

1910603

by Benjamin Brickle

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Executive Summary

This report analyses the behaviour of RC and RL circuits when charging and discharging. Each section analyses voltage and/or current, and how it reacts in a RC, complex RC or RL circuit. Task 1 and 2 use practical methods of generating data, alongside calculations and Multisim. Task 3 and 4 have calculations and Multisim, generating graphs and curves to assist with the analysis of the circuits.

The data gathered by a variety of sources, such as practical testing, calculations and Multisim values are all compared and contrasted, using this data to analyse the circuit as well as discussing possible reasons for any discrepancies between data if possible, and whether certain data types may be more suitable than others.

Practical task, circuit analysis and calculations

Task 1- Practical values for charging capacitor

Time(s)	Current(A)	Voltage(V)
0	0	0
5	0.92	0.58
10	0.89	1.04
15	0.77	1.49
20	0.7	1.86
25	0.64	2.21
30	0.59	2.55
35	0.54	2.87
40	0.49	3.13
45	0.45	3.39
50	0.41	3.61
55	0.38	3.82
60	0.35	4
70	0.29	4.35
80	0.24	4.62
90	0.21	4.85
100	0.17	5.05
110	0.15	5.2
120	0.12	5.35
130	0.1	5.47
140	0.09	5.56
150	0.07	5.65
160	0.06	5.72
170	0.05	5.77
180	0.04	5.82
190	0.04	5.87
200	0.03	5.9
210	0.03	5.93
220	0.02	5.95
230	0.02	5.98
240	0.02	5.99
250	0.01	6
260	0.01	6.02
270	0.01	6.02
280	0.01	6.03

Figure 1- Practical values obtained for charging capacitor

$$\tau = R \times C$$

$$\tau = 5600 \times 10,000 \times 10^{-6}$$

$$\tau = 56s$$

$$V_c = 0.632 \times 6$$

$$V_c = 3.792V$$

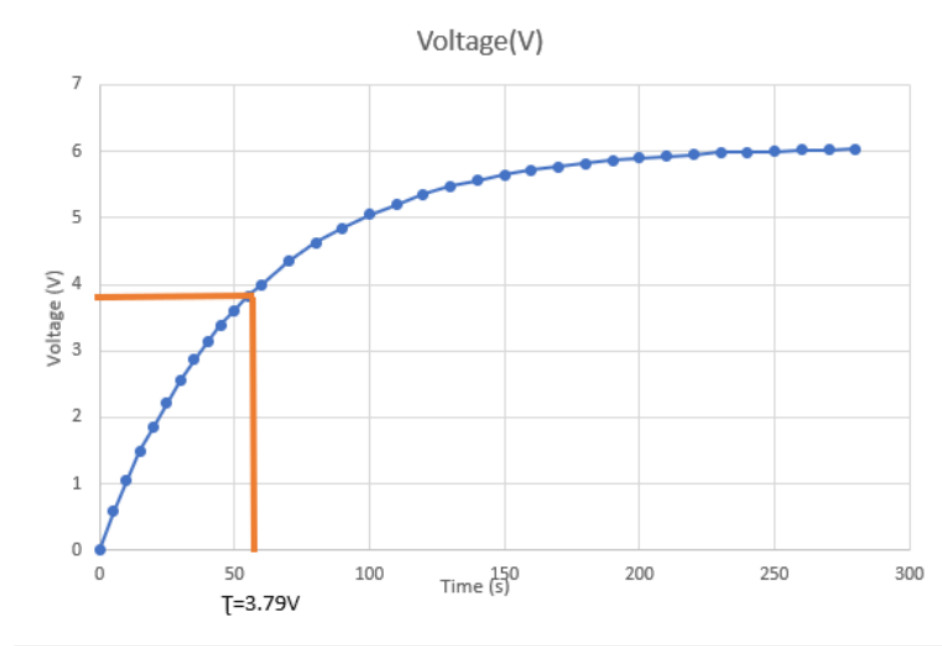


Figure 2- Graph showing voltage whilst charging capacitor

Current whilst charging a capacitor

$$I_{max} = V/R$$

$$I_{max} = 6/5600$$

$$I_{max} = 1.07mA$$

At one time constant, on decline, so $1 - 0.632 = 0.368$

Therefore:

$$I_c = 0.368 \times 1.07mA$$

$$I_c = 393.74\mu A$$

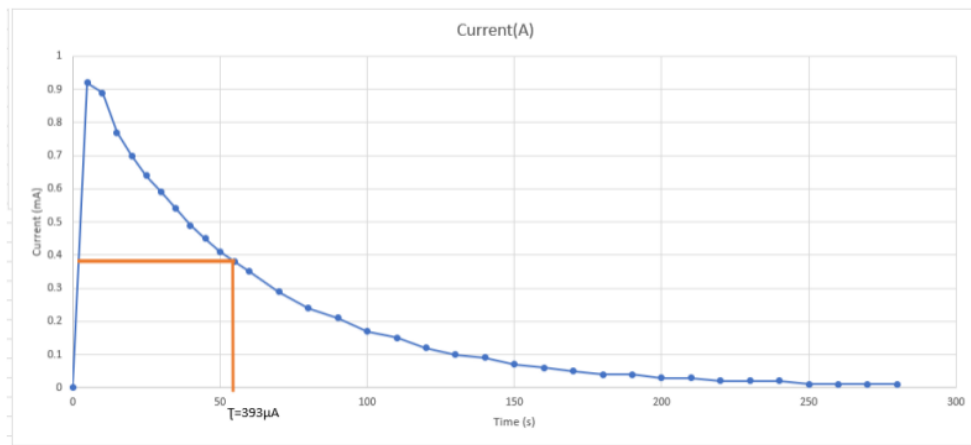


Figure 3- Graph showing current whilst charging capacitor

Task 2- Practical for discharging capacitor

Time (s)	Current (A)	Voltage (V)
0	0	5.99
5	-0.92	5.56
10	-0.84	5.07
15	-0.77	4.65
20	-0.7	4.24
25	-0.64	3.97
30	-0.59	3.56
35	-0.54	3.24
40	-0.49	2.98
45	-0.45	2.72
50	-0.41	2.5
55	-0.38	2.28
60	-0.35	2.1
70	-0.29	1.75
80	-0.24	1.48
90	-0.2	1.24
100	-0.17	1.04
110	-0.14	0.88
120	-0.12	0.75
130	-0.1	0.62
140	-0.08	0.55
150	-0.07	0.44
160	-0.06	0.37
170	-0.05	0.32
180	-0.04	0.27
190	-0.03	0.23
200	-0.03	0.19
210	-0.02	0.16
220	-0.02	0.14
230	-0.01	0.12
240	-0.01	0.1
250	-0.01	0.08
260	-0.01	0.07
270	-0.01	0.06
280	-0.01	0.05

Figure 4- Practical values obtained whilst discharging capacitor

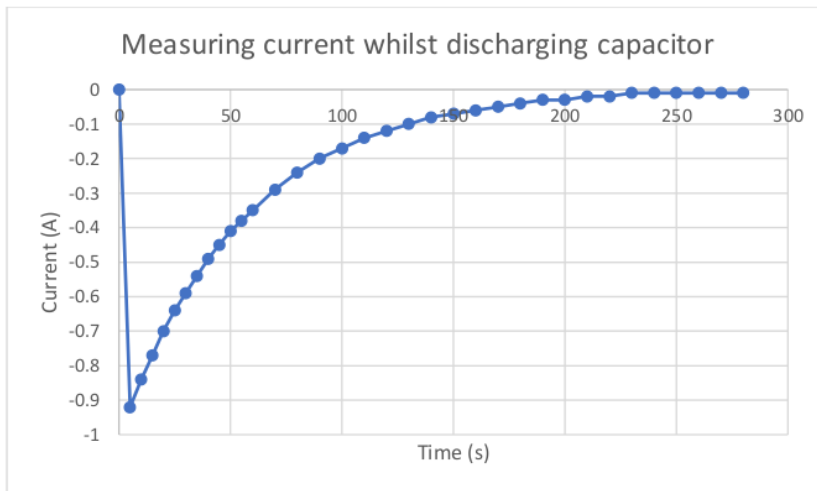


Figure 5- Graph showing current whilst discharging capacitor

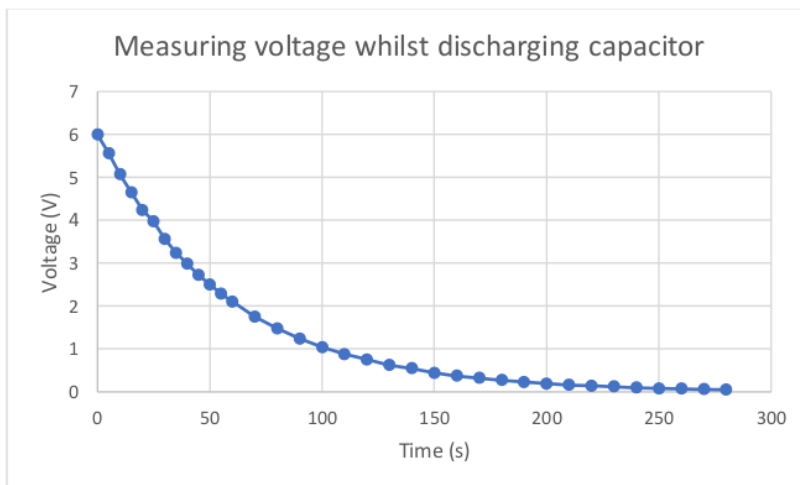


Figure 6- Graph showing voltage whilst discharging capacitor

Task 1 Charging capacitor- Multisim and calculations

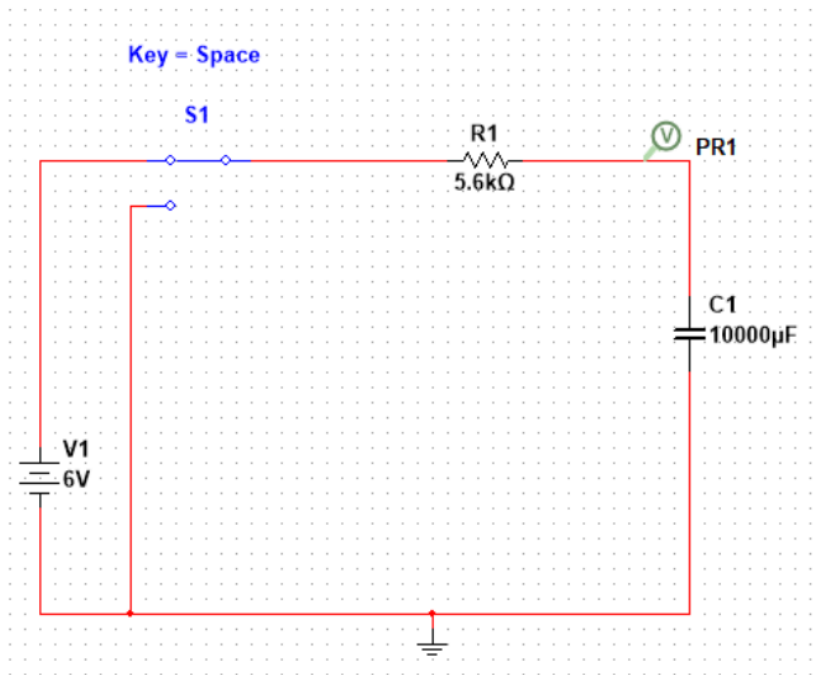


Figure 7- Multisim simulation for charging capacitor

Measuring voltage whilst charging capacitor

$$\tau = R \times C$$

$$\tau = 5600 \times 10,000 \times 10^{-6}$$

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

$$V_c = 0.632 \times 6$$

$$V_c = 3.792\text{V}$$

Voltage-Three random times for charging capacitor, calculations and Multisim

$$V_c = 6(1 - e^{-\frac{t}{\tau}})$$

Task 1

Measuring voltage whilst charging a capacitor

Cursor	V(1)	V(2)
x1		
y1	55.9313	55.9313
x2	6.0000	3.7899
y2		
slope		
dV/dx		
1/dx		

