EECS 16A Designing Information Devices and Systems I
Spring 2022 Midterm 2

PRINT your student ID: ________________________________

PRINT AND SIGN your name: ________________, ________________ ________________
(last name) (first name) (signature)

PRINT the time of your discussion section and your GSI(s) name: ________________________________

PRINT the student IDs of the person sitting on your right: ________________ and left: ________________

1. HONOR CODE
Please read the following statements of the honor code, and sign your name (you don't need to copy it).

I will respect my classmates and the integrity of this exam by following this honor code. I affirm:

- *I have read the instructions for this exam. I understand them and will follow them.*
- *All of the work submitted here is my original work.*
- *I did not reference any sources other than my one reference cheat sheet.*
- *I did not collaborate with any other human being on this exam.*

2. Tell us about something that something you like about this class (1 point) *All answers will be awarded full credit.*

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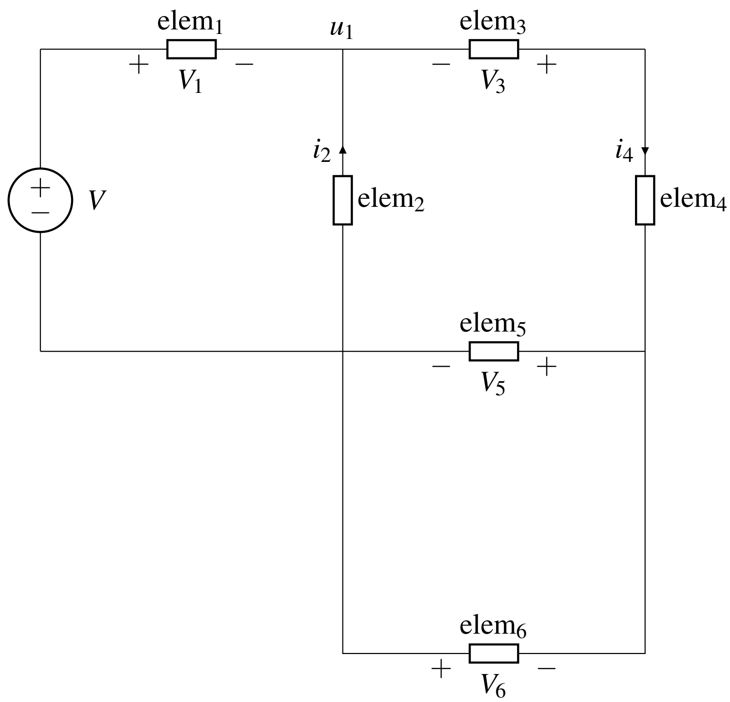
3. KCL and KVL (3.5 points)

(a) (1.5 points) Given the circuit below, label all the missing **element** voltages and currents using passive sign convention. You do not need to label the voltage source or node voltages.



(b) (1 point) Using your labeled voltages/currents, write the KCL equation for node u_1.

(c) (1 point) Using your labeled voltages/currents, write the KVL equation for the loop containing $\text{elem}_2, \text{elem}_3, \text{elem}_4$ and elem_5.

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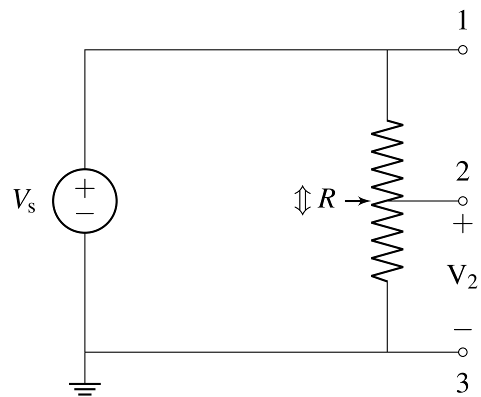
4. Potentiometers (10 Points)

(a) (2 points) A potentiometer is a component that can provide variable resistance. As shown in the figure, terminals 1 and 3 of the potentiometer are fixed, and the resistance between them is always equal to R. By moving the wiper at terminal 2 up and down, the length between terminals 1 & 2 and 2 & 3 vary, changing R_{12} (the resistance between terminals 1,2) and R_{23} (The resistance between terminals 2,3).



