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by Cai Llewellyn

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Your Name: Cai Llewellyn

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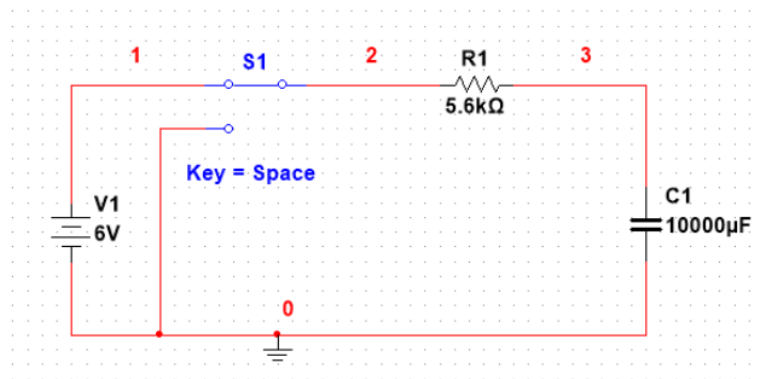
Introduction

This assignment looks into the assessment of the behaviour of R-L and R-C circuits during their connection to a direct current voltage source. This search is done using simulation, testing, theoretical prediction and practical construction. Results for the practical will then be studied whilst emphasising of comparing the two methods undergone. The findings will then represent the conclusion of this practical.

Task 1

Method

Figure 1: Multisim circuit



The aim of task 1 was to investigate transient behaviour for the charging of a capacitor. To begin I constructed circuit one on multisim, as shown on the assignment brief. This was followed by calculating the time constant using the equation $\tau = Rc = 56000 \times 10000 \times 10^{-6} = 56$ seconds. Additionally, I calculated 5τ , which is the length of time it takes for a capacitor to charge up. Two time values were then chosen at random; these being 45 seconds and 98 seconds. Next was the task of calculating predicted current and voltage values, at my individual and randomly chosen times. The equation used to calculate voltage was:

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

The practical commenced shortly, after where the experiment was set up; two multimeters, one set up to read current and the other to read voltage, and a stop watch to take note of both readings at my selected times as shown above. All results from the practical were entered onto an excel sheet. Following this, I was able to collate the results in the form of a graph. Using multisim and the circuit built as 'figure 1', I ran a simulation. This simulation

created two graphs, one displaying voltage against time and the other, current against time. This allowed me to cross reference values for current and voltage with the times selected (45s, 56, 98s). All results for the times selected were put into two tables (one representing voltage and the other, current). Using these tables I was not able to compare results gathered via calculation, practical and simulation.

Calculations

To calculate the time constant I used the following equation:

$$\tau = R_c = 56000 \times 10000 \times 10^{-6} = 56 \text{ seconds}$$

$$5\tau = 5 \times 56 = 280 \text{ seconds}$$

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

$$= 6(1 - e^{-\frac{45}{56}}) \quad (45\text{seconds})$$

$$= 3.314\text{V}$$

$$= 6(1 - e^{-\frac{56}{56}}) \quad (56 \text{ seconds})$$

$$= 3.792\text{V}$$

$$= 6(1 - e^{-\frac{98}{56}}) \quad (98 \text{ seconds})$$

$$= 4.957\text{V}$$

$$I_{\max} = V_s/R = 6/5.6 \times 10^3 = 1.071$$

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

$$1.071 \times (e^{-\frac{45}{56}}) \quad (45\text{seconds})$$

$$= 0.48\text{Amps}$$

$$1.071 \times (e^{-\frac{56}{56}}) \quad (56\text{seconds})$$

$$= 0.39\text{Amps}$$

$$1.071 \times (e^{-\frac{98}{56}}) \quad (98\text{seconds})$$

$$= 0.19\text{Amps}$$

Results

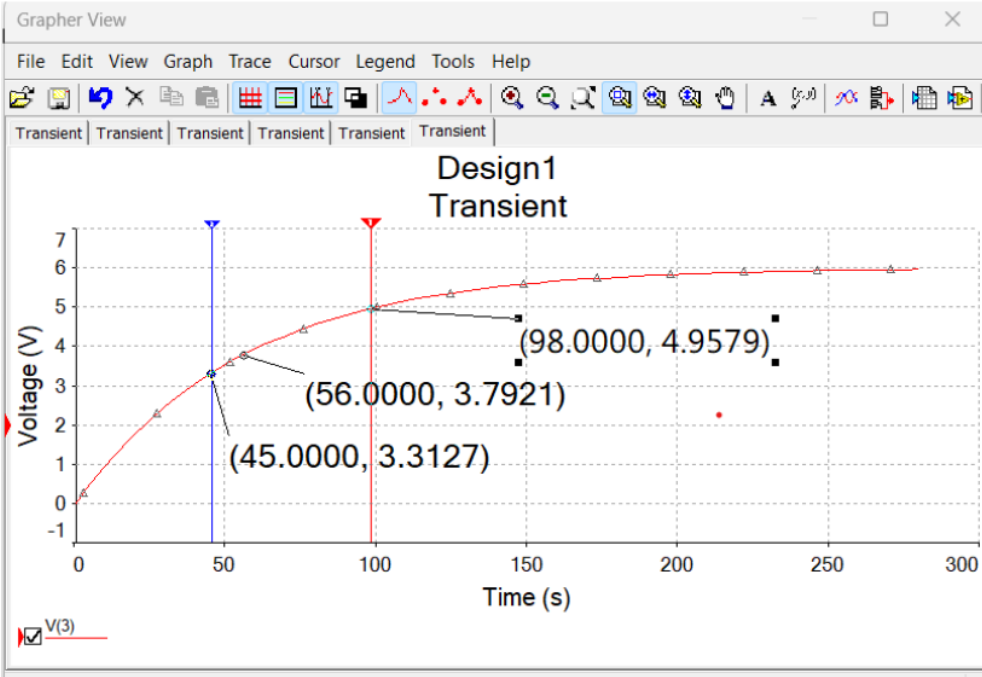
Below are the results collated from carrying out the experiment described above.