10

t=30s y2 showing 2.35V

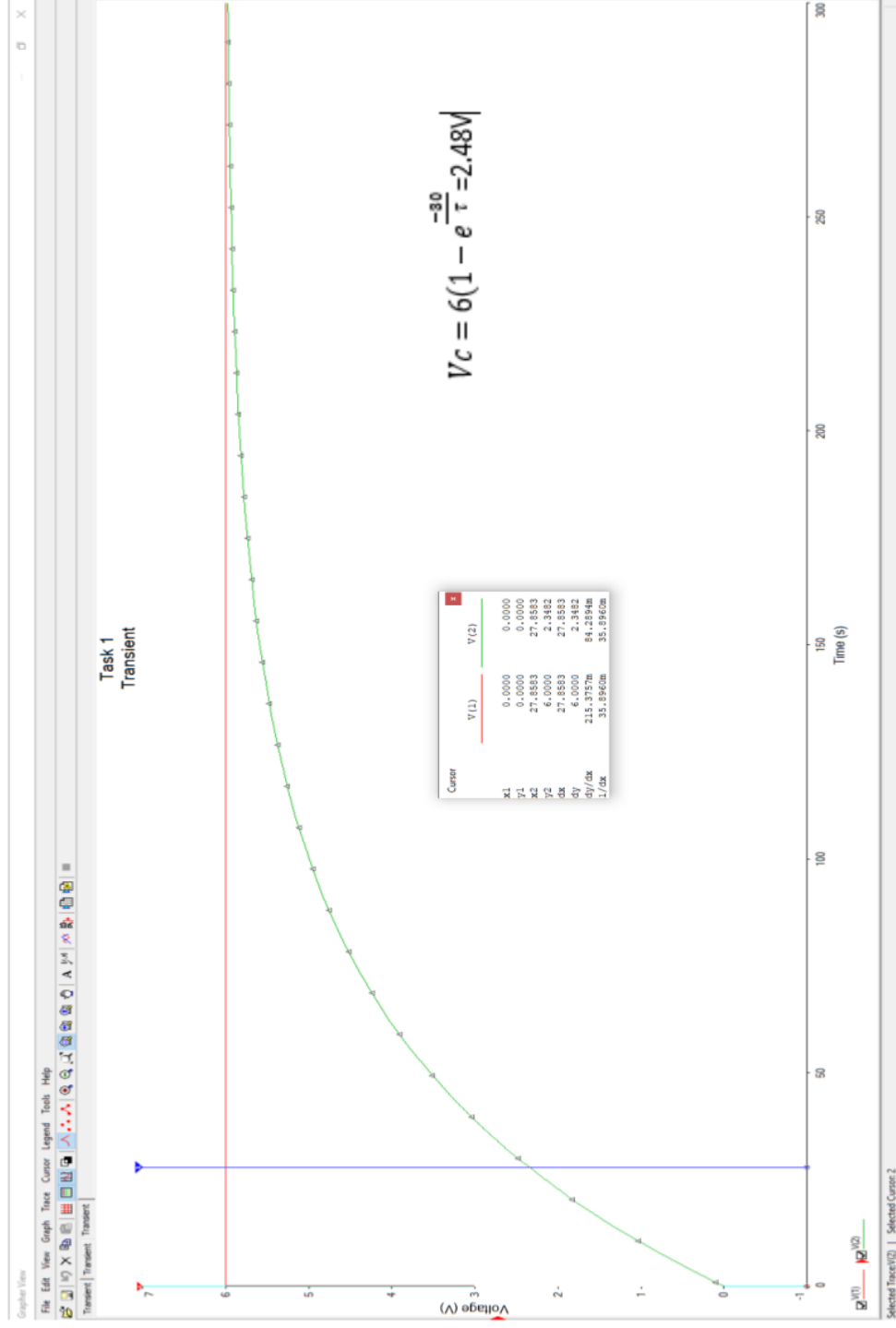


Figure 9- Voltage whilst charging at 30s

t=80s, Y2 showing 4.56V

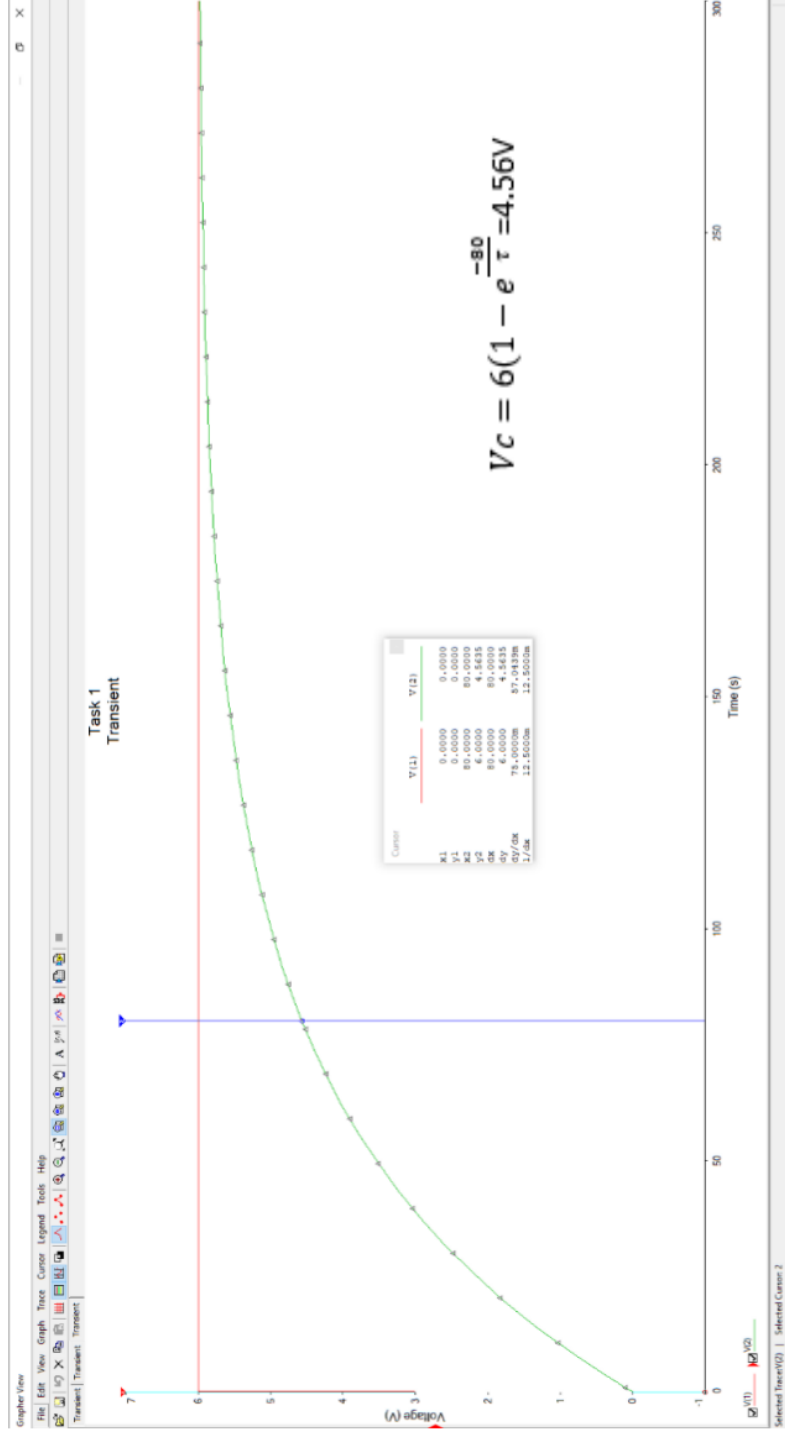


Figure 10-Voltage whilst charging at 80s

t=100s, y2 showing 4.99V

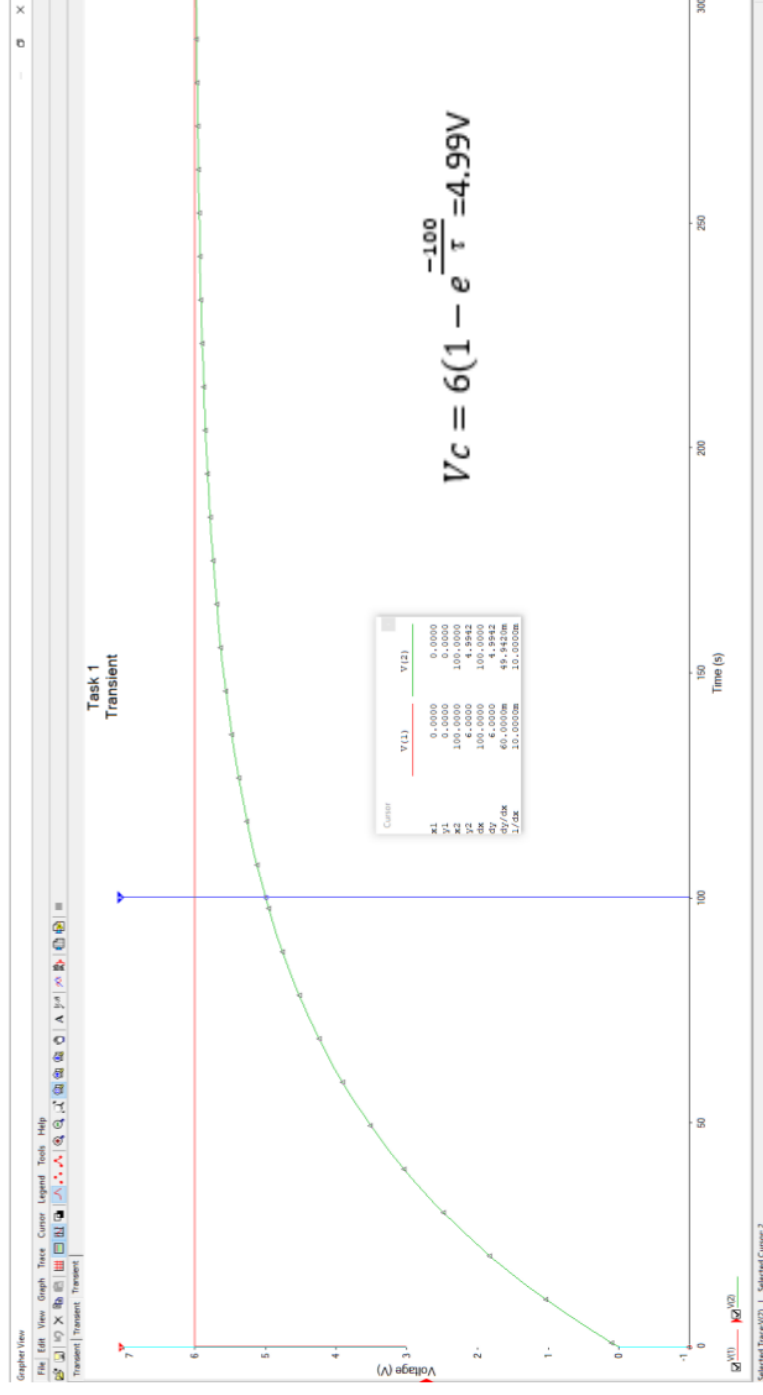


Figure 11- Voltage whilst charging at 100s

Current-Three random times for charging capacitor, calculations and multisim

Current whilst charging a capacitor

$$I_{max} = \frac{V}{R}$$

$$I_{max} = 6/5600$$

$$I_{max} = 1.07mA$$

At one time constant, on decline, so $1 - 0.632 = 0.368$

Therefore:

$$I_c = 0.368 \times 1.07mA$$

$$I_c = 0.368 \times 1.07mA$$

$$I_c = 393.74mA$$

$$I_c = 393.74\mu A$$

t=56s, y1 showing 393.92μA

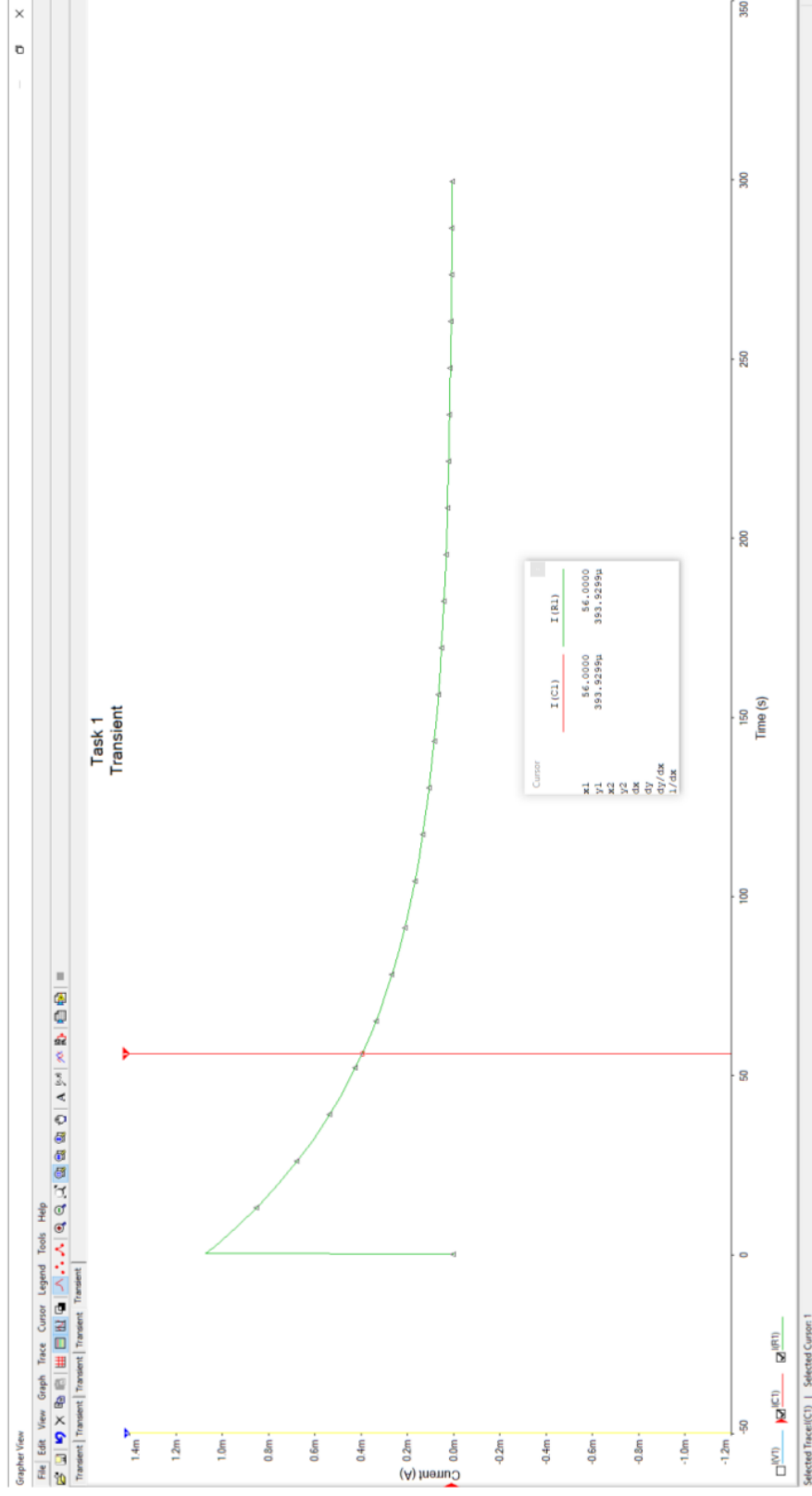


Figure 12- Current whilst charging at one time constant

T=30s, y2 showing 627.54μA

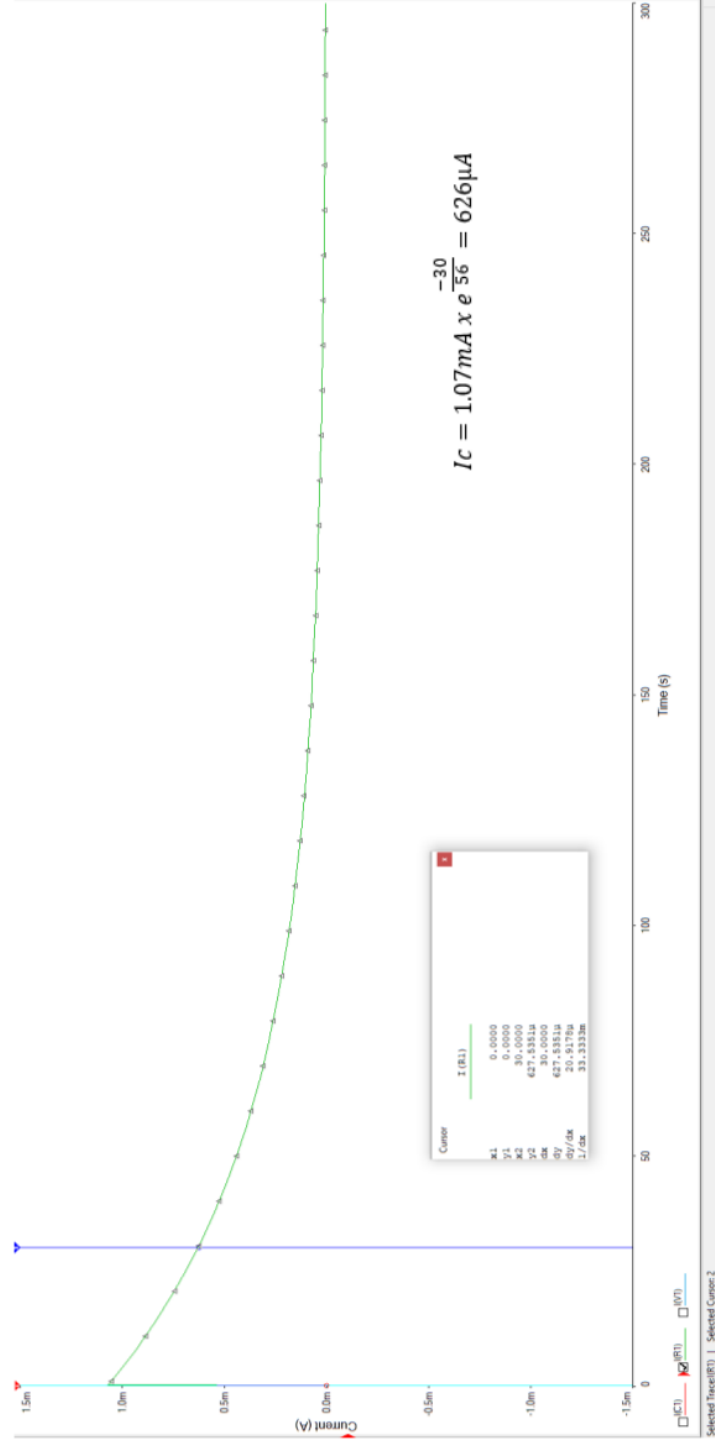


Figure 13- Current whilst charging at 30s

T=80s, y1 showing 256.52μA

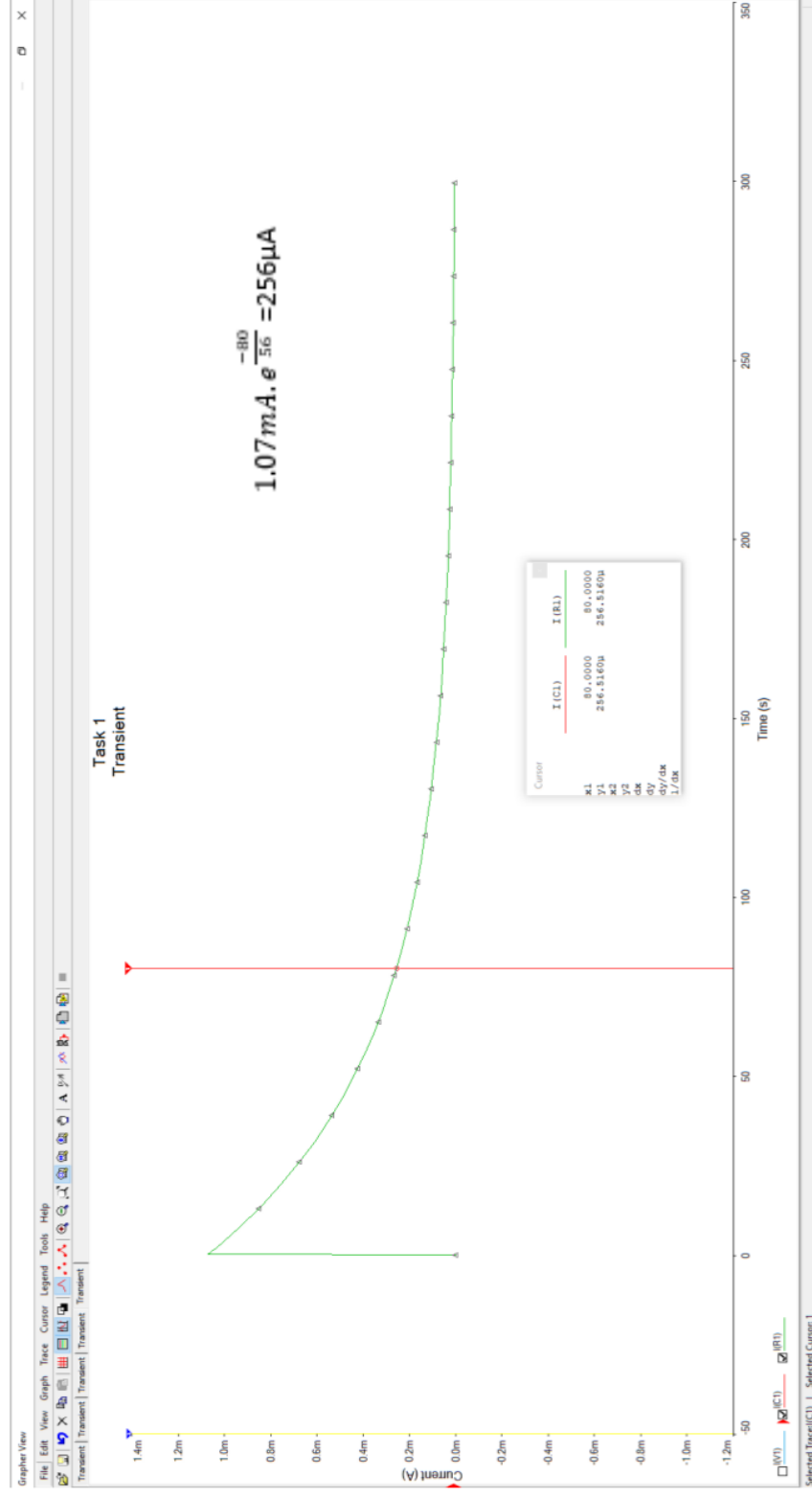


Figure 14- Current whilst charging at 80s

T=100s, y1 showing 179.61μA

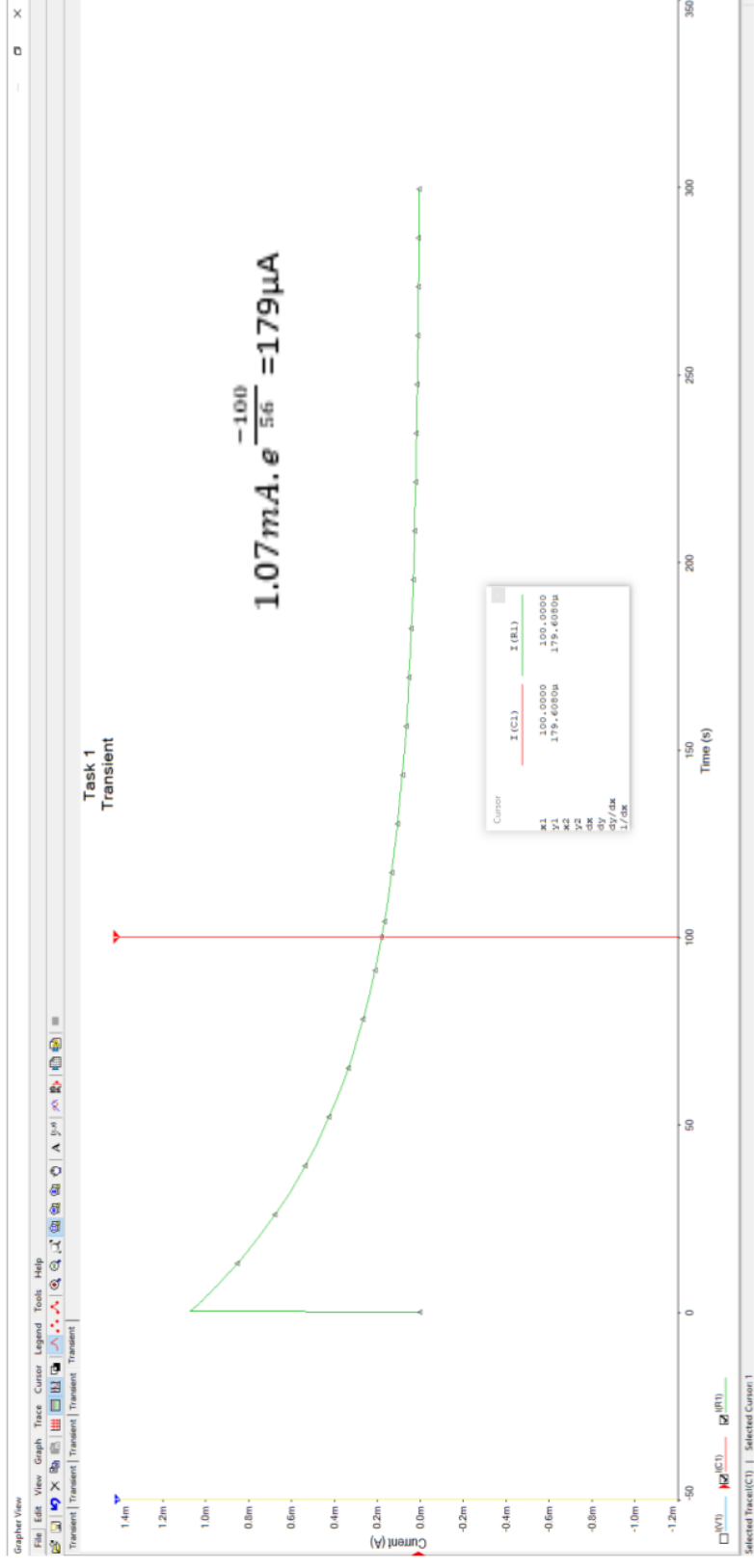


Figure 15- Current whilst charging at 100s

Task 2 Discharging capacitor- Multisim and calculations

Multisim

The power source was changed to a pulse voltage.

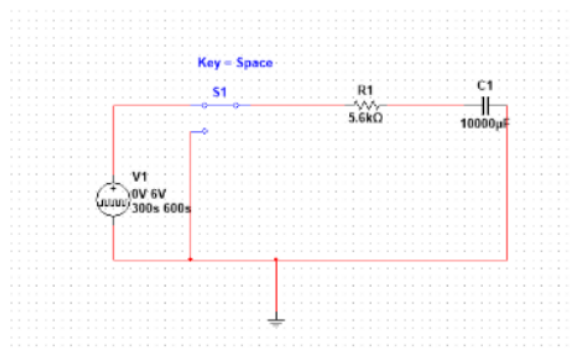


Figure 16- Multisim circuit showing discharging of capacitor

Voltage-Three random times for discharging capacitor, calculations and multisim

$$V_{c2} = 0.368 \times 6$$

$$V_c = 2.208V$$

(Multisim calculation includes 300s of charge time, before using the 56s τ)

T=356s, y2 showing 2.2V

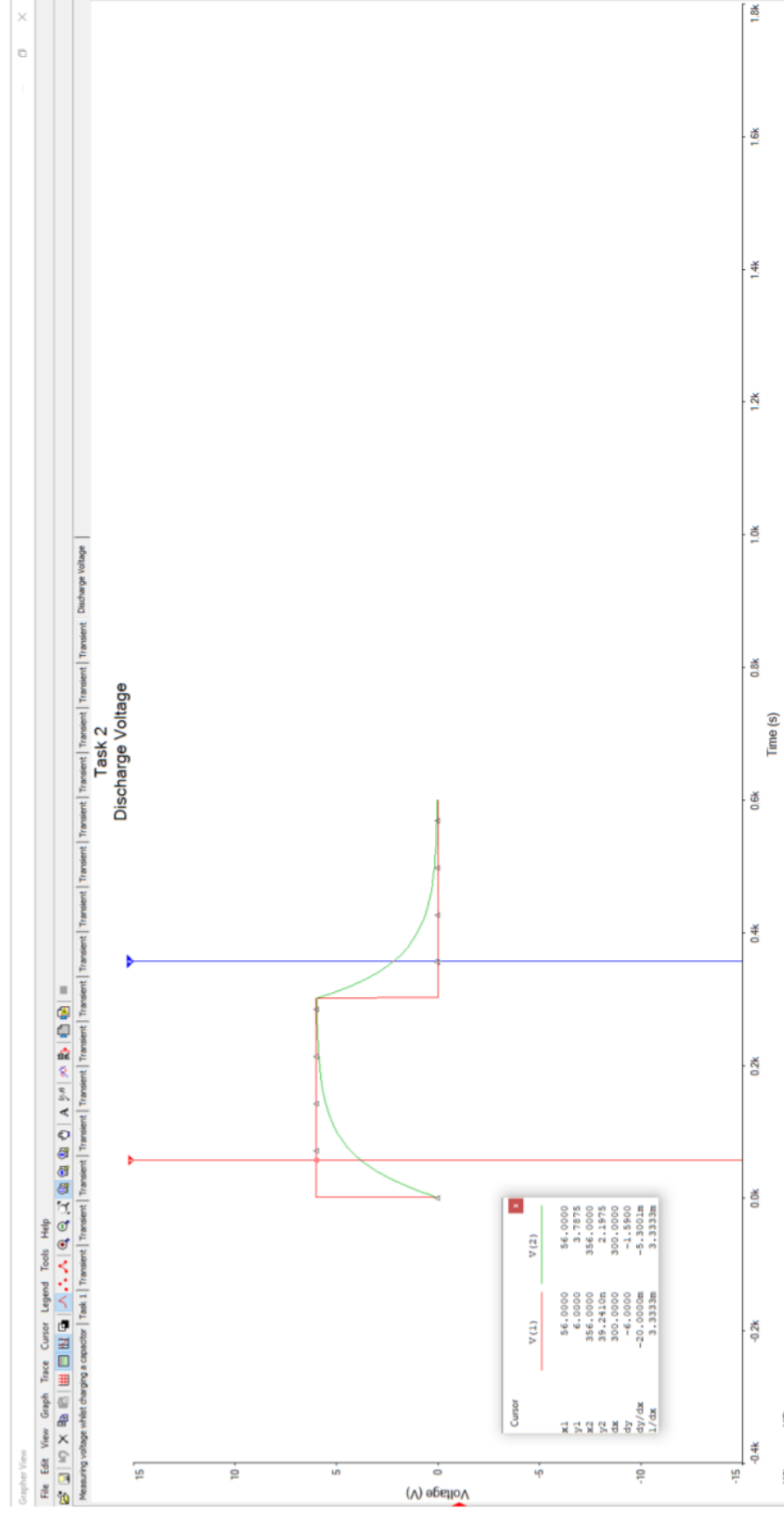


Figure 17- Voltage whilst discharging at one time constant

When calculating voltage on discharge of a capacitor, this formula should be used: (Time on Multisim is 300 + t)

