□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 3/3/25 Date Submitted 3/18/25

Lab (*such as #1: UNC*) #4: RC-CIR

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)*

RC-CIR Worksheet

Your Name: Trevor Sun **Signature:** [signature]

Lab partner(s): Pratham Bhashyakarla

Course & Section: 122 - 118 **Station #** B **Date:** 3/18/25

1. (Section E.2.) The nominal values of the resistance and capacitance are 10 kΩ and 47 µF, respectively. What are your measured values?

R = 10.31 ± 0.01 kΩ (units)

C = 44.3 ± 0.1 µF (units)

2. (Section E.2.) What is the value of the time constant based on the measured values and nominal (labeled) values?

$\tau_{measured}$ = 0.457 ms (units)

$\tau_{labeled}$ = 0.470 ± 0.02 ms (units)

$$\left.\begin{array}{l} k\Omega = \Omega \times 10^{3} \\ \mu F = F \times 10^{-6} \end{array}\right\} \Omega F \times 10^{-3} = s \times 10^{-3}$$

3. (Section E.7.) What is the maximum amount of charge stored on the capacitor during charging?

Q = 132.9 ± 0.1 µC (units)

$44.3\,\mu F \times 3V = 132.9\,\mu C$

$\delta_Q = \sqrt{0.1^2 + 0.1^2} = 0.14$

Note that you have taken two pairs of data sets, two while charging the capacitor and two while discharging it. From those graphs, read off the voltage across the resistor and the voltage across the capacitor at the end of each run.

Charging

V_R = 0 ± 0.1 V (units)

V_C = 2.5 ± 0.1 V (units)

Discharging

V_R = 0 ± 0.1 V (units)

V_C = 2.1 ± 0.1 V (units)

4. (Section E.7.) What should the two pairs of voltages add up to? Do they? Why or why not?

They should add to the power supply output value of 3V. This is due to Kirchoff's Loop Rule, $V_R + V_C = V_0 = 3V$.

Charging	Discharging
$V_0 = 2.5V$	$V_0 = 2.1V$

These numbers are not consistent with the predicted 3V, indicating battery decay.

5. (Section G) What are the five values of the time constant?

$\tau_{measured}$ = 0.4570 ± 0.0001 s (units) $\delta_\tau = \sqrt{0.1^2 + 0.01^2} = 0.1 ms = 0.0001 s$

$\tau_{charging\_C}$ = 0.4735 ± 0.0005 s (units)

$\tau_{discharging\_C}$ = 0.4745 ± 0.0005 s (units)

$\tau_{charging\_R}$ = 0.4755 ± 0.0006 s (units)

$\tau_{discharging\_R}$ = 0.4737 ± 0.0005 s (units)

Compare these five values of the time constant to each other and discuss whether or not they are in agreement, within estimated errors.

Calculated from 4 non-measured values

τ_{mean} = 0.4743 s (units) $\frac{0.4735 + 0.4745 + 0.4755 + 0.4737}{4} = 0.4743$

$\tau_{std\ dev}$ = 0.0009 s (units) $\sqrt{\frac{(0.4735-.4743)^2 + (0.4745-.4743)^2 + (0.4755-.4743)^2 + (0.4737-.4743)^2}{4-1}} = 9\times10^{-4} s$

Therefore, τ = 0.4743 ± 0.0009 s (units)

All τ values except the measured & charging R values agree within their errors. These values are also captured by the mean ± std dev τ value. Ultimately, the five values are <u>not</u> in agreement!

6. (Section G) Does the residual plot indicate you had a good fit or a bad fit? Explain.

Not necessarily...

- Non-random pattern: There seems to be a wave-like pattern, not appearing randomly scattered around 0. This suggests systematic deviation from the model.

To be a good fit for the model, the residuals should mostly be near zero and should be randomly distributed with no obvious trend with the points and their error bars pointing to a sinusoidal pattern. This indicates that our model is not necessarily a good fit for the data. Roughly, the Residuals paint a shape close to:  , which is <u>not</u> random (2/3 of it is not).

7. (Section H) What are your measured values of the resistance and capacitance of the two capacitors?

R = 10.31 ± 0.01 kΩ (units)

C_1 = 44.3 ± 0.1 μF (units)

C_2 = 44.0 ± 0.1 μF (units)

8. (Section H) What is your calculated time constant for parallel capacitors? For series capacitors?

$C_{eq} = C_1 + C_2 = 44.3 + 44.0 = 88.3\ mF$

$\tau_{calc\_parallel}$ = 0.9104 ± 0.0001 __s__ (units) $\delta_C = \sqrt{0.1^2 + 0.1^2} = 0.1$ | $\delta_\tau = \sqrt{0.14^2 + 0.01^2} = 0.14\ ms$

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{44.3} + \frac{1}{44.0} \Rightarrow C_{eq} = 22.07\ mF$

τ_{calc_series} = 0.22754 ± 0.00001 __s__ (units) $\delta_{C_1} = \left(\frac{1}{C_1^2}\right)\delta_{C_1} = \frac{1}{44.3^2}(0.1) = 5.1\times10^{-5}\ mF$ $\delta_C = \sqrt{(5.1\times10^{-5})^2 + (5.2\times10^{-5})^2} = 7.3\times10^{-5}$

$\delta_{C_2} = \left(\frac{1}{C_2^2}\right)\delta_{C_2} = \frac{1}{44.0^2}(0.1) = 5.2\times10^{-5}\ mF$ | $\delta_\tau = \sqrt{(7.3\times10^{-5})^2 + 0.01^2} = 0.01\ ms$

9. (Section H) What is the time constant from the fit for parallel capacitors? For series capacitors?

$\tau_{fit\_parallel}$ = 0.941 ± 0.001 __s__ (units)

τ_{fit_series} = 0.2393 ± 0.0005 __s__ (units)

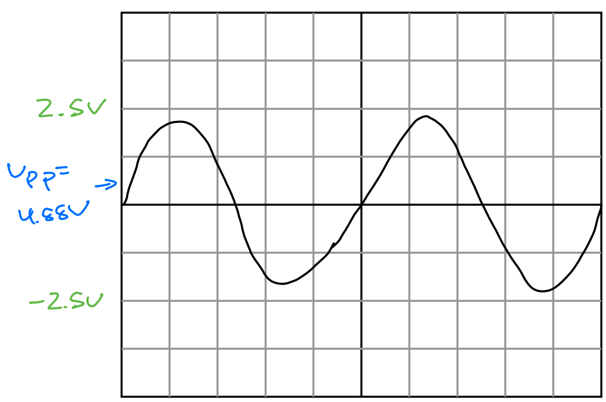
10. (Section I) What are your measured values of the resistance and capacitance? What is the theoretical time constant?

