RC Circuits

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This Experiment is to find the capacitance of the various capacitors in different circuit situations, the first being 1 capacitor and resistor in series, the second is 2 capacitors and 1 resistor in series and the third is 2 capacitors in parallel both in series with a resistor. The time constant for each situation was calculated and was used to find the point when 63% of the charge for each circuit was used up. With this a graph could be made and the values for the actual time constant and the actual capacitance can be found and these were all find to be within .3% and 14% of the expected values.

Section I: Background

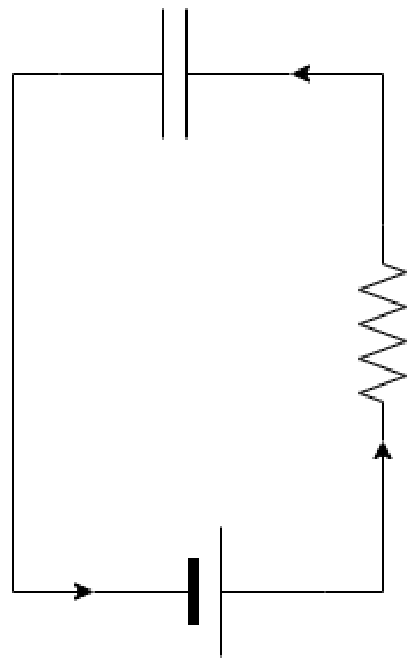
An RC circuit is a type of electrical circuit consisting of any number of 1 or more Resistors and Capacitators in either series or parallel. A resistor is a circuit component that can very in value of resistivity which is measured in ohms, and the use of the component is to provide a point of resistance in the circuit. A capacitator is another type of circuit component which typically consists of two metal plates with separation between them, which when a current is passed through the component the charge of the plates become opposite which creates an electric field between the two plates, which allows the capacitator to be charged up and de-charged. Capacitators are measured by their capacitance which is the amount they can be charged up. A circuit in series means the flow of electrons passes through every single component and has only a single route to take to complete the circuit, whereas a parallel circuit the electrons have multiple paths to take to complete the circuit and don't go through every component. The combination of resistor and capacitator in either series, parallel or both, change the rate of charge and discharge of capacitator because of the electrons travel through the circuit, which will demonstrate by the experiment.

Section II: Theory and Procedure

The purpose of the experiment is to compare the expected time constant for the discharging of various capacitators in different scenarios, being by itself, in series with another capacitator and in parallel with another capacitator. The variation in the circuits provide different cases where the charge and discharge of capacitor occur differently because of the properties that being series or parallel can have on a component in a circuit.

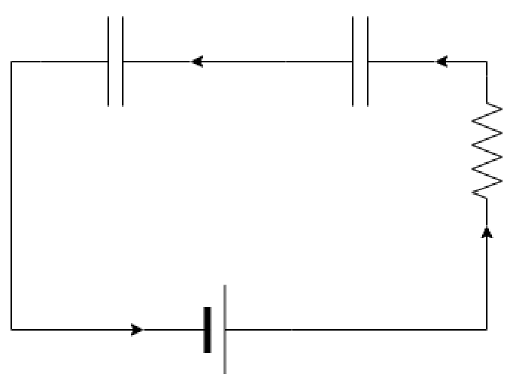
The process for each circuit is the same, the circuit will be gradually brought up to the voltage level of 4.8 V, once there the recording of the voltage was started and then the circuit was disconnected from the power supply where the data will be recorded until it reaches the time constant, which for the voltage level the experiment is done at, is at 1.656 V remaining which is about 63% discharged. The time constant is a calculated value for the amount of time for the charge of a capacitator to be reduced 63% from the max or initial value.

Situation I: 1 Capacitor and Resistor



This Situation has the Resistor and Capacitor in series. The capacitance is measured at .0000033 and the resistor value is 21800 Ohms.

Situation II: 2 Capacitors and 1 Resistor

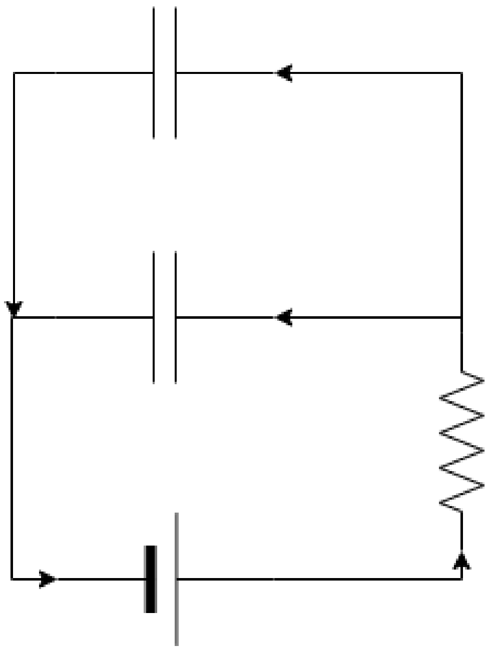


This Situation has the resistor and the 2 capacitors in series with each other. The equivalent capacitance for the two capacitors is .0000065 and the resistance is still 21800.