Voltage Table

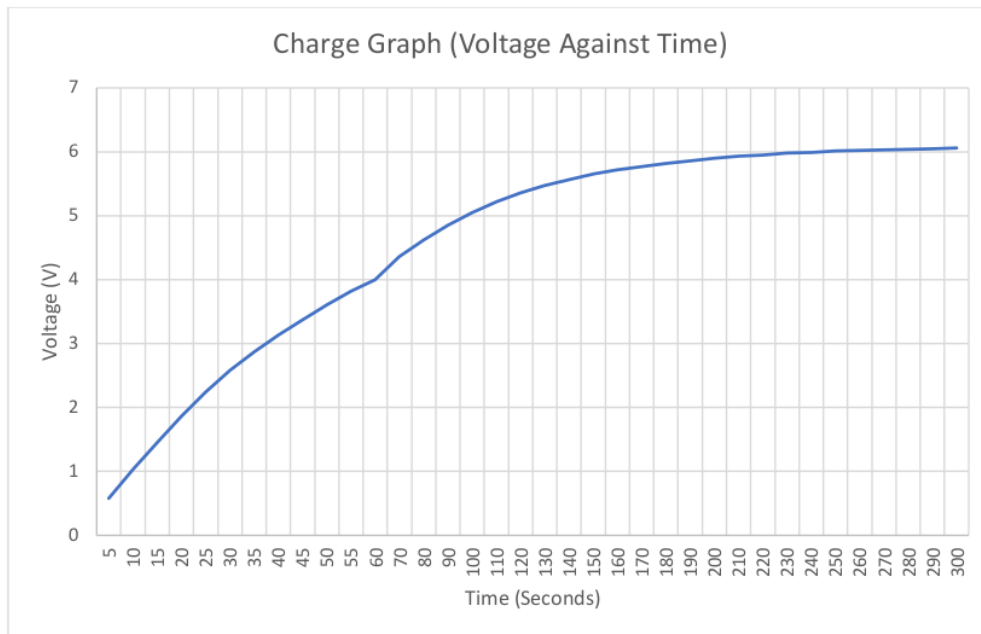
	Calculated	Multisim	Practical
T1(45s)	3.314V	3.3127V	3.37V
T2(56s)	3.792V	3.7921V	3.87V
T3(98)	4.957V	4.9579V	5.01V

The above table shows that as time goes on, voltage calculated increases. This is a reliable trend between each column; the voltage obtained through calculation, the multisim and practical. This also marries up with the graphs created in excel and by multlisim; as displayed below.

Graph to show Voltage against Time (Charge)



The graph above shows voltage against time produced by multisim. Voltage is increased as time proceeds.



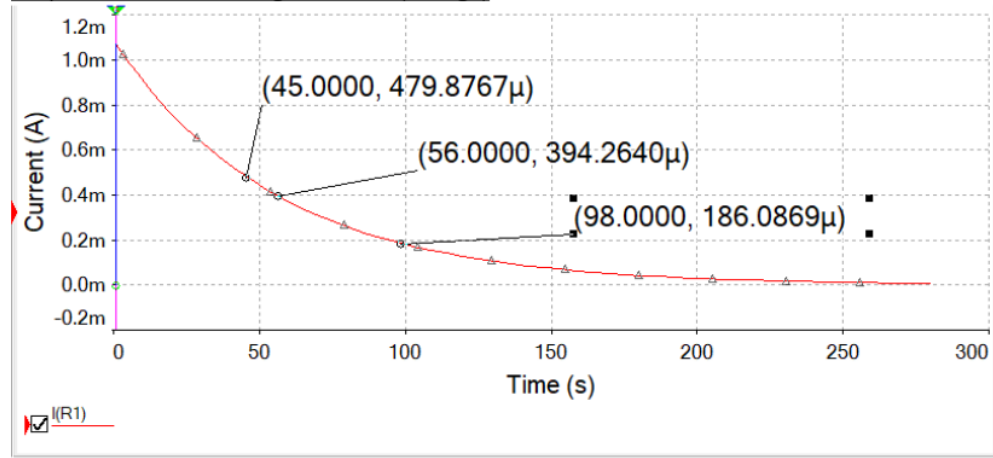
As time proceeds, the charge graphs show that voltage increases steadily, plateauing at 230 seconds.

Current Table

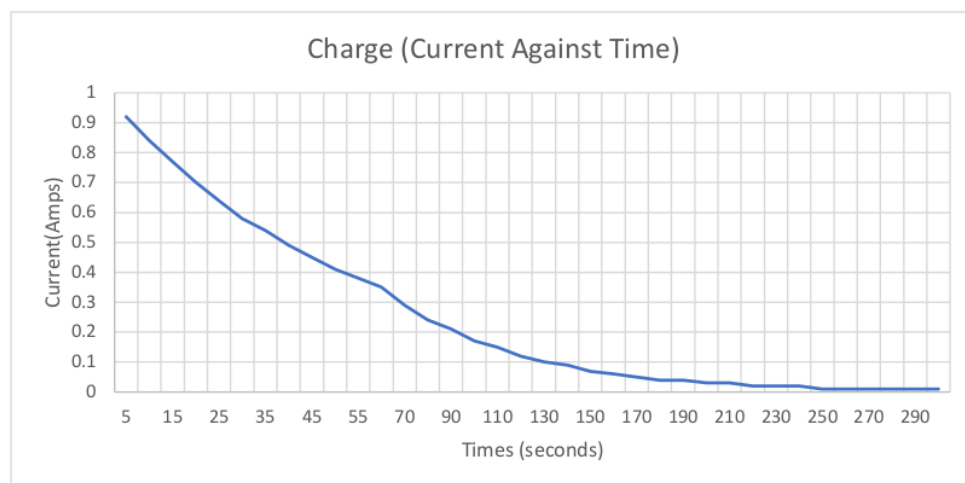
	Calculated	Multisim	Practical
T1(45s)	0.48 Amps	0.48 Amps	0.45 Amps
T2(56s)	0.39 Amps	0.39 Amps	0.37 Amps
T3(98)	0.19Amps	0.19 Amps	0.18 Amps

As time goes on, current decreases. This is a consistent trends between the calculations, multisim results and practical results.

