

2320271

by Lewis Bell

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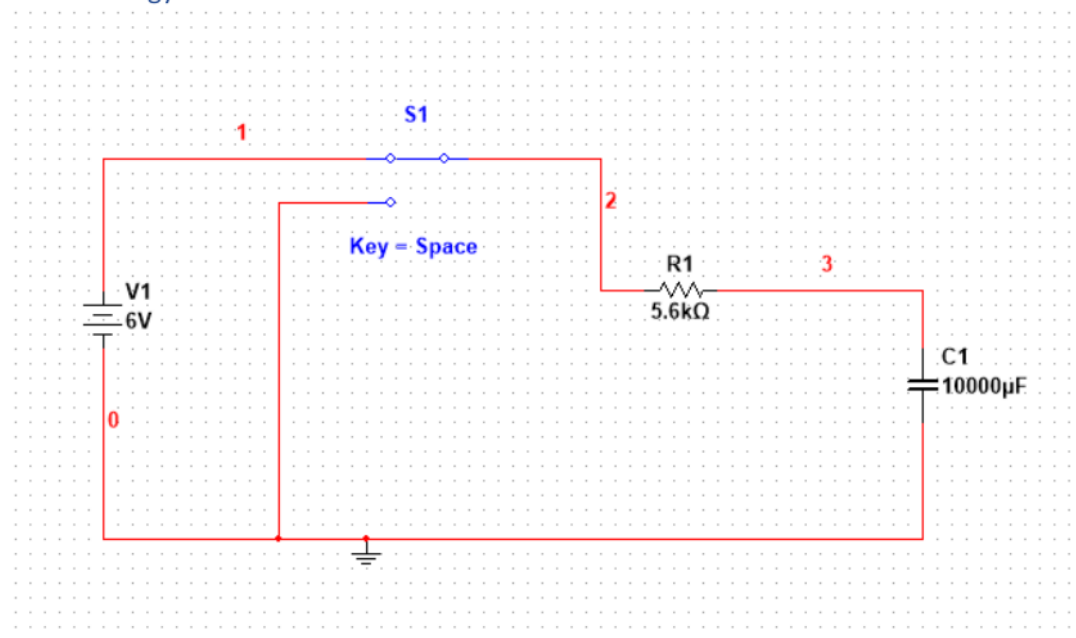
Introduction

This assignment documents the behavior of RC and RL circuits when connected to a direct current voltage source. A variety of tests will be conducted on each circuit, encompassing calculations, simulations and practical experiments. Subsequently all findings and results will be compared throughout.

Task 1: Transient Behavior for a Charging Capacitor

Given that certain values for the resistor and capacitor were chosen to provide an appropriate time constant that is long enough to observe practically and also provides a nice smooth increase in voltage across the capacitor as shown in graphs to come, this task specifically illustrates the transient behavior of a capacitor that is being charged within the circuit.

Methodology Simulated



Shown above is the DC transient circuit created and used on multi-sim for a charging capacitor. Used within this circuit are a 6V DC supply, 5.6kΩ resistor and a 10000μF capacitor. This circuit was used to provide results on the behavior of the DC transient at the unique values chosen.

Methodology Practical

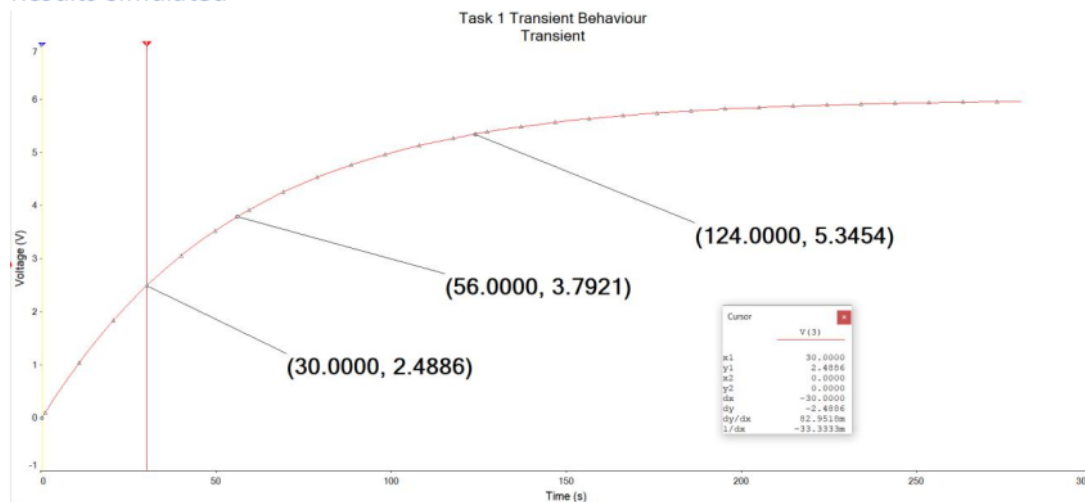
During this task an RC circuit was constructed on a circuit board, voltage and current readings were then taken using two multimeters and fused leads, this was also timed for 5 minutes as after 5 minutes the charged capacitor would then be at its steady state error



Methodology Calculated

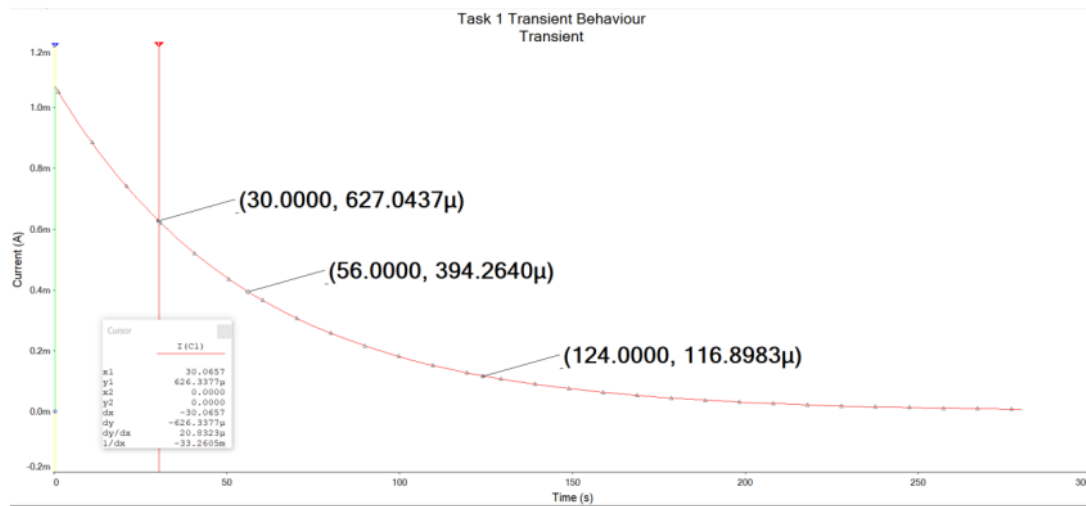
3 unique time values were chosen for this task which were 30s, 56s and 120s. These values were then put into an exponential equation and the capacitor voltage and current was calculated at the given times.