In the figure, the potentiometer is connected to a voltage source. Express the output voltage, V_2 (the voltage at terminal 2), as a function of the source voltage V_s, R_{12}, and R_{23}.

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(b) (3 points) Now you are given a different type of variable resistor R_{var} with initial length L_0 (mm), area A_0 (mm^2), and resistivity ρ ($\Omega \cdot mm$). By squeezing the variable resistor, you decrease its length and increase its area: each squeeze of 1 mm will cause the *length* to decrease by 1 mm and the *area* to increase by 1/10 of A_0. Suppose the variable resistor is squeezed by d (mm), express the resistance R_{var} as a function of d and other variables in the problem.

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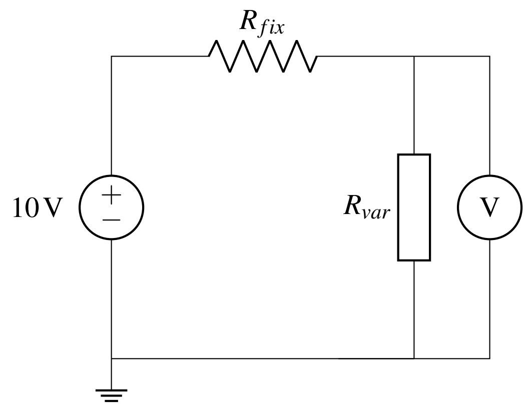
(c) (5 points) You would like to use a variable resistor as a pressure sensor. To do so you must choose an R_{fix} and setup the following circuit to measure the voltage change across R_{var} with a voltmeter. Assume initially R_{var} is 2kΩ. When the pressure increases, R_{var} becomes 3kΩ. You only have resistors of three values: 2Ω, 2kΩ, 2MΩ to choose for R_{fix}. If your voltmeter can only detect changes larger than 0.5V, which one of these resistors would you choose? Justify your answer mathematically.



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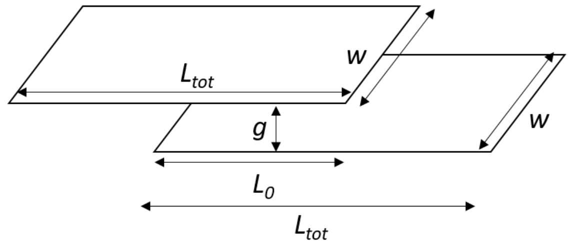
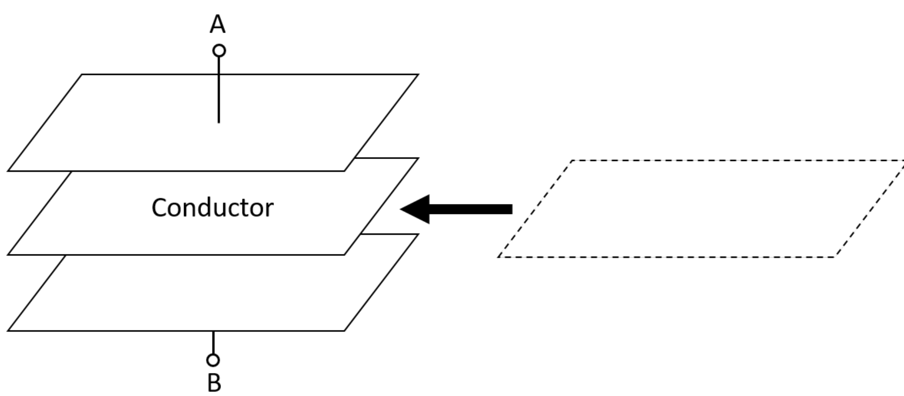
5. Physical Capacitors (5.5 points)

(a) (1.5 point) A parallel plate capacitor with area, A, separated by a gap, g, and contains an insulating layer with permittivity, ε, is shown below. The plates are perfectly aligned in the w direction. Express the capacitance with the given variables.



(b) (4 points) For the capacitors in the following questions, assume air is between the plates, and permitivity of air is ε. For each of the following statements, decide if it is true or false. Circle your answer and justify (intuitive arguments are valid) with a sentence or two.

i. Inserting an **infinitely thin, uncharged, conductive** plate between a parallel plate capacitor changes the overall capacitance between A and B.



