1) Consider the circuit shown in Figure 1 below.

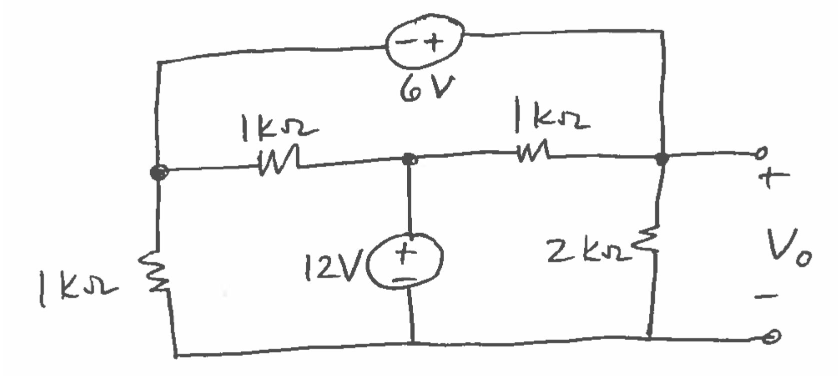


Figure 1. Circuit for Problem 1.

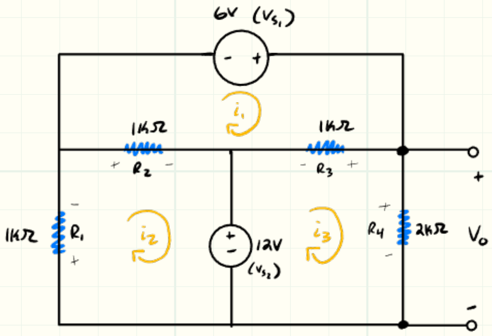
a) Find V_0 by the mesh current method. *Show your work and clearly indicate your defined mesh currents on your schematic*. List your numerical answer with appropriate units and in proper engineering notation format.

b) Verify your by-hand answer for V_0 in LTSpice. Write out the answer you got from LTSpice and attach any supporting evidence that you actually simulated the circuit to verify your work. The answer you write out for this part should be the same as the result you provided in part (a); if it doesn't match **by both sign and magnitude**, expect zero credit. Also, expect zero credit 1) if your by-hand and simulated results agree but the results are incorrect, 2) if you do not perform the LTSpice verification altogether, 3) if you only do the LTSpice verification but not the by-hand solution, or 4) if you do not label the voltage node and have LTSpice compute the value of V_0 for you.

Make sure to include appropriate units with your numerical answers and list your answers in proper engineering notation format with 2 decimal places of precision! **That means no fractions, no square roots, no instances of π, etc.** Note that this applies to all problems in this course, not just this one!

[**continued on next page**]

Austin Riha | Problem 1



KVL at i_1

$$-V_{s_1} + R_3(i_1 - i_3) - R_2(i_2 - i_1) = 0$$
$$-V_{s_1} + R_3 i_1 - R_3 i_3 - R_2 i_2 + R_2 i_1 = 0$$
$$R_3 i_1 - R_3 i_3 - R_2 i_2 + R_2 i_1 = V_{s_1}$$
$$(R_2 + R_3) i_1 + (-R_2) i_2 + (-R_3) i_3 = V_{s_1} \quad ①$$

KVL at i_2

$$R_1 i_2 + R_2(i_2 - i_1) + V_{s_2} = 0$$
$$R_1 i_2 + R_2 i_2 - R_2 i_1 + V_{s_2} = 0$$
$$R_1 i_2 + R_2 i_2 - R_2 i_1 + V_{s_2} = 0$$
$$(-R_2) i_1 + (R_1 + R_2) i_2 = -V_{s_2} \quad ②$$

