Duke University

Edmund T. Pratt, Jr. School of Engineering

EGR 224 Spring 2014

Test I

Michael R. Gustafson II

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: Solution

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.

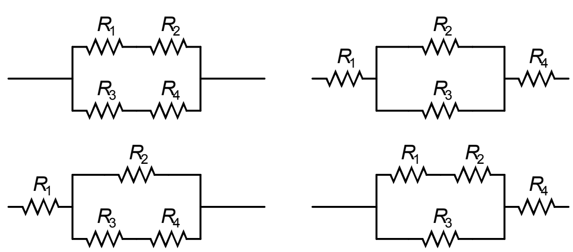
Make sure that your name *and* NET ID are *clearly* written at the top of *every* page, just in case problem parts come loose in the shuffle. Make sure that the work you are submitting for an answer is clearly marked as such. Finally, when turning in the test, individually staple all the work for each 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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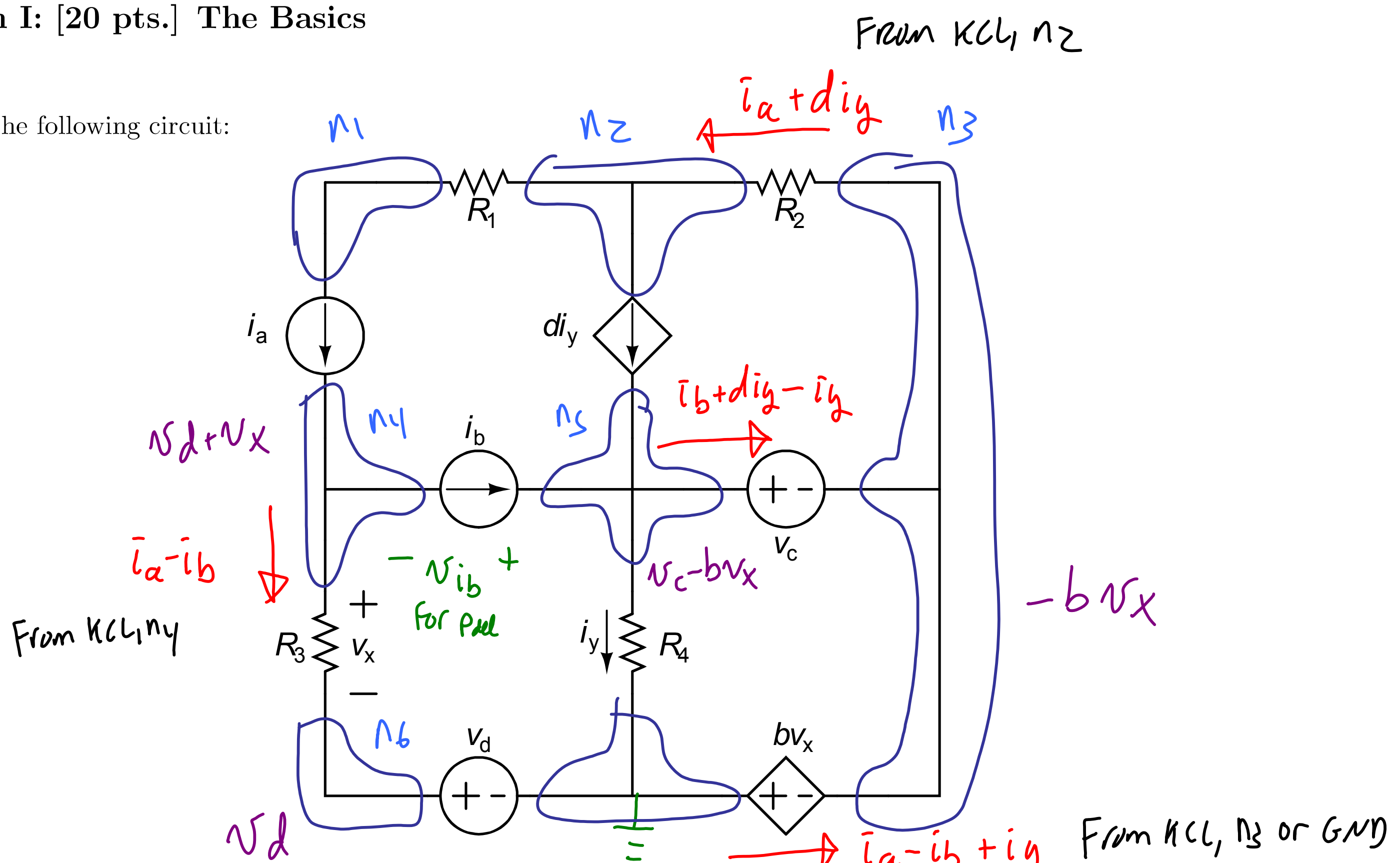
Problem I: [20 pts.] The Basics

