PHYS228 Lab Report

1 – Data Analysis with Origin

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Introduction

While Origin is a software not used by any company or any industry or, frankly, anywhere outside of physics lab in favor of software like *excel*, *mathematica*, or *python*, being able to plot data and perform analysis like polynomial regression is important to physics and most disciplines of science and life. In this lab data was input manually and graphed, imported from files and graphed, mathematical functions were graphed, and math problems were solved numerically inside Origin. Perhaps even multiple functions or sets of data were graphed at once. All in all, Origin is just a way for us to practice representing and analyzing data in the sciences, even if the software is riddled with a very annoying bug where sometimes it won't open dialogues, niche, and older than anyone in the lab including the TA.

Procedure

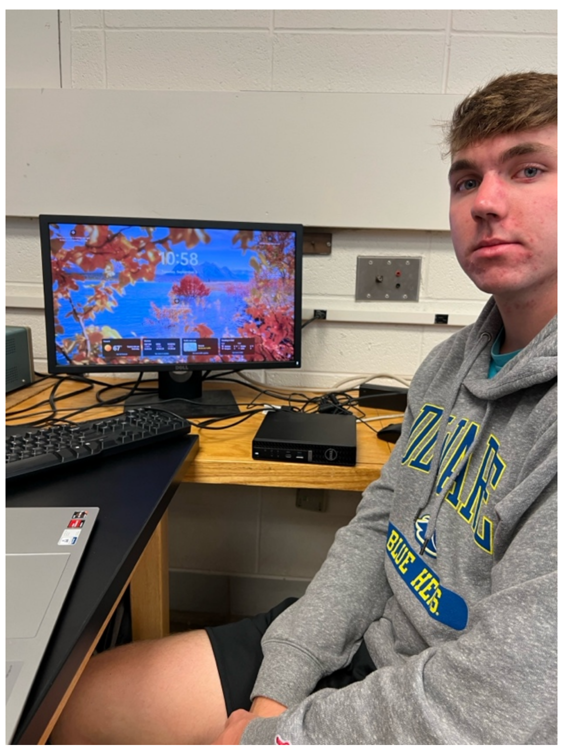


Figure 1: 'experimental' setup. (lab computer + ian looking like a thug)

The procedure followed was the manual "PHYS228 – Lab 1 – Data Analysis with Origin – Fall 2024". The following specifications/exceptions were noted:

