LUMS
A Not-for-Profit University

Department of Electrical Engineering
School of Science and Engineering

EE240 Circuits I - Fall 2020

ASSIGNMENT 1

Due Date: 23:55, Friday. October 02, 2020 (Submit online on LMS)
Format: 7 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 [8 marks]: Potential Divider and Current Divider

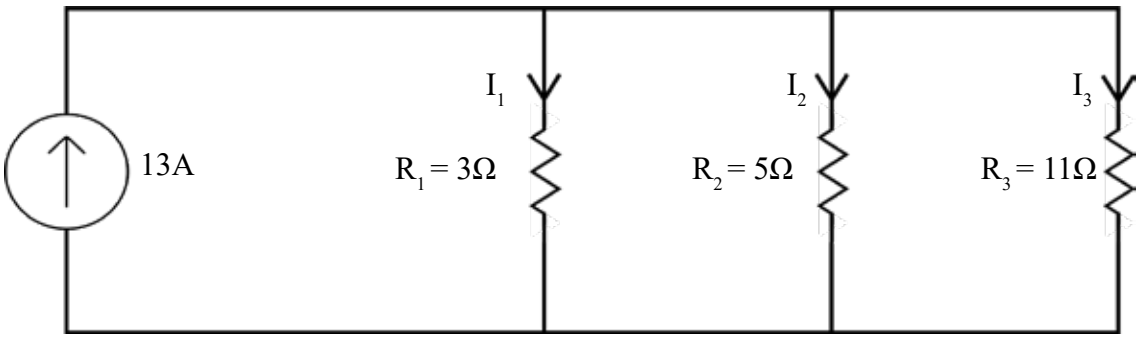
You have been provided with a 12V battery using which you intend to power your RGB Strip Lights which have been rated for 5V only. The lights will be modeled by R_L= 17 KΩ.

(a) **[2 marks]** By using two resistors(R_1 and R_2) construct a potential divider circuit. Connect R_L parallel to R_2. Draw the complete circuit and specify the values for R_1 and R_2 for which the lights get 5V volts across their terminals.

(b) **[1 mark]** Find the power dissipated by the lights.

(c) **[2 marks]** When the lights are disconnected, what is the voltage across R_2? What conclusion can you draw from adding resistance in parallel?

(d) **[3 marks]** Using the given circuit, find current through all three resistors i.e. I_1, I_2 & I_3.



Problem 2 [5 marks]: Energy and Power

For a given circuit element for $t \geq 0$:

$$\frac{dw}{dq} = 50e^{-1600t} - 50e^{-400t}$$

$$\frac{dq}{dt} = 5e^{-1600t} - 5e^{-400t}$$

(a) **[2 marks]** Find the expression for power for the element and discuss how you used these expressions.

(Hint: use dimensional analysis)

(b) **[1 mark]** Find the power at t = 625μs.

(c) **[2 marks]** Find the total energy supplied to the element.

Problem 3 [12 marks]: Capacitance Parameter

A parallel plate capacitor in a flash camera is able to store 32J for 300V.

