

Tyler Lloyd - Assignment 1

by Tyler Lloyd

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Assignment 1

HNC Electrical and Electronic Engineering

Investigation into DC Transients

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1. Introduction

This assignment covers the investigation of DC transients. The aim of this assignment is to carry out circuit analysis of RC and RL circuits using different methods such as; through simulation, using practical tests to form results and by prediction based on theory.

The circuits will be analysed when a DC voltage is applied to them, the analysis will be carried out using circuit simulation and practical circuits with calculations. Measurement instruments including multi-meters, oscilloscopes and probes will be used to show the characteristics of RC and RL circuits. Various mathematical formula will be used to calculate the predicted values.

The first two tasks require me to examine the provided circuit and give reasoning for the selection of suitable values for resistance and capacitance to provide a suitable time constant. It is required to take voltage and current readings until steady state conditions are met. current and voltage needs to be plotted against a base of time. Simulation is required for the circuit and comparison of the simulated values with the manually plotted ones. This task also requires to discharge the circuit and take current/voltage readings until both reach zero. The voltage and current need to be plotted against time to show its discharge condition. Random time values are to be selected and compared with calculated values. There needs to be a graph from MultiSim to compare simulated values with the manually plotted values.

The third task requires the investigation into the given circuit and to show the resistance in parallel is a combination of R1 and R2. simulation the circuit is required and plotting the currents against time for both charge and discharge conditions is required. Calculations need to be carried out for the time constants for both conditions and compare them to the simulated values. Calculations for the initial and final currents from the supply need to be carried out.

The final task requires evidence of the current growth for the first one second after the voltage source is applied to the circuit. Calculations need to be carried out and manually plotted against the current. Results should be compared from the simulation. The current flowing in the circuit and immediately before the switch is changed needs to be determined. Calculation of the circuit's time constant and comparison with estimates from manual and simulated plots need to be carried out. Finally, the time elapsed before the current falls to 100mA and 10mA should be worked out.

2. Circuit Testing

Transient behaviour for the charging/discharging of a capacitor

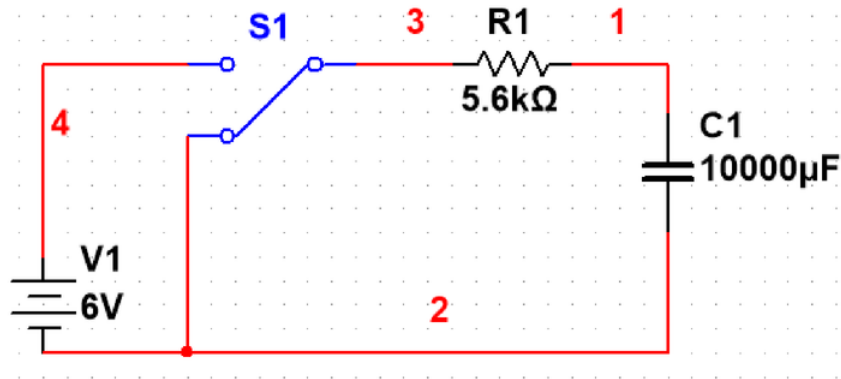


Figure 1: Charging of a Capacitor

Formula used for voltage:

$$V_C = V_S (1 - e^{-\frac{t}{RC}})$$

Using the formula to calculate randomly selected time periods:

$$10 \text{ seconds: } V_C = 6 (1 - e^{-\frac{10}{56}}) = 0.98 \text{ (to 2dp)}$$

$$60 \text{ seconds: } V_C = 6 (1 - e^{-\frac{60}{56}}) = 3.94 \text{ (to 2dp)}$$

$$100 \text{ seconds: } V_C = 6 (1 - e^{-\frac{100}{56}}) = 4.99 \text{ (to 2dp)}$$

As you can see from Figure 2: Voltage for 60 seconds and Figure 3: Voltage 100 seconds the simulated results match the calculated results.

