

2117071

by Benjamin Naylor

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04 SGEE4000 - Assignment

Course: HNC Electrical and Electronic Engineering

Module: Electrical and Electronic Principles

Assignment: Investigation into DC Transients

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- ① A GOOD LEVEL OF KNOWLEDGE WITH SOME CRITICAL ANALYSIS.
- ② FEEDBACK AND COMMENTS PROVIDED.

MARK AS PER

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Introduction

The aims of this project are to investigate the behaviour of R-C and R-L circuits when they are connected up to a direct current voltage source. This will be done by testing through practical construction and testing, through simulation and theoretical prediction, these will all be compared to get the best results for the test.

The results will be discussed and analysed. Relevant conclusions will be drawn by comparing the results. I need to show an understanding of fundamental scientific principles that are used to produce solutions to engineering problems. I need to show the ability to use and collect data and apply it to scientific principles. I will use practical circuits, take readings and plot these results in graphs. I will make a simulation of the circuit and annotate and interpret the information.

Task 1 (Transient Behaviour for the Charging of a Capacitor)

The circuit below is used to show the Transient Behaviour for the Charging of a Capacitor

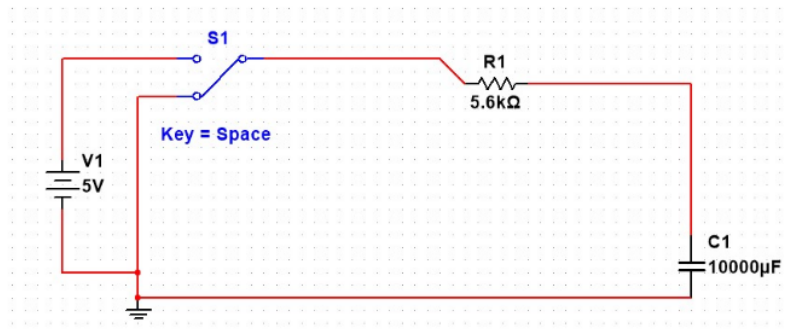


Figure 1

Practical method

I used a practical design of the circuit above (figure 1) to measure voltage and current until steady state conditions are reached with a charging capacitor. Every 5s the current and voltage was measured and recorded until I reached 300s. To make the practical circuit I used a bread board, 5.6k resistor, 10000uF capacitor, wires and 2 multimeters.

The practical Circuit:

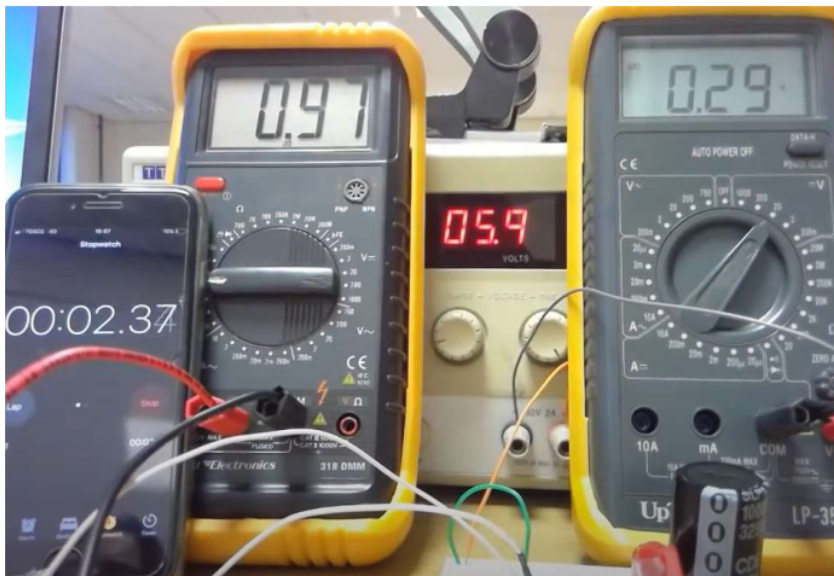


Figure 1 Multimeters

The Graph below (figure 2) is a Current over Time graph for the charging of a capacitor made from my practical circuit. The current was taken after every 5s from 0-300s:

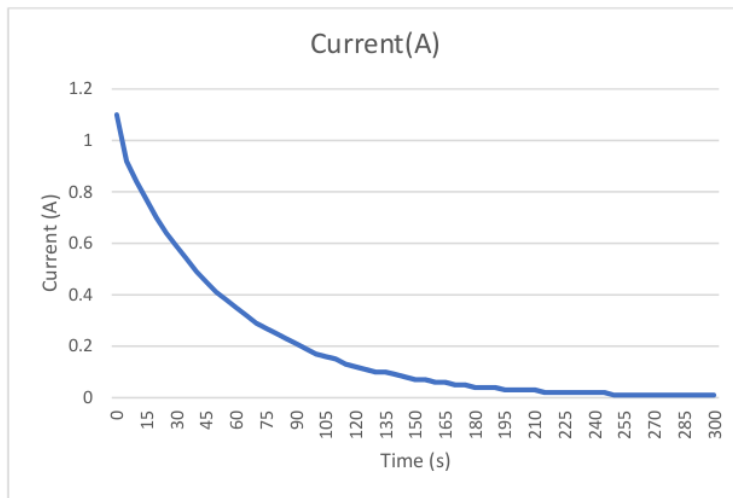


Figure 2 current task 1

The longer the time goes on the lower the current gets, this is easily seen on the graph above (figure 2)