Graph to show Current against Time (Charge)



Current decreases with the lengthening of time. There is a net decrease of 0.29Amps (rounded to 2 decimal places) between 45 and 98 seconds.



The above graphs show that as time proceeds, current decreases.

Analysis

As time proceeds, the charge graph shows that voltage increases steadily up until 60 seconds. This increase in voltage then speeds up until 230 seconds, steadily plateauing after 230 seconds and then increasing slightly at 280 seconds. I have observed a slight change in the trend at 60 seconds as explained above. Reasons for this could be as a result of human error as I was stopping the stop watch. Whilst analysing the graph created by multisim and comparing this to the graph created by myself in excel (using practical results), the anomaly at 60 seconds is not observed in the multisim graph. This is confirmation that the anomaly is

likely to be down to human error. This also solidifies that the results obtained through the multisim are highly repeatable and reliable, compared to the practical results, as it eliminates all possibilities of human error.

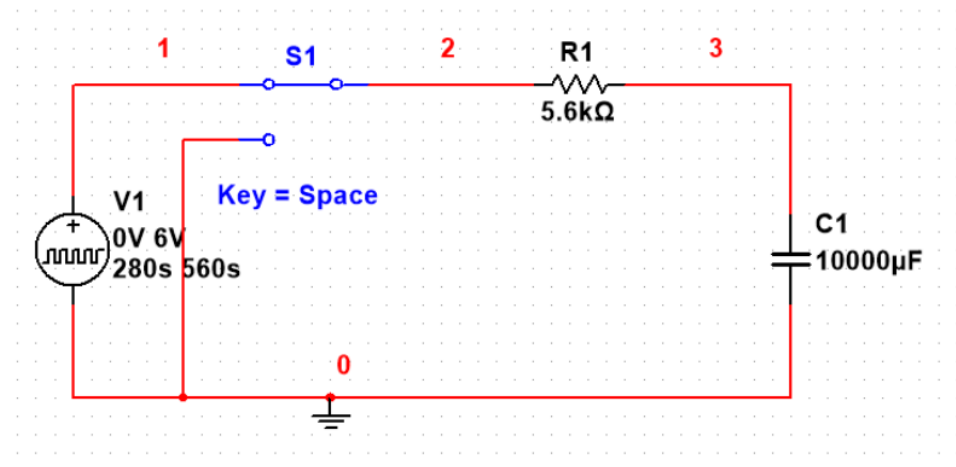
On analysis of the current against time graphs, similar to the voltage against time graphs, it is easy to make the observation that at 60 seconds, there is a change to the curvature of the graph, an anomaly in the speed at which current decreases. This is not an anomaly you observe whilst analysing the multisim graph. It is plausible to consider that this is again, down to human error and that for increased repeatability and reliability, in future, it would be sensible to obtain results from multisim rather than manually, to avoid errors. However for comparison, running a manual practical and collating results manually, is always favourable in order to carefully cross reference results and to ensure you are on track to matching your hypothesis and predictions.

After careful analysis of all results, in my opinion, multisim is the most dependable and well-founded way of gathering results. This is because multisim factors out losses that may be obtained and observed during the experiment practical, where there is much room for human error. Examples of these may be losses in current and voltage through wires and components.

Task 2

Method

Circuit for task 2



Task two involved investigating transient behaviour for the discharging of a capacitor. This relies on a similar circuit to task one, the difference being the power source. Task 2 involved a pulse voltage generator rather than a DC power source as used in task 1. The times were used during task two were 45 seconds, 56 seconds and 98 seconds. The time constant was calculated using $\tau = R \times C = 56000 \times 10000 \times 10^{-6} = 56$ seconds. Additionally, I calculated 5τ ,

which is the length of time it takes for a capacitor to charge up. I calculated current and voltage values at my specific times. The equation used for voltage was:

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

Next was the practical using two multimeters, one set up to record current and one set up to record voltage. A stop watch was used in order to make an observation of the current and voltage readings at my particular times chosen. An excel sheet was used in order to organise all of my results and from this, I was able to create a graph of these figures. A simulation was ran shortly after that created a graph representing voltage and a graph representing current, both of these units against time; my particular times being 45 seconds, 56 seconds and 98 seconds. In this simulation, after 280 seconds (which is 5τ), I closed the switch of the circuit, allowing for the capacitor to discharge. Lastly, the results for these individual times against current and voltage were put into two tables and allowed a comparison to be made between results collated by calculations, practical work and stimulation.

