□PHYS115 □PHYS121 □PHYS123
□PHYS116 □PHYS122 □PHYS124

Lab Cover Letter

Author (*You*) Trevor Swan Signature: Trevor Swan

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Lab Partner(s) Pratham Bhashyakarla

Date Performed 1/21/25 Date Submitted 1/27/25

Lab (*such as #1: UNC*) #1: DCCIR

TA: Samantha

GRADE (*to be filled in by your TA*) See your TA for detailed feedback.
An '*x*' next to a subcategory means you need to improve this aspect of your work.

Paper Subtotals (points)

( ) ***General*** **(6)**
_____ Sig. figs.
_____ Units
_____ Clarity of Presentation
_____ Format

( ) ***Abstract*** **(4)**
_____ Quantity or principle
_____ How measurement was made
_____ Numerical Results
_____ Conclusion

( ) ***Intro & Theory*** **(9)**
_____ Basic principle
_____ Main equations to be used
_____ Apparatus
_____ What will be plotted
_____ Fitting parameters related

( ) ***Exp. Procedures*** **(15)**
_____ Description
_____ Stating and justifying uncertainties
_____ Data Record
_____ Quality of Lab Work

( ) ***Analysis & Error Analysis*** **(20)**
_____ Discussion
_____ Equations & Calculations
_____ Presentation inc. Graphs, Tables
_____ Results Reported & Reasonable
_____ Underlined items addressed

( ) ***Discussion & Conclusions*** **(6)**
_____ Numerical comparison of results
_____ Logical conclusions
_____ Discussion of pos. errors
_____ Suggestions to reduce errors

( ) **Paper Total (60 points)**
(30 points for CME or EPF)

( ) **Notebook (10 points)**
_____ Format (*proper style, following directions*)
_____ Apparatus (*brief description of equipment, including sketches*)
_____ Data (*including computer file names and manually recorded data*)
_____ Experimental Technique (*describing your procedures; stating & justifying uncerts.*)
_____ Analysis (*results and errors*)

( ) **Worksheet(s)/Fill-in-the-Blank-Report (30 points)** *if applicable*

( ) **Adjustments** – late submissions, improper procedures, etc. – or bonus points for exceptional work.

( ) Total Grade

Graded by ___________ *(TA's initial)*

DC-CIR Worksheet

Your Name: Trevor Swan **Signature:** [illegible]

Lab partner(s): Pratham Bhashyakarla

Course & Section: 122 & 118-B **Station #** 118-B **Date:** 1/26/25

Section D: Ohm's Law

1. DMM reading for the resistor: 99.0 ± 0.1 Ω

2. List your data for minimum and maximum current, with error estimates. Don't forget units. Also, staple to this worksheet a copy of your plot, including the linear fit.

I_{min}: 0.0202 ± 0.0001 A (*units*) V: 1.99 ± 0.01 V

I_{max}: 0.0244 ± 0.0001 A V: 2.40 ± 0.01 V

3. List your linear fit parameters, with error estimates from *Origin*. Also attached

SLOPE: 98.0 ± 1.1 Ω INTERCEPT: 0.013 ± 0.024 V

4. Comment on the comparison of the DMM value and Origin fit. (Use additional sheets if necessary.)

The measured value for our resistor using the DMM was 99.0 ± 0.01 Ω. The slope determined using origin was 98.0 ± 1.1 Ω. With this in mind, we can claim that our DMM was functioning properly as the values agree within their errors. Specifically 99.0 ∈ (97.9, 99.1).

Section E.1: Series Resistors

5. Enter below the data (*with error estimates*) for series resistors.

Error estimates needed — Error estimates needed

Resistor #	Resistance (*ohms*)	Theoretical Sum (*ohms*)	Voltage (*V*)	Current (*A or mA*) (circle one)	Experimental Sum (*ohms*)
1	99.0 ± 0.1	99.0 ± 0.1	2.55±0.01	0.0258 ± 0.0001	98.8 ± 0.5
2	99.2 ± 0.1	198.2 ± 0.1	2.64±0.01	0.0133±0.0001	199 ± 2
3	980 ± 10	1178.2 ± 10.0	2.7 ±0.1	0.0023 ± 0.0001	1217 ± 15
4	48.4 ± 0.1	1226.6 ± 10.0	2.7 ± 0.1	0.0022 ± 0.0001	1227 ± 58

6. Attach a sheet that describes in detail how you found the errors in each entry for two resistors in series. This should include errors in any raw data you took as well as error propagation through any equations that you used (see App. V of the lab manual).