Given the following circuit:



and assuming that constants b and d, the values for the passive elements (R_1 through R_4), and the values for the independent sources (i_a, i_b, v_c, and v_d) are known, determine expressions for the following items 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 that unknown in later calculations without substitution. Put your expressions next to the appropriate bullet below even if your work is elsewhere:

- v_x $\quad v_x = R_3(i_a - i_b)$ Ohm's Law
- i_y $\quad i_y = \dfrac{v_c - bv_x}{R_4} = \dfrac{v_c - bR_3 i_a + bR_3 i_b}{R_4}$ (now known)

For the values below, you may assume that v_x and i_y are *solved* and can thus be a part of your expressions:

- $p_{abs,R_2} =$ $\quad i_{R_2} = i_a + di_y \qquad p_{abs,R_2} = (i_a + di_y)^2 R_2$
- $p_{del,i_b} =$ $\quad v_{ib} = (v_c - bv_x) - (v_d + v_x) \qquad p_{del,ib} = i_b(v_c - bv_x - v_d - v_x)$
- $p_{del,VCVS} =$ $\quad p_{del,VCVS} = -(bv_x)(i_a - i_b + i_y)$ due to PSC

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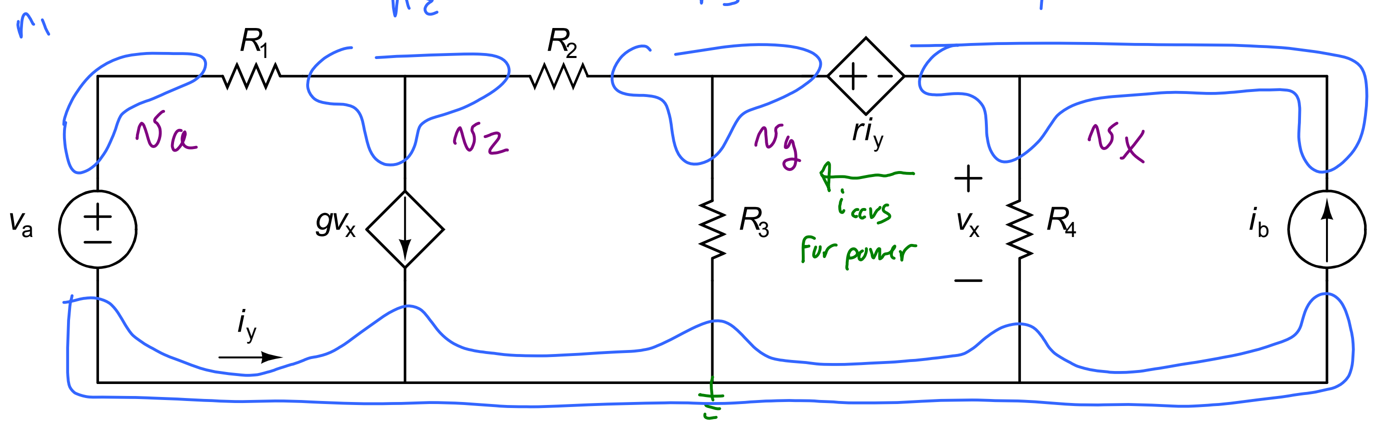
Problem II: [20 pts.] Node Voltage Method

v_y could be $v_x + r i_y$

Given the following circuit:



and assuming that constants g and r, the values for the passive elements (R_1 through R_4), and the values for the independent sources (v_a and i_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 and in a box; you can label the circuit above.

(2) Assuming you are able to solve for those unknowns, write expressions for the following. Put your expressions next to the appropriate bullet below even if your work is elsewhere:

- $p_{\text{abs},R_2} =$ $(v_z - v_y)^2 / R_2$
- $p_{\text{abs},R_3} =$ $(v_3)^2 / R_2$
- $p_{\text{del,VCCS}} =$ $-v_z g v_x$ (PSC)
- $p_{\text{del,CCVS}} =$ $r i_y \, i_{ccvs}$

Unknowns: v_x, v_y, v_z, i_y

KCL, n_2: $\frac{v_z - v_a}{R_1} + g v_x + \frac{v_z - v_y}{R_2} = 0$

KCL, sn_{34}: $\frac{v_y - v_z}{R_2} + \frac{v_y}{R_3} + \frac{v_x}{R_4} - i_b = 0$

SRC, ccvs: $r i_y = v_y - v_x$

MEAS, i_y: $i_y = \frac{v_z - v_a}{R_1}$

To get i_{ccvs},

KCL, n_3: $\frac{v_y - v_z}{R_2} + \frac{v_y}{R_3} - i_{ccvs} = 0$ so $i_{ccvs} = v_y\left(\frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{v_z}{R_3}$

OR

KCL, n_4: $i_{ccvs} + \frac{v_x}{R_4} - i_b = 0$ $\quad i_{ccvs} = i_b - \frac{v_x}{R_4}$

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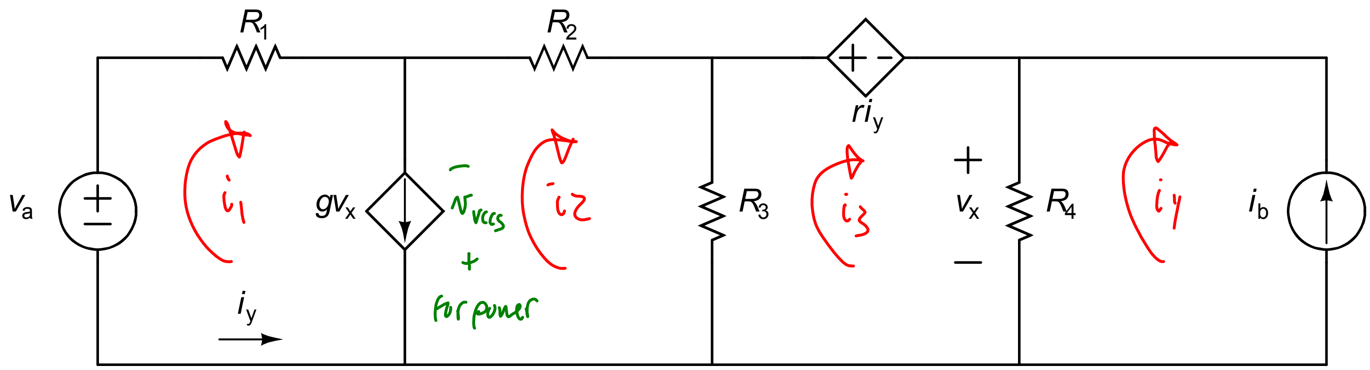
Problem III: [20 pts.] Branch/Mesh Current Method

Given the following circuit:



and assuming that constants g and r, the values for the passive elements (R_1 through R_4), and the values for the independent sources (v_a and i_b) are known,

(1) *Clearly* demonstrate the use of either the Branch Current Method or Mesh 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. Indicate which method (BCM or MCM) you are using. 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 and in a box; you can label the circuit above.

(2) Assuming you are able to solve for those unknowns, write expressions for the following. Put your expressions next to the appropriate bullet below even if your work is elsewhere

Unknowns: $i_1, i_2, i_3, i_4, i_y, v_x$

KVL, sl_{12}: $-v_a + R_1 i_1 + R_2 i_2 + R_3(i_2 - i_3) = 0$

KVL, l_3: $R_3(i_3 - i_2) + r i_y + R_4(i_3 - i_4) = 0$

SRC, vccs: $g v_x = i_1 - i_2$

SRC, i_b: $i_b = -i_4$

MEAS, i_y: $i_y = -i_1$

MEAS, v_x: $v_x = R_4(i_3 - i_4)$

- $p_{\mathrm{abs},R_2} =$ $(i_2)^2 R_2$
- $p_{\mathrm{abs},R_3} =$ $(i_2 - i_3)^2 R_3$
- $p_{\mathrm{del,VCCS}} =$

to get v_{vccs}, KVL, l_1: $-v_a + R_1 i_1 - v_{vccs} = 0 \rightarrow v_{vccs} = -v_a + R_1 i_1$ or