Calculations

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

$$= 6(e^{\frac{-45}{56}})$$

$$= \mathbf{2.686V} \quad (45 \text{ seconds})$$

$$= 6(e^{\frac{-56}{56}})$$

$$= \mathbf{2.207V} \quad (56 \text{ seconds})$$

$$= 6(e^{\frac{-98}{56}})$$

$$= \mathbf{1.043V} \quad (98 \text{ seconds})$$

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

$$I_{max} = V_s/R = 6/5.6 \times 10^{-3} = 1.071$$

$$-1.071x(e^{\frac{-45}{56}}) \quad (45 \text{ seconds})$$

$$= \mathbf{-0.48Amps}$$

$$-1.071x(e^{\frac{-56}{56}}) \quad (56 \text{ seconds})$$

$$= \mathbf{-0.39Amps}$$

$$-1.071x(e^{\frac{-98}{56}}) \quad (98 \text{ seconds})$$

$$= \mathbf{-0.19Amps}$$

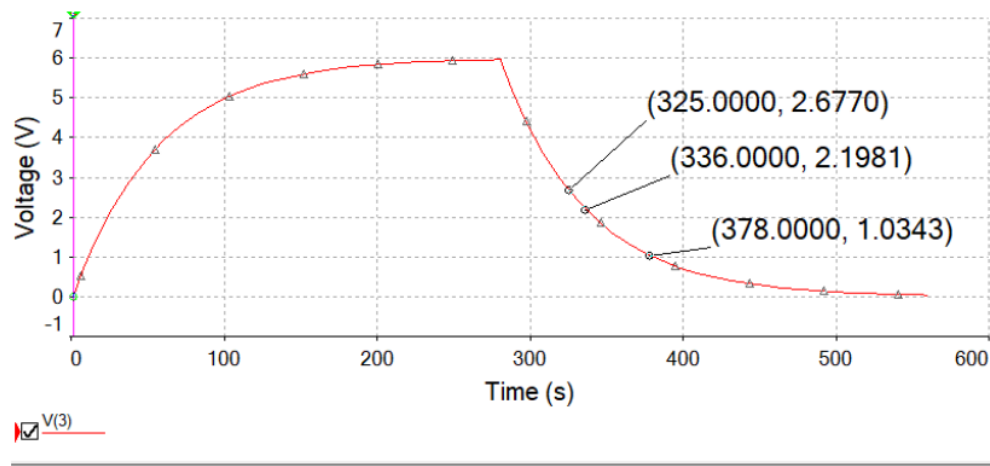
Results

Voltage Table

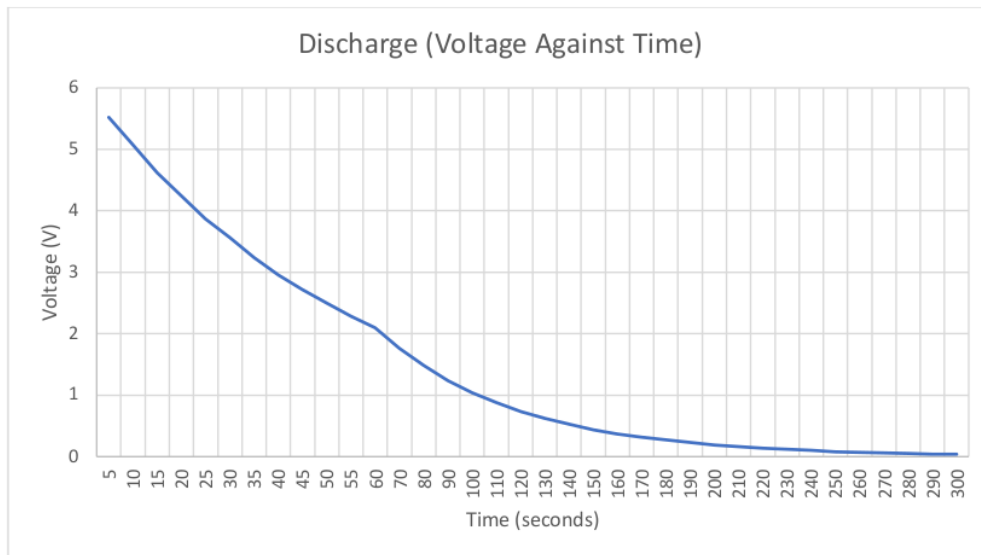
	Calculated	Multisim	Practical
T1(45s)	2.686V	2.677V	2.72V
T2(56s)	2.207V	2.198V	2.25V
T3(98)	1.043V	1.034V	1.08V

As displayed above with time proceeding, this causes a decrease in voltage, this trends being followed with each set of results; calculation, multisim and practical.

Graph to show Voltage against Time (Discharge)



The above graph shows that as the capacitor begins to discharge at 280 seconds (this being at $5T$), the voltage begins to decrease as times goes on. 45 seconds post discharge, the graph shows voltage at 2.677V. At 98 seconds post discharge, voltage decreases to 1.0343V, this being a decrease of 1.6427V from 45 seconds post discharge.



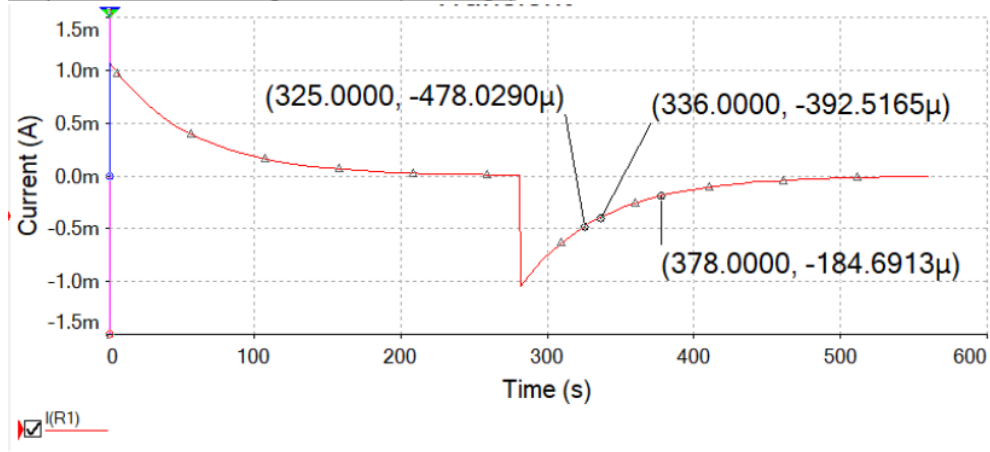
Between 0 and 60 seconds, the voltage decreases as a steady state. At 60 seconds and thereafter, the rate of decrease changes, although still a negative gradient.