- *Data analysis was performed on the laboratory computers.*

Data and Analysis

Part B – Creating a Graph

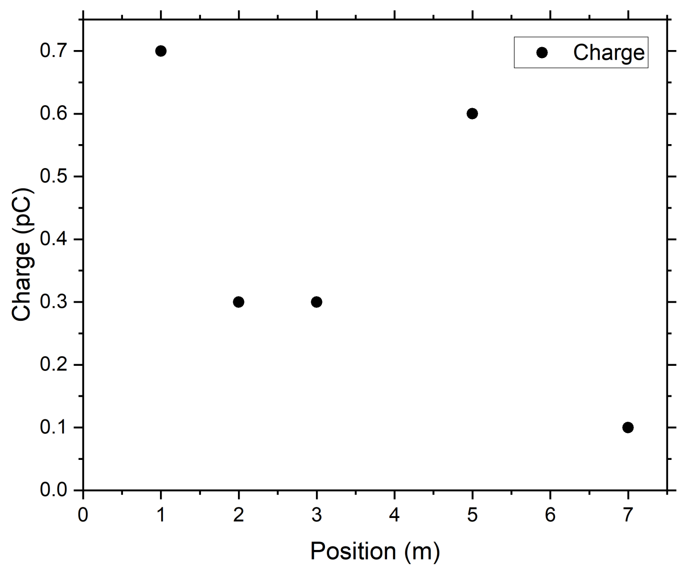


Figure 2: charge (pC) vs. position (m) scatter plot generated from given data

Parts C and D – Importing Data and Fitting Data

First Data Set

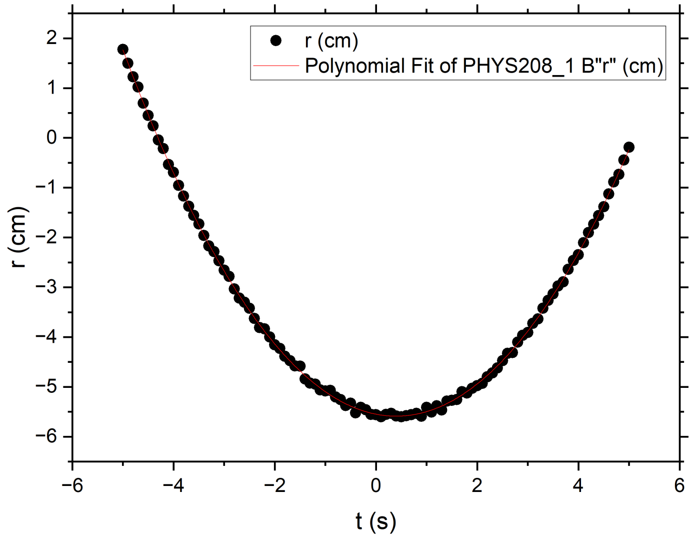


Figure 3: Scatter plot (r (cm) vs. t (s)) and 2nd order polynomial fit for the first set of data

Polynomial Fit Equation:

$$y = -5.549 – 0.201x + 0.2526x^2$$

Fit information for First Data Set

Fit Parameter	Value	Standard Error
Intercept	-5.549	0.00598
B1	-0.201	0.00137
B2	0.2526	5.25e-4

What are the meanings of the values listed for intercept, B1, and B2?

The intercept is the term in the polynomial fit which is multiplied by x^0 (1), the B1 is the coefficient multiplied by x^1, and B2 Is the coefficient multiplied by x^2.

What are the meanings of the Standard Errors?

The standard errors are a measure of variability and uncertainty in the value of the parameter. The higher the standard error the lower the certainty, and adding or subtracting two standard errors would result in the upper and lower bounds for a 95% confidence interval.

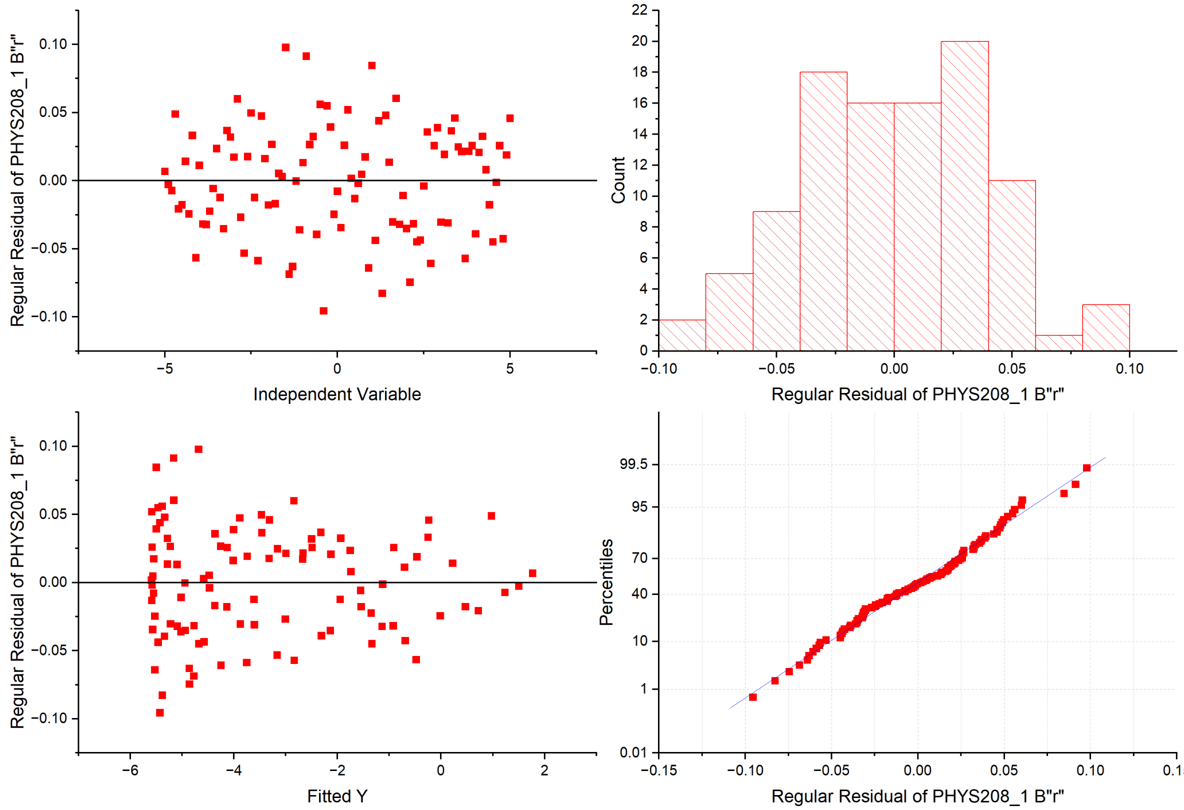


Figure 4: residual plot for 2nd order polynomial fit on the first data set

<u>In this case, do the residuals seem to form a pattern or are they distributed randomly?</u>

The residuals look to be distributed randomly/normally. The histogram looks very much like a gaussian (normal) distribution, and the top left graph of residuals as a function of the independent variable looks like random noise with no clean pattern.

Second Data Set

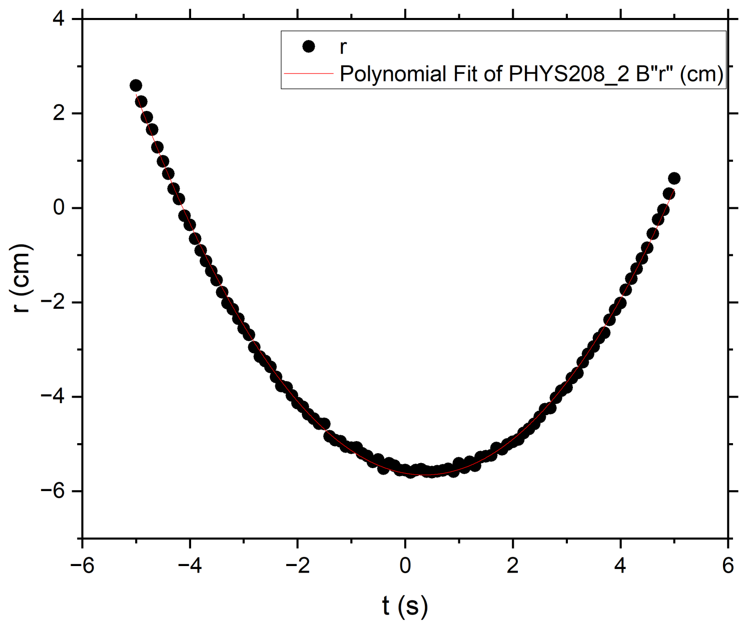


Figure 5: r (cm) vs. t (s) for second set of data with fitted 2nd degree polynomial

Fitted Polynomial Equation:

$$y = -5.621 - 0.201x + 0.281x^2$$

Fit information for Second Data Set

Fit Parameter	Value	Standard Error
Intercept	-5.62	0.012
B1	-0.201	0.0027
B2	0.281	0.0010

What is the highest order term that you need to include for the residuals to become uniformly distributed

