

EE240 – Circuits I  
Mid Examination (Fall 2018)

November 6, 2018

06:00 pm–08:30 pm

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Student ID .....

Name .....

Signature .....

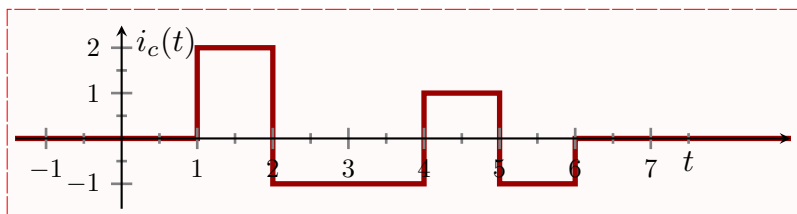
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**INSTRUCTIONS:**

- Do not flip this page over until told to do so.
- **The exam needs to be solved on this book and not on blue book.**
- If you need the blue book for rough work, please ask the exam staff.
- The exam is closed book and notes. You are allowed to bring calculator and one A4 sheet with you with *hand-written* notes on both sides.
- Read all the questions before you start working on the exam.
- You cannot keep your mobile phone(s) with you (even on silent mode or switched off).

## Part 1: Sources and I-V Characteristics of R, L, C

**Problem 1.** (10 pts) The current  $i_c(t)$  through the capacitor of capacitance  $\frac{1}{2}F$  is shown in Figure 1 below.



(a) (1 pts) Express  $i_c(t)$  as piecewise function of time.

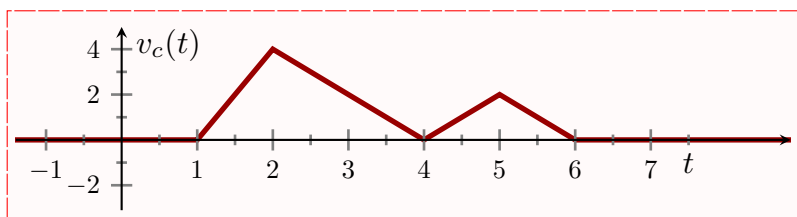
$$i_c(t) = \begin{cases} 0 & t < 1 \\ 2 & 1 \leq t < 2 \\ -1 & 2 \leq t < 4 \\ 1 & 4 \leq t < 5 \\ -1 & 5 \leq t < 6 \\ 0 & 6 \leq \end{cases}$$

(b) (8 pts) Assuming that the voltage is zero for times  $t \leq -1$  seconds, determine the voltage across the capacitor and **plot** for  $0 \leq t \leq 7$  seconds.

Let  $v_c(t)$  be the voltage across capacitor.

$$v_c(t) = \frac{1}{C} \int_{-\infty}^t i_c(t) dt$$

$$v_c(t) = 2 \begin{cases} 0 & t < 1 \\ 2t - 2 & 1 \leq t < 2 \\ -t + 4 & 2 \leq t < 4 \\ t - 4 & 4 \leq t < 5 \\ -t + 6 & 5 \leq t < 6 \\ 0 & 6 \leq \end{cases}$$

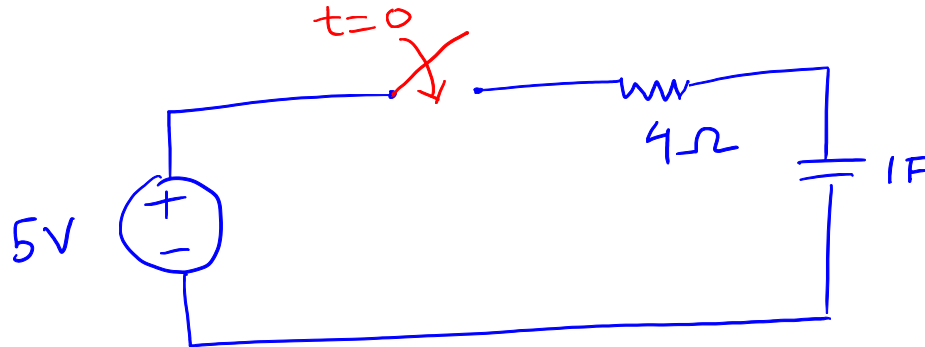


(c) (1 pts) Determine the energy stored in the capacitor at  $t = 3.5$  seconds.