Results Simulated



In the graph above provided by multi-sim results show that voltage starts at 0V, as time goes on the transients voltage continues to grow before reaching 5τ which is its max voltage of nearly 6V. Once the transient reaches 5τ , its then at its steady state where the voltage balances out. All Voltage result values at chosen times are shown within this image.

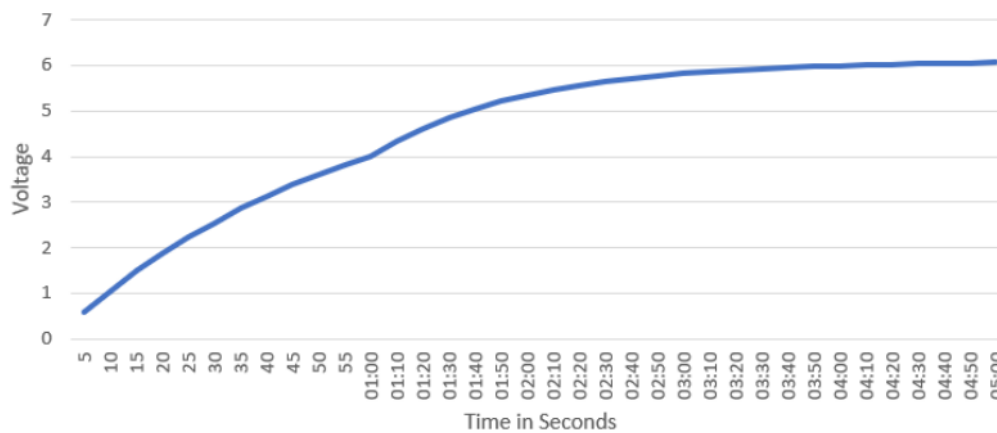




The graph above shows that the current starts at I_{max} and continues to decrease steadily in value until 5τ , this is due to the fact at 5τ the steady state has been reached. All current result values at chosen times are shown within this image.

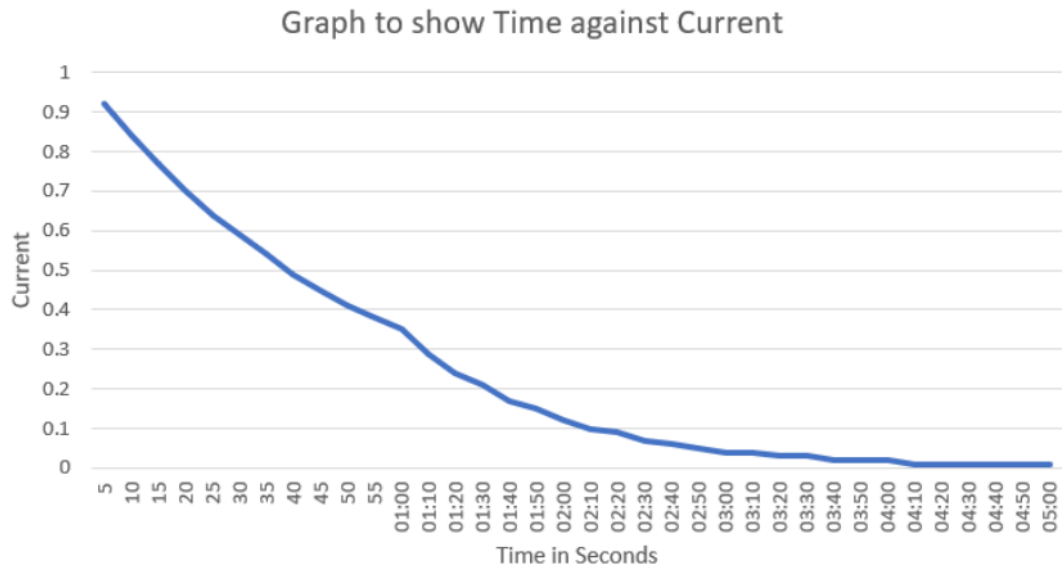
Results Practical

Graph to show Time against Voltage



Shown in the image above is the graph provided by the voltage readings from the multimeter at given times, every 5 seconds for the first minute then every 10 seconds for the next 4 minutes. The graph shows that the voltage is certainly increasing showing the feedback is positive and after 5τ the voltage increase reaches its steady state.

All results to create the graph above are shown within the appendix labelled as 'Figure 1'.



Pictured above is the graph provided by the current readings from the multimeter at given times, every 5 seconds for the first minute then every 10 seconds for the next 4 minutes. It is clear from the graph that the current soon decreases before maintaining the steady state after five minutes.

All results to create the graph above are shown within the appendix labelled as 'Figure 2'.

Results Calculated

$$\tau = R \times C = 5600 \times 10000 \times 10^{-6}$$

$$\tau = 56 \text{ Seconds}$$

$$5\tau = 56 \times 5 = 280 \text{ Seconds (Steady State Error)}$$

Calculation to find 3 voltage values using an exponential equation at the chosen times;

$$V_c = V(e^{-t/\tau})$$

$$30s = V_c = 6(1 - e^{-30/56}) = 2.488V$$

$$56s = V_c = 6(1 - e^{-56/56}) = 3.792V$$

$$124s = V_c = 6(1 - e^{-124/56}) = 5.334V$$

Prior to calculating the current values, I_{max} must be calculated using the following equation;

$$I_{max} = V_s \div R$$
$$I_{max} = 6 \div 5.6(5.6 \times 10^3) = 1.071mA$$

Calculation to find 3 current values using an exponential equation at the chosen times;

$$Time(S) = I_{max}(e^{-t/T})$$
$$30s = I_c = 1.07(e^{-30/56}) = 0.6262A$$
$$56s = I_c = 1.07(e^{-56/56}) = 0.3936A$$
$$124s = I_c = 1.07(e^{-124/56}) = 0.1168A$$

Analysis

	30 Seconds	56 Seconds	124 Seconds
Calculated	2.488V	3.792V	5.296V
Simulated	2.4886V	3.7921V	5.3454V
Practical	2.55V	3.87V	5.41V

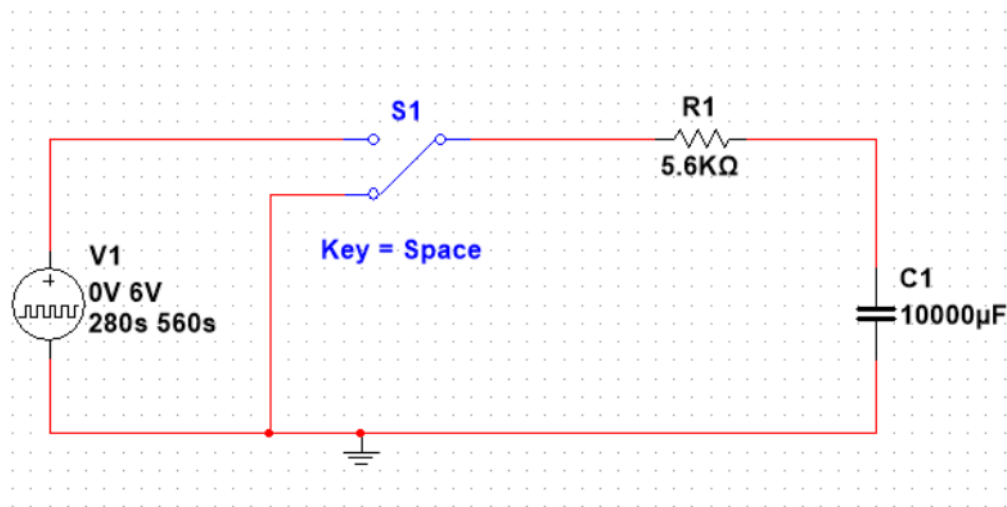
The table above provides the voltage results for calculated, simulated and also practical. The differences observed in the charge values from the calculated results and the practical experiment are more pronounced, this could possibly be human error, exact times were unable to be taken due to the times being off by milli seconds at each stop. Other reasonings for this could be the resistance in the fused leads or loose connections. There are subtle variations between calculated and simulated results, this could be attributed towards rounding of numbers.

	30 Seconds	56 Seconds	124 Seconds
Calculated	0.6262A	0.3936A	0.1168A
Simulated	0.627A	0.394A	0.116A
Practical	0.59A	0.38A	0.11A

The table below provides the current results for calculated, simulated and also practical. The differences observed in the charge values from the calculated results and the practical experiment are more pronounced, this could possibly be human error, exact times were unable to be taken due to the times being off by milli seconds at each stop  11 Other reasonings for this could be the resistance in the fused leads or loose connections. While there are subtle variations between calculated and simulated results, this could be attributed towards rounding of numbers.

Task 2: Transient Behavior For a Discharging Capacitor

Methodology Simulated



The DC transient circuit for a discharging capacitor that was developed and used on Multisim is displayed above. A 10000μF capacitor, 5.6KΩ resistor, and 6V DC pulse supply are used in this circuit. Results about the DC transient's behavior at the particular values selected were obtained using this circuit.

Methodology Practical

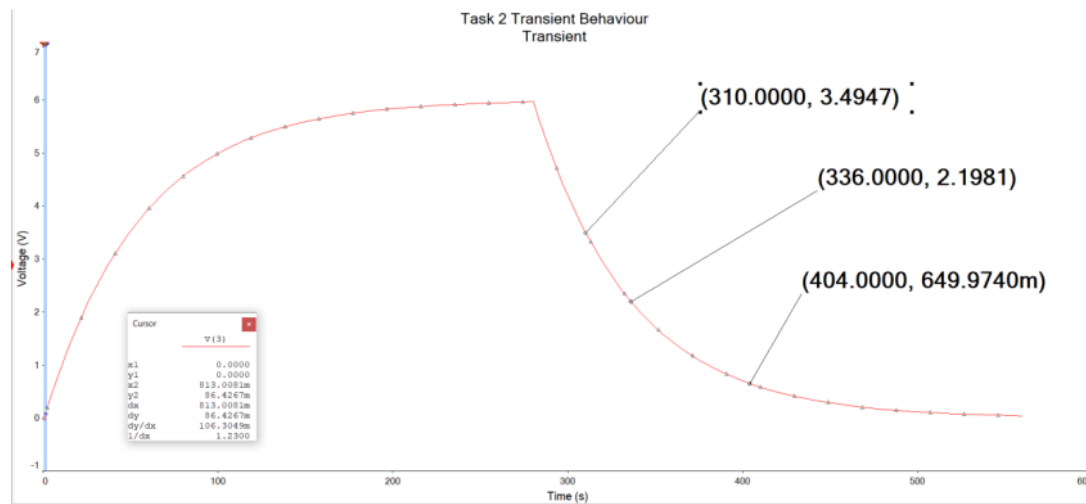
This task involved building an RC circuit on a circuit board, then timing it for five minutes so that after five minutes the capacitor would have discharged and the results could be used since they would be at their steady state  12. Voltage and current readings were then taken using two multimeters and fused leads.

Methodology Calculated

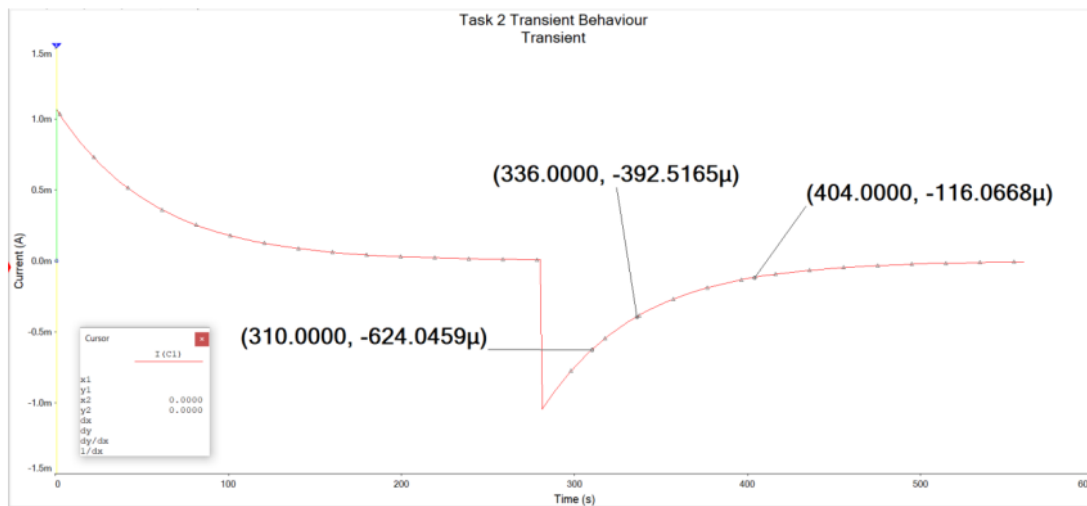
Three different time values 30s, 56s, and 124 seconds were used for this exercise. Following that, an exponential equation was utilised to determine the capacitor's voltage and current at each instant.



Result Simulated

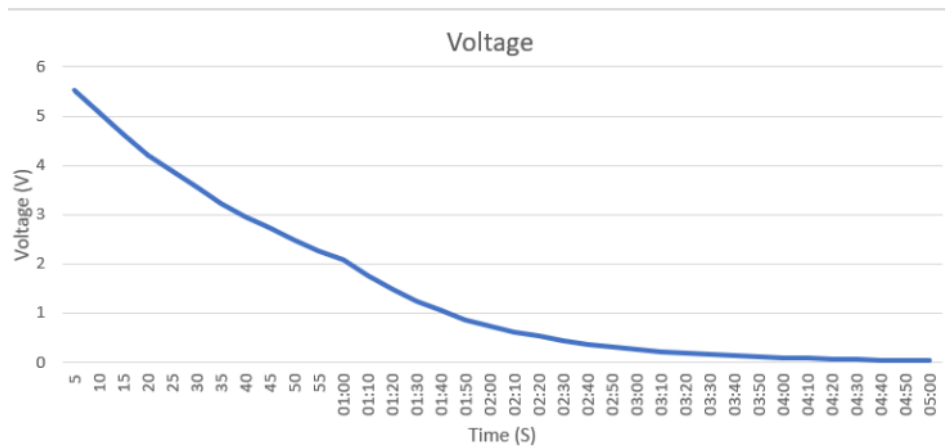


Pictured above is the graph provided by multi-sim with the voltage discharge results labelled at each chosen time.



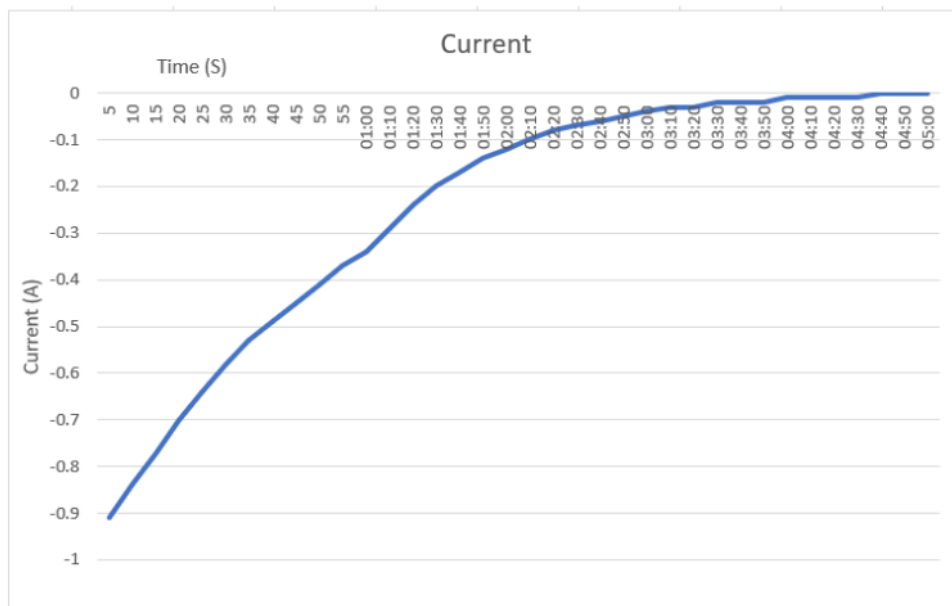
Pictured above is the graph provided by multi-sim with the current discharge results labelled at each chosen time.

Results Practical



The graph produced by the voltage readings from the multimeter at specific intervals, every 5 seconds for the first minute and every 10 seconds for the following 4 minutes is seen in the image above. The graph indicates that the voltage will undoubtedly drop until it hits 5τ , or steady state.

All results to create the graph above are shown within the appendix labelled as 'Figure 3'.



Shown in the graph above are the results from the multimeter used within the practical experiment. It is evident from the graph that the current is increasing until its at its steady state of 5τ .

All results to create the graph above are shown within the appendix labelled as 'Figure 4'

Results Calculated

Calculation to find 3 voltage values using an exponential equation at the chosen times;

$$V_c = V(e^{-t/\tau})$$

$$30s = V_c = 6(e^{-30/56}) = 3.5115V$$

$$14s = V_c = 6(e^{-56/56}) = 2.2072V$$

$$124s = V_c = 6(e^{-124/56}) = 0.6553V$$

Prior to calculating the current values, I_{max} must be calculated using the following equation;

$$I_c = -I_{max}(e^{-t/\tau})$$

$$I_{max} = V_s \div R = 6 \div 5.6(5.6 \times 10^3) = 1.071mA$$

Calculation to find 3 current values using an exponential equation at the chosen times:

$$I_c = -I_{max}(e^{-t/\tau})$$

$$30s = I_c = -1.071(e^{-30/56}) = -0.626A$$

$$56s = I_c = -1.071(e^{-56/56}) = -0.393A$$

$$124s = I_c = -1.071(e^{-124/56}) = -0.116A$$

Analysis

	30 Seconds	56 Seconds	124 Seconds
Calculated	3.5115V	2.2072V	0.6553V
Simulated	3.4947V	2.1981V	0.649V
Practical	3.56V	2.25V	0.69A

The voltage findings for calculated, simulated, and practical scenarios are shown in the table above. The discharge numbers from the practical experiment and the calculated findings varied more than from each other. This discrepancy could be the consequence of human error; the times at each pause were milliseconds off, making it impossible to determine exact times. Additional explanations for this could include loose connections or resistance in the fused leads. Although there are minor differences between the simulated and calculated outcomes, this could be explained by how the numbers are rounded during calculations.

	30 Seconds	56 Seconds	124 Seconds
Calculated	-0.626A	-0.393A	-0.116A
Simulated	-624.0459	-392.5165A	-0.1160668A
Practical	-0.58A	-0.37A	-0.11A

Present calculated, simulated, and practical findings are shown in the table above. The observed discrepancies between the discharge levels in the calculated findings and the actual experiment are more noticeable; these variances may be the consequence of human error, the times at each pause were out by milliseconds, making it impossible to determine exact times. Loose connections or resistance in the leads could be other explanations for this. Even though the calculated and simulated values differ somewhat, this could be explained by the rounding of numbers.

Task 3: Transient Behavior using a more Complex Circuit

Method

In order to determine the time constant values for this task, a more intricate circuit has to be used. The RC circuit shown in 'figure 1' was further simplified by using just one resistor rather than two. Ne 17
further simplified circuit can then be simulated and the results provided can then be compared with calculated results.