Current Table

	Calculated	Multisim	Practical
T1(45s)	-0.48 Amps	-0.48 Amps	-0.45 Amps
T2(56s)	-0.39 Amps	-0.39 Amps	-0.37 Amps
T3(98)	-0.19 Amps	-0.18 Amps	-0.18 Amps

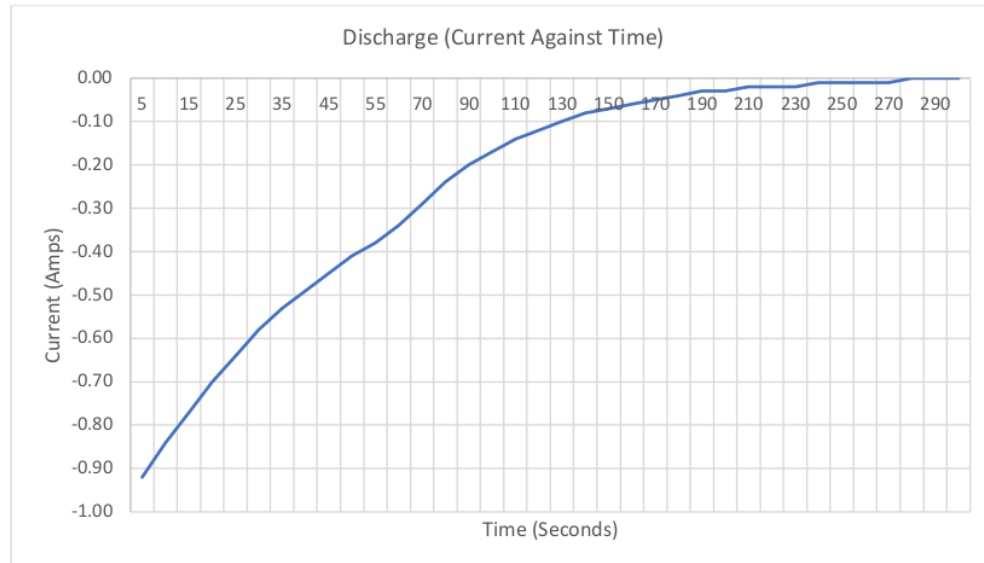
As time goes on, current decreases. This is a consistent trends between the calculations, multisim results and practical results.

Graph to show Current against Time (Discharge)



Current increases with the lengthening of time. There is a net increase of 0.29Amps (rounded to 2 decimal places) between 45 and 98 seconds.

Practical



The above graphs show that as time proceeds, current increases.

Analysis

As time proceeds voltage decreases at a steady rate, slowing down and plateauing at 280 seconds. The results collated from the practical and those from the Multisim exercise go hand in hand and results are similar. At 60 seconds I note a small anomaly in my practical graph; this evidence by the discontinuation of what would have been a uniform decrease in the graph line as above. Contrary to this, there is a continuous decrease in the voltage as time goes on when analysing the Multisim graph. This could be as a result of human error. Also, the Multisim does not take into consideration losses as a result of the wires and components.

Whilst analysing the current graphs, one observation I made was that current decreases as time goes on. This is a true representation in both graphs and my calculations. The same anomaly is present in the practical graph as discussed in the voltage section, which leads me to believe that more accurate results are attainable through carrying out the Multisim method of experimenting. This is because Multisim removes the human error factor, nor does it take into consideration the loss of the wires. It gives me results that are closer in accuracy, to my calculated results.

Task 3

Method

In task 3, I was observing transient behaviour in a more complex circuit. To start, the circuit needed to be reduced down to one resistor. This was done by combining R1 and R2:

$$R = \frac{(6 \times 12)}{(6 + 12)} = 4k\Omega$$
$$V_s = \frac{12}{6 + 12} \times 12 = 8V$$

The next step was to simulate this new circuit and create a graph from it using Multisim. From this graph I calculated the time constant using the following equation:

$$e^{-1} = 0.36$$
$$I_{max} = \frac{V}{R} = \frac{8}{4000} = 2mA$$
$$2 \times 10^{-3} \times 0.36 = 736\mu A$$

I then set the cursor on the to 736uA to find τ . This came to 7.9996 Seconds. I then began to calculate τ using the following equation:

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

Then I began to repeat the experiment, however this time whilst looking for the discharge values. I used the same circuit, just replacing the power source with a pulse generator. The circuit was then simulated and a graph formed from this. The graph was then used to calculate the time constant, using the following equation:

$$-2 \times 10^{-3} \times -0.36 = -736\mu A$$

I then set the cursor on the graph to -736uA, to find out the value of τ this being 47.9441 seconds. Again, I calculated τ using the following equation:

$$5 \tau + 8 = 5 \times 8 = 40 + 8 = 48 \text{ Seconds}$$

Results

Charge

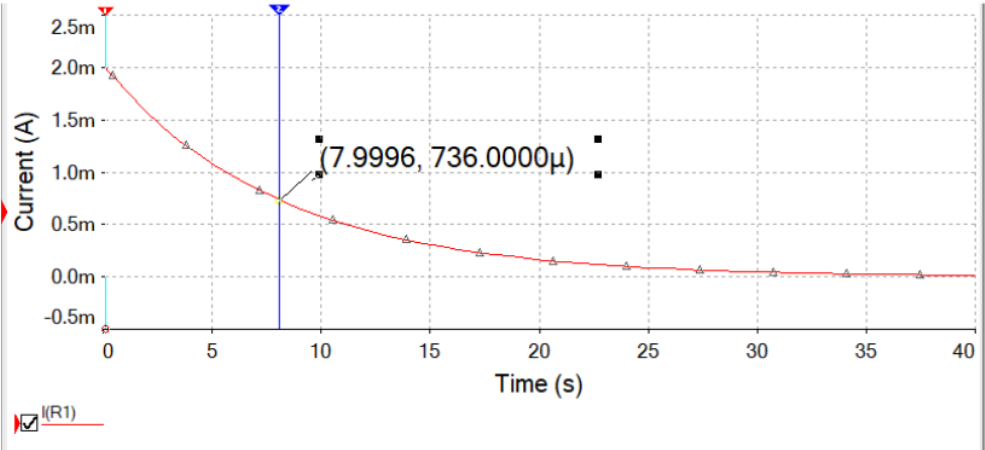


Table Charge

	Calculated	Multisim
τ	8 Seconds	7.9996 Seconds

Discharge

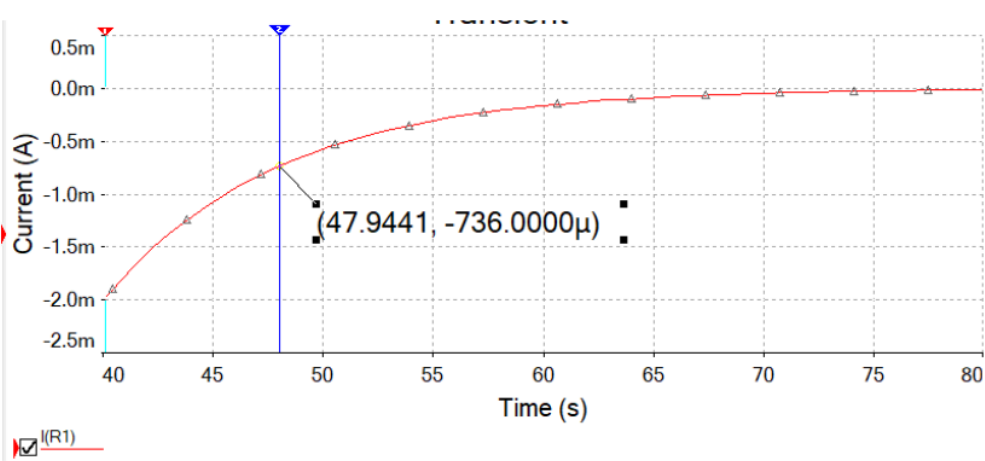


Table Discharge

	Calculated	Multisim
τ	48 Seconds	47.9441 Seconds

Analysis

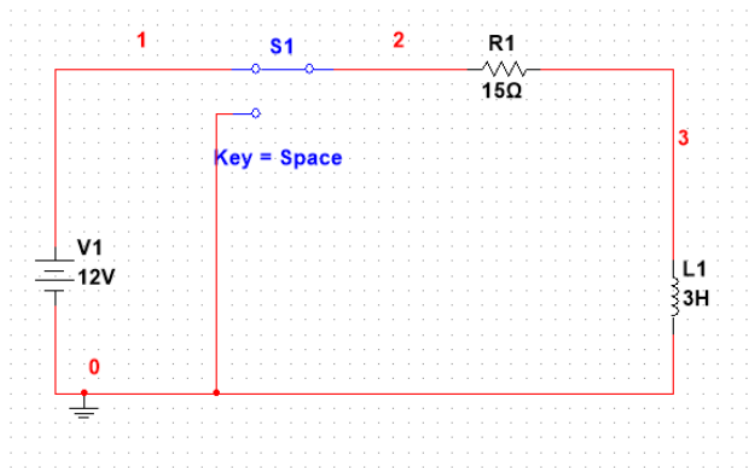
For charge, I calculated τ to be 8 seconds. From running the circuit on multisim, τ turned out to be 7.9996 seconds. This indicates to me that my experiments and calculations thereafter were as accurate as possible, the different between my calculations and the Multisim calculations only being 0.0004 seconds. Reasons for the 0.0004 difference between two sets of results could be because of rounding errors.

For discharge, I calculated τ to be 48 seconds. After conducting the experiment and calculating τ from the graph, the Multisim values came out as 47.9441 seconds. This is a small difference of 0.0559 seconds. A reason for the minimal difference but a difference none the less, could be down to errors within my rounding.

Task 4

Method

During task 4, the assessment that needed carrying out was assessing transient behaviour for the inductive circuit. To start, I built the circuit given to me in the assignment brief as demonstrated below:



Using the following equations I calculate τ and I_{max} .

$$\tau = L/R$$

$$\tau = 3/15 = 0.2 \text{ seconds}$$

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

$$I_{max} = 12/15 = 0.8A$$

I carried out current calculations and manually plotted these into a graph as 0.05s intervals. To do this I used excel software. The equation used of this is as follows:

$$=I_{max}*(1-EXP(-t/\tau))$$

From these results a graph was created. I then determined the current flowing in the circuit, immediately before the switch was changed over using the following equation:

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

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

$$I = 0.505696A$$

Next I compared all the time constant results against each other. These results are as follows:

$$\text{Calculated} = \tau = 0.2 \quad I = 0.505696A$$

$$\text{Manual plots} = \tau = 0.2 \quad I = 0.505696A$$

$$\text{Multisim} = \tau = 0.2 \quad I = 0.5056165A$$

The next task was to calculate the time that elapses before the current flowing in the circuit has fallen to 2 different currents, these being (i) 100mA, (ii) 10mA. To calculate this the following equation was used:

$$\tau = 3/15 = 0.2 \text{ seconds}$$

$$I_{max} = 12/15 = 0.8A$$

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

$$(i) 0.1 = 0.8(e^{-t/0.2})$$

$$0.1/0.8 = e^{-t/0.2}$$

$$\ln(0.1/0.8) = -t/0.2$$

$$\text{Therefor } t = -0.2\ln(0.1/0.8) = 0.415\text{seconds}$$

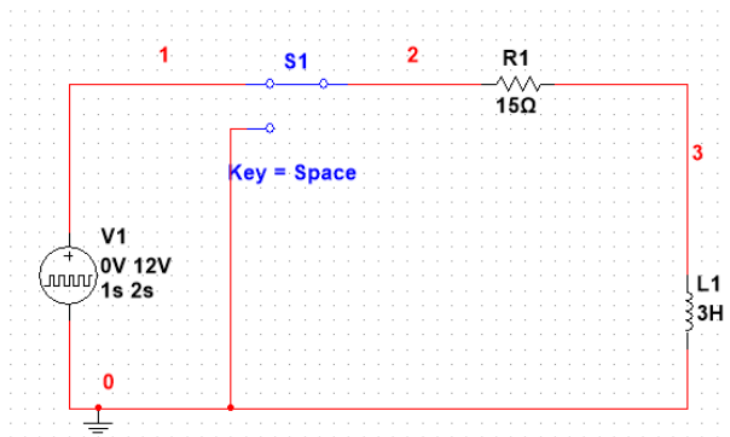
$$(ii) 0.01 = 0.8(e^{-t/0.2})$$

$$0.01/0.8 = e^{-t/0.2}$$

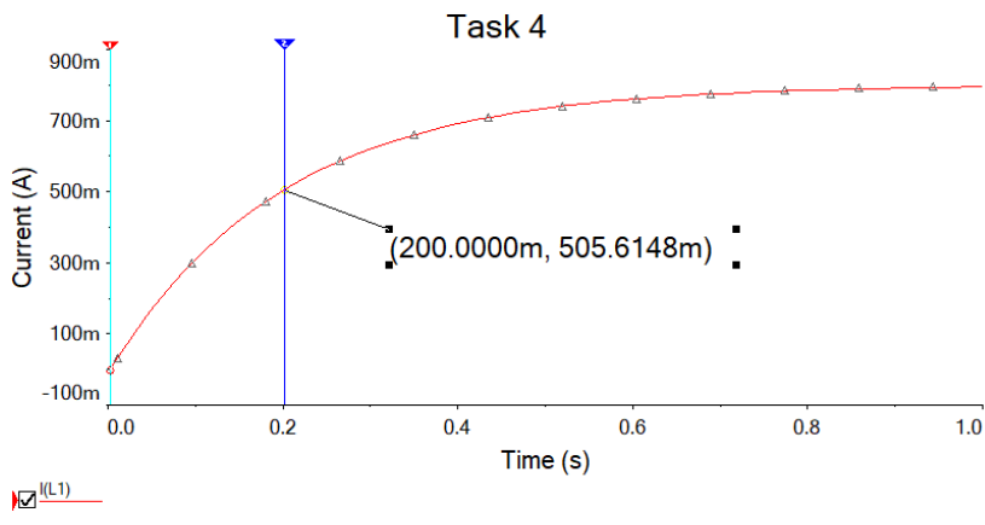
$$\ln(0.01/0.8) = -t/0.2$$

$$\text{Therefor } t = -0.2\ln(0.01/0.8) = 0.876\text{seconds}$$

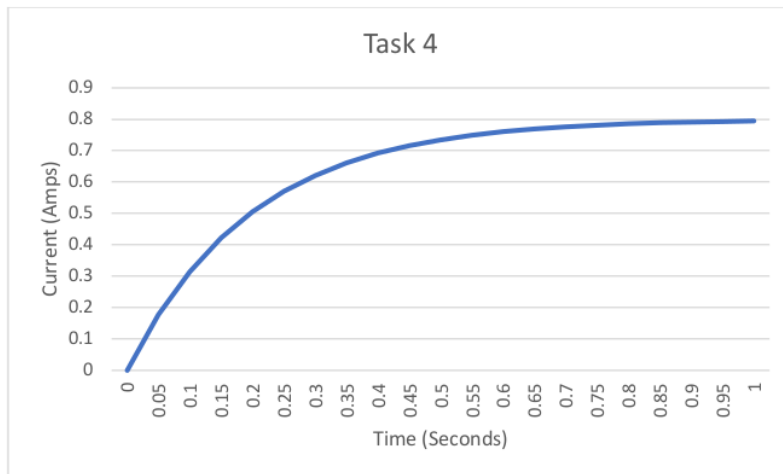
I then added a pulse generator to the circuit and created a graph that displayed time and current.



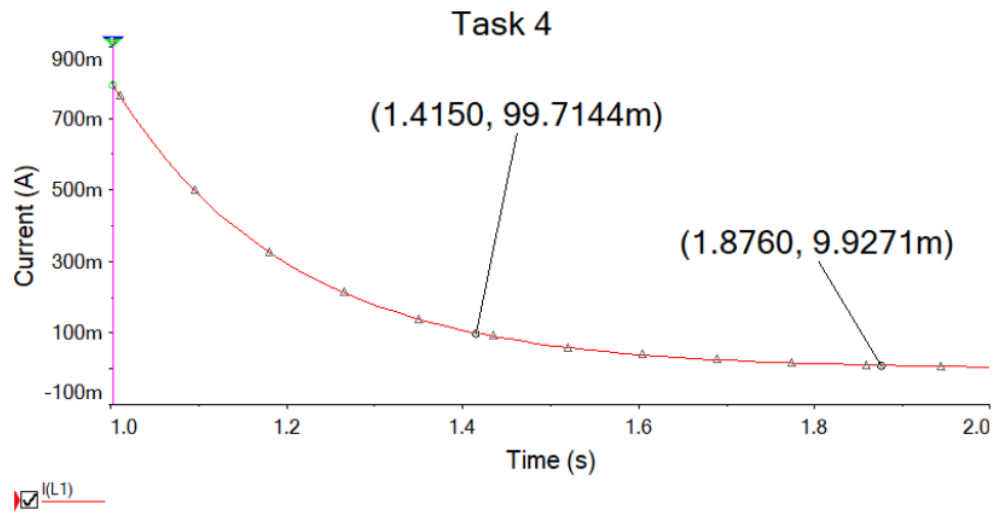
Results



This graph was created using the original circuit and shows the increase in current as time goes on. I have annotated the graph at 0.2s which represents τ . It shows the current value given at this point.