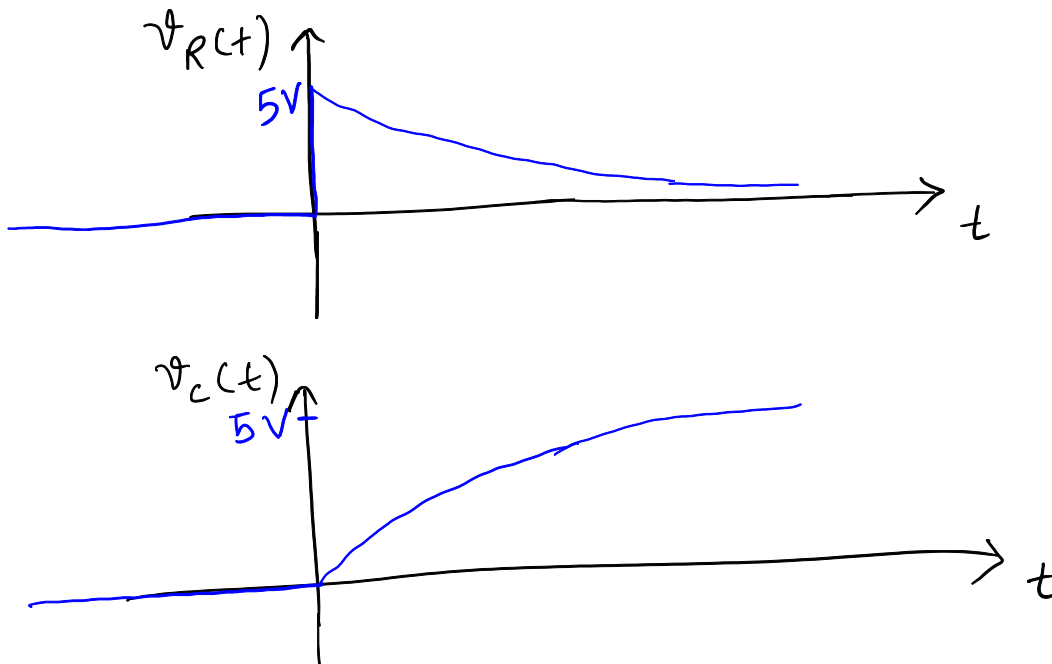
$$w_c(t) = \frac{1}{2}C(v_c(t))^2 \Rightarrow w_c(3.5) = \frac{1}{4}(v_c(3.5))^2 = 0.25J.$$

**Problem 2. (6 pts)** Consider a circuit where the DC voltage source of  $5V$  is connected to a series combination of  $4\ \Omega$  resistor and  $1F$  capacitor through the switch. Assume that the switch is initially open and is closed at  $t = 0$  and the capacitor is uncharged before the switch is closed, that is, the capacitor voltage  $v_c(t) = 0$  for all  $t < 0$ .