KVL at i_3

$$-V_{s_2} - R_3(i_1 - i_3) + R_4(i_3) = 0$$
$$-R_3 i_1 + R_3 i_3 + R_4 i_3 = V_{s_2}$$
$$(-R_3) i_1 + (R_3 + R_4) i_3 = V_{s_2} \quad ③$$

plug ①②③ into matrix

$$\begin{bmatrix} V_{s_1} \\ -V_{s_2} \\ V_{s_2} \end{bmatrix} = \begin{bmatrix} (R_2+R_3) & (-R_2) & (-R_3) \\ (-R_2) & (R_1+R_2) & 0 \\ (-R_3) & 0 & (R_3+R_4) \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix}$$

$$\begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 2k\Omega & -1k\Omega & -1k\Omega \\ -1k\Omega & 2k\Omega & 0 \\ -1k\Omega & 0 & 3k\Omega \end{bmatrix}^{-1} \begin{bmatrix} 6V \\ -12V \\ 12V \end{bmatrix}$$

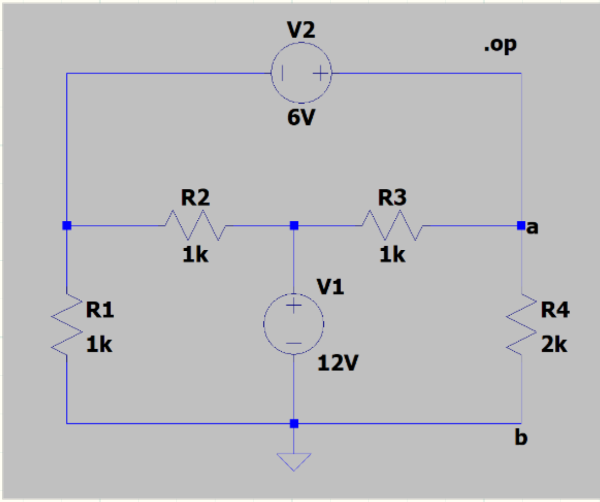
$i_1 = 0.003428A$
$i_2 = -0.00428A$
$i_3 = 0.00514A$

$V = IR$

$V_o = i_3 \cdot R_4$

$V_o = (0.00514\,A)(2000\,\Omega)$

$\boxed{V_o = 10.28\,V}$



--- Operating Point ---

V(n001):	4.28571	voltage
V(n002):	12	voltage
V(a):	10.2857	voltage
I(R1):	0.00428571	device_current
I(R2):	0.00771429	device_current
I(R3):	0.00171429	device_current
I(R4):	0.00514286	device_current
I(V1):	-0.00942857	device_current
I(V2):	-0.00342857	device_current

2) Consider the circuit shown in Figure 2 below.

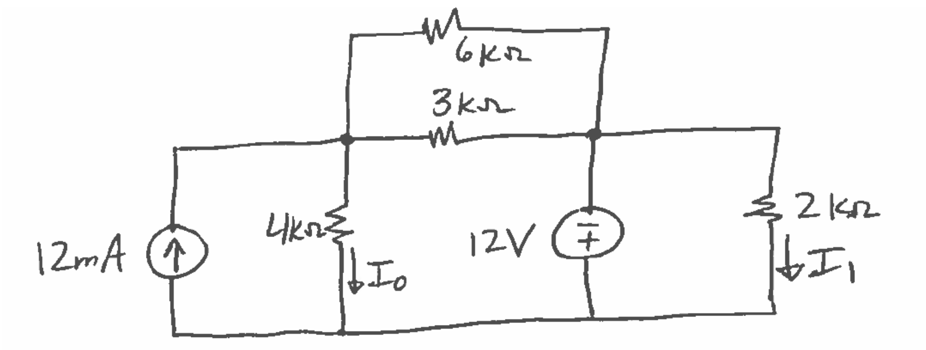


Figure 2. Circuit for Problem 2.

a) Find both I_0 and I_1 by the mesh current method. *Show your work and clearly indicate your defined mesh currents on your schematic*. List your numerical answers with appropriate units and in proper engineering notation format.

b) Verify your by-hand answers for I_0 and I_1 in LTSpice. Write out the answers you got from LTSpice and attach any supporting evidence that you actually simulated the circuit to verify your work. The answers you write out for this part should be the same as the results you provided in part (a); if they don't match **by both sign and magnitude**, expect zero credit. Also, expect zero credit 1) if your by-hand and simulated results agree but the results are incorrect, 2) if you do not perform the LTSpice verification altogether, 3) if you only do the LTSpice verification but not the by-hand solution, or 4) if you do not use a properly oriented 0-V voltage source ammeter to capture the I_0 and I_1 currents in simulation.