Looking at higher order fits and their associated residual plots

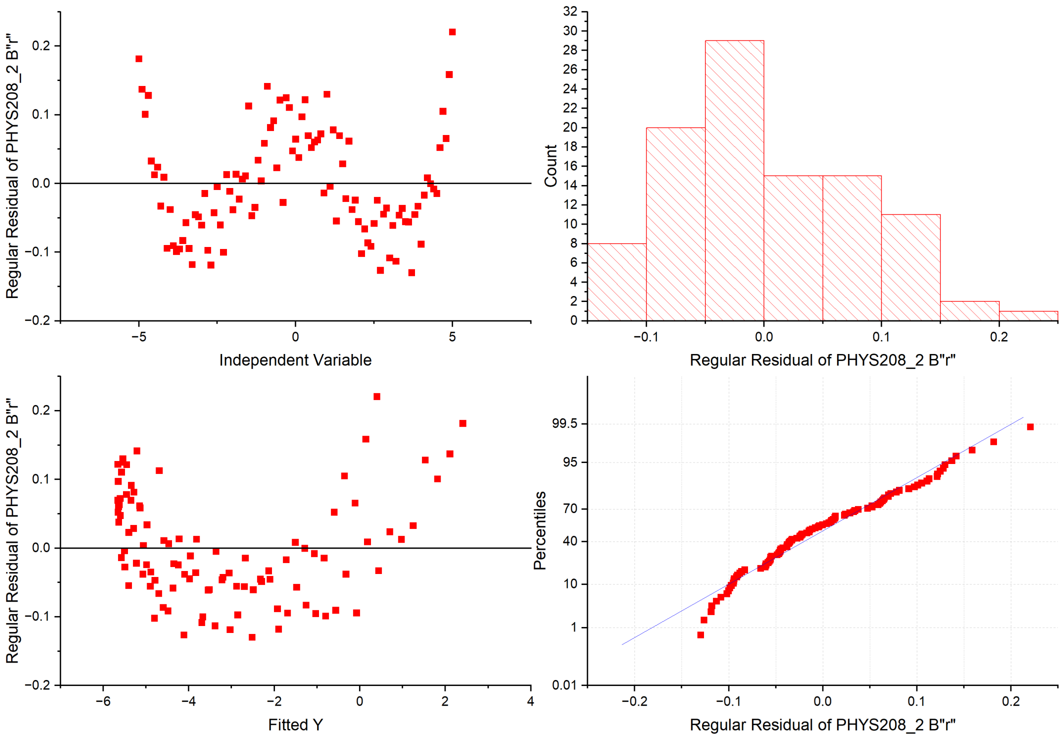


Figure 6: Residual plot of 2nd order polynomial fit on second data set

The residuals for the 2nd order polynomial fit do not look like noise and rather look like some sort of systematic failure of the regression. The degree was increased until the histogram (pictured in the top right of Figure 6) looked like a Normal distribution, and the resultant 5th order polynomial fit's residual plot is pictured in Figure 7.

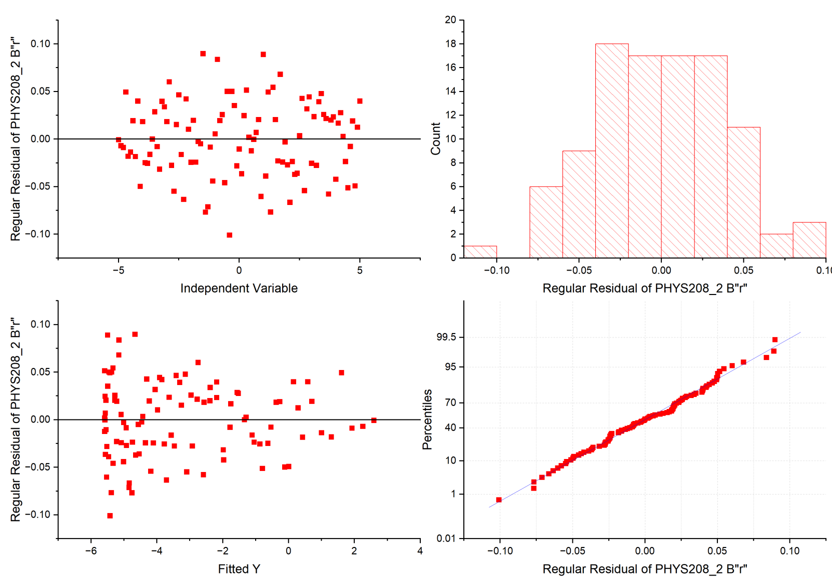


Figure 7: Residual plot of 5th order polynomial fit on second set of data

Fit information for Second Data Set

Fit Parameter	Value	Standard Error
Intercept	-5.546	0.00752
B1	-0.207	0.00603
B2	0.251	0.00185
B3	9.5 * 10^-4	9.2E-4
B4	0.00135	8.108E-5
B5	-2.71E-5	3.19E-5

We needed to include the 5^{th} order term in order for the residual histogram (top right) to look uniformly distributed. It looked a little skewed with the 4^{th} order polynomial.

What is the highest order coefficient that you can extract that is significantly (one order of magnitude) larger than its reported standard error?

The highest order coefficient that is at least one order of magnitude grater than its error is the 4^{th} degree coefficient.

Which of these coefficients should be considered when finding the values that characterize your data and why?

All the coefficients ***except B3 and B5*** should be considered when characterizing the data because the value of B1 B2 B4 and the intercept are all significant. For B3 and B5, 0 is within two standard errors (one standard error for B5) meaning that the value of these is quite uncertain. In other words, parameters B3 and B5's error is on the same magnitude as it's error.

Parts E – Plotting Several Sets of Data in a Single Graph

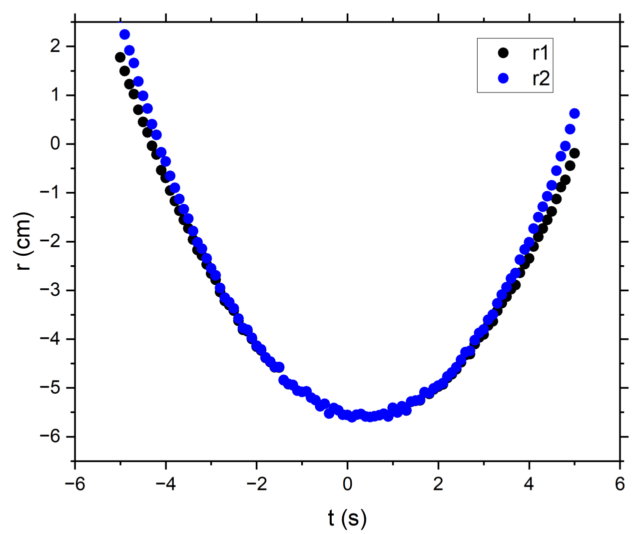


Figure 8: scatter plot of both data sets 1 and 2 in the same axis. Data set 2 is pictured in blue.