The graph below (figure 3) shows how the voltage changes through time on a charging of a capacitor

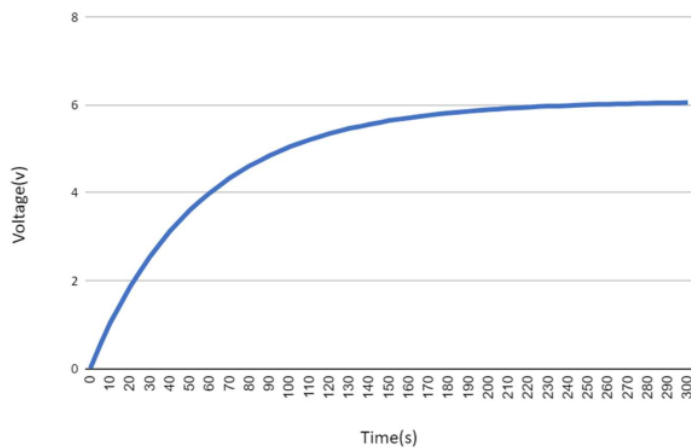


Figure 3 Voltage task 1

The graph above (figure 3) shows that the voltage increases through time when charging a capacitor.

Simulated Method

Through using "multisim" and by using the circuit in figure 1 I made a simulation that shows voltage over time, this can be seen below on figure 4.

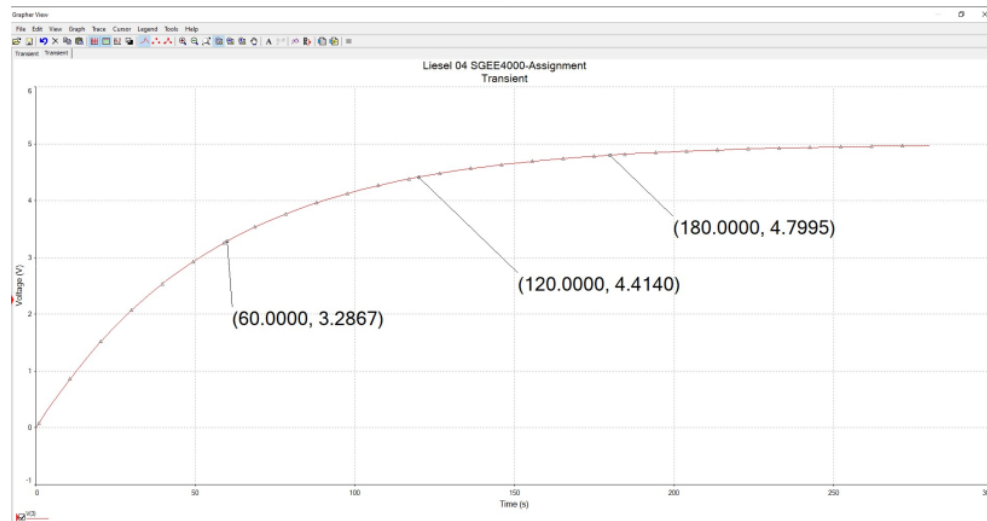


Figure 4 Simulations voltage task 1

The simulation shows that as time goes on the voltage goes up.

My simulation for current over time can be seen below:

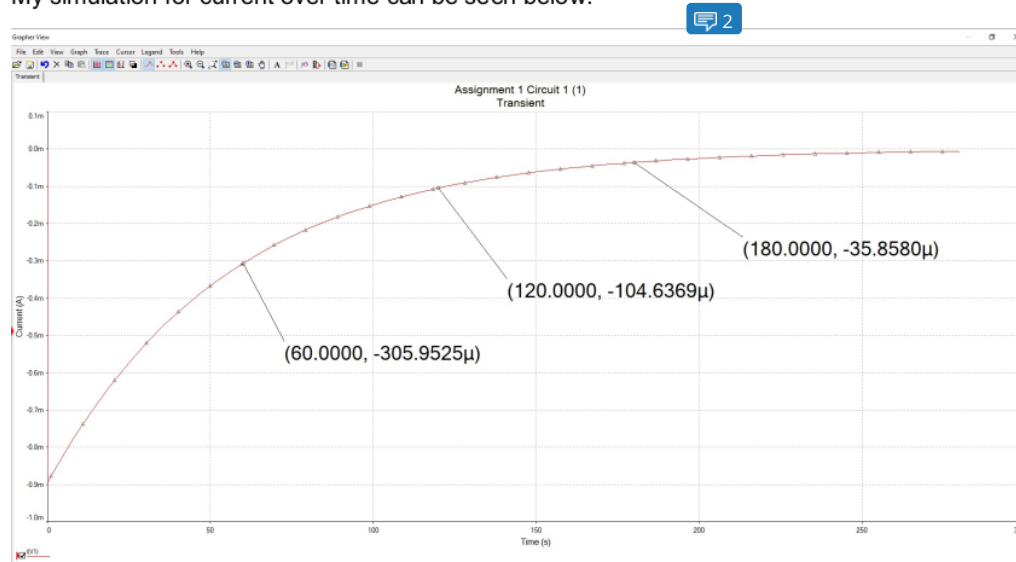


Figure 5 Current simulation task 1

As time goes on the current goes up.