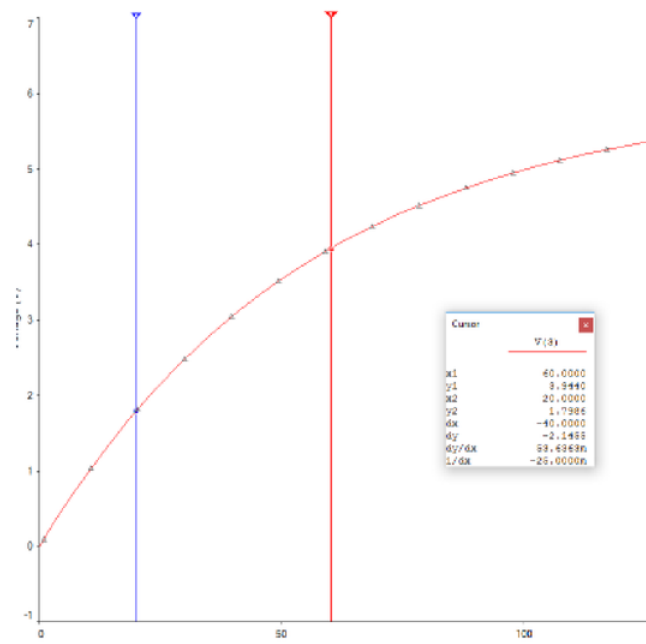


Figure 2: Voltage for 60 seconds

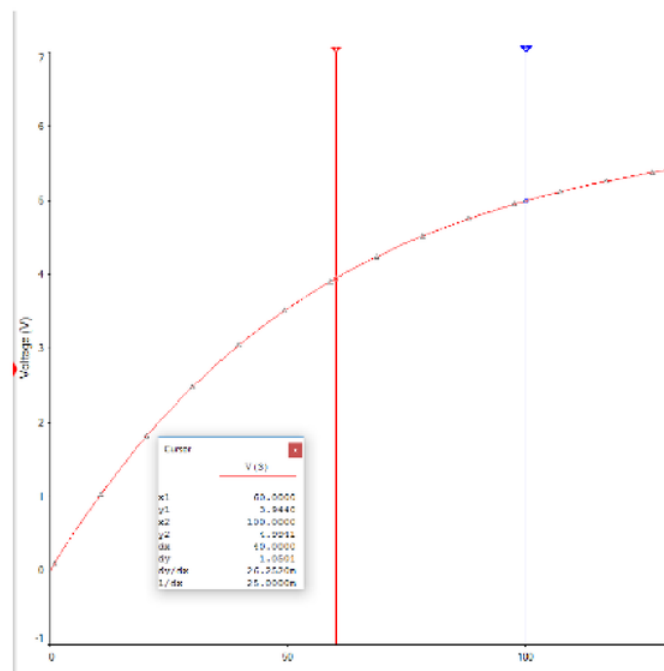


Figure 3: Voltage 100 seconds

Formula used for Current:

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

Using the formula to calculate randomly selected time periods:

$$10 \text{ seconds: } IC = 0.00107 (e^{\frac{-10}{56}}) = 0.9 \text{ (to 2dp)}$$

$$60 \text{ seconds: } IC = 0.00107 (e^{\frac{-60}{56}}) = 0.37 \text{ (to 2dp)}$$

$$100 \text{ seconds: } IC = 0.00107 (e^{\frac{-100}{56}}) = 0.18 \text{ (to 2dp)}$$