Parts F – Functions and Mathematical Manipulations

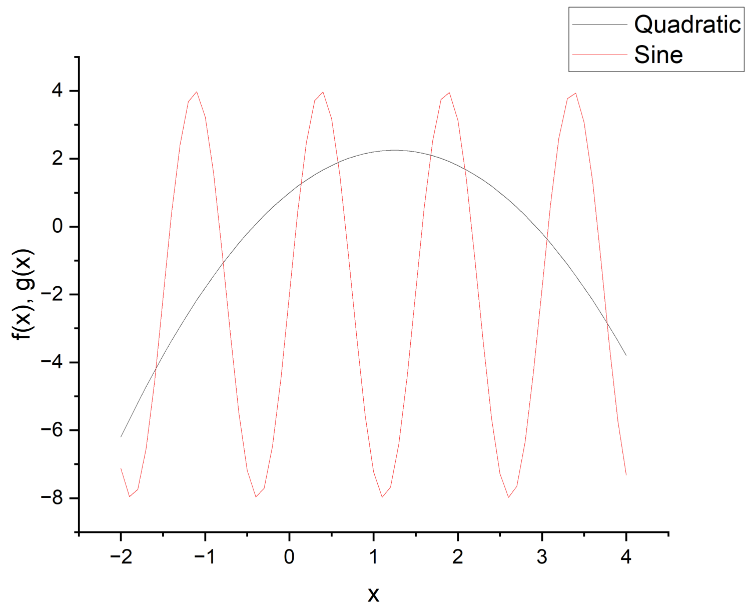


Figure 9: plot of quadratic and sine functions on the same axis. ***see next figure for the actual plot since our software was bugged*** *for a while and didn't display the right graph, and we never got a picture of the updated graph.*

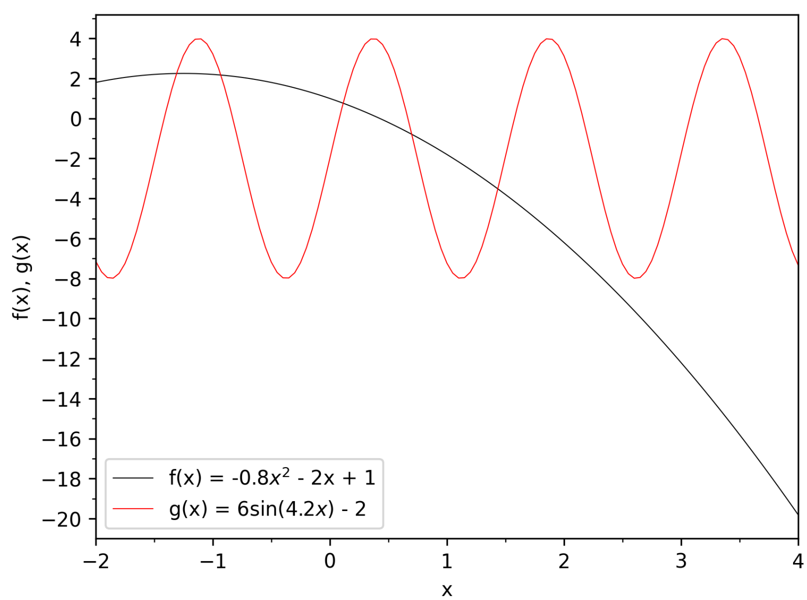


Figure 10: Python recreation of actual plot with f(x) and g(x) since the software was buggin'

Intersection Points of Both Specified Curves

	x	y
1	-1.30748	2.2468
2	-0.9359	2.16923
3	0.11538	0.75754
4	0.69961	-0.79091
5	1.43416	-3.51556

The intersection method used was **gizmos/intersection**.