Mathematical Method

Calculations:

Note: These calculations below are used for the charging and discharging of a capacitor calculation:

$$\tau = RC$$

$$\tau = (5.6 \times 10^3) \times (10000 \times 10^{-6}) = 56\text{s}$$

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

$$I_{MAX} = \frac{V}{R} = \frac{5}{5.6 \times 10^3} = 892.857 \mu\text{A}$$

Chosen Numbers charging of a capacitor:

60s, 120s, 180s

60s:

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

$$= 5(1 - e^{-\frac{60}{56}})$$

$$= 3.28\text{V}$$

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

$$I = 892.857 \times 10^{-6} (e^{-\frac{60}{56}})$$

$$I = 305.820 \mu\text{A}$$

120s:

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

$$= 5(1 - e^{-\frac{120}{56}})$$

$$= 4.41\text{V}$$

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

$$I = 892.857 \times 10^{-6} (e^{-\frac{120}{56}})$$

$$I = 104.749 \mu\text{A}$$

180s:

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

$$= 5(1 - e^{-\frac{180}{56}})$$

$$= 4.799V$$

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

$$I = 892.857 \times 10^{-6} (e^{-\frac{180}{56}})$$

$$I = 35.878 \mu A$$

Note: Calculations were made with 5V supply and so was the simulated, the practical was done with 6V and this will affect the measured values compared to the calculated values.

Comparing Results

<u>Time (s)</u>	<u>Practical (μA)</u>	<u>Simulation (μA)</u>	<u>Calculated (μA)</u>
60	350	305.9525	305.820
120	120	104.6369	104.749
180	40	35.8580	35.878

As seen in the comparison table the simulation and calculation method are very similar. The practical however has a big difference to the simulation and the calculation, this is due to the practical having an incorrect voltage input of 6V instead of 5V. My calculated and simulated values are worst case around 0.1uA difference.

<u>Time (s)</u>	<u>Practical (V)</u>	<u>Simulation (V)</u>	<u>Calculated (V)</u>
60	4	3.2867	3.28
120	5.35	4.4140	4.41
180	5.82	4.7995	4.799

As seen in the comparison table the simulation and calculation method are very similar. The practical however has a big difference to the simulation and the calculation, this is due to the practical having an incorrect voltage input of 6V instead of 5V. My calculated and simulated values are worst case around 0.001V difference.

Task 2 (Transient Behaviour for the Discharging of a Capacitor)

The circuit below is used to show the Transient Behaviour for the Discharging of a Capacitor:

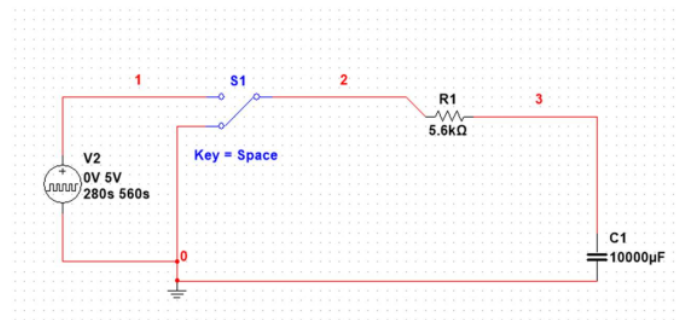


Figure 6 Discharging circuit

I used a practical design of the circuit above (figure 6) to measure voltage and current until steady state conditions are reached with a discharging capacitor. Every 5s the current and voltage was measured and recorded until I reached 300s.

Practical Method

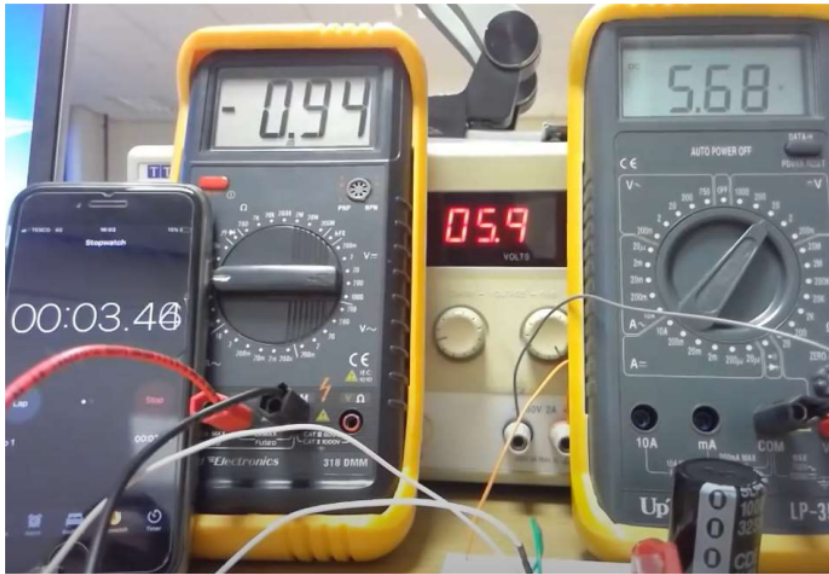


Figure 7 Multimeters task 2

The Graph below is a Current over Time graph for the discharging of a capacitor made from my practical circuit. The current was taken after every 5s from 0-300s:

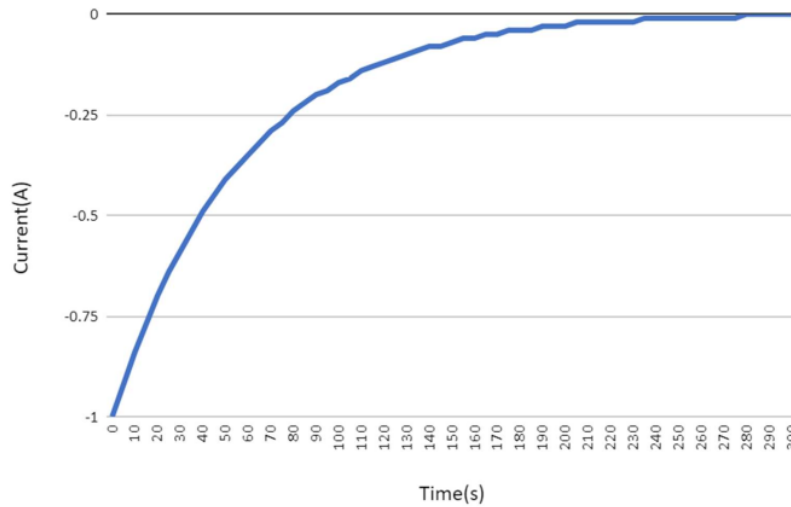


Figure 8 Practical current task 2

The longer the time goes on the higher the current gets, this is easily seen on the graph above (figure 8)

The graph below (figure 9) shows how the voltage changes through time on a discharging of a capacitor:

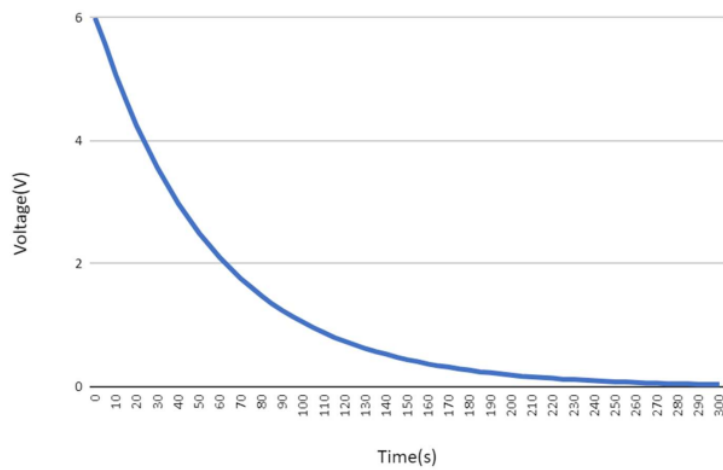


Figure 9 Voltage practical task 2

The graph above (figure 9) shows that the voltage decreases through time when charging a capacitor.

Simulated Method

Through using “multisim” and by using the circuit in figure 1 I made a simulation that shows voltage over time, this can be seen below on figure 10.