KVL, l_2: $v_{vccs} + R_2 i_2 + R_3(i_2 - i_3) = 0 \rightarrow v_{vccs} = -R_2 i_2 - R_3(i_2 - i_3)$

$p_{del,vccs} = g v_x v_{vccs}$

- $p_{\mathrm{del,CCVS}} =$

$-r i_y i_3$ (PSC)

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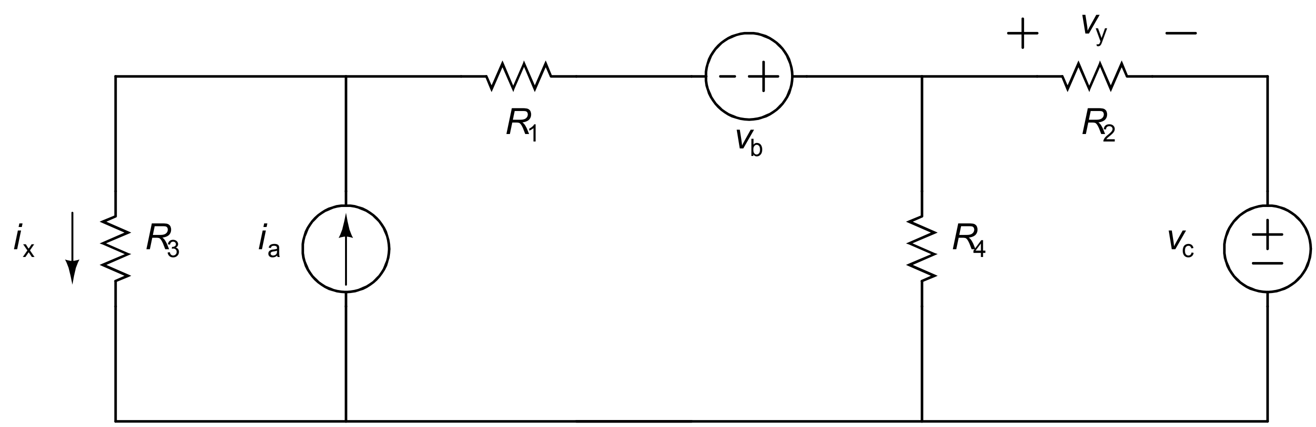
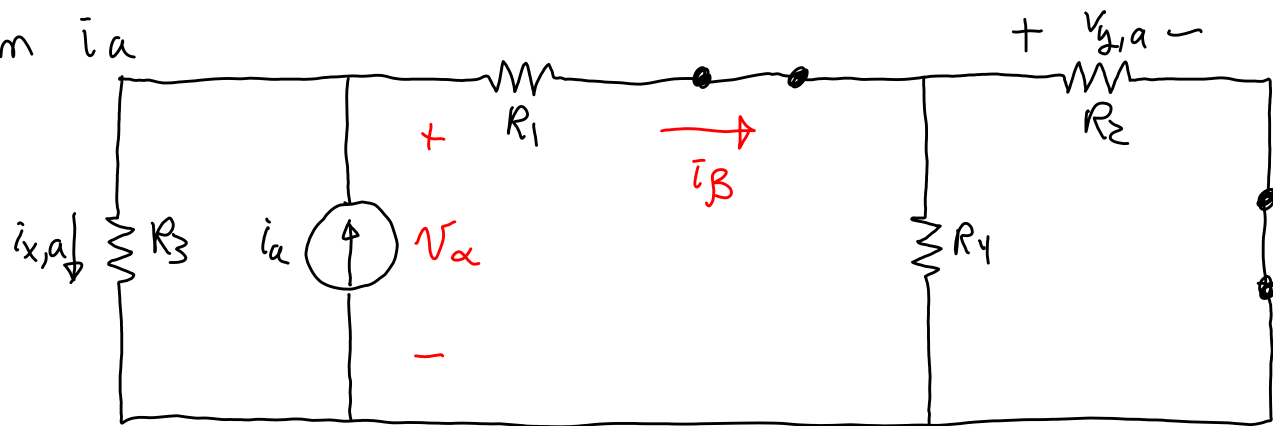
Problem IV: [20 pts.] Superposition