[**continued on next page**]

Austin Riha | Problem 2

KVL at i_1

$i_1 = 12mA$

KVL at i_2

$R_1(i_2) - R_2(i_3 - i_2) = 0$

$R_1 i_2 - R_2 i_3 + R_2 i_2 = 0$

$(R_1 + R_2) i_2 + (-R_2) i_3 = 0$ (1)

KVL at i_3

$R_3(i_3 - i_1) + R_2(i_3 - i_2) - V_s = 0$

$R_3 i_3 - R_3 i_1 + R_2 i_3 - R_2 i_2 = V_s$

$(-R_3) i_1 + (-R_2) i_2 + (R_2 + R_3) i_3 = V_s$

$(-4k\Omega)(12mA) + (-R_2) i_2 + (R_2 + R_3) i_3 = V_s$

$-48V + (-R_2) i_2 + (R_2 + R_3) i_3 = 12V$

$(-R_2) i_2 + (R_2 + R_3) i_3 = 60V$ (2)

KVL at i_4

$V_s + R_4(i_4) = 0$

$R_4 i_4 = V_s$

$(R_4) i_4 = V_s$ (3)

Plug 1, 2, 3 into matrix.

$$\begin{bmatrix} 0 \\ 60V \\ 12V \end{bmatrix} = \begin{bmatrix} (R_1+R_2) & (-R_2) & 0 \\ (-R_2) & (R_2+R_3) & 0 \\ 0 & 0 & (R_4) \end{bmatrix} \begin{bmatrix} i_2 \\ i_3 \\ i_4 \end{bmatrix} \longrightarrow \begin{bmatrix} i_2 \\ i_3 \\ i_4 \end{bmatrix} = \begin{bmatrix} 9k\Omega & -3k\Omega & 0 \\ -3k\Omega & 7k\Omega & 0 \\ 0 & 0 & 2k\Omega \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 60 \\ 12 \end{bmatrix}$$

$i_1 = 12mA$

$i_2 = 3.33mA$

$i_3 = 10mA$

$i_4 = 6mA$

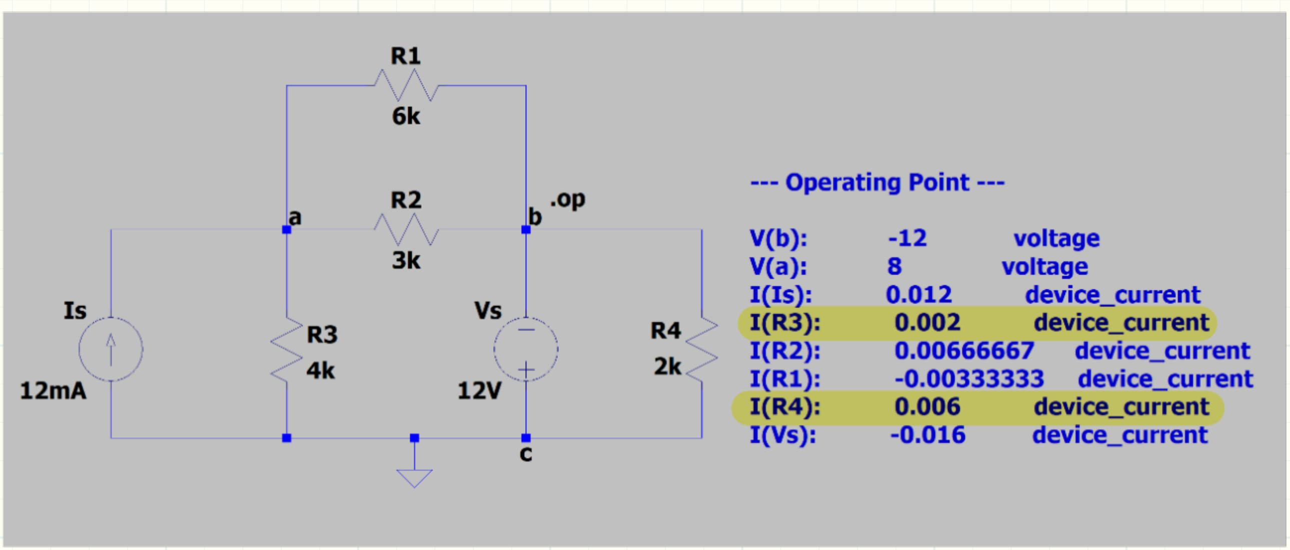
$I_0 = i_1 - i_3$

$I_0 = 12mA - 10mA$

$\boxed{I_0 = 2mA}$

$I_1 = i_4$

$\boxed{I_1 = 6mA}$



3) Consider the circuit shown in Figure 3 below.

