

2117073

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Submission date: 13-Feb-2022 09:56AM (UTC+0000)

Submission ID: 171380789

File name: 17432_Tomos_Williams_2117073_179522_1187459935.pdf (1.8M)

Word count: 3776

Character count: 24433

HNC Electrical and Electronic Engineering
SGEE4000 – Electrical and Electronic Principles
Investigation into DC Transients
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2117073
13/2/22
2120

- ① GOOD LEVEL OF KNOWLEDGE DEMONSTRATED
- ② GOOD FEEDBACK FROM THE LECTURER.

MARK AS REQ.

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Introduction

Throughout this assignment I will conduct investigations into the behaviour of R-L and R-C transient circuits through MultiSim simulations, practical construction and testing and through theoretical calculations. The results gathered will be discussed and comparisons will be given between the three different methods of calculation, and suitable conclusions will be drawn.

During the assignment I will also manipulate relevant formulae in order to solve engineering problems, in addition to correctly annotating MultiSim simulations and extracting the required data using an array of engineering principles. Furthermore, I will extract readings from the practical circuits and contrast the relevant data with the two other methods.

Task 1 - Transient Behaviour for the Charging of a Capacitor

In Task 1, we will investigate the current and voltage readings at randomly chosen time values during the charging state of a capacitor. We will use calculated theoretical values, values derived from MultiSim simulations and values taken from a practical and later compare these values.

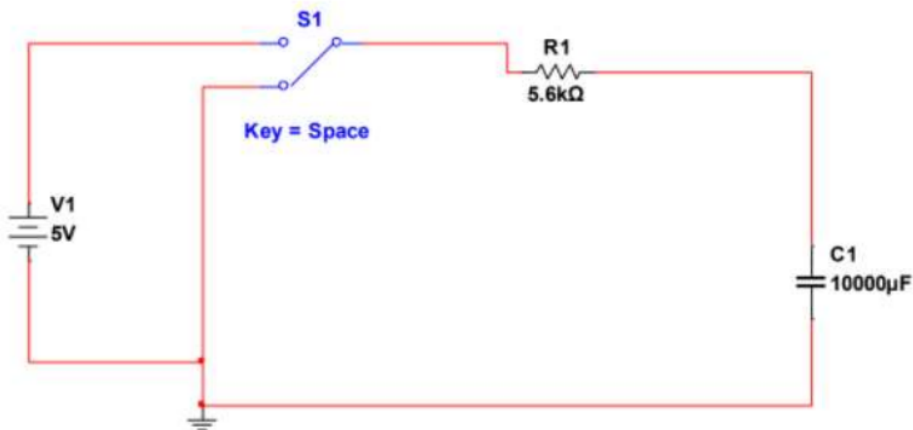


Figure 1 - Task 1 circuit for the Charging of a Capacitor

Suitable practical values of R and C should be chosen in order to provide the best overall results and to allow the values to be easily comparable. Additionally, if suitable values are derived then an appropriate value for the time constant can be calculated. The time constant (τ) is the product of the resistance of the circuit and the capacitance of the circuit.

$$\tau = RC \text{ [seconds]}$$

The time constant is the time taken to charge the capacitor from 0V to 63.2% of the applied voltage or to discharge the capacitor 36.8% of its charge voltage.

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Practical

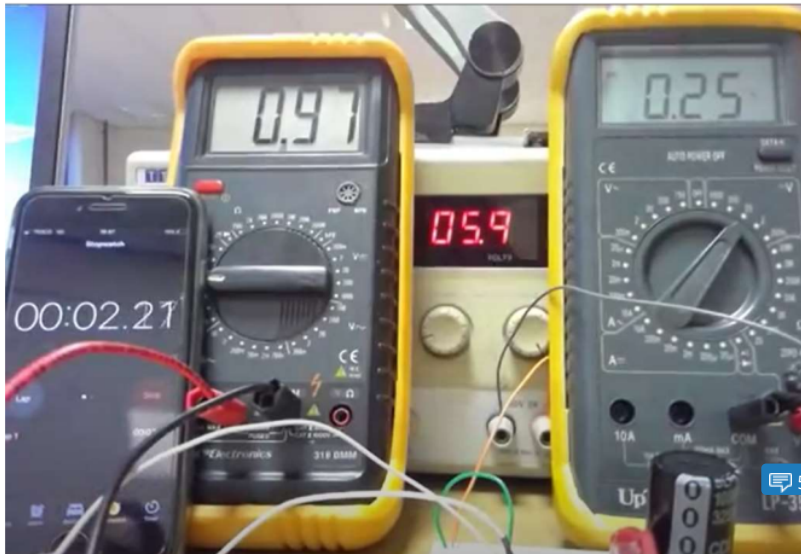


Figure 2 - Practical for the Charging of a Capacitor

In Figure 2, the left Multimeter shows the current value and the right Multimeter shows the voltage value during the charging state of the capacitor. After reading off the current values, we converted them into mA for ease of rounding and it allows for better quality graphs to be produced later. We took these voltage and current readings until steady state conditions were reached at around 300 seconds. See Figure 27 in the appendices for the table showing the voltage and current at each time point.

Charge - Voltage vs Time

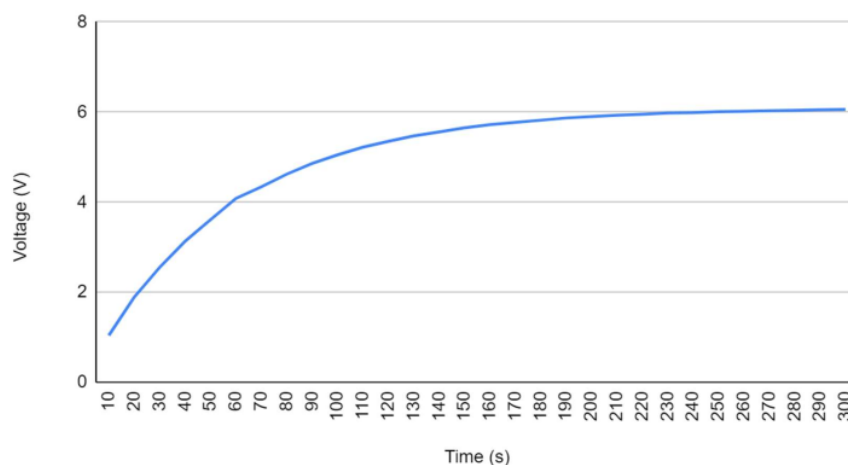


Figure 3 - This line graph shows the growth of the voltage over a 300 second time period while the capacitor is charging

Charge - Current vs Time

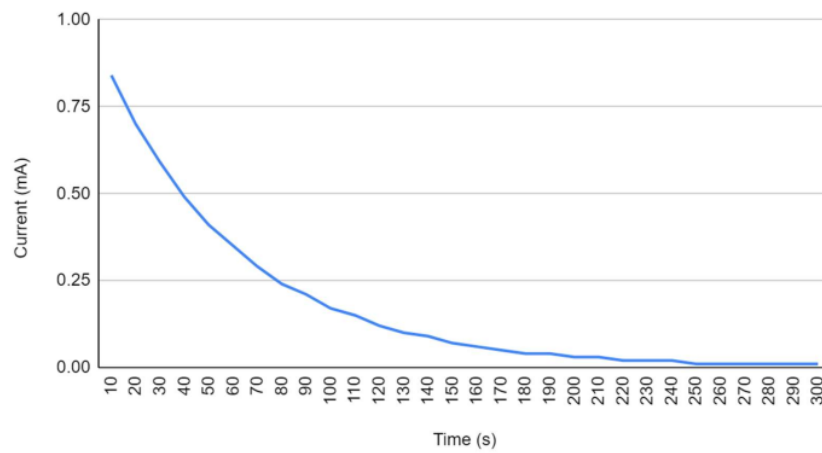


Figure 4 - This line graph shows the decay of the current over a 300 second time period while the capacitor is charging

Figures 3 and 4 are the graphs produced from the data collected from the practical where current and voltage values were recorded at each time value until steady state conditions were reached while the capacitor was charging.

Calculations

In this section, the current and voltage was calculated at each randomly chosen time value while the capacitor would be charging.

$$\tau \text{ (time constant)} = RC$$

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

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

$$I_{\text{max}} = V/R = 5/(5.6 \times 10^3) = 892.857 \mu\text{A}$$

My randomly chosen time values are 46s, 135s and 190s.

46s –

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

$$V_c = 5(1 - e^{-46/56}) = 2.8 \text{ V}$$

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

$$I = 892.857 \times 10^{-6}(e^{-46/56})$$

$$I = 3.927 \times 10^{-4} \text{ A} = 0.393 \text{ mA}$$

135s –

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

$$V_c = 5(1 - e^{-135/56}) = 4.551 \text{ V}$$

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

$$I = 892.857 \times 10^{-6}(e^{-135/56})$$

$$I = 8.013 \times 10^{-5} \text{ A} = 0.08013 \text{ mA}$$

190s –

$$V_c = V_{\max} (1 - e^{-t/\tau})$$

$$V_c = 5(1 - e^{-190/56}) = 4.832V$$

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

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

$$I = 3.001 \times 10^{-5} \text{ A} = 0.03\text{mA}$$

MultiSim Simulations

After recreating the circuit in MultiSim I then simulated the circuit plotting current and voltage to a base of time. I would then set the x values to 46 seconds, 135 seconds, and 190 seconds, adding data labels at each point. This allows for easier comparison of values later on, compared to practical values and the theoretically calculated values.

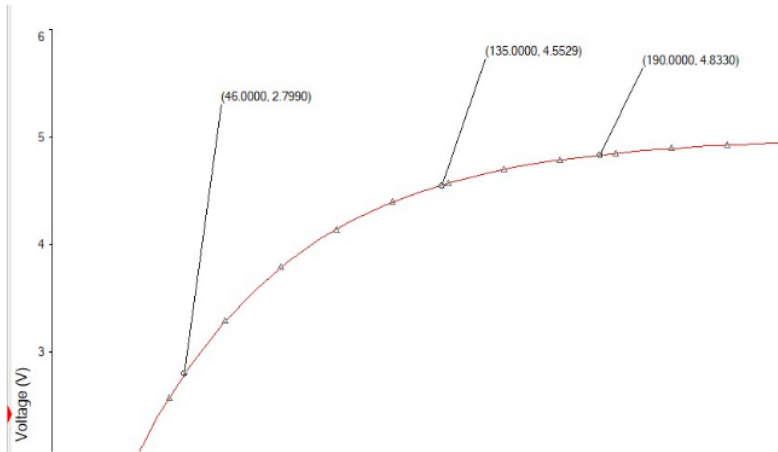


Figure 5 - This is a graph taken from a Multisim simulation showing the voltage at my randomly chosen time values while the capacitor is charging

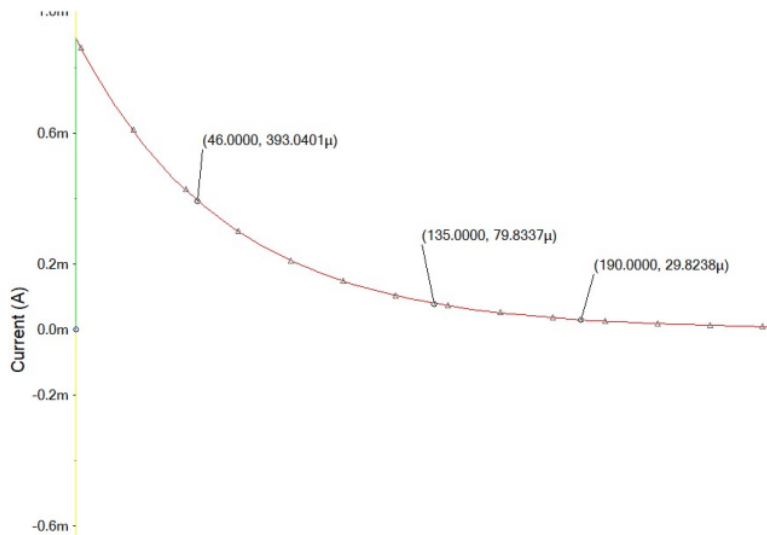


Figure 6 - This is a graph taken from a Multisim simulation showing the current at my randomly chosen time values while the capacitor is charging

Comparison of Results

Time (s)	Practical	Calculated	Simulated
46	3.3V 0.44mA	2.8V 0.393mA	2.799V 0.393mA
135	5.51V 0.095mA	4.551V 0.08013mA	4.5529V 0.079mA
190	5.87V 0.04mA	4.832V 0.03mA	4.833V 0.029mA

Figure 7 - Comparison table showing all the results while the capacitor is charging

Figure 7 shows that the calculated and the simulated values are all very similar at each time point for both voltage and current and the very slight differences can be put down to rounding. The values gathered from the practical are slightly further off the other two sets of results and this can be caused by things like the resistance in the wires and the tolerance of the resistor, neither of which are taken into consideration with the other sets of results.

Task 2 – Transient Behaviour for the Discharging of a Capacitor

In Task 2, we will investigate the current and voltage readings at randomly chosen time values during the discharging state of a capacitor. We will use calculated theoretical values, values derived from MultiSim simulations and values taken from a practical and later compare these values.

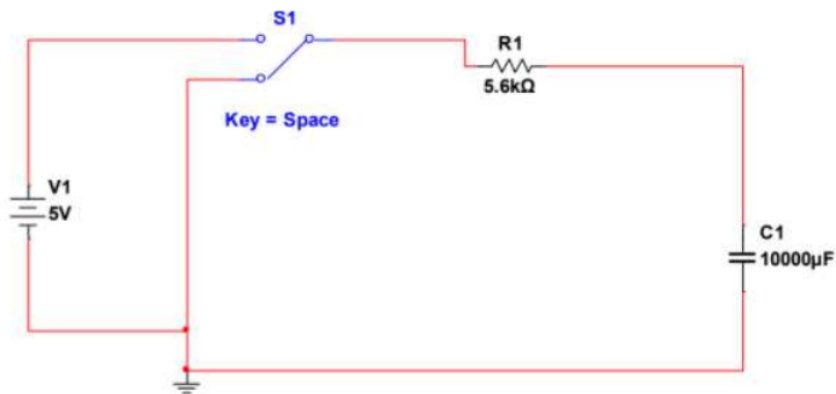


Figure 8 - Task 2 circuit for the discharging of a capacitor

Practical

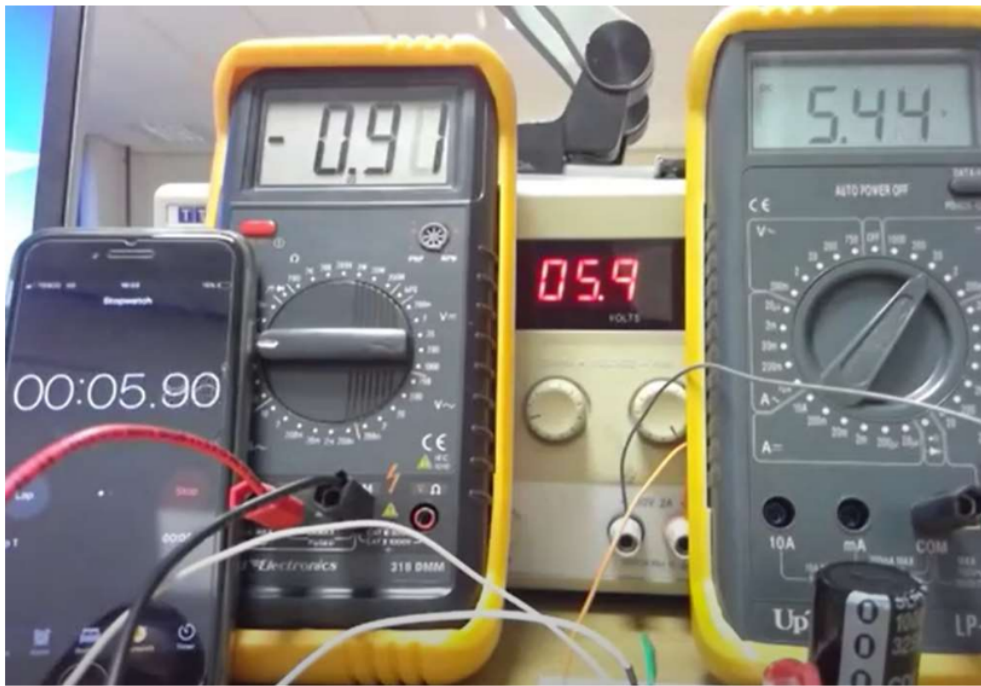


Figure 9 - Practical for the discharging of a capacitor

In Figure 9, the left Multimeter shows the current value and the right Multimeter shows the voltage value during the discharging state of the capacitor. We took these voltage and current readings until steady state conditions were reached at around 300 seconds. See Figure 28 in the appendices for the table showing the voltage and current at each time point.

Discharge - Voltage vs Time

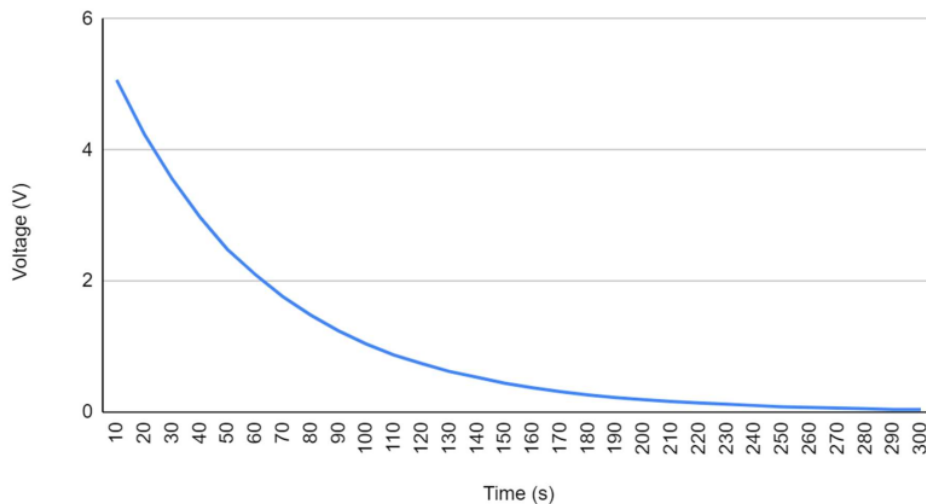


Figure 10 - This line graph shows the decay of the voltage over a 300 second time period while the capacitor is discharging

Discharge - Current vs Time

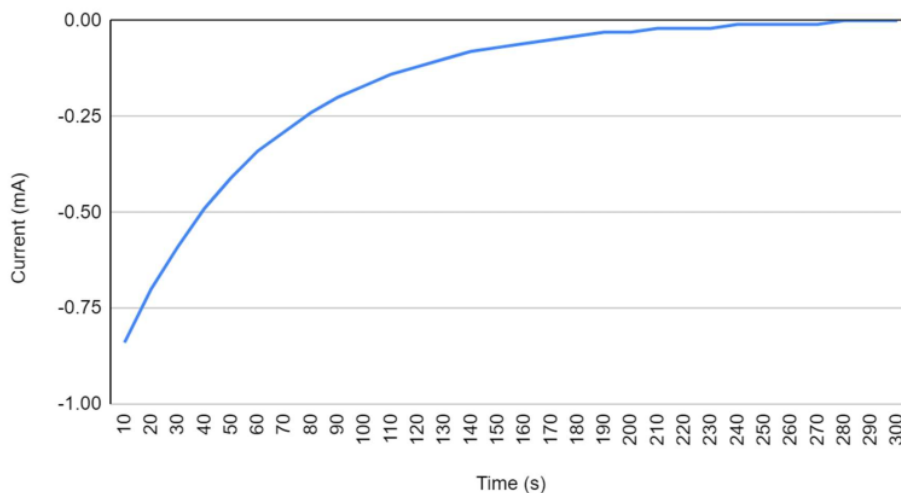


Figure 11 - This line graph shows the growth of the current over a 300 second time period while the capacitor is discharging

Figures 10 and 11 are the graphs produced from the data collected from the practical where current and voltage values were recorded at each time value until steady state conditions were reached while the capacitor was discharging.

Calculations

In this section, the current and voltage was calculated at each randomly chosen time value while the capacitor would be discharging.

72s –

$$\begin{aligned}V_c &= V \times e^{(-t/\tau)} \\&= 5 \times e^{(-72/56)} = 1.382V\end{aligned}$$

$$\begin{aligned}I &= -I_{\max} \times e^{(-t/\tau)} \\&= -892.857 \times 10^{-6} \times e^{(-72/56)} \\&= -0.247\text{mA}\end{aligned}$$

121s –

$$\begin{aligned}V_c &= V \times e^{(-t/\tau)} \\&= 5 \times e^{(-121/56)} = 0.576V\end{aligned}$$

$$\begin{aligned}I &= -I_{\max} \times e^{(-t/\tau)} \\&= -892.857 \times 10^{-6} \times e^{(-121/56)} \\&= -0.103\text{mA}\end{aligned}$$

210s –

$$\begin{aligned}V_c &= V \times e^{(-t/\tau)} \\&= 5 \times e^{(-210/56)} = 0.118V\end{aligned}$$

$$\begin{aligned}I &= -I_{\max} \times e^{(-t/\tau)} \\&= -892.857 \times 10^{-6} \times e^{(-210/56)} \\&= -0.021\text{mA}\end{aligned}$$

MultiSim Simulations

After discharging the capacitor on the circuit in MultiSim I then simulated the circuit plotting current and voltage to a base of time. I would then set the x values to 352 (72 seconds), 401 (121 seconds), and 490 (210 seconds), adding data labels at each point. I set the x values to these numbers because the circuit didn't start to discharge until after 280 seconds.

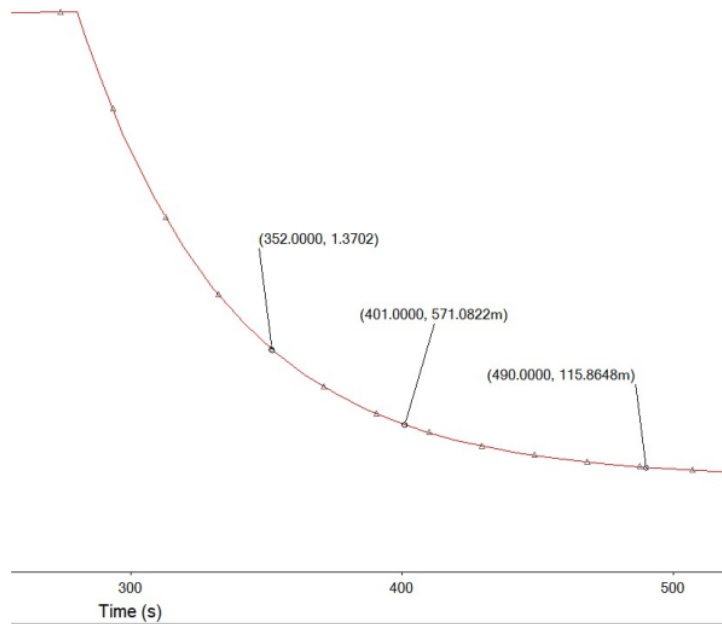


Figure 12 - This a graph taken from a Multisim simulation showing the voltage at my randomly chosen time values while the capacitor is discharging

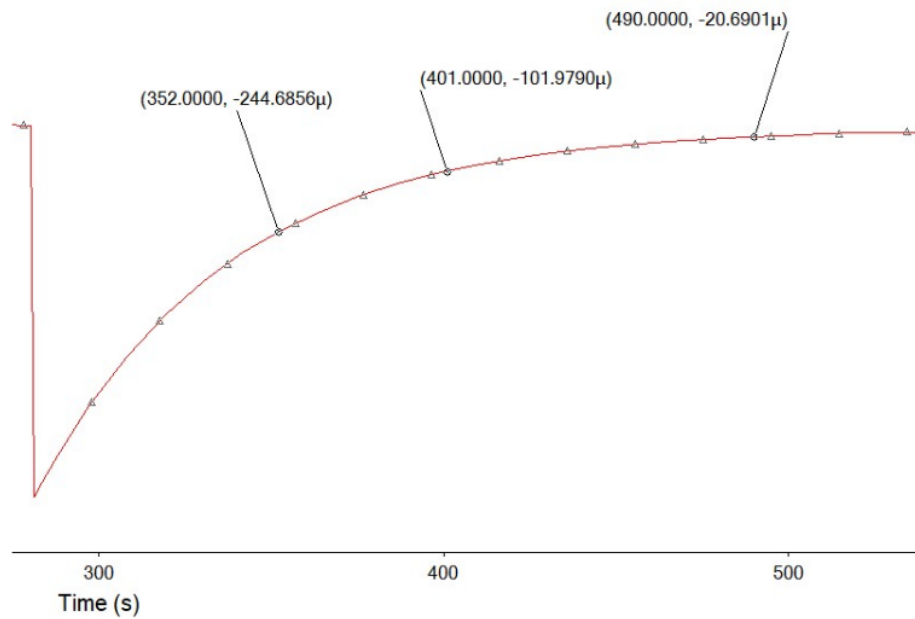


Figure 13 - This is a graph taken from a Multisim simulation showing the current at my randomly chosen time values while the capacitor is discharging

Comparison of Results

Time (s)	Practical	Calculated	Simulated
72 (352)	1.69V -0.28mA	1.382V -0.247mA	1.3702V -0.245mA
121 (401)	0.73V -0.12mA	0.576V -0.103mA	0.571V -0.102mA
210 (490)	0.16V -0.02mA	0.118V -0.021mA	0.116V -0.021mA

Figure 14 - Comparison table showing all the results while the capacitor is discharging

Figure 14 shows that the calculated and the simulated values are almost perfectly alike at each time point for both voltage and current just like for the charging values. These extremely minor differences can again be put down to rounding. The values gathered from the discharging practical are much closer than with the charging experiment. The majority of the values are very similar to the calculated and simulated values with only two integers slightly more different from the other data sets. These differences could again be reasoned towards the resistance of the wires and the tolerance of the resistor.



Task 3 – Transient Behaviour for a more Complex Circuit

In task 3, we are provided with a more complex circuit. The total resistance should be calculated alongside a new voltage in order to determine the time constant. The circuit will then be simulated in MultiSim where the current will be recorded while the capacitor is both charging and discharging. These values will later be contrasted to calculated current values.

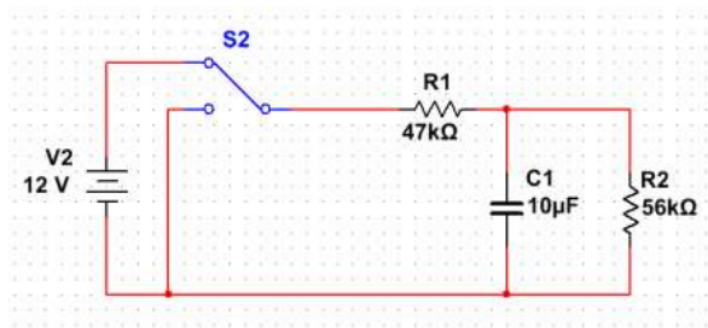


Figure 15 - Task 3 original circuit

Equivalent Circuit

New resistance – $(47,000 \text{ ohm} \times 56,000 \text{ ohm}) / (47,000 + 56,000)$

$$= 25,553.4 \text{ ohm}$$

New voltage – $56,000 / (56,000 + 47,000) \times 12$

$$= 6.5\text{V}$$

Time constant (τ) – $25,553.4 \times 10 \times 10^{-6} = 0.225 \text{ seconds}$

5 τ = 1.275 seconds

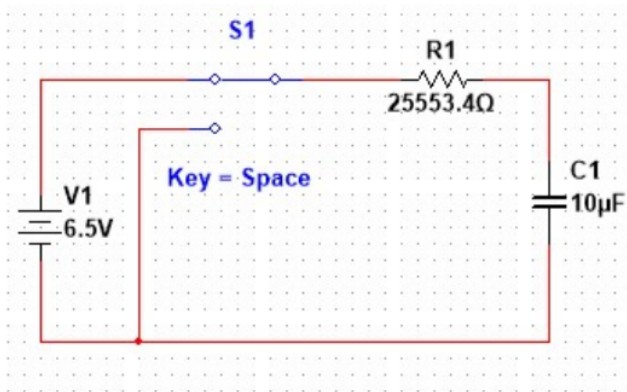


Figure 16 - Task 3 Equivalent Circuit

MultiSim Simulation

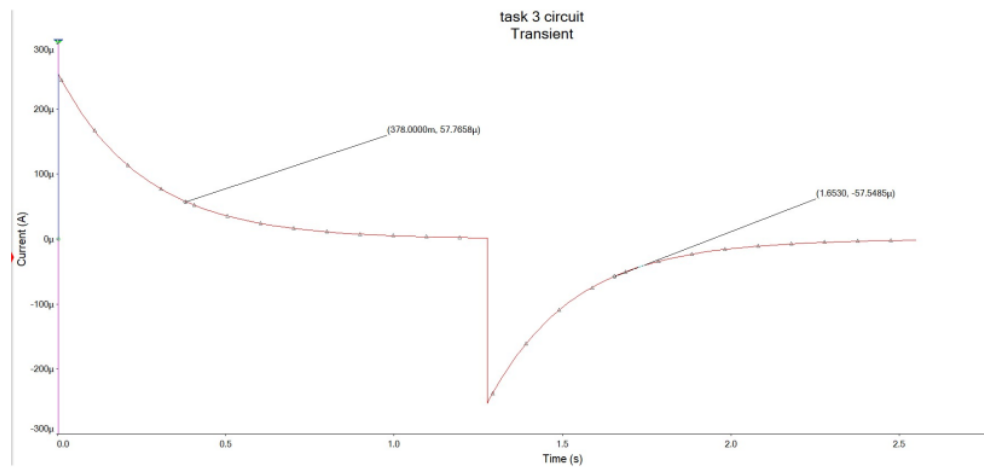


Figure 17 - Task 3 MultiSim graph showing the currents at the time for constant while the capacitor is both charging and discharging

After recreating the equivalent circuit in MultiSim I simulated the circuit, plotting current to a base of time for the charge and discharge conditions. I set the x values to 0.378 seconds and 1.653 seconds. 0.378 is the first time constant while 1.653 is the first time constant added on to 5tau which is where the capacitor begins to discharge.

Calculations

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

$$I_{\max} = 6.5/25,553.4 = 0.00025437\text{A}$$

$$= 0.254\text{mA}$$

$$0.254\text{mA} \times 0.378 = \pm 96.012\mu\text{A} \text{ for charge and discharge}$$

Comparison of Results

	Time (s)	Calculated	Simulated
charging	0.378	96.012 μA	57.7658 μA
discharging	0.378 (1.653)	-96.012 μA	-57.5485 μA

Figure 18 - Comparison table for the currents while the capacitor is charging and discharging

In Figure 18 you can see that for both the charging and discharging conditions the calculated and simulated values are considerably contrasting from each other. The calculated charging values being much larger than the simulated integer while the simulated discharging value is approximately 40 μA larger than the calculated integer.



Initial and Final Current

$$\text{Initial current} = \text{new } V / \text{new } R$$

$$= 6.5/25,553.4 = 0.254\text{mA}$$

$$\text{Final current} = I_{\max} (e^{-(T/\tau)})$$

$$= 0.254\text{mA} (e^{-2.55/0.225}) = 3.0397\text{nA}$$

Task 4 - Transient Behaviour for the Inductive Circuit

In task 4, we will capture the current growth in the inductive circuit for the first five time constants on MultiSim and then manually plot calculated current values to compare against the MultiSim simulation. We will then calculate how much time elapses prior to the current dropping to 400mA and 200mA and compare these values with the graphs.

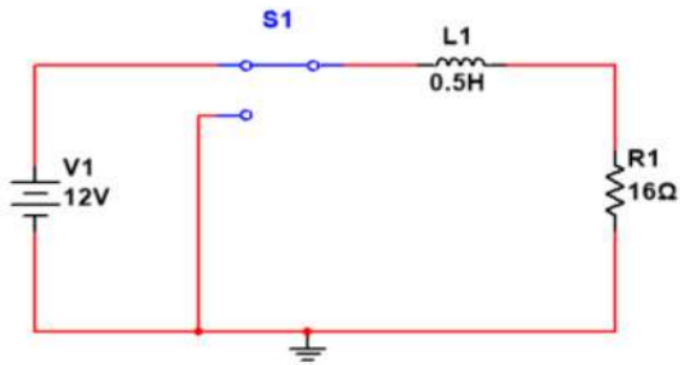


Figure 19 - Task 4 inductive circuit

MultiSim Simulation

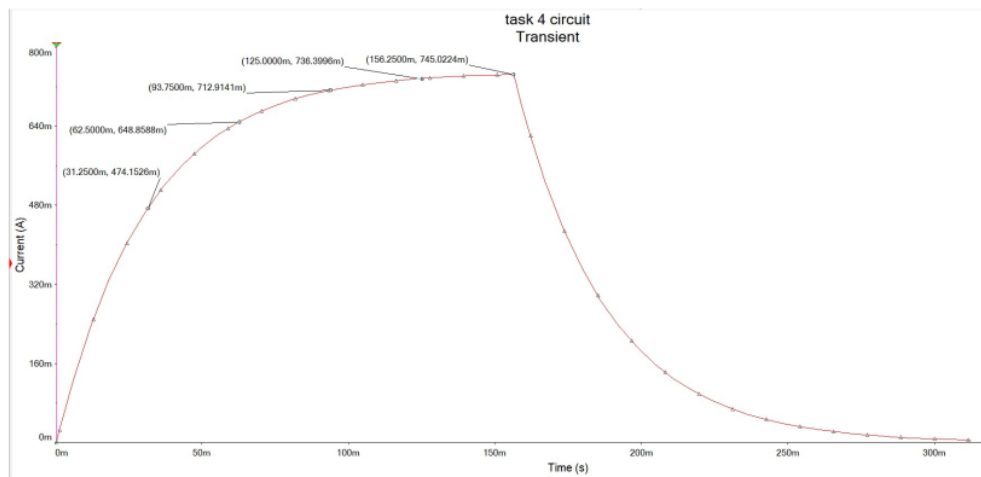


Figure 20 - MultiSim graph showing the growth of the current over the first 5 time constants

Calculations

$$I = V/R$$

$$I = 12/16 = 0.75\text{A}$$

$$\text{Time constant } (\tau) = L/R$$

$$\text{Time constant} = 0.5 / 16 = 0.03125 \text{ seconds}$$

$$5\tau = 0.15625 \text{ seconds}$$

$$\text{Value of current at a given time - } = I(1 - e^{-t/\tau})$$

$$\text{Value of current after 1 time constant} = I = 0.75 (1 - e^{-(0.03125/0.03125)})$$

$$= 0.4740904191\text{A}$$

$$= 474.09\text{mA}$$

$$\text{Value of current after 2 time constants} = I = 0.75 (1 - e^{-(0.0625/0.03125)})$$

$$= 0.6484985376\text{A}$$

$$= 648.49\text{mA}$$

$$\text{Value of current after 3 time constants} = I = 0.75 (1 - e^{-(0.09375/0.03125)})$$

$$= 0.7126596987\text{A}$$

$$= 712.66\text{mA}$$

$$\text{Value of current after 4 time constants} = I = 0.75 (1 - e^{-(0.125/0.03125)})$$

$$= 0.7362632708\text{A}$$

$$= 736.26\text{mA}$$

$$\text{Value of current after 5 time constants} = I = 0.75 (1 - e^{-(0.15625/0.03125)})$$

$$= 0.7449465398\text{A}$$

$$= 744.95\text{mA}$$

Manually Plotted Graph

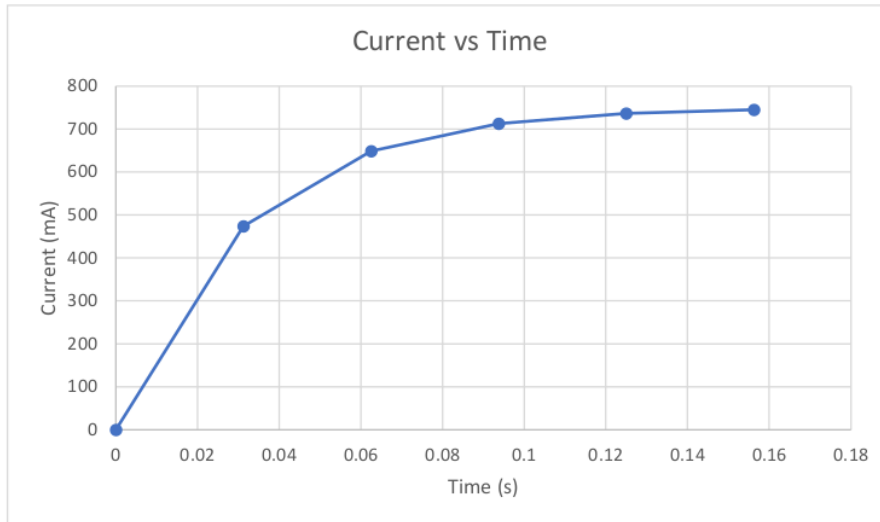


Figure 21 - Line graph showing the calculated current growth against a base of time

Comparison of Results

Time (s)	Simulation	Calculated
0.03125 (1 tau)	474.15 mA	474.09 mA
0.0625 (2 tau)	648.86 mA	648.49 mA
0.09375 (3 tau)	712.91 mA	712.66 mA
0.125 (4 tau)	736.39 mA	736.26 mA
0.15625 (5 tau)	745.02 mA	744.95 mA

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Figure 22 - Comparison table for the current values after the first 5 time constants for both simulated and calculated methods

The theoretically calculated values are extremely similar to the simulated values with very minor differences that could be put down to rounding.

Discharging

Value of current in the circuit immediately before the switch is changed over -

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

12

The switch would change over at 0.15625 seconds

Value of current at 0.15625 seconds = $I = 0.75(1 - e^{-(0.15625/0.03125)})$

$$= 0.7449465398\text{A}$$

$$= 744.95\text{mA}$$

The circuit time constant is calculated using the formula - Time constant (τ) = L/R

Time constant = $0.5 / 16 = 0.03125$ seconds

$5\tau = 0.15625$ seconds

For both my simulated graph and my manually plotted graph I will need to find approximately

36. the maximum current value which equates to the time constant (1 τ).

13

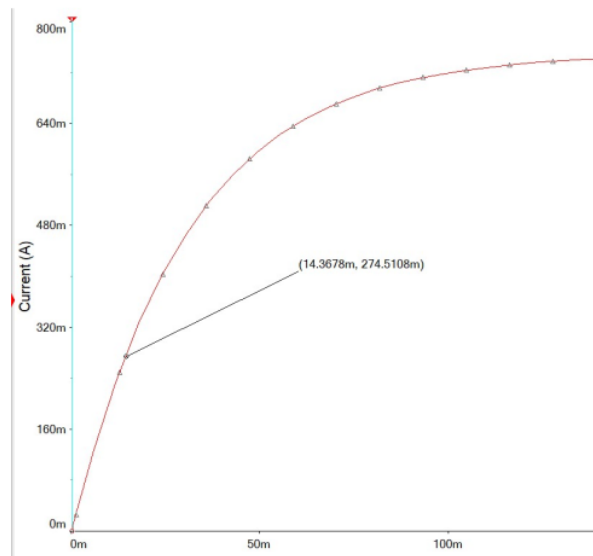


Figure 23 - MultiSim graph showing the approximate time constant of the circuit

Simulated	Manually Plotted
0.01436 seconds	0.018 seconds

Figure 24 - Comparison table for the approximate time constants of both graphs

Figure 24 shows the estimated time constants for both graphs yet regardless of these being estimates they are drastically dissimilar from my calculated time constant value.

Time that has elapsed before the current flowing in the circuit has fallen by a given current value –

$$T = \tau (\ln i/i_{\max})$$

Time that has elapsed before the current flowing in the circuit has fallen to 400mA –

$$T = 0.03125 (\ln 400 \times 10^{-3} / 744.95 \times 10^{-3}) = -0.0194 \text{ seconds}$$

Time that has elapsed before the current flowing in the circuit has fallen to 200mA –

$$T = 0.03125 (\ln 200 \times 10^{-3} / 744.95 \times 10^{-3}) = -0.0411 \text{ seconds}$$

The negative value means the circuit is discharging so 0.0194 seconds and 0.0411 seconds after the circuit begins to discharge at 0.15625 seconds.

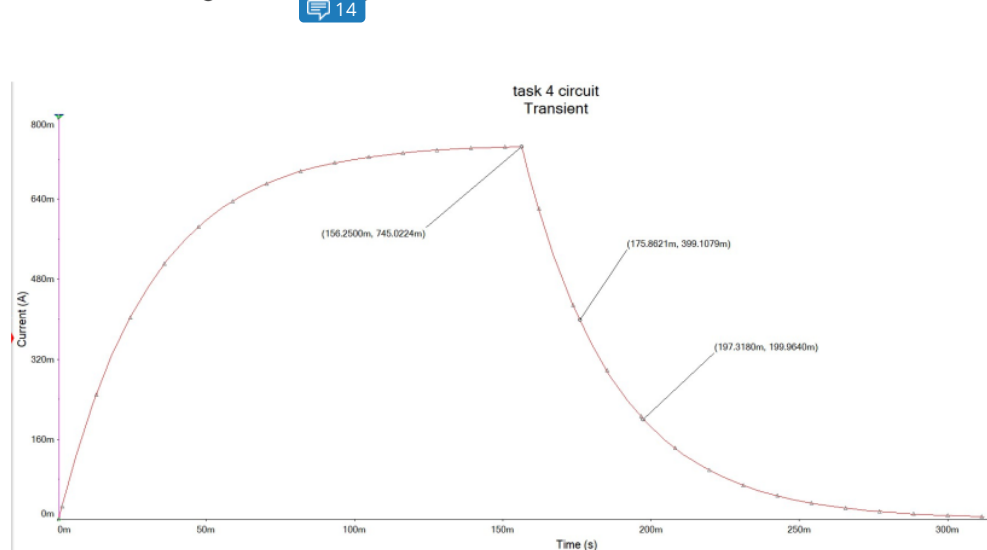


Figure 25 - MultiSim graph showing approximately when the current falls to 400mA and 200mA

	Calculated	Simulated
400mA	0.0194 seconds	0.0196 seconds
200mA	0.0411 seconds	0.0411 seconds

Figure 26 - Comparison table showing how long it took the current to fall to 400mA and 200mA for both my calculated values and the simulated values

Figure 26 shows that for both the calculated integers and the simulated integers the values are almost identical. At 400mA the values are 0.0002 seconds apart which can be put down to rounding and at 200mA both values are exactly identical.

Task 5 – Discussion of Results, Conclusions and Recommendations

Discussion of Results

In task 1, we investigated voltage and current readings during the charging state of a capacitor. We used calculated theoretical values, manually plotted values from a practical test and values from a MultiSim simulation. After collecting all the data, it was concluded that the simulated and calculated values were almost identical with minor differences due to rounding, while the practical values were very dissimilar from the other data sets. These differences could largely be explained through the resistance in the wires and the tolerance of the resistor in addition to human error in the recording of the values. The other two methods of calculation didn't consider these factors.

Task 2, where the discharge state of the capacitor was investigated, was largely the same as the previous task with the simulated and theoretical values being almost identical yet this time however, the practical values were much more similar than for the charging state of the capacitor. The majority of the practical results collected were extremely close to the values from the other two methods, especially the later time values where the integers collected are almost indistinguishable. Human error with the recording of the values could again be blamed as to why the integers were slightly different.  15

However, for task 3 where currents values were calculated and simulated during the charging and discharging of a capacitor in a more complex circuit, the results accumulated were drastically different for both the charging and discharging state of the capacitor. For both states of the capacitor the simulated and theoretical values were approximately 40 μ A apart from each other.  16

In task 4, we investigated the current growth in an inductive circuit for the first five time constants on MultiSim and contrasted these values with manually plotted theoretical current integers. We then computed how much time elapsed prior to the current dropping to 400mA and 200mA again contrasting these values with the graphical values. The values collected while measuring the current growth of the first 5 time constants are almost indistinguishable to the calculated values with very minor differences that could be caused by rounding during the calculations. Nonetheless, the simulated and manually plotted graphs provided dissimilar values for the circuit time constants, bearing in mind these integers are estimates. Finally, for the time elapsed for the current reading to fall to 400mA and then to 200mA, the time values collected for calculated and simulated values are identical.

Conclusions and Recommendations

In conclusion, I believe I have learnt a great deal during these investigations. I have become greatly more comfortable in producing MultiSim simulations and manifest important data points to contrast against calculated and practical integers. In addition, I have been exposed to more transient equations in a practical setting and I've been tasked with employing the correct equation at the correct opportunity in order to problem solve and produce reliable and comparable results. I have also become far more accustomed to comparing appropriate data and drawing conclusions from these comparisons to provide appropriate reasons for contrasting integers. All these things I have learnt during these investigations have provided me with a greater background knowledge in DC and LC transients and producing and simulating circuits in MultiSim, in addition to broadcasting these results and findings in this technical report.

If I was to repeat these investigations, I would conduct practicals for task 3 and task 4 to gather a third data set to enhance the comparisons for the final two tasks. This would allow us to establish which data sets are the most reliable and having a third set of results to compare would allow for more in-depth conclusions to be drawn, alongside making these investigations more insightful into transients as practicals bring more real-life factors into play to use during comparisons. I would also introduce the final part of task 4, where the time it took for the current to fall to a chosen value was calculated and measured, to the other three tasks. I think this is an interesting measure and it would be very intriguing to see how the other two RC circuits would contrast to the LC circuit of task 4.

Appendices

Charge		
Time (s)	Voltage (V)	Current (mA)
10	1.04	0.84
20	1.89	0.7
30	2.55	0.59
40	3.13	0.49
50	3.61	0.41
60	4.08	0.35
70	4.34	0.29
80	4.62	0.24
90	4.86	0.21
100	5.05	0.17
110	5.22	0.15
120	5.35	0.12
130	5.47	0.1
140	5.56	0.09
150	5.65	0.07
160	5.72	0.06
170	5.77	0.05
180	5.82	0.04
190	5.87	0.04
200	5.9	0.03
210	5.93	0.03
220	5.95	0.02
230	5.98	0.02
240	5.99	0.02
250	6.01	0.01
260	6.02	0.01
270	6.03	0.01
280	6.04	0.01
290	6.05	0.01
300	6.06	0.01

Figure 27 - Table showing the voltage and current values at every time point while the capacitor is charging

Discharge		
Time (s)	Voltage (V)	Current (mA)
10	5.07	-0.84
20	4.24	-0.7
30	3.56	-0.59
40	2.98	-0.49
50	2.48	-0.41
60	2.1	-0.34
70	1.76	-0.29
80	1.48	-0.24
90	1.24	-0.2
100	1.04	-0.17
110	0.87	-0.14
120	0.74	-0.12
130	0.62	-0.1
140	0.53	-0.08
150	0.44	-0.07
160	0.37	-0.06
170	0.31	-0.05
180	0.26	-0.04
190	0.22	-0.03
200	0.19	-0.03
210	0.16	-0.02
220	0.14	-0.02
230	0.12	-0.02
240	0.1	-0.01
250	0.08	-0.01
260	0.07	-0.01
270	0.06	-0.01
280	0.05	0
290	0.04	0
300	0.04	0

Figure 28 - Table showing the voltage and current values at every time point while the capacitor is discharging

FINAL GRADE

GENERAL COMMENTS

Instructor

68/100

PAGE 1

PAGE 2

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PAGE 4



Comment 1

Use third person



Comment 2

Good start

PAGE 5



Comment 3

third person



Comment 4

Essential theory, well done, perhaps you could go deeper and relate to equations

PAGE 6



Comment 5

label the image

PAGE 7

PAGE 8

PAGE 9

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Comment 6

Excellent presentation

PAGE 12

PAGE 13

PAGE 14

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Comment 7

Good explanation

PAGE 17

PAGE 18



Comment 8

Excellent work, straight to the point and accurate, well done

PAGE 19

PAGE 20

PAGE 21



Comment 9

where did this value come from?

PAGE 22



Comment 10

This mistake requires investigation, I think you have used incorrect values for the time constant

PAGE 23

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PAGE 27



Comment 11

Good work here

PAGE 28



Comment 12

poor quality, avoid images, type the equations



Comment 13

decay?

PAGE 29



Comment 14

rather direction

PAGE 30

PAGE 31



Comment 15

expand



Comment 16

error has occurred, you should pick this up with such a discrepancy

PAGE 32



Comment 17

leave out



Comment 18

what is the difficulty with this?

PAGE 33

PAGE 34

PAGE 35

GRADING FORM: NEW CSG-RUBRIC

TOMOS WILLIAMS

68

1. ENGAGEMENT WITH LITERATURE



NA

0

2. KNOWLEDGE AND UNDERSTANDING



Competent knowledge shown in the report save one error which should have come to light. Theme is introduced and explained well, results are mostly good.

17

3. COGNITIVE AND INTELLECTUAL



Testing has been applied well and lead to sound evaluations, save the task 3 error, see comments. Conclussions and recommendations could be expanded in more depth.

20

4. PRACTICAL APPLICATION



Very good application of skills in testing and the quality of the results presentation is excellent, a shame you did not spot your mistake.

17

5. TRANSFERABLE SKILLS



Very fluent report, which explains essential detail in a concise way, it shows good overall skills and understanding.

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