LUMS
A Not-for-Profit University

Department of Electrical Engineering
School of Science and Engineering

EE240 Circuits I - Fall 2021

ASSIGNMENT 1

Due Date: 23:55, Monday, September 27, 2021 (Submit online on LMS)
Format: 9 problems, for a total of 100 marks

Instructions:

- Solve the assignment on blank A4 sheets and either scan the document using a scanner or use CamScanner proficiently.
- Upload the solved assignment on LMS in the "Assignments" tab under Assignment 1.
- Naming convention should be as follows: "Name_RollNumber_Assignment_1.pdf"
- Feel free to contact the instructor or the teaching assistants if you have any concerns.

- You represent the most competent individuals in the country, do not let plagiarism come in between your learning. In case any instance of plagiarism is detected, the disciplinary case will be dealt with according to the university's rules and regulations.

Course Learning Outcomes Covered:

Derive and apply working principle of passive components R, L,C and independent and controlled energy sources for device and circuit modeling and analysis

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Problem 1 (12 marks)

Overview: Potential Divider Circuit

EE-240 requires you to implement a potential divider circuit to power a model of an amusement park. You are given the following components:

- 1 x 210 V Battery
- 6 x Loads (Each representing a different ride)
- 3 x 90 Ω Resistor
- 2 x 20 Ω Resistor
- 2 x 15 Ω Resistor
- 10 x 10 Ω Resistor
- 2 x 6 Ω Resistor
- 3 x 3 Ω Resistor
- 1 x 4 Ω Resistor

The following are the voltage requirements of each ride:

- L1: 10V
- L2: 20V
- L3: 30V
- L4: 40V
- L5: 50V
- L6: 60V

(a) [**6 marks**] Construct a model of the amusement park, which is essentially a voltage divider circuit, fulfilling the requirements of each ride.

(b) [**3 marks**] One of the rides was considered too fast for the children, so the authorities decided to slow it down. L4 now has a voltage requirement of 30 V. Make changes to the previous circuit to adjust this change in voltage. You cannot use additional components other than the ones provided to you.

(c) [**3 marks**] To reduce the voltage supplied to a ride, I decide to change the resistance across that specific ride.

i Should I increase or decrease the resistance?

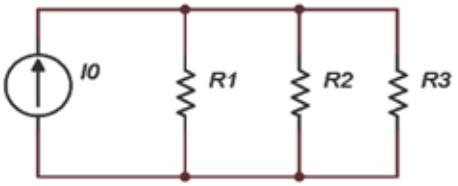
ii Would changing the resistance be the right choice? Why, explain your answer?

iii If there was just 1 ride in the entire model, what other change could be made to reduce the voltage supplied to that ride?

Problem 2 (10 marks)

Overview: Current Divider Circuit

For the following current divider circuit, let i_1, i_2, i_3 be the current passing through R_1,R_2,R_3. Similarly let V_1, V_2, V_3 be the voltages across R_1,R_2,R_3.



(a) [**4 marks**] Express i_1, i_2, i_3 in terms of R_1,R_2,R_3 and V_1, V_2, V_3. Hence express I_0 in terms of R_1,R_2,R_3 and V_1, V_2, V_3? State the relationship between V_1, V_2, V_3.

(b) [**5 marks**] Assume that each resistor R_1,R_2,R_3 represents an LED (R_1: Red, R_2: Blue, R_3: Green). The three of them contribute to 1 light source. The more the current that passes through the LED, the brighter it glows. It works in the following way:

- If an LED glows brighter than the other two, then the resulting color is the color of that LED.
- If two LEDs glow with the same intensity, **and** are brighter than the third one, then the resulting color is a combination of the two LEDs. *(Hint: This is where you mix primary colors.)*
- If all three LEDs glow with the same intensity, then the resulting color is White.

What colors can you possibly see in each of the following cases? If there are multiple outcomes, indicate all of them.

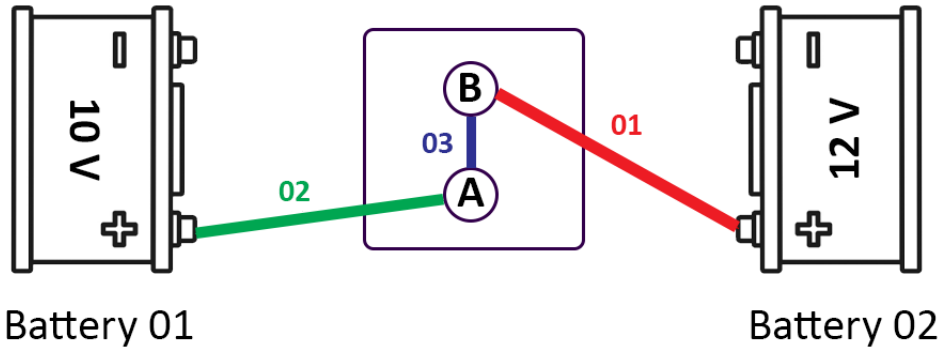
i $R3 < R2 < R1$
ii $R2 = R3$, $R2 < R1$
iii $R2 = R3$, $R3 > R1$
iv $R2 = R3$, $R2 > R1$
v $R2 = R3 = R1$

(c) [**1 mark**] What can you notice about the answers for part (b)(iii) and (iv)? Provide a brief explanation.

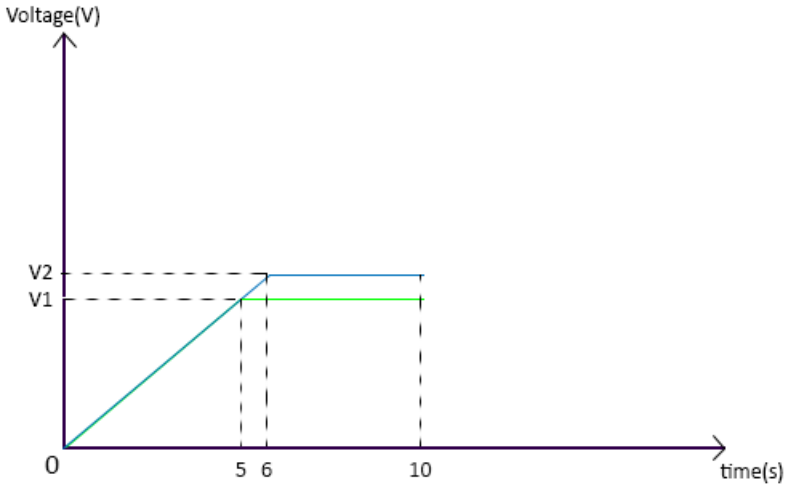
Problem 3 (7 marks)

Overview: Passive Sign Induction

The following is a setup of two batteries connected to 2 terminals, A and B, which were initially at zero potential. Assume that the negative terminals of the batteries are at the same potential (ground).



The graph below represents the voltage at terminals A and B at different times.



(a) **[2 marks]** One of the three connections, labelled **1 2 and 3** in the above diagram, was not made for the first 10 seconds. Identify the connection and give a valid reason for your answer.

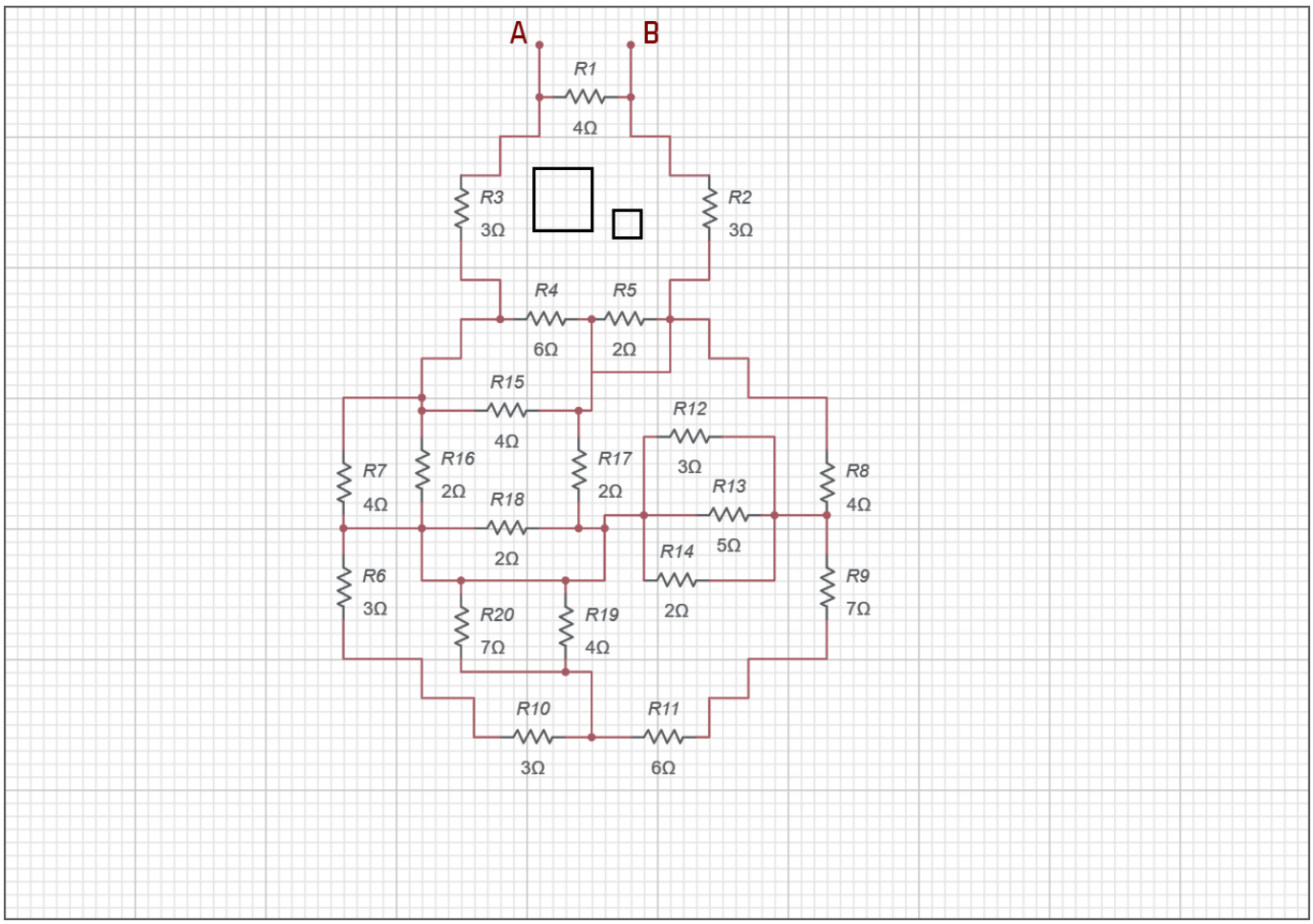
(b) **[1 mark]** For the other 2 connections, state the direction of the current.

(c) **[1 mark]** State V_1 and V_2, and mention which of them relates to which terminal.

(d) **[3 marks]** At t=*10s*, the existing 2 connections were removed and the one mentioned in part(a) was made. Continue sketching the graph for $t \geq 10s$. Explain your graph and state the direction of the current in this connection as well.

Problem 4 (10 marks)

Overview: Equivalent Resistance



(a) [**8 marks**] The above BB8-droid contains an encrypted message. You must decode the message by finding the equivalent resistance, R_{eq}, between its two antennas, A and B. Show all your working.

(b) [**2 marks**] What would R_{eq} be if R_1 is replaced with a simple wire? Show all your working.

Problem 5 (6 marks)

Overview: Energy and Power

(a) **[2 marks]** Given that

$$\frac{dq}{dW} = (150e^{34t} + 486 + 540e^{17t})^{-1}$$

$$\frac{dq}{dt} = (5e^{17t} + 9)^{-1}$$

Find the expression for power, p(t).