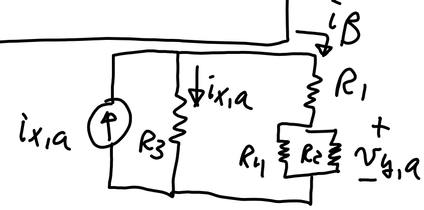
Given the following circuit:



and assuming that the values for the passive elements (R_1 through R_4) and the values for the independent sources (i_a, v_b, and v_c) are known, *clearly* demonstrate the use of superposition to find expressions for i_x and v_y. *Note:* you must *fully solve* expressions for any variables that are unknown; you cannot simply leave unsolved systems of equations. You do *not*, however, need to simplify any compound fractions, nor do you need to expand any use of the parallel resistance symbol discussed on the cover page. Furthermore, once a variable is fully solved in terms of known values, that variable can also be considered "known" - you do not need to back-substitute.

From i_a





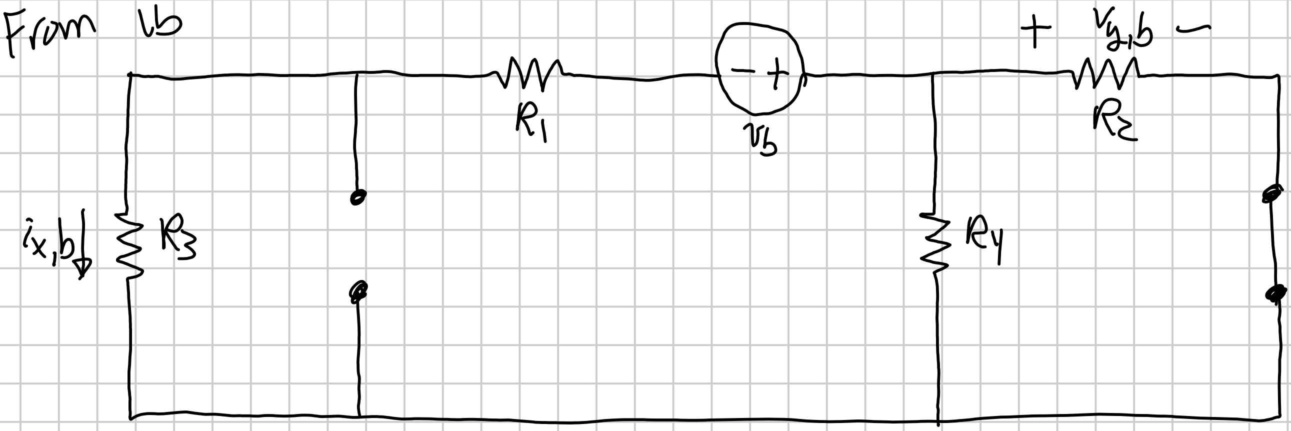
$$R_{eq} \text{ from } i_a = R_3 \| (R_1 + (R_2 \| R_4))$$

$$v_\alpha = i_a R_{eq}$$

$$i_{x,a} = \frac{v_\alpha}{R_3} = i_a \frac{R_{eq}}{R_3} \text{ or } i_a \frac{\frac{1}{R_3}}{\frac{1}{R_3} + \frac{1}{R_1 + (R_2 \| R_4)}} \text{ or } \frac{i_a (R_1 + (R_2 \| R_4))}{R_3 + (R_1 + (R_2 \| R_4))}$$

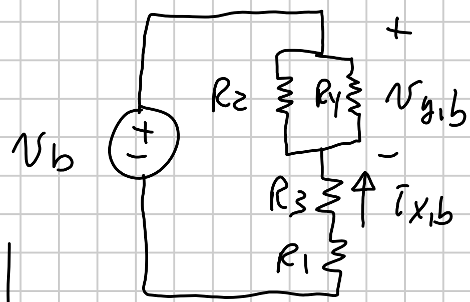
$$v_{y,a} = \frac{v_\alpha (R_2 \| R_4)}{R_1 + (R_2 \| R_4)} \text{ or } \underbrace{\frac{i_a R_3}{R_3 + (R_1 + (R_2 \| R_4))}}_{i_\beta} (R_2 \| R_4)$$