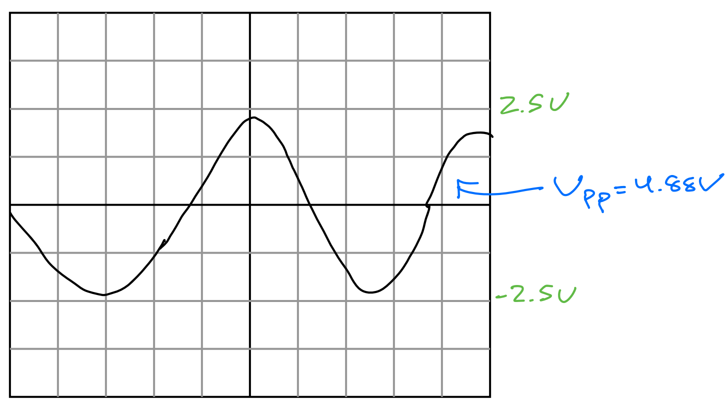
R = 1.00 ± 0.01 __kΩ__ (units)

C = 0.455 ± 0.001 __mF__ (units)

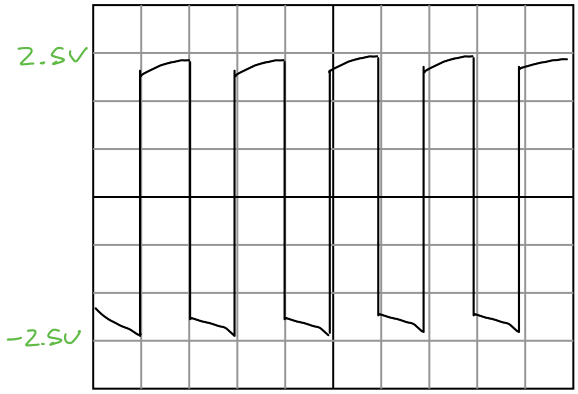
τ = 0.46 ± 0.01 __ms__ (units) $\delta_\tau = \sqrt{.01^2 + .001^2} = 0.01\ ms$

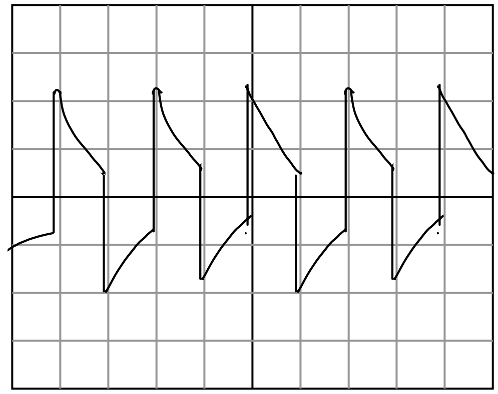
11. (Section I-analog differentiator) Sketch the waveforms you see for the sine wave and its derivative.



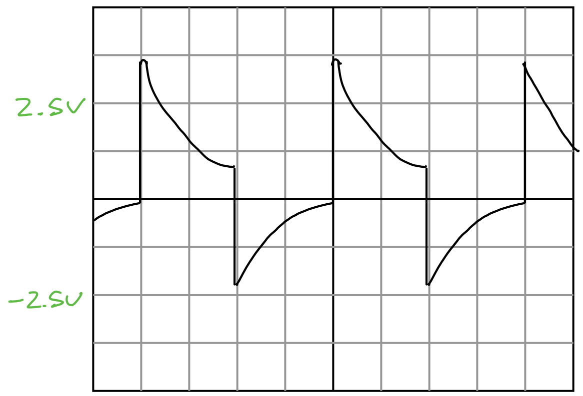


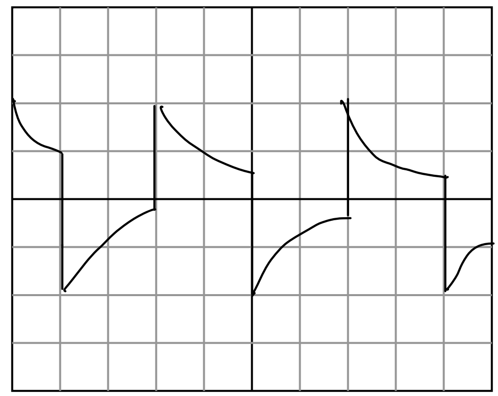
12. (Section I-analog differentiator) Sketch the waveforms you see for the triangle wave and its derivative.