True False

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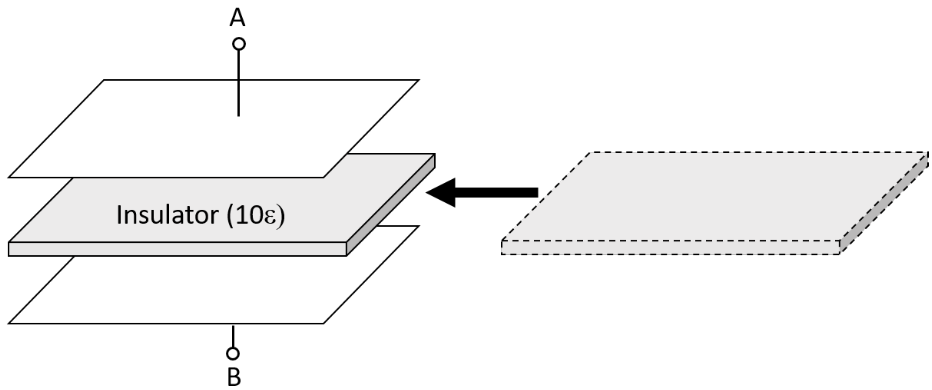
ii. Inserting a **finitely thick, uncharged, insulating** plate between a parallel plate capacitor changes the overall capacitance between A and B.



True	False

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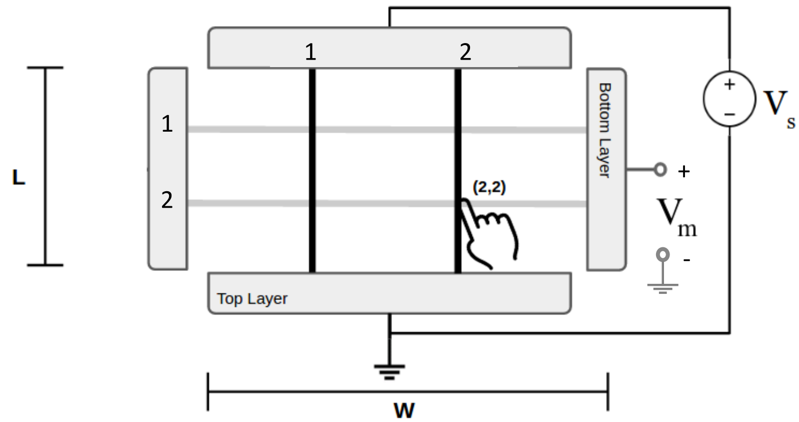
6. 2D Resistive Touch (11 points)

(a) (3 points) Consider the 2x2 touchscreen below where the strips are equally spaced and connected by an ideal conducting plate on each end. There is no contact being made between overlapping strips except where the finger is touching. Draw an equivalent circuit diagram for when touch occurs at (2,2). Be sure to include V_s, V_m in your diagram. You don't have to label the equivalent resistors.



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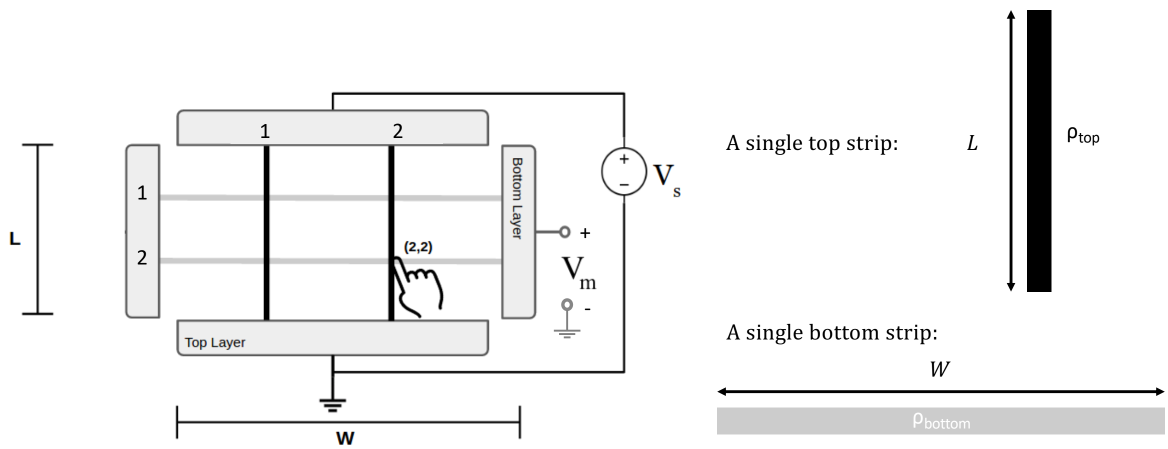
(b) (3 points) In this resistive touchscreen, the top strips are made of a material with resistivity ρ_{top} and the bottom strips are made of a material with resistivity ρ_{bottom}.