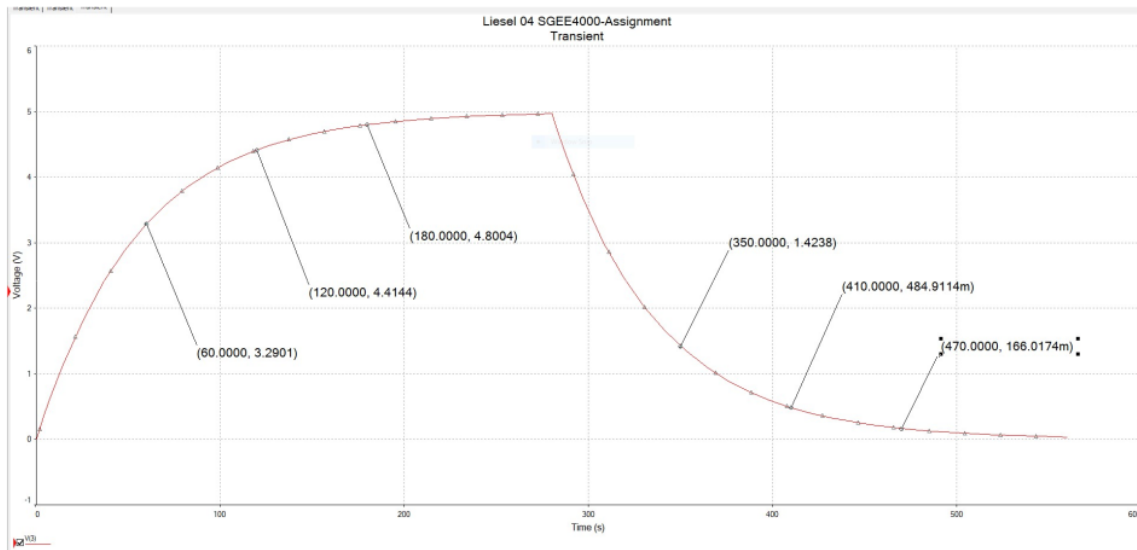


Figure 10 simulation discharge

The simulation shows that as the capacitor starts to discharge and the time goes up, the voltage goes down.

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Through using "multisim" and by using the circuit in figure 1 I made a simulation that shows current over time, this can be seen below on figure 11.

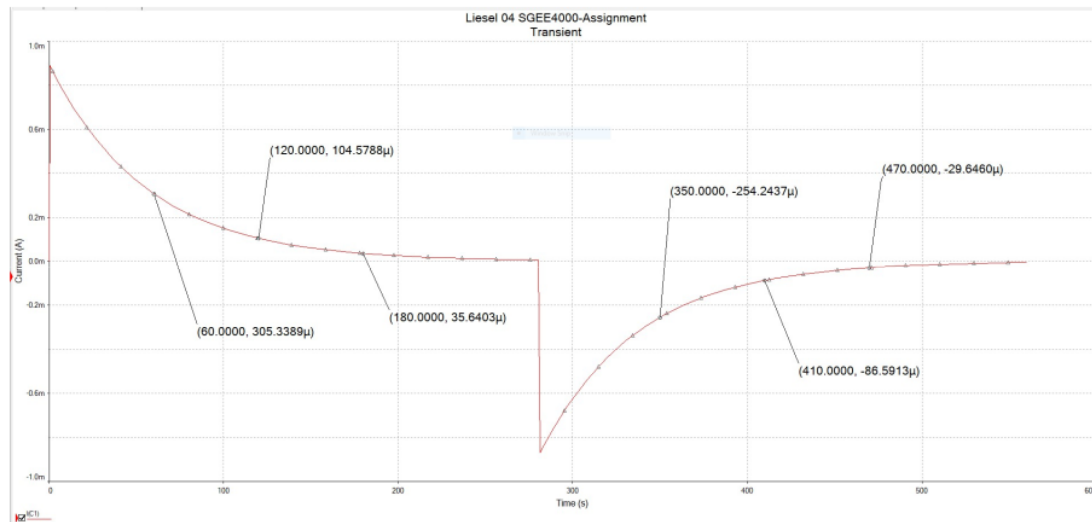


Figure 11 current simulation discharge

Mathematical Method

Chosen Numbers for Discharging of a capacitor:

70s, 130s, 190s

70s:

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

$$= 5(e^{-\frac{70}{56}})$$

$$= 1.4325V$$

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

$$I = 892.857 \times 10^{-6} (e^{-\frac{70}{56}})$$

$$I = 255.807 \mu A$$

130s:

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

$$= 5(1 - e^{-\frac{130}{56}})$$

$$= 0.49V$$

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

$$I = 892.857 \times 10^{-6} (e^{-\frac{130}{56}})$$

$$I = 87.619 \mu A$$



190s:

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

$$= 5(e^{-\frac{190}{56}})$$

$$= 0.168V$$

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

$$I = 892.857 \times 10^{-6} (e^{-\frac{190}{56}})$$

$$I = 30 \mu A$$

Note: Calculations were made with 5V supply and so was the simulated, the practical was done with 6V and this will affect the measured values compared to the calculated values.

Results comparison

Two tables will be created, one for the voltage and the other for the current. Both tables will be comparing the practical, simulation and calculated values.

<u>Time (s)</u>	<u>Practical (μA)</u>	<u>Simulation (μA)</u>	<u>Calculated (μA)</u>
70	290	254.2437	255.807
130	100	86.5913	87.619
190	30	29.6460	30

As seen in the comparison table the simulation and calculation method are very similar. The practical however has a big difference to the simulation and the calculation, this is due to the practical having an incorrect voltage input of 6V instead of 5V. My calculated and simulated values are worst case around 1 μA difference.

<u>Time (s)</u>	<u>Practical (V)</u>	<u>Simulation (V)</u>	<u>Calculated (V)</u>
70	1.76	1.4238	1.4325
130	0.62	0.484	0.49
190	0.23	0.166	0.168

As seen in the comparison table the simulation and calculation method are very similar. The practical however has a big difference to the simulation and the calculation, this is due to the practical having an incorrect voltage input of 6V instead of 5V. My calculated and simulated values are worst case around 0.01V difference.

Task 3 (Transient Behaviour for a more Complex Circuit)

Task 3 is an investigation on the behaviour of a capacitor in a complex circuit when discharging and charging.