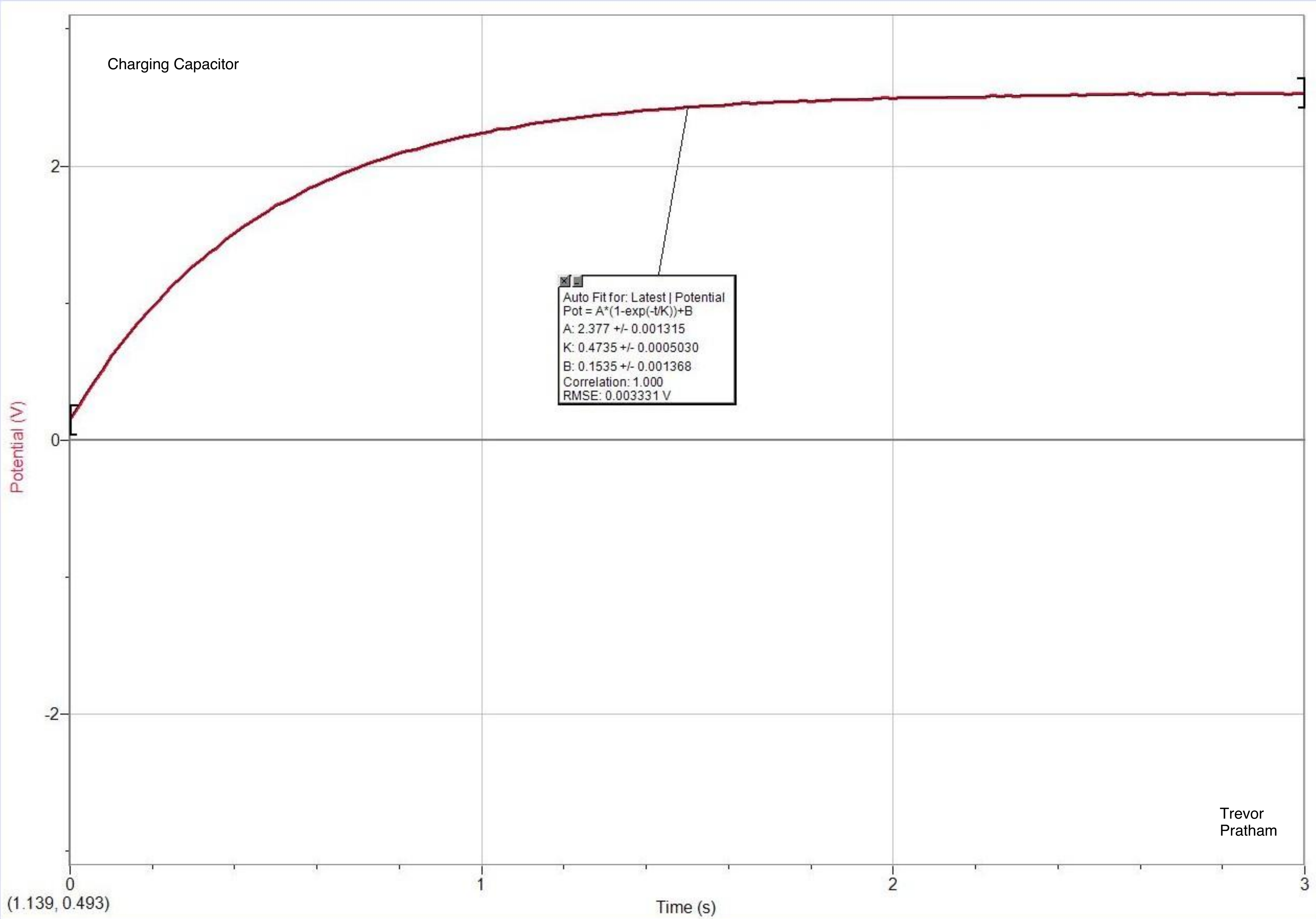
13. (Section I-analog differentiator) Sketch the waveforms you see for the square wave and its derivative.

