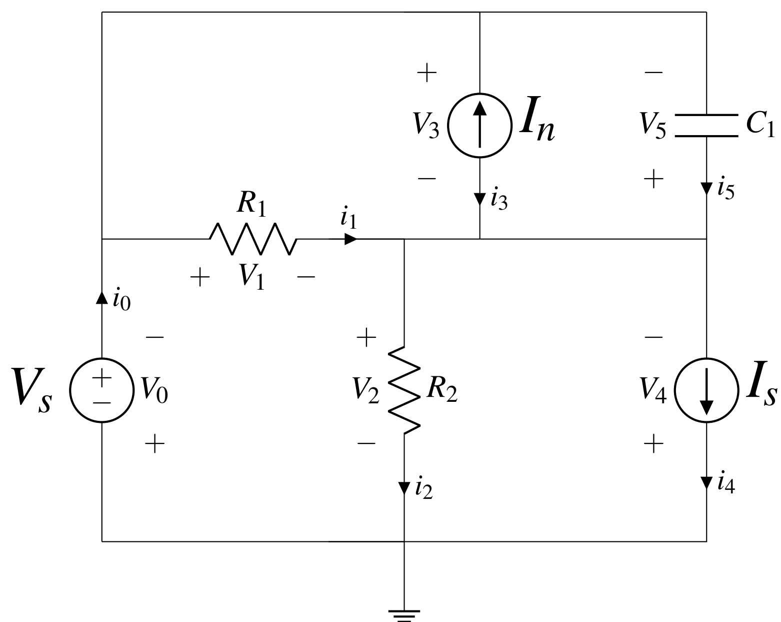
EECS 16A Designing Information Devices and Systems I
Fall 2021 Midterm 2

1. Passive Sign Convention (2 points)

Version 1:



Which of the following components in the circuit have correct passive sign convention labels? Select True, if the element is labeled correctly and False if the element is labeled incorrectly.

V_s : True/False?

R_1 : True/False?

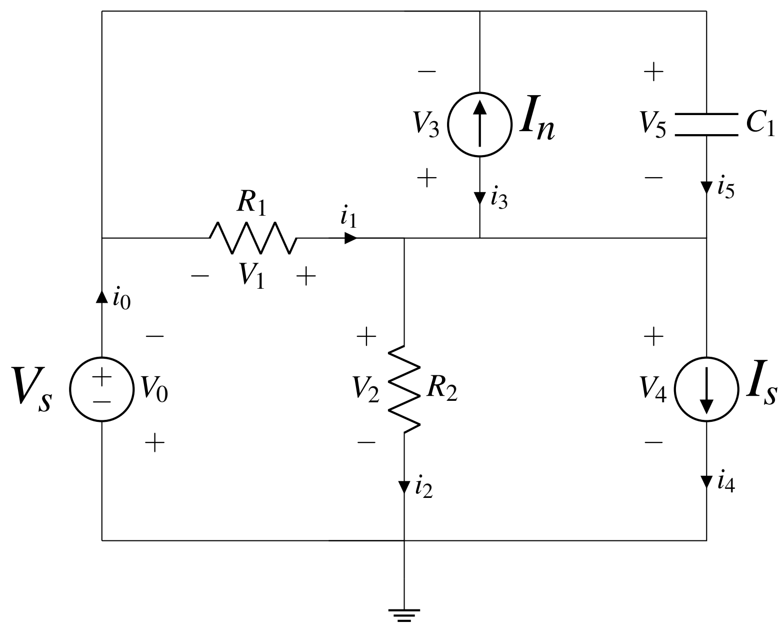
R_2 : True/False?

C_1 : True/False?

I_s : True/False?

I_n : True/False?

Version 2 Which of the following components in the circuit have correct passive sign convention labels? Select True, if the element is labeled correctly and False if the element is labeled incorrectly.



V_s : True/False?

R_1 : True/False?

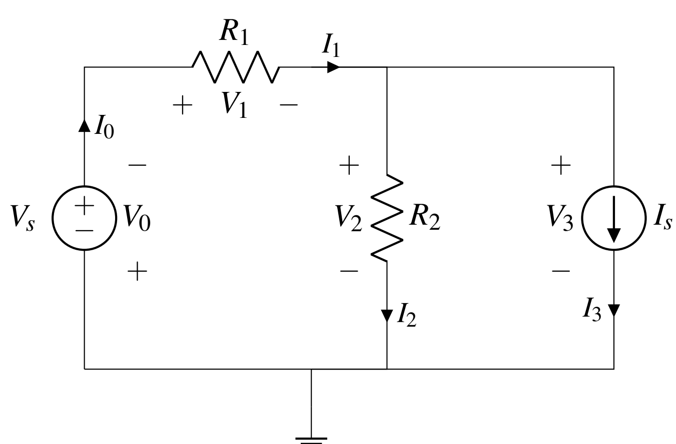
R_2 : True/False?

C_1 : True/False?

I_s : True/False?

I_n : True/False?

2. Kirchoff's Laws (3 points)



Version 1: Based on the circiut schematics above, which of the following equations are valid according to the Kirchoff's Laws? Select True if the equation is valid and False if the equation is not valid.

$V_0 = -V_2 - V_3$: True/False?

$I_0 - I_1 = 0$: True/False?

$V_0 + V_1 + V_3 = 0$: True/False?

$V_0 + V_1 = V_2$: True/False?

$I_2 = I_3$: True/False?

$I_2 + I_3 = I_0$: True/False?

Version 2: Based on the above circuit schematics, which of the following equations are valid according to the Kirchoff's Laws? Select True if the equation is valid and False if the equation is not.