The equation for finding equivalent capacitance in series is the following.

$$C_{eq} = \frac{1}{\left(\frac{1}{C_1}\right)+\left(\frac{1}{C_2}\right)+\left(\frac{1}{C_n}\right)} \text{ [1]}$$

Situation III: 2 Capacitors and 1 Resistor



This situation consists of two capacitors both in series with the resistor but in parallel to each other. The equivalent capacitance for a circuit in parallel is .0000066 and the resistance is the same.

The equation for the finding the equivalent capacitance in parallel is the following.

$$C_{eq} = C_1 + C_2 + C_n$$

Section III: Results

The results for the three situations are as follows.

The first situation is a single capacitor and resistor in series, with the following values.

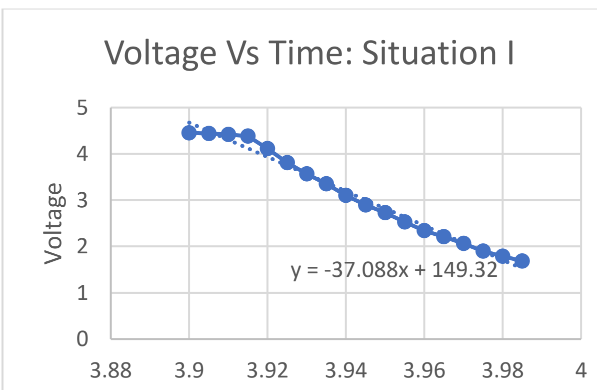
Name	Value
Resistor	21800
Capacitance	.0000033
Expected Time Constant	.07194
Measured Time Constant	.07
Percent Difference	2.77%

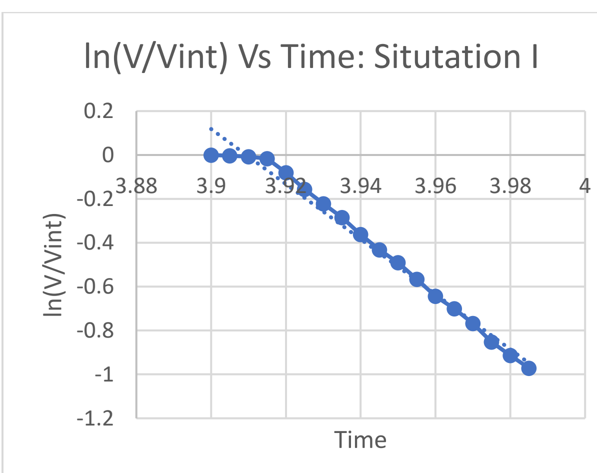
Time (s)	Voltage (V)
3.9	4.454
3.905	4.438
3.91	4.419
3.915	4.383
3.92	4.111
3.925	3.807
3.93	3.568
3.935	3.348
3.94	3.099
3.945	2.891
3.95	2.726
3.955	2.528
3.96	2.341
3.965	2.211
3.97	2.066
3.975	1.899
3.98	1.788
3.985	1.686

Time (s)	ln(V/Vint)
3.9	0
3.905	-0.0035987
3.91	-0.0078891
3.915	-0.0160691
3.92	-0.0801363
3.925	-0.1569611
3.93	-0.2217974

3.935	-0.2854394
3.94	-0.3627231
3.945	-0.4322001
3.95	-0.4909672
3.955	-0.5663741
3.96	-0.6432244
3.965	-0.7003577
3.97	-0.7681882
3.975	-0.8524751
3.98	-0.9127049
3.985	-0.9714437

From the above two tables a decaying trend for the data which is what is expected due the removal of the power source the charge in the capacitor will decrease as it goes through the circuit.