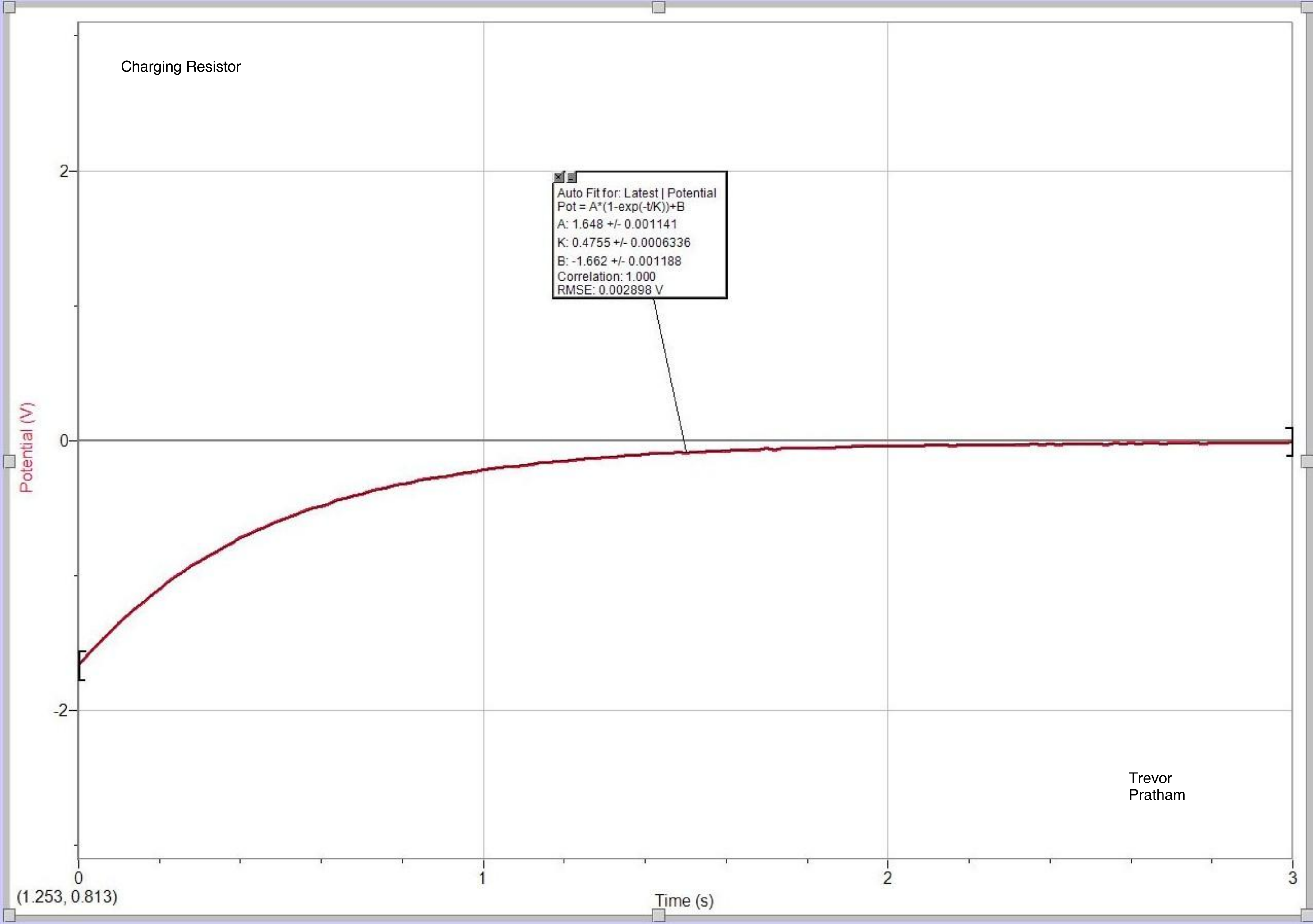




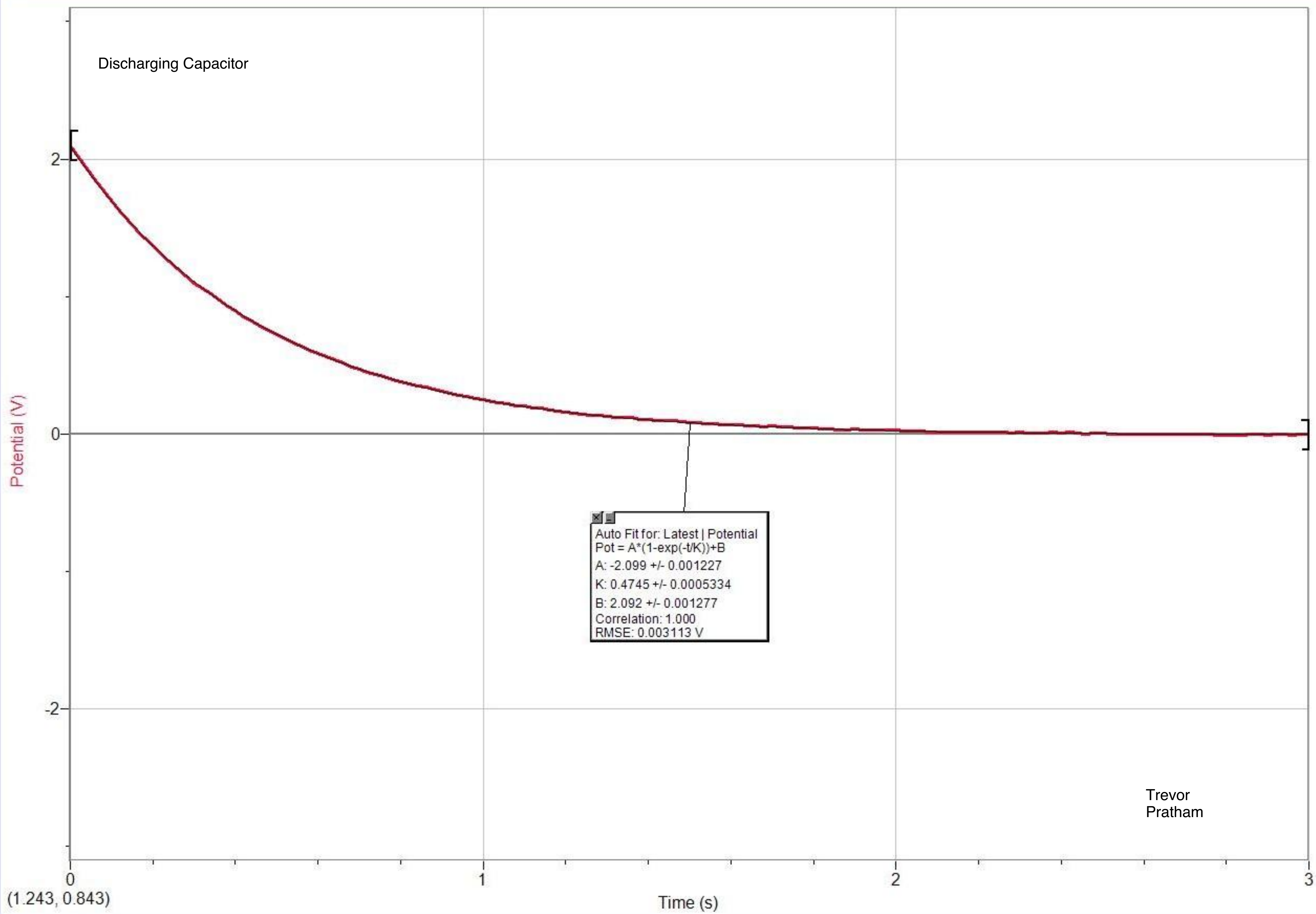
GRADE:_______
(out of 30 points)