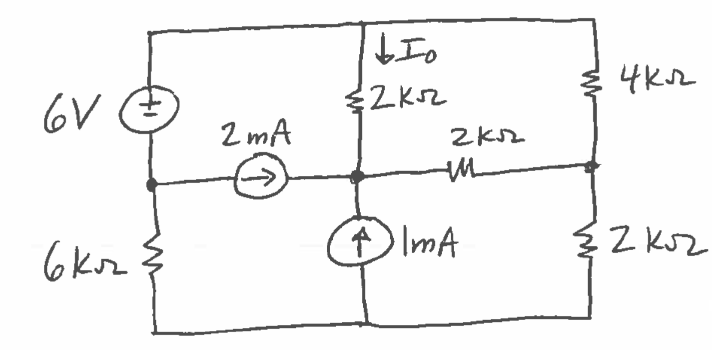


Figure 3. Circuit for Problem 3.

a) Find I_0 by performing mesh analysis. *Show your work and clearly indicate your defined mesh currents on your schematic*. List your numerical answer with appropriate units and in proper engineering notation format.

b) Verify your by-hand answer for I_0 in LTSpice. Write out the answer you got from LTSpice and attach any supporting evidence that you actually simulated the circuit to verify your work. The answer you write out for this part should be the same as the result you provided in part (a); if it doesn't match **by both sign and magnitude**, expect zero credit. Also, expect zero credit 1) if your by-hand and simulated results agree but the results are incorrect, 2) if you do not perform the LTSpice verification altogether, 3) if you only do the LTSpice verification but not the by-hand solution, or 4) if you do not use a properly oriented 0-V voltage source ammeter to capture the I_0 current in simulation.

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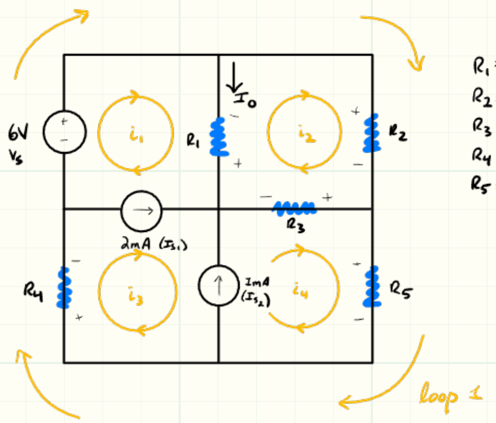
Austin Riha

Problem 3



$R_1 = 2k\Omega$
$R_2 = 4k\Omega$
$R_3 = 2k\Omega$
$R_4 = 6k\Omega$
$R_5 = 2k\Omega$

$2mA = i_3 - i_1$ ①

$1mA = i_4 - i_3$ ②

KVL at i_2

$R_1(i_2 - i_1) + R_2(i_2) + R_3(i_2 - i_4) = 0$

$R_1 i_2 - R_1 i_1 + R_2 i_2 + R_3 i_2 - R_3 i_4 = 0$

③ $(-R_1)i_1 + (R_1 + R_2 + R_3)i_2 + (-R_3)i_4 = 0$

KVL at loop 1

$-V_s + R_2(i_2) + R_5(i_4) + R_4(i_3) = 0$

$R_2(i_2) + R_5(i_4) + R_4(i_3) = V_s$

④ $(R_2)i_2 + (R_4)i_3 + (R_5)i_4 = V_s$

Plug 1,2,3,4 into matrix

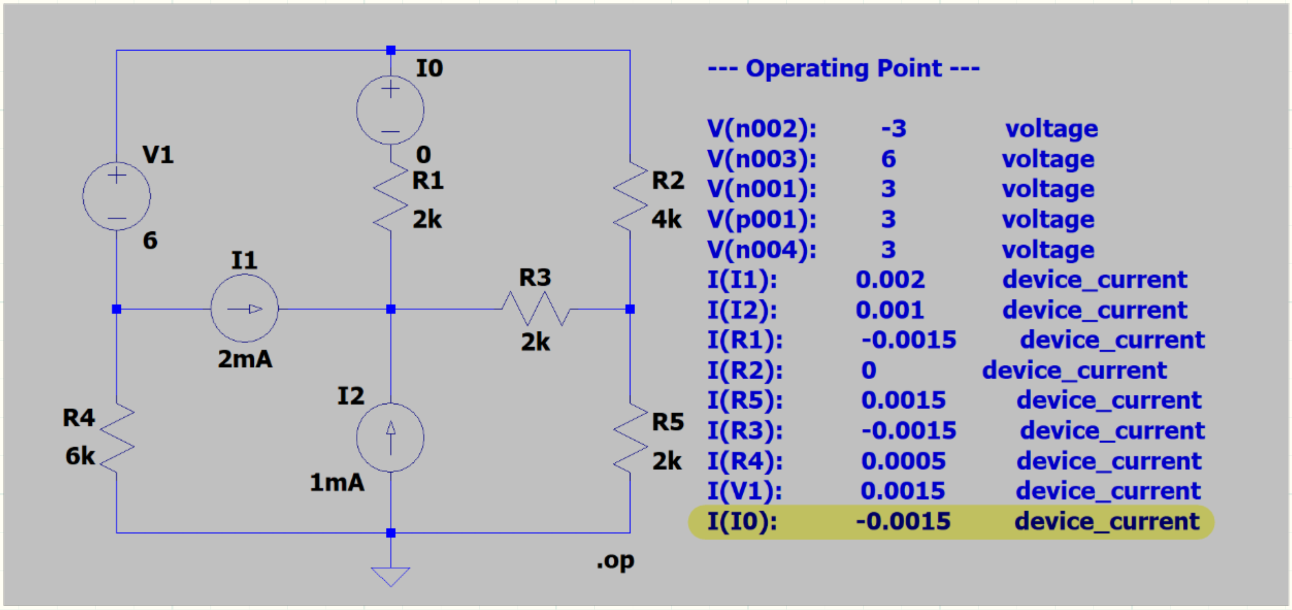
$$\begin{bmatrix} 0.002 \\ 0.001 \\ 0 \\ V_s \end{bmatrix} = \begin{bmatrix} -1 & 0 & 1 & 0 \\ 0 & 0 & -1 & 1 \\ (-R_1) & (R_1+R_2+R_3) & 0 & (-R_3) \\ 0 & (R_2) & (R_4) & (R_5) \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{bmatrix} \longrightarrow \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 1 & 0 \\ 0 & 0 & -1 & 1 \\ -2K & 8K & 0 & -2K \\ 0 & 4K & 6K & 2K \end{bmatrix} \begin{bmatrix} 0.002 \\ 0.001 \\ 0 \\ 6 \end{bmatrix}$$

$i_1 = -1.5mA$
$i_2 = 0$
$i_3 = 0.5mA$
$i_4 = 1.5mA$

$I_o = i_1 - i_2$

$I_o = -1.5mA - 0$

$\boxed{I_o = -1.5mA}$



4) Consider the circuit shown in Figure 4 below.

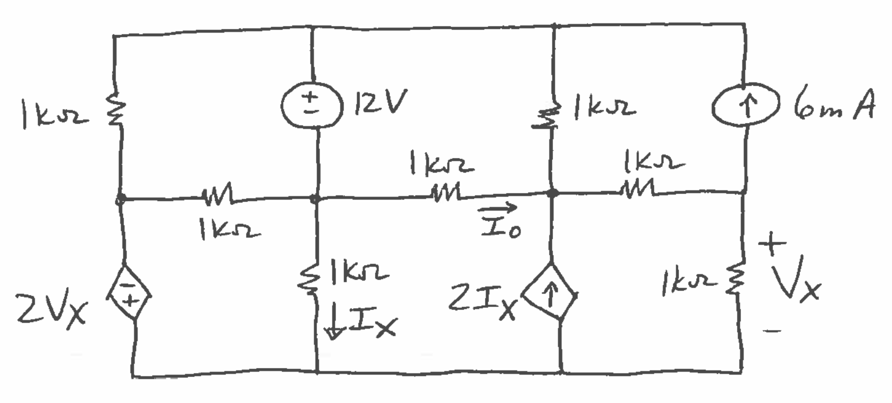
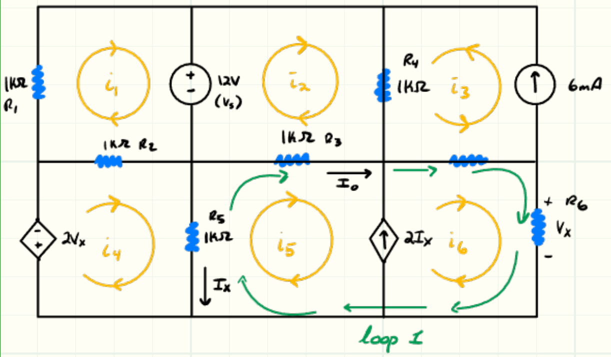


Figure 4. Circuit for Problem 4.

a) Find I_0 by performing mesh analysis. *Show your work and clearly indicate your defined mesh currents on your schematic*. List your numerical answer with appropriate units and in proper engineering notation format.

b) Verify your by-hand answer for I_0 in LTSpice. Write out the answer you got from LTSpice and attach any supporting evidence that you actually simulated the circuit to verify your work. The answer you write out for this part should be the same as the result you provided in part (a); if it doesn't match **by both sign and magnitude**, expect zero credit. Also, expect zero credit 1) if your by-hand and simulated results agree but the results are incorrect, 2) if you do not perform the LTSpice verification altogether, 3) if you only do the LTSpice verification but not the by-hand solution, or 4) if you do not use a properly oriented 0-V voltage source ammeter to capture the I_0 current in simulation.

Austin Riha | Problem 4



$i_3 = 6mA$ (1)

$I_x = i_4 - i_5$

$i_6 - i_5 = 2I_x$

$i_6 - i_5 = 2[i_4 - i_5]$

$i_6 - i_5 = 2i_4 - 2i_5$

$-2i_4 + i_5 + i_6 = 0$ (2)

Since all resistors are 1kΩ I will write them all as R.

KVL at i_1

$R(i_1) + V_s + R(i_1 - i_4) = 0$

$Ri_1 + Ri_1 - Ri_4 = -V_s$

$(2R)i_1 + (-R)i_4 = -V_s$

(3)

KVL at i_2

$R(i_2 + i_3) + R(i_2 - i_5) - V_s = 0$

$Ri_2 + Ri_3 + Ri_2 - Ri_5 = V_s$

$(2R)i_2 + (R)i_3 + (-R)i_5 = V_s$

(4)

KVL at i_4 $V_x = Ri_6$

$R(i_4 - i_1) + R(i_4 - i_5) + 2V_x = 0$

$Ri_4 - Ri_1 + Ri_4 - Ri_5 + 2Ri_6 = 0$

$(-R)i_1 + (2R)i_4 + (-R)i_5 + (2R)i_6 = 0$

(5)

KVL at loop 1

$R(i_5 - i_4) + R(i_5 - i_2) + R(i_6 + i_3) + Ri_6 = 0$

$Ri_5 - Ri_4 + Ri_5 - Ri_2 + Ri_6 + Ri_3 + Ri_6 = 0$

$(-R)i_2 + (R)i_3 + (-R)i_4 + (2R)i_5 + (2R)i_6 = 0$ (6)