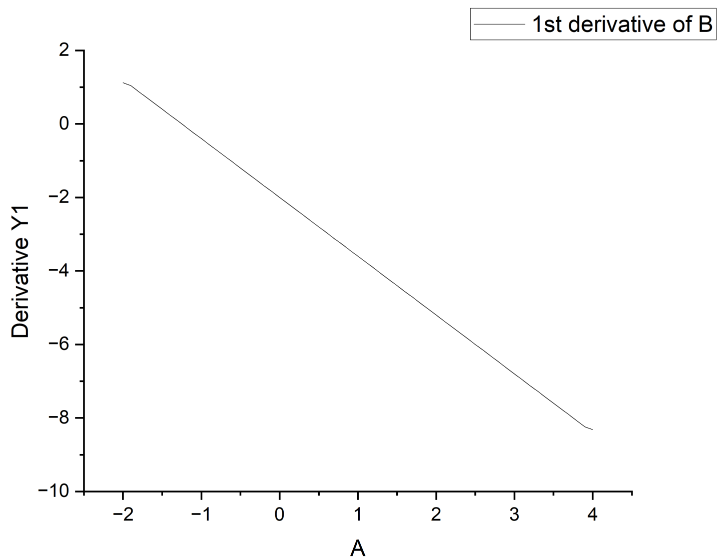
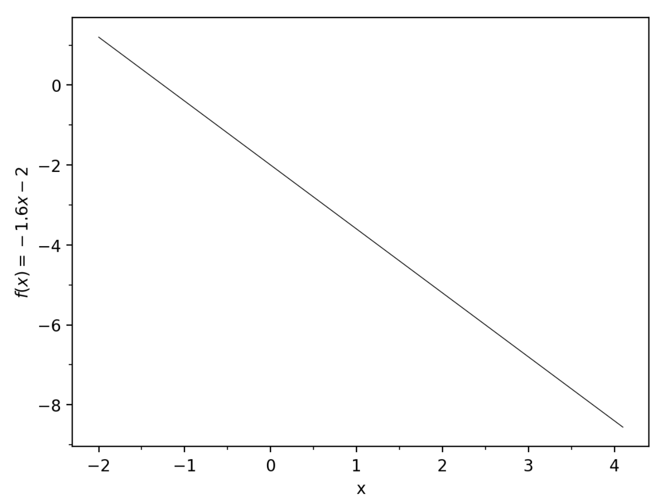


