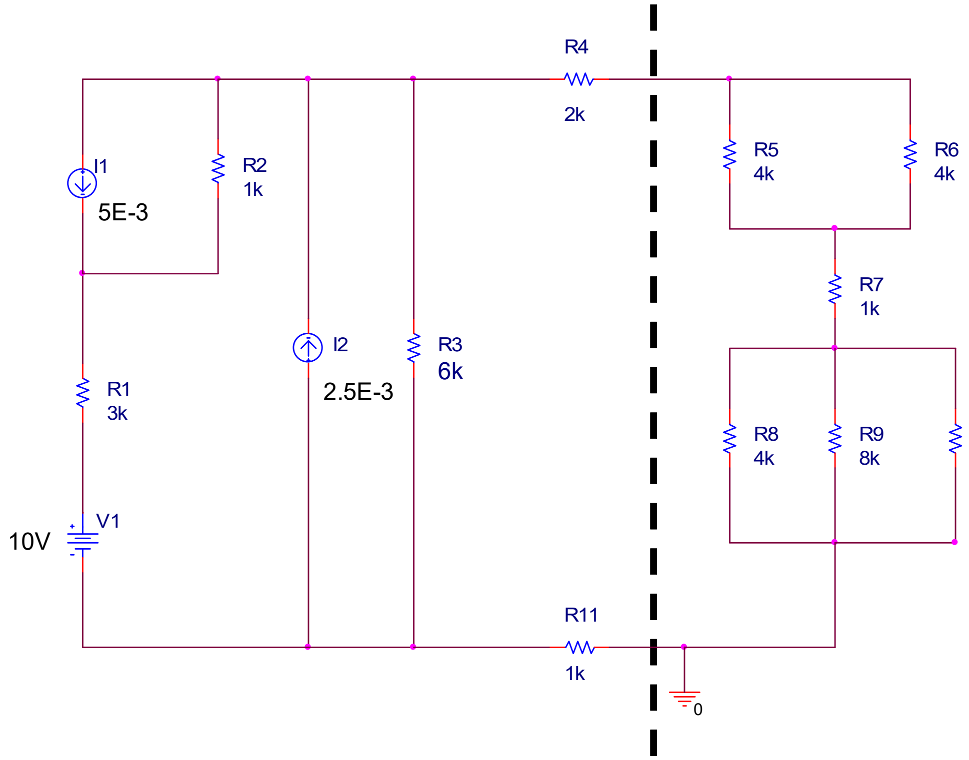
1) Equivalent Circuits/Circuit Reduction



1.1: Use source conversion to find a single equivalent ***voltage source*** and source resistor for the circuit to the left of the dashed line.

1.2: Find a single equivalent ***current source*** and source resistor for the circuit to the left of the dashed line.

1.3: Find the equivalent load resistor for the circuit to the right of the dashed line. (*It is best to draw each step of reduction just in case you make a mistake in order to get partial credit!)*

1.4: How much power is **consumed** on the source side of the circuit?

1.5: How much power is **consumed** on the load side of the circuit?

1.6: For the given sources, is the power to the load maximized?

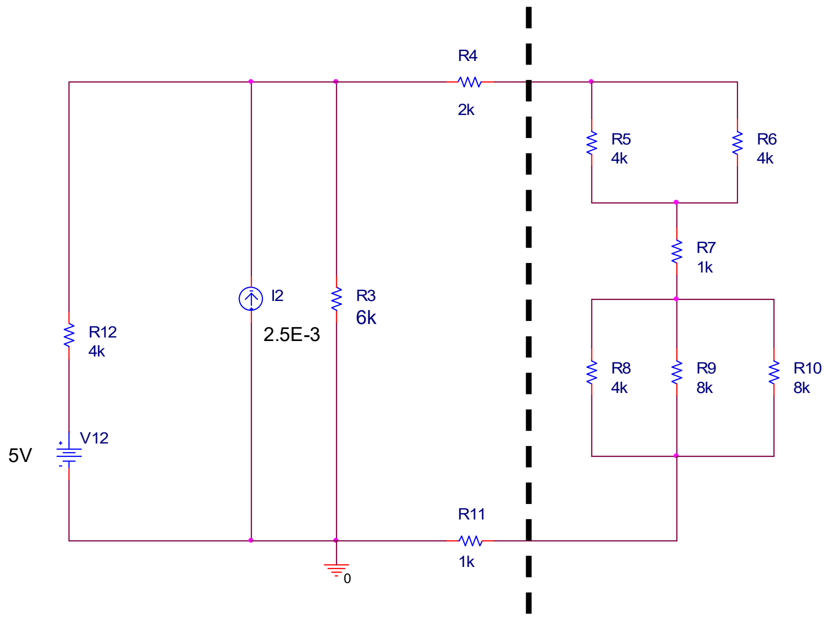
1.1: Step 1:
Source conversion of I2 $I_2 := 5mA \quad R_2 := 1k\Omega$