From ib

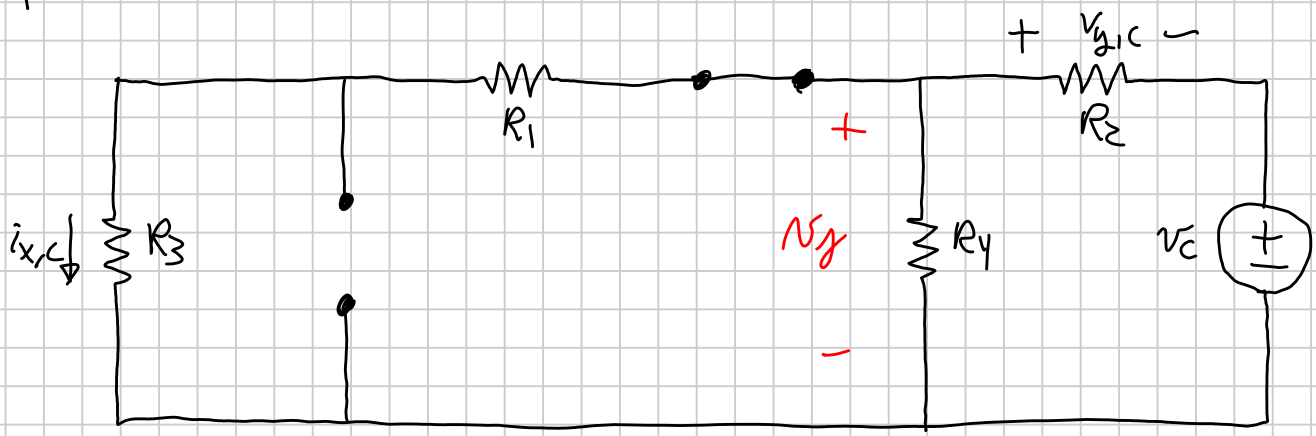


$$i_{x,b} = \frac{-v_b}{(R_2 \| R_4) + R_3 + R_1}$$

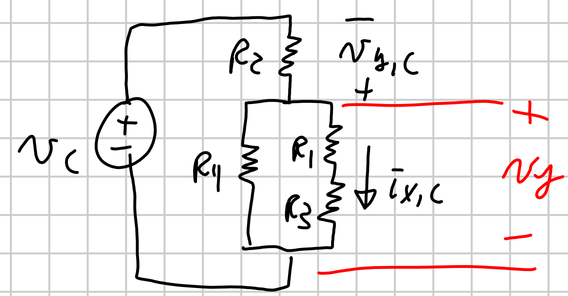
$$v_{y,b} = \frac{v_b \, (R_2 \| R_4)}{(R_2 \| R_4) + R_1 + R_3}$$



From v_c



$$i_{x,c} = \underbrace{\frac{v_c \, (R_4 \| (R_1 + R_3))}{R_2 + (R_4 \| (R_1 + R_3))}}_{v_y} \cdot \frac{1}{R_1 + R_3}$$