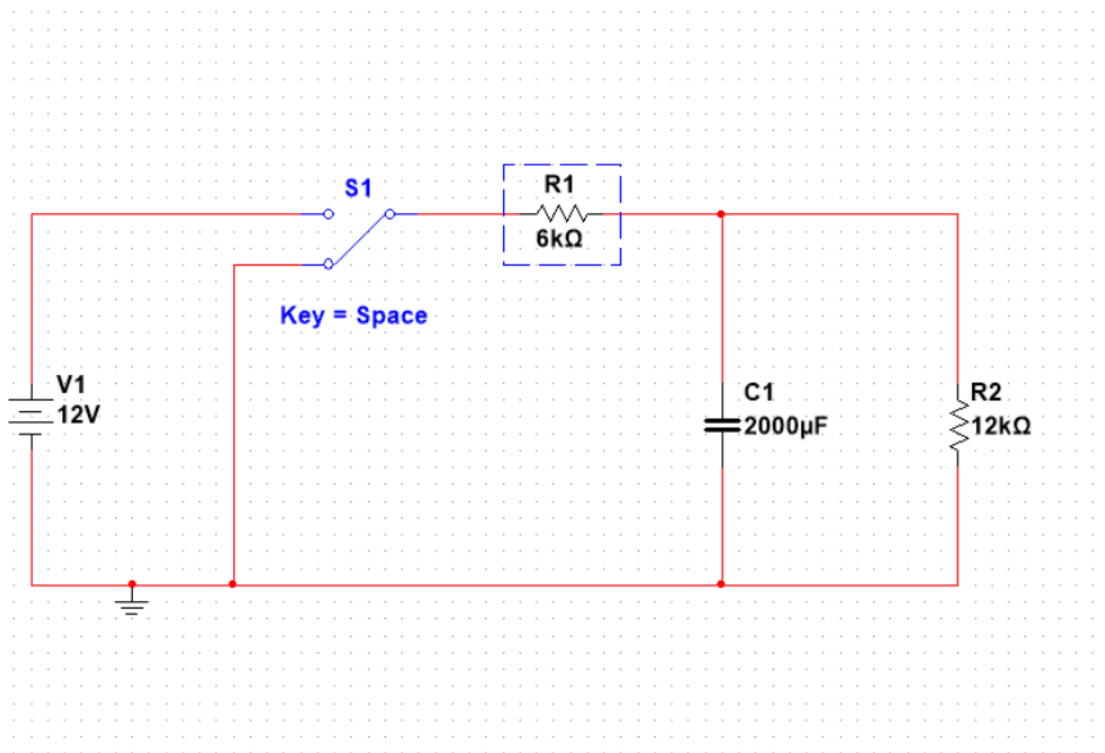


Figure 1

Following on from researching in to the circuit labelled 'figure 1' needed to be simplified. The simplified circuit which is represented in 'figure 2' is made up of a new input voltage and resistor value.

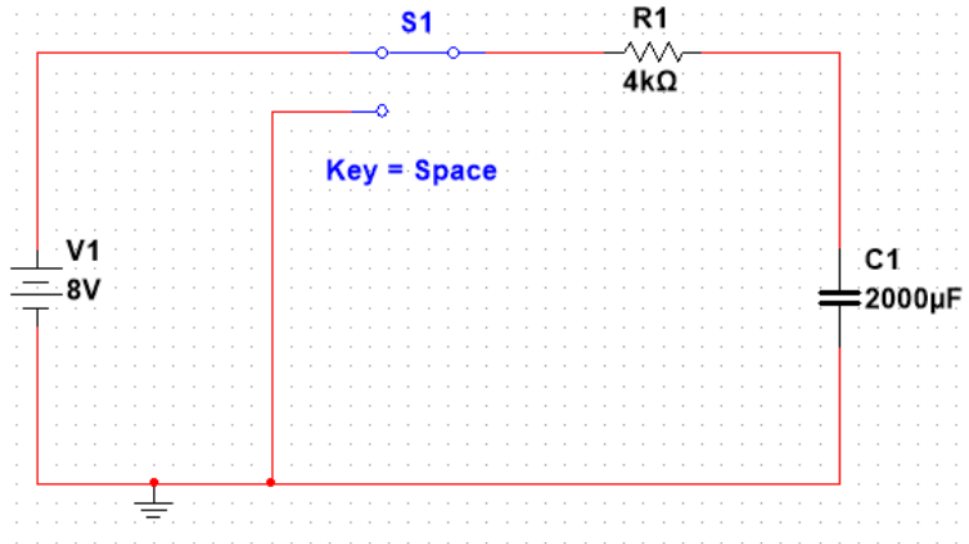


Figure 2

Shown below are the calculations found to be used within the new simplified circuit.

$$R/V_s = \frac{\text{Product}}{\text{Sum}}$$

$$R = \frac{6 \times 12}{6 + 12} = 4K\Omega$$

$$V_s = \frac{12}{12 + 6} = 8V$$

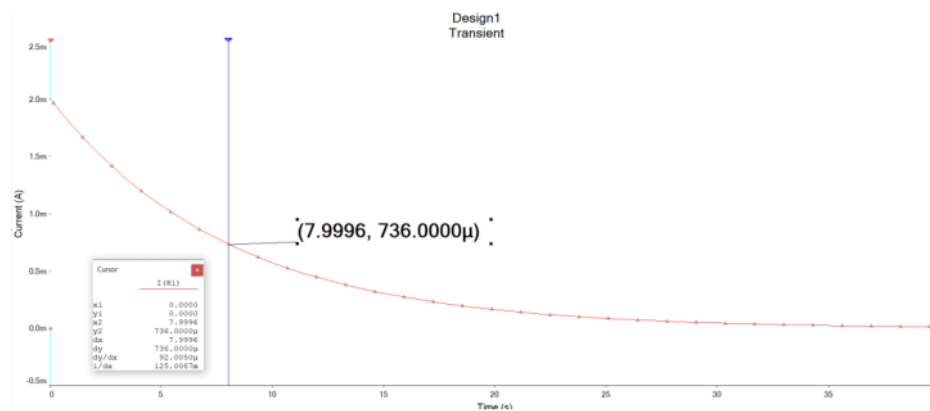
Shown below are the calculations used to find τ and 5τ .

$$\tau = C \times R = 2000 \times 10^{-6} \times 4000 = 8 \text{ Seconds}$$

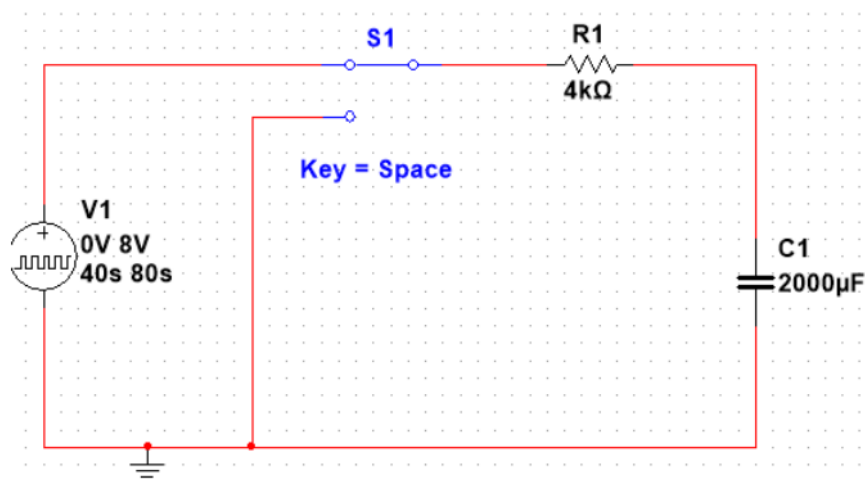
$$5\tau = 5 \times 8 = 40 \text{ Seconds}$$

