Duke University
Edmund T. Pratt, Jr. School of Engineering

ECE 110 Fall 2012
Test I
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Name (please print) SOLUTION

In keeping with the Community Standard, I have neither provided nor received any assistance on this test. I understand if it is later determined that I gave or received assistance, I will be brought before the Undergraduate Conduct Board and, if found responsible for academic dishonesty or academic contempt, fail the class. I also understand that I am not allowed to speak to anyone except the instructor about any aspect of this test until the instructor announces it is allowed. I understand if it is later determined that I did speak to another person about the test before the instructor said it was allowed, I will be brought before the Undergraduate Conduct Board and, if found responsible for academic dishonesty or academic contempt, fail the class.

Signature:

Instructions

First - please turn **off** any cell phones or other annoyance-producing devices. Vibrate mode is not enough - your device needs to be in a mode where it will make no sounds during the course of the test, including the vibrate buzz or those acknowledging receipt of a text or voicemail.

Please be sure to put each problem on its own page or pages - do *not* write answers to more than one problem on any piece of paper and do not use the back of a problem for work on a *different* problem. You will be turning in each of the problems independently. This cover page should be stapled to the front of Problem 1.

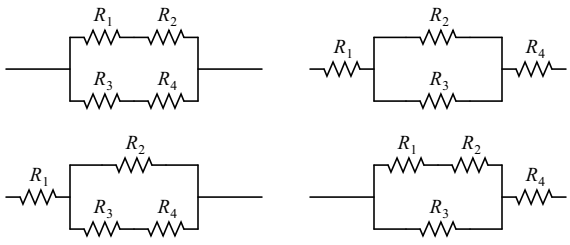
Make sure that your name *and* NET ID are *clearly* written at the top of *every* page, just in case problem parts come loose in the shuffle. Make sure that the work you are submitting for an answer is clearly marked as such. Finally, when turning in the test, individually staple all the work for each problem and place each problem's work in the appropriate folder.

Note that there may be people taking the test after you, so you are not allowed to talk about the test - even to people outside of this class - until I send along the OK. This includes talking about the specific problem types, how long it took you, how hard you thought it was - really anything. Please maintain the integrity of this test.

You may use the $\|$ symbol for resistances in parallel and do not need to expand that construction. Be clear with your use of parentheses, however; simply writing something like

$$R_{\text{eq}} = R_1 + R_2 \parallel R_3 + R_4$$

is too vague since it could refer to any of the four combinations below:



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Problem I: [20 *pts.*] Digital Logic

(a) Given the following logical function:

$$f(A,B,C,D) = \overline{\mathrm{A}}\,\overline{\mathrm{B}}\,\overline{\mathrm{C}}\,\overline{\mathrm{D}} + \mathrm{A}\,\overline{\mathrm{B}}\,\overline{\mathrm{C}}\,\overline{\mathrm{D}} + \overline{\mathrm{A}}\,\overline{\mathrm{B}}\,\overline{\mathrm{C}}\,\mathrm{D} + \overline{\mathrm{A}}\,\mathrm{B}\,\overline{\mathrm{C}}\,\mathrm{D} + \overline{\mathrm{A}}\,\overline{\mathrm{B}}\,\mathrm{C}\,\mathrm{D} + \mathrm{A}\,\mathrm{B}\,\mathrm{C}\,\mathrm{D} + \overline{\mathrm{A}}\,\overline{\mathrm{B}}\,\mathrm{C}\,\overline{\mathrm{D}} + \mathrm{A}\,\overline{\mathrm{B}}\,\mathrm{C}\,\overline{\mathrm{D}}$$

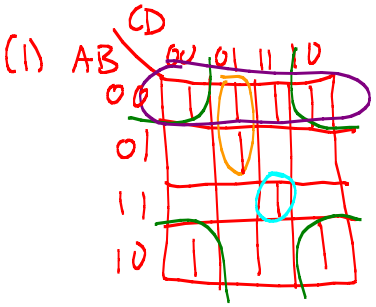
(1) Clearly construct a Karnaugh map for the function. Be sure to label it appropriately and completely.
(2) Determine the Minimum Sum of Products (MSOP) form for the function. Be sure to show your process.
(3) Using standard 2-input logic gates, draw a logic circuit which implements the MSOP form of the expression. Be sure to clearly indicate whether two wires are connected or merely overlapping. Also be sure to draw your gates correctly and neatly!

(b) Given the following logical function:

$$g(P,Q,R) = \overline{\mathrm{P}}\,\overline{\mathrm{Q}}\,\mathrm{R} + \overline{\mathrm{P}}\,\mathrm{Q}\,\mathrm{R} + \mathrm{P}\,\overline{\mathrm{Q}}\,\mathrm{R}$$

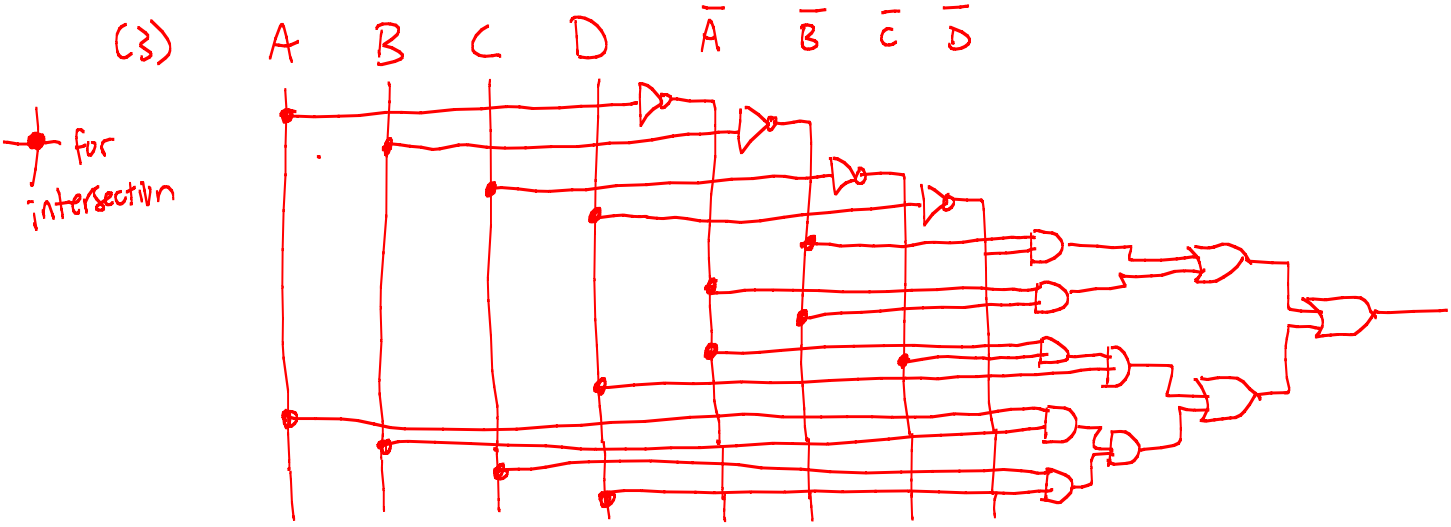
(4) Clearly construct a Karnaugh map for the function. Be sure to label it appropriately and completely.
(5) Determine the Minimum Product of Sums (MPOS) form for the function. Be sure to show your process.

(1)

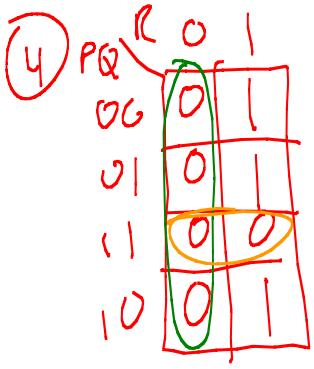


(2) $\overline{B}\,\overline{D} + \overline{A}\,\overline{B} + \overline{A}\,\overline{C}\,D + A\,B\,C\,D$

(3)



(4)



$\bar{g} = \overline{R} + PQ$

$g = \overline{\overline{R} + PQ} = (\overline{\overline{R}})\,(\overline{PQ}) = (R)(\overline{P} + \overline{Q})$

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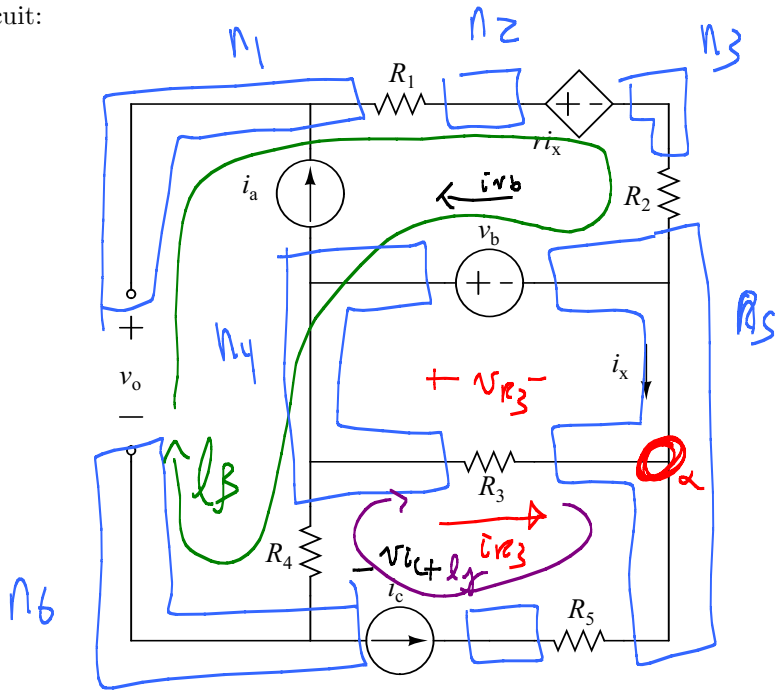
Problem II: [20 *pts.*] The Basics

Given the following circuit:



and assuming that constant r, the values for the passive elements (R_1 through R_5), and the values for the independent sources (i_a, v_b, and i_c) are known, determine expressions for the following values in terms of known values. Note - if you solve for an unknown in terms of known quantities and clearly indicate that expression, you may use it in later calculations without substitution. Put your expressions next to the appropriate bullet below:

- i_x $v_{R_3} = v_b$; KCL$_Q$ = $-i_x - i_{R_3} - i_c = 0$ $i_x = -i_{R_3} - i_c = \frac{-v_b}{R_3} - i_c$
- v_o KVL$_{1B}$: $-v_o + i_a R_1 + r i_x + R_2 i_a - v_b + i_c R_4 = 0$
  $v_o = i_a R_1 + r i_x + R_2 i_a - v_b + i_c R_4$ (i_x)
- p_{abs,R_3} = v_b^2 / R_3
- p_{abs,R_4} = $i_c^2 R_4$
- p_{del,v_b} = $i v_b = i_a - i_x$ so $(i_a - i_x) v_b$
- p_{del,i_c} = KVL$_{1B}$: $-i_c R_1 + v_b - i_c R_5 + v_{i_c} = 0$ $v_{i_c} = i_c R_4 - v_b + i_c R_5$
  $p_{del,i_c} = i_c v_{i_c} = i_c (i_c R_4 - v_b + i_c R_5)$
- $p_{del,CCVS}$ = $-i_a r i_x$

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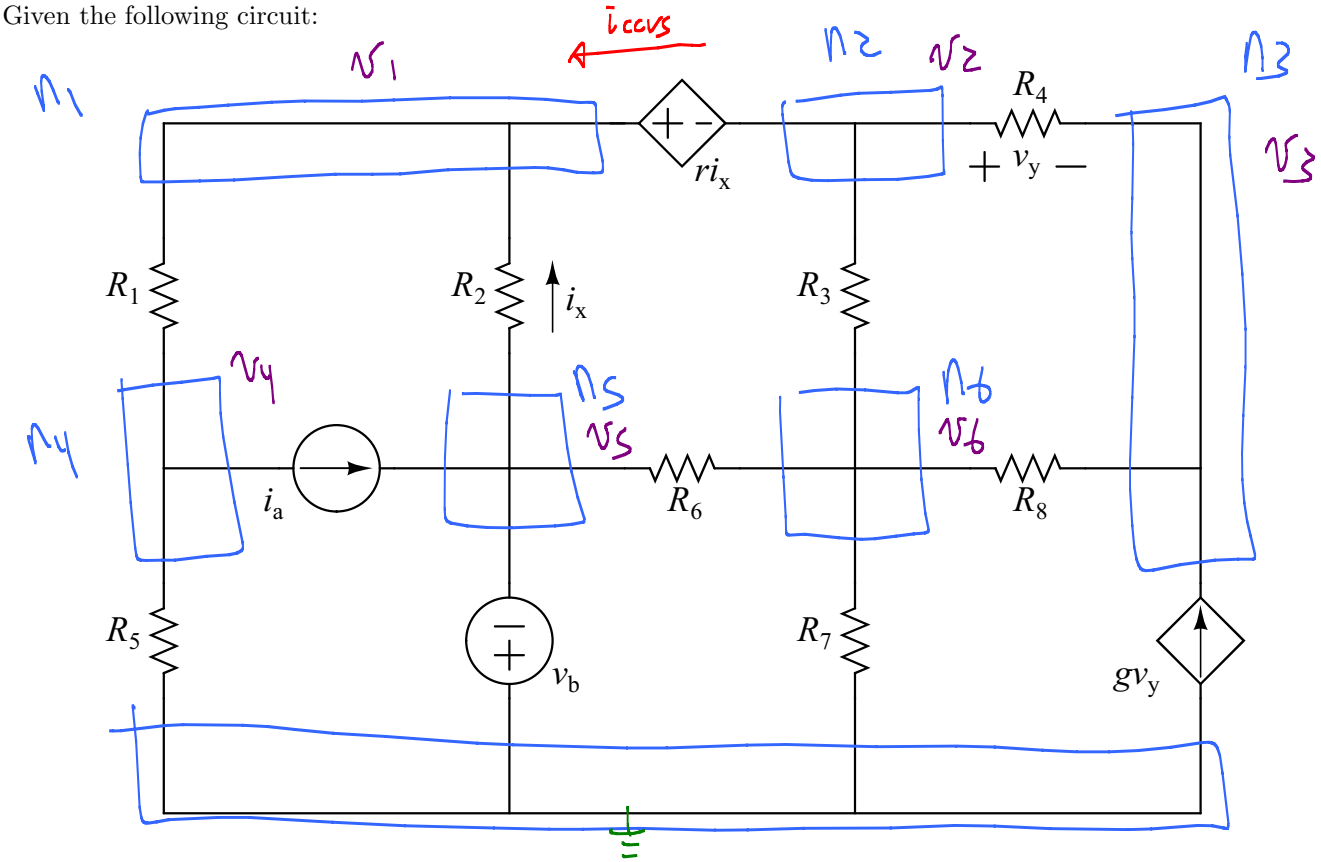
Problem III: [20 *pts.*] Node Voltage Method