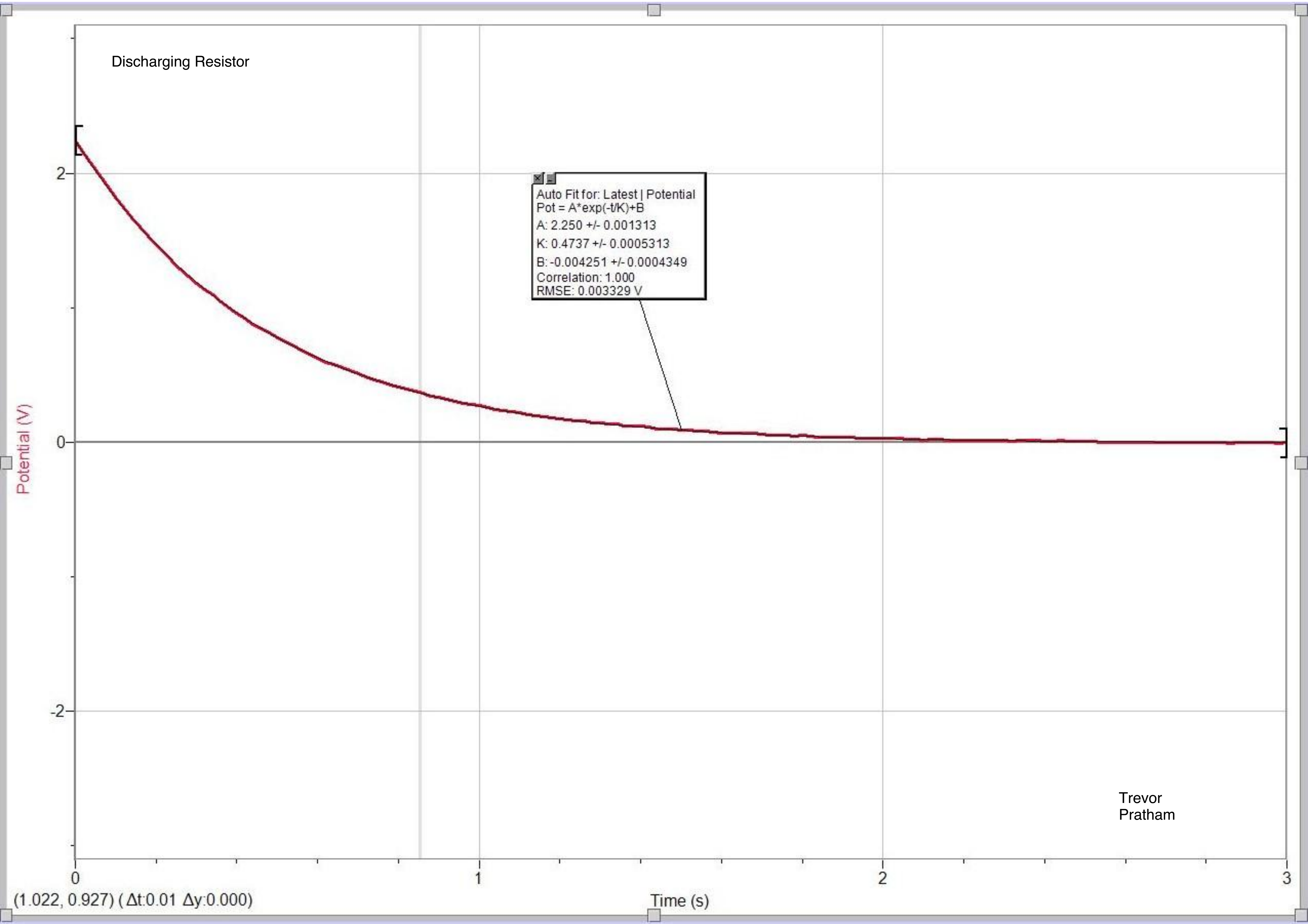
GRADED BY ________
(TA's initials)


Charging Capacitor
Auto Fit for: Latest | Potential
Pot = A*(1-exp(-t/K))+B
A: 2.377 +/- 0.001315
K: 0.4735 +/- 0.0005030
B: 0.1535 +/- 0.001368
Correlation: 1.000
RMSE: 0.003331 V
Trevor
Pratham
Potential (V)
2
0
-2
0
1
2
3
Time (s)
(1.139, 0.493)

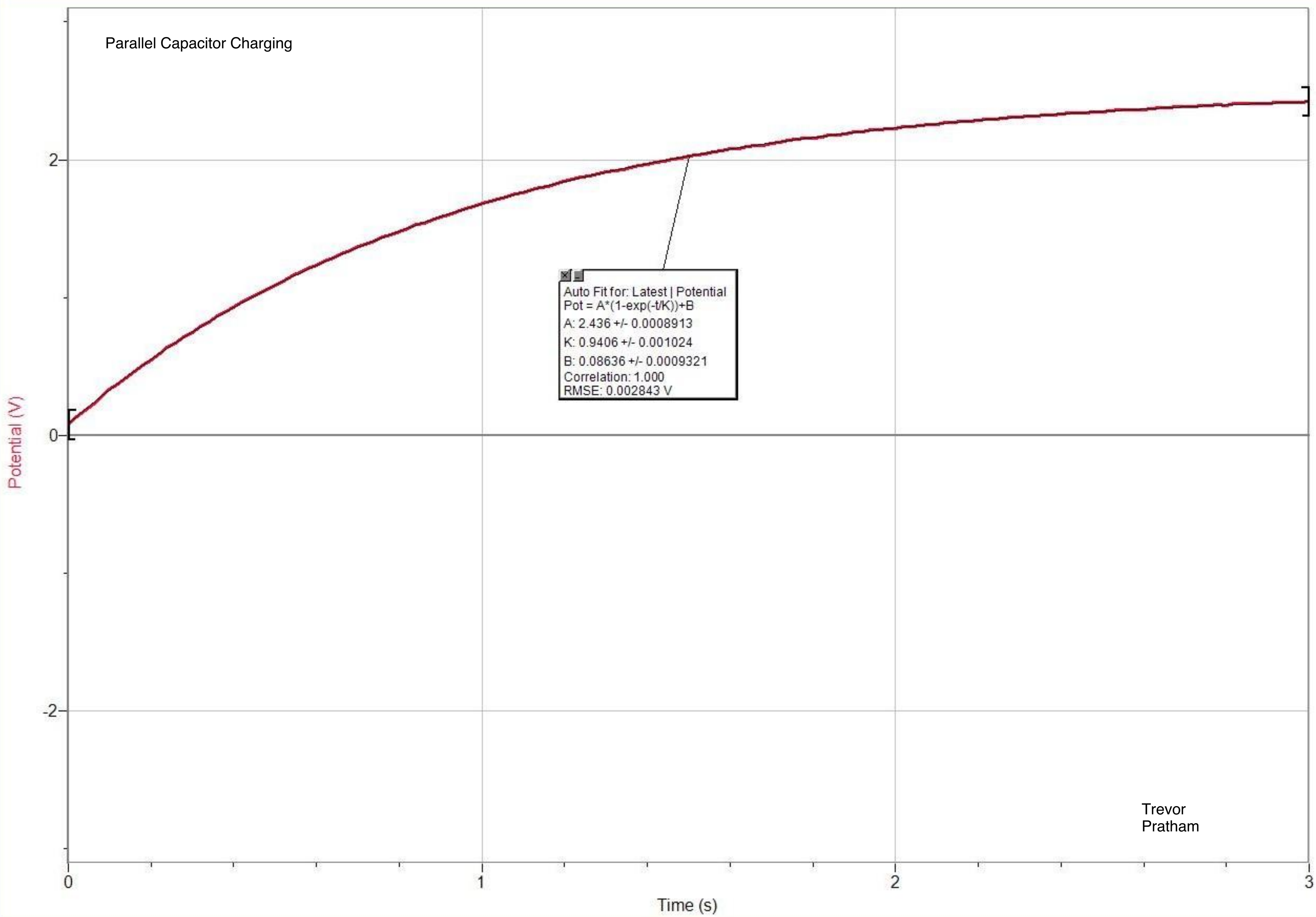


Charging Resistor
Auto Fit for: Latest | Potential
Pot = A*(1-exp(-t/K))+B
A: 1.648 +/- 0.001141
K: 0.4755 +/- 0.0006336
B: -1.662 +/- 0.001188
Correlation: 1.000
RMSE: 0.002898 V
Potential (V)
2
0
-2
0
1
2
3
Time (s)
(1.253, 0.813)
Trevor
Pratham