What is V_m when touch occurs at (2,2)?

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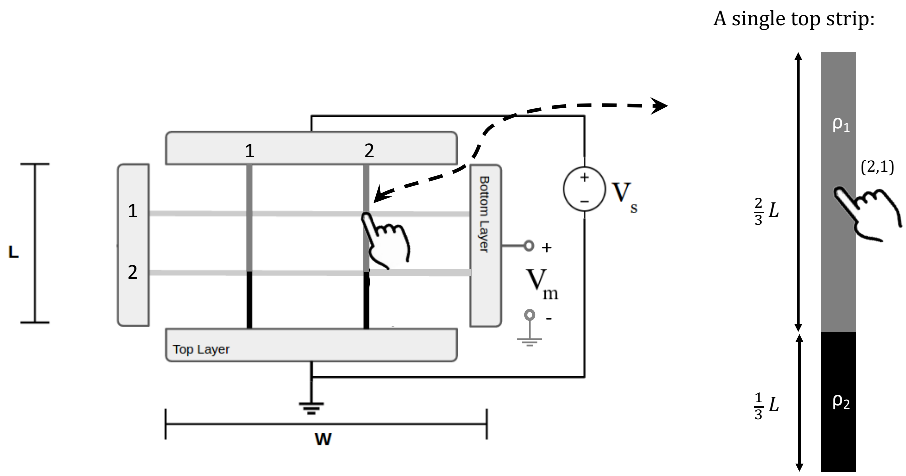
(c) (5 points) Now consider that the bottom strips are made from not one, but two materials such that the first two thirds of the strip has resistivity ρ_1 and the last third of the strip has resistivity ρ_2 as shown. What is V_m when touch occurs at (2,1)? You may express your answer in terms of the following variables: L, W, ρ_1, ρ_2 and V_s.



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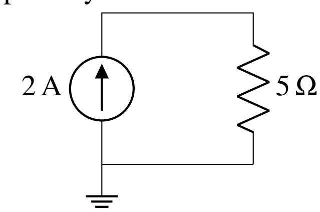
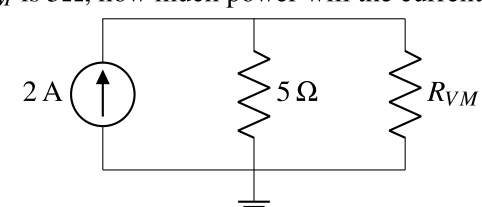
7. Non-Ideal Measurement (20 points)

(a) (10 points) You are asked to find the power **supplied** by the current source in the circuit below. (Remember, the power supplied by an element to a circuit is the negative of the power dissipated by that element.)

i. (2 points) Calculate the power supplied by the current source.



ii. (3 points) You would like to verify your calculation by measuring the voltage across the resistor. Unfortunately, you only have a **non-ideal** voltmeter. We will model the voltmeter as a resistor with resistance R_{VM}. If R_{VM} is 5Ω, how much power will the current source supply to the circuit?



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iii. (5 points) Let P_0 be the power supplied by the source if the voltmeter is not present in the circuit (i.e. your answer from part (i)), and P_I the power supplied after adding the non-ideal voltmeter (as shown in part (ii)). We would like to ensure $P_I \geq 0.8 * P_0$. You may again assume that the voltmeter can be modeled as a resistance R_{VM}. What constraint should you put on the value of R_{VM}?