$$V_2 := I_2 \cdot R_2 = 5\,V$$

Step 2:
Adding DC voltage sources (watch signs and direction!) and R1 and R2 $V_1 := 10V \quad R_1 := 3k\Omega$

$$V_{12} := V_1 - V_2 = 5\,V$$

$$R_{12} := R_1 + R_2 = 4 \cdot k\Omega$$



(ground should be to right of R11, typo)

Just to get it out the way for future drawings....right side.....

$R_5 := 4k\Omega$ $R_6 := 4k\Omega$ $R_7 := 1k\Omega$ $R_8 := 4k\Omega$ $R_9 := 8k\Omega$ $R_{10} := 8k\Omega$

$$R_{Right} := \frac{R_5 \cdot R_6}{R_5 + R_6} + R_7 + \frac{\frac{R_9 \cdot R_{10}}{R_9 + R_{10}} \cdot R_8}{\frac{R_9 \cdot R_{10}}{R_9 + R_{10}} + R_8}$$

$$R_{Right} = 5 \cdot k\Omega$$

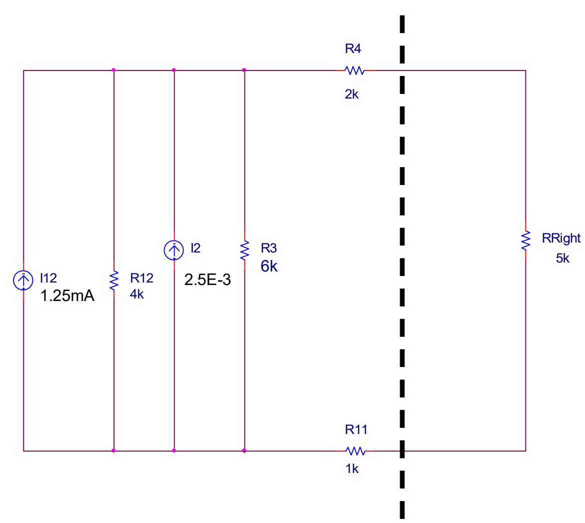
Step 3: Another source conversion to combine easily (converting voltage source)

$$I_{12} := \frac{V_{12}}{R_{12}} = 1.25 \cdot mA$$

$I_{2b} := 2.5mA$ $R_3 := 6k\Omega$

$$I_{12b} := I_{12} + I_{2b} = 3.75 \cdot mA$$

$$R_{123} := \frac{R_{12} \cdot R_3}{R_{12} + R_3} = 2.4 \cdot k\Omega$$

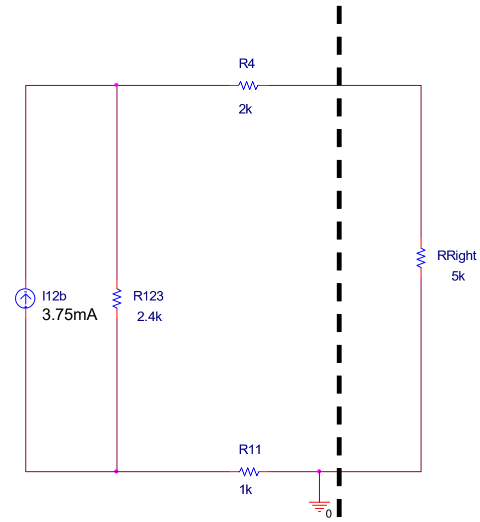


Step 4: After combining current sources and resistors, convert to voltage source so R4 and R11 can be added

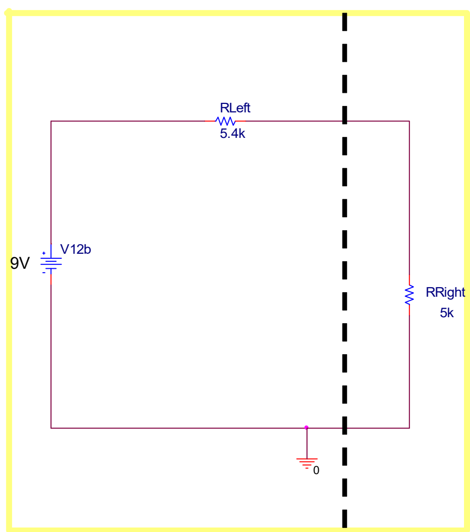
$V_{12b} := I_{12b} \cdot R_{123} = 9\,V \qquad R_4 := 2k\Omega \quad R_{11} := 1k\Omega$