(a) **[7 marks]**

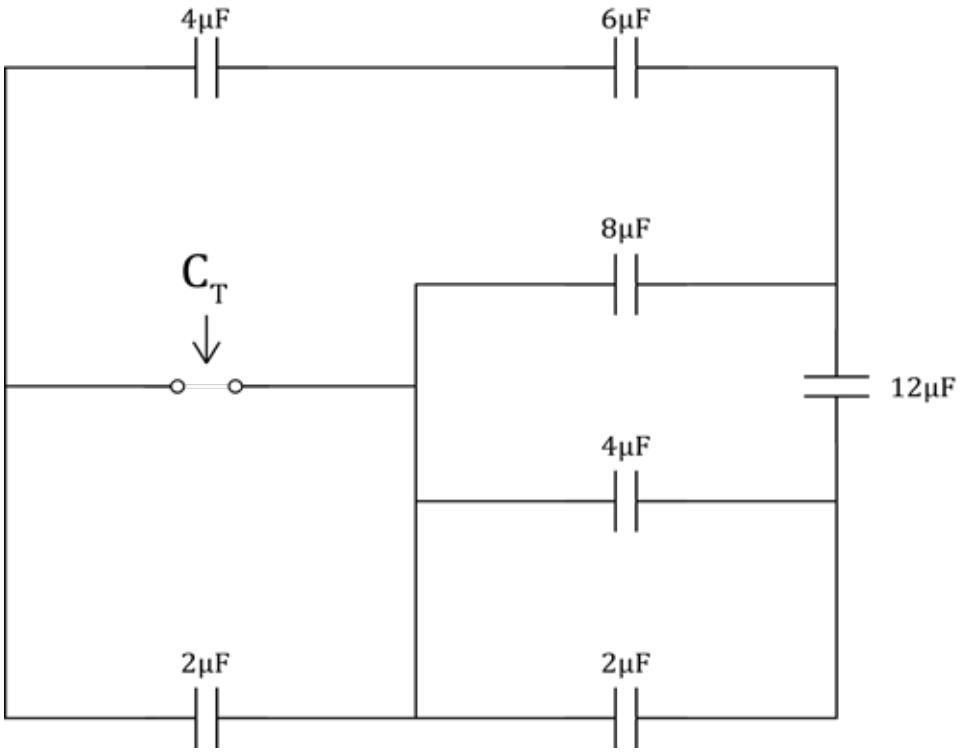
(i) **[2 marks]** What is the capacitance of the capacitor?

(ii) **[1 mark]** Suppose that the distance between the two capacitor plates is d = 0.5cm, find the area of the plates.

(iii) **[2 marks]** The distance between the two plates is now decreased to half of d, keeping the plates at the same potential, what is the change in the capacitance? What about when the area is halved keeping the distance and potential constant?

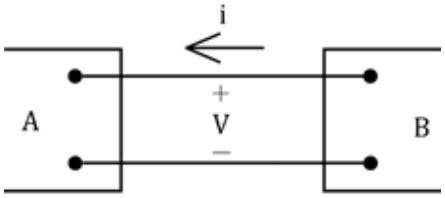
(iv) **[2 marks]** What is the amount of the current that needs to be discharged in both cases mentioned in (iii)?

(b) **[5 marks]** Find the capacitance C_T shown in the network below.



Problem 4 [20 marks]: Passive Sign Convention and Inductors

The dead battery of a car can be charged using a functional battery of another car. The positive terminals of the batteries are connected as are the negative terminals. For the purpose of this course, the two cars can be imagined as boxes, each representing cars A and B as shown in the figure. Assume that the current i is 10A and the batteries are 12V each.



(a) **[3 marks]** Which battery was initially dead?

(b) **[2 marks]** If the batteries are connected for 6 minutes, how much energy is transferred to the dead battery?

Fascinated by the developments in wireless charging that essentially uses two coils (one in the transmitter and one in the receiver) to transmit power over a distance, you and your project partner decide to develop a toy model for charging cars wirelessly using your knowledge of inductors.

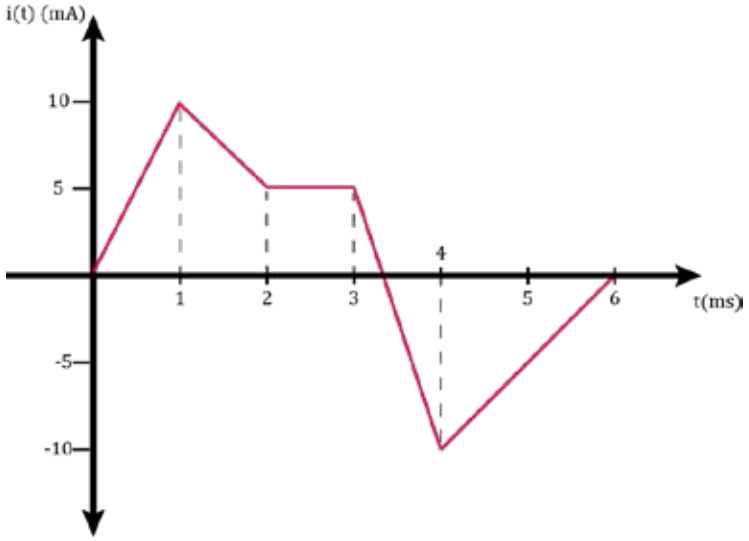
(c) **[4 marks]** You decide to experiment with a 25 mH inductor, suppose that the current through your inductor is given by the following expression:

$$i(t) = \begin{cases} 0, & t < 0 \\ 10(1 - e^{-t})mA, & t \geq 0 \end{cases}$$

(i) **[2 marks]** Find the voltage across the inductor.

(ii) **[2 marks]** The expression for the energy stored in it.

(d) **[11 marks]** After several trials, you decide to use a 0.25H inductor for the transmitter and 0.5H inductor for the receiver. Once the experiment is set up and set running, the waveform due to power transfer from one coil to the other for the current across the receiver inductor is obtained as shown in the figure:



(i) **[5 marks]** Accurately sketch the inductor voltage versus time.

(ii) **[2 marks]** Determine the energy stored in the inductor at t = 1.7s and t = 4.2s.

(iii) **[4 marks]** Determine the power absorbed by the inductor at t = 1.2s and t = 2.8s Do you think this is a good model?

Problem 5 [11 marks]: Equivalent Resistance

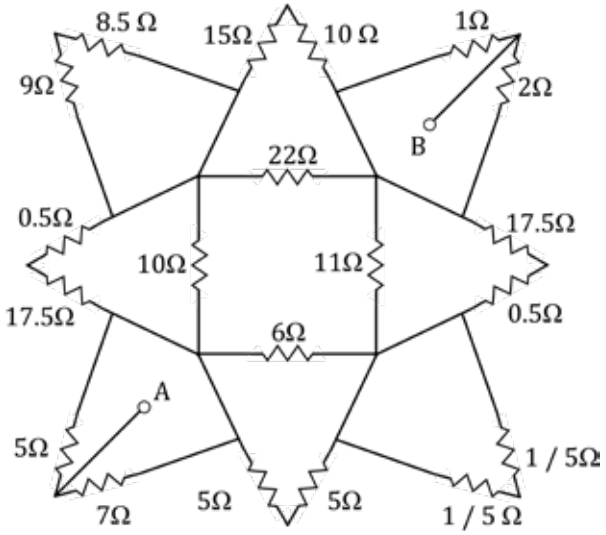
(a) **[6 marks]** In part of your job as a circuit designer, you have been asked to design a configuration of resistors with the following constraints:

A-B: 3.5Ω
A-C: 13.2Ω
B-C: 11.7Ω

Note: Values are rounded off to 1 decimal place.

You have been provided with 10, 7, 5 and 2Ω resistor each.

(b) **[5 marks]** In an unfortunate series of events, you are presented with the following circuit to analyze as part of your project. Find R_{eq} between points A and B.



Problem 6 [15 marks]: Inductance Parameter

Inductors have wide applications in electrical circuits. While working on a project you require an inductor with self-inductance 110μH, length 2cm and cross section radius to be 5mm. Eager to experiment, you decide to make a solenoid from the available wires of 50μm, 100μm, 150μm thickness.

(a) **[5 marks]**

(i) **[2 marks]** Specify your choice of wire and number of turns and prove indeed that your inductor meets your criteria.

(ii) **[1 mark]** Using a thinner wire, more loops per unit length can be achieved, however state one affect on the physical parameter of the inductor.

(iii) **[2 marks]** If the area of cross section is halved and the length of solenoid is doubled, what is the new self-inductance of the solenoid.

(b) **[2 marks]** What is the rate of change of flux linking a 1250 turn coil when 24V is applied across it.

(c) **[8 marks]** After successfully making an inductor you set up a parallel RL circuit with a 5A current source and a 10Ω resistor. Sketch appropriate waveforms and provide appropriate descriptions of the following parameters:

(i) **[2 marks]** Current through the inductor

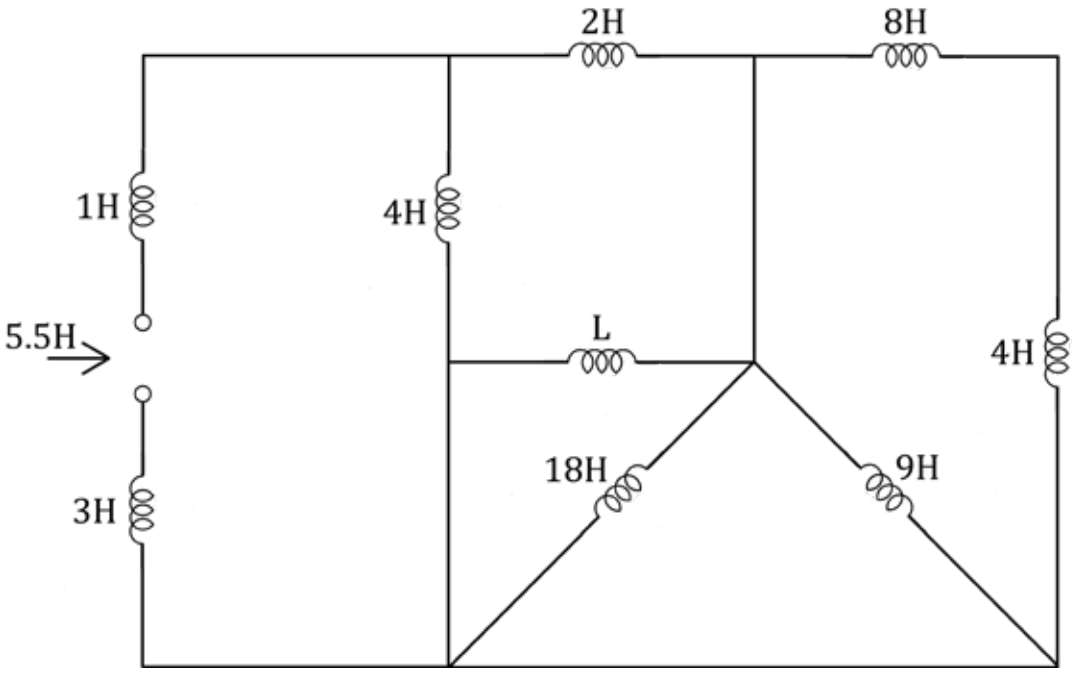
(ii) **[2 marks]** Current through resistor

(iii) **[2 marks]** Voltage through the inductor

(iv) **[2 marks]** Voltage through the resistor

Problem 7 [9 marks]: Equivalent Inductance

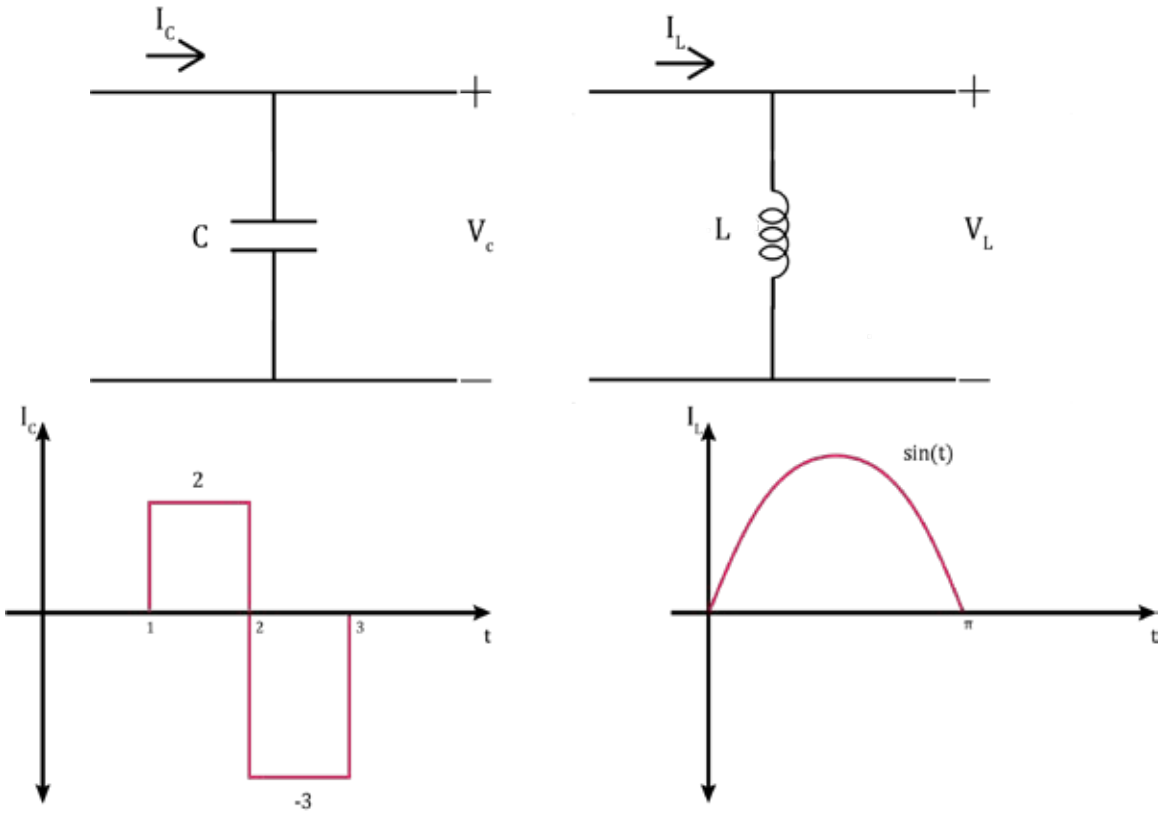
(a) **[5 marks]** If the equivalent inductance of the circuit is 5.5H, find the value of L.



(b) **[4 marks]** Using only 2H inductors, create a network with an equivalent inductance of 1.5H.

Problem 8 [10 marks]: Capacitance and Inductance Parameter

(a) **[4 marks]** For the following two segments of circuits, waveforms of I_C and I_L have been given. Plot the waveforms for V_C and V_L.



(b) **[4 marks]**

(i) **[2 marks]** If the energy stored in the capacitor at t = 2s is 3MJ, find the capacitance.

(ii) **[2 marks]** If the energy stored in the inductor at t = π/2s is 3.5mJ , find the inductance.

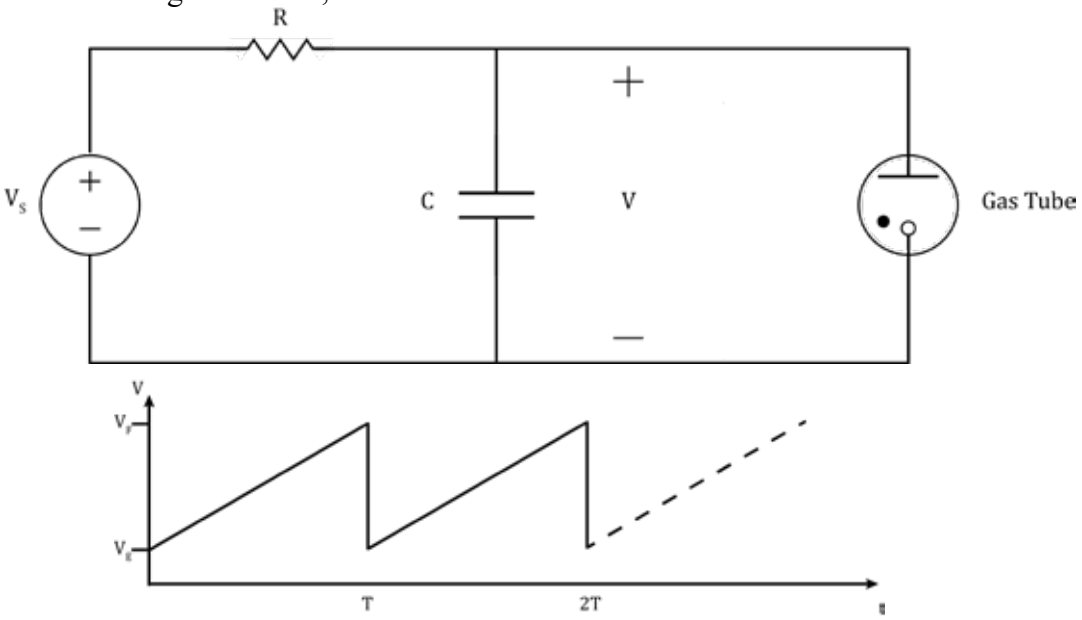
(c) **[2 marks]** Briefly explain using the given expressions below, why a capacitor does not allow an instantaneous change in voltage and an inductor does not allow an instantaneous change in current.

$$V = L\frac{di}{dt} \qquad I = C\frac{dv}{dt}$$

Keeping in mind these properties, suggest which component would be best for use in a circuit in which you need to reduce voltage spikes/ and another in which you need to reduce current surges.

Problem 9 [10 marks]: RC Timer and Oscillator

An important application of capacitors is in RC timers, where at the beginning of the time interval the switch is closed so that the capacitor starts charging and the switch is opened at the end, the corresponding voltage provides a measure of the time. These simple timers can be used to make oscillators that produces a recurring waveform. One such oscillator can be made using a gas tube, that has a high resistance at low voltages (an open circuit) but a low resistance at small voltages (a short circuit). The capacitor charges up to a certain voltage before the gas tube starts conducting and then discharges to a certain voltage before being charged up again. (The details of the model are not important here but you read more on it on page 157 *"Theory and problems of basic circuit analysis"*). A carefully set up oscillator produces the following waveform,

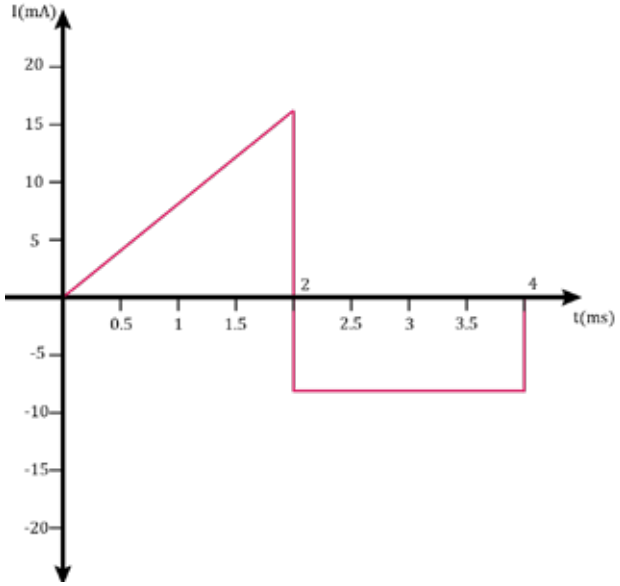


(a) **[4 marks]** Sketch the corresponding wavefunction for the current for the capacitor, assuming V_F= 10V, V_E= 2V, and T = 1s, and C = 1F.

(Hint: The waveform is called sawtooth signal, it is not differentiable at values that are multiples of T, you are encouraged to consult the TAs).

For another setup, the waveform for the current across a capacitor of C = 4μF is shown below.

(b) **[6 marks]** Sketch the corresponding waveform for the voltage.



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