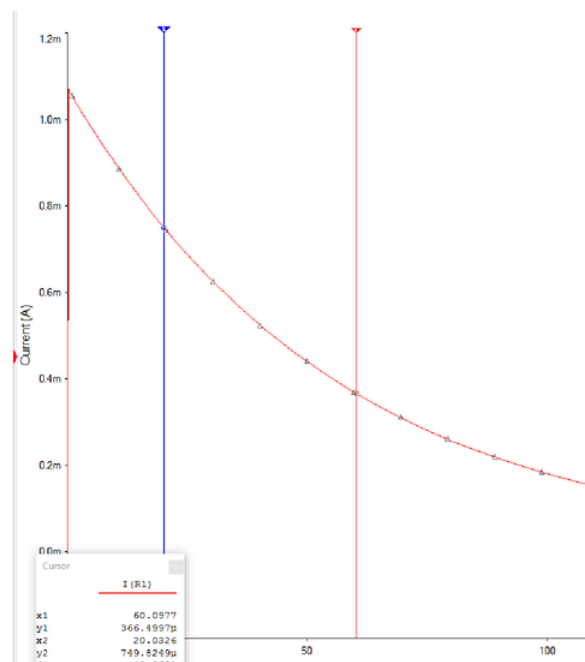


Figure 4: Current for 60 seconds

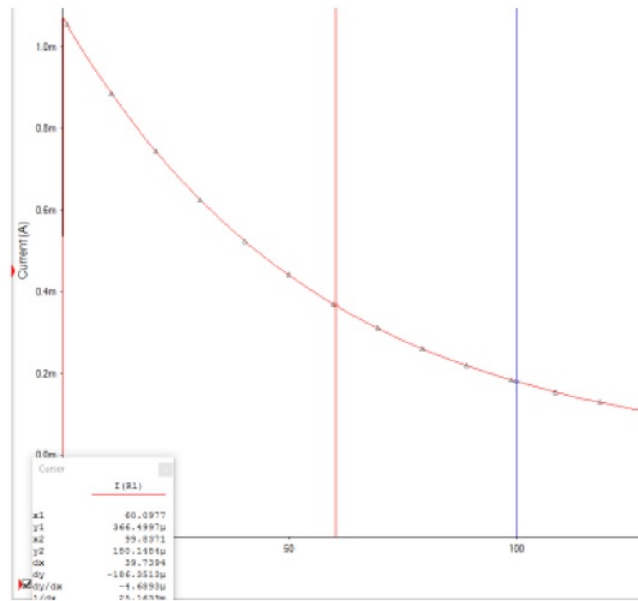


Figure 5: Current for 100 seconds

As you can see from Figure 4: Current for 60 seconds and Figure 5: Current for 100 seconds the simulated results match the calculated results as expected.

Practical Testing

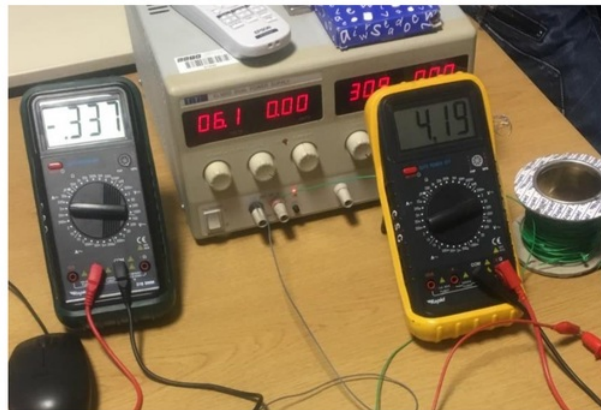


Figure 6: Practical Testing setup using multi-meters and oscilloscope

See Figure 6: Practical Testing setup using multi-meters and oscilloscope, for how the practical testing phase was setup using an oscilloscope and multi-meters. The charge period is recorded by taking down the values of VL and IL in 20 second increments until the capacitor reached steady state conditions. We then did the same for the discharge of the capacitor, measuring values of VL and IL in 20 second increments. The values were then put into a table and a graph to display the values plotted against time.

Calculations

Choosing a suitable time constant using the formula:

$$T = R \times L$$

So:

$$T = 5.6k \times 10000\mu F$$

$$T = 56$$

If I don't have a capacitance value, I can rearrange that formula to give me:

$$\frac{T}{R} = C$$

Formula Used to calculate 5T:

$$\text{Time Constant} = 56 \text{ seconds}$$

$$(5.6K\Omega \times 10,000\mu F = 56 \text{ seconds})$$

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

Formula for I_{max}:

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

$$I_{max} = \frac{6}{5600}$$

$$I_{max} = 1.07 \text{ mA}$$

Results of the charging capacitor:

Time	Charge	
	VL	IL
20	1.7	0.766
40	3.02	0.54
60	3.78	0.383
80	4.48	0.275
100	4.91	0.2
120	5.21	0.144
140	5.43	0.106
160	5.65	0.67
180	5.74	0.57
200	5.81	0.4
220	5.86	0.31
240	5.89	0.23
260	5.93	0.18
280	5.95	0.15