$R_{123} + R_4 + R_{11} = 5.4 \cdot k\Omega$

$R_{Left} := R_{123} + R_4 + R_{11} = 5.4 \cdot k\Omega$



Voltage source and source resistor with RLoad

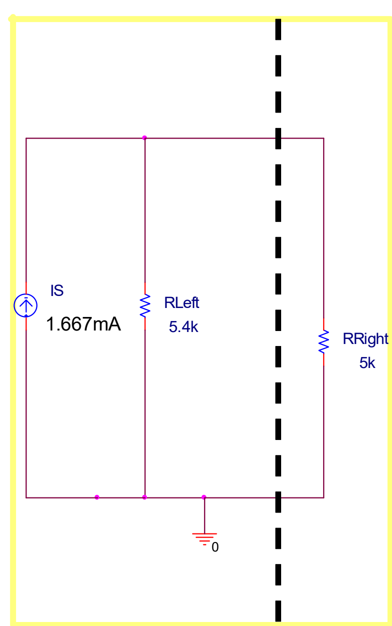


If you used P-Spice to check your answer Voltage divide solution to A and it should be the same as the voltage of the node right above R5 in original diagram. 4.327V

Convert to current source

$$\frac{V_{12b}}{R_{Left}} = 1.667 \cdot mA$$

1.2: Current source and source reistor with RLoad

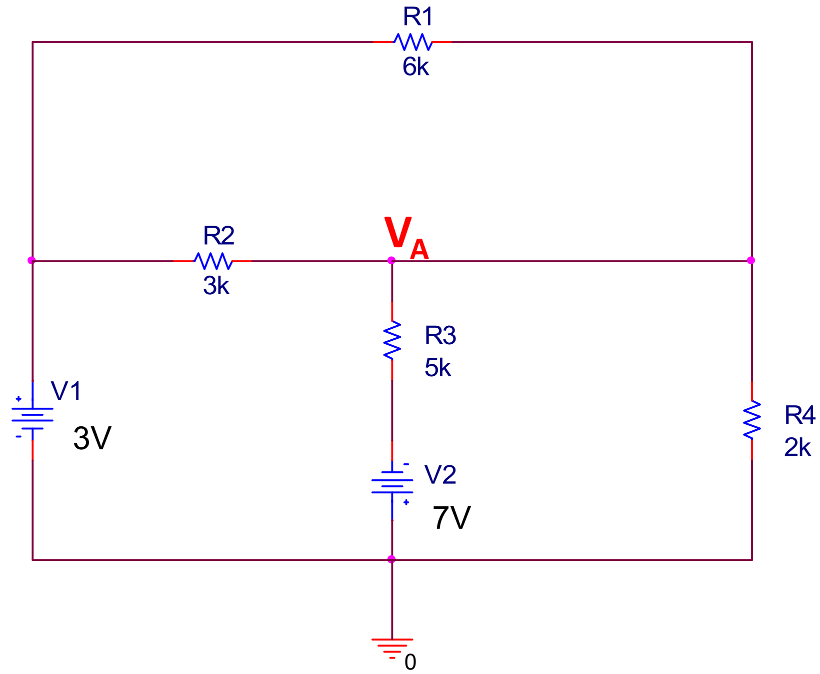


1.4: $$P_{RLeft} := \left(\frac{V_{12b}}{R_{Left} + R_{Right}}\right)^2 \cdot R_{Left} = 4.044 \cdot mW$$

1.5: $$P_{RRight} := \left(\frac{V_{12b}}{R_{Left} + R_{Right}}\right)^2 \cdot R_{Right} = 3.744 \cdot mW$$

1.6: It's close but not exactly, power is maximized when RLoad = Rsource

2) Node/Mesh Analysis



2.1: How many nodes are in the diagram above?