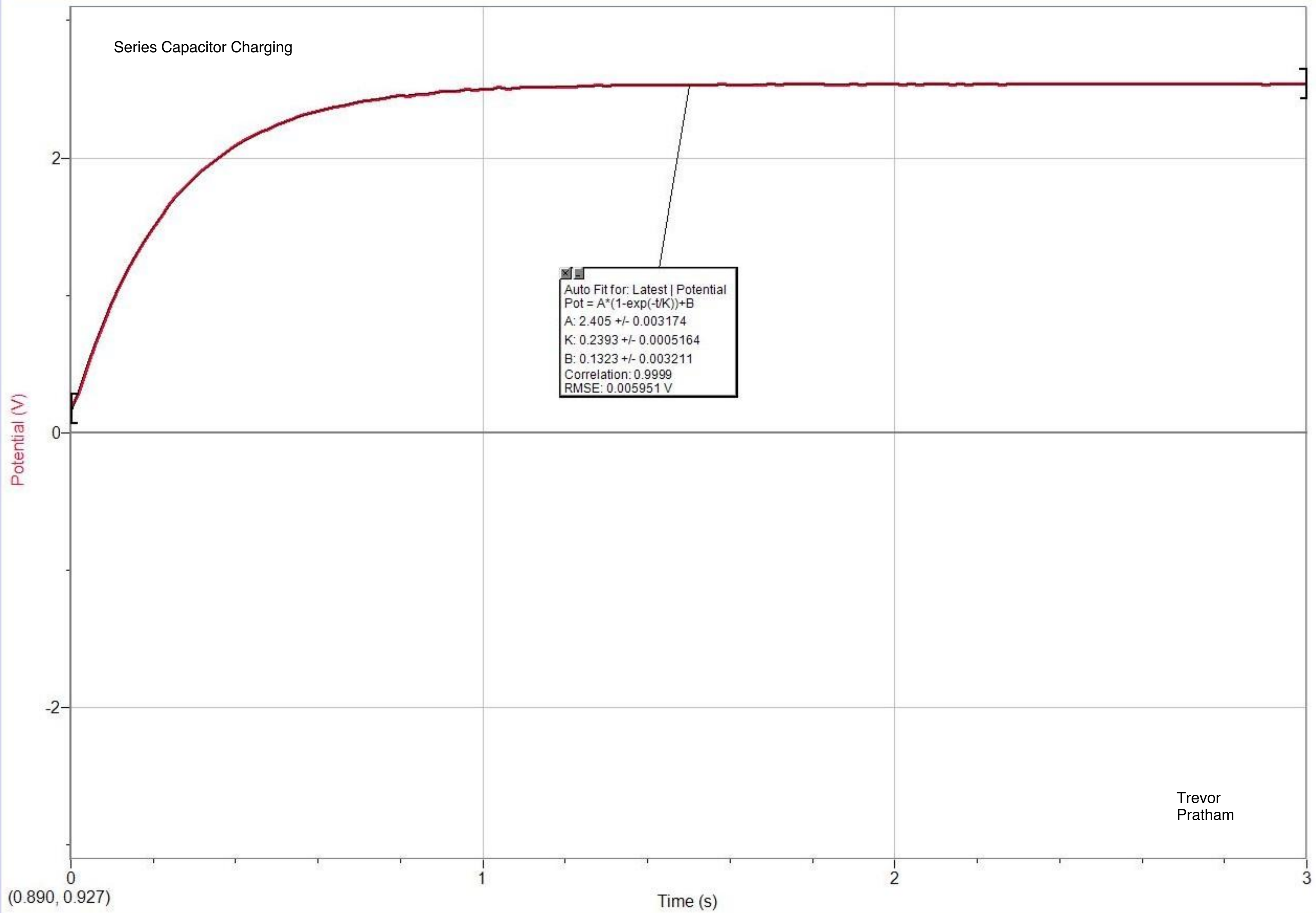

Discharging Capacitor
Potential (V)
2
0
-2
0
1
2
3
Time (s)
(1.243, 0.843)
Auto Fit for: Latest | Potential
Pot = A*(1-exp(-t/K))+B
A: -2.099 +/- 0.001227
K: 0.4745 +/- 0.0005334
B: 2.092 +/- 0.001277
Correlation: 1.000
RMSE: 0.003113 V
Trevor
Pratham