Figure 11: Graph of the derivative of the quadratic from Origin

Equation of derivative of quadratic (derived by hand): f(x) = -1.6x – 2

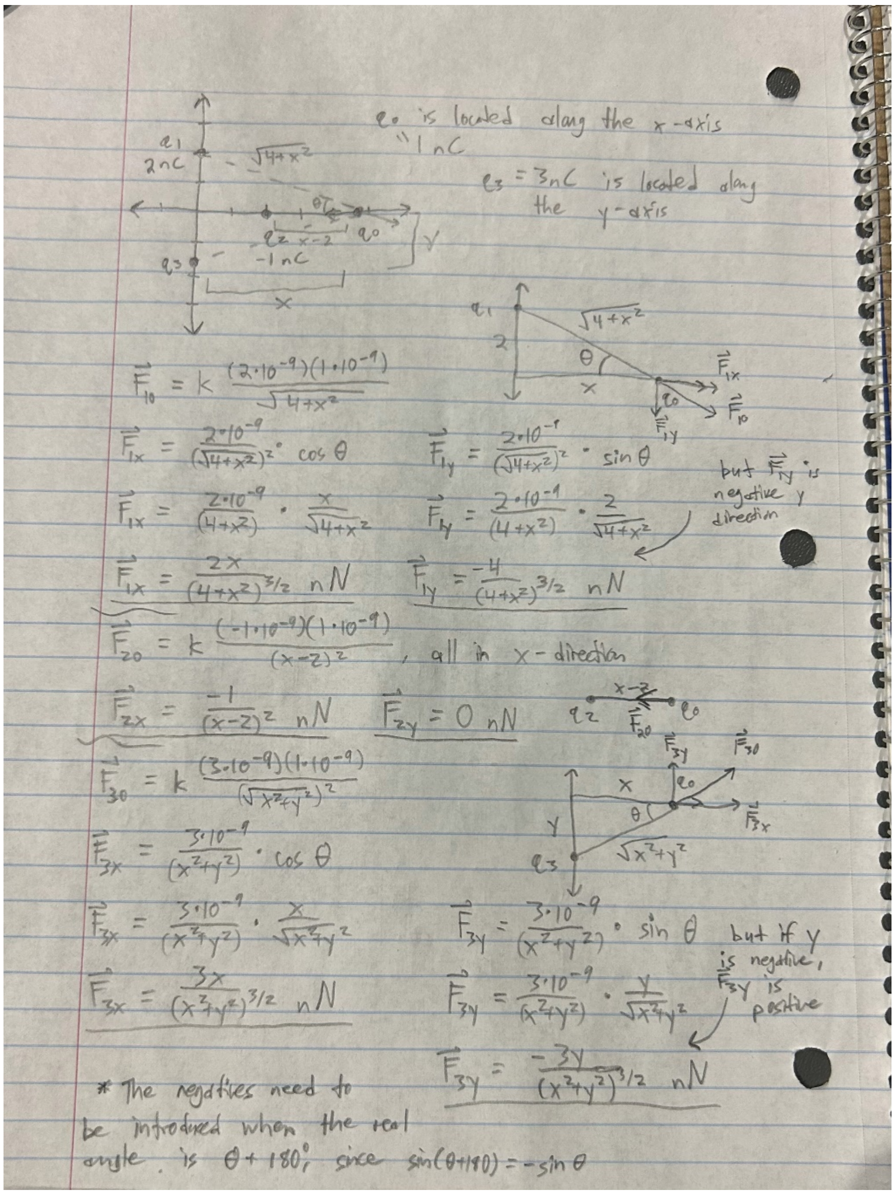
Verify the Input is the correct curve

To verify, we can plot the calculated derivative with some code and see if it looks the same. (below is the generated plot)



Yes, origin plotted derivative is the correct plot. In the origin plot there is weird edge behavior, not sure why, but the line it plotted is most definitely the right derivative

Parts G – Numerically Solving Mathematical Problems



q_0 is located along the x-axis
" 1 nC
$q_3 = 3nC$ is located along the y-axis

q_1 2 nC, $\sqrt{4+x^2}$, q_2 -1 nC, $x-2$, q_0, q_3, x, y

$$\vec{F}_{10} = k\frac{(2\cdot10^{-9})(1\cdot10^{-9})}{\sqrt{4+x^2}}$$

$$\vec{F}_{1x} = \frac{2\cdot10^{-9}}{(\sqrt{4+x^2})^2}\cdot\cos\theta \qquad \vec{F}_{1y} = \frac{2\cdot10^{-9}}{(\sqrt{4+x^2})^2}\cdot\sin\theta$$

$$\vec{F}_{1x} = \frac{2\cdot10^{-9}}{(4+x^2)}\cdot\frac{x}{\sqrt{4+x^2}} \qquad \vec{F}_{1y} = \frac{2\cdot10^{-9}}{(4+x^2)}\cdot\frac{2}{\sqrt{4+x^2}}$$

but $\vec{F}_{1y}$ is negative y direction

$$\vec{F}_{1x} = \frac{2x}{(4+x^2)^{3/2}}\ nN \qquad \vec{F}_{1y} = \frac{-4}{(4+x^2)^{3/2}}\ nN$$

$$\vec{F}_{20} = k\frac{(-1\cdot10^{-9})(1\cdot10^{-9})}{(x-2)^2}$$, all in x-direction

$$\vec{F}_{2x} = \frac{-1}{(x-2)^2}\ nN \qquad \vec{F}_{2y} = 0\ nN$$

$$\vec{F}_{30} = k\frac{(3\cdot10^{-9})(1\cdot10^{-9})}{(\sqrt{x^2+y^2})^2}$$

$$\vec{F}_{3x} = \frac{3\cdot10^{-9}}{(x^2+y^2)}\cdot\cos\theta$$

$$\vec{F}_{3x} = \frac{3\cdot10^{-9}}{(x^2+y^2)}\cdot\frac{x}{\sqrt{x^2+y^2}} \qquad \vec{F}_{3y} = \frac{3\cdot10^{-9}}{(x^2+y^2)}\cdot\sin\theta$$

but if y is negative, $\vec{F}_{3y}$ is positive

$$\vec{F}_{3x} = \frac{3x}{(x^2+y^2)^{3/2}}\ nN \qquad \vec{F}_{3y} = \frac{3\cdot10^{-9}}{(x^2+y^2)}\cdot\frac{y}{\sqrt{x^2+y^2}}$$

$$\vec{F}_{3y} = \frac{-3y}{(x^2+y^2)^{3/2}}\ nN$$

* The negatives need to be introduced when the real angle is $\theta + 180°$, since $\sin(\theta+180) = -\sin\theta$

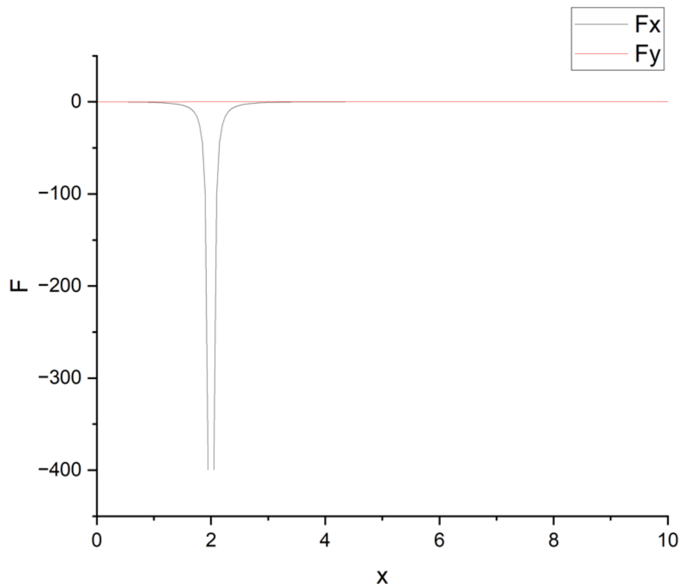


Figure 12: initial plot of Force vs. x with y=-3

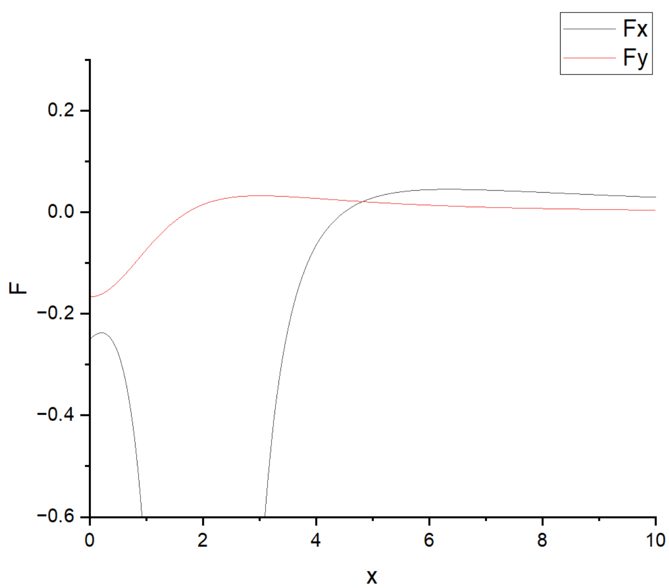


Figure 13: Zoomed in plot of forces vs. x with y=-3

As the manual says, the forces are not 0 at the same x value. The value of *y* was adjusted until both Fx and Fy were (effectively) zero simultaneously. The value of *y* chosen was -0.2188 after some guessing and checking.

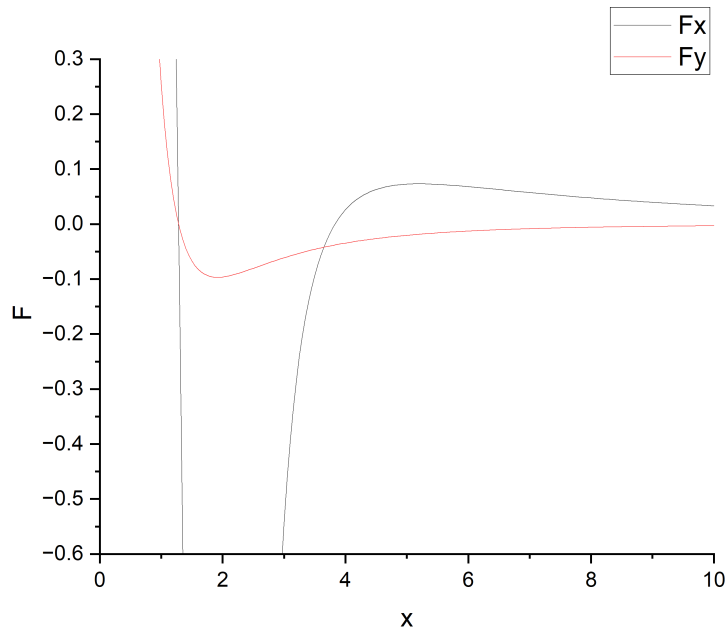


Figure 14: Force vs. x plot with adjusted y value showing F = 0 for Fx and Fy simultaneously.

The field is zero when the force on the particle is zero, since the definition of a field is a force per charge, so since F_x and F_y are zero at (1.28126, -0.2188) the field is zero at the point. this was found using the intersect finder under gadgets.

Conclusion:

Origin may be completely and utterly useless outside of phys228, but in this lab the true power of origin was still unleashed. Data was input manually and imported by files; data was fit to a polynomial; multiple plots of data were plotted on the same axis; complex numerical problems were solved with origin. All of these tasks were completed with a high degree of aesthetics. It almost begs the question of what origin can't do. In short, origin may have its quirks and learning curve paired with an overall lack of use outside of physics lab in favor of free and widely used software, but through this lab most use cases (line, scatter, regression, intersects) were figured out and are ready to be used in future labs for all our plotting and numerical solving needs!