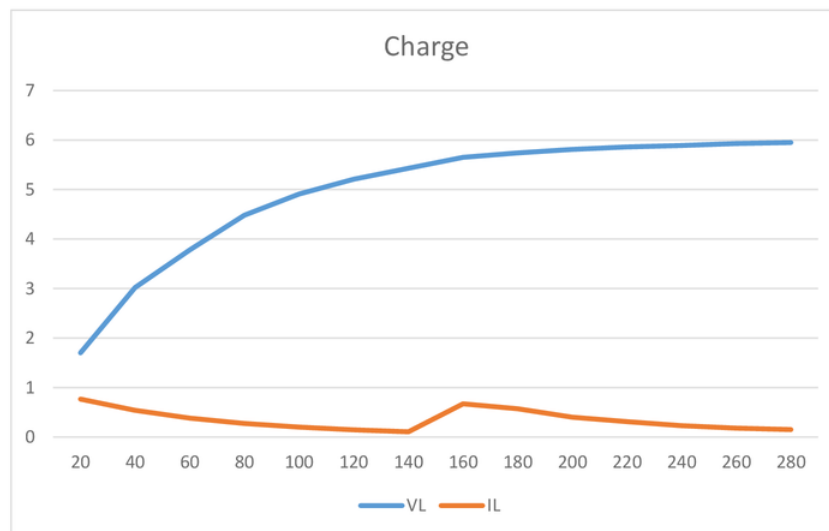


Figure 7: Graph for Charge practical

Results for the discharging capacitor:

Time	Discharge	
	VL	IL
20	4.2	-0.754
40	2.99	-0.531
60	2.11	-0.378
80	1.5	-0.264
100	1.07	-0.19
120	0.76	-0.135
140	0.54	-0.097
160	0.39	-0.067
180	0.27	-0.05
200	0.2	-0.032
220	0.14	-0.026
240	0.1	-0.019
260	0.08	-0.014
280	0.06	-0.01

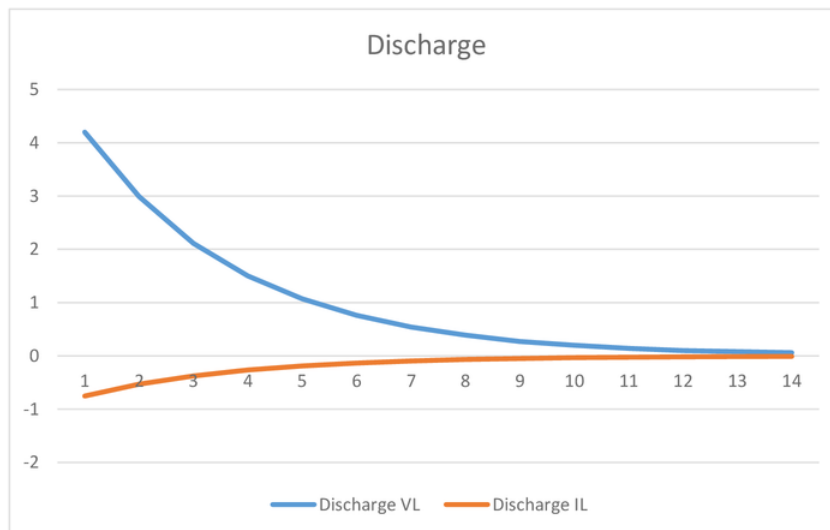


Figure 8: Graph for Discharge practical

Transient behaviour for a more complex circuit

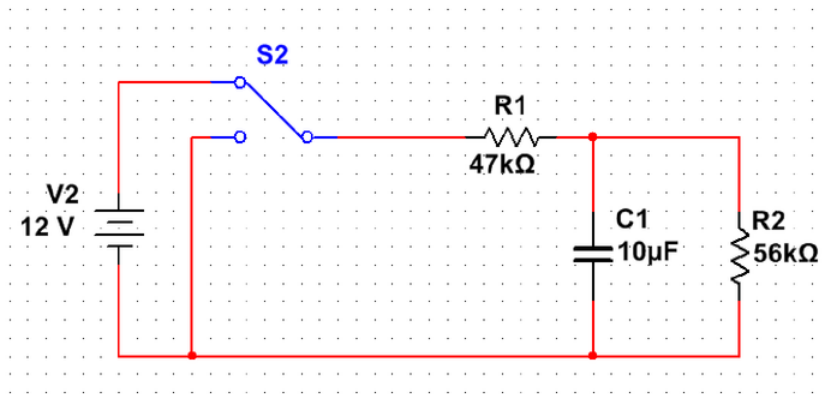


Figure 9: Complex circuit

To calculate the time constant the following formula is used:

$$\text{Time Constant} = R^T \times C$$

To find R total:

$$R^T = \frac{R1 \times R2}{R1 + R2}$$

$$R^T = \frac{47 \times 56}{47 + 56}$$

$$R^T = 25.55k$$

Now to calculate the time constant:

$$\text{Time Constant} = R^T \times C$$

$$\text{Time Constant} = 25.55k \times 10\mu F$$

$$\text{Time Constant} = 0.2555$$

$$5T = \text{Time const} \times 5$$

$$5T = 1.28 \text{ (to 2dp)}$$

Due to there being 2 resistors in the circuit the time constant stays under 12V, when the capacitor reaches full charge it would create an open circuit, meaning it makes the resistors into a series circuit.

The complex circuit requires us to look at it like a voltage divider with 2 resistors.

To calculate VR1:

$$VR1 = \frac{R1}{R1 + R2} \times VS$$

$$VR1 = \frac{47}{47 + 56} \times 12$$

$$VR1 = 5.48 \text{ (to 2dp)}$$

To find Vout (VR2):

$$VR2 = \frac{R2}{R1 + R2} \times VS$$

$$VR2 = \frac{56}{47 + 56} \times 12$$

$$V_{out} \text{ (new VS)} = 6.52 \text{ (to 2dp)}$$

To find the instantaneous voltage the following formula can be used:

$$VC = V_{max} \left(1 - e^{-\frac{t}{T}} \right)$$

Where Vmax, is now VR2

To find VC at specific times 't' should be changed to the time required:

$$0.25 \text{ seconds: } VC = V_{max} \left(1 - e^{-\frac{0.25}{T}} \right)$$

$$VC = 6.52 \left(1 - e^{-\frac{2}{0.2555}} \right)$$

$$VC = 4.07 \text{ (to 2dp)}$$

$$1 \text{ second: } VC = V_{max} \left(1 - e^{-\frac{t}{T}} \right)$$

$$VC = 6.52 \left(1 - e^{-\frac{1}{0.2555}} \right)$$

$$VC = 6.39 \text{ (to 2dp)}$$

As you can see in Figure 10: Simulated evidence for Voltage charge for 0.25 seconds and 1 second the simulated values match the calculated values as expected.

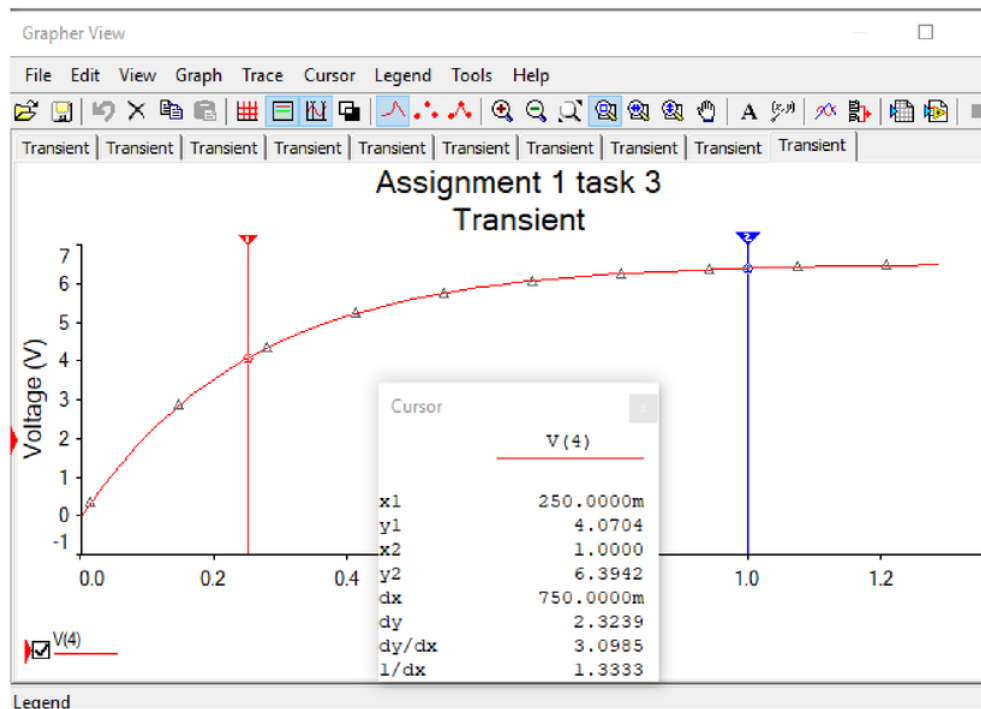


Figure 10: Simulated evidence for Voltage charge for 0.25 seconds and 1 second

To calculate current the following formula can be used:

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

Where I_{max} :

$$I_{max} = \frac{V_c}{R1}$$

$$I_{max} = \frac{12}{47k}$$

$$I_{max} = 0.255 \text{ mA}$$

So, therefore:

$$\text{For 0.25 seconds: } IC = 0.255mA \left(e^{\frac{-0.25}{0.255}} \right)$$

$$IC = 9.57 \times 10^{-6} \text{ (to 2dp)}$$

$$\text{For 1 second: } IC = 0.255mA \left(e^{\frac{-1}{0.255}} \right)$$

$$IC = 5.05 \times 10^{-6} \text{ (to 2dp)}$$

The large current is due to the capacitor causing a short circuit as it's choosing the path of least resistance. Initially the capacitor is a short circuit and R_c is being bypassed. Therefore, all the current goes through R_1 .

To calculate with the 2 resistors, to achieve the final current:

$$I_{max} = \frac{Vs}{R_1 + R_2}$$

$$I_{max} = \frac{12}{47k + 56k}$$

$$I_{max} = 0.116 \text{ mA}$$

This gives us a final current of 0.116mA.

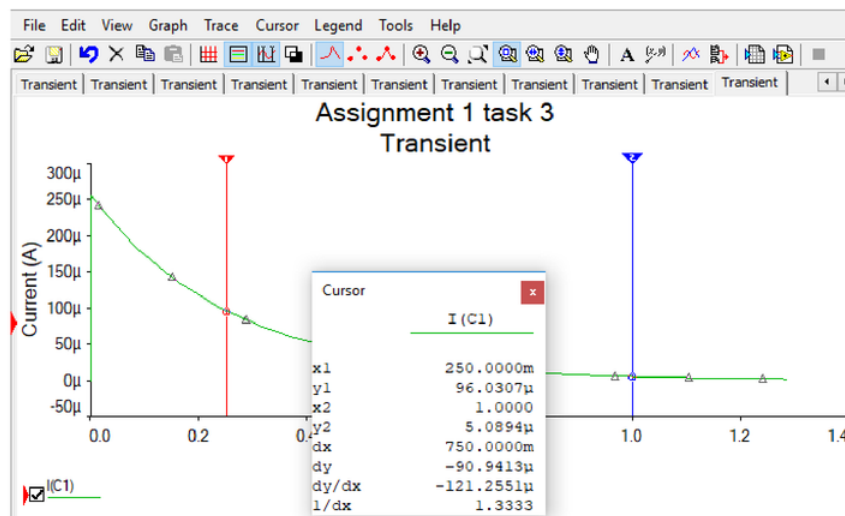


Figure 11: Simulated evidence for current for 0.25 seconds and 1 second

To calculate the discharge:

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

$$IC = 0.116\text{mA} \left(e^{\frac{-0.25}{0.255}} \right)$$

I_{max} at 0.25 seconds = 0.31 (to 2 dp)

$$IC = 0.116\text{mA} \left(e^{\frac{-1}{0.255}} \right)$$

I_{max} at 1 second = 5.86 (to 2 dp)

The current here is leaving the capacitor and flowing through the parallel resistors. The -Ve value tells us that the current flows in the opposite direction. The rate of change is the same but in the opposite way.

