The RC Circuit: Oscilloscope Study

Lab #5

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Objective

The objective of the lab is to measure the time constant of an RC circuit based on an oscilloscope.

Introduction

As written about in previous labs, for some charging capacitor in an RC circuit, meaning a circuit with a resistor, a capacitor, and a DC power source, it can be derived that $V = V_0(1 - e^{\frac{-t}{RC}}) = V_0(1 - e^{\frac{-t}{\tau}})$, where $\tau = RC$, signifying the time constant for the RC circuit. Since exponential functions must take a unitless input, the time constant as a result must also have a unit of seconds. As a result, we can say that when $t = \tau$, $V = V_0(1 - e^{-1}) = V_0(0.63)$, such that at that point, the voltage is equal to 63% of the maximum voltage it will achieve. Similarly, the discharging is described by the equation $V = V_0 e^{\frac{-t}{RC}} = V_0 e^{\frac{-t}{\tau}}$.

In an AC circuit, on the other hand, there does not need to be a cyclical current flow, due to it being unable to travel infinitely, but rather reversing itself after a brief period of time, discharging the capacitor again, such that it can be connected in series, creating alternating charging and discharging. As a result though, the time it takes to reach 63% of the maximum height can be found as tau.

Procedures and Results

First,

Capacitor 1:

$$C = 5100\mu F$$

$$R = 1350\Omega$$

Charging Time (s)	Charging Voltage (V)	Discharging Voltage (V)
0	0	8.87
4	3.48	5.48
8	5.47	3.37
12	6.8	2.12
16	7.53	1.43
20	8.06	0.9
24	8.31	0.6
28	8.51	0.38
32	8.63	0.26
36	8.72	0.17
40	8.77	0.12

Capacitor 2:

$$C = 4200\mu F$$

$$R = 1350\Omega$$

Charging Time (s)	Charging Voltage (V)	Discharging Voltage (V)
0	0	8.91
4	5.18	4.74
8	7.16	2.30
12	7.84	1.13
16	8.26	0.6
20	8.60	0.33
24	8.75	0.16
28	8.81	0.10
32	8.87	0.06
36	8.89	0.03
40	8.90	0.02

Discussion

Sample calculations for the non-measured data are as shown using the formulas found above:

$$\text{Average Slope (Capacitor 1)} = \frac{\text{Charging Slope} + \text{Discharging Slope}}{2} = \frac{-0.108 - 0.11}{2} = -0.1091/F{*}s$$

$$RC(\text{Measured, Capacitor 1}) = \frac{-1}{\text{Average Slope}} = \frac{-1}{-0.109} = 9.174F * s$$

$$RC(\text{Calculated, Capacitor 1}) = R * C = 5100 * 10^-6 * 1350 = 6.885F * s$$

$$\text{Percent Error (Capacitor 1)} = \frac{|\text{Expected - Actual}| * 100\%}{\text{Expected}} = \frac{|6.885 - 9.174| * 100\%}{6.885} = 33.2\%$$

Capacitor 1:

$V_0 = 8.87V$

Charging Time (s)	Charging $V_0 - V$	Charging $ln(V_0 - V)$	Discharging $ln(V)$
0	8.87	2.18	2.18
4	5.39	1.68	1.7
8	3.4	1.22	1.21
12	2.07	0.73	0.75
16	1.34	0.29	0.36
20	0.81	-0.21	-0.11
24	0.56	-0.58	-0.51
28	0.36	-1.02	-0.97
32	0.24	-1.43	-1.35
36	0.15	-1.9	-1.77
40	0.10	-2.3	-2.12

$$\text{Charging Slope} = -0.111/F*s$$

$$\text{Discharging Slope} = -0.1081/F*s$$

$$\text{Average Slope} = -0.1091/F*s$$

$$RC(\text{Measured}) = 9.174F*s$$

$$RC(\text{Calculated}) = 6.885$$

$$\text{Percent Error} = 33.2\%$$

Capacitor 2:

$V_0 = 8.91V$

Charging Time (s)	Charging $V_0 - V$	Charging $ln(V_0 - V)$	Discharging $ln(V)$
0	8.91	2.19	2.19
4	3.73	1.32	1.56
8	1.75	0.56	0.83
12	1.07	0.07	0.12
16	0.65	-0.43	-0.51
20	0.31	-1.17	-1.11
24	0.16	-1.83	-1.83
28	0.1	-2.3	-2.3
32	0.04	-3.22	-2.81
36	0.02	-3.91	-3.5
40	0.01	-4.61	-3.91

$$\text{Charging Slope} = -0.1651/F*s$$

$$\text{Discharging Slope} = -0.1541/F*s$$

$$\text{Average Slope} = -0.15951/F*s$$

$$RC(\text{Measured}) = 6.27F*s$$

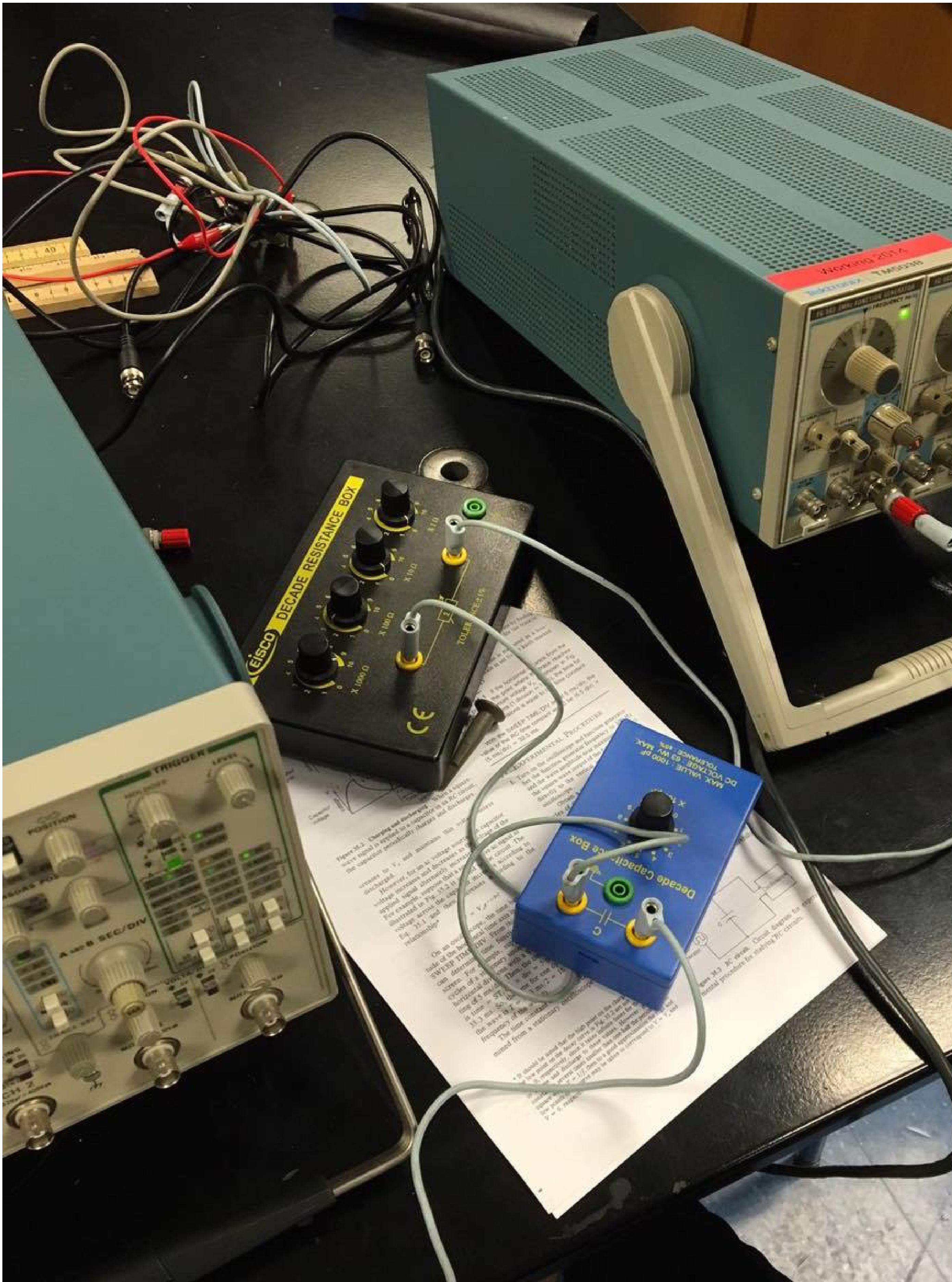
$$RC(\text{Calculated}) = 5.67$$

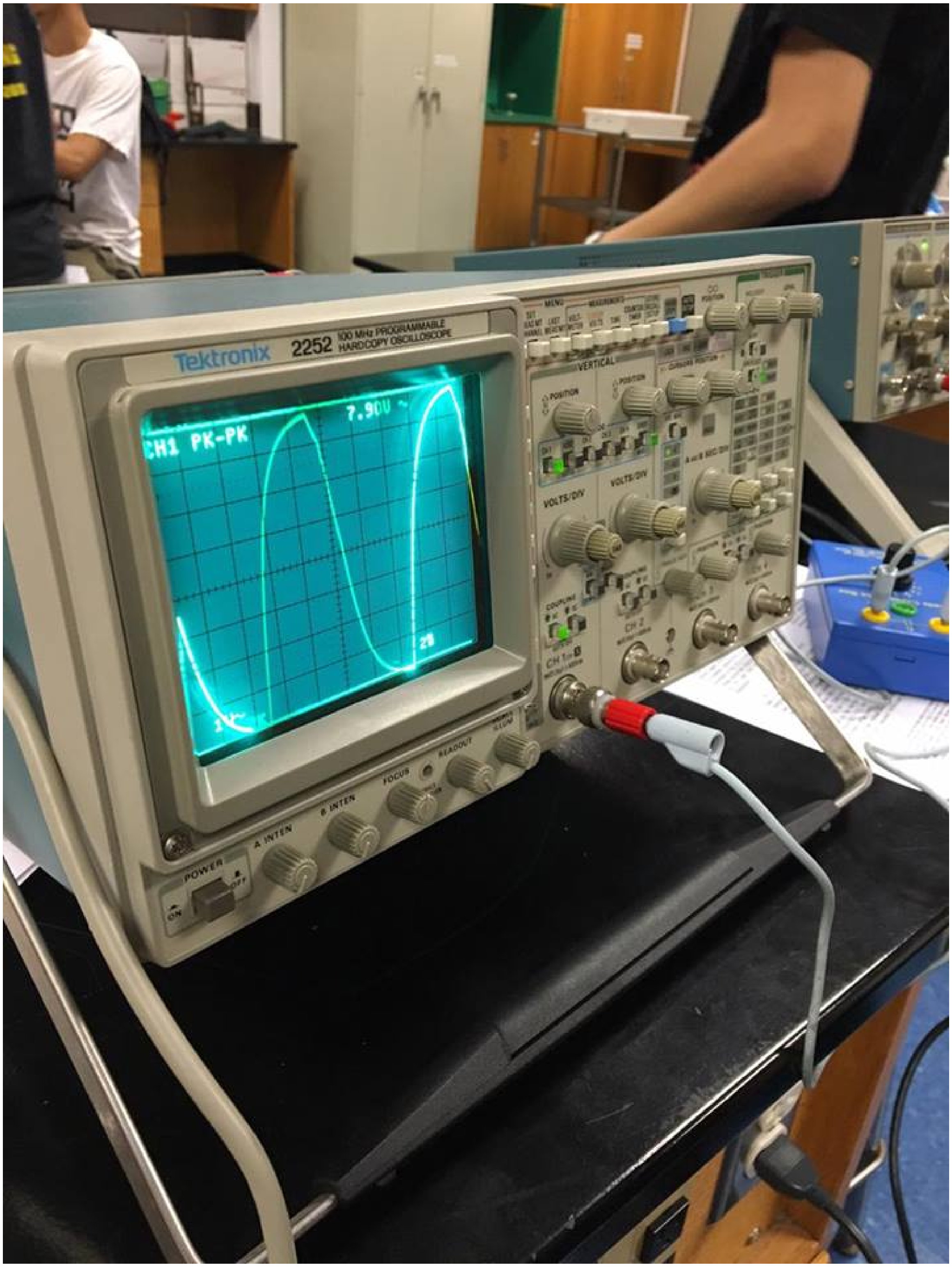
$$\text{Percent Error} = 10.6\%$$

The most likely cause of error is the inaccuracy of measuring such rapid change in the voltmeter reading, both due to the limitation of the voltmeter measurement rate itself, as well as in the human capacity of record the change quickly enough. In addition, since the wires themselves are not ideal, there is some resistance from that, such that the measured RC value would be likely higher than the calculated value, due to the added in series resistance of the wire. In addition, the non-ideal voltmeter most likely would not have an infinitely high resistance, changing the flow of current.