$$v_{y,c} = \frac{-v_c \, R_2}{R_2 + (R_4 \| (R_1 + R_3))}$$

$$i_x = i_{x,a} + i_{x,b} + i_{x,c}$$

$$v_y = v_{y,a} + v_{y,b} + v_{y,c}$$

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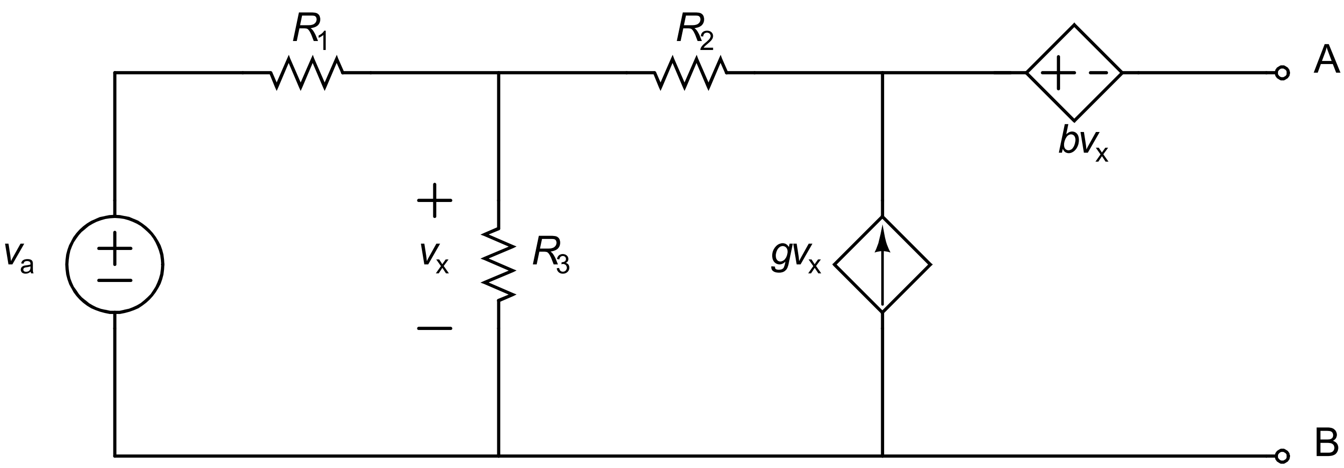
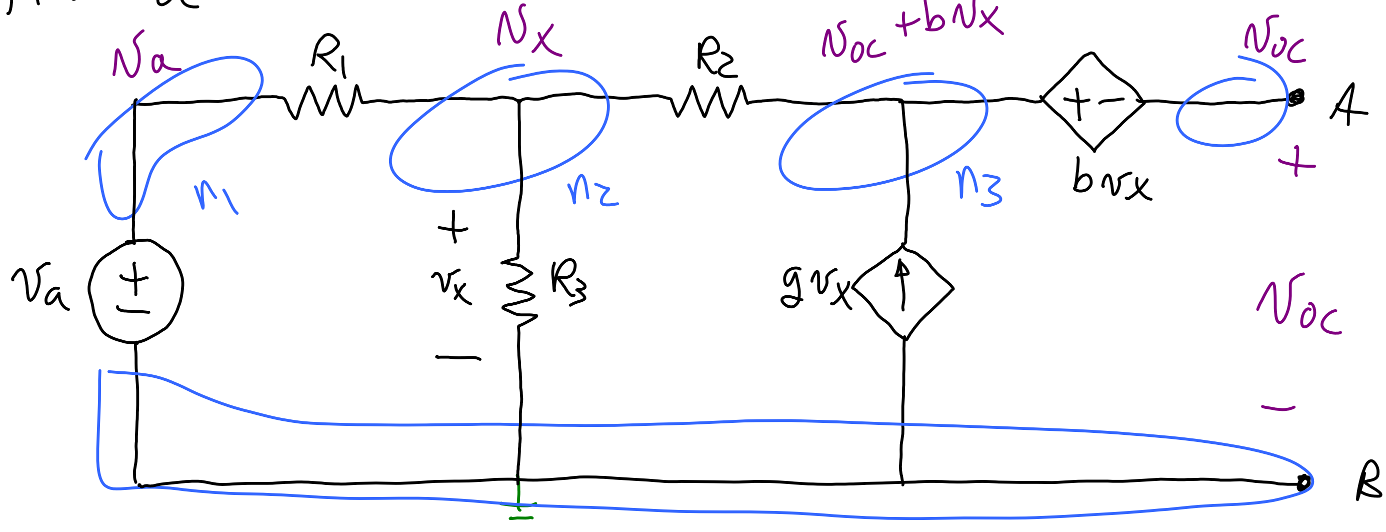
Problem V: [20 pts.] Thévenin/Norton

Given the following circuit:



and assuming that the values for the passive elements (R_1 through R_3) and the values for the constants b and g are known, draw both the Thévenin and Norton equivalent circuits with respect to terminals α and β in terms of the known values. Be sure to show your process clearly. *Note:* you must *fully solve* expressions for any variables that are unknown; you cannot simply leave unsolved systems of equations. You do *not*, however, need to simplify any compound fractions, nor do you need to expand any use of the parallel resistance symbol discussed on the cover page. Furthermore, once a variable is fully solved in terms of known values, that variable can also be considered "known" - you do not need to back-substitute. Be sure to clearly indicate where **A** and **B** are in your equivalent circuit drawings.