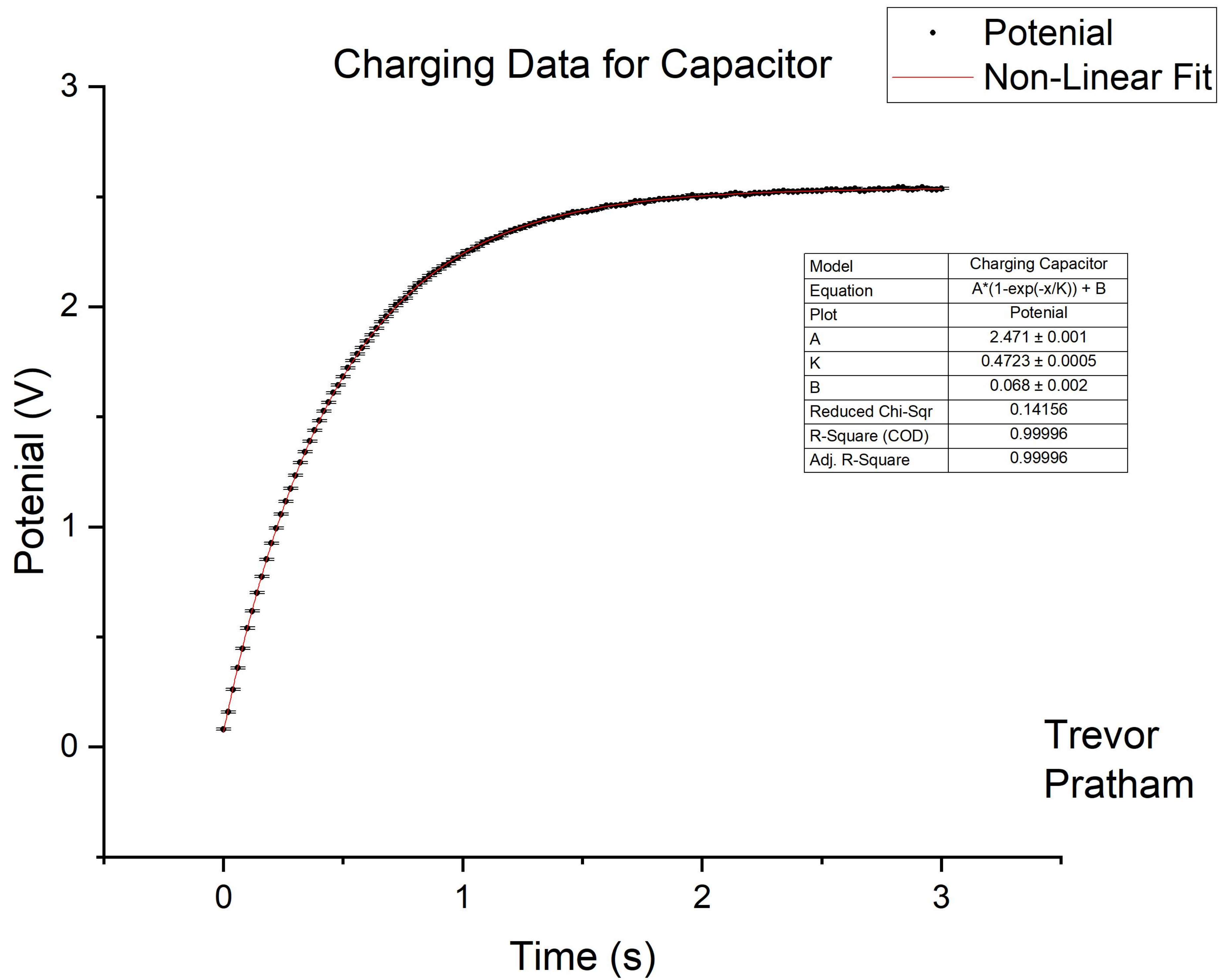


Discharging Resistor
Auto Fit for: Latest | Potential
Pot = A*exp(-t/K)+B
A: 2.250 +/- 0.001313
K: 0.4737 +/- 0.0005313
B: -0.004251 +/- 0.0004349
Correlation: 1.000
RMSE: 0.003329 V
Trevor
Pratham
Potential (V)
2
0
-2
0
1
2
3
Time (s)
(1.022, 0.927) (Δt:0.01 Δy:0.000)