Conclusion

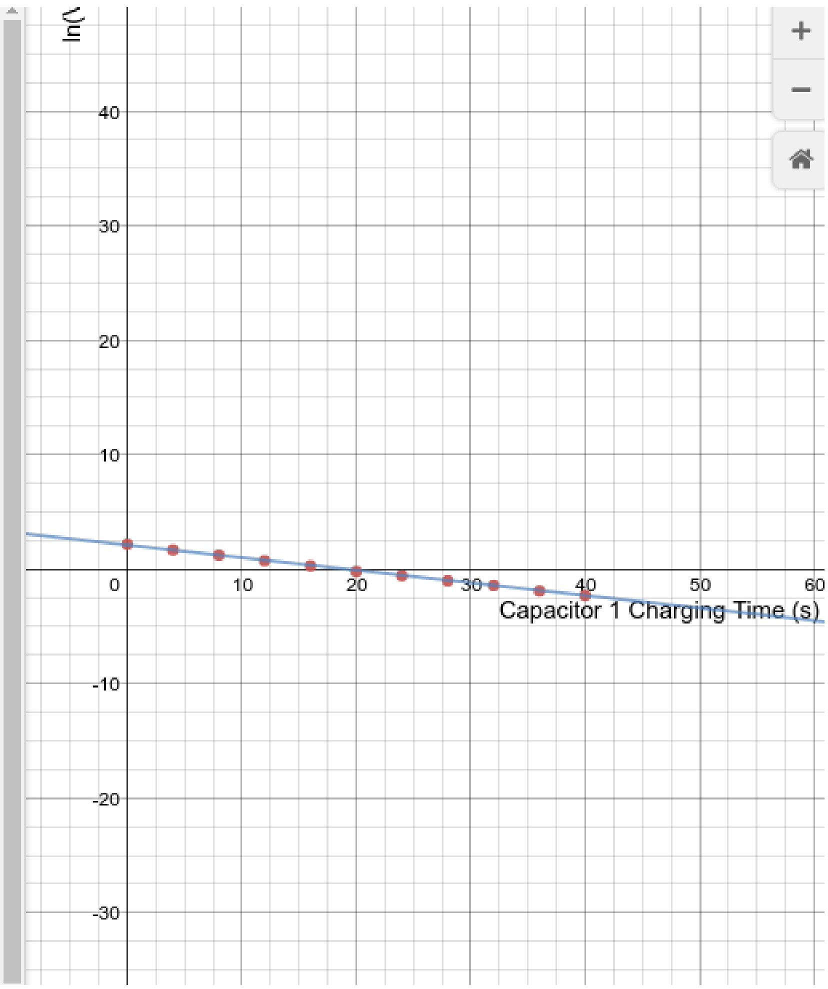
The capacitor with a capacitance of 4200 μF with a resistor of 1350 Ω measured an RC constant of 6.27 F*s to the actual RC of 5.67 F*s, with a percent error of 10.6%. The capacitor with a capacitance of 5100 μF with a resistor of 1350 Ω measured an RC constant of 9.174 F*s to the actual RC of 6.885 F*s, with a percent error of 33.2%.


DECADE RESISTANCE BOX
eisco
Working 2014
Decade Capacitance Box
TRIGGER
POSITION


Tektronix
2252
100 MHz PROGRAMMABLE HARDCOPY OSCILLOSCOPE
CH1 PK-PK
7.90V
VERTICAL
VOLTS/DIV
POWER
A INTEN
B INTEN
FOCUS
READOUT