4 nodes

2.2: If nodal analysis is used, how many equations are needed to solve for V_A? *(Hint: There is an equation to help you determine this...use it!)*

total number of nodes - number of voltage sources -1 = 4 - 2 - 1 = 1

2.3: Using nodal analysis, determine the equation(s) needed to find the voltage at V_A.

$$\frac{V_A - 3}{3k} + \frac{V_A - (-7)}{5k} + \frac{V_A - 0}{2k} + \frac{V_A - 3}{6k} = 0$$

$$\frac{V_A}{3k} - \frac{3}{3k} + \frac{V_A}{5k} + \frac{7}{5k} + \frac{V_A}{2k} + \frac{V_A}{6k} - \frac{3}{6k} = 0$$

$$\frac{-3}{3000} + \frac{7}{5000} - \frac{3}{6000} = -1 \times 10^{-4}$$

$$V_A\left(\frac{1}{3k} + \frac{1}{5k} + \frac{1}{2k} + \frac{1}{6k}\right) = 1 \cdot 10^{-4}$$

$$\frac{1}{3000} + \frac{1}{5000} + \frac{1}{2000} + \frac{1}{6000} = 1.2 \times 10^{-3}$$

$$V_A := \frac{1 \cdot 10^{-4} V}{1.2 \cdot 10^{-3}} = 0.083\ V$$

2.4: How many equations are needed to solve for V_A using mesh analysis?

total # of nodes - current sources = 3 -0 = 3

2.5: Using mesh analysis, determine the equation(s) needed to find the voltage at V_A.

$$6k \cdot i_1 + 3k \cdot i_1 - 3k \cdot i_2 = 0$$

$$9k \cdot i_1 - 3k \cdot i_2 = 0$$

$$-3 + 3k \cdot i_2 - 3k \cdot i_1 + 5k \cdot i_2 - 5k \cdot i_3 - 7 = 0$$

$$-3k \cdot i_1 + 8k \cdot i_2 - 5k \cdot i_3 = 10$$

$$7 + 5k \cdot i_3 - 5k \cdot i_2 + 2k \cdot i_3 = 0$$

$$-5k \cdot i_2 + 7k \cdot i_3 = -7$$

$$M_1 := \begin{pmatrix} 9000 & -3000 & 0 \\ -3000 & 8000 & -5000 \\ 0 & -5000 & 7000 \end{pmatrix}$$

$$C_1 := \begin{pmatrix} 0 \\ 10 \\ -7 \end{pmatrix}$$

$$X_1 := M_1^{-1} \cdot C_1 = \begin{pmatrix} 4.861 \times 10^{-4} \\ 1.458 \times 10^{-3} \\ 4.167 \times 10^{-5} \end{pmatrix}$$

$$i_1 := 4.861mA$$

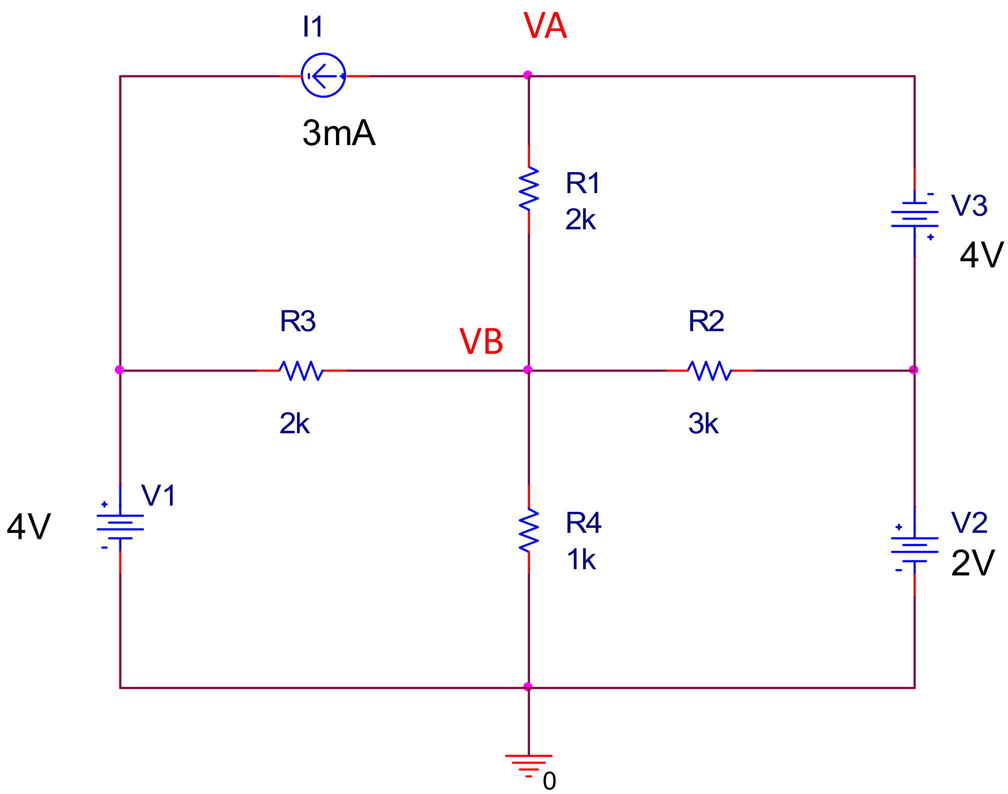
$$i_2 := 1.458mA$$

$$i_3 := 0.04167mA$$

$$V_{A2} := i_2 \cdot 5k\Omega - i_3 \cdot 5k\Omega - 7V = 0.082\,V$$

rounding errors might bring this up to 0.9...