7. Compare the theory to the experiment. (Use additional sheets if necessary.)

All of our measurements, except the third, are almost perfectly in line with the theoretical sums. Excluding R_3, all theoretical results are well within the errors of the experimental results, indicating strong correlation and support for Resistances in series.* Ultimately, ohm's law holds for resistors in series.

*The large discrepancy in R_3 is most likely due to improper circuit design that was fixed for R_4. This would result in different I, V, and R values!

Section E.2: Parallel Resistors

8. Enter below the data from your table of part E.2 for parallel resistors

Resistor #	Resistance (*ohms*)	Theoretical Sum (*ohms*)	Voltage (*V*)	Current (*A or mA*) (*circle one*)	Experimental Sum (*ohms*)
1	99.0 ± 0.1	99.01 0.1	2.56 ± 0.01	0.0260 ± 0.0001	98.46 ± 0.54
2	99.2 ± 0.1	49.55 ± 0.04	2.40 ± 0.01	0.0240 ± 0.0001	49.38 ± 0.59
3	980 ± 10	47.17 ± 0.04	2.5 ± 0.1	0.0511 ± 0.0001	48.92 ± 1.96
4	48.4 ± 0.1	23.89 ± 0.03	2.3 ± 0.1	0.0908 ± 0.0001	25.33 ± 1.10

9. Attach a sheet that describes in detail how you found the errors in each entry for 2 resistors in parallel.

10. Compare the theory to the experiment. (Use additional sheets if necessary.)

All theoretical sums, except for R_4, agree with their corresponding experimental sums. While R_1 is barely in the margin of error, R_2 and R_3 both are well within their experimental error values. Similar to my comment on the discrepancy found in our series experiment, this is likely due to issues with our circuit setup. Due to the number of resistors we placed between to connections, I would not be surprised if our final measurement was off due to some sort of interference. Though this resistor doesn't agree with ohm's law, it is close enough, and the other data points support the inverse sum relationship between resistance (resistors in parallel). It is for that reason that I'd argue ohm's law is valid for resistors in parallel!

Sections F & G. Where Ohm's Law Fails & Power Limits

11. What resistance did you measure with the DMM? 1.4 ± 0.1 Ω

12. Attach your Origin plot of *R vs. I*.

13. Comment on Ohm's Law as it applies to the incandescent bulb and compare the DMM reading to the data in your plot: (Use additional sheets if necessary.)

Ohms Law fails with the bulb as it requires constant Resistance for the linear $V = IR$ to hold. With this model, we got a resistance value of ~1.4 for the first few data points, but the resistance increased as the current increased. This increase in resistance was clearly non-linear, and actually more sigmoidal or quadratic. This is much different than the predicted (constant) resistance of $R = 1.4 \pm 0.1\,\Omega$. This can be explained by the fact that bulbs contain a fillament whose resistance increases as the temperature of it increases. As the increased current heats the fillament, resistance increases, violating the key assumption of Ohm's Law.

14. What is the maximum rated voltage for a 100 Ω, ¼-watt resistor 5 V $P = \frac{V^2}{R} \Rightarrow V = \sqrt{RP} = \sqrt{100 \cdot 0.25}$

$P = IV = I^2R = V^2/R$

15. What is your personal resistance? 50.4 kΩ

16. What voltage across your hands would result in a power that could destroy a 100 Ω, ¼-watt resistor?

2,520V

$$P = I^2R \Rightarrow I = \sqrt{\frac{P}{R}} = \sqrt{\frac{0.25\,W}{100\,\Omega}} = 0.05A$$

$$\Rightarrow V = 0.05A \cdot 50.4\,k\Omega = 2520\,V$$

GRADE:_______ (out of 30 points) **GRADED BY** ________ (TA's initials)