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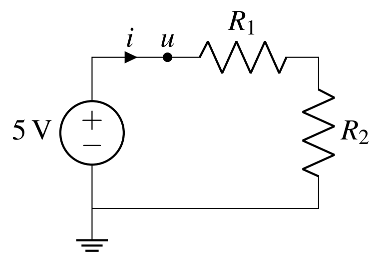
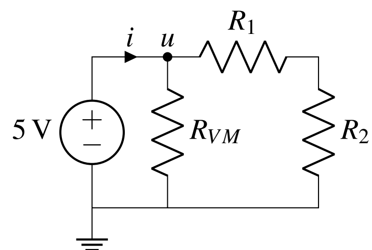
(b) (4 points) You want to measure the voltage at node u in the following circuit:



You decide to attach a **non-ideal** voltmeter into the circuit below.



How will adding the voltmeter change the voltage at node u and the current i? Circle your answer, and justify with math or a brief written explanation.

u will: Increase Decrease Stay the same

i will: Increase Decrease Stay the same

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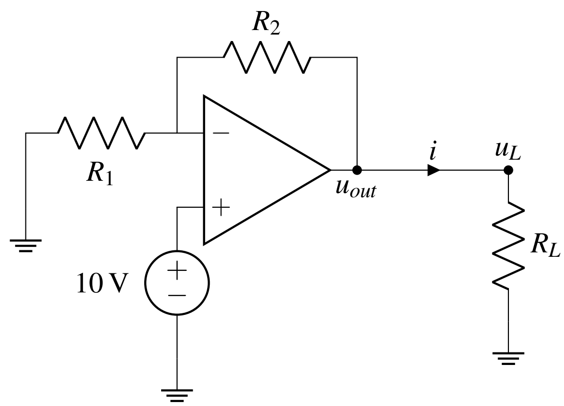
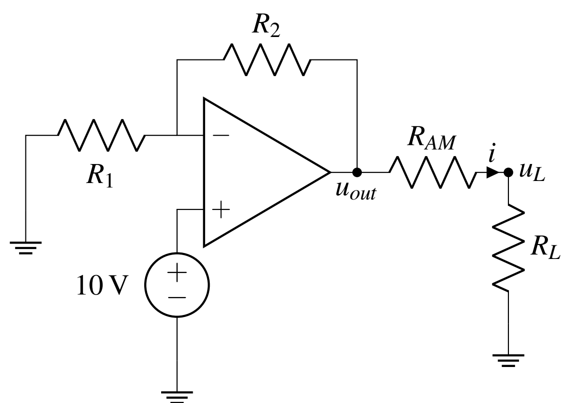
(c) (6 points) Now you want to measure the current in the following circuit:



You attach a **non-ideal** ammeter, which can be modeled as a resistor with some finite non-zero resistance R_{AM}, and the resulting circuit is shown below:



How will adding the ammeter change the following quantities? You may assume the op amp is ideal. Circle your answer and justify with math or a brief written explanation.

u_{out} will:	Increase	Decrease	Stay the same

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u_L will: Increase Decrease Stay the same

i will: Increase Decrease Stay the same

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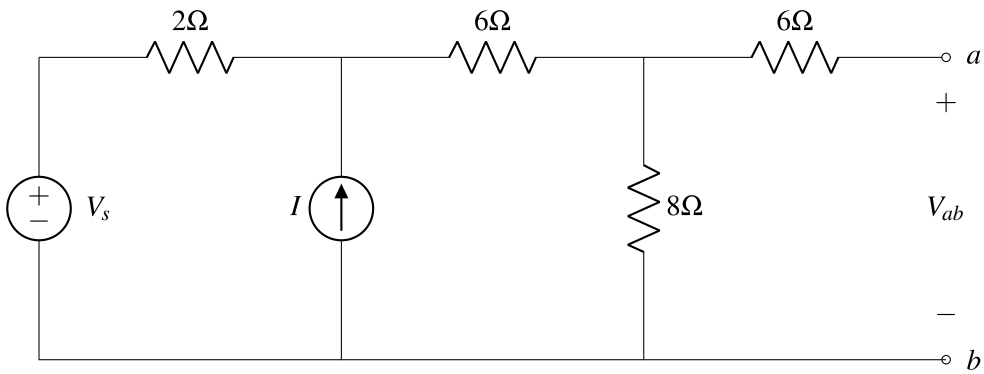
8. Equivalence and Superposition (15 points)

(a) (12 points)



i. (4 points) Find the Thevenin equivalent resistance between terminals *a* and *b*.