Given the following circuit:



and assuming that constants g and r, the values for the passive elements (R_1 through R_8), and the values for the independent sources (i_a and v_b) are known,

(1) *Clearly* demonstrate the use of the Node Voltage Method in labeling unknowns for the circuit and in determining a complete set of linearly independent equations that could be used to solve for these unknowns. List the set of unknowns you believe your equations will find. Please put the list of unknowns and the equations on a separate piece of paper; you can label the circuit above.

(2) Assuming you are able to solve for those unknowns, write expressions for

- $p_{\text{abs},R_3} =$ $(v_2 - v_6)^2 / R_3$

- $p_{\text{del,CCVS}} =$ Get i_{ccvs} from n_1 or n_2

$$i_{ccvs} = \frac{v_1 - v_4}{R_1} + \frac{v_1 - v_5}{R_2}$$

$$\text{or} \quad i_{ccvs} = \frac{v_6 - v_2}{R_3} + \frac{v_3 - v_2}{R_4}$$

$p_{del} = r i_x \, i_{ccvs}$

Using v_1 v_2 v_3 v_4 v_5 v_6 v_y i_x ; Need M NODES − 1 GROUND − #VSRC = # KCL, 2 SOURCE 2 CTRL

KVL, sh12: $\frac{v_1 - v_4}{R_1} + \frac{v_1 - v_5}{R_2} + \frac{v_2 - v_6}{R_3} + \frac{v_2 - v_3}{R_4} = 0$

KVL, n3: $\frac{v_3 - v_2}{R_4} + \frac{v_3 - v_6}{R_8} - g v_y = 0$

KVL, n4: $\frac{v_4 - v_1}{R_4} + i_a + \frac{v_4 - 0}{R_5}$

SRC1: $v_6 = 0 - v_5$

SRC2: $r i_x = v_1 - v_2$

CTRL 1: $v_y = v_2 - v_3$

CTRL 2: $i_x = (v_5 - v_1)/R_2$

KVL, n6: $\frac{v_6 - v_2}{R_3} + \frac{v_6 - v_3}{R_8} + \frac{v_6 - 0}{R_7} + \frac{v_6 - v_5}{R_6} = 0$

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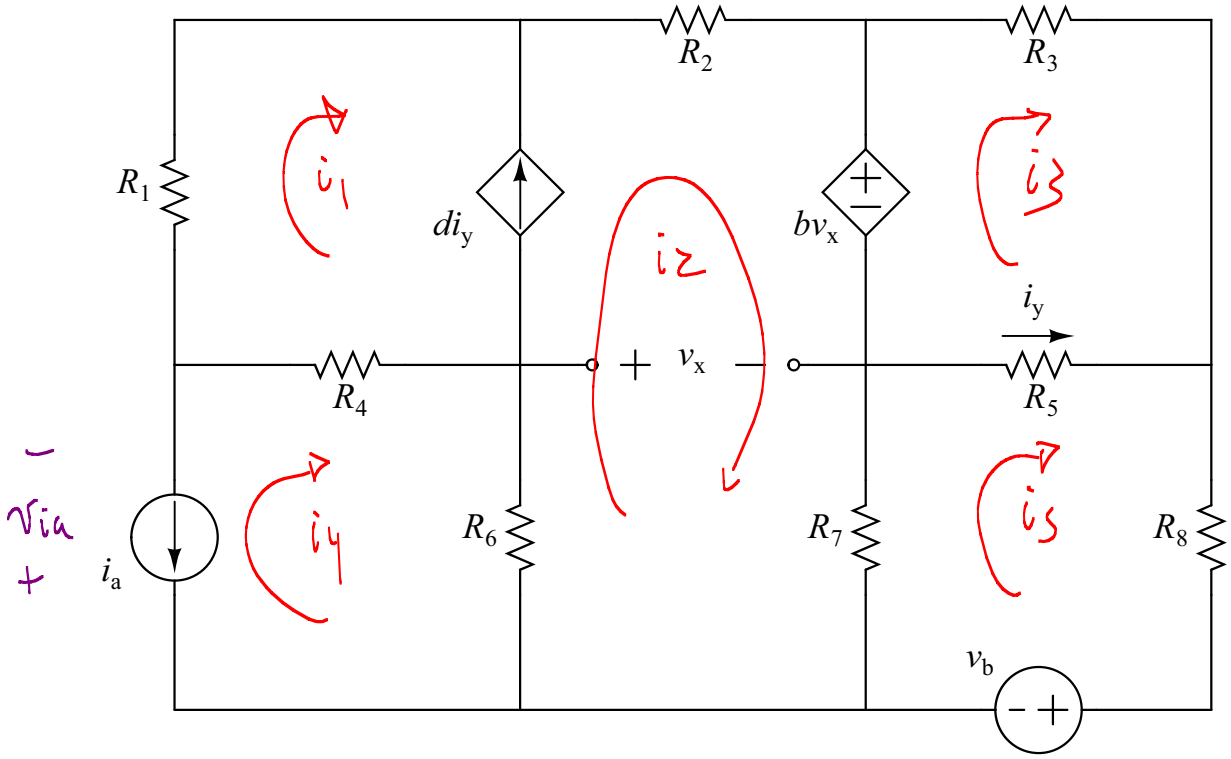
Problem IV: [20 *pts.*] Mesh/Branch Current Method

Given the following circuit:



and assuming that constants b and d, the values for the passive elements (R_1 through R_8), and the values for the independent sources (v_a, i_b) are known,

(1) *Clearly* demonstrate the use of *either* the Mesh or Branch Current Method in labeling unknowns for the circuit and in determining a complete set of linearly independent equations that could be used to solve for these unknowns. List the set of unknowns you believe your equations will find. Please put the list of unknowns and the equations on a separate piece of paper; you can label the circuit above.

(2) Assuming you are able to solve for those unknowns, write an expression for:

- $p_{\text{abs},R_6} =$ $(i_4 - i_2)^2 R_6$
- $p_{\text{del},i_a} =$ use KVL/KCL to get v_{ia}: $v_{ia} + R_4(i_4 - i_1) + R_6(i_4 - i_2) = 0$
  $v_{ia} = R_4(i_1 - i_4) + R_6(i_2 - i_4)$
  $p_{\text{del},i_a} = i_a v_{ia}$

5 Mesh - 2 I src = 3 KVL; 2 src 2 CTRL

KVL, sl 2: $R_1 i_1 + R_2 i_2 + bv_x + R_7(i_2 - i_5) + R_6(i_2 - i_4) + R_4(i_1 - i_4) = 0$

KVL, l3: $-bv_x + R_3 i_3 + R_5(i_3 - i_5) = 0$

KVL, l5: $R_7(i_5 - i_2) + R_5(i_5 - i_3) + R_8 i_5 + v_b = 0$

src1: $i_a = -i_4$ CTRL1 $i_y = i_5 - i_3$

src2: $di_y = i_2 - i_1$ CTRL2: $v_x = R_6(i_4 - i_2) - R_7(i_2 - i_5)$, other answers possible