3) Node/Mesh Analysis



3.1: In the above circuit, how many nodes are present?

5 nodes

3.2: How many nodes are constrained by voltage sources and ground? *(also list contrained nodes and relationships, add node labels to diagrams for identification purposes)*

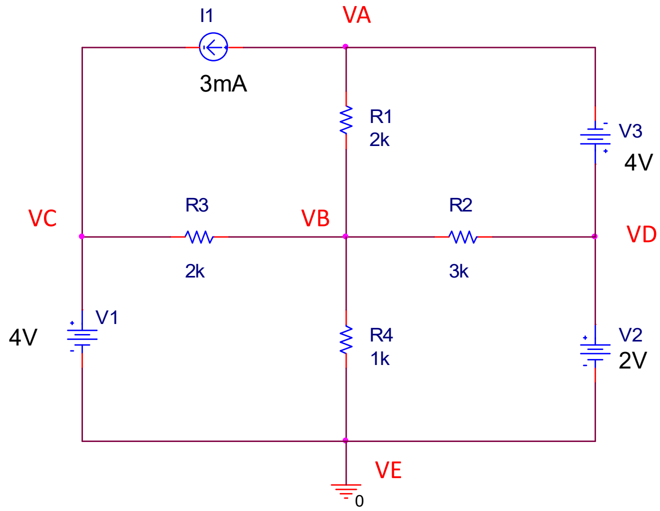
3 nodes are constrained

$V_C = 4V$ same as Vc=Ve+4

$V_D = 2V$ same as Vd=Ve+2

$V_A = -2V$ same as Va=Vd-4

3.3: Write the equation(s) needed to determine unknown nodes and find the voltage at VB. (Redraw circuit and label nodes for identification)



Apply KCL at node B

$$\frac{V_B - 4}{2k} + \frac{V_B - (-2)}{2k} + \frac{V_B - 2}{3k} + \frac{V_B - 0}{1k} = 0$$

$$\frac{5V}{7} = 0.714\,V$$

3.4: In the above circuit, how many meshes are present?

There are 4 mesh loops.

3.5: How many of those loops are constrained by current sources? *(also list contrained nodes and relationships)*

1 constrained loop

$$i_1 := -3mA$$

3.6: Write the equation(s) needed to determine unknown mesh loops and find the voltage at VB. (Redraw circuit and label mesh loops for identification)

Treating the loops as: top left corner (loop 1), top right corner (loop 2), bottom left corner (loop 3) and bottom right corner (loop 4)
Applying KVL to each loop

Loop1 contrained i1=-3mA

Loop2 $i_2 \cdot 2k - (-3mA) \cdot 2k - 4 + i_2 \cdot 3k - i_4 \cdot 3k = 0$

$$5k \cdot i_2 - i_4 \cdot 3k = -2$$

Loop3

$$-4 + i_3 \cdot 2k - (-3mA) \cdot 2k + i_3 \cdot 1k - i_4 \cdot 1k = 0$$

$$3k \cdot i_3 - i_4 \cdot 1k = -2$$

Loop4

$$i_4 \cdot 1k - i_3 \cdot 1k + i_4 \cdot 3k - i_2 \cdot 3k + 2 = 0$$

$$-3k \cdot i_2 - 1k \cdot i_3 + 4k \cdot i_4 = -2$$

$$M_2 := \begin{pmatrix} 5000 & 0 & -3000 \\ 0 & 3000 & -1000 \\ -3000 & -1000 & 4000 \end{pmatrix}$$

$$C_2 := \begin{pmatrix} -2 \\ -2 \\ -2 \end{pmatrix}$$

$$M_2^{-1} \cdot C_2 = \begin{pmatrix} -1.643 \times 10^{-3} \\ -1.357 \times 10^{-3} \\ -2.071 \times 10^{-3} \end{pmatrix}$$

$i_{1b} := -3mA$

$i_{2b} := -1.643mA$

$i_{3b} := -1.357mA$

$i_{4b} := -2.071mA$

$$(i_{3b} - i_{4b}) \cdot 1k\Omega = 0.714\,V$$

3.7: Which method is easier in this case?

Nodal analysis