The circuit for task 3 can be seen below.

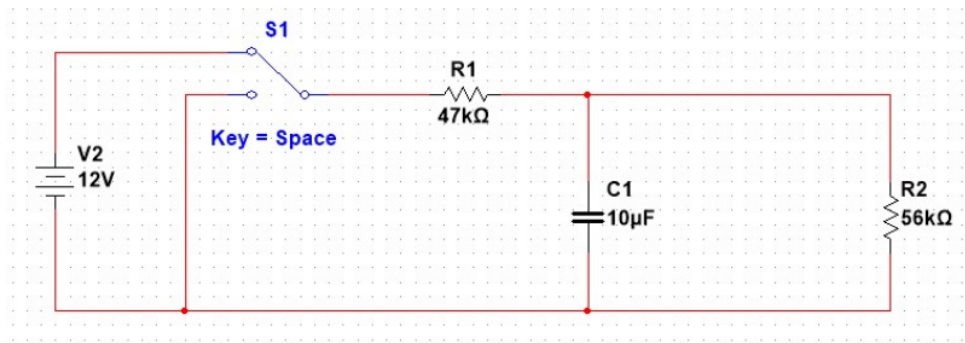


Figure 12 task 3 circuit

The time constant will be calculated by firstly working out the total resistance of the capacitor.

Simulation Method

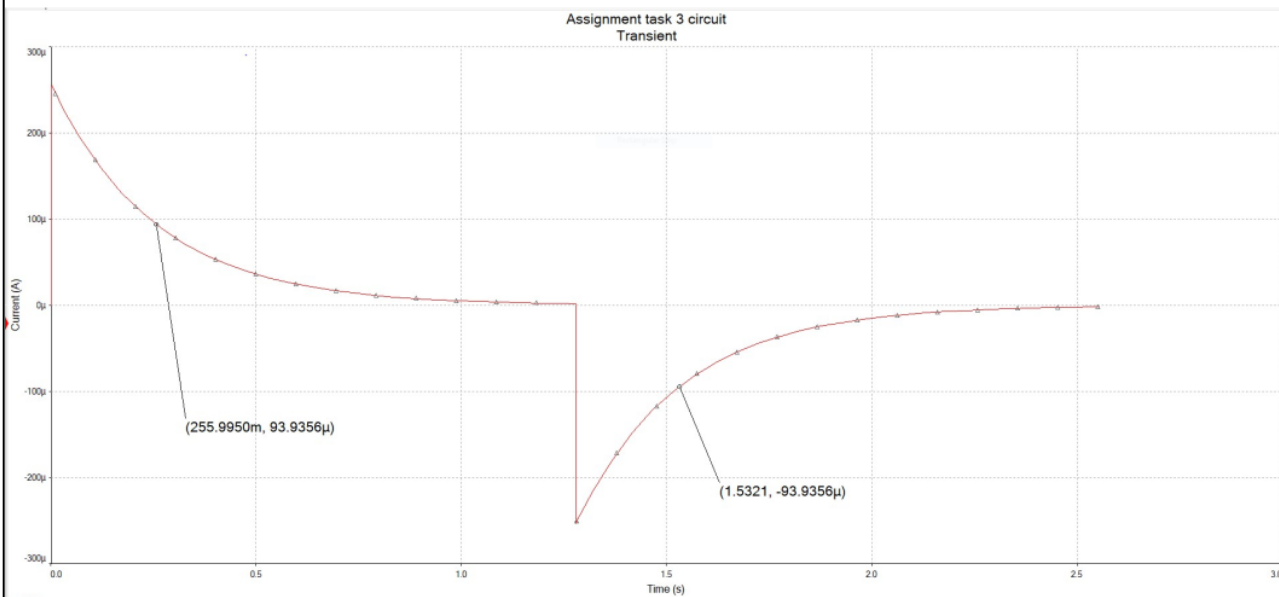
The circuit has been made on multisim as seen in figure 12, the currents will be plotted to a base of time for the discharging and the charging conditions, the time constant will be estimated for discharge and the charge of the circuit. The time constant is 36.8% of the current.



My estimation calculations:

$$I_{Max} = \frac{6.5243}{25.5594 \times 10^3} = 255.260 \mu A$$

$$(255.260 \times 10^{-6}) \times 0.368 = 93.9356 \mu A$$



Charging current is positive, and the discharging current is negative.

Figure 13 task 3

Mathematical Method

Calculations for total resistance of the circuit:

$$V_r = \frac{R_2}{R_1 + R_2} \times V$$

$$\frac{56}{47 + 56} \times 12 = 6.5243V$$

$$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$\frac{47 \times 56}{47 + 56} = 25.5594k\Omega$$

Calculations for max current:



$$I_{max} = \frac{V_r}{R_t} = \frac{6.5243}{25.5594 \times 10^3} = 255.260\mu A$$

Calculations for tau (τ), and how long it takes to get to steady state:

$$\tau = R_t \times C = (25.5594 \times 10^3) \times (10 \times 10^{-6}) = 255.594ms$$

$$5 \times \tau = (255.594 \times 10^{-3}) \times 5 = 1.278s$$

Calculations for current at 1τ :

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

$$I = 255.260 \times 10^{-6} \left(e^{\frac{-255.594 \times 10^{-3}}{255.594 \times 10^{-3}}} \right) = 93.905\mu A$$

Current calculation won't change for discharging and charging. Discharging current is negative and charging current is positive.