The two graphs support the discharging of the capacitor over time. To test the accuracy of the data collected the following equation can be used to the get the capacitance using the slope of the graph.

$$C = \frac{-1}{Slope * R} \quad [1]$$

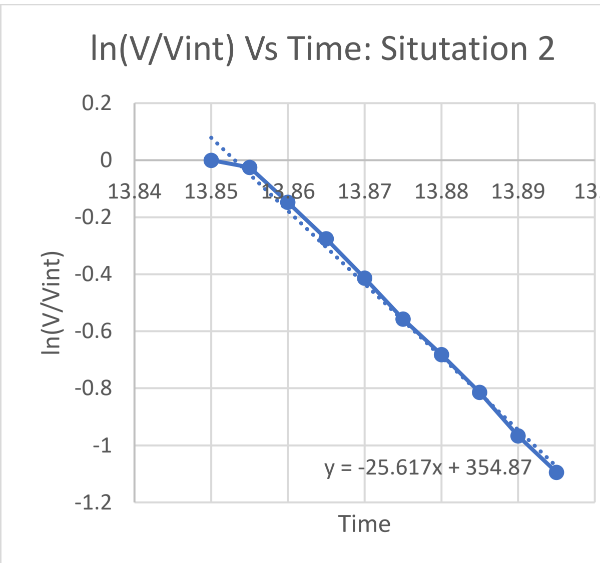
Name	Value
Measured Capacitance	.0000033
Calculated Capacitance	.0000036
Percent Difference	9.7%

The second situation is two capacitors and a resistor all in series, with the following values.

Name	Value
Resistor	21800
Capacitance	.00000165
Expected Time Constant	.03597
Measured Time Constant	.042
Percent Difference	14.35%

Time (s)	Voltage (V)
13.85	4.522
13.855	4.408
13.86	3.902
13.865	3.435
13.87	2.99
13.875	2.59
13.88	2.287
13.885	2.003
13.89	1.72
13.895	1.514

Time (s)	ln(V/Vint)
13.85	0
13.855	-0.0255333
13.86	-0.14746513
13.865	-0.27493745
13.87	-0.41368099
13.875	-0.5572965
13.88	-0.68171346
13.885	-0.81430832
13.89	-0.96663008
13.895	-1.09419922



To test the accuracy of this data we need to use same previous equation using slope and resistor.

Name	Value
Measured Capacitance	.0000033
Calculated Capacitance	.0000018
Percent Difference	7.8%

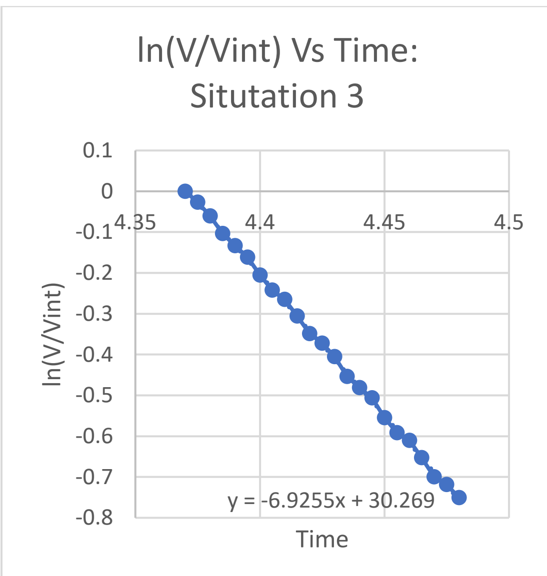
The third situation is two capacitors each in series with the resistor but in parallel to each other, with the following values.

Name	Value
Resistor	21800
Capacitance	.0000066
Expected Time Constant	.14388
Measured Time Constant	.14
Percent Difference	2.77%

Time (s)	Voltage (V)
4.37	3.458
4.375	3.367
4.38	3.256
4.385	3.117
4.39	3.025
4.395	2.943
4.4	2.815
4.405	2.715
4.41	2.652
4.415	2.547
4.42	2.439
4.425	2.383
4.43	2.306
4.435	2.197
4.44	2.137
4.445	2.084
4.45	1.986
4.455	1.914
4.46	1.878
4.465	1.8
4.47	1.718
4.475	1.686
4.48	1.632

Time (s)	ln(V/Vint)
4.37	3.458
4.375	3.367
4.38	3.256
4.385	3.117
4.39	3.025
4.395	2.943
4.4	2.815
4.405	2.715
4.41	2.652

4.415	2.547
4.42	2.439
4.425	2.383
4.43	2.306
4.435	2.197
4.44	2.137
4.445	2.084
4.45	1.986
4.455	1.914
4.46	1.878
4.465	1.8
4.47	1.718
4.475	1.686
4.48	1.632



To test the accuracy of this data, the previous equation must be used using the slope and the resistance to find the capacitance.

Name	Value
Measured Capacitance	.0000066
Calculated Capacitance	.00000662
Percent Difference	.35%

From these three situations it can be concluded that capacitors discharge faster in parallel, then in series, and the measured values match the calculated values.

The discrepancy causing the percent differences can be attributed to inaccurate/precise data, because when doing the math for the measured time constant, the numbers did not always match up exactly so an estimation would be made to try and get the 63% gone time

Section IV: References

[1] Department of Physical Sciences. “RC Circuits.” Daytona Beach: Embry-Riddle Aeronautical University, 2016. PDF File