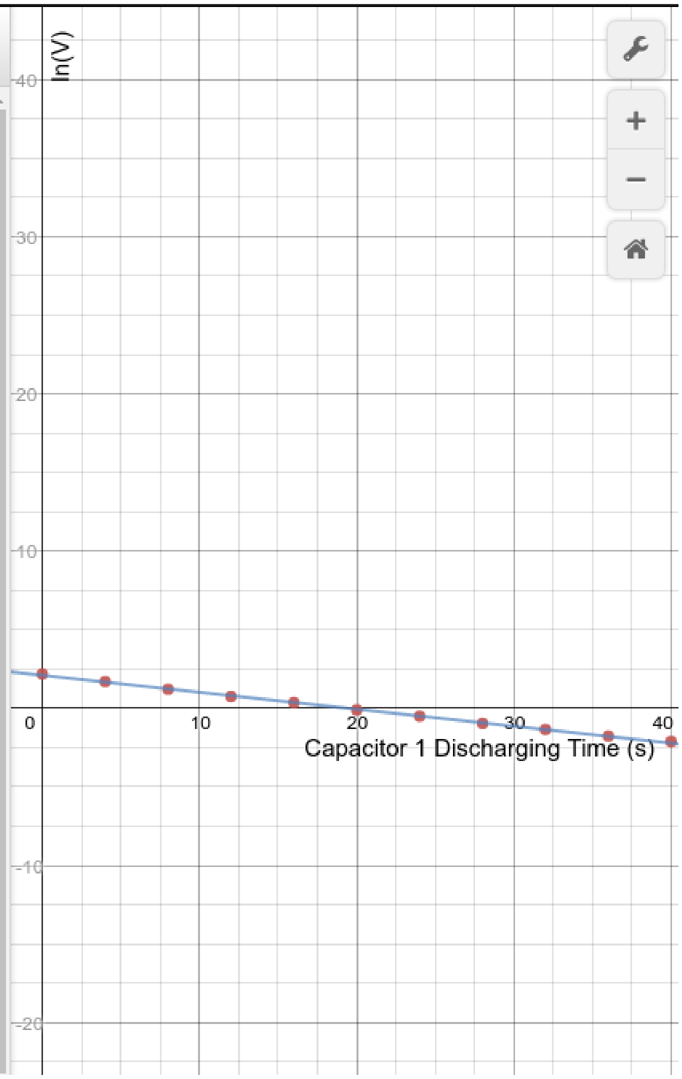
x	y
28	−1.02
32	−1.43
36	−1.9
40	−2.3
0	2.18
4	1.68
8	1.22
12	0.73
16	0.29
20	−0.21
24	−0.58

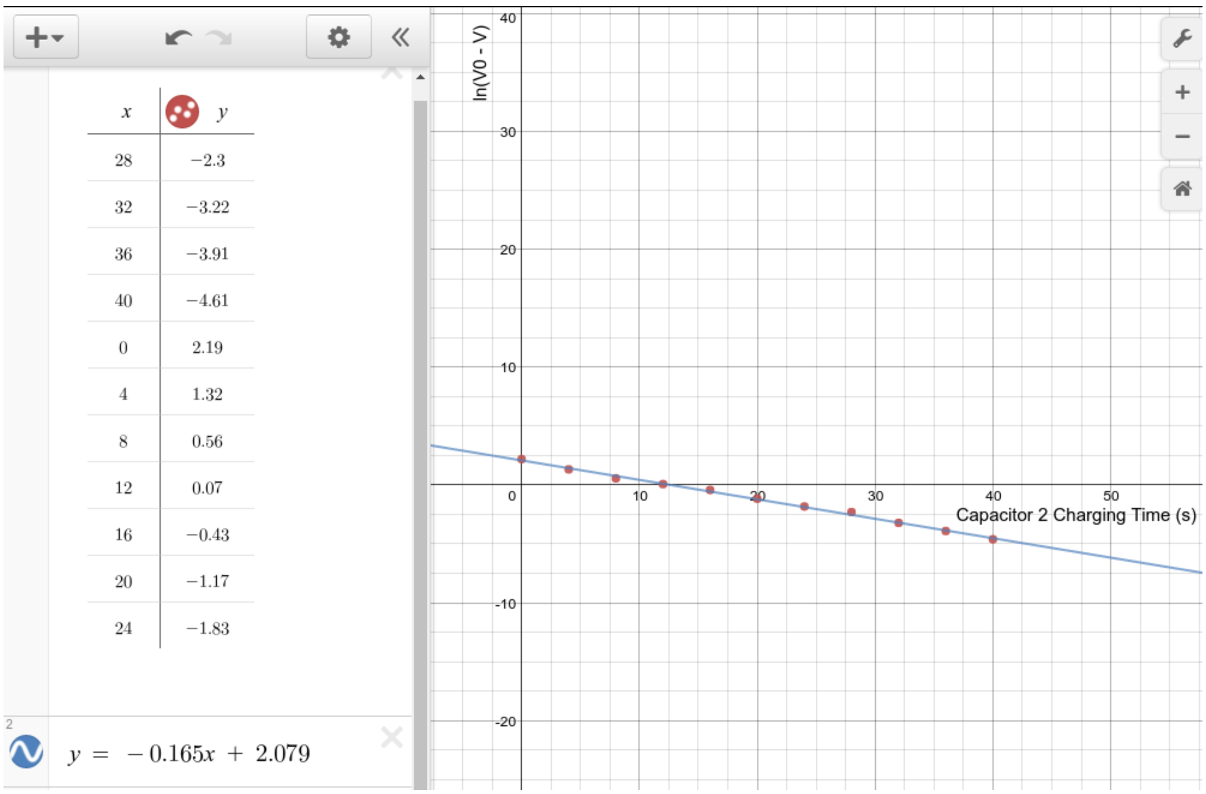
$$y = -0.11x + 2.11$$



x	y
28	−0.97
32	−1.35
36	−1.77
40	−2.12
0	2.18
4	1.7
8	1.21
12	0.75
16	0.36
20	−0.11
24	−0.51