Results comparison:

Results are in the table below:

Charging

Time constant	Calculation	Estimated
1τ	93.905 μA	93.9356 μA

Discharging

Time constant	Calculation	Estimated
1τ	-93.905 μA	-93.9356 μA

From the comparison tables it's easy to see that the Simulation and calculation results are similar for both discharging and charging circuits, the difference is only 0.0306 μA .

$$\text{Initial current} = I_{\text{max}} = 255.260 \mu\text{A}$$

$$\text{Final current} = I_{\text{Max}} \left(e^{-\frac{5\tau}{\tau}} \right) = 255.260 \times 10^{-6} \left(e^{-\frac{1.278}{255.594 \times 10^{-3}}} \right) = 1.719 \mu\text{A}$$

Task 4 (Transient Behaviour for the Inductive Circuit)

Task 4 is to investigate transient behaviour for an inductive circuit as seen in figure 14, this is a RL Circuit. To find the first 5-time constants of the circuit I will simulate it using multisim. Calculations will be made to compare to the simulation, readings for the current before the switch has been changed will be made and calculations of elapsed time will be made before the current drops to the readings of 400mA and 200mA.

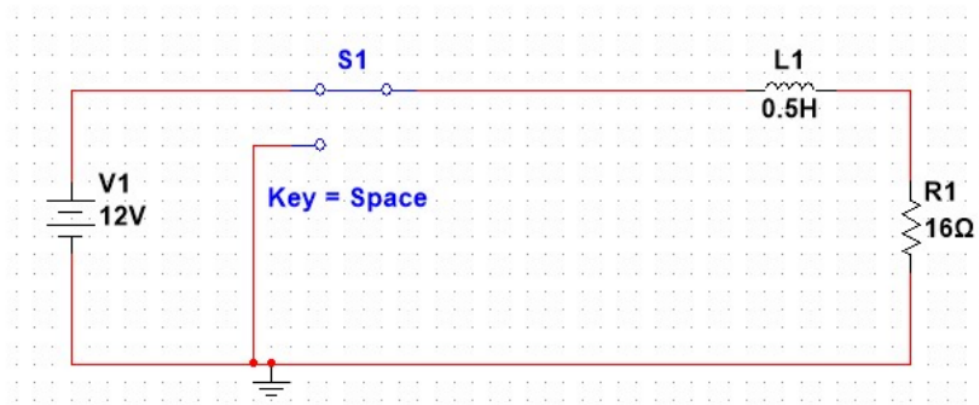


Figure 14 task 4 circuit

Mathematical Method

5-time constant calculations:

$$1\tau = \frac{L}{R} = \tau = \frac{0.5}{16} = 31.25ms$$

$$2\tau = \frac{L}{R} = 2\tau = \frac{0.5}{16} = 62.5ms$$

$$3\tau = \frac{L}{R} = 3\tau = \frac{0.5}{16} = 93.75ms$$

$$4\tau = \frac{L}{R} = 4\tau = \frac{0.5}{16} = 125ms$$

$$5\tau = \frac{L}{R} = 5\tau = \frac{0.5}{16} = 156.25ms$$

$$I_m = \frac{V}{R} = A \quad I_m = \frac{12}{16} = 0.75A$$

$$I = I_m \left(e^{\frac{-t}{\tau}} \right) = 0.75 \left(1 - e^{\frac{-31.25 \times 10^{-3}}{31.25 \times 10^{-3}}} \right) = 474.090mA$$

$$I = I_m \left(e^{\frac{-t}{\tau}} \right) = 0.75 \left(1 - e^{\frac{-62.5 \times 10^{-3}}{31.25 \times 10^{-3}}} \right) = 648.499mA$$

$$I = I_m \left(e^{\frac{-t}{\tau}} \right) = 0.75 \left(1 - e^{\frac{-93.75 \times 10^{-3}}{31.25 \times 10^{-3}}} \right) = 712.660mA$$

$$I = I_m \left(e^{\frac{-t}{\tau}} \right) = 0.75 \left(1 - e^{\frac{-125 \times 10^{-3}}{31.25 \times 10^{-3}}} \right) = 736.263mA$$

$$I = I_m \left(e^{\frac{-t}{\tau}} \right) = 0.75 \left(1 - e^{\frac{-156.25 \times 10^{-3}}{31.25 \times 10^{-3}}} \right) = 744.947mA$$

Simulation method

I have created a simulation using the circuit in figure 14. For the charging circuit I have plotted the currents to base of time.

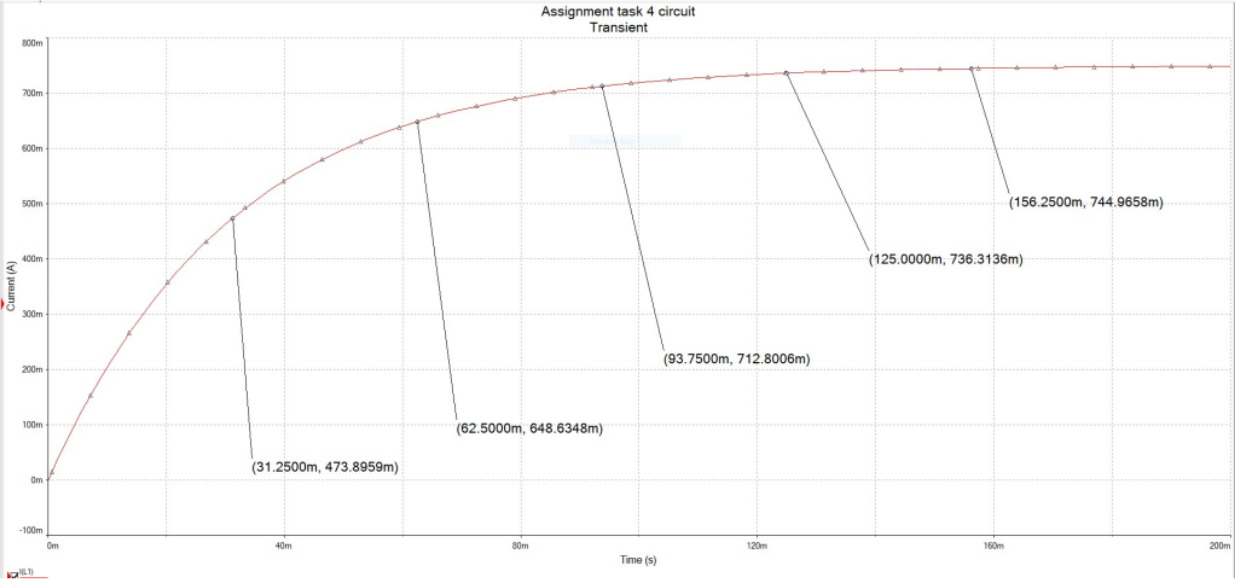


Figure 15 task 4 simulation

Comparing results

Below is a table of my simulated and calculated currents for each time constant from 1τ to 5τ .

<u>Current (mA)</u>	<u>1τ</u>	<u>2τ</u>	<u>3τ</u>	<u>4τ</u>	<u>5τ</u>
Calculated	474.090	648.499	712.660	736.263	744.947
Simulated	473.8959	648.6348	712.8006	736.3136	744.9658

As seen in the comparison table above, the simulation and calculated current is very similar with the worst error around 0.2mA difference.



Conclusion

After completing the first and second task on the transient behaviour of a charging and discharging capacitor the results were very promising with the calculated and simulated values of the current and voltage when discharging and charging being very similar and almost identical. However, the simulated and calculated values were quite different to the practical circuits as these circuit were being ran on a 6V circuit unlike the simulated and calculated versions which were using 5V circuits. If this were to be done again I would make sure that all different ways of testing these circuit had all the same input values so I would run the practical test on a 5V power supply to give better results in the task.

Task 3 (Transient Behaviour for a more Complex Circuit) was also a success with the calculated and estimated currents only having an error of 0.0306uA between them. Task 4 (Transient Behaviour for the Inductive Circuit) was also a success with the comparison table at the end of the task showing very low error margins, the biggest error was around 0.2mA difference.

All simulations through these task's went very well and all calculations matched up very closely, however the practical did not for task 1 and 2 due to a different input voltage on the power supply. Through doing these tests I have concluded that the theoretical and practical testing was a success into looking into RL and RC circuits with a charging and discharging capacitor. All the results complemented each other throughout the experiment.



FINAL GRADE

GENERAL COMMENTS

Instructor

68/100

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Comment 1

write in the third person, past tense

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Comment 2

incorrect graph here



Comment 3

not correct

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Comment 4

numbers? be more specific

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Comment 5

polarity?

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Comment 6

of the capacitor?

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Comment 7

why?

PAGE 20



Comment 8

you have worked this out correctly

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Comment 9



Comment 10

avoid vague statements like promising and successful, you must have success criteria and explain what the results tell you

GRADING FORM: NEW CSG-RUBRIC

BENJAMIN NAYLOR

68

1. ENGAGEMENT WITH LITERATURE



NA

0

2. KNOWLEDGE AND UNDERSTANDING



A competent level of knowledge displayed in report, though some of task 4 is missing. 16/25

16

3. COGNITIVE AND INTELLECTUAL



Sound evaluation has been offered in terms of practical, simulated and calculated results. avoid repetition and offer logical explanations of results rather than vague statements claiming success. 20/30

20

4. PRACTICAL APPLICATION



Application of advanced technical methods for simulated results, with good quality characteristic graphs and clear, accurate results. 18/25

18

5. TRANSFERABLE SKILLS



Accurate and coherent results and a report which flows well and is clear in its approach. Missing some work for task 4. 14/20

14