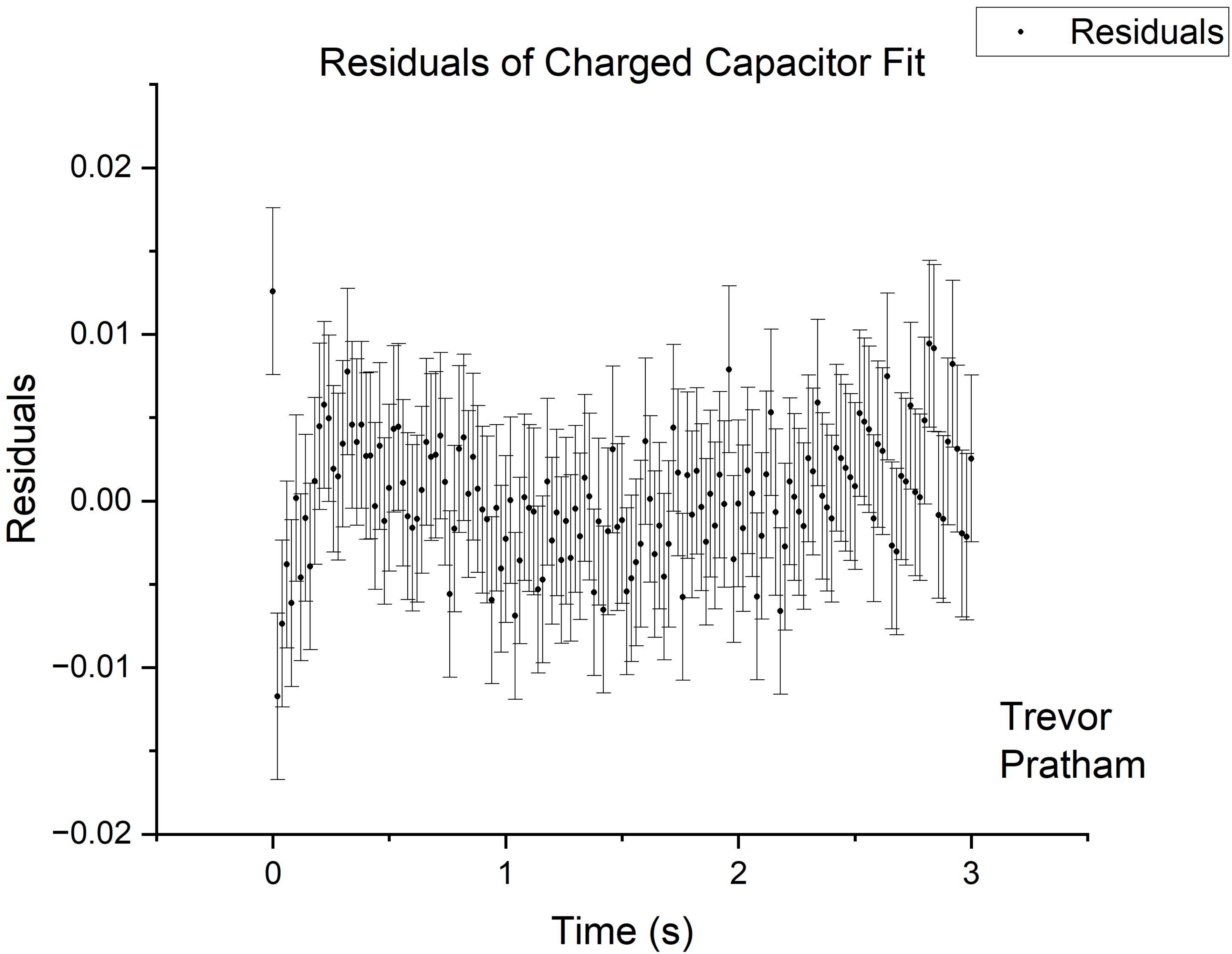


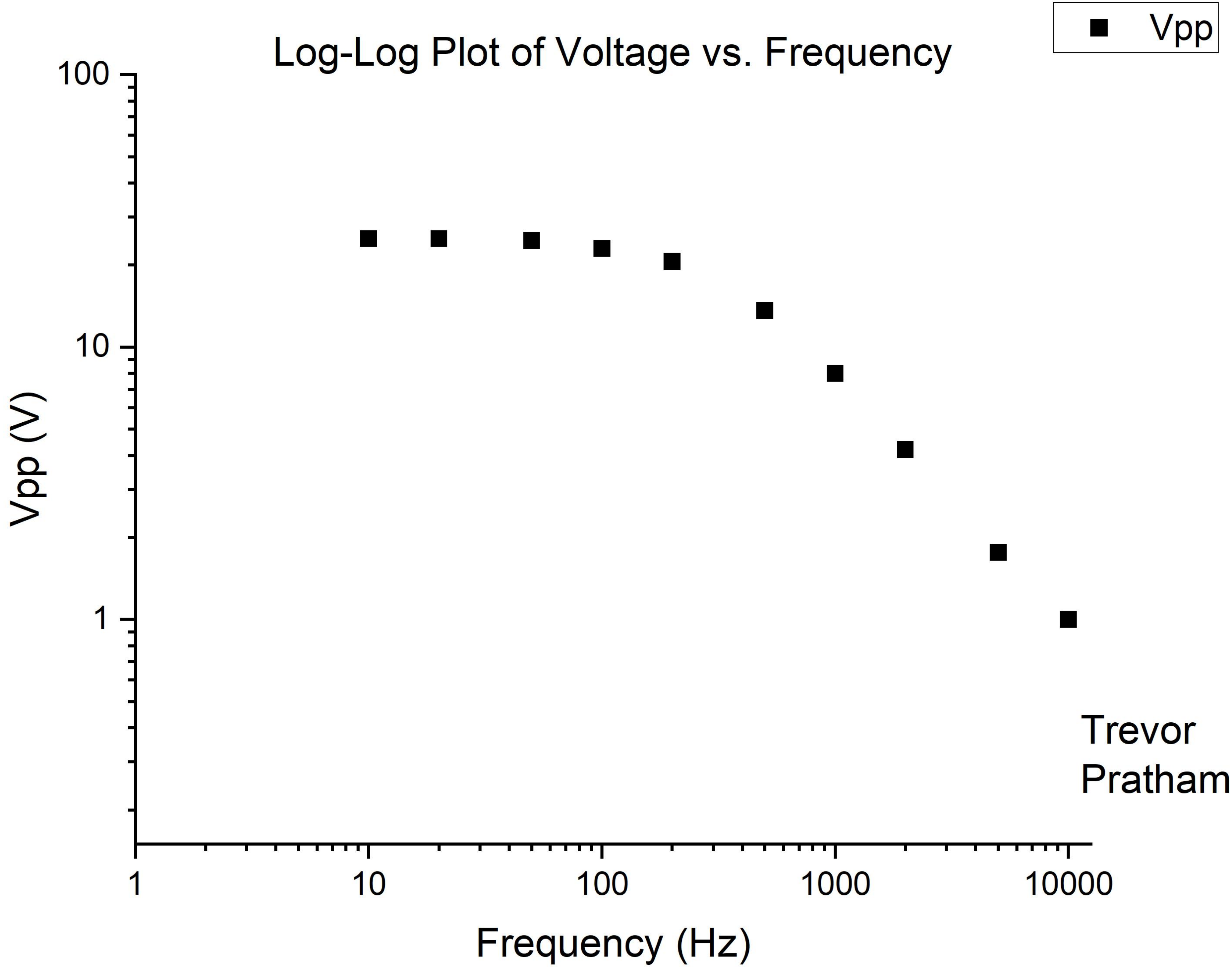
Parallel Capacitor Charging
Auto Fit for: Latest | Potential
Pot = A*(1-exp(-t/K))+B
A: 2.436 +/- 0.0008913
K: 0.9406 +/- 0.001024
B: 0.08636 +/- 0.0009321
Correlation: 1.000
RMSE: 0.002843 V
Trevor
Pratham
Potential (V)
2
0
-2
0
1
2
3
Time (s)


Series Capacitor Charging
Auto Fit for: Latest | Potential
Pot = A*(1-exp(-t/K))+B
A: 2.405 +/- 0.003174
K: 0.2393 +/- 0.0005164
B: 0.1323 +/- 0.003211
Correlation: 0.9999
RMSE: 0.005951 V
Potential (V)
Time (s)
(0.890, 0.927)
Trevor
Pratham



Charging Data for Capacitor
Potenial
Non-Linear Fit
Model | Charging Capacitor
Equation | A*(1-exp(-x/K)) + B
Plot | Potenial
A | 2.471 ± 0.001
K | 0.4723 ± 0.0005
B | 0.068 ± 0.002
Reduced Chi-Sqr | 0.14156
R-Square (COD) | 0.99996
Adj. R-Square | 0.99996
Potenial (V)
Time (s)
0
1
2
3
Trevor
Pratham


Residuals of Charged Capacitor Fit
Residuals
0.02
0.01
0.00
−0.01
−0.02
Residuals
0
1
2
3
Time (s)
Trevor
Pratham


Log-Log Plot of Voltage vs. Frequency
Vpp
100
10
1
Vpp (V)
1
10
100
1000
10000
Frequency (Hz)
Trevor
Pratham