

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

EGR 224 Spring 2022 Test I

Name (please print):

NetID (please print):

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 communicate with 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 communicate with 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.

**Only write on one side of any given page and please be sure that your name and NetID are clearly written at the top of every page.** If an answer box is provided, **please be sure to put each answer in the correct box.** If you absolutely need more space for a particular problem, or want to show work, put that work **on one side** of its own piece of paper, clearly write your name, NetID, and the problem number (in either Arabic or Roman numerals) at the **top center** of that page and submit those extra pages in problem-order **after** all preprinted pages of the test. Also, in the box for the problem, write a note that says "see extra page."

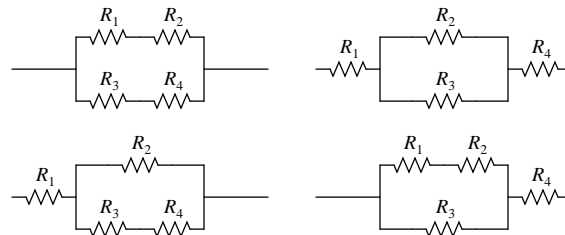
You will *not* be stapling your test but instead will be turning in your test in its original folder to the box at the front of the room. Carefully stack the test pages in order (with any additional pages properly labeled and **after all the original test pages**), put them in the folder you received with the test, and bring the folder to the front of the room.

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 unless you are required to determine a numerical answer. Be clear with your use of parentheses, however; simply writing something like

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

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



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**Problem I: [10 pts.] An Oldie But A Goodie!**

Fill in the 18 blanks in the table below. For the **Equation** column, you can put it any valid equation for the given variable in terms of any other variable in the table (and time) - you may only use Ohm's Law once, however.

Name	Variable	Units	Equation
current			
	$q$		N/R
	$R$		
	$w$		N/R
		$\mathcal{U}$ or S	N/R
		W	
			$\frac{dw}{dq}$

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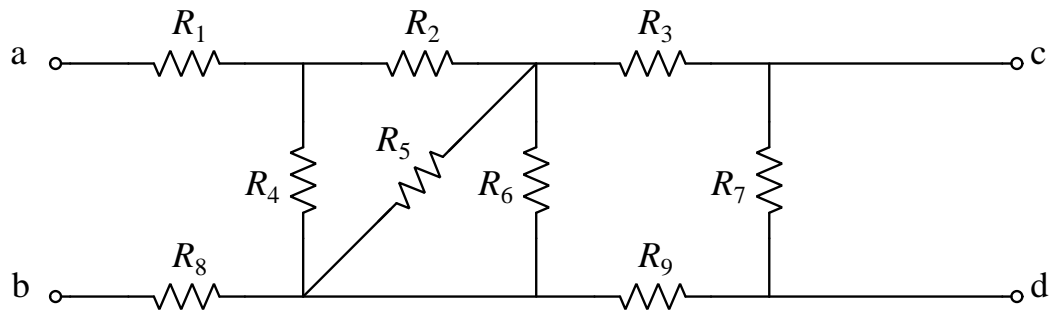
### Problem II: [10 pts.] Basics

Numerical answers may be left as (unsimplified) fractions. Your work and answers for each part must be in the boxes provided.

- (1) A 6 V lantern battery is listed as having a capacity of “18 Ah (amp-hours).” Does that have the same units as charge, current, energy, power, or voltage?

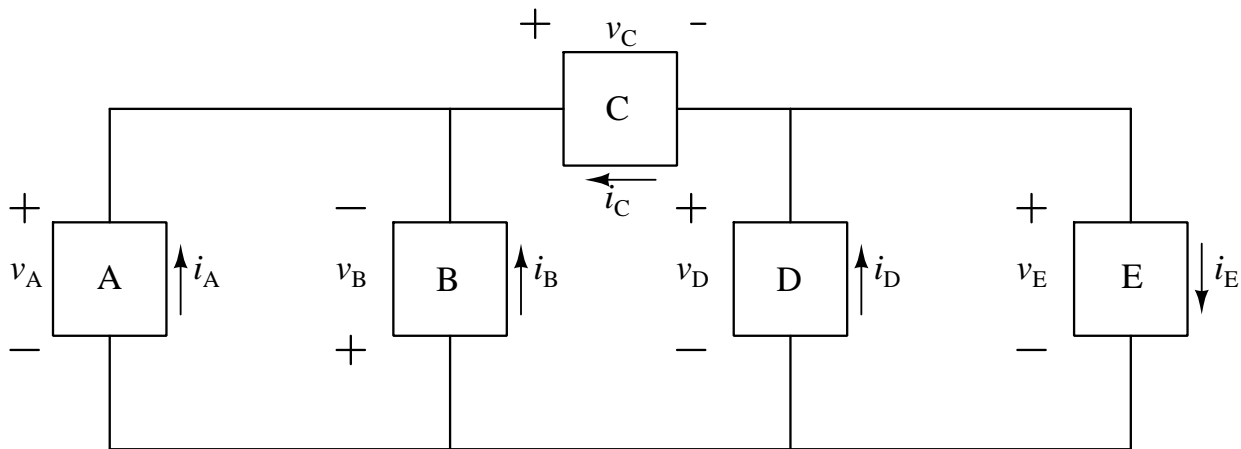
- (2) You are given a 6 V light and measure the resistance of the filament at  $12\ \Omega$ . When using the 6 V battery above to energize this light: (a) how much current flows through the light? (b) how much electrical power does the light absorb? (c) how long can the battery keep the light lit? Be sure to include units in all three answers.