$V_0 = -V_1 - V_2$: True/False?

$I_0 + I_1 = 0$: True/False?

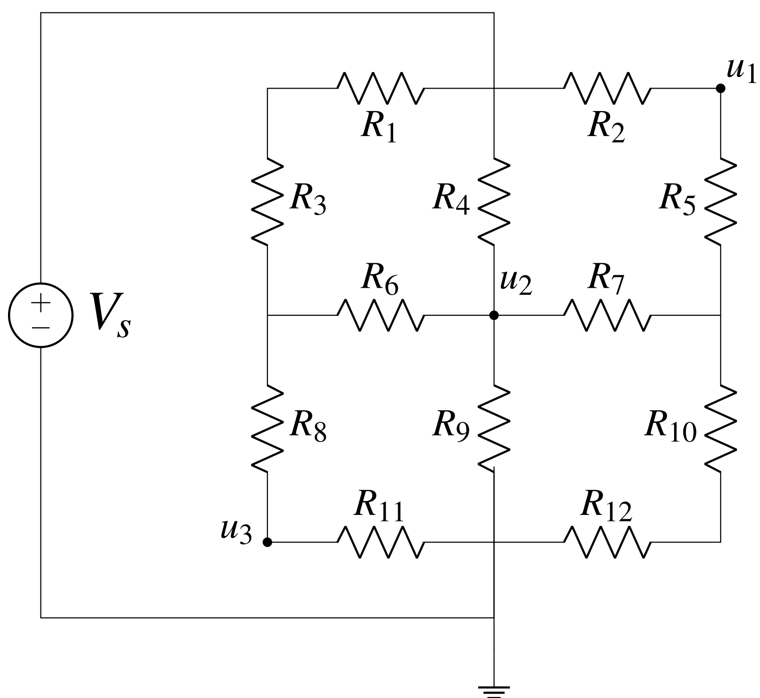
$V_0 + V_2 + V_3 = 0$: True/False?

$V_0 + V_1 = V_3$: True/False?

$I_2 = I_3$: True/False?

$I_2 + I_3 = I_1$: True/False?

3. Resistive 2D Touchdscreen (1) (3 points)

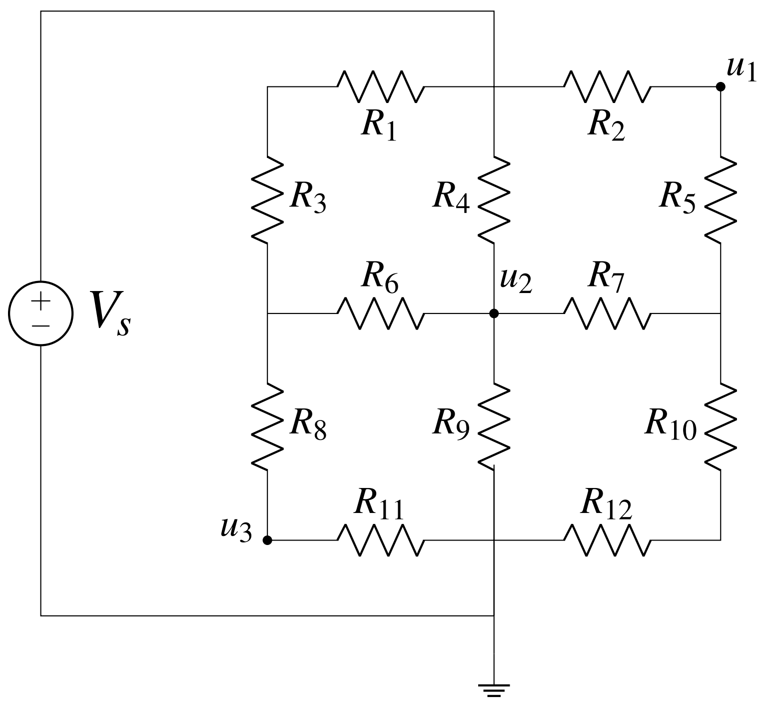


Version 1: Given the above circuit, find node voltages at the given nodes u_1, u_2, and u_3 where all resistors have resistance $R = 500\Omega$ and $V_s = 5V$.

Version 2: Given the above circuit, find node voltages at the given nodes u_1, u_2, and u_3 where all resistors have resistance $R = 500\Omega$ and $V_s = 10V$.

Version 3: Given the above circuit, find node voltages at the given nodes u_1, u_2, and u_3 where all resistors have resistance $R = 400\Omega$ and $V_s = 16V$.

4. Resistive 2D Touchscreen (2) (4 points)



Using the above circuit schematics, indicate which node voltages, if any, will change if the value of the given resistor is changed.

Version 1: By default, every resistor has the same resistance $R = 500\,\Omega$. $V_s = 5V$.

Version 2: By default, every resistor has the same resistance $R = 600\,\Omega$. $V_s = 4V$.

Version 3: By default, every resistor has the same resistance $R = 700\,\Omega$. $V_s = 8V$.

For each response, select a combination of the following values: u_1, u_2, u_3, None. For example, if u_1 and u_2 change, select "u_1, u_2". And if the node voltages are unchanged then you can select None.

(a) **Version 1:**R_6 is changed to $R = 1000\,\Omega$, all others stay at $R = 500\,\Omega$.
Version 2:R_6 is changed to $R = 1200\,\Omega$, all others stay at $R = 600\,\Omega$.
Version 3:R_6 is changed to $R = 1400\,\Omega$, all others stay at $R = 700\,\Omega$.

(b) **Version 1:** R_2 is changed to $R = 1000\,\Omega$, $R_5 = 0\,\Omega$, all others stay at $R = 500\,\Omega$.
Version 2: R_2 is changed to $R = 1200\,\Omega$, $R_5 = 0\,\Omega$, all others stay at $R = 600\,\Omega$.
Version 3: R_2 is changed to $R = 1400\,\Omega$, $R_5 = 0\,\Omega$, all others stay at $R = 700\,\Omega$.

(c) **Version 1:** R_1 is changed to $R = 1000\,\Omega$, $R_2 = 1000\,\Omega$, $R_3 = R_5 = 0\,\Omega$, and all others stay at $R = 500\,\Omega$.
Version 2: R_1 is changed to $R = 1200\,\Omega$, $R_2 = 1200\,\Omega$, $R_3 = R_5 = 0\,\Omega$, and all others stay at $R = 600\,\Omega$.
Version 3: R_1 is changed to $R = 1400\,\Omega$, $R_2 = 1400\,\Omega$, $R_3 = R_5 = 0\,\Omega$, and all others stay at $R = 700\,\Omega$.

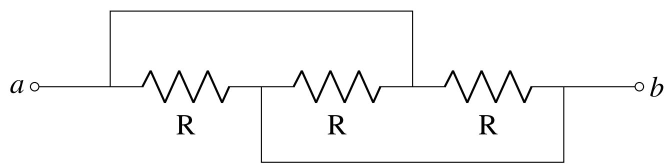
(d) **Version 1:** R_4 is changed to $R = 1000\,\Omega$, and all others stay at $R = 500\,\Omega$.
Version 2: R_4 is changed to $R = 1200\,\Omega$, and all others stay at $R = 600\,\Omega$.
Version 3: R_4 is changed to $R = 1400\,\Omega$, and all others stay at $R = 700\,\Omega$.

5. Resistor Equivalence (1) (2 points)

Choose the equivalent circuit to circuit 1, options A-E show potential simplified equivalent circuits.

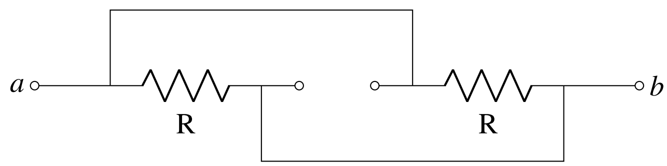
Circuit 1 is equivalent to ___

Circuit 1:

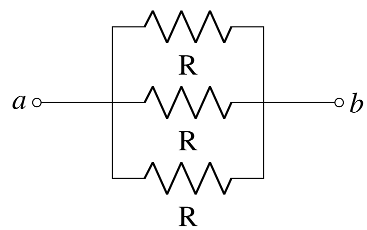


Version 1:

A:

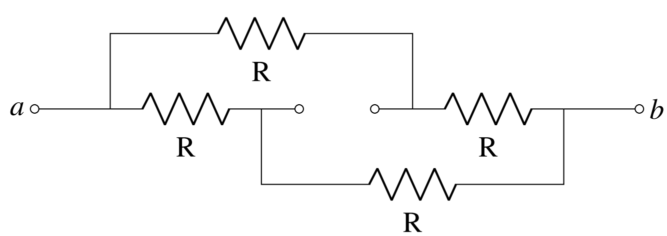


B:



C:

D:



E:

None of the above

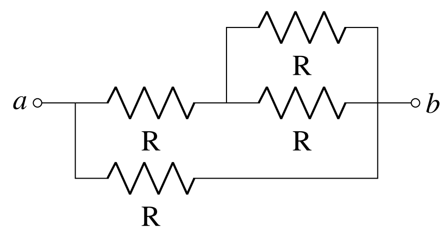
6. **Resistor Equivalence (2) (2 points)**

Version 1: The value of R for this question is $15k\Omega$.

Version 2: The value of R for this question is $10k\Omega$.

Version 3: The value of R for this question is $25k\Omega$.

The equivalent resistance of this circuit between nodes a and b is ___ $k\Omega$.



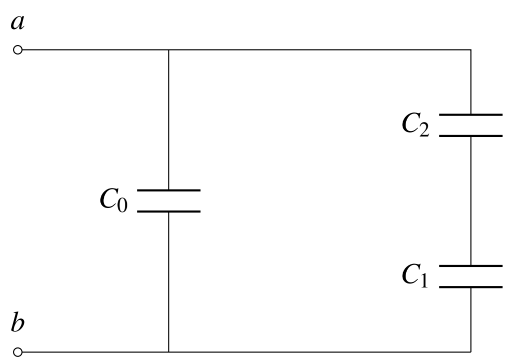
7. Capacitance Equivalence (2 points)

Calculate the equivalent capacitance of the following circuit between nodes a and b given the corresponding capacitance.

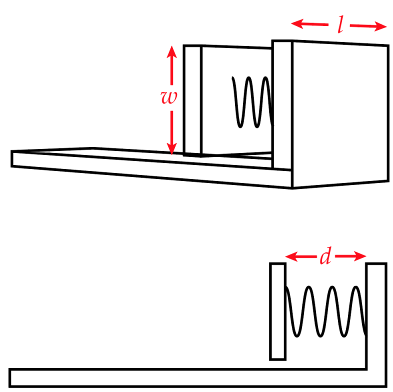
Version 1: Assuming that the capacitance values are C_0=35μF and C_1=C_2=10μF.

Version 2: Assuming that the capacitance values are C_0=15μF and C_1=C_2=20μF.

Version 3: Assuming that the capacitance values are C_0=10μF and C_1=C_2=20μF.



The following diagram is related to the next two questions. A micro-electromechanical systems (MEMS) accelerometer can be modeled as two plates–a fixed plate and a moving plate–connected by a spring, shown below. As acceleration changes, the force exerted on the moving plate changes, and the distance between the plates also changes. We can detect this physical change in distance by measuring the capacitance between the two plates. You can assume that $\varepsilon = \varepsilon_0$ where ε_0 is the permittivity of free space.



8. Accelerometer - Physical Capacitors (2 points)

At 0g acceleration, the two plates have distance $d = d_0$ between them. What is the capacitance between the two accelerometer plates?

9. Accelerometer - Physical Capacitors (2 points)

Version 1: At 1g acceleration, the two plates have distance $d = 2d_0$ between them. How does the capacitance change from the 0g case?

Version 2: At 1g acceleration, the two plates have distance $d = 4d_0$ between them. How does the capacitance change from the 0g case?

Version 3: At 1g acceleration, the two plates have distance $d = 0.5d_0$ between them. How does the capacitance change from the 0g case?

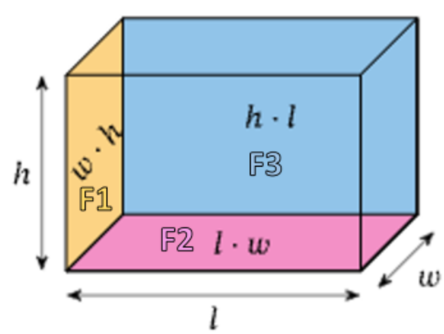
10. Physical Resistors (3 points)

Version 1: Using the rectangular prism ($h = 1$mm, $w = 4$mm, $l = 10$mm) made using carbon film ($\rho = 50 \times 10^{-4}\Omega$m) as a resistor, measuring the resistance across which two opposing faces of the prism will result in $R = 2\Omega$? Note that mm $= 10^{-3}$m.

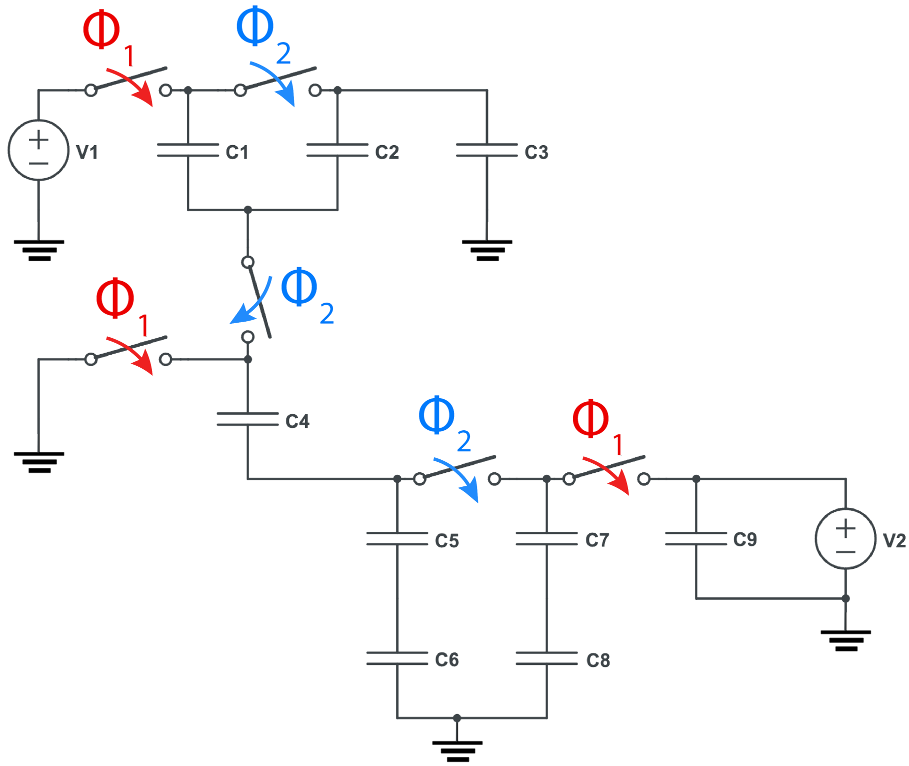
Version 2: Using the rectangular prism ($h = 1$mm, $w = 4$mm, $l = 10$mm) made using carbon film ($\rho = 50 \times 10^{-4}\Omega$m) as a resistor, measuring the resistance across which two opposing faces of the prism will result in $R = 12.5\Omega$? Note that mm $= 10^{-3}$m.

Version 3: Using the rectangular prism ($h = 1$mm, $w = 4$mm, $l = 10$mm) made using carbon film ($\rho = 50 \times 10^{-4}\Omega$m) as a resistor, measuring the resistance across which two opposing faces of the prism will result in $R = 0.125\Omega$? Note that mm $= 10^{-3}$m.

Version 4: Using the rectangular prism ($h = 1$mm, $w = 4$mm, $l = 10$mm) made using carbon film ($\rho = 50 \times 10^{-4}\Omega$m) as a resistor, measuring the resistance across which two opposing faces of the prism will result in $R = 5\Omega$? Note that mm $= 10^{-3}$m.

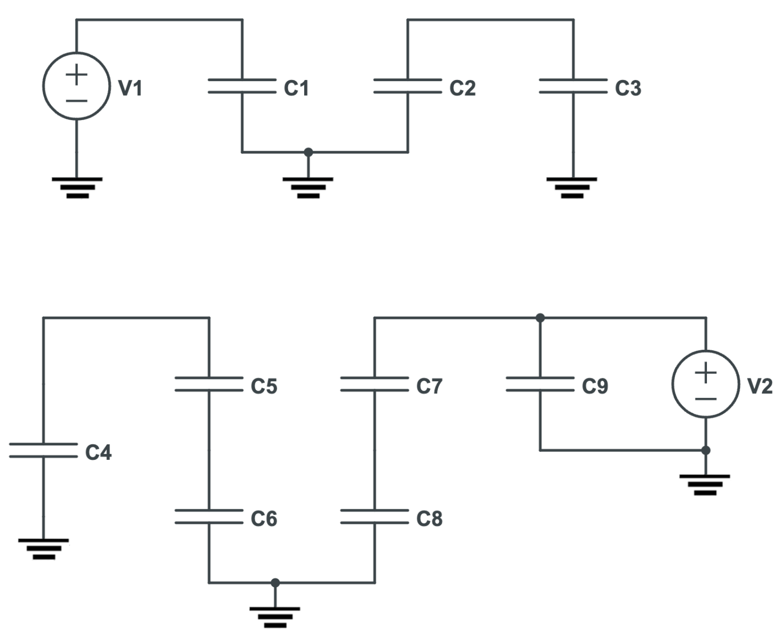


11. Charge Sharing 1 (2 points)

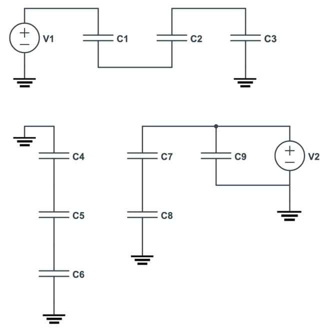


What will the above circuit look like after the phase 1 switches (labeled $\phi 1$) are closed? Note that phase 2 switches (labeled $\phi 2$) remain open.

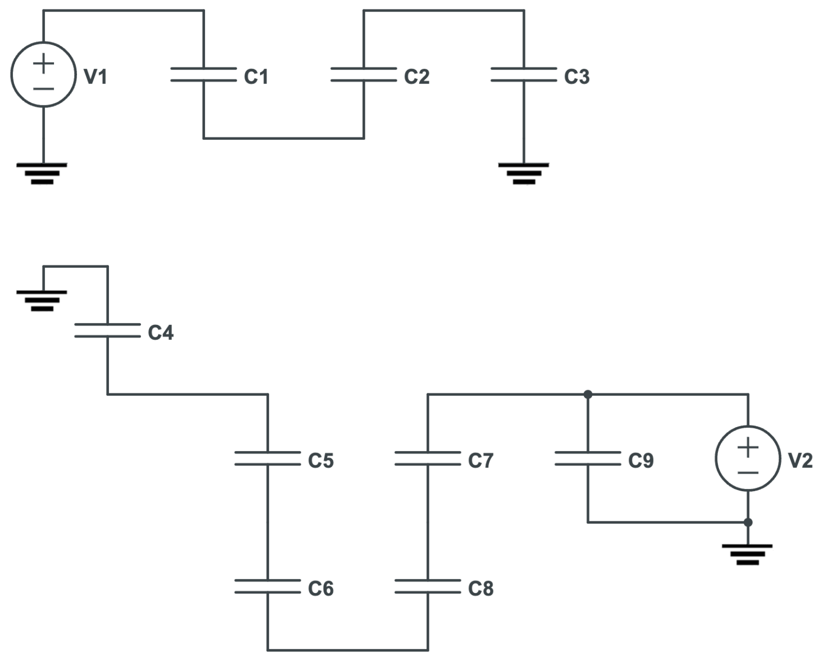
A.



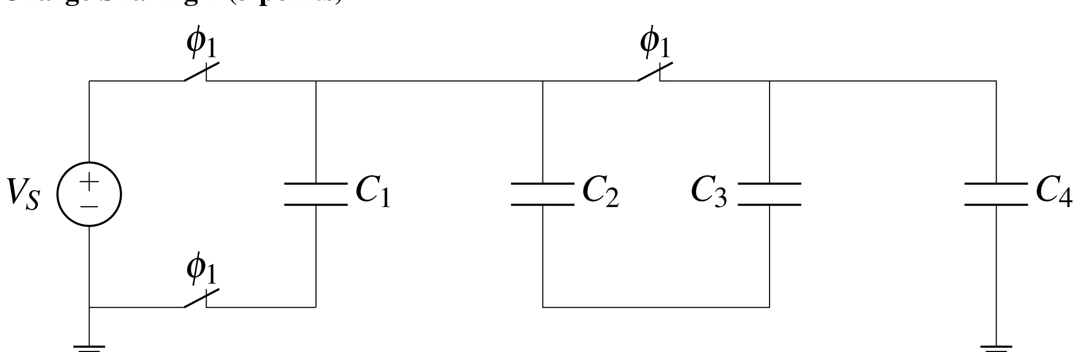
B.



C.



12. Charge Sharing 2 (3 points)



Version 1: Assume $V_s = 3V$ and $C_1 = C_2 = C_3 = C_4 = 5F$.

Version 2: Assume $V_s = 2V$ and $C_1 = C_2 = C_3 = C_4 = 3F$.

Version 3: Assume $V_s = 1V$ and $C_1 = 1F, C_2 = 2F, C_3 = 3F, C_4 = 4F$. All capacitors are initially uncharged before the switches are closed. The switches are closed and the circuit reaches steady state.

(a) How much charge is on C_4 after the switches are closed?

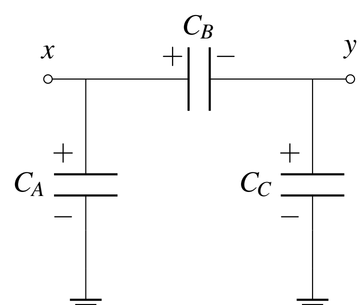
(b) How much charge is on C_2 after the switches are closed?

13. Charge Sharing 3 (6 points)

Version 1: In the following circuit, you are given that capacitors C_A, C_B, and C_C have charges Q_A, Q_B, and Q_C and stored in them, respectively, where the polarity of the charges are depicted in the schematics below. You are also told that $C_A = C_B = C_C = 1F$ and the total charge at node x is $Q_x = 4$ Coulombs and the total charge at node y is $Q_x = 1$ Coulomb. What are the voltages at node $y(V_y)$ and node x (V_x)?

Version 2: In the following circuit, you are given that capacitors C_A, C_B, and C_C have charges Q_A, Q_B, and Q_C and stored in them, respectively, where the polarity of the charges are depicted in the schematics below. You are also told that $C_A = C_B = C_C = 1F$ and the total charge at node x is $Q_x = 5$ Coulombs and the total charge at node y is $Q_x = 2$ Coulomb. What are the voltages at node $y(V_y)$ and node x (V_x)?

Version 3: In the following circuit, you are given that capacitors C_A, C_B, and C_C have charges Q_A, Q_B, and Q_C and stored in them, respectively, where the polarity of the charges are depicted in the schematics below. You are also told that $C_A = C_B = C_C = 1F$ and the total charge at node x is $Q_x = 7$ Coulombs and the total charge at node y is $Q_x = 4$ Coulomb. What are the voltages at node $y(V_y)$ and node x (V_x)?

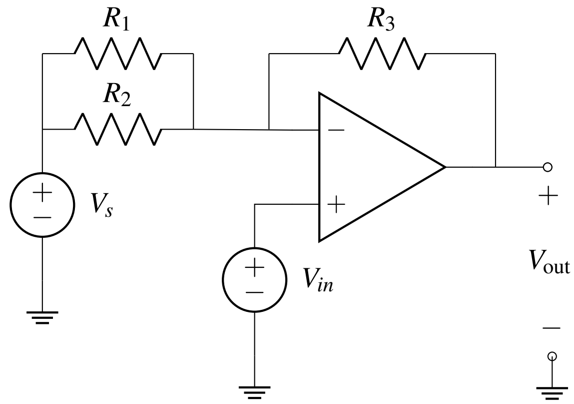


14. Op Amps (5 points)

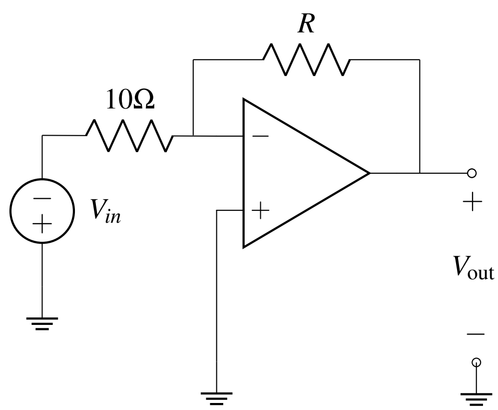
Version 1: Oscar has built the following circuit. What is the output V_{out} from his circuit when $V_s = 5V$, $R_1 = R_2 = R_3 = 1\Omega$, and $V_{in} = 6V$?

Version 2: Oscar has built the following circuit. What is the output V_{out} from his circuit when $V_s = 5V$, $R_1 = R_2 = R_3 = 4\Omega$, and $V_{in} = 5V$?

Version 3: Oscar has built the following circuit. What is the output V_{out} from his circuit when $V_s = 6V$, $R_1 = R_2 = R_3 = 2\Omega$, and $V_{in} = 7V$?



15. Op Amps (3 points)



Version 1: Alex has a $V_{in} = 1.1V$ input voltage source, but wants an output $V_{out} = 4.4V$ to power their Launchpad. They are planning to use the following circuit to implement that.

Version 2: Alex has a $V_{in} = 1.1V$ input voltage source, but wants an output $V_{out} = 3.3V$ to power their Launchpad. They are planning to use the following circuit to implement that.

Version 3: Alex has a $V_{in} = 1.1V$ input voltage source, but wants an output $V_{out} = 2.2V$ to power their Launchpad. They are planning to use the following circuit to implement that.

What resistance value R should Alex choose to get their desired voltage?

16. Comparators (4 points)

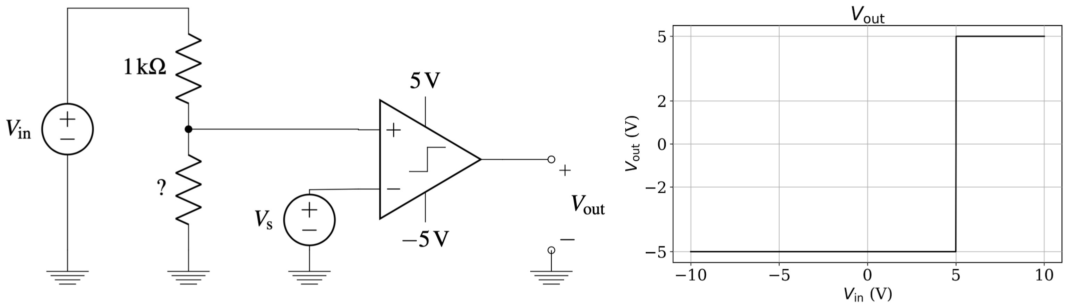
For the circuit shown above (left), we aim to find the value of an unknown resistor from the comparator outputs. The right plot shows the measured V_{out} for V_{in} ranging from -10V to 10V and

Version 1: $V_s = 4\text{V}$

Version 2: $V_s = 3\text{V}$

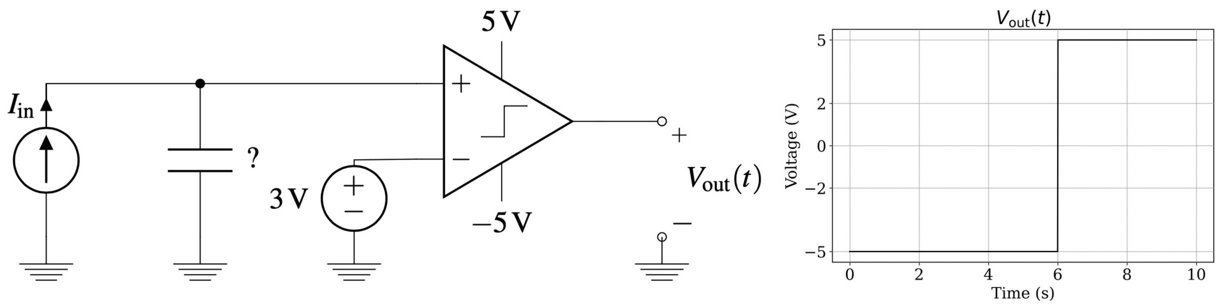
Version 3: $V_s = 1\text{V}$

What is the value of the unknown resistor?



17. Comparators 2 (4 points)

Now, we want to find the value of an unknown capacitor using the comparator outputs. For the circuit shown above (left), **Version 1:** $I_{\text{in}} = 1\mu$A , **Version 2:** $I_{\text{in}} = 3\mu$A, **Version 3:** $I_{\text{in}} = 0.5\mu$A and the initial voltage across the capacitor is 0 when $t = 0$. The plot of $V_{\text{out}}(t)$for time tt from 0-10s is shown on the right. Note that $\mu = 10^{-6}$. What is the value of the capacitor?



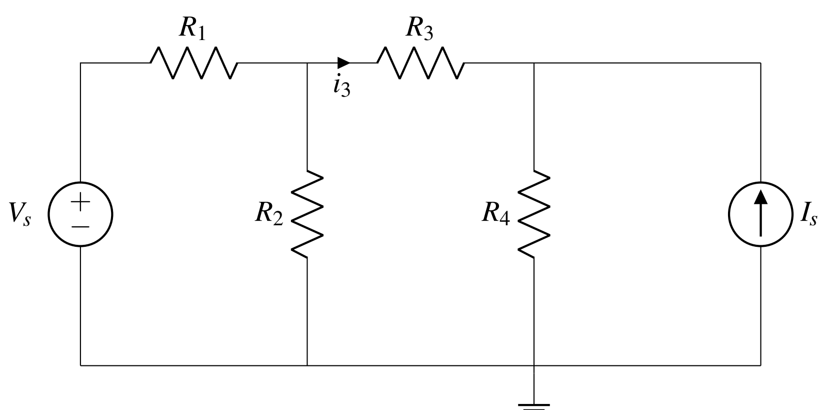
18. Superposition (4 points)

Find the current i_3 in the circuit diagram.

Version 1: Note that V_s=15 V, I_s=4.5 A, R_1=R_2=10 Ω, and R_3=R_4=5 Ω.

Version 2: Note that V_s=15 V, I_s=6 A, R_1=R_2=10 Ω, and R_3=R_4=5 Ω.

Version 3: Note that V_s=15 V, I_s=3 A, R_1=R_2=10 Ω, and R_3=R_4=5 Ω.



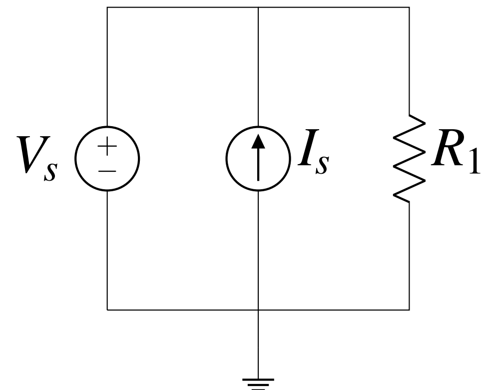
19. Energy/Power (6 points)

In the circuit below,

Version 1: $V_s = 5V$, $I_s = 2mA$, and $R_1 = 5000\,\Omega$

Version 2: $V_s = 4V$, $I_s = 2mA$, and $R_1 = 4000\,\Omega$

Version 3: $V_s = 4V$, $I_s = 1.5mA$, and $R_1 = 8000\,\Omega$



(a) (2 points) What is the power dissipated by R_1?

(b) (2 points) What is the power supplied by I_s?

(c) (2 points) What is the power dissipated by V_s?

20. Circuit Design (6 points)

In this problem, you are going to design a system that detects a broken wire. The red wire, the wire connecting box y to ground in figures 1 and 2 below, is the wire we are interested in. Figure 1 shows a circuit equivalent of the system in normal operation where the alarm should not be triggered. Figure 2 shows a circuit equivalent of the system where the alarm should be triggered. The broken wire, shown in figure 2, should cause a non-zero voltage drop across box y which will trigger the alarm.

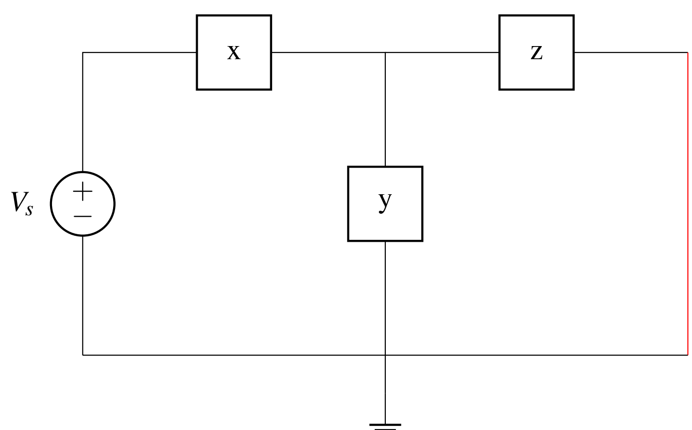


Figure 1: Alarm is off.

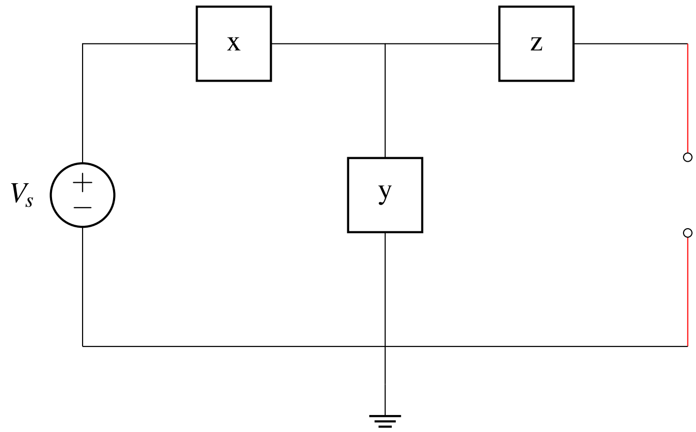


Figure 2: Alarm is triggered.

Given this information, choose the appropriate elements for box1, box2 and box 3 from options (a)-(d). **Note that you are only allowed to use each component once.**

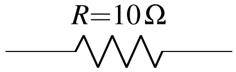
(a) Wire

(b) Alarm

R_{alarm}=5 Ω

(c) Resistor

R=10 Ω

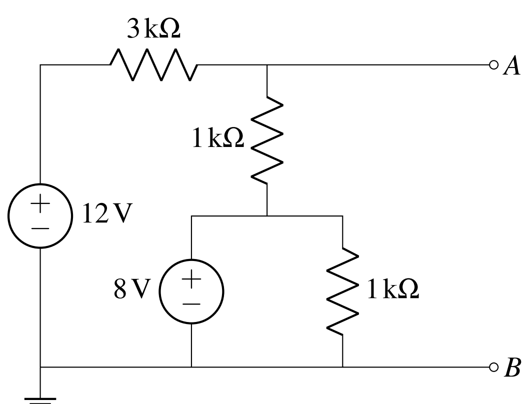


(d) Open circuit

21. Thevenin and Norton (5 points)

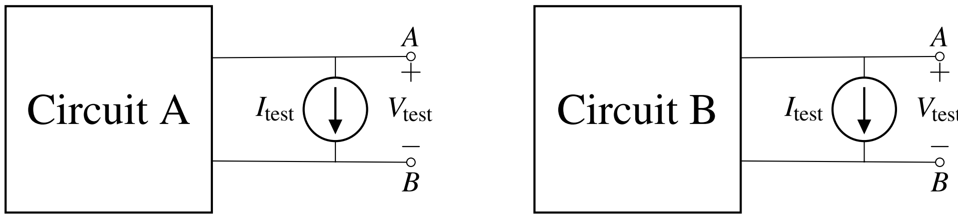
Version 1: Find the Thevenin equivalent voltage and resistance of the given circuit between terminals A and B.

Version 2: Find the Norton equivalent current and resistance of the given circuit between terminals A and B:



22. Thevenin and Norton (5 points)

Version 1: You have two circuits. Circuit A can be modeled with $V_{th} = 5\,\text{V}$ and $R_{th} = 10\,\Omega$. Circuit B can be modeled with $I_{no} = 2\,\text{A}$ and $R_{no} = 4\,\Omega$.
Version 2: You have two circuits. Circuit A can be modeled with $V_{th} = 5\,\text{V}$ and $R_{th} = 7\,\Omega$. Circuit B can be modeled with $I_{no} = 3\,\text{A}$ and $R_{no} = 1\,\Omega$.
Version 3: You have two circuits. Circuit A can be modeled with $V_{th} = 5\,\text{V}$ and $R_{th} = 8\,\Omega$. Circuit B can be modeled with $I_{no} = 2\,\text{A}$ and $R_{no} = 3\,\Omega$.



You want to choose a current source with value I_{test} so that when you attach the source to each circuit and measure the voltage across it, you find the voltage to be equal to the same value, V_{test} in both cases.

You decide to set up a system of equations to solve for I_{test} and V_{test} in the form $A\vec{x} = \vec{y}$, where $\vec{x} = \begin{bmatrix} I_{test} \\ V_{test} \end{bmatrix}$.

Version 1: Your TA Dahlia suggests you use $\vec{y} = \begin{bmatrix} 5 \\ 8 \end{bmatrix}$.

Version 2: Your TA Dahlia suggests you use $\vec{y} = \begin{bmatrix} 15 \\ 3 \end{bmatrix}$.

Version 3: Your TA Dahlia suggests you use $\vec{y} = \begin{bmatrix} 5 \\ 6 \end{bmatrix}$.

With this value of $\vec{y}$, what should you select for the matrix A? Do not include units in your answer.