$$V_C = V_S \times e^{\frac{-t}{\tau}}$$

When t=30s , y2 showing 3.51V

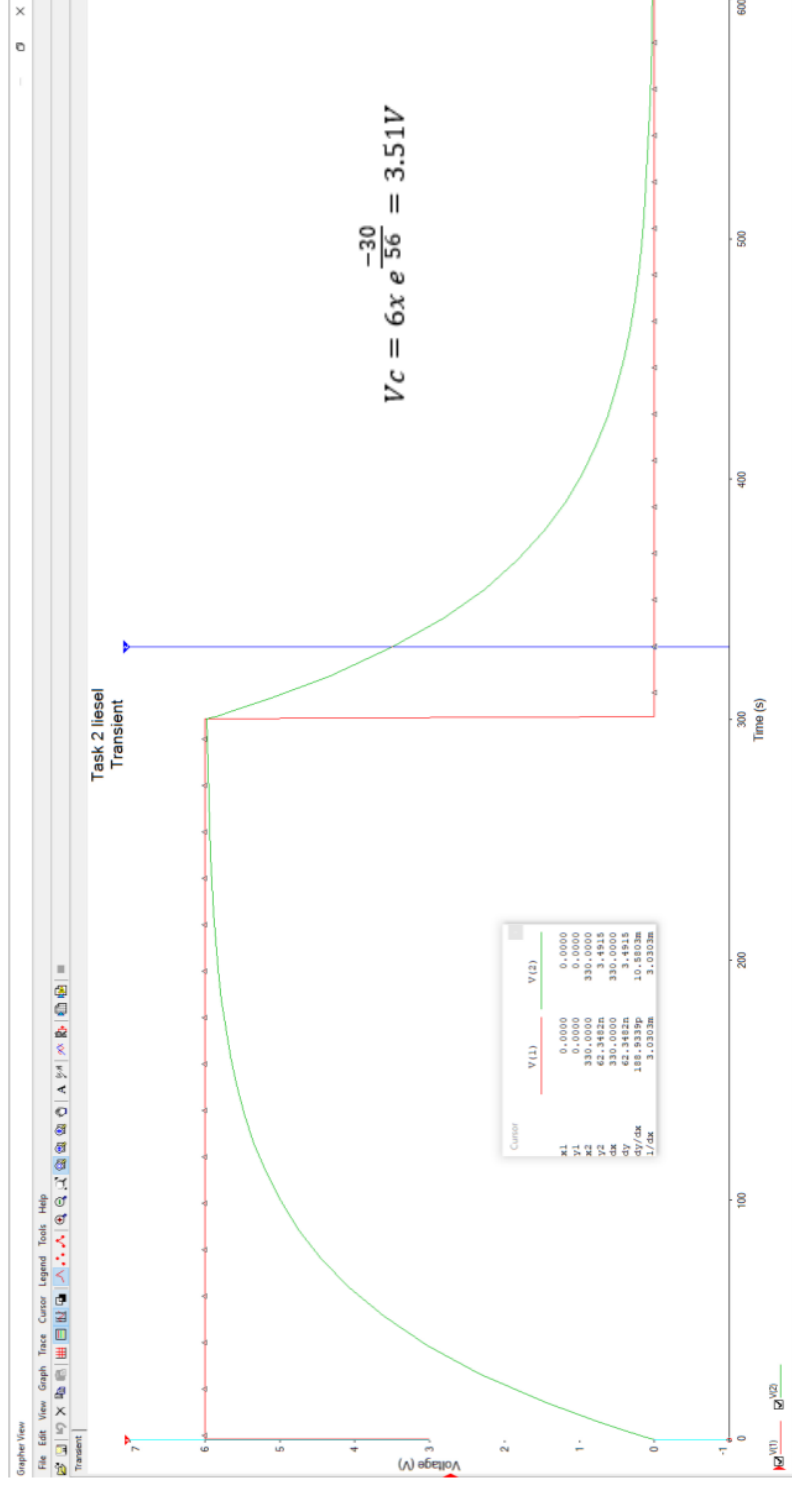


Figure 18- Voltage whilst discharging at 30s

T=80s, v2 showing V=1.44V

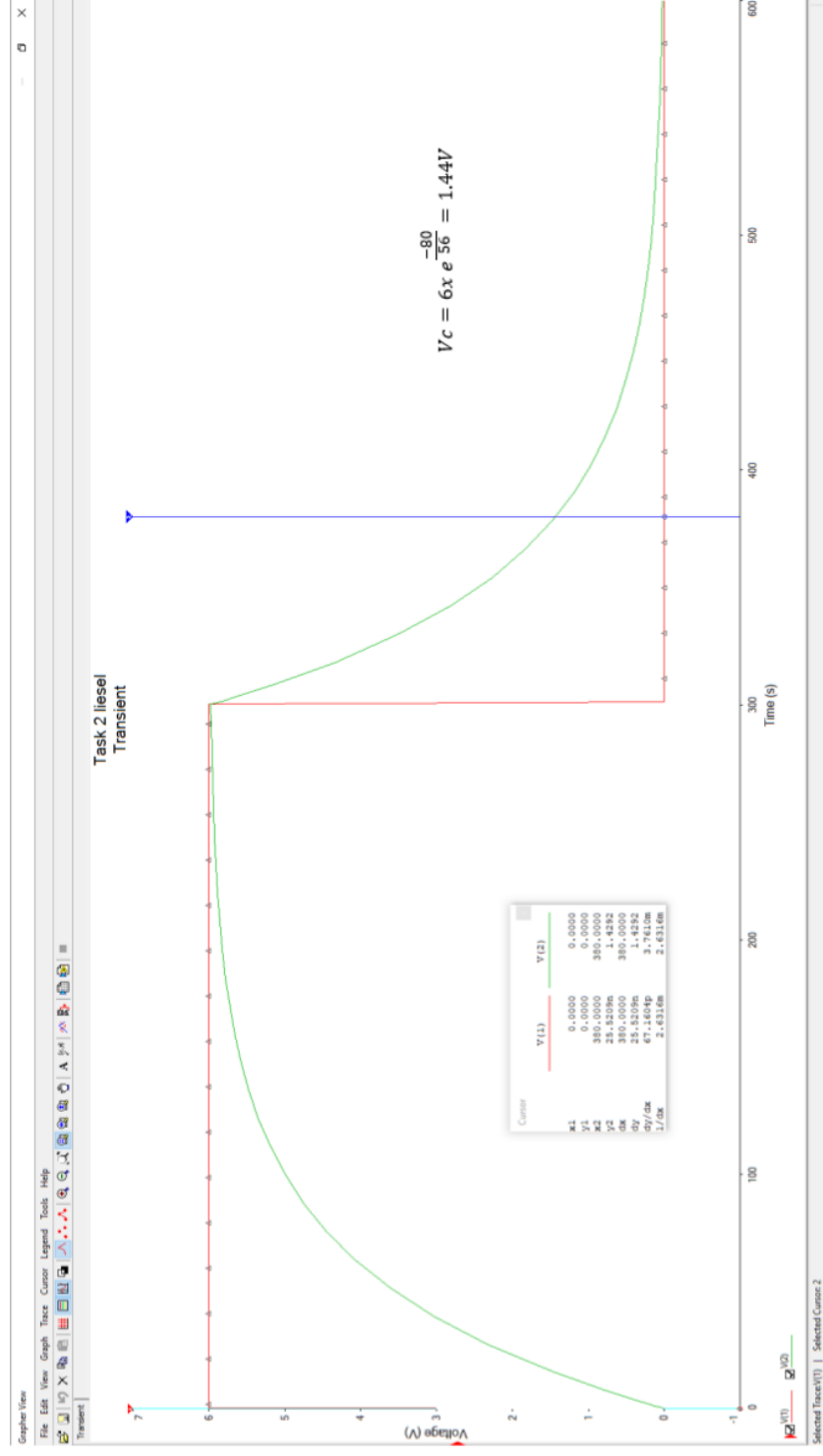


Figure 19- Voltage whilst discharging at 80s

t=100s, y2 showing 0.998 V

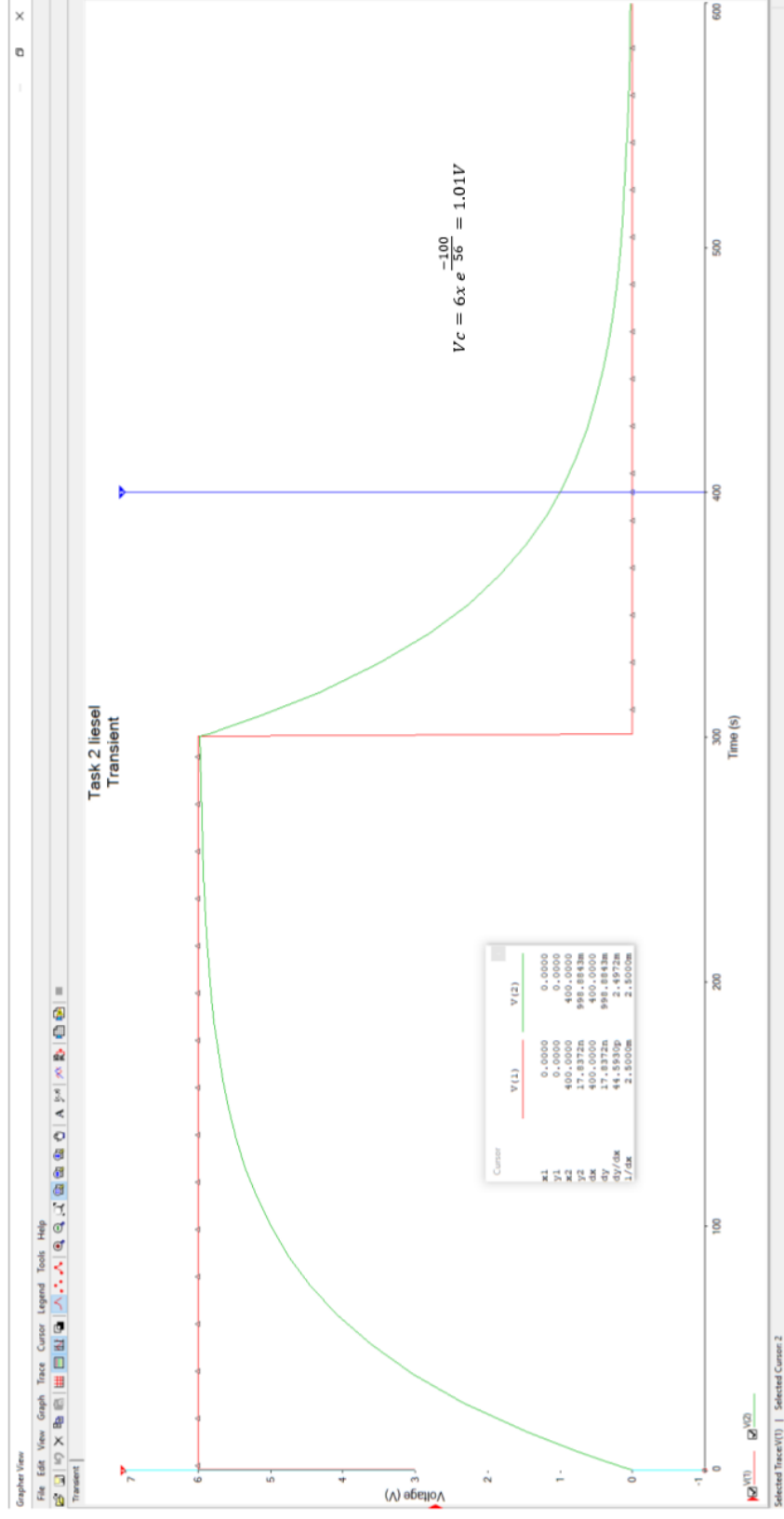


Figure 20- Voltage whilst discharging at 100s

Voltage-Three random times for discharging capacitor, calculations and multisim

$$I_c = I_{max} \times e^{-\frac{t}{\tau}} \quad I_{max} = -1.07\text{mA}$$

When $t=30\text{s}$, I_2 showing $-626\mu\text{A}$

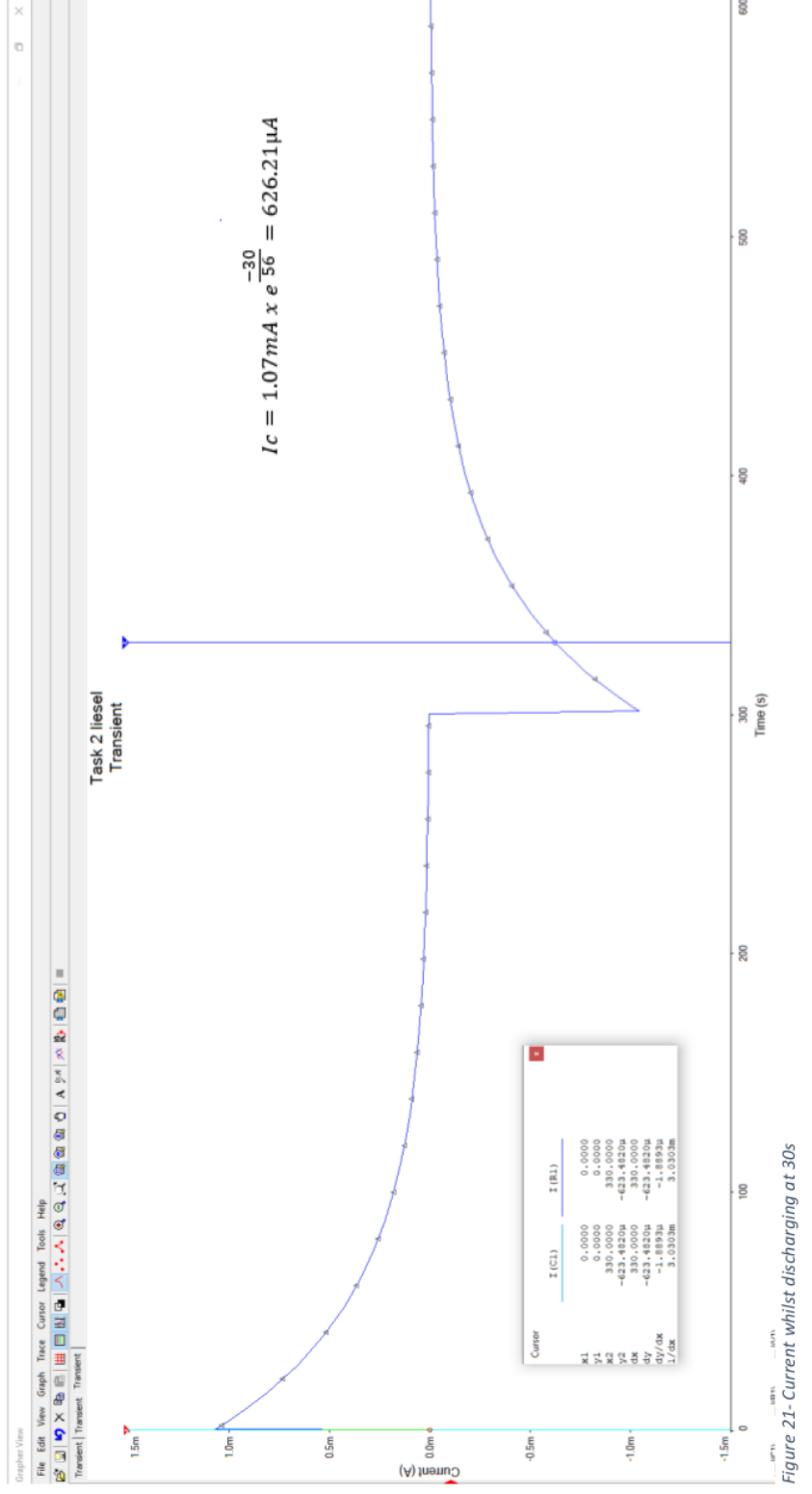


Figure 21- Current whilst discharging at 30s

T=80s, y2 showing -256.42μA

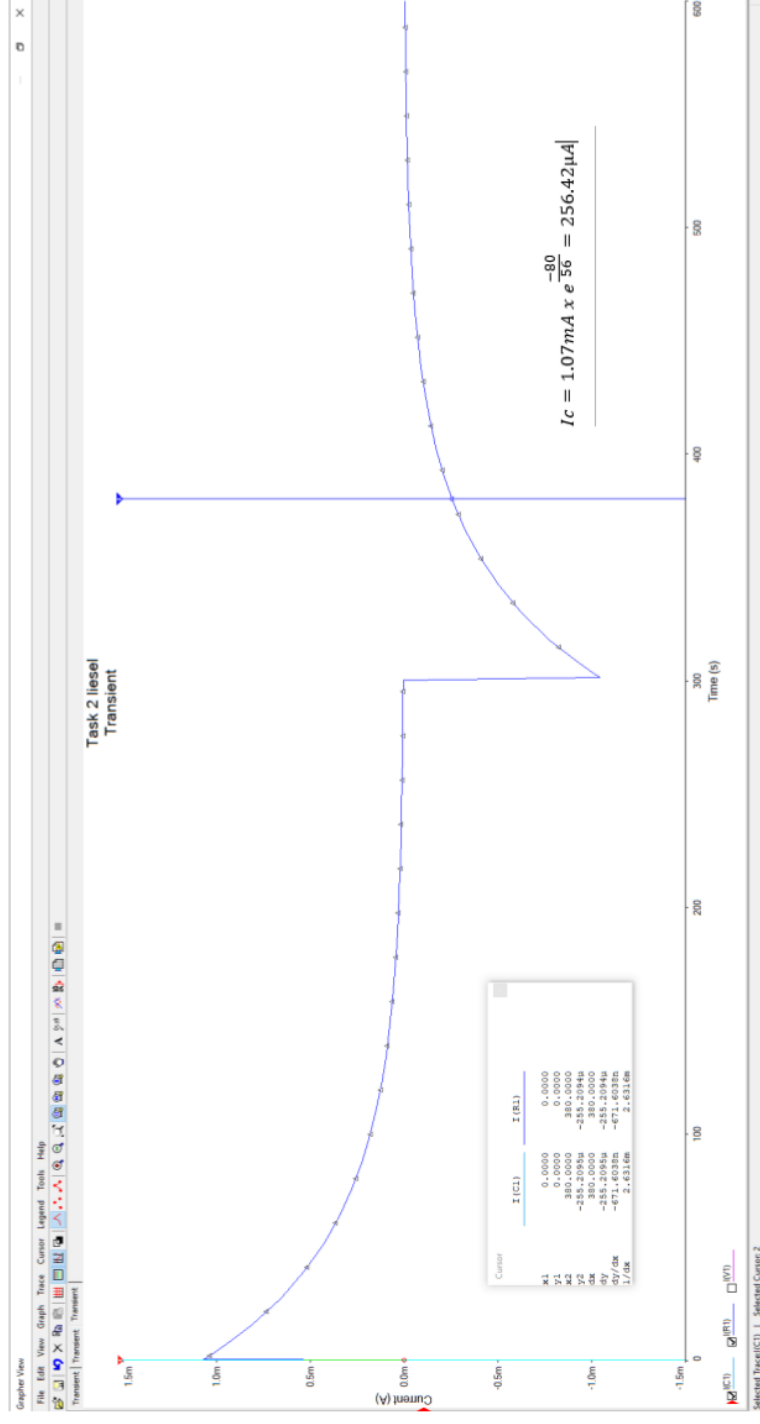


Figure 22- Current whilst discharging at 80s

T=100s, y2 showing -17

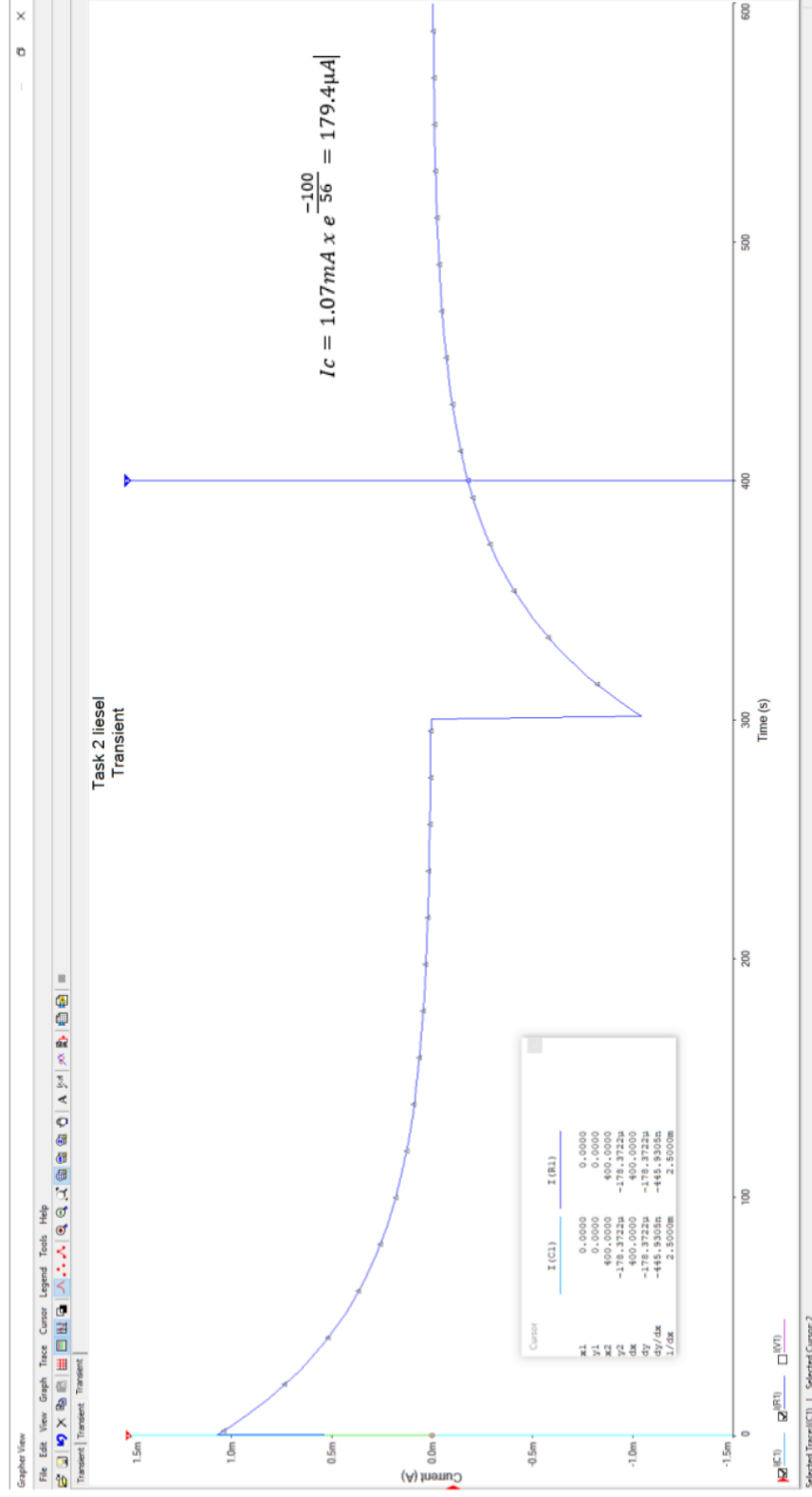


Figure 23- Current whilst discharging at 100s

Task 3

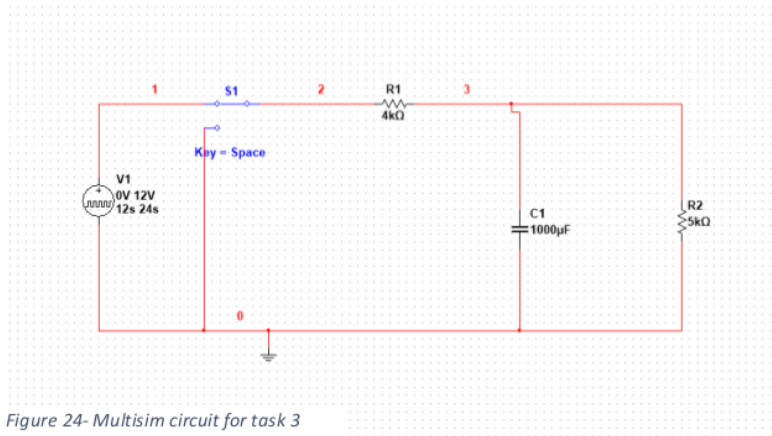


Figure 24- Multisim circuit for task 3

An equivalent circuit can be made using Thevenin's resistance equation:

$$\frac{4k\Omega \times 5k\Omega}{4k\Omega + 5k\Omega} = 2.2k\Omega$$

The time constant for this circuit can be calculated using: R stated as equivalent circuit resistor value.

$$\tau = R \times C$$

$$\tau = 1000\mu F \times 2.2k\Omega = 2.2s$$

$$\text{Transient period} = 5\tau = 11s$$

Charging Circuit

To calculate I_{Max} , V_{Max} must be obtained. This can be done by using:

$$V_{Max} = \left(\frac{R1}{R1 + R2} \right) \times V_S$$

$$V_{Max} = \left(\frac{4k\Omega}{4k\Omega + 4k\Omega} \right) \times V_S$$

$$V_{Max} = 5.3V$$

$$V_{Max} = \left(\frac{R2}{R1 + R2} \right) \times V_S$$

$$V_{Max} = \left(\frac{5k\Omega}{4k\Omega + 4k\Omega} \right) \times 12$$

$$V_{Max} = 6.67V$$

Current

$$I_{Max} = \frac{V_{Max}}{R_T}$$

$$I_{Max} = \frac{6.67V}{2.2k\Omega}$$

$$I_{Max} = 3.03mA$$

Instantaneous Current calculations

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

$$\text{At } 1 \tau: 3mA \left(e^{\frac{-2.2}{2.2}} \right) = 3.03mA$$

$$\text{At } 3 \tau: I_c = 3mA \left(e^{\frac{-2.2}{2.2}} \right) = 1.51mA$$

$$\text{At } 5 \tau: I_c = 3mA \left(e^{\frac{-11}{2.2}} \right) = 20.02\mu A$$

Multisim – τ values are shown in fig.25, I_{Max} values shown in fig.26

Table 1-Comparing current values for charging circuit, task 3

Time constant	Calculated Value	Multisim Value
I_{max}	3.03mA	2.99mA
1τ	1.1mA	1.15mA
3τ	151 μ A	153 μ A
5τ	20.02 μ A	21.14 μ A

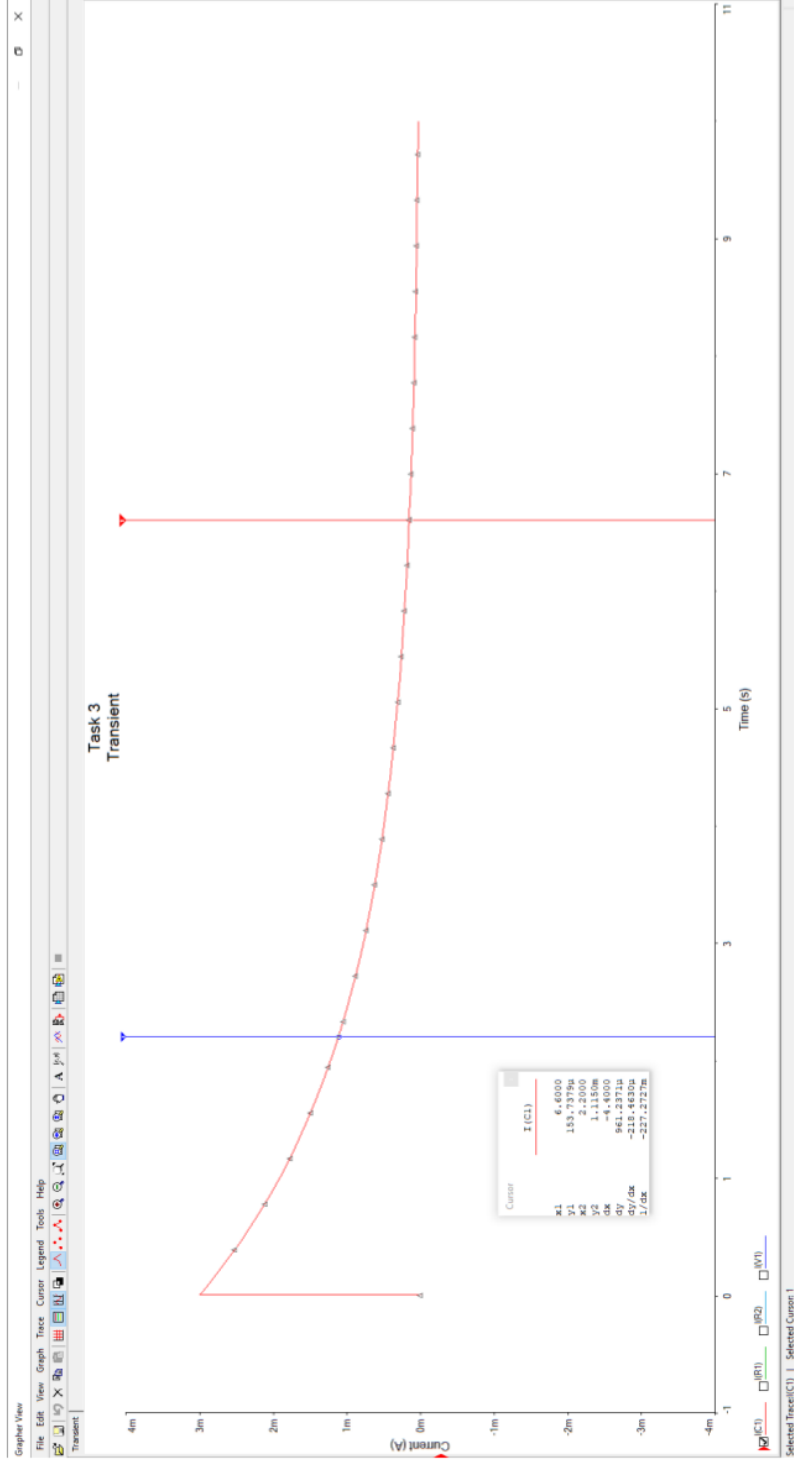


Figure 25- Current for charging, 1τ showing 1.15mA at Y1, 3τ showing 153.74uA at Y2

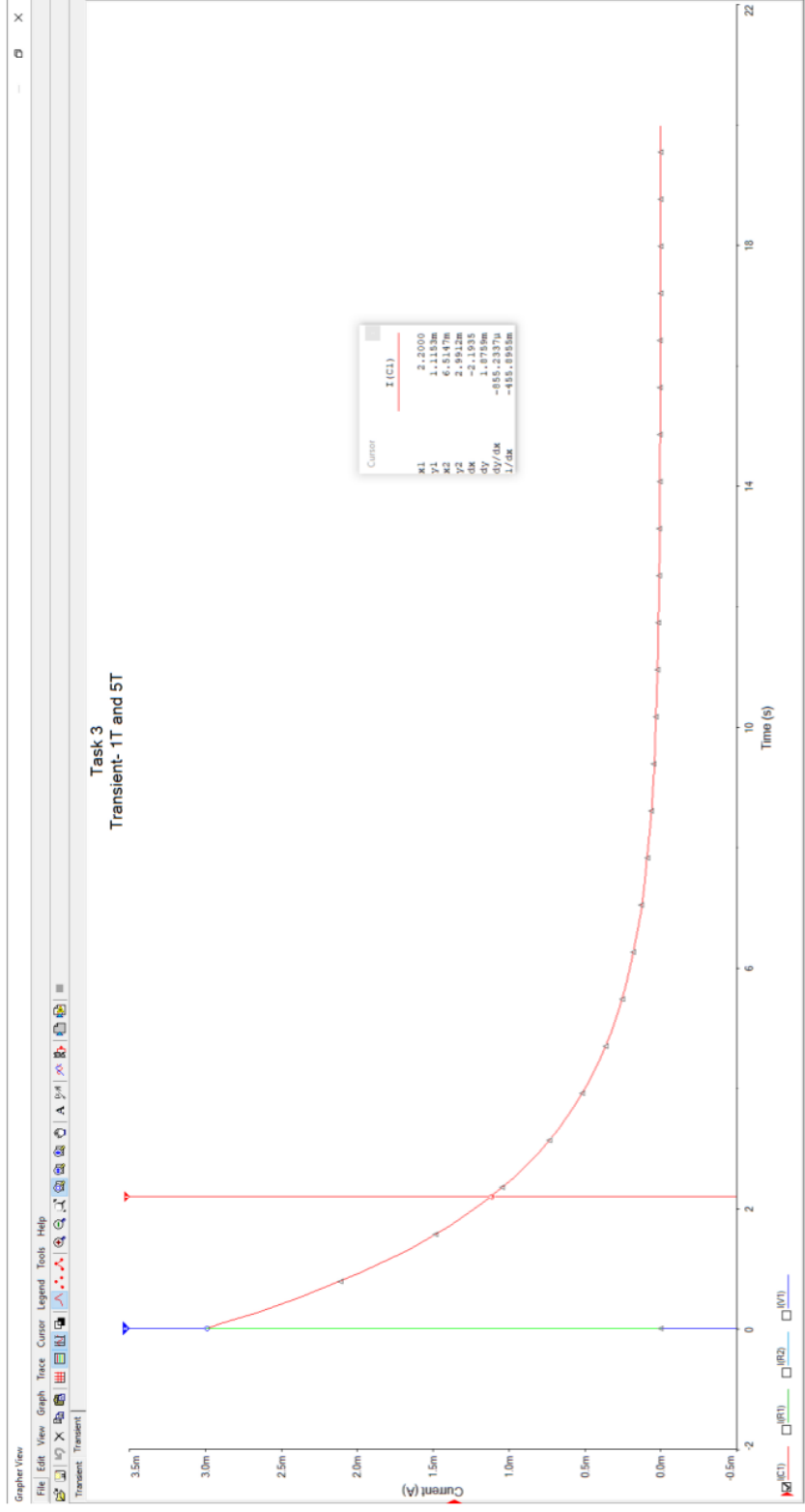


Figure 26-Imax value simulated showing 2.99mA at y2

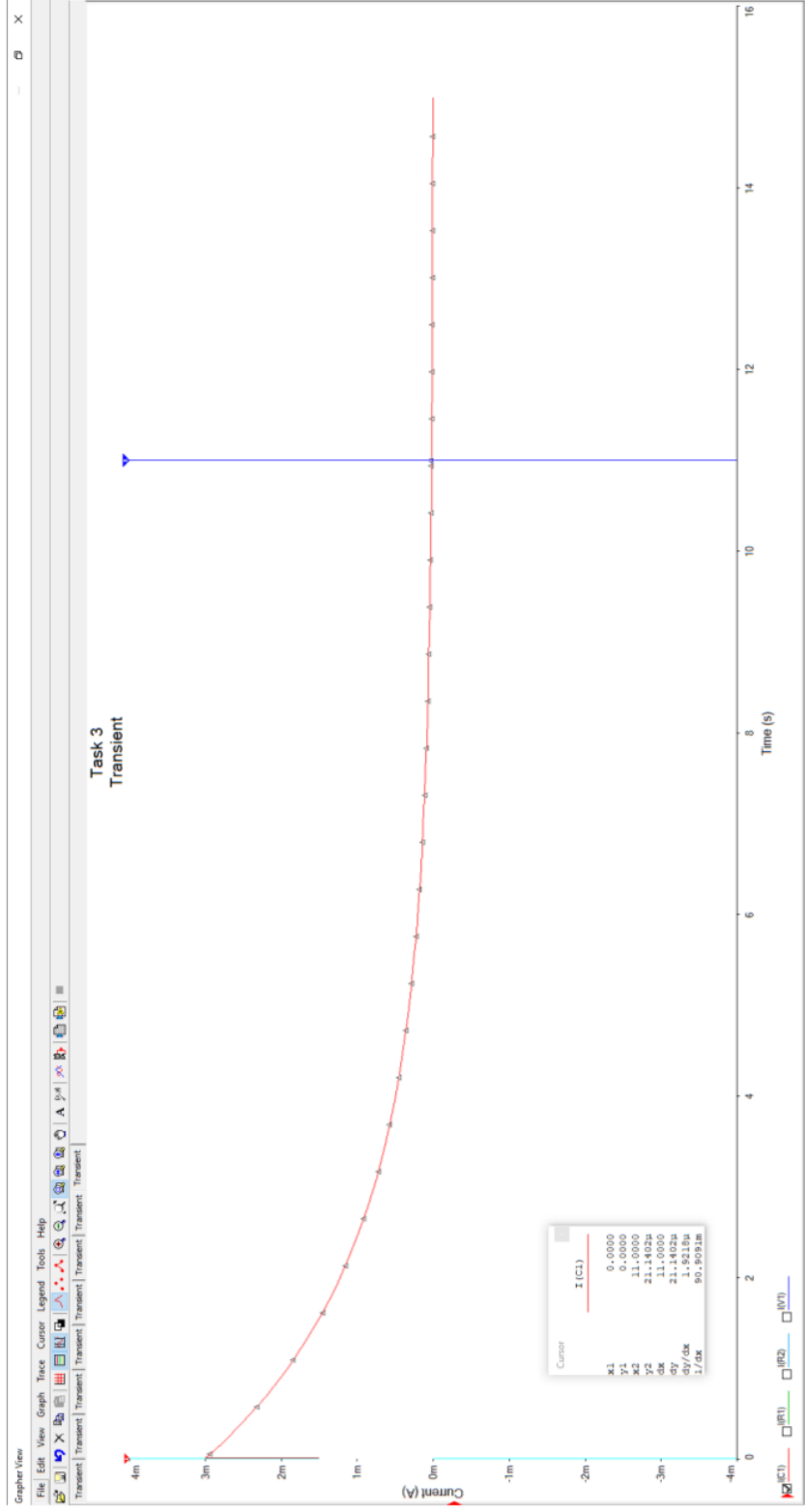


Figure 27-Fully discharged at 11s, showing 21.14uA at y2

Discharging Circuit

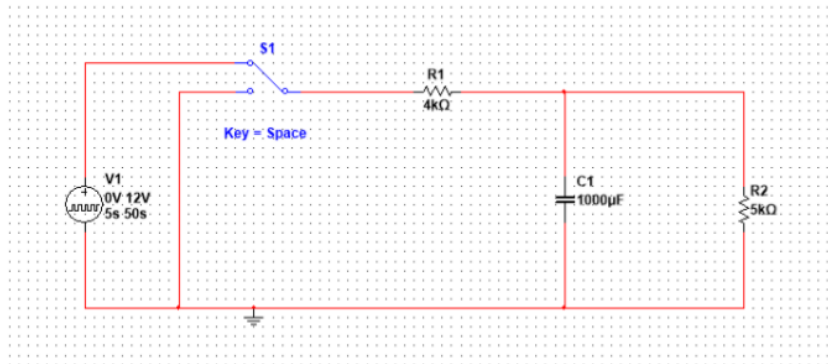


Figure 28- Source changed to pulse voltage to allow discharge of C1

The current at each time constant be calculated using;