- (3) Given the resistive network below, find both the equivalent resistance as seen between terminals  $a$  and  $b$  ( $R_{ab}$ ) and the equivalent resistance as seen between terminals  $c$  and  $d$  ( $R_{cd}$ ). You can absolutely leave the  $\parallel$  operator in your answers!



**Problem III: [12 pts.] Power**

Given the block diagram below and the labeled quantities, fill out the table’s missing entries for sign convention (**A** or **P**), voltage measurement, current measurement, and power absorbed. Put any work below the table.



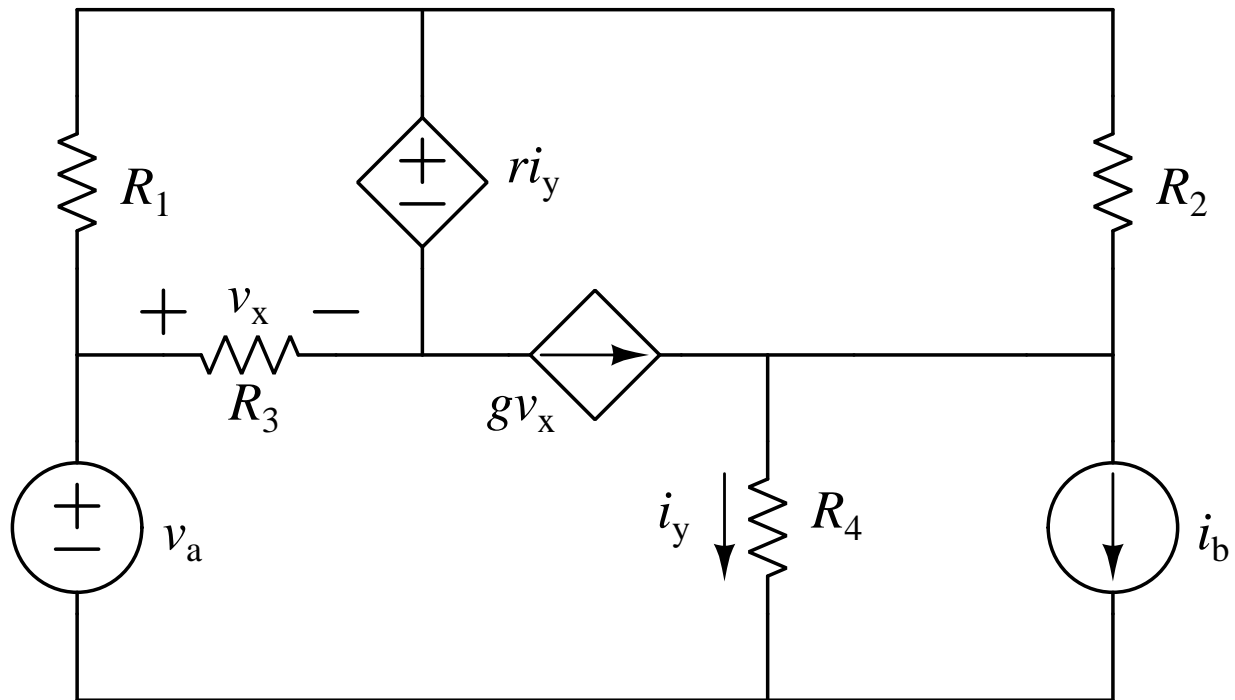
Element	Conv.	Voltage $v$ , V	Current $i$ , A	Power Absorbed $p_{\text{abs}}$ , W
A		30		
B			-6	
C		12		
D				36
E				54

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### Problem IV: [18 pts.] Node Voltage Method

Given the following circuit:



and assuming that constants  $r$  and  $g$ , 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. Clearly label the circuit above and then put the list of unknowns and the equations in the box below:

(2) Assuming you are able to solve for those unknowns, write expressions for the following. Put your expressions and any work done in the box below the expression.

- $p_{\text{abs}, R_2} =$

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

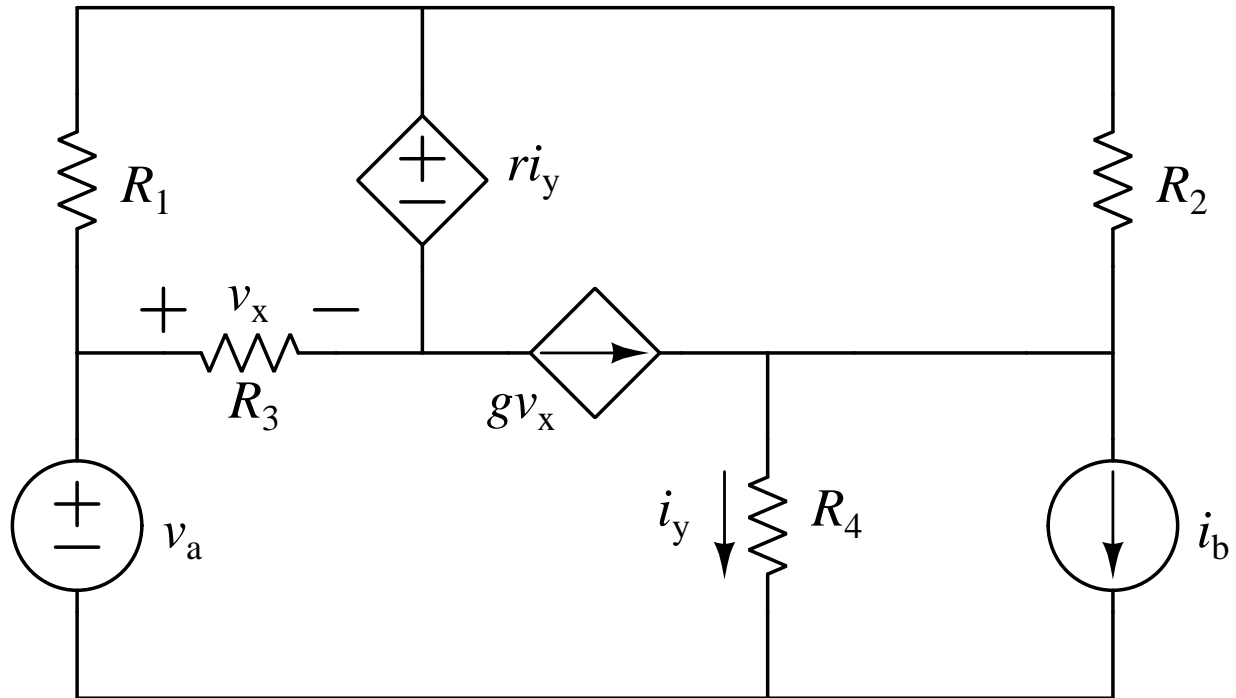
- $p_{\text{del}, \text{VCCS}} =$

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**Problem V: [18 pts.] Branch / Mesh Current Method**

Given the following circuit:



and assuming that constants  $r$  and  $g$ , 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 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. List the set of unknowns you believe your equations will find. Clearly label the circuit above and then put the list of unknowns and the equations in the box below:

(2) Assuming you are able to solve for those unknowns, write expressions for the following. Put your expressions and any work done in the box below the expression.

- $p_{\text{abs}, R_2} =$

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

- $p_{\text{del}, \text{VCCS}} =$

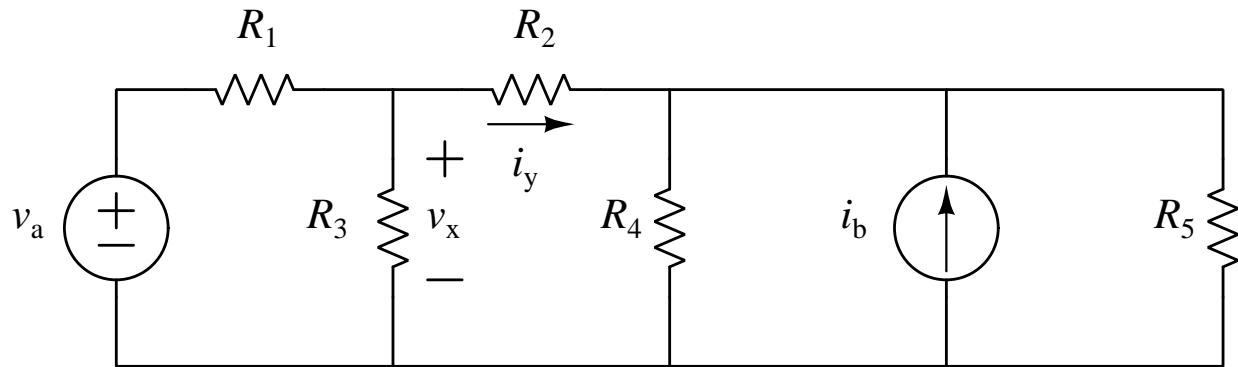


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**Problem VI: [12 pts.] Superposition**

Given the following circuit:



- (1) Clearly using superposition, re-draw the circuit to determine the contribution of independent source  $v_a$  alone to the output voltage  $v_x$  and the output current  $i_y$ . Your final expressions for each variable should be only in terms of known values, but you are allowed to use the  $\parallel$  notation for parallel resistances without expanding it and you may leave your answer in the form of a fraction.

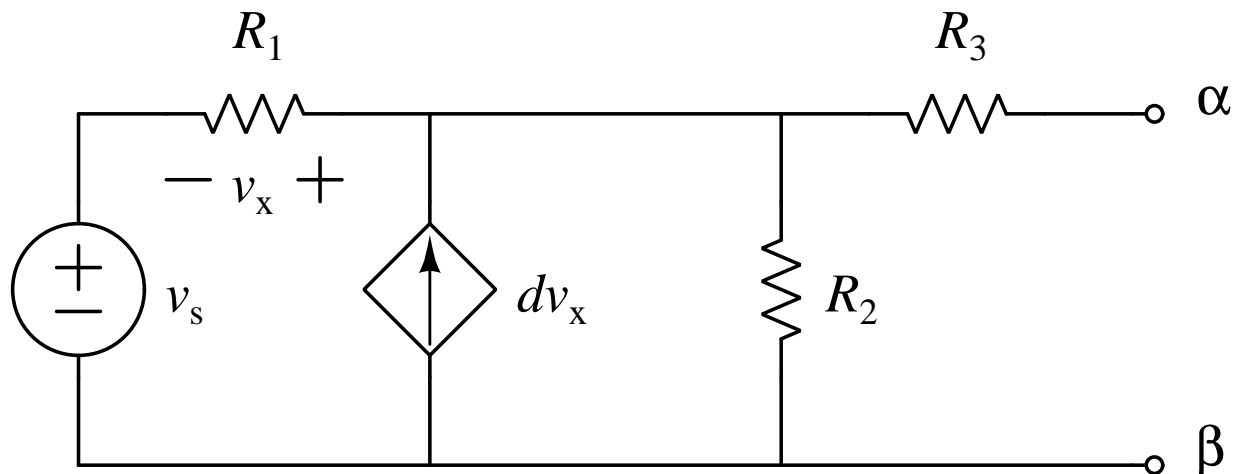
- (2) Clearly using superposition, re-draw the circuit to determine the contribution of independent source  $i_b$  alone to the output voltage  $v_x$  and the output current  $i_y$ . Your final expressions for each variable should be only in terms of known values, but you are allowed to use the  $\parallel$  notation for parallel resistances without expanding it and you may leave your answer in the form of a fraction.

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**Problem VII: [20 pts.] Thévenin/Norton**

*Note:* for the problem below 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. Given the following circuit:



and assuming that the values for the passive elements ( $R_1$ ,  $R_2$ ,  $R_3$ ), the value for the source ( $v_s$ ), and the value for the constant  $d$  are known,

- (1) Find expressions for  $v_{Th}$ ,  $i_N$ , and  $R_{Th}$ , then draw **both** the Thévenin and Norton equivalent circuits with respect to terminals  $\alpha$  and  $\beta$  in terms of the known values. Be sure to show your process clearly and indicate where  $\alpha$  and  $\beta$  are in your equivalent circuit drawings. **All your work for this part should be on the following page, please!**
- (2) Assuming  $v_{Th}$ ,  $i_N$ , and  $R_{Th}$  are known, determine the value of the load resistance  $R_L$  that could be placed between terminals  $\alpha$  and  $\beta$  that would maximize the power transferred to that load. Also determine the power transferred to that load. Put your work and answers for this part here:

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Work and results of finding Thévenin and Norton equivalent circuits: