	$5.15 * 10^{-7}$	*dependent*
Time (h)	0	25.0	50.0	75.0	*independent*

1. **Convert** the [NH_3] concentration data (above) into **ln [NH_3]** and **1 / [NH_3]** data.
    i. "ln" stands for natural logarithm which can be calculated easily on your calculator (for example, the value of $8.00 * 10^{-7}$ is -14.039.) Record ln [NH_3] to 0.001 sig figs.
    ii. 1/ [NH_3] values are the inverse of the number; i.e. 1 / $8.00 * 10^{-7}$ is $1.25 * 10^{6}$. ***Note:*** You may have to enter the data as "1.25E6" to make the computer program understand your values. Record 1/ [NH_3] to 3 sig figs.
2. **Prepare a graph of ln [NH_3] versus time** (time is the x-axis) and perform a linear regression analysis on the data.
3. **Prepare a graph of 1 / [NH_3] versus time** (time is the x-axis) and perform a linear regression analysis on the data.
4. **Which graph gives a *better* linear regression?** Why? *Hint:* look for the better correlation coefficient.
5. **What order of reaction** does the decomposition of NH_3 follow?
    i. Graphs of ln [NH_3] versus time that are linear are called *first order reactions*
    ii. Graphs of 1 / [NH_3] versus time that are linear are called *second order reactions*.
    iii. *Hint:* the better linear regression (and correlation coefficient) will determine the order of the reaction!

Convert the four concentration (M) values into ln [NH_3] and 1/ [NH_3] below.

Concentration [NH_3] (mol/L)	**ln [NH_3]** *(to 0.001)*	**1/ [NH_3]** *(3 sig figs)*
0.418	________	________
0.149	________	________
0.058	________	________
0.0260	________	________

Show a sample calculation below for converting 6.75 x 10^{-7} M into ln [NH_3] and 1 / [NH_3] below.

Plot **ln [NH_3] versus time** and **1 / [NH_3] versus time** on separate graphs. Staple computer generated graphs to the back of the lab. Complete a linear regression on both sets of data and determine the correlation coefficient.

Linear Regression (ln [NH_3] vs. time) equation: **y =** ______________________________ **r =** __________

Linear Regression (1/[NH_3] vs. time) equation: **y =** ______________________________ **r =** __________

Which data set gives a better linear regression? Why?

Does this data behave as a first order reaction or a second order reaction? Explain briefly.

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