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

Current Calculations

$$\text{At } 1\tau: -I_c = 3mA \left(e^{\frac{-2.2}{2.2}} \right) = -1.1mA$$

$$\text{At } 3\tau: -I_c = 3mA \left(e^{\frac{-6.6}{2.2}} \right) = -149\mu A$$

$$\text{At } 5\tau: I_c = 3mA \left(e^{\frac{-11}{2.2}} \right) = -20\mu A$$

Multisim figures:

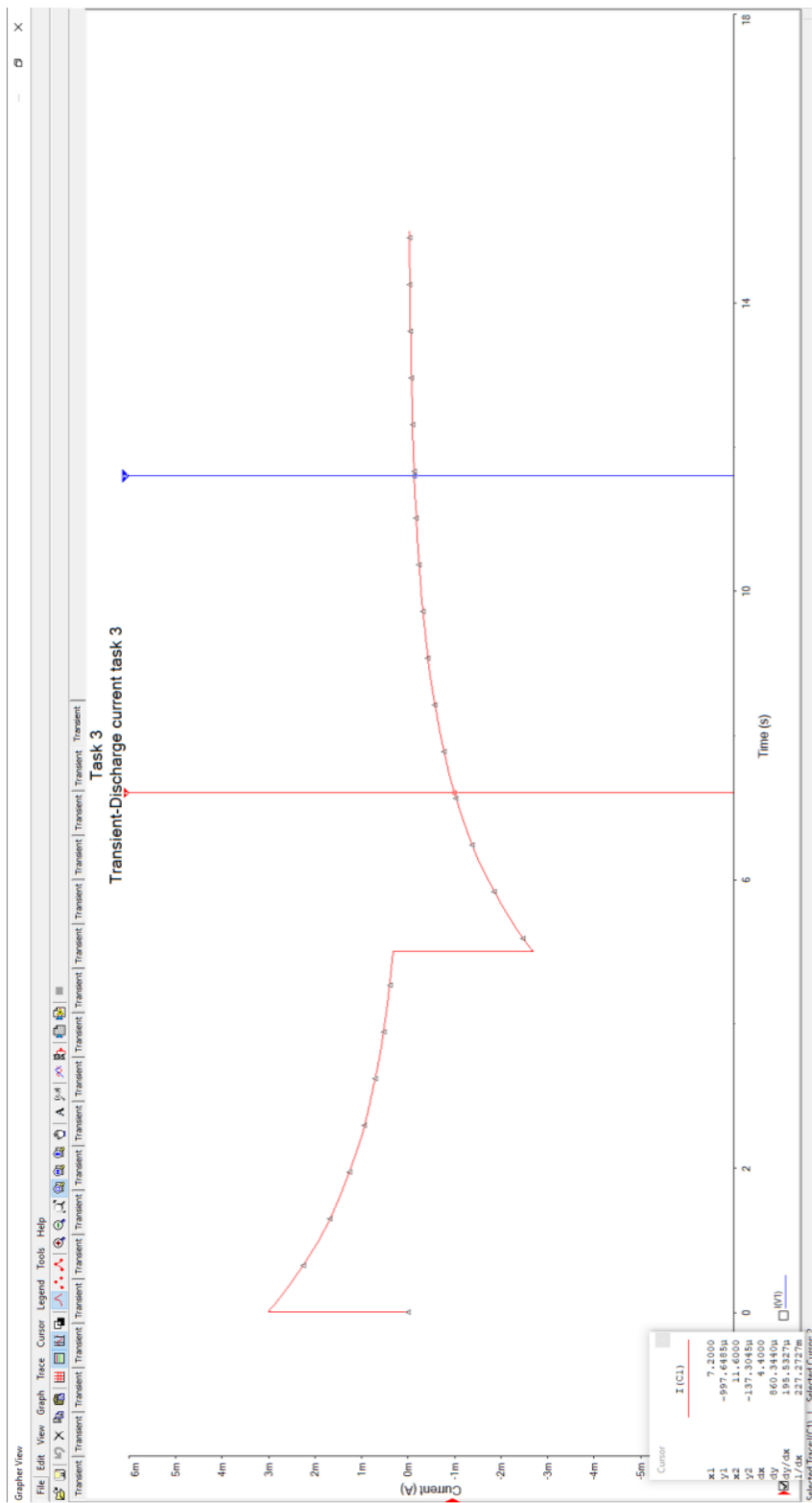
$$1\tau = -1.1mA$$

$$3\tau = -149.6\mu A$$

Table 2- Comparing results for discharging current, task 3

Time Constant	Calculated Value	Multisim Value
1 τ	-1.1mA	-997 μA
3 τ	-149.6 μA	-137.31 μA
5 τ	-20 μA	-20.66 μA

Times for constants are $T+5s$ to account for pulse voltage delay.





Task 4

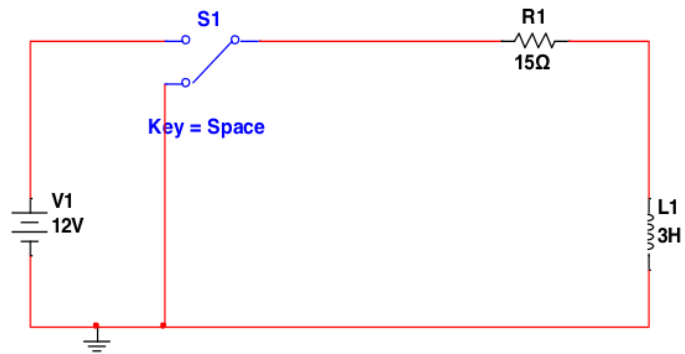


Figure 31- Circuit for task 4

$$\tau = L/R$$

$$\tau = 3/15$$

$$\tau = 0.2$$

$$\text{Transient period} = 5\tau = 1s$$

Charging

$$I_{MAX} = \frac{V_S}{R}$$

$$I_{MAX} = \frac{12}{15}$$

$$I_{MAX} = 0.8A = 800mA$$

Current Calculations

The current across the inductor must be calculated. This can be done using;

$$I_L = I_{MAX}(1 - e^{\frac{-t}{T}})$$

$$I_L = 0.8A(1 - e^{\frac{-t}{T}})$$

At 0.2 (1 τ) and 0.5s (2.5 τ)

$$1 \tau: I_L = 0.8A \left(1 - e^{\frac{-0.2}{0.2}}\right) = 0.51A$$

$$2.5 \tau: I_L = 0.8A \left(1 - e^{\frac{-0.5}{0.2}}\right) = 0.73A$$

After 5T, or 1 second, the current is;

$$I_L = 0.8A \left(1 - e^{\frac{-1}{0.2}}\right) = 0.79A$$

Table 3-Current charge up to 1s

Time (s)	Current (mA)	Multisim value (mA)
0	0	
0.1	314.78	309.4
0.2	505.7	500.59
0.3	621.5	620.36
0.4	691.73	692.21
0.5	734.33	735.32
0.6	760.17	761.19
0.7	775.84	776.71
0.8	785.35	786.03
0.9	791.11	791.61
1	794.61	794.97

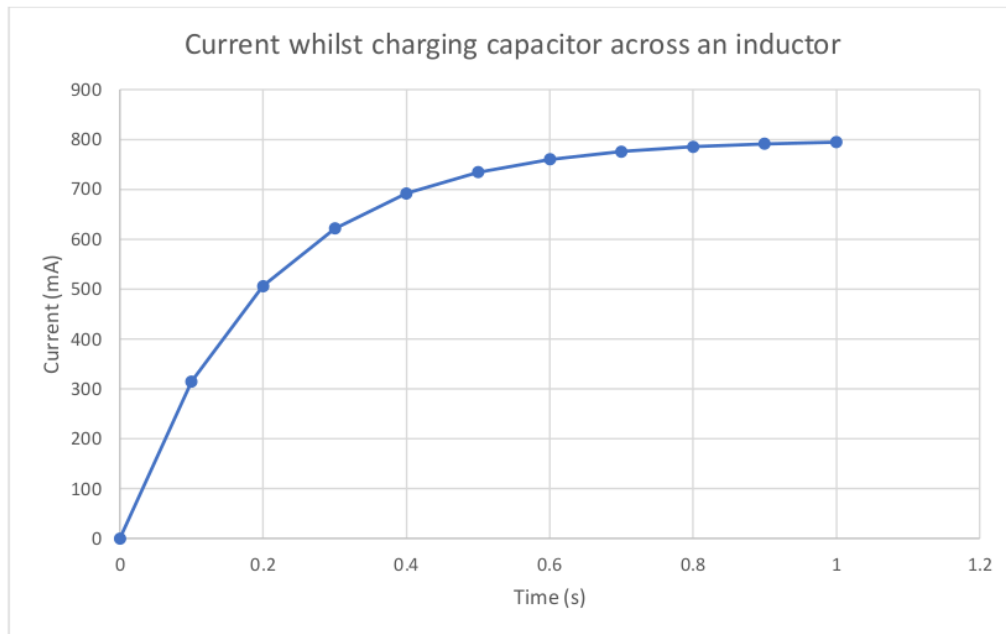
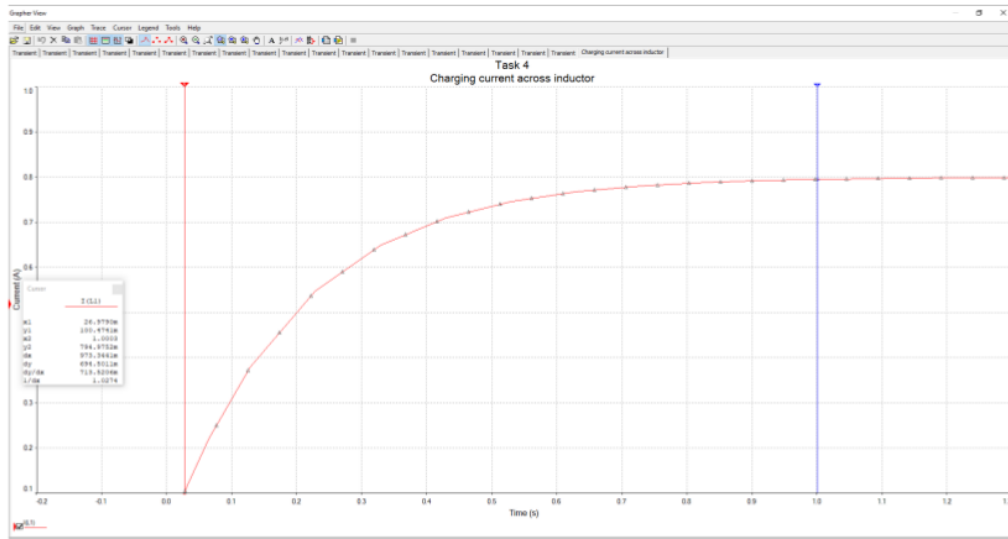


Figure 32- Charging current across an inductor- task 4





Discharging

As with the charging circuit, measurements will be taken at 0.2 s (1τ) and 0.5 s (2.5τ), as well as 1 s (5τ). The power source was changed to a pulse voltage to measure discharge values. The way this circuit is created on Multisim, the discharge starts at 1s. Therefore, each value is simulated at 1s + t.

$$I_L = I_{MAX}(e^{\frac{-t}{T}})$$

Calculated values for each time:

$$I_L = 0.8 \left(e^{\frac{-0.2}{0.2}} \right) = 294mA$$

$$I_L = 0.8 \left(e^{\frac{-0.5}{0.2}} \right) = 65.67mA$$

$$I_L = 0.8 \left(e^{\frac{-1}{0.2}} \right) = 5.39mA$$

Calculation above used for table 4 calculations.

Table 4-Current whilst discharging across an inductor

Time (s)	Current (mA)	Multisim value (mA)
0	790	794.69
0.1	485.22	483.83
0.2	294.3	291.97
0.3	178.5	177.4
0.4	108.26	107.04
0.5	65.67	65.04
0.6	39.83	39.25
0.7	24.16	23.85
0.8	14.65	14.4
0.9	8.89	8.74
1	5.39	5.27

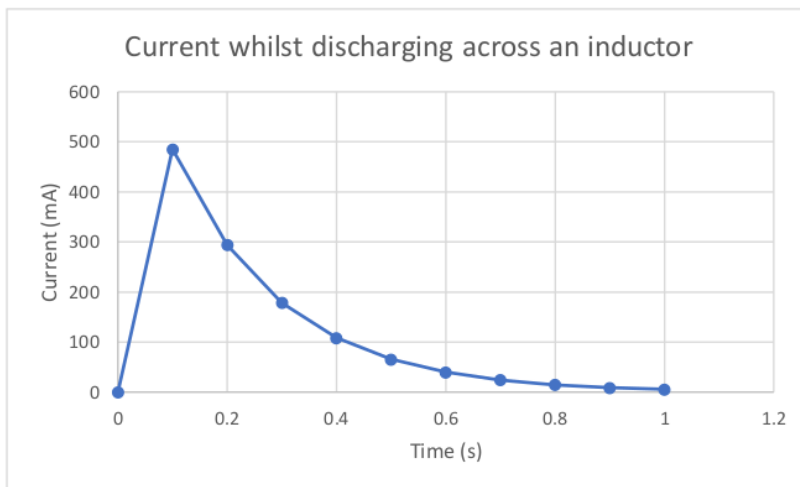


Figure 34-Graph showing current discharge across an inductor, task 4

To calculate the time before current has fallen to 100mA and 10mA, the formula below must be re-arranged.

$$I_L = I_{MAX}(e^{\frac{-t}{T}})$$

$$\frac{I_L}{I_{MAX}} = (e^{\frac{-t}{T}})$$

$$\ln\left(\frac{I_L}{I_{MAX}}\right) = \frac{-t}{T}$$

$$\ln\left(\frac{I_L}{I_{MAX}}\right)T = -t$$

Therefore, time to reach 100mA:

$$-t = \ln\left(\frac{100mA}{0.8}\right)0.2 = -0.42s$$

Therefore;

$$t = 0.42s$$

The time taken to reach 10mA, is calculated as;

$$-t = \ln\left(\frac{10mA}{0.8}\right)0.2 = -0.88s$$

Therefore;

$$t = 0.88s$$

Multisim simulation shows these values at 0.41s and 0.87s, as seen in fig. 44 and 45 in appendix.

Testing, Results and Analysis

Task 1) Comparisons of Voltage Measurements whilst charging

Table 5- Comparison of voltage measurements whilst charging capacitor

Time (s)	Multisim value (V)	Calculated Value (V)	Practical Value (V)
30	2.35	2.48	2.55
80	4.56	4.56	4.62
100	4.99	4.99	5.05

Comparisons of current measurements whilst charging

Table 6-Comparison of current measurements whilst charging capacitor

Time (s)	Multisim value (μA)	Calculated Value (μA)	Practical Value (mA)
30	627.54	626	0.59
80	256.51	256	0.24
100	179.6	179	0.17

Values have been selected from the three random times chosen in the previous section, as a way of comparing methods. Transient behavior can be seen as voltage cannot reach its maximum value instantly, as it would require an infinite current to achieve this, which it does not have. As a result, the capacitor will charge, as shown by values above and graphs in this report. The speed of voltage increase is governed by the current. Whilst current flow rises through the capacitor, the charge across the capacitor increases, causing voltage to increase. As this happens, the voltage passing through the resistor decreases, and therefore the current will also reduce its rate of flow. With a high current, the voltage is at its greatest increase, shown by the large initial increase of voltage as current decreases significantly. As the rate of change slows for both voltage and current, the rate of change decreases, before reaching its period of 'steady state'. The values for all three measurements are similar, with slight discrepancies between the practical, calculated and multisim values. The practical values are arguably more useful, showing true readings rather than the theory based values for calculations and multisim. With regards to the practical values, several factors may affect the accuracy. It is very unlikely that the capacitor used was exactly $10,000\mu\text{F}$, and that the resistor was exactly $5.6\text{k}\Omega$. This will immediately affect the readings given. Other factors such as multimeter calibration and human error with regards to timings and multimeter and timer only giving to a couple of decimal places. Calculations and multisim provide very similar readings, generally with a slight deviation in the decimal values. These values are both purely theory based, and use exact figures for capacitance, resistance and time. It is likely that the multisim values are exact, due to the software using a higher degree of accuracy with regards to decimal places or the method to achieve the values.