$i_1 = -6.48mA$

$i_2 = 3.12mA$

$i_3 = 6mA$

$i_4 = -0.96mA$

$i_5 = 0.24mA$

$i_6 = -2.16mA$

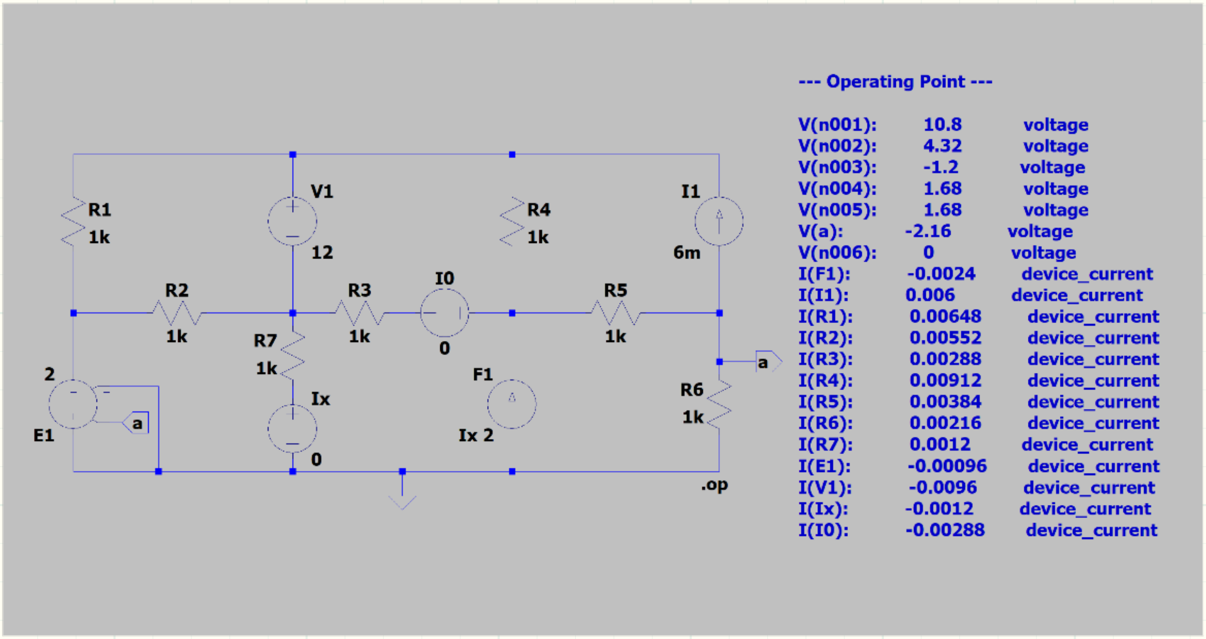
$I_o = i_5 - i_2$

$I_o = [0.24mA] - [3.12mA]$

$\boxed{I_o = -2.88mA}$

Plug 1,2,3,4,5,6 into matrix

$$\begin{bmatrix} 0.006 \\ 0 \\ -V_s \\ V_s \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -2 & 1 & 1 \\ 2R & 0 & 0 & -R & 0 & 0 \\ 0 & 2R & R & 0 & -R & 0 \\ -R & 0 & 0 & 2R & -R & 2R \\ 0 & -R & R & -R & 2R & 2R \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \\ i_5 \\ i_6 \end{bmatrix} \longrightarrow \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \\ i_5 \\ i_6 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -2 & 1 & 1 \\ 2K & 0 & 0 & -1K & 0 & 0 \\ 0 & 2K & 1K & 0 & -1K & 0 \\ -1K & 0 & 0 & 2K & -1K & 2K \\ 0 & -1K & 1K & -1K & 2K & 2K \end{bmatrix}^{-1} \begin{bmatrix} 0.006 \\ 0 \\ -12 \\ 12 \\ 0 \\ 0 \end{bmatrix}$$



Note: The same LTSpice verification rules mentioned above will be in place for future assignments: key voltage nodes must be labeled and *unless the node voltage is directly related to the voltage of interest relative to your reference node*, <u>voltages of interest should be created with an E source having a voltage gain of 1</u>, and any currents that need verifying should be captured with a properly oriented 0-V voltage source ammeter. You should expect zero credit for not following these instructions.

Additionally, you should write out your LTSpice verification results and attach any supporting evidence that you verified your by-hand work in LTSpice; include your supporting evidence in your ONE PDF FILE that you submit on Canvas. If these instructions are not followed, expect zero credit.

Furthermore, on all future assignments, expect zero credit 1) if your by-hand and simulated results agree but the results are incorrect, 2) if you do not perform the LTSpice verification altogether, 3) if you only do the LTSpice verification but not the by-hand solution, or 4) if your by-hand and simulated results do not match by both sign and magnitude.