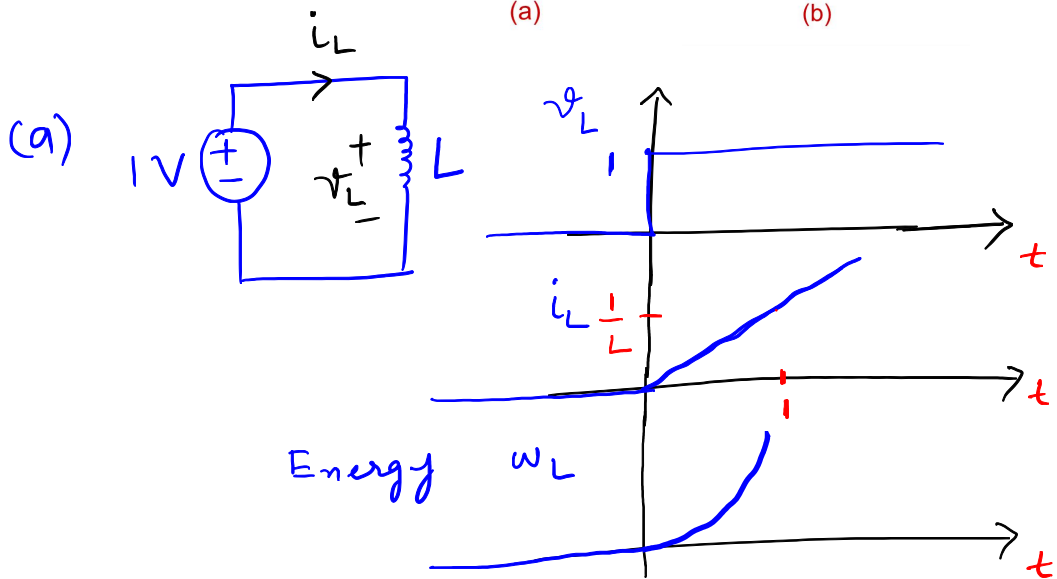
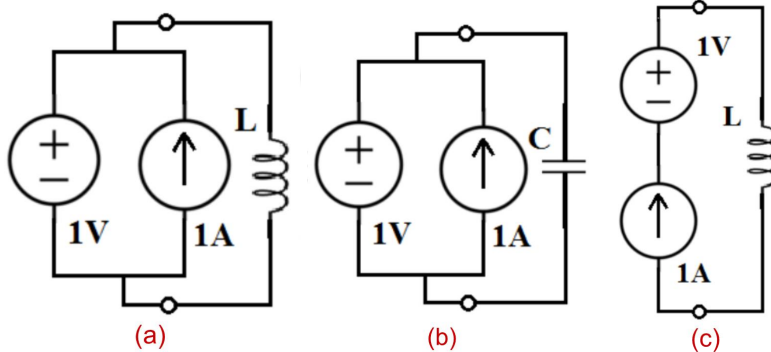
- (a) (1 pts) Draw the circuit and indicate the current  $i(t)$  through the circuit and the voltages  $v_R(t)$  and  $v_C(t)$  across the resistor and the capacitor respectively.



- (b) (5 pts) Plot the waveforms (not to the scale) of the voltages  $v_R(t)$  and  $v_C(t)$ .



**Problem 3. (9 pts)** Consider the following four circuits. Assuming that the sources are switched on at  $t = 0$  and the elements do not carry any current or voltage before the sources are turned-on, draw the voltage, current and energy waveform for  $0 \leq t \leq 1$  seconds for each circuit (element). Total of 9 waveforms.

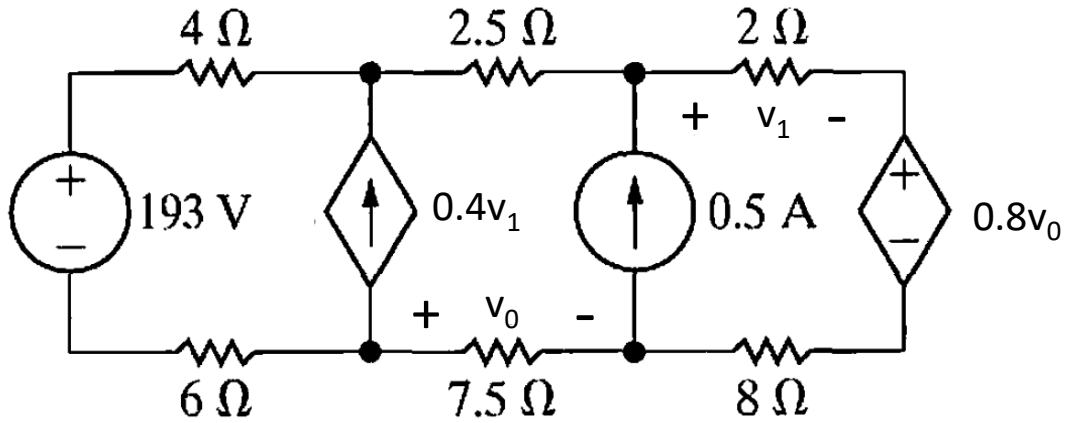


$$i_L = \frac{1}{L} \int_{-\infty}^t v dt$$

## Part 2: Network Topology, Network Equations and Equivalent Circuits

### Problem 4. (20 pts)

Consider the circuit given below.



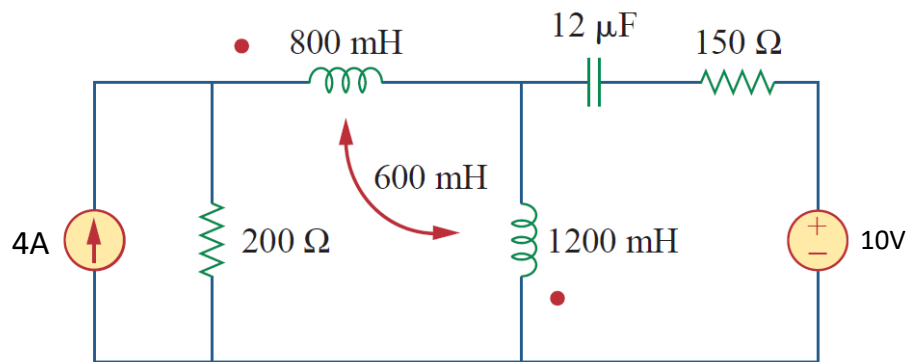
- (a) (5 pts) Draw the graph and one tree of the circuit. Determine the number of nodes and number of branches in a circuit.

- (b) (2 pts) Determine the number of network equations required for carrying out i) nodal analysis and ii) loop analysis.

(c) (**9 pts**) Carry out the loop analysis, that is, identify and determine the loop currents.

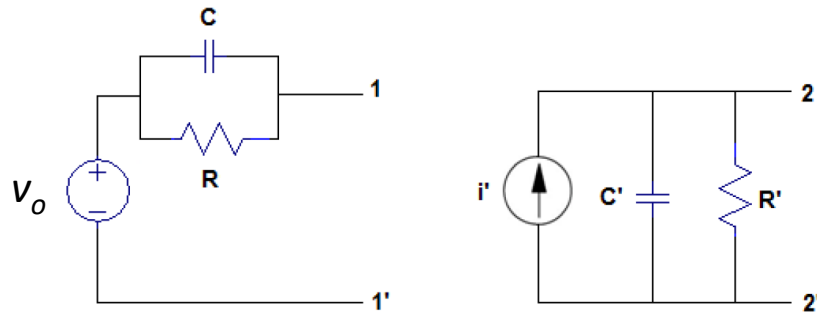
(d) (**4 pts**) Determine the power delivered by the independent current source.

**Problem 5.** (10 pts) Consider the circuit given below.



- (a) (5 pts) Formulate the network equations using loop analysis.
- (b) (4 pts) Find an equivalent circuit where each coupled inductor is replaced with an uncoupled inductor and a controlled source. Draw the equivalent circuit.

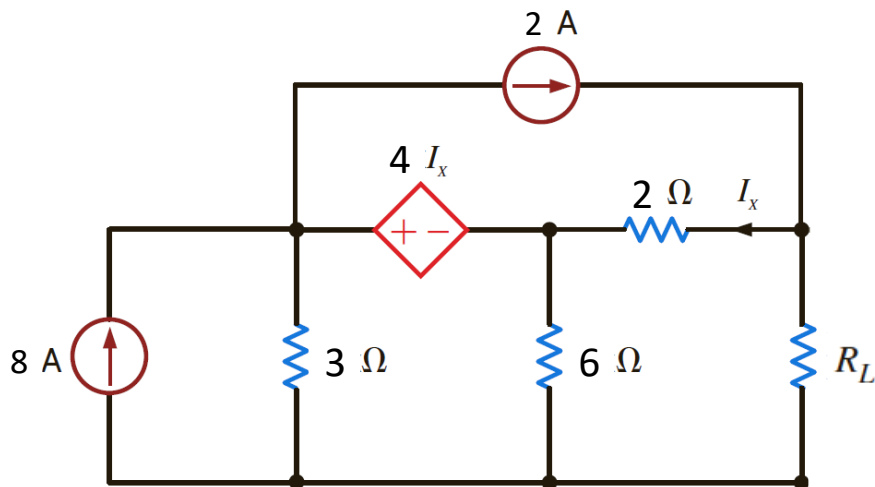
**Problem 6.** (6 pts) Find the values of  $i'$ ,  $R'$  and  $C'$  in terms of  $R$ ,  $C$  and  $v_o$  such that the networks shown below are equivalent at terminals 11 and 22.



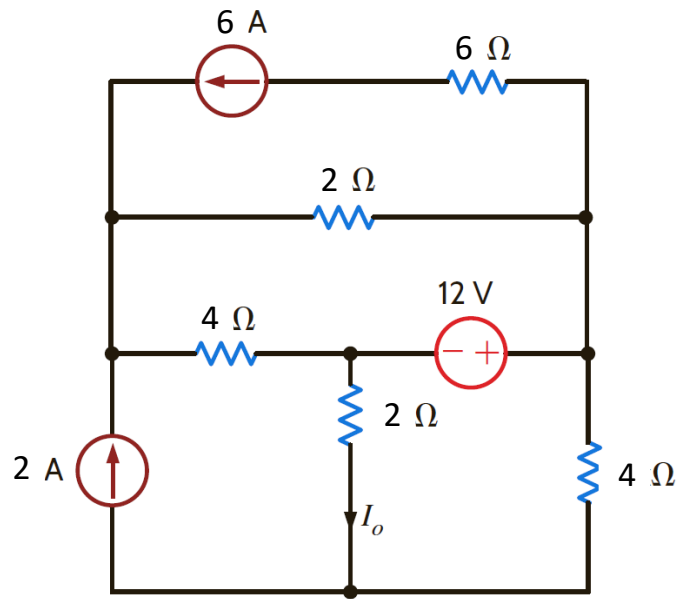


### Part 3: Additional Analysis Techniques

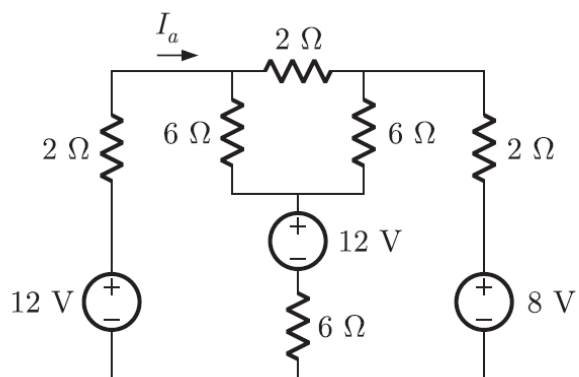
**Problem 7.** (12 pts) For the circuit given below, determine the value of  $R_L$  for maximum power transfer to  $R_L$  using Thevenin's Theorem.



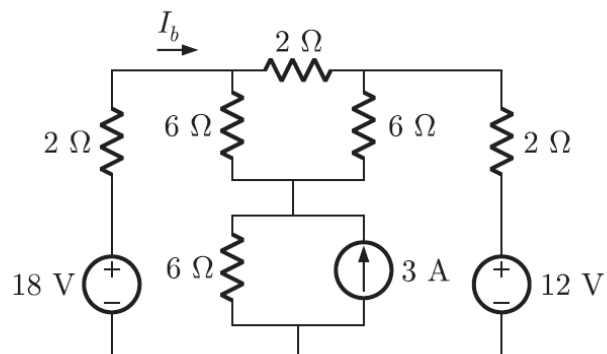
**Problem 8.** (9 pts) Determine  $I_o$  using the superposition theorem (principle) for the circuit given below.



**Problem 9.** (4 pts) Given the following two circuits, determine the relation between  $I_a$  and  $I_b$ . You must provide justification to support your answer. (Hint: Use the concept of linearity.)



(a)



(b)

**Problem 10.** (5 pts) Consider the network shown below, where the rest of the circuit is pure resistive in nature. The voltage  $V_R = 6V$  for  $R = 4\Omega$  and the current  $i_R = 2.4A$  for  $R = 0\Omega$ . Determine the voltage  $V_R$  in volts when  $R = \infty$ .