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ii. (8 points) Use superposition to find the Thevenin equivalent voltage between terminals a, b as a function of I and V_s.

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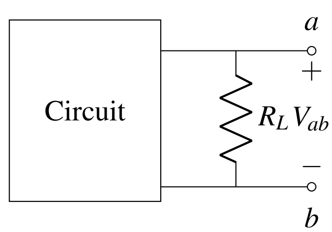
(b) (3 points) Now you are given a new mystery circuit! You connect a load resistor R_L to your circuit, as shown below. You know that the Norton equivalent circuit from nodes a and b has $I_{no} = 3A$ and $R_{no} = 2\Omega$. Find the value of R_L such that $V_{ab} = 4V$.



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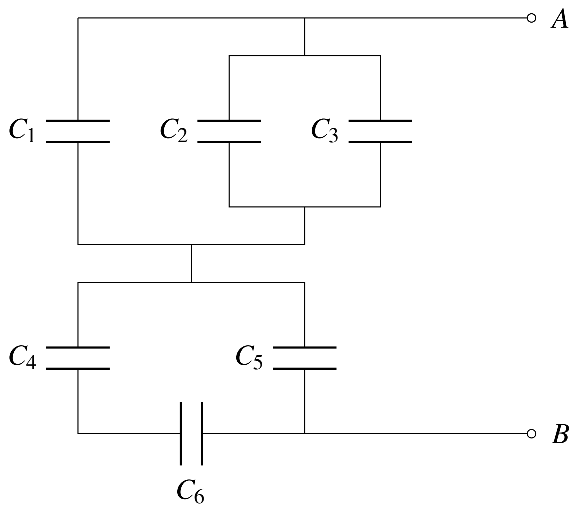
9. Capacitors in the Wild (10 points)

(a) (2 points) Find the equivalent capacitance between nodes A and B in terms of each of the capacitors, C_i. You can use the parallel operator ($\|$) for simplification.



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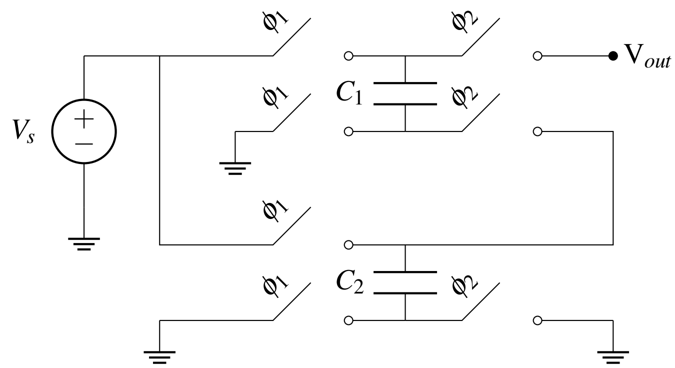
(b) (8 points) In the following circuit, switches labeled ϕ_1 are closed during phase 1 and open during phase 2; switches labeled ϕ_2 are closed during phase 2 and open during phase 1. Assume before phase 1 both capacitors are fully discharged. Each phase is long enough that the circuit reaches steady-state. Find V_{out} in phase 2 in terms of V_s, C_1 and C_2.