1) Find v_{oc}

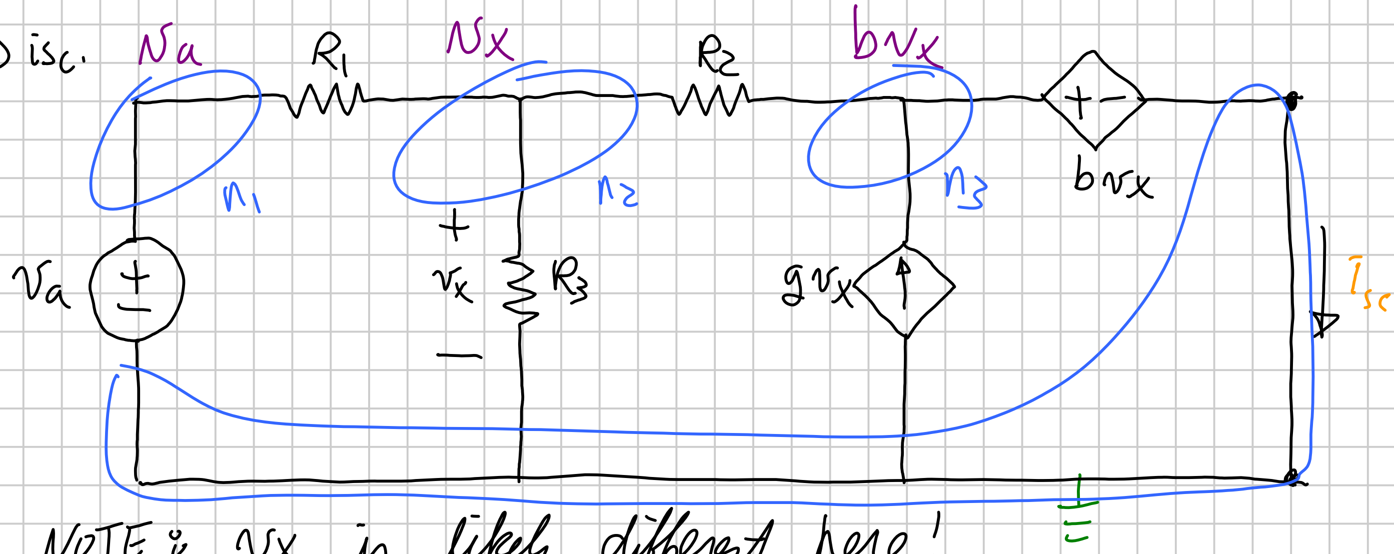


KCL, sn 23: $\frac{v_x - v_a}{R_1} + \frac{v_x}{R_3} - g v_x = 0$ $\quad v_x = \frac{\frac{v_a}{R_1}}{\frac{1}{R_1} + \frac{1}{R_3} - g}$

KCL, n3: $\frac{v_{oc} + b v_x - v_x}{R_2} - g v_x = 0$ $\quad v_{oc} = g R_2 v_x - b v_x + v_x$

$$v_{oc} = (gR_2 - b + 1)\frac{\frac{v_a}{R_1}}{\frac{1}{R_1} + \frac{1}{R_3} - g}$$

2) i_{sc}.



NOTE: v_x is likely different here!

KCL, n_2: $\frac{v_x - v_a}{R_1} + \frac{v_x}{R_3} + \frac{v_x - bv_x}{R_2} = 0$

$$v_x = \frac{\frac{v_a}{R_1}}{\frac{1}{R_1} + \frac{1}{R_3} + \frac{1-b}{R_2}}$$

KCL, n_3: $\frac{bv_x - v_x}{R_2} - gv_x + i_{sc} = 0$

$$i_{sc} = \left(g + \frac{1-b}{R_2}\right) v_x = \frac{\left(g + \frac{1-b}{R_2}\right)\frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_3} + \frac{1-b}{R_2}} v_a$$

$R_{TH} = v_{oc} / i_{sc}$

Thévenin