(electronics; a systems approach: Neil Storey)

Task 2 Measuring discharge voltage

Table 7-Comparison of voltage measurements whilst discharging capacitor

Time (s)	Multisim value (V)	Calculated Value (V)	Practical Value (V)
30	3.49	3.51	3.56
80	1.492	1.44	1.48
100	0.998	1.01	1.04

Task 2) Measuring discharge current

Table 8-Comparison of current measurements whilst discharging capacitor

Time (s)	Multisim value (μA)	Calculated Value (μA)	Practical Value (μA)
30	-623.48	-626.21	-500
80	-255.2	-256.42	-240
100	-178.37	-179.4	-170

Voltage is defined as the potential energy, whereas current is defined as the rate of flow of electrons. Therefore whilst the capacitor is fully charged, voltage is at its maximum, as it is storing its maximum energy, whereas current is very low, due to no electron flow as it is full. When the capacitor discharges, there is suddenly movement of electrons in the circuit. This means that the potential energy, or voltage will start to decrease, whilst the flow of electrons or current will start to increase, as shown by figures below. As is the case with charging, the change in voltage and current cannot happen instantly, and therefore have transient behaviour. Calculations previously show that at 5τ , the capacitor should've discharged 63% of its voltage (1τ), 86.3% at 2τ , increasing exponentially at each time constant until it reaches 99.3% of its value before achieving steady state. At 5τ (280s) with the practical values, the current is -0.01A with a voltage of 0.05V. As the capacitor has been fully discharged, there is no potential energy left (voltage), and there is no energy causing electrons to flow, so therefore the current is near to zero. As stated above, there are several reasons for discrepancies between the multisim, calculated and practical values. The current will discharge in the opposite direction that it charged in, and therefore will give a negative value, as seen above.

Task 3

Charging Circuit

Time constant	Calculated Value	Multisim Value
I_{max}	3.03mA	2.99mA
1τ	1.1mA	1.15mA
3τ	151 μ A	153 μ A
5τ	20.02 μ A	21.14 μ A

Discharging Circuit

Time Constant	Calculated Value	Multisim Value
1τ	-1.1mA	-997 μ A
3τ	-149.6 μ A	-137.31 μ A
5τ	-20 μ A	-20.66 μ A

Before the capacitor is charged, the circuit is effectively shorted to earth. Calculations in previous section state how this circuit could be made into an equivalent circuit, by replacing the two resistors, with one 2.2k Ω resistor only when the switch is closed. This circuit also displays expected behavior with charging and discharging. With charging, the current is initially very high, due to a sudden change in electron movement. As the capacitor charges, this rate slowly decreases, before achieving transience at 5τ , with approx. 20.02 μ A. At 5τ , the capacitor is full and causes zero current flow. When the capacitor is discharging, the voltage is dissipated through both resistors to ground.

As is the case with circuits drawn in task 1 and 2, the discrepancies between calculated and multisim values are very small. The subtle differences between calculated value and multisim value can be expected, as slightly different methods are used, with Multisim likely opting for a far more accurate method of calculation. The discharged current values are the negative values for the charging current, as the I_{Max} is the same, and ratios for each time constant.

Task 4

Time (s)	Current (mA)	Multisim value (mA)
0	0	
0.1	314.78	309.4
0.2	505.7	500.59
0.3	621.5	620.36
0.4	691.73	692.21
0.5	734.33	735.32
0.6	760.17	761.19
0.7	775.84	776.71
0.8	785.35	786.03
0.9	791.11	791.61
1	794.61	794.97

Table 3

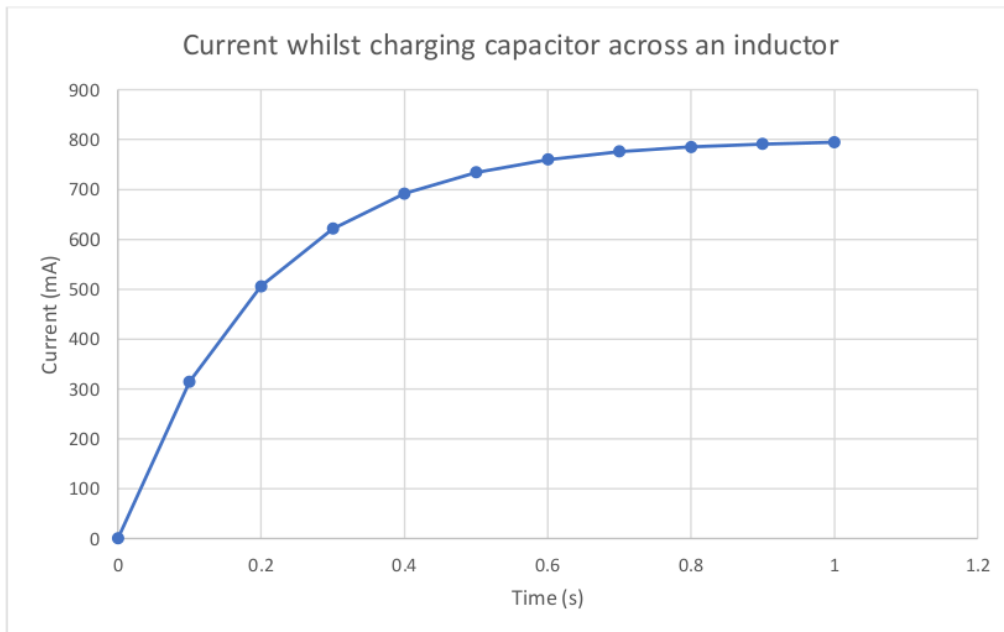


Table and graph above are labelled as table 3 and fig. 32 in previous section.

As seen above, the behavior of current whilst charging an inductive circuit contrasts the behavior in a capacitive circuit. Current increases through an inductor whilst the circuit is charged, whereas a current is initially high and decreases through a capacitive circuit. An inductor will create a back emf. Which will create opposition to the current trying to flow into the coil. This causes energy to be taken through the coil, therefore increasing the current through it. On the discharge circuit, the emf created will cause opposition to the decrease of current across the coil, and therefore putting more energy/current through the circuit. This behavior is defined under Lenz's law. (Hughes, 2016)

This current will continue to increase, until it reaches I_{Max} , stated as 0.8A in previous section. The voltage in this circuit will perform the opposite, initially be very high and fall through a transient curve. As shown by approx. 790mA when fully charged, falling to 5.27mA at 5τ . As is the case with the previous sections, there are very small discrepancies between calculated values and Multisim values, due to possible rounding errors. Voltage simulation for Multisim is included in appendix.

Time (s)	Current (mA)	Multisim value (mA)
0	790	794.69
0.1	485.22	483.83
0.2	294.3	291.97
0.3	178.5	177.4
0.4	108.26	107.04
0.5	65.67	65.04
0.6	39.83	39.25
0.7	24.16	23.85
0.8	14.65	14.4
0.9	8.89	8.74
1	5.39	5.27

Table 4- Discharge

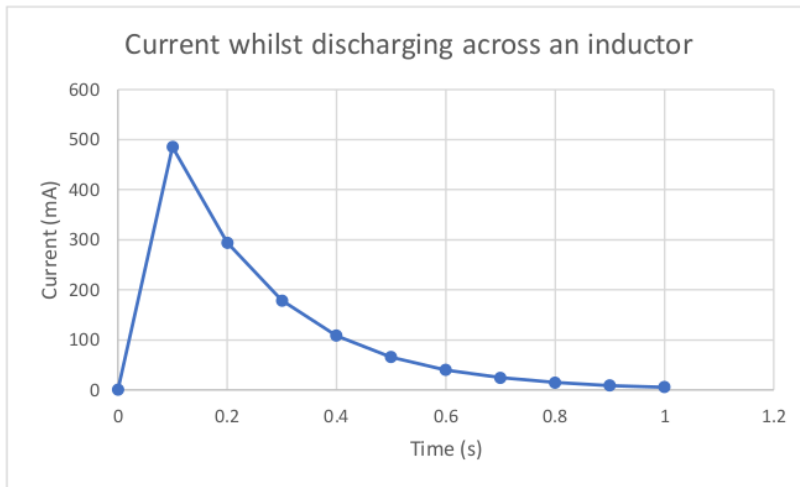


Fig 34

The discharge circuit, graph and table shown above performs the opposite. The inductor will be storing energy, as it has been charged. Full charge and discharge curves have been included in appendix. This inductor will dissipate its current through R1, but in the same direction. This therefore causes current to show a positive reading at all times. As with the RC circuit, the inductor will discharge fully after 5τ . At this point, the inductor will effectively act as a short, giving near 0Ω resistance.

This circuit had to be performed via multisim and equations as it was not suitable for a practical test. A 3H inductor is relatively large for a college environment, and produces an unsuitably high current, with a chance of sparking when changing state of the circuit.

Conclusions and recommendations

Each RC circuit behaves in a similar manner, with voltage increasing with a transient curve and current decreasing with a charging circuit, and the opposite with a discharging circuit. Inductive circuits behave in the opposite manner. When comparing calculations with Multisim values, they are generally very similar. There are slight discrepancies that could've been avoided. Rounding values down to one or two decimal places for calculations will affect the final value, whereas Multisim will use full values. Throughout, comparison between calculated, multisim and practical values are similar where performed. The extent at which results are accurate and reliable depend on the application of the findings. Practical tasks are more likely give more genuine readings, but will include slight deviations in readings dependent on true value of components and calibration of test equipment. Calculations and Multisim will provide very accurate readings, which are possibly unachievable with a practical task dependent on test equipment and component quality. The report has given a wider view and understanding of transient behavior for capacitive and inductive circuits.

To improve the quality of results made, several factors could be addressed:

- Ensuring that full numbers are used when performing calculations. Rounding to one or two decimal places causes larger errors when performing several calculations. Using full numbers will provide greater accuracy when comparing to Multisim values
- Performing the practical test several times with a sample of electrical components, generating average values for measurements, or measuring components to ensure they are the exact value required. It is likely that most components slightly differ to their advertised value, which will cause discrepancies when analysing circuits.
- Performing calculations within excel when making spreadsheets. Formulae could've been introduced to perform many calculations at much smaller intervals. This would've provided many more points for sampling, creating a more genuine curve. Excel could've performed current measurements at every 100th of a second, proving a far greater resolution and making a much smoother graph.

Annex

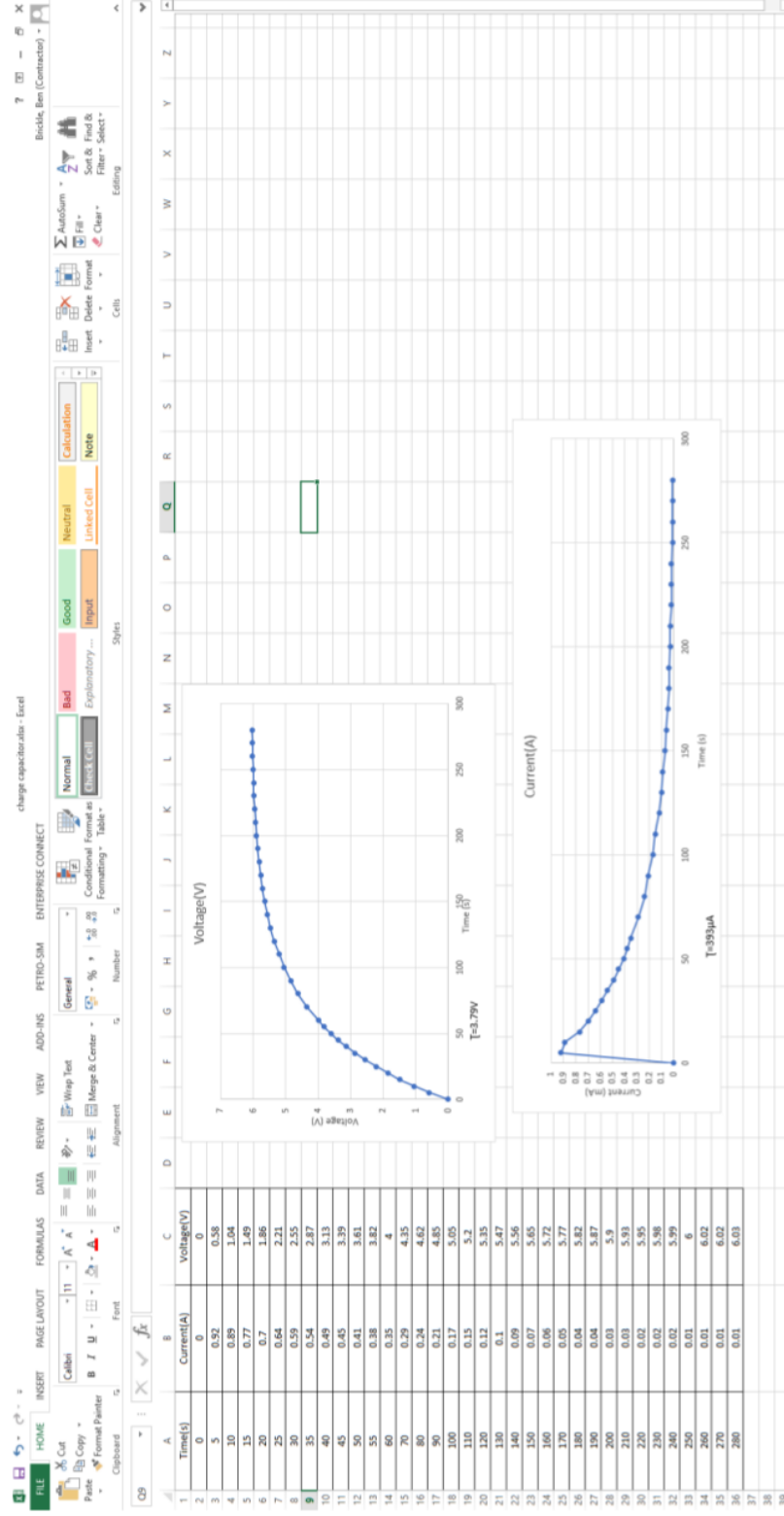


Figure 35- Practical Values for task 1



1	Charge Voltage Task 1			
2	Time (s)	Multisim value (V)	Calculated Value (V)	Practical Value (V)
3	30	2.35	2.48	2.55
4	80	4.56	4.56	4.62
5	100	4.99	4.99	5.05
6				
7				
8	Charge Current Task 1			
9	Time (s)	Multisim value (µA)	Calculated Value (µA)	Practical Value (µA)
10	30	627.54	626	590
11	80	256.51	256	240
12	100	179.6	179	170
13				
14				
15				
16				
17	Discharge Voltage Task 2			
18	Time (s)	Multisim value (V)	Calculated Value (V)	Practical Value (V)
19	30	3.49	3.51	3.56
20	80	1.492	1.44	1.48
21	100	0.998	1.01	1.04
22				
23				
24	Discharge Current Task 2			
25	Time (s)	Multisim value (µA)	Calculated Value (µA)	Practical Value (µA)
26	30	-623.48	-626.21	-500
27	80	-255.2	-256.42	-240
28	100	-178.37	-179.4	-170