Simulations

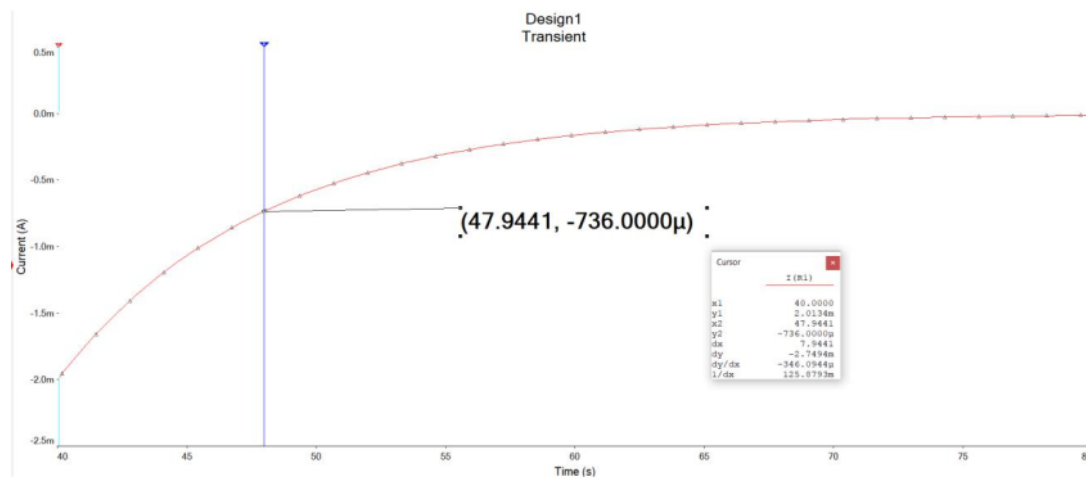
The Graph below provided by NI Multisim shows that the transient is charging and labelled at the calculated 1τ .



Shown below is an updated circuit using a DC pulse instead of a regular DC input supply, the DC pulse is used to provide a transient discharging graph.



Shown below is a graph provided by NI Multisim, it shows the transient discharging at the calculated 1τ .



Calculations

Shown below is the calculation used to calculate the I_{max} , which is then further used in the charge and discharge equations.

$$I_{max} = \frac{V}{R} = \frac{8}{4000} = 2mA(2 \times 10^{-3})$$

Shown below are the calculations used to calculate the current value for charge and discharge.

$$Charge = e^{-1} \times I_{max}$$

$$Charge = e^{-1} \times 2 \times 10^{-3} = 735.75888 \mu A$$

$$Discharge = e^{-1} \times -I_{max}$$

$$Discharge = e^{-1} \times -2 \times 10^{-3} = -735.75888 \mu A$$

Analysis

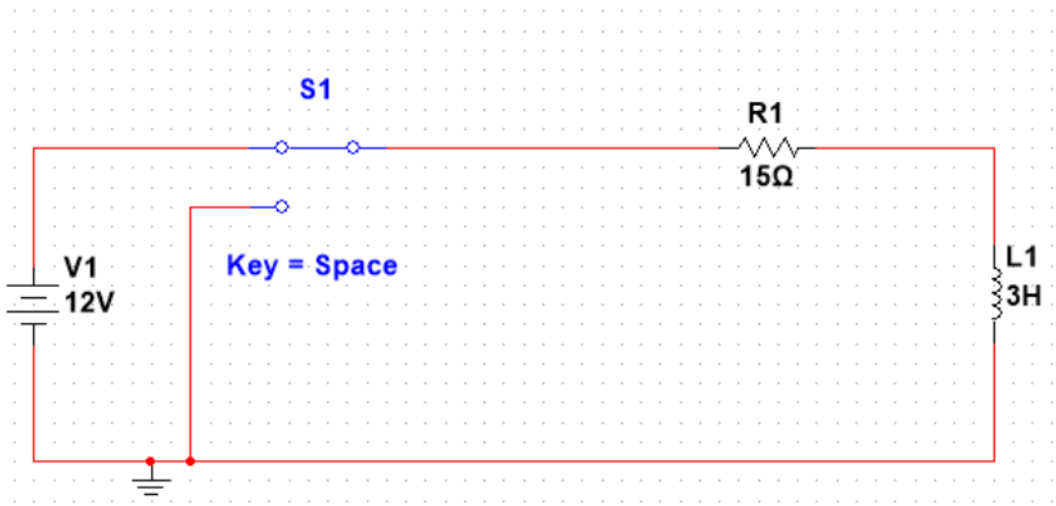
	Charge	Discharge
Simulated	736μA	-736μA
Calculated	735.758μA	-735.75888μA

Shown in the table above are the calculated results for charging and discharging of the transient. These values have a slight differ between each. This difference between each value can possibly be caused by rounding of numbers to a certain amount of decimal places during calculations.

Task 4 Transient Behaviour for an Inductive Circuit

Method

Below is the circuit used within this task which includes a resistor, inductor, DC input voltage and a switch. The circuit was designed using a inductor instead of a capacitor to show the transient behaviour within an RL circuit.



Results

Prior to calculating the current values for every 0.05 Seconds I_{max} and τ was calculated using the equations below ;

$$I_{max} = \frac{V}{R}$$
$$I_{max} = \frac{12}{15} = 0.8A$$

$$\tau = \frac{L}{R}$$
$$\tau = \frac{3}{15} = 0.2 \text{ Seconds}$$

The calculation used to calculate the current values for every 0.05 Seconds starting at 0 up to 1 Second within this task is shown below ;

$$I_{max}(1 - e^{-t/\tau})$$



The calculation below was used to calculate the current flowing in the circuit before the switch is changed.

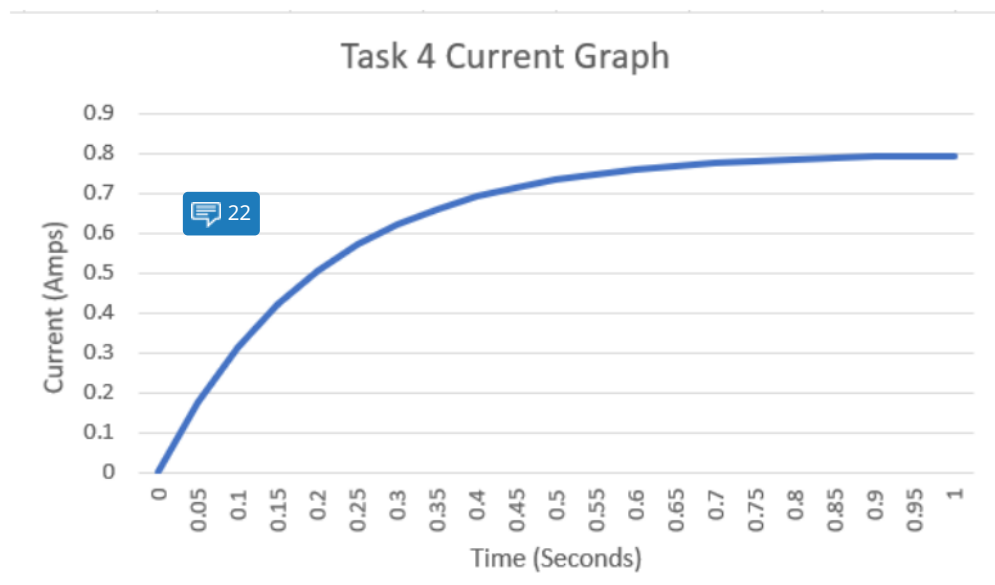
$$i = I_{max}(1 - e^{-t/\tau})$$

$$i = 0.8(1 - e^{-0.2/0.2})$$

$$i = 0.50569 \text{ mA}$$

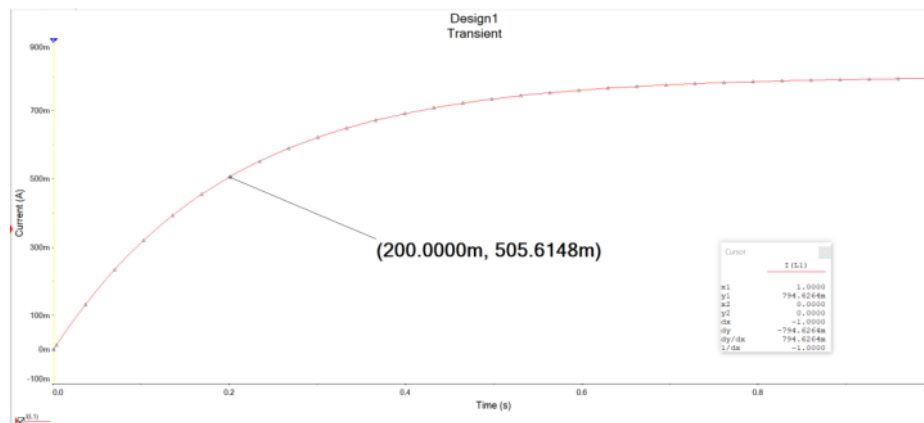


Shown below is the graph created on Microsoft excel, this graph was created using current values calculated from the equation above, Readings were taken every 0.05 of a second up until 1 second. This then shows that the current is steadily and smoothly increasing.



All results to create the graph above are shown within the appendix labelled as 'Figure 5'.

Shown below is a graph provided by NI Multisim showing the current flowing within the circuit immediately before the switch is closed.



Shown below is the changed circuit using a DC pulse instead of a regular DC input voltage. The DC pulse was used to provide a discharging graph. With the circuit altered, the goal is to determine how long it takes for the circuit to drop to 100mA and 10mA.

Charging time constant calculated values equation

$$IC = I_{max}(1 - e^{-t/\tau})$$

Calculated time constant values

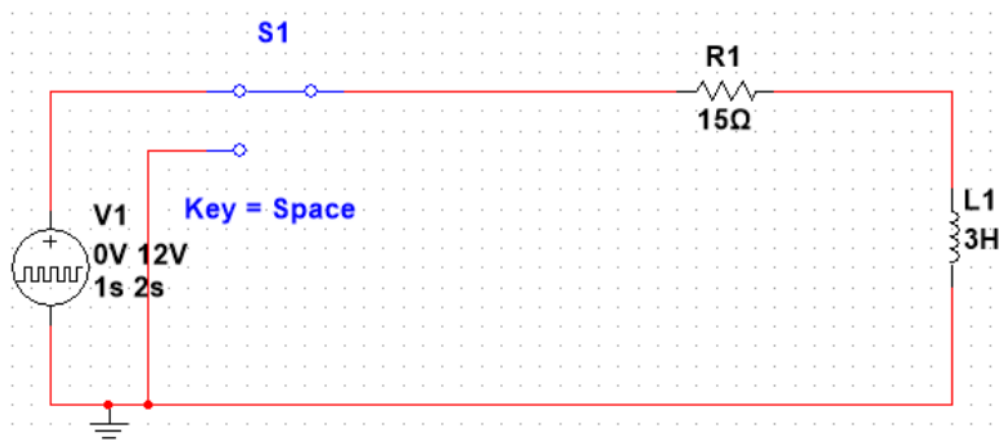
$$0.8(1 - e^{-0.2/0.2}) = 0.505A$$

$$0.8(1 - e^{-1/0.2}) = 0.794A$$

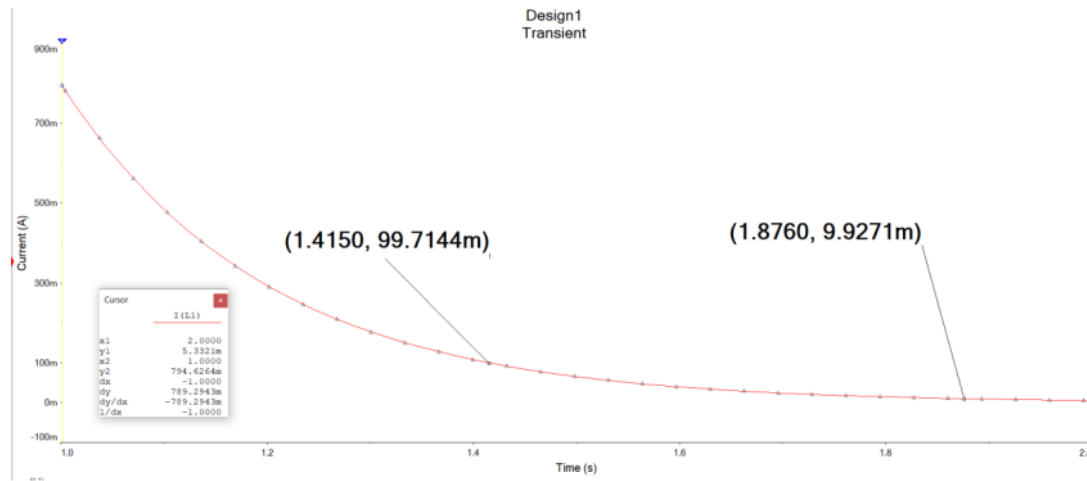


Time	Calculated/Manual	Simulated
0.2 Seconds	0.505A	0.5056148A
1 Second	0.794A	0.7946264A

Shown in the table above are the results for estimates from the manual plots and simulated plots. As shown in the results provided by the estimated manual plots the results are provided with only 3 decimal places leaving slight inaccuracy between answers due to the fact the simulated answers are provided with many decimal places.



Shown in the graph below is a simulated graph provided by multi-sim. This graph is a result of modifying the circuit, seen below are plots at 100mA and 10mA and its readings.



The calculation to calculate the decay in current is shown below

$$IL = I_{max} \left(\frac{-t}{T} \right)$$

Time must be the subject of the formula above, meaning it needs to be transposed

$$\left(\frac{IL}{I_{max}} \right) = \left(e^{\frac{-t}{\tau}} \right)$$

$$\ln \left(\frac{IL}{I_{max}} \right) = \left(\frac{-t}{\tau} \right)$$

$$\ln\left(\frac{IL}{I_{max}}\right)(\tau) = t$$

Below are the calculated values at 100mA and 10mA

$$t = \ln\left(\frac{100 \times 10^{-3}}{0.8}\right) \times (0.2) = 0.41588$$

$$t = \ln\left(\frac{10 \times 10^{-3}}{0.8}\right) \times (0.2) = 0.87640$$



Analysis

	100mA	10mA
Calculated	0.41588 Seconds	0.87640 Seconds
Simulated	0.4150 Seconds	0.8760 Seconds

Shown in the table above is the results for this task in seconds. The results were calculated and simulated using NI Multisim. When using NI Multisim the graph provided shows the time in seconds at the specific current values 1 second ahead of the actual time value due to the fact the circuit used, takes a second to charge to its steady state before the discharge starts. The slight differ between all results are due to rounding of numbers during calculations, also if NI Multisim provided users with further decimal pointed answers this could attribute towards accuracy.

Conclusion

In conclusion, during examination of task 1 the time constant and two random time values were chosen and the voltage and current readings were provided via calculated, simulated and practical forms. Whilst analyzing all results in a chart format the results of the charging capacitor were very similar for each form except the practical was slightly out and the reason being was due to rounding of numbers throughout calculation, resistance within the fused leads or even loose connections. For task 2 similar to the First, but this time for a discharging capacitor the calculated, simulated  25 practical results were taken and thoroughly analyzed. The same circuit was used within task 2 as task 1 meaning there are no further unorthodox reasons to be added for the simulated part of the task. The same reasons follow as task 1 as to why the results are slightly out. For task 3 a new RC circuit was made and investigated, this circuit was then further simplified with a new input voltage and resistor value. The time constant ' τ ' was then calculated and used within NI Multisim to provide current values for both charge and discharge. The calculated values were then compared to the simulated values and a slight difference was evident. Again the only reason for this is rounding of numbers during calculation. Task 4 included an RL circuit, the circuit was examined and calculations were carried out to determine the current flowing within the circuit before the switch closed. A current against time graph was configured by NI Multisim and compared to a manually plotted graph made via excel as task 4 progressed the circuit altered in order to calculate the time that elapses before the current flowing in the circuit fell to provided current values. These values were then compared in table format with the calculated values and the difference in which is very minimal reason being rounding of numbers during calculation. Overall all tasks went well, the main issue within that would be changed if done so again would be rounding of numbers as this always gave a slight error and using further decimal places during calculation will minimize that error as much as possible.

Appendix

-Figure 1

Time in S	Voltage
5	0.58
10	1.04
15	1.49
20	1.86
25	2.24
30	2.55
35	2.87
40	3.13
45	3.39
50	3.61
55	3.82
01:00	4
01:10	4.34
01:20	4.62
01:30	4.85
01:40	5.05
01:50	5.21
02:00	5.34
02:10	5.47
02:20	5.56
02:30	5.65
02:40	5.71
02:50	5.77
03:00	5.82
03:10	5.86
03:20	5.9
03:30	5.93
03:40	5.95
03:50	5.98
04:00	5.99
04:10	6.01
04:20	6.02
04:30	6.03
04:40	6.04
04:50	6.05
05:00	6.06

-Figure 2

Time in S	Current
5	0.92
10	0.84
15	0.77
20	0.7
25	0.64
30	0.59
35	0.54
40	0.49
45	0.45
50	0.41
55	0.38
01:00	0.35
01:10	0.29
01:20	0.24
01:30	0.21
01:40	0.17
01:50	0.15
02:00	0.12
02:10	0.1
02:20	0.09
02:30	0.07
02:40	0.06
02:50	0.05
03:00	0.04
03:10	0.04
03:20	0.03
03:30	0.03
03:40	0.02
03:50	0.02
04:00	0.02
04:10	0.01
04:20	0.01
04:30	0.01
04:40	0.01
04:50	0.01
05:00	0.01

-Figure 3

Time in S	Voltage
5	5.52
10	5.07
15	4.62
20	4.21
25	3.87
30	3.56
35	3.22
40	2.96
45	2.72
50	2.48
55	2.25
01:00	2.08
01:10	1.75
01:20	1.48
01:30	1.24
01:40	1.05
01:50	0.87
02:00	0.74
02:10	0.61
02:20	0.53
02:30	0.44
02:40	0.37
02:50	0.32
03:00	0.26
03:10	0.22
03:20	0.19
03:30	0.16
03:40	0.14
03:50	0.12
04:00	0.1
04:10	0.08
04:20	0.07
04:30	0.06
04:40	0.05
04:50	0.04
05:00	0.04

-Figure 4

Time in S	Current
5	0.92
10	0.84
15	0.77
20	0.7
25	0.64
30	0.59
35	0.54
40	0.49
45	0.45
50	0.41
55	0.38
01:00	0.35
01:10	0.29
01:20	0.24
01:30	0.21
01:40	0.17
01:50	0.15
02:00	0.12
02:10	0.1
02:20	0.09
02:30	0.07
02:40	0.06
02:50	0.05
03:00	0.04
03:10	0.04
03:20	0.03
03:30	0.03
03:40	0.02
03:50	0.02
04:00	0.02
04:10	0.01
04:20	0.01
04:30	0.01
04:40	0.01
04:50	0.01
05:00	0.01

-Figure 5

Time	Current
0	0
0.05	0.176959
0.1	0.314775
0.15	0.422107
0.2	0.505696
0.25	0.570796
0.3	0.621496
0.35	0.660981
0.4	0.691732
0.45	0.715681
0.5	0.734332
0.55	0.748858
0.6	0.76017
0.65	0.768981
0.7	0.775842
0.75	0.781186
0.8	0.785347
0.85	0.788589
0.9	0.791113
0.95	0.793079
1	0.79461

55/100

PAGE 1

PAGE 2

PAGE 3



Comment 1

be specific



Comment 2

increase in what? be specific



Comment 3

what kind of values? time values?

PAGE 4



Comment 4

incorrect terminology



Comment 5

balances what out?

PAGE 5



Comment 6

explain this by relating to theory

PAGE 6



Comment 7

incorrect terminology



Comment 8

is this growth or decay?

PAGE 7



Comment 9

how can time equal current?



Comment 10

how can this be minimised?

PAGE 8



Comment 11

avoid repetition



Comment 12

see previous comment

PAGE 9



Comment 13

this equation should be related to theory, include an image of a transient growth/decay

PAGE 10

PAGE 11



Comment 14

this is bad practice

PAGE 12



Comment 15

off what?



Comment 16

avoid repetition, in particular where the original statement is vague

PAGE 13



Comment 17

why?

PAGE 14

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Comment 18

what does this depend on?



Comment 19

where is the discharge graph?

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Comment 20

why are you underlining?



Comment 21

rather this is the value at 1 time constant

PAGE 19



Comment 22

show the equation used in excel

PAGE 20



Comment 23

this needs an explanation

 **Comment 24**
unit?

 **Comment 25**
too vague, were there loose connections or not? how could you tell?

GRADING FORM: NEW CSG-RUBRIC

LEWIS BELL

55

1. ENGAGEMENT WITH LITERATURE

 NA

0

2. KNOWLEDGE AND UNDERSTANDING



Knowledge of basic underlying concepts is evident in the calculations and graphical results, however there are a lot of ambiguous statements in written text 12/25

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3. COGNITIVE AND INTELLECTUAL



Evaluation and conclusion are limited to superficial analysis and descriptions of discrepancies. Realte the outcomes of your findings to underlying theory. 15/30

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4. PRACTICAL APPLICATION



Good and appropriate application of methods including simulation and calculations, more explanation of theory related to practical should be included. 16/25

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5. TRANSFERABLE SKILLS



Mostly coherent and accurate work, report structure is good, there is some vagueness and ambiguity in written explanations as marked. 12/20

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