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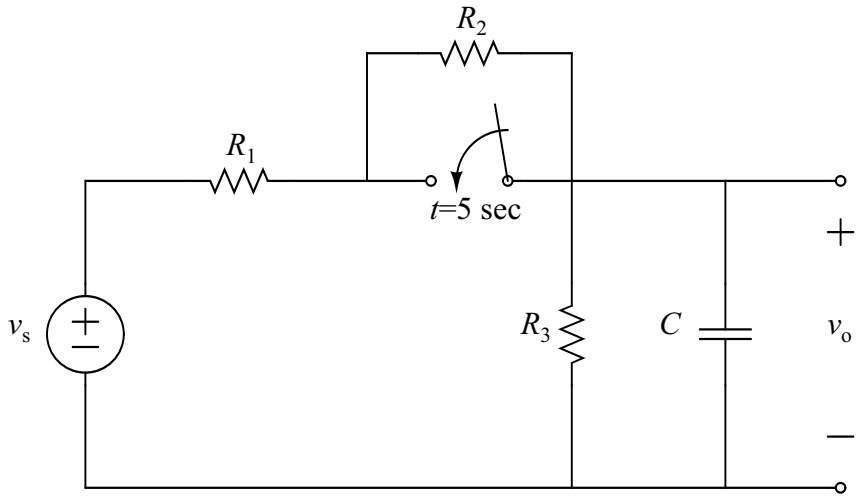
Problem V: [20 *pts.*] RC Circuits and Transients

This problem involves the following circuit:



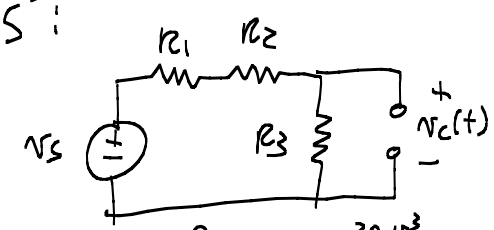
with a switch that is initially open for a very long time before $t = 5$ sec and then closes at $t = 5$ sec and remains closed from that point forward. Assuming that the voltage $v_s(t)$ is a constant 24 V and the values of the reactive elements are

$$R_1 = 10000\ \Omega = 10\ \text{k}\Omega \qquad R_2 = 40000\ \Omega = 40\ \text{k}\Omega \qquad R_3 = 30000\ \Omega = 30\ \text{k}\Omega \qquad C = 0.0002\ \text{F} = 200\ \mu\text{F}$$

Further assume that the circuit has been in place for a very long time prior to time 5 sec.

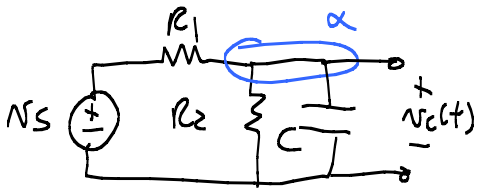
(1) Determine mathematical expressions for the output voltage for all times. Clearly show your work in doing so.
(2) Make an accurate sketch of the output voltage for times $0 \le t \le 10$ sec. Be sure to label your axes and show how you made an accurate sketch.

$t = 5^-$:



V. div. $v_c(t) = \frac{R_3}{R_1+R_2+R_3} v_s = \frac{30\cdot10^3}{80\cdot10^3} \cdot 24 = 9\text{V}$

$t = 5$



$v_c(5^+) = v_c(5^-) = 9\text{V}$

KCL, α: $\frac{v_c - v_s}{R_1} + \frac{v_c}{R_2} + C\frac{dv_c}{dt} = 0$

$C\frac{dv_c}{dt} + \left(\frac{1}{R_1}+\frac{1}{R_3}\right)v_c = \frac{1}{R_1}v_s$

$\frac{R_1R_3C}{R_1+R_3}\frac{dv_c}{dt} + v_c = \frac{R_3}{R_1+R_3}v_s$

$\frac{10\cdot10^3 \cdot 30\cdot10^3 \cdot 200\cdot10^{-6}}{40\cdot10^3}\frac{dv_c}{dt} + v_c = \frac{30\cdot10^3}{40\cdot10^3}\cdot 24$

$\frac{6\cdot10^4}{4\cdot10^4} = 1.5\frac{dv_c}{dt} + v_c = 18$

$\tau = 1.5 \quad x_i = 9\text{V} \quad t_i = 5 \quad x_f = 18$

$v_c(t) = 18 + (9-18)e^{-(t-5)/1.5}$

$= 18 - 9e^{-(t-5)/1.5}$