The above graph shows the manual plots of current against time, current increase as time proceeds, of the manual.



The above graph shows time that elapses before the current flowing in the circuit has fallen to (i) 100mA, (ii) 10mA.

Analysis

When looking at the original graph generated by the original circuit, I can see that at τ , the current value is 0.5056148A. The current I calculated at τ came out at 0.505696A. When comparing these results, I can see that there is minimal difference between the two. Reasons for this difference could be rounding error. Other reasons could be component tolerances or human interference. When observing the manual plot graph there is a general increase in current with no anomalies. Reasons for a smooth curve like this could be down to

the fact the graph was created in excel using an excel formula that would accurately plot results, no errors.

Whilst analysing my values for current at T_c , the calculated, manual plot and Multisim, I was relieved to see all figures coming out similarly, identical to the 4th decimal place. My calculated and manual plot results were identical. Reasons for such accuracy as a result of equations being used, not measuring tools, such as the Multisim.

In part V of task 4, I was asked to equate the amount of time that lapses before value of the travelling current decreases to (i) 100mA, (ii) 10mA. After working these out, I simulated this in a circuit. The graph shows the time at these values. As you can see they marry up well to my calculated values as you have to wait 1 second for the circuit to charge. Therefore you would take 1 second away from the results on the graph and that leaves you with 100mA = 0.415 and 10mA = 0.876. which is exactly like the times I calculated.

Evaluation

Upon reflection, the assessment went well, confirmed by the results obtained. Areas I succeeded in were teamwork and communication, important in this experiment to allow for a smooth running experiment. My independent working was of high standard, working efficiently and being a reliable member of the team. I was able to use figures and calculations with ease and the software to create graphs. This allowed for easy analysis.

However as always, there are areas I believe could have been improved in order to produce a more successful outcome. Firstly my excel skills show room for improvement. Although I got there in the end, a lot of my time was taken up fathoming the software out. In future a course in this software would be beneficial to carry out so that time efficiency can be improved upon. Another was human error, which in future should be reduced with the more experience gained in this field. Additionally, if errors overall could be pre-empted, they can be better avoided in the future.

Conclusion

To conclude, task 1 stressed the importance of analysing the transient behaviour whilst a capacitor is charging, in order to understand the dynamic response of a circuit. As time goes on and the capacitor charges, voltage increased exponentially. Things that we had to keep in mind, so to not falsely alter the results obtained, were resistance, conditions to begin and human errors. These, we had to keep in the forefront of our mind, to guarantee a slick and efficient operation.

In task 2 the aim was to assess the transient behaviour of a discharging capacitor. To summarise, voltage decreases over time as it experiences discharge. This is at a steady exponential decrease. As in task 1, there are factors outside of the circuit that were essential to consider, for example, the resistance and size of the capacitor. Again, human error such as with calculations was crucial to avoid. The skills gathered by analysing transient behaviours during the discharge of a capacitor, may become in the future whilst designing circuits with precise timings, ensuring energy released is controlled and optimising performance.

The difference between task 1 and the more complex circuits of task 3 are the more detailed communications between different and more parts that make up the circuit. To allow for this, I combined the two resistors in task 3 to allow for results to be produced. Analysis of these resistors and other components are central to foreseeing how the circuit response during changes.

Finally, task 4 asked to look at the transient behaviours in an inductive circuit. Inductive circuits are impacted by change to current or voltage. This results in a resistance to current flow. As a result, altering the response of the current. These influences are a crucial part of crafting a reliable and efficient circuit that takes into consideration all different factors. Performance can only peak when the operator of the system understands and develops these.

Appendix

Time	Current	Voltage
5	0.92	0.58
10	0.84	1.04
15	0.77	1.45
20	0.7	1.86
25	0.64	2.24
30	0.58	2.58
35	0.54	2.87
40	0.49	3.13
45	0.45	3.37
50	0.41	3.61
55	0.38	3.82
60	0.35	4
70	0.29	4.36
80	0.24	4.62
90	0.21	4.85
100	0.17	5.05
110	0.15	5.22
120	0.12	5.36
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	5.86
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	6.01
260	0.01	6.02
270	0.01	6.03
280	0.01	6.04
290	0.01	6.05
300	0.01	6.06

Excel results for task 1

Time	Current	Voltage
5	-0.92	5.52
10	-0.84	5.07
15	-0.77	4.62
20	-0.70	4.24
25	-0.64	3.87
30	-0.58	3.56
35	-0.53	3.24
40	-0.49	2.96
45	-0.45	2.72
50	-0.41	2.5
55	-0.38	2.28
60	-0.34	2.1
70	-0.29	1.76
80	-0.24	1.48
90	-0.20	1.24
100	-0.17	1.04
110	-0.14	0.88
120	-0.12	0.73
130	-0.10	0.62
140	-0.08	0.53
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	-0.02	0.12
240	-0.01	0.1
250	-0.01	0.08
260	-0.01	0.07
270	-0.01	0.06
280	0.00	0.05
290	0.00	0.04

300	0.00	0.04
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Excel results for task 2

Time (s)	Current (i)
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

Excel results for task 4