Transient behaviour for the inductive circuit

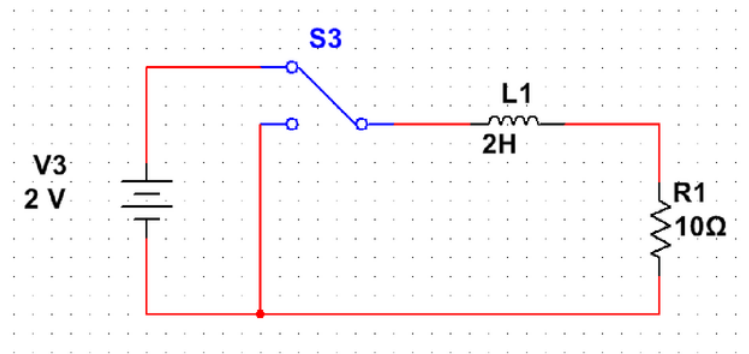


Figure 12: Inductive circuit

To calculate the Time constant the following formulas are used:

$$T = \frac{L}{R}$$

$$T = \frac{2}{10}$$

$$T = 0.2$$

If 'R' is not provided then you can use the below method to find 'R'.

Rearrange formula to find R:

$$R = \frac{L}{T}$$

$$R = \frac{2}{0.2}$$

$$R = 10$$

Full charge is at **5 x T**:

$$5T = 0.2 \times 5$$

$$5T = 1 \text{ second}$$

To calculate charge with VR and VL the following formulas are used:

$$1) \quad VL = VS \left(e^{\frac{-R}{L} t} \right)$$

$$2) \quad VR = VS \left(1 - e^{\frac{-R}{L} t} \right)$$

For IL or I_{max} the following formulas are used:

$$1) \quad IL = I_{max} \left(1 - e^{\frac{-R}{L} t} \right)$$

$$2) \quad I_{max} = \frac{VS}{R}$$

For discharge the following formulas are used:

$$1) \quad VL = VS \left(e^{\frac{-R}{L} t} \right)$$

$$2) \quad IL = I_{max} \left(1 - e^{\frac{-R}{L} t} \right)$$

Using $[t = 0.3]$, $[t=0.6]$, $[t=0.9]$ and $[t=1]$ the below formula is used to calculate charge:

$$VR = 2 \left(1 - e^{\frac{-10}{2} t} \right)$$

$$VR = 2 \left(1 - e^{\frac{-10}{2} 0.3} \right) = 1.55 \text{ (to 2dp)}$$

$$VR = 2 \left(1 - e^{\frac{-10}{2} 0.6} \right) = 1.90 \text{ (to 2dp)}$$

$$VR = 2 \left(1 - e^{\frac{-10}{2} 0.9} \right) = 1.98 \text{ (to 2dp)}$$

$$VR = 2 \left(1 - e^{\frac{-10}{2} 1} \right) = 1.99 \text{ (to 2dp)}$$

As you can see from Figure 13: Evidence of simulated results for charge at 0.3 seconds and 1 second, the results match the calculated results at both 0.3 seconds and the final 1 second mark.

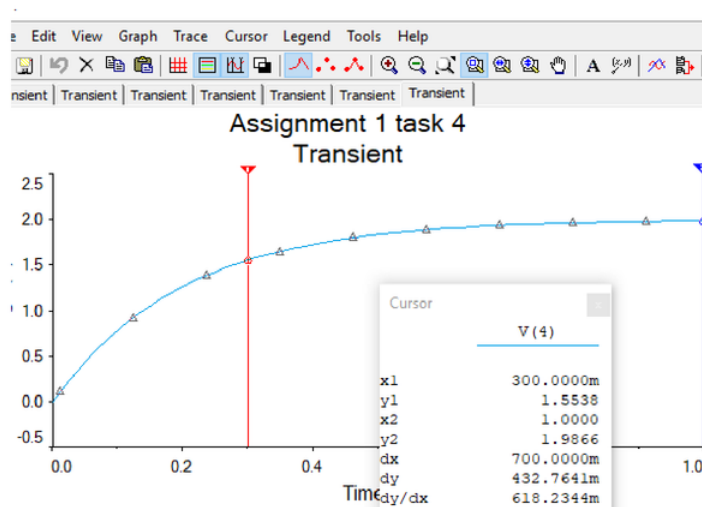


Figure 13: Evidence of simulated results for charge at 0.3 seconds and 1 second

To calculate the time elapsed before the current flowing in the circuit has fallen to a specific value, the following formula can be used:

For IL Discharge the following formula can be used:

$$IL = I_{max} (e^{\frac{-R}{L}t})$$

Which can be rearranged to give us:

$$\frac{IL}{I_{max}} = e^{\frac{-R}{L}t}$$

$$t = T(\ln(\frac{IL}{I_{max}}))$$

This is because $\frac{R}{L} = \frac{1}{T}$ and log rules tell us that $\text{Log}(x^y) = y \times \text{Log}(x)$, which gives us:

$$= 1 \times e^{\frac{-R}{L}t}$$

For 100mA:

$$t = 0.2(\ln \frac{100mA}{200mA})$$

$$t = 139ms$$

For 10mA:

$$t = 0.2(\ln \frac{10mA}{200mA})$$

$$t = 599ms$$

As you can see from Figure 14: Evidence of simulated results for Discharge, the results match the calculated results at 100mA.

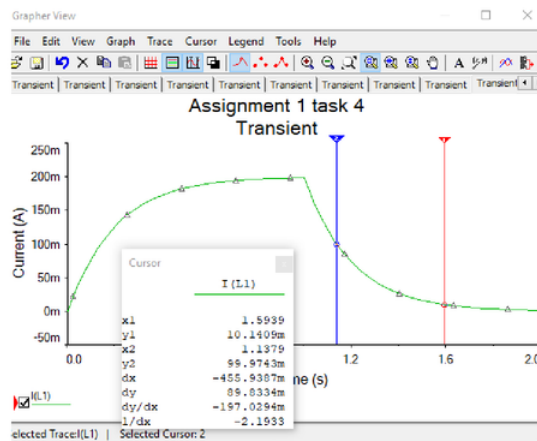


Figure 14: Evidence of simulated results for Discharge

3. Testing and results discussion

Here are the compared results for tasks 1 and task 2:

Voltage for task 1 and 2

Time	Calculated	Simulated	Practical
10	0.98	0.97	1
60	3.94	3.94	3.87
100	4.99	4.99	4.91

Current for task 1 and 2

Time	Calculated	Simulated	Practical
10	0.9	0.89	0.95
60	0.37	0.366	0.383
100	0.18	0.18	0.2

For the complex circuit (the third task), the results given by the simulation match those of the calculated results. There were very minute differences which resistance values can be to blame - where the values get automatically rounded up. There is a slightly bigger variation with the practical results which will be due to human error from the delay in reading out the time/monitoring the meter and also the resistance in the test leads and circuit which wouldn't be accounted for in the other calculations.

The inductive circuit (fourth task) gives very similar results yet again. There is no variation (when rounding) between the simulated and calculated values. This information proves that both methods of testing resulted in very reliable results. See below for a table of comparison between the two methods:

Task 4 comparison table

Time	Calculated Current	Simulated Current
0.3	1.55	1.55
0.6	1.90	1.90
0.9	1.98	1.98

4. Conclusions and recommendations

The assignment task was to investigate into DC Transients. The tests carried out through theory, practical and simulations all seem to provide accurate results as there was little variation between them. There were no discrepancies as such, the largest variation in results as stated is the practical method. This is due to resistance caused from the circuit and testing equipment. The testing equipment could possibly be slightly out and may need calibration. There is also a delay caused by inputting the information by hand. The information was recorded by eye and data needed to be recorded off the meter at a specific time (from a stopwatch) having to look at the exact time and take values from the meter won't be as precise as simulations and calculated values.

A recommendation to the task would be to include practical testing for the complex circuit and inductive circuit. Although this may be difficult it would allow us to see any trends that occur while manual testing compared to the calculations and simulations. To compare the practical results more accurately, resistance could be calculated and accounted for in the circuits for simulation and calculations. It would also be interesting to test the circuits at higher values of voltage/resistance to compare the values and trends to that of the lower voltage circuits.

5. Appendix

This was not required for this assignment.

Tyler Lloyd - Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

59/100

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GRADING FORM: CSG-RUBIC

TYLER LLOYD**0****RESEARCH-INFORMED LITERATURE****KNOWLEDGE AND UNDERSTANDING**

Some sim and calc errors, but understanding is demonstrated.

15/25**ANALYSIS**

Errors in analysis and needs more explanations.

24/40**PRACTICAL APPLICATION AND DEP.**

Prac is tied in with theory despite the errors.

14/25**SKILLS FOR PROFESSIONAL PRAC.**

Report is good.

6/10