Series Resistors - Error Propagation

Measured Resistors

$R_1 = 99.0 \pm 0.1$

$R_2 = 99.2 \pm 0.1$

$R_3 = 980 \pm 10$

$R_4 = 48.4 \pm 0.1$

Theoretical Sum's Error calculation

$\delta_{tot_1} = 0.1$

$\delta_{tot_2} = \sqrt{\delta_{R_1} + \delta_{R_2}} = \sqrt{0.1^2 + 0.1^2} = 0.14 = 0.1$

$\delta_{tot_3} = \sqrt{\delta_{R_1} + \delta_{R_2} + \delta_{R_3}} = \sqrt{0.1^2 + 0.1^2 + 10^2} = 10.0$

$\delta_{tot_4} = \sqrt{\delta_{R_1} + \delta_{R_2} + \delta_{R_3} + \delta_{R_4}} = \sqrt{0.1^2 + 0.1^2 + 10^2 + 0.1^2} = 10.0$

Experimental Sum's Error

$R_{equiv} = \frac{V}{I}$ (refer to as R) $\rightarrow \delta_R = \sqrt{\left(\frac{\delta_V}{I}\right)^2 + \left(\frac{\delta_I \cdot V}{I^2}\right)^2}$

$\Rightarrow \delta_R = \sqrt{\delta_{R_V}^2 + \delta_{R_I}^2}$

$\delta_{R_V} = \left|\frac{\delta R}{\delta V}\right| \cdot \delta_V = \frac{\delta_V}{I}$, $\delta_{R_I} = \left|\frac{\delta R}{\delta I}\right| \cdot \delta_I = \left|\frac{-V}{I^2}\right| \cdot \delta_I = \frac{\delta_I \cdot V}{I^2}$

Original Data

	$V \pm \delta_V$ {V}	$I \pm \delta_I$ {A}
R_1:	2.55 ± 0.01	0.0258 ± 0.0001
R_2:	2.64 ± 0.01	0.0133 ± 0.0001
R_3:	2.7 ± 0.1	0.0023 ± 0.0001
R_4:	2.7 ± 0.1	0.0022 ± 0.0001

→ Calculations

$$\delta_{R_1} = \sqrt{\left(\frac{0.01}{0.0258}\right)^2 + \left(\frac{0.0001 \cdot 2.55}{0.0258^2}\right)^2} = 0.54497 = 0.5$$

$$\delta_{R_2} = \sqrt{\left(\frac{0.01}{0.0133}\right)^2 + \left(\frac{0.0001 \cdot 2.64}{0.0133^2}\right)^2} = 1.6711 = 2$$

$$\delta_{R_3} = \sqrt{\left(\frac{0.1}{0.0023}\right)^2 + \left(\frac{0.0001 \cdot 2.7}{0.0023^2}\right)^2} = 15.2245 = 15$$

$$\delta_{R_4} = \sqrt{\left(\frac{0.1}{0.0022}\right)^2 + \left(\frac{0.0001 \cdot 2.7}{0.0022^2}\right)^2} = 55.9700 = 58$$

Parallel Resistors - Error Propagation

Measured Resistors

$R_1 = 99.0 \pm 0.1$

$R_2 = 99.2 \pm 0.1$

$R_3 = 980 \pm 10$

$R_4 = 48.4 \pm 0.1$

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$\Rightarrow R_{total} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} \right)^{-1}$$

$$\delta_{R_{tot}} = \sqrt{\underbrace{\left|\frac{\delta R}{\delta R_1}\right| \delta_{R_1}^2 + \left|\frac{\delta R}{\delta R_2}\right| \delta_{R_2}^2}_{\delta_{tot_2}} + \underbrace{\left|\frac{\delta R}{\delta R_3}\right| \delta_{R_3}^2}_{\delta_{tot_3}} + \underbrace{\left|\frac{\delta R}{\delta R_4}\right| \delta_{R_4}^2}_{\delta_{tot_4}}}$$

$\delta_{tot_1} = 0.1 \rightarrow \delta_{tot_1}$ $\quad \delta_{tot_2}$ $\quad \delta_{tot_3}$ $\quad \delta_{tot_4}$

Partial Derivatives found using wolfram calculator with python

$$\delta_{tot_2} = \sqrt{\left(\frac{R_2^2}{(R_1+R_2)^2} \cdot \delta_{R_1}\right)^2 + \left(\frac{R_1^2}{(R_1+R_2)^2} \cdot \delta_{R_2}\right)^2} = 0.0354$$

$$\delta_{tot_3} = \sqrt{\left(\frac{R_2^2 R_3^2}{(R_1(R_2+R_3)+R_2R_3)^2} \cdot \delta_{R_1}\right)^2 + \left(\frac{R_1^2 R_3^2}{(R_1(R_2+R_3)+R_2R_3)^2} \cdot \delta_{R_2}\right)^2 + \left(\frac{R_1^2 R_2^2}{(R_1(R_2+R_3)+R_2R_3)^2} \cdot \delta_{R_3}\right)^2}$$

$$= 0.0395$$

$$\delta_{tot_4} = \sqrt{\left(\frac{1}{R_1^2\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\right)^2} \cdot \delta_{R_1}\right)^2 + \left(\frac{1}{R_2^2\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\right)^2} \cdot \delta_{R_2}\right)^2 + \left(\frac{1}{R_3^2\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\right)^2} \cdot \delta_{R_3}\right)^2 \cdots}$$

$$\cdots + \left(\frac{1}{R_4^2\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\right)^2} \cdot \delta_{R_4}\right)^2 = 0.0264$$

where $\begin{cases} R_1 = 99.0 \\ R_2 = 99.2 \\ R_3 = 960 \\ R_4 = 48.4 \end{cases}$ and $\begin{cases} \delta_{R_1} = 0.1 \\ \delta_{R_2} = 0.1 \\ \delta_{R_3} = 10 \\ \delta_{R_4} = 0.1 \end{cases}$

Experimental Sims Error $\left(R = \frac{V}{I}\right)$

$$\delta_R = \sqrt{\left(\frac{\delta_V}{I}\right)^2 + \left(\frac{\delta_I \cdot V}{I^2}\right)^2}$$

(Derived on Previous Page)

	$V \pm \delta_V$ {V}	$I \pm \delta_I$ {A}
R_1 :	2.56 ± 0.01	0.0260 ± 0.0001
R_2 :	2.40 ± 0.01	0.0240 ± 0.0001
R_3 :	2.5 ± 0.1	0.0511 ± 0.0001
R_4 :	2.3 ± 0.1	0.0908 ± 0.0001