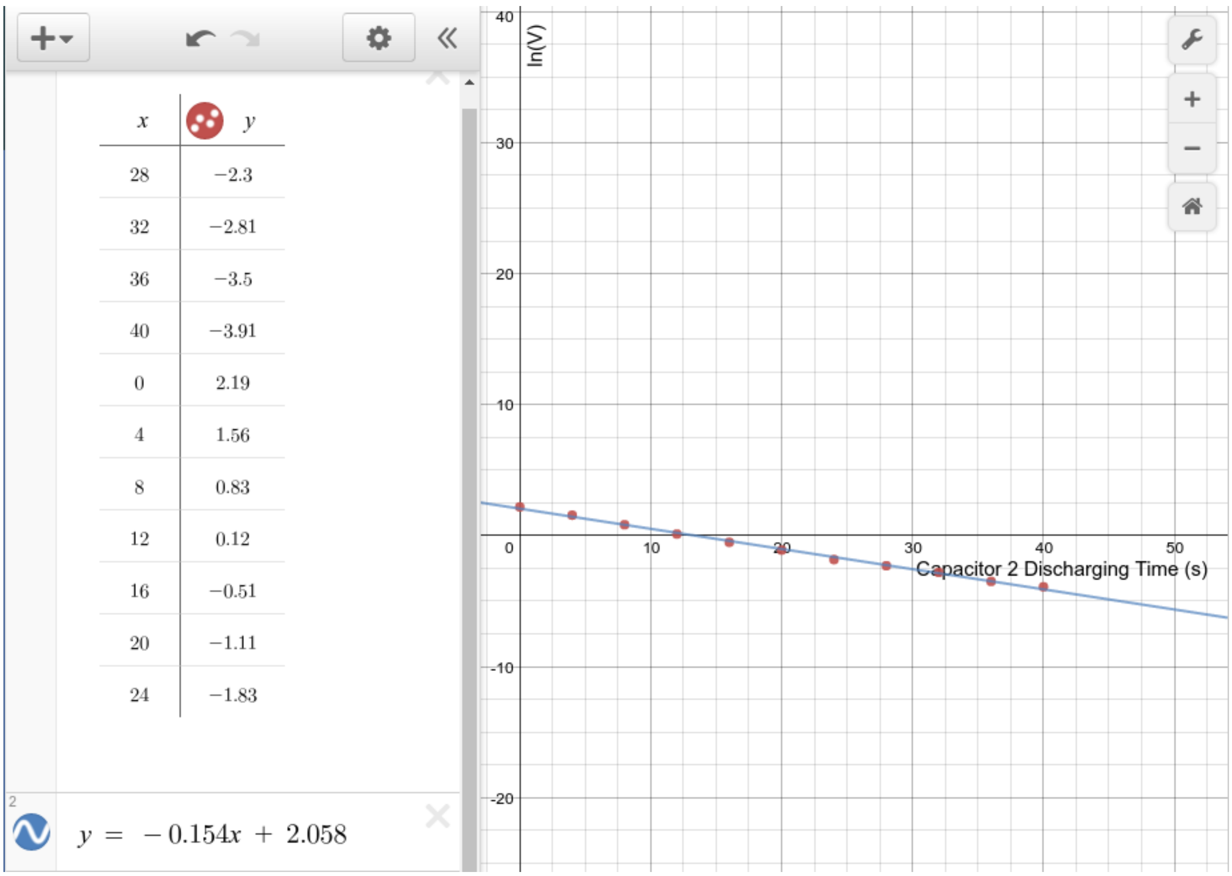
$$y = -0.108x + 2.096$$





x	y
28	−2.3
32	−3.22
36	−3.91
40	−4.61
0	2.19
4	1.32
8	0.56
12	0.07
16	−0.43
20	−1.17
24	−1.83

$y = -0.165x + 2.079$


x y
28 −2.3
32 −2.81
36 −3.5
40 −3.91
0 2.19
4 1.56
8 0.83
12 0.12
16 −0.51
20 −1.11
24 −1.83
y = − 0.154x + 2.058
ln(V)
Capacitor 2 Discharging Time (s)
40
30
20
10
0
-10
-20
10
20
30
40
50