Figure 37- Values obtained at 3 random times for task 1 and 2

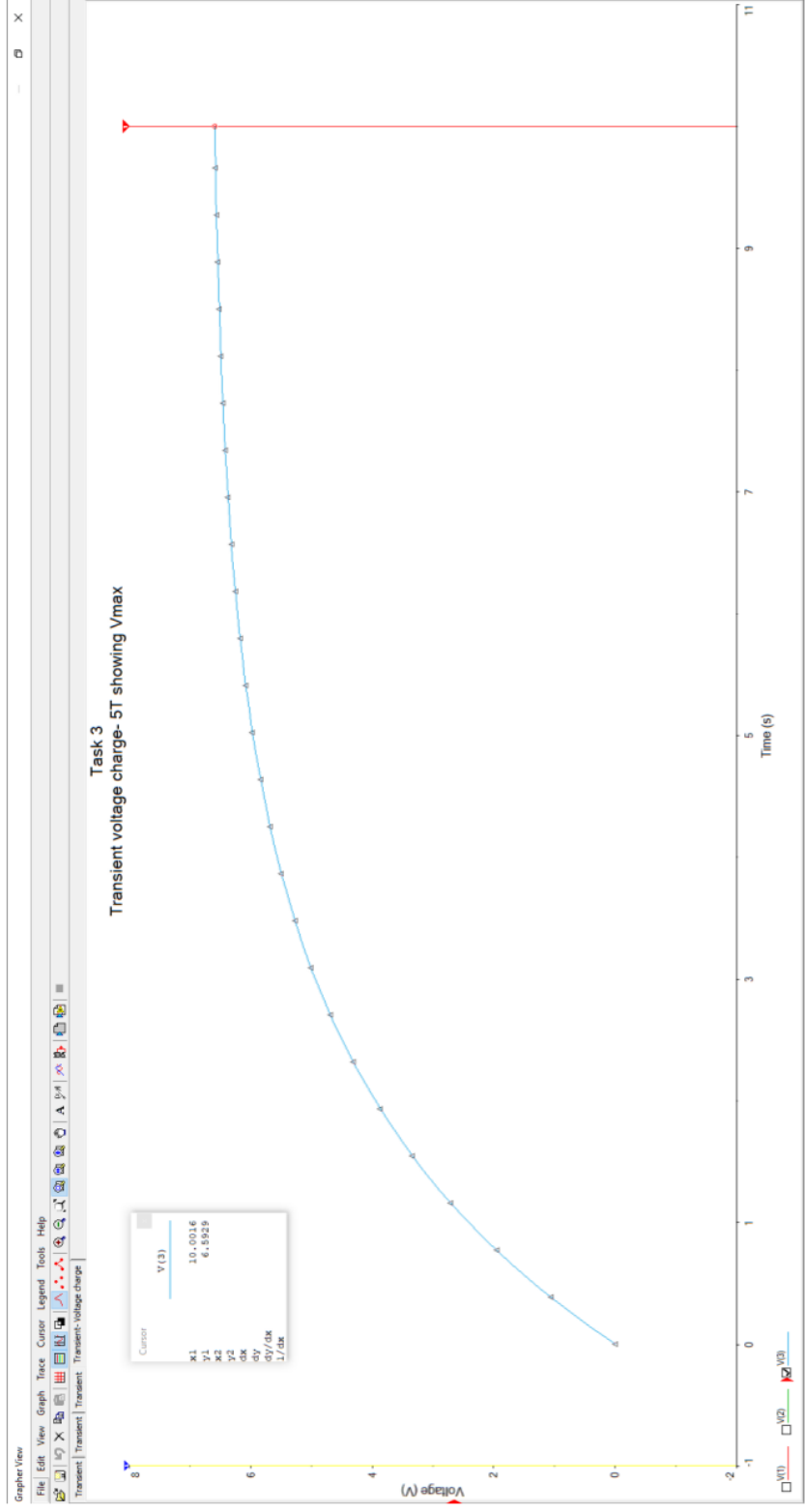


Figure 38- Voltage curve for charging circuit at 5T

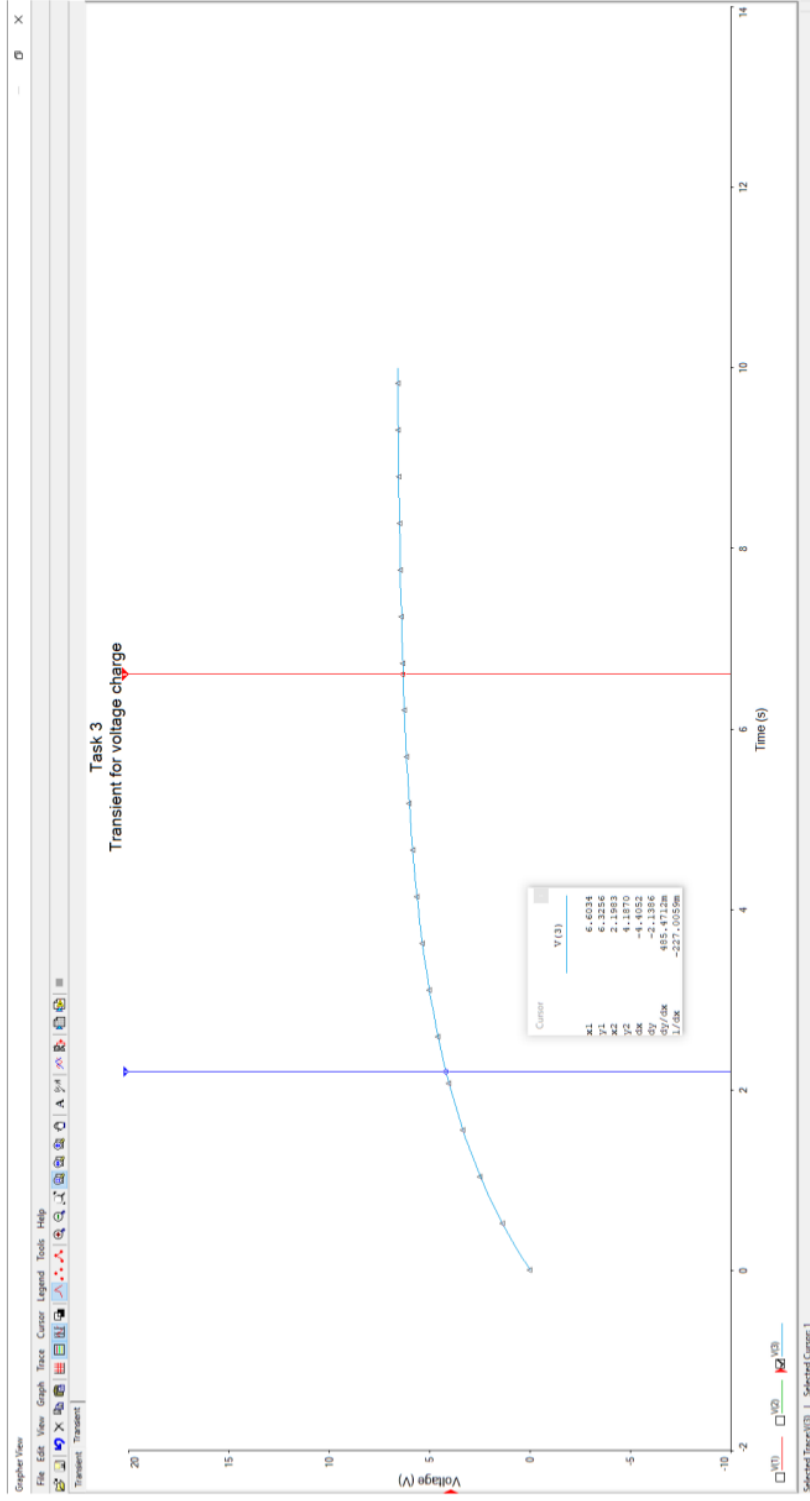


Figure 39- Voltage at 1T and 3T

$$V_{\max} = (R_1 / (R_1 + R_2)) \times V_s$$

$$V_{\max} = (4k / (4k + 5k)) \times 12$$

$$V_{\max} = 5.3V$$

$$V_{\max} = (R_2 / (R_1 + R_2)) \times V_s$$

$$V_{\max} = (5k / (4k + 5k)) \times 12$$

$$V_{\max} = 6.67V$$

Above calculations show that the maximum voltage produced by this circuit is 6.7V. The two-time values that are going to be used are 1T and 3T

$$1 \tau = 2.2s$$

$$3 \tau = 6.6s$$

$$1 \tau \text{ for } V_c = V_{out} (1 - e^{-t/T})$$

$$V_c = 6.7 (1 - e^{-2.2/2.2})$$

$$V_c = 4.23V$$

$$3 \tau \text{ for } V_c = V_{out} (1 - e^{-t/T})$$

$$V_c = 6.7 (1 - e^{-6.6/2.2})$$

$$V_c = 6.36V$$

Fig. 25 shows that at 1 τ voltage is 4.23V and 3 τ is 6.36V

Discharging

Voltage Calculations

$$V_C = V_S \left(e^{\frac{-t}{\tau}} \right)$$

$$\text{At } 1\tau: V_C = 6.67 \left(e^{\frac{-2.2}{2.2}} \right) = 2.45V$$

$$\text{At } 3\tau: V_C = 6.67 \left(e^{\frac{-6.6}{2.2}} \right) = 0.33V$$

$$\text{At } 5\tau: V_C = 6.67 \left(e^{\frac{-11}{2.2}} \right) = 44.9mV$$

Task 4

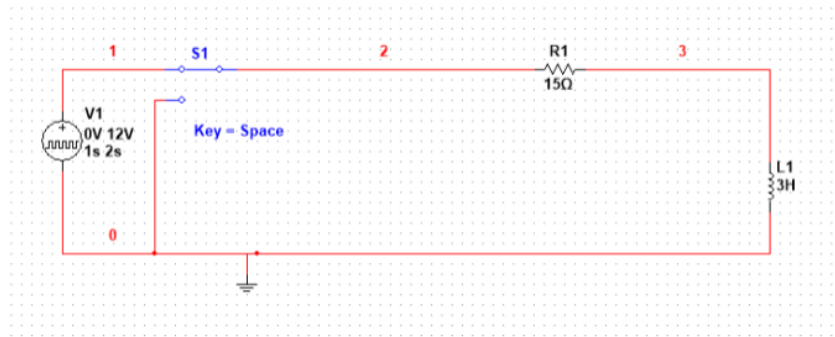


Figure 40- Task 4 circuit

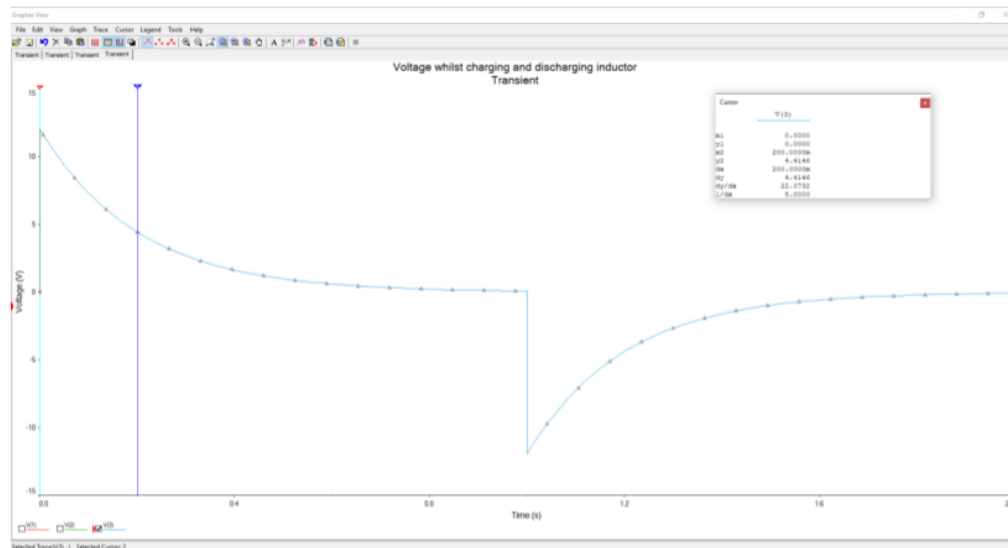


Figure 41- Voltage whilst charging inductor



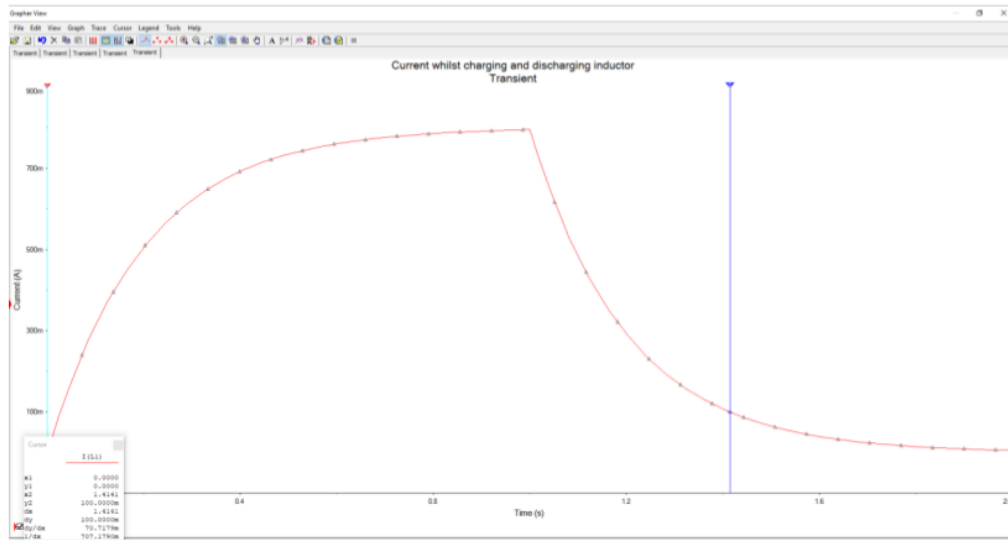


Figure 44- Time taken to reach 100mA shown as 1.41s. Therefore, 0.41s after 1s charge time has been subtracted

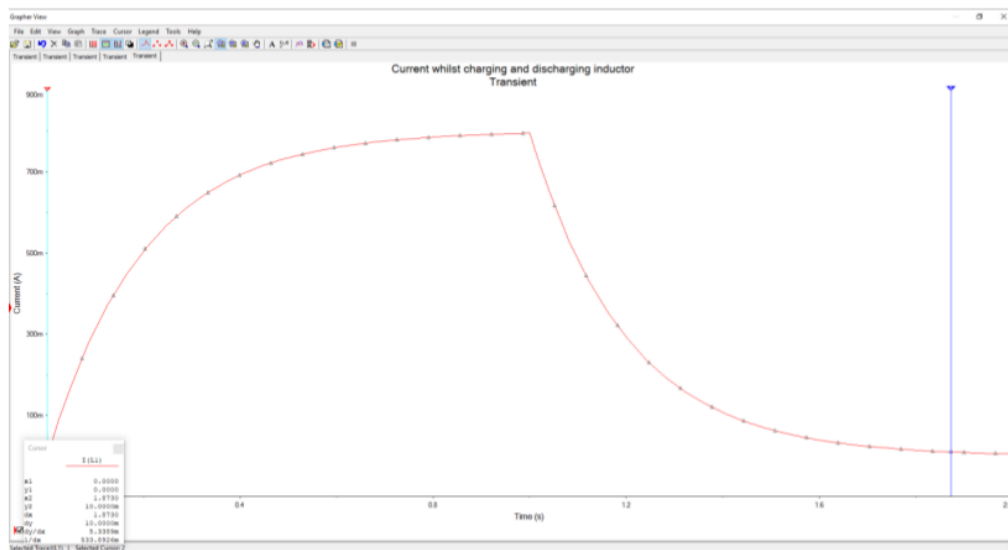


Figure 45- Time taken to reach 10mA shown as 1.87s. Therefore, 0.87s after 1s charge time has been subtracted

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: NEW CSG-RUBRIC

**BENJAMIN
BRICKLE**

68

1. ENGAGEMENT WITH LITERATURE

2. KNOWLEDGE AND UNDERSTANDING

- 

2. Competent knowledge of underlying principles demonstrated in your analysis. Report main body lacks depth in terms of equation explanation. 16/25
- 16

3. COGNITIVE AND INTELLECTUAL

- 

3. Sound results generally few areas need to be checked as marked, Analysis in your final section is very good 20/30
- 20

4. PRACTICAL APPLICATION

- 

4. A very good application of methods with mostly clear results, some room for improvement as marked 18/25
- 18

5. TRANSFERABLE SKILLS

- 

5. Accurate, coherent and fluent work, well presented generally, not good practice to place a table of results at the beginning, explain your method and circuit first. Your overall analysis and conclusion is good 14/20
- 14