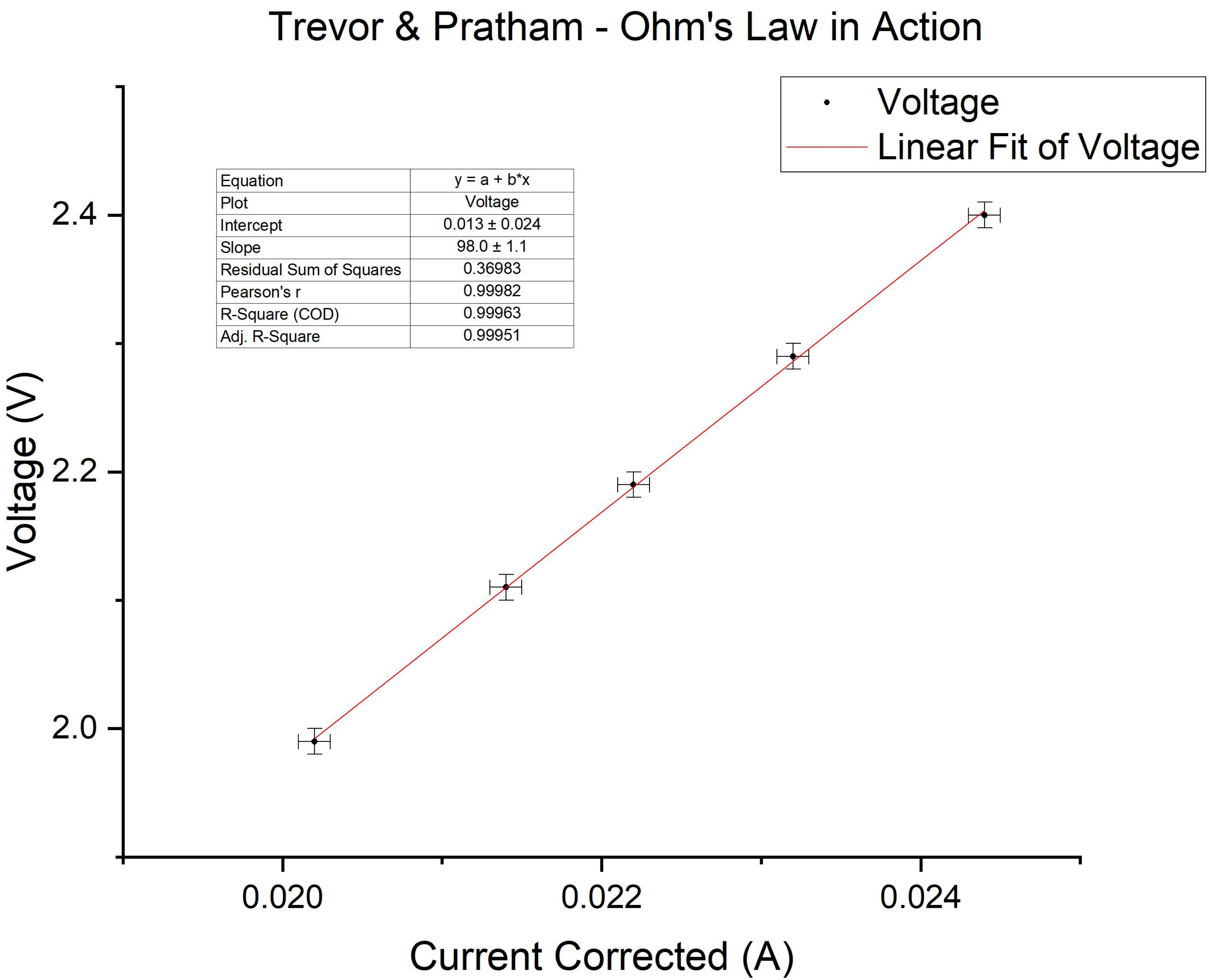
→ Calculations

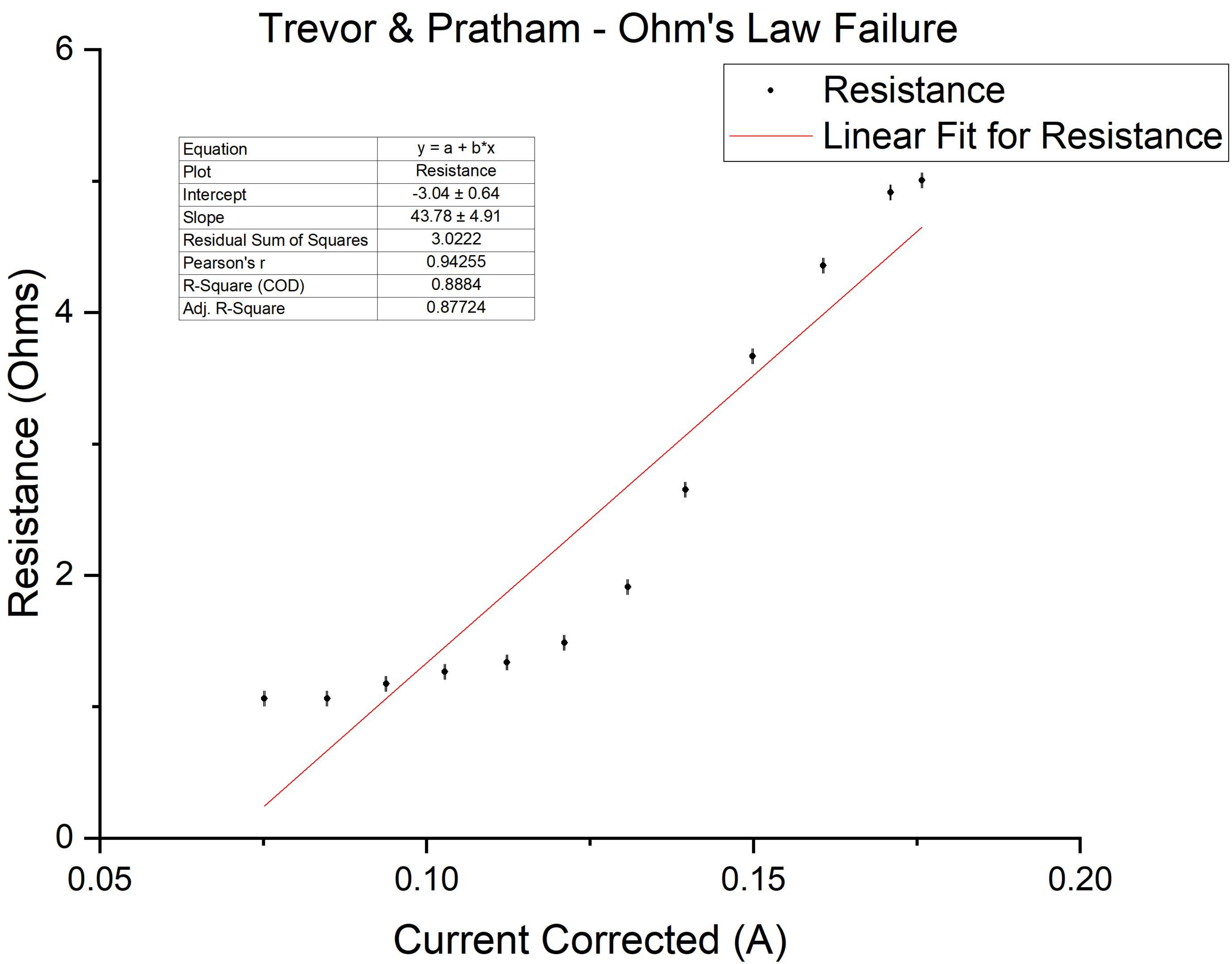
$$\delta_{R_1} = \sqrt{\left(\frac{0.01}{0.0260}\right)^2 + \left(\frac{0.0001 \cdot 2.56}{0.0260^2}\right)^2} = 0.5398 = 0.54$$

$$\delta_{R_2} = \sqrt{\left(\frac{0.01}{0.0240}\right)^2 + \left(\frac{0.0001 \cdot 2.40}{0.0240^2}\right)^2} = 0.5893 = 0.59$$

$$\delta_{R_3} = \sqrt{\left(\frac{0.1}{0.0511}\right)^2 + \left(\frac{0.0001 \cdot 2.5}{0.0511^2}\right)^2} = 1.9593 = 1.96$$

$$\delta_{R_4} = \sqrt{\left(\frac{0.1}{0.0908}\right)^2 + \left(\frac{0.0001 \cdot 2.3}{0.0908^2}\right)^2} = 1.1017 = 1.10$$


Trevor & Pratham - Ohm's Law in Action
Voltage
Linear Fit of Voltage
Equation y = a + b*x
Plot Voltage
Intercept 0.013 ± 0.024
Slope 98.0 ± 1.1
Residual Sum of Squares 0.36983
Pearson's r 0.99982
R-Square (COD) 0.99963
Adj. R-Square 0.99951
2.4
2.2
2.0
Voltage (V)
0.020
0.022
0.024
Current Corrected (A)



Trevor & Pratham - Ohm's Law Failure
Resistance
Linear Fit for Resistance
Equation | y = a + b*x
Plot | Resistance
Intercept | -3.04 ± 0.64
Slope | 43.78 ± 4.91
Residual Sum of Squares | 3.0222
Pearson's r | 0.94255
R-Square (COD) | 0.8884
Adj. R-Square | 0.87724
Resistance (Ohms)
Current Corrected (A)
0
2
4
6
0.05
0.10
0.15
0.20