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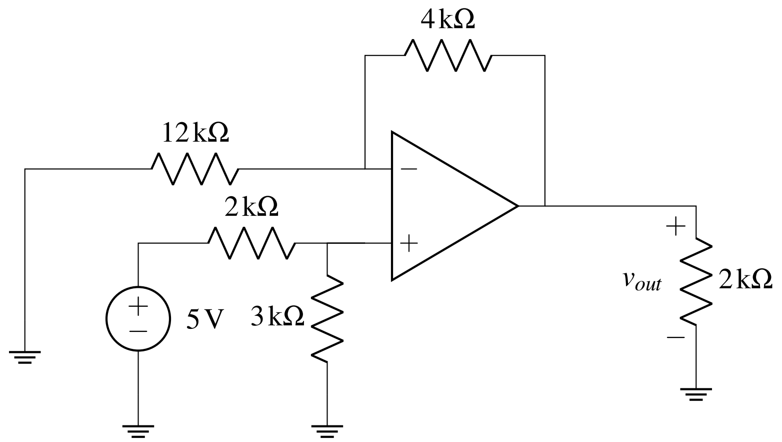
10. Op-amps and Comparators (9 points)

(a) (3 points) You are given the following op-amp in negative feedback. Find v_{out}.



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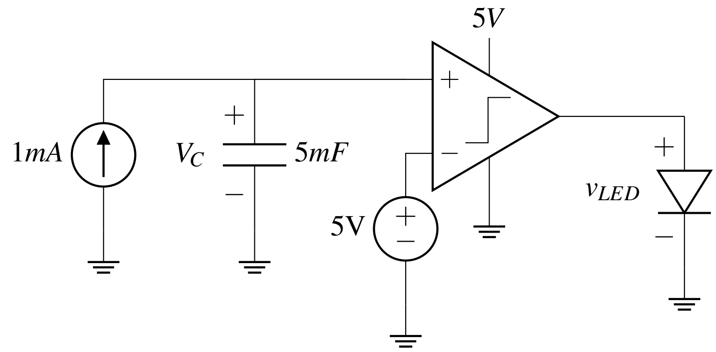
(b) (3 points) You are given the circuit below. The capacitor is initially uncharged. At time t = 0, the current source is turned on. Find V_c(t).



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(c) (3 points) The LED turns on when the voltage across it is greater than 3.3V. Using the same setup as part (b), at what time t does the LED turn on?

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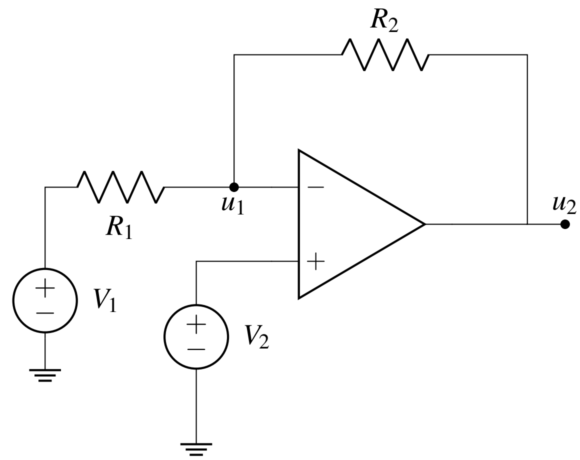
11. Eigen Circuits (19 points)

(a) (7 points) You are given the following op-amp circuit in negative feedback.

i. (5 points) Express u_1 and u_2 in terms of V_1, V_2, R_1 and R_2. Assume the op-amp is ideal.



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ii. (2 points) Write the above equations in the form of $A\vec{x} = \vec{b}$. $\vec{x}$ is $\begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$ and $\vec{b}$ is $\begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$.

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(b) (6 points) Assume that after plugging in values for R_1 and R_2, the matrix $\mathbf{A}$ you get is $\begin{bmatrix} 0 & 1 \\ -2 & 3 \end{bmatrix}$, find the eigenvalue(s) and the eigenvector(s) of this matrix.

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(c) (6 points) Assume you are given another linear circuit with inputs V_1 and V_2 and outputs u_1 and u_2. The eigenvalues for this circuit are $\lambda_1 = 1$ and $\lambda_2 = 2$. The corresponding eigenvectors are $\vec{v}_1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$, $\vec{v}_2 = \begin{bmatrix} 1 \\ 3 \end{bmatrix}$. If we want $u_1 = 3V$, $u_2 = 7V$, what would the input values be?

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Work on this page will NOT be graded.

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