(b) **[2 marks]** Let the expression calculated in part(a) be denoted by $p(t)$.

$$P(t) = \begin{cases} 0 & t < 0 \\ p(t) & t \geq 0 \end{cases}$$

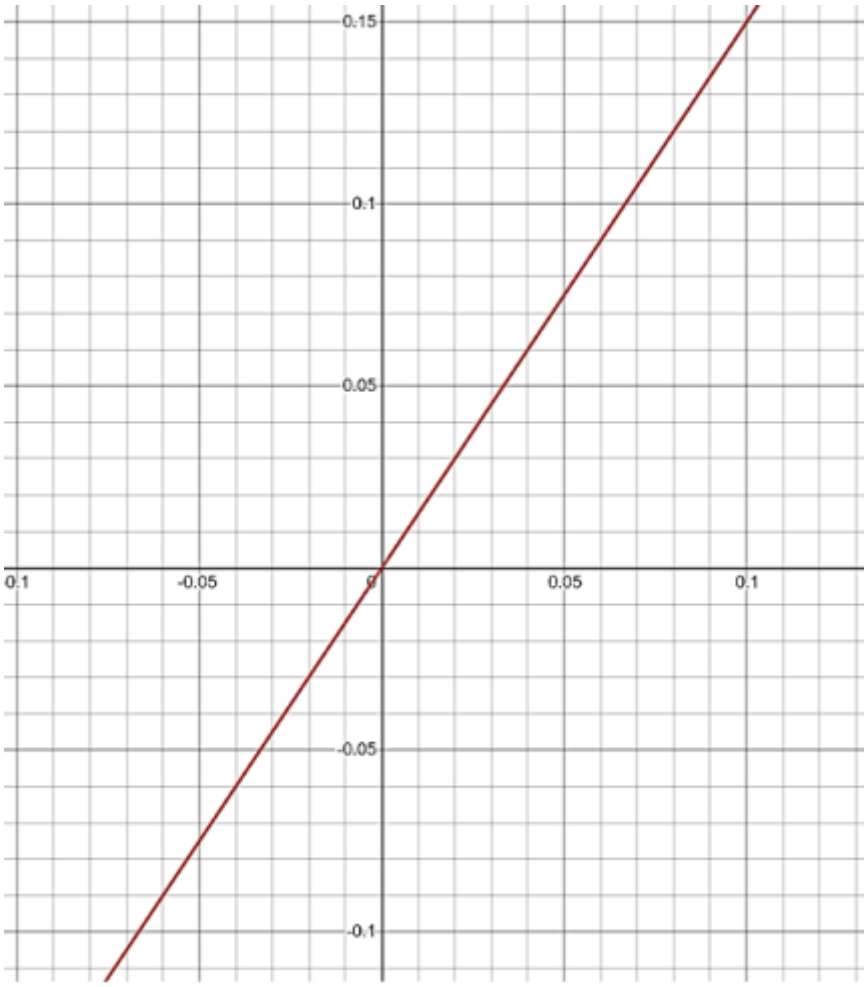
For $P(t)$, find the expression for Energy, w(t).

(c) **[2 marks]** Plot both power and energy against time and describe the relationship between the two graphs.

Problem 6 (8 marks)

Overview: Capacitor Parameter

The following is a graph of a parallel plate capacitor (charge vs potential difference).



(a) [**1 mark**] State the capacitance for the given capacitor?

(b) [**2 marks**] Using the value of the capacitance, find the ratio between the cross-sectional surface area of the plates and the perpendicular distance between the plates? What can you interpret from this value?

(c) [**2 marks**] Is it possible for the graph to not pass through the origin? Explain your answer.

(d) [**3 marks**] Given

- d: perpendicular distance between parallel plates
- A: cross-sectional surface area of the plates
- V: potential difference across a capacitor's plates
- q: charge stored in a capacitor
- E: potential energy within a capacitor

If d is increased by twice its value, and E does not change, then what is the effect on:

i A?

ii V?

iii q?

Problem 7 (17 marks)

Overview: Inductor Parameter

A student decides to make a solenoid by wrapping a piece of wire around a battery cell of length 4.25 cm and diameter 1.0 cm. The magnetic field density is 1.15T, and the current flowing through the solenoid is 3.2 mA.

(a) [**6 marks**] Find the inductance L of the solenoid?

(b) [**4 marks**] Find the thickness t and the cross-sectional area A of the wire?

(c) [**4 marks**] Suppose you must carry out the same experiment, but you don't have a wire of the exact same thickness available. You have one that is thicker and another that is thinner than the one the student used. (Assume the rest of the equipment is the same)

- i State which wire you would use.
- ii Would there be a change in the number density? Use equations to explain your answer.
- iii Will this cause a greater or smaller change in flux? Keeping your choice of wire in mind, what conclusion can you draw?

(d) [**2 marks**] Suppose you carry out the same experiment, but this time with a battery of diameter 2.0 cm. (Assume the rest of the equipment is the same)

- i Do you think this will cause a greater or smaller change in flux? Explain your answer.
- ii What generalized conclusion can you draw?

(e) [**1 mark**] Name the two quantities in which inductors do not allow instantaneous change.

Problem 8 (17 marks)

Overview: Voltage and Current Relationship for Capacitor

Below are two circuits. At time $t = 0$, the switch S1 is closed.

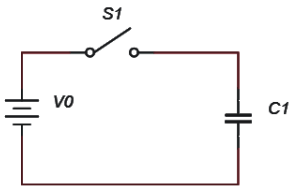


Figure (a)

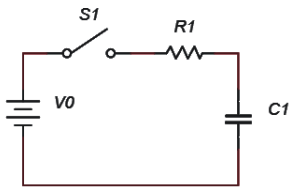


Figure (b)

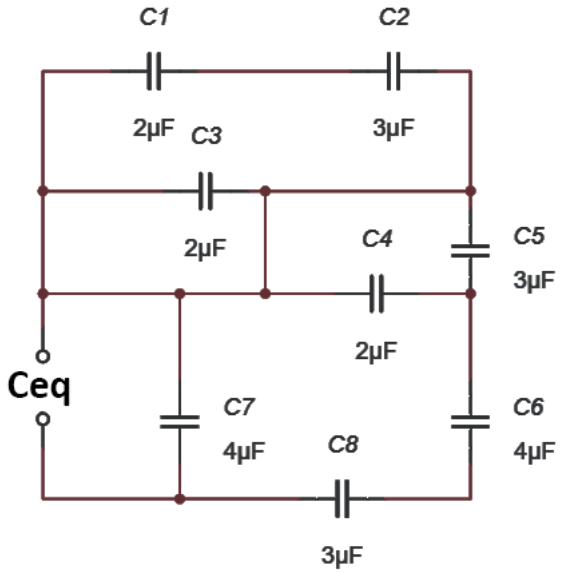
(a) **[4 marks]** Sketch the graphs for $V_c(t)$ (voltage across capacitor) against time for both the circuits. Briefly explain the shape of each graph.

(b) **[7 marks]** Find the expression for $V_c(t)$ if the following current is flowing through the capacitor of capacitance 0.5F.

$$i(t) = \begin{cases} 3t & 0 \leq t < 6 \\ 18 & 6 \leq t < 10 \\ -12 & 10 \leq t < 15 \\ 0 & t \geq 15 \end{cases}$$

(c) **[2 marks]** Is the expression $i(t)$ given in (b) is for the circuit given in Figure(a) or Figure(b)? Explain your answer.

(d) **[4 marks]** For the following circuit, find C_{eq}.



Problem 9 (13 marks)

Overview: Voltage and Current Relationship for Inductor

(a) **[6 marks]** Determine and sketch the current $i(t)$ through a 200mH inductor if the voltage across inductor is given by:

$$v(t) = \begin{cases} (1-2t)e^{-2t}mV & t \geq 0 \\ 0mV & t < 0 \end{cases}$$

(b) **[3 marks]** An inductor when connected directly to a *specific kind of source* causes instantaneous change in *either voltage or current* due to the infinite presence of another *voltage or current*.

i Rewrite the statement while choosing the correct quantities and the source.

ii Can this statement be true in practice? Give reasoning to support your answer.

(c) **